The Astrophysical Journal, 985:183 (23pp), 2025 June 1 https://doi.org/10.3847/1538-4357/adc681

Search for Gravitational Waves Emitted from SN 2023ixf

A. G. Abac[1], R. Abbott[2], I. Abouelfettouh[3], F. Acernese[4,5], K. Ackley[6], S. Adhicary[7], N. Adhikari[8], R. X. Adhikari[2], V. K. Adkins[9], D. Agarwal[10,11], M. Agathos[12], M. Aghaei Abchouyeh[13], O. D. Aguiar[14], I. Aguilar[15], L. Aiello[16,17,18], A. Ain[19], T. Akutsu[20,21], S. Albanesi[22,23,24], R. A. Alfaidi[25], A. Al-Jodah[26], C. Alléné[27], A. Allocca[5,28], S. Al-Shammari[18], P. A. Altin[29], S. Alvarez-Lopez[30], A. Amato[31,32], L. Amez-Droz[33], A. Amorosi[33], C. Amra[34], A. Ananyeva[2], S. B. Anderson[2], W. G. Anderson[2], M. Andia[35], M. Ando[36], T. Andrade[37], N. Andres[27], M. Andrés-Carcasona[38], T. Andrić[1,39,40,41], J. Anglin[42], S. Ansoldi[43,44], J. M. Antelis[45], S. Antier[46], M. Aoumi[47], E. Z. Appavuravther[48,49], S. Appert[2], S. K. Apple[50], K. Arai[2], A. Araya[36], M. C. Araya[2], J. S. Areeda[51], L. Argianas[52], N. Aritomi[3], F. Armato[53,54], N. Arnaud[35,55], M. Arogeti[56], S. M. Aronson[9], G. Ashton[57], Y. Aso[20,58], M. Assiduo[59,60], S. Assis de Souza Melo[55], S. M. Aston[61], P. Astone[62], F. Attadio[62,63], F. Aubin[64], K. AultONeal[65], G. Avallone[66], S. Babak[67], F. Badaracco[53], C. Badger[68], S. Bae[69], S. Bagnasco[22], E. Bagui[70], J. G. Baier[71], L. Baiotti[72], R. Bajpai[20], T. Baka[73], M. Ball[74], G. Ballardin[55], S. W. Ballmer[75], S. Banagiri[76], B. Banerjee[41], D. Bankar[11], P. Baral[8], J. C. Barayoga[2], B. C. Barish[2], D. Barker[3], P. Barneo[37,77], F. Barone[5,78], B. Barr[25], L. Barsotti[30], M. Barsuglia[67], D. Barta[79], A. M. Bartoletti[80], M. A. Barton[25], I. Bartos[42], S. Basak[81], A. Basalaev[82], R. Bassiri[15], A. Basti[83,84], D. E. Bates[18], M. Bawaj[48,85], P. Baxi[86], J. C. Bayley[25], A. C. Baylor[8], P. A. Baynard II[56], M. Bazzan[87,88], V. M. Bedakihale[89], F. Beirnaert[90], M. Bejger[91], D. Belardinelli[17], A. S. Bell[25], V. Benedetto[92], W. Benoit[93], J. D. Bentley[82], M. Ben Yaala[94], S. Bera[95], M. Berbel[96], F. Bergamin[39,40], B. K. Berger[15], S. Bernuzzi[23], M. Beroiz[2], D. Bersanetti[53], A. Bertolini[32], J. Betzwieser[61], D. Beveridge[26], N. Bevins[52], R. Bhandare[97], U. Bhardwaj[32,98], R. Bhatt[2], D. Bhattacharjee[71,99], S. Bhaumik[42], S. Bhowmick[100], A. Bianchi[32,101], I. A. Bilenko[102], G. Billingsley[2], A. Binetti[103], S. Bini[104,105], O. Birnholtz[106], S. Biscoveanu[76], A. Bisht[40], M. Bitossi[55,84], M.-A. Bizouard[46], J. K. Blackburn[2], L. A. Blagg[74], C. D. Blair[26,61], D. G. Blair[26], F. Bobba[66,107], N. Bode[39,40], G. Boileau[19,46], M. Boldrini[62,63], G. N. Bolingbroke[108], A. Bolliand[34,109], L. D. Bonavena[87], R. Bondarescu[37], F. Bondu[110], E. Bonilla[15], M. S. Bonilla[51], A. Bonino[111], R. Bonnand[27], P. Booker[39,40], A. Borchers[39,40], V. Boschi[84], S. Bose[112], V. Bossilkov[61], V. Boudart[113], A. Boudon[114], A. Bozzi[55], C. Bradaschia[84], P. R. Brady[8], M. Braglia[115], A. Branch[61], M. Branchesi[41,116], J. Brandt[56], I. Braun[71], M. Breschi[23], T. Briant[117], A. Brillet[46], M. Brinkmann[39,40], P. Brockill[8], E. Brockmueller[39,40], A. F. Brooks[2], B. C. Brown[42], D. D. Brown[108], M. L. Brozzetti[48,85], S. Brunett[2], G. Bruno[10], R. Bruntz[118], J. Bryant[111], F. Bucci[60], J. Buchanan[118], O. Bulashenko[37,77], T. Bulik[119], H. J. Bulten[32], A. Buonanno[1,120], K. Burtnyk[3], R. Buscicchio[121,122], D. Buskulic[27], C. Buy[123], R. L. Byer[15], G. S. Cabourn Davies[124], G. Cabras[43,44], R. Cabrita[10], V. Cáceres-Barbosa[7], L. Cadonati[56], G. Cagnoli[125], C. Cahillane[75], J. Calderón Bustillo[126], T. A. Callister[127], E. Calloni[5,28], J. B. Camp[128], M. Canepa[53,54], G. Caneva Santoro[38], K. C. Cannon[36], H. Cao[108], L. A. Capistran[129], E. Capocasa[67], E. Capote[75], G. Carapella[66,107], F. Carbognani[55], M. Carlassara[39,40], J. B. Carlin[130], M. Carpinelli[55,121,131], G. Carrillo[74], J. J. Carter[39,40], G. Carullo[132], J. Casanueva Diaz[55], C. Casentini[16,17,133], S. Y. Castro-Lucas[100], S. Caudill[32,73,134], M. Cavaglià[99], R. Cavalieri[55], G. Cella[84], P. Cerdá-Durán[135,136], E. Cesarini[17], W. Chaibi[46], P. Chakraborty[39,40], S. Chalathadka Subrahmanya[82], J. C. L. Chan[137], M. Chan[138], K. Chandra[7], R.-J. Chang[139], S. Chao[140,141], E. L. Charlton[118], P. Charlton[142], E. Chassande-Mottin[67], C. Chatterjee[143], Debarati Chatterjee[11], Deep Chatterjee[30], M. Chaturvedi[97], S. Chaty[67], A. Chen[12], A. H.-Y. Chen[144], D. Chen[145], H. Chen[140], H. Y. Chen[146], J. Chen[30], K. H. Chen[141], Y. Chen[140], Yanbei Chen[147], Yitian Chen[148], H. P. Cheng[149], P. Chessa[48,85], H. T. Cheung[86], S. Y. Cheung[150], F. Chiadini[107,151], G. Chiarini[88], R. Chierici[114], A. Chincarini[53], M. L. Chiofalo[83,84], A. Chiummo[5,55], C. Chou[144], S. Choudhary[26], N. Christensen[46], S. S. Y. Chua[29], P. Chugh[150], G. Ciani[87,88], P. Ciecielag[91], M. Cieślar[119], M. Cifaldi[17], R. Ciolfi[88,152], F. Clara[3], J. A. Clark[2,56], J. Clarke[18], T. A. Clarke[150], P. Clearwater[153], S. Clesse[70], E. Coccia[38,41,116], E. Codazzo[41], P.-F. Cohadon[117], S. Colace[54], M. Colleoni[95], C. G. Collette[33], J. Collins[61], S. Colloms[25], A. Colombo[121,122,154], M. Colpi[121,122], C. M. Compton[3], G. Connolly[74], L. Conti[88], T. R. Corbitt[9], I. Cordero-Carrión[155], S. Corezzi[48,85], N. J. Cornish[156], A. Corsi[157], S. Cortese[55], C. A. Costa[14], R. Cottingham[61], M. W. Coughlin[93], A. Couineaux[62], J.-P. Coulon[46], S. T. Countryman[158], J.-F. Coupechoux[114], P. Couvares[2,56], D. M. Coward[26], M. J. Cowart[61], R. Coyne[159], K. Craig[94], R. Creed[18], J. D. E. Creighton[8], T. D. Creighton[160], P. Cremonese[95], A. W. Criswell[93], J. C. G. Crockett-Gray[9], S. Crook[61], R. Crouch[3], J. Csizmazia[3], J. R. Cudell[113], T. J. Cullen[2], A. Cumming[25], E. Cuoco[55,84], M. Cusinato[135], P. Dabadie[125], T. Dal Canton[35], S. Dall'Osso[62], S. Dal Pra[62], G. Dálya[123], B. D'Angelo[53], S. Danilishin[31,32], S. D'Antonio[17], K. Danzmann[39,40], K. E. Darroch[118], L. P. Dartez[3], A. Dasgupta[89], S. Datta[161], V. Dattilo[55], A. Daumas[67], N. Davari[131,162], I. Dave[97], A. Davenport[100], M. Davier[35], T. F. Davies[26], D. Davis[2], L. Davis[26], M. C. Davis[93], P. J. Davis[163,164], M. Dax[1], J. De Bolle[90], M. Deenadayalan[11], J. Degallaix[165], M. De Laurentis[5,28], S. Deléglise[117], F. De Lillo[10], D. Dell'Aquila[131,162], W. Del Pozzo[83,84], F. De Marco[62,63], F. De Matteis[16,17], V. D'Emilio[2], N. Demos[30], T. Dent[126], A. Depasse[10], N. DePergola[52], R. De Pietri[166,167], R. De Rosa[5,28], C. De Rossi[55], R. DeSalvo[168], R. De Simone[151], A. Dhani[1], R. Diab[42],

M. C. Díaz[160], M. Di Cesare[28], G. Dideron[169], N. A. Didio[75], T. Dietrich[1], L. Di Fiore[5], C. Di Fronzo[33], M. Di Giovanni[62,63], T. Di Girolamo[5,28], D. Diksha[31,32], A. Di Michele[85], J. Ding[67,170], S. Di Pace[62,63], I. Di Palma[62,63], F. Di Renzo[114], Divyajyoti[171], A. Dmitriev[111], Z. Doctor[76], E. Dohmen[3], P. P. Doleva[118], D. Dominguez[172], L. D'Onofrio[62], F. Donovan[30], K. L. Dooley[18], T. Dooney[73], S. Doravari[11], O. Dorosh[173], M. Drago[62,63], J. C. Driggers[3], J.-G. Ducoin[67,174], L. Dunn[130], U. Dupletsa[41], D. D'Urso[131,162], H. Duval[175], P.-A. Duverne[35], S. E. Dwyer[3], C. Eassa[3], M. Ebersold[27], T. Eckhardt[82], G. Eddolls[75], B. Edelman[74], T. B. Edo[2], O. Edy[124], A. Effler[61], J. Eichholz[29], H. Einsle[46], M. Eisenmann[20], R. A. Eisenstein[30], A. Ejlli[18], R. M. Eleveld[176], M. Emma[57], K. Endo[177], A. J. Engl[15], E. Enloe[56], L. Errico[5,28], R. C. Essick[178], H. Estellés[1], D. Estevez[64], T. Etzel[2], M. Evans[30], T. Evstafyeva[179], B. E. Ewing[7], J. M. Ezquiaga[137], F. Fabrizi[59,60], F. Faedi[59,60], V. Fafone[16,17], S. Fairhurst[18], A. M. Farah[127], B. Farr[74], W. M. Farr[180,181], G. Favaro[87], M. Favata[182], M. Fays[113], M. Fazio[94], J. Feicht[2], M. M. Fejer[15], R. Felicetti[183], E. Fenyvesi[79,184], D. L. Ferguson[146], S. Ferraiuolo[62,63,185], I. Ferrante[83,84], T. A. Ferreira[9], F. Fidecaro[83,84], P. Figura[91], A. Fiori[83,84], I. Fiori[55], M. Fishbach[178], R. P. Fisher[118], R. Fittipaldi[107,186], V. Fiumara[107,187], R. Flaminio[27], S. M. Fleischer[188], L. S. Fleming[189], E. Floden[93], E. M. Foley[93], H. Fong[138], J. A. Font[135,136], B. Fornal[190], P. W. F. Forsyth[29], K. Franceschetti[166], N. Franchini[67], S. Frasca[62,63], F. Frasconi[84], A. Frattale Mascioli[62,63], Z. Frei[191], A. Freise[32,101], O. Freitas[135,192], R. Frey[74], W. Frischhertz[61], P. Fritschel[30], V. V. Frolov[61], G. G. Fronzé[22], M. Fuentes-Garcia[2], S. Fujii[193], T. Fujimori[194], P. Fulda[42], M. Fyffe[61], B. Gadre[73], J. R. Gair[1], S. Galaudage[195], V. Galdi[168], H. Gallagher[196], S. Gallardo[197], B. Gallego[197], R. Gamba[23], A. Gamboa[1], D. Ganapathy[30], A. Ganguly[11], B. Garaventa[53,54], J. García-Bellido[115,189], C. García-Quirós[198], J. W. Gardner[29], K. A. Gardner[138], J. Gargiulo[55], A. Garron[95], F. Garufi[5,28], C. Gasbarra[16,17], B. Gateley[3], V. Gayathri[8], G. Gemme[53], A. Gennai[84], V. Gennari[123], J. George[97], R. George[146], O. Gerberding[82], L. Gergely[199], Archisman Ghosh[90], Sayantan Ghosh[200], Shaon Ghosh[182], Shrobana Ghosh[39,40], Suprovo Ghosh[11], Tathagata Ghosh[11], L. Giacoppo[62,63], J. A. Giaime[9,61], K. D. Giardina[61], D. R. Gibson[189], D. T. Gibson[179], C. Gier[94], P. Giri[83,84], F. Gissi[92], S. Gkaitatzis[83,84], J. Glanzer[9], F. Glotin[35], J. Godfrey[74], P. Godwin[2], N. L. Goebbels[82], E. Goetz[138], J. Golomb[2], S. Gomez Lopez[62,63], B. Goncharov[41], Y. Gong[201], G. González[9], P. Goodarzi[202], S. Goode[150], A. W. Goodwin-Jones[26], M. Gosselin[55], A. S. Göttel[18], R. Gouaty[27], D. W. Gould[29], K. Govorkova[30], S. Goyal[1], B. Grace[29], A. Grado[5,203], V. Graham[25], A. E. Granados[93], M. Granata[165], V. Granata[66], S. Gras[30], P. Grassia[2], A. Gray[93], C. Gray[3], R. Gray[25], G. Greco[48], A. C. Green[32,101], S. M. Green[124], S. R. Green[204], A. M. Gretarsson[65], E. M. Gretarsson[65], D. Griffith[2], W. L. Griffiths[18], H. L. Griggs[56], G. Grignani[48,85], A. Grimaldi[104,105], C. Grimaud[27], H. Grote[18], D. Guerra[135], D. Guetta[205], G. M. Guidi[59,60], A. R. Guimaraes[9], H. K. Gulati[89], F. Gulminelli[163,164], A. M. Gunny[30], H. Guo[190], W. Guo[26], Y. Guo[31,32], Anchal Gupta[2], Anuradha Gupta[206], Ish Gupta[7], N. C. Gupta[89], P. Gupta[32,73], S. K. Gupta[42], T. Gupta[156], N. Gupte[1], J. Gurs[82], N. Gutierrez[165], F. Guzman[129], H.-Y. H[140], D. Haba[172], M. Haberland[1], S. Haino[207], E. D. Hall[30], E. Z. Hamilton[95], G. Hammond[25], W.-B. Han[208], M. Haney[32], J. Hanks[3], C. Hanna[7], M. D. Hannam[18], O. A. Hannuksela[209], A. G. Hanselman[127], H. Hansen[3], J. Hanson[61], R. Harada[36], A. R. Hardison[210], K. Haris[32,73], T. Harmark[132], J. Harms[41,116], G. M. Harry[211], I. W. Harry[124], J. Hart[71], B. Haskell[91], C.-J. Haster[212], J. S. Hathaway[196], K. Haughian[25], H. Hayakawa[47], K. Hayama[213], R. Hayes[18], A. Heffernan[95], A. Heidmann[117], M. C. Heintze[61], J. Heinze[111], J. Heinzel[30], H. Heitmann[46], F. Hellman[214], P. Hello[35], A. F. Helmling-Cornell[74], G. Hemming[55], O. Henderson-Sapir[108], M. Hendry[25], I. S. Heng[25], E. Hennes[32], C. Henshaw[56], T. Hertog[103], M. Heurs[39,40], A. L. Hewitt[179,215], J. Heyns[30], S. Higginbotham[18], S. Hild[31,32], S. Hill[25], Y. Himemoto[216], N. Hirata[20], C. Hirose[217], S. Hoang[35], S. Hochheim[39,40], D. Hofman[165], N. A. Holland[32,101], K. Holley-Bockelmann[143], Z. J. Holmes[108], D. E. Holz[127], L. Honet[70], C. Hong[15], J. Hornung[74], S. Hoshino[217], J. Hough[25], S. Hourihane[2], E. J. Howell[26], C. G. Hoy[124], C. A. Hrishikesh[16], H.-F. Hsieh[140], C. Hsiung[218], H. C. Hsu[141], W.-F. Hsu[103], P. Hu[143], Q. Hu[25], H. Y. Huang[141], Y.-J. Huang[7], A. D. Huddart[219], B. Hughey[65], D. C. Y. Hui[220], V. Hui[27], S. Husa[95], R. Huxford[7], T. Huynh-Dinh[61], L. Iampieri[62,63], G. A. Iandolo[31], M. Ianni[16,17], A. Iess[84,221], H. Imafuku[36], K. Inayoshi[222], Y. Inoue[141], G. Iorio[87], M. H. Iqbal[29], J. Irwin[25], R. Ishikawa[223], M. Isi[180,181], M. A. Ismail[141], Y. Itoh[194,224], H. Iwanaga[194], M. Iwaya[193], B. R. Iyer[81], V. JaberianHamedan[26], C. Jacquet[123], P.-E. Jacquet[117], S. J. Jadhav[225], S. P. Jadhav[153], T. Jain[179], A. L. James[2], P. A. James[118], R. Jamshidi[33], J. Janquart[32,73], K. Janssens[19,46], N. N. Janthalur[225], S. Jaraba[115], P. Jaranowski[226], R. Jaume[95], W. Javed[18], A. Jennings[3], W. Jia[30], J. Jiang[42], J. Kubisz[227], C. Johanson[134], G. R. Johns[118], N. A. Johnson[42], M. C. Johnston[212], R. Johnston[25], N. Johny[39,40], D. H. Jones[29], D. I. Jones[228], R. Jones[25], S. Jose[171], P. Joshi[7], L. Ju[26], K. Jung[229], J. Junker[29], V. Juste[70], T. Kajita[230], I. Kaku[194], C. Kalaghatgi[32,73,231], V. Kalogera[76], M. Kamiizumi[47], N. Kanda[194,224], S. Kandhasamy[11], G. Kang[232], J. B. Kanner[2], S. J. Kapadia[11], D. P. Kapasi[29], S. Karat[2], C. Karathanasis[38], R. Kashyap[7], M. Kasprzack[2], W. Kastaun[39,40], T. Kato[193], E. Katsavounidis[30], W. Katzman[61], R. Kaushik[97], K. Kawabe[3], R. Kawamoto[194], A. Kazemi[93], D. Keitel[95], J. Kelley-Derzon[42], J. Kennington[7], R. Kesharwani[11], J. S. Key[233], R. Khadela[39,40], S. Khadka[15], F. Y. Khalili[102], F. Khan[39,40], I. Khan[34,234], T. Khanam[157], M. Khursheed[97], N. M. Khusid[180,181], W. Kiendrebeogo[46,235], N. Kijbunchoo[108], C. Kim[236], J. C. Kim[237], K. Kim[238], M. H. Kim[239], S. Kim[220], Y.-M. Kim[238], C. Kimball[76], M. Kinley-Hanlon[25], M. Kinnear[18], J. S. Kissel[3], S. Klimenko[42], A. M. Knee[138], N. Knust[39,40], K. Kobayashi[193], P. Koch[39,40], S. M. Koehlenbeck[15], G. Koekoek[31,32], K. Kohri[240,241], K. Kokeyama[18], S. Koley[41], P. Kolitsidou[111], M. Kolstein[38], K. Komori[36], A. K. H. Kong[140],

A. Kontos[242], M. Korobko[82], R. V. Kossak[39,40], X. Kou[93], A. Koushik[19], N. Kouvatsos[68], M. Kovalam[26], D. B. Kozak[2], S. L. Kranzhoff[31,32], V. Kringel[39,40], N. V. Krishnendu[81], A. Królak[173,243], K. Kruska[39,40], G. Kuehn[39,40], P. Kuijer[32], S. Kulkarni[206], A. Kulur Ramamohan[29], A. Kumar[225], Praveen Kumar[126], Prayush Kumar[81], Rahul Kumar[3], Rakesh Kumar[89], J. Kume[36,87,88], K. Kuns[30], N. Kuntimaddi[18], S. Kuroyanagi[115,244], N. J. Kurth[9], S. Kuwahara[36], K. Kwak[229], K. Kwan[29], J. Kwok[179], G. Lacaille[25], P. Lagabbe[27], D. Laghi[123], S. Lai[144], A. H. Laity[159], M. H. Lakkis[33], E. Lalande[245], M. Lalleman[19], P. C. Lalremruati[246], M. Landry[3], B. B. Lane[30], R. N. Lang[30], J. Lange[146], B. Lantz[15], A. La Rana[62], I. L. Rosa[95], A. Lartaux-Vollard[35], P. D. Lasky[150], J. Lawrence[157], M. N. Lawrence[9], M. Laxen[61], A. Lazzarini[2], C. Lazzaro[87,88], P. Leaci[62,63], Y. K. Lecoeuche[138], H. M. Lee[237], H. W. Lee[247], K. Lee[239], R.-K. Lee[140], R. Lee[30], S. Lee[238], Y. Lee[141], I. N. Legred[2], J. Lehmann[39,40], L. Lehner[169], M. Le Jean[165], A. Lematre[248], M. Lenti[60,249], M. Leonardi[20,104,105], M. Lequime[34], N. Leroy[35], M. Lesovsky[2], N. Letendre[27], M. Lethuillier[114], S. E. Levin[202], Y. Levin[150], K. Leyde[67], A. K. Y. Li[2], K. L. Li[139], T. G. F. Li[103,209], X. Li[147], Z. Li[25], A. Lihos[118], C-Y. Lin[250], C.-Y. Lin[141], E. T. Lin[140], F. Lin[141], H. Lin[141], L. C.-C. Lin[139], Y.-C. Lin[140], F. Linde[32,231], S. D. Linker[197], T. B. Littenberg[251], A. Liu[209], G. C. Liu[218], Jian Liu[26], F. Llamas Villarreal[160], J. Llobera-Querol[95], R. K. L. Lo[137], J.-P. Locquet[103], L. T. London[30,68,98], A. Longo[59,60], D. Lopez[113], M. Lopez Portilla[73], M. Lorenzini[16,17], A. Lorenzo-Medina[126], V. Loriette[35], M. Lormand[61], G. Losurdo[84], T. P. Lott IV[56], J. D. Lough[39,40], H. A. Loughlin[30], C. O. Lousto[196], M. J. Lowry[118], N. Lu[29], H. Lück[39,40], D. Lumaca[17], A. P. Lundgren[124], A. W. Lussier[245], L.-T. Ma[140], S. Ma[169], M. Ma'arif[141], R. Macas[124], A. Macedo[51], M. MacInnis[30], R. R. Maciy[39,40], D. M. Macleod[18], I. A. O. MacMillan[2], A. Macquet[35], D. Macri[30], K. Maeda[177], S. Maenaut[103], I. Magaña Hernandez[8], S. S. Magare[11], C. Magazzù[84], R. M. Magee[2], E. Maggio[1], R. Maggiore[32,101], M. Magnozzi[53,54], M. Mahesh[82], S. Mahesh[252], M. Maini[159], S. Majhi[11], E. Majorana[62,63], C. N. Makarem[2], E. Makelele[71], J. A. Malaquias-Reis[14], U. Mali[178], S. Maliakal[2], A. Malik[97], N. Man[46], V. Mandic[93], V. Mangano[62,63], B. Mannix[74], G. L. Mansell[30,75], G. Mansingh[211], M. Manske[8], M. Mantovani[55], M. Mapelli[87,88,253], F. Marchesoni[48,49,254], D. Marín Pina[37,77,255], F. Marion[27], S. Márka[158], Z. Márka[158], A. S. Markosyan[15], A. Markowitz[2], E. Maros[2], S. Marsat[123], F. Martelli[59,60], I. W. Martin[25], R. M. Martin[182], B. B. Martinez[129], M. Martinez[38,256], V. Martinez[125], A. Martini[104,105], K. Martinovic[68], J. C. Martins[14], D. V. Martynov[111], E. J. Marx[30], L. Massaro[31,32], A. Masserot[27], M. Masso-Reid[25], M. Mastrodicasa[62,63], S. Mastrogiovanni[62], T. Matcovich[48], M. Matiushechkina[39,40], M. Matsuyama[194], N. Mavalvala[30], N. Maxwell[3], G. McCarrol[61], R. McCarthy[3], D. E. McClelland[29], S. McCormick[61], L. McCuller[2], S. McEachin[118], C. McElhenny[118], G. I. McGhee[25], J. McGinn[25], K. B. M. McGowan[143], J. McIver[138], A. McLeod[26], T. McRae[29], D. Meacher[8], Q. Meijer[73], A. Melatos[130], S. Mellaerts[103], A. Menendez-Vazquez[38], C. S. Menoni[100], F. Mera[3], R. A. Mercer[8], L. Mereni[165], K. Merfeld[157], E. L. Merilh[61], J. R. Mérou[95], J. D. Merritt[74], M. Merzougui[46], C. Messenger[25], C. Messick[8], M. Meyer-Conde[194], F. Meylahn[39,40], A. Mhaske[11], A. Miani[104,105], H. Miao[257], I. Michaloliakos[42], C. Michel[165], Y. Michimura[2,36], H. Middleton[111], A. L. Miller[32], S. Miller[2], M. Millhouse[56], E. Milotti[44,183], V. Milotti[87], Y. Minenkov[17], N. Mio[36], Ll. M. Mir[38], L. Mirasola[62,258], M. Miravet-Tenés[135], C.-A. Miritescu[38], A. K. Mishra[81], A. Mishra[11], C. Mishra[171], T. Mishra[42], A. L. Mitchell[32,101], J. G. Mitchell[65], S. Mitra[11], V. P. Mitrofanov[102], R. Mittleman[30], O. Miyakawa[47], S. Miyamoto[193], S. Miyoki[47], G. Mo[30], L. Mobilia[59,60], S. R. P. Mohapatra[2], S. R. Mohite[7], M. Molina-Ruiz[214], C. Mondal[163], M. Mondin[197], M. Montani[59,60], C. J. Moore[179], D. Moraru[3], A. More[11], S. More[11], G. Moreno[3], C. Morgan[18], S. Morisaki[36,193], Y. Moriwaki[177], G. Morras[115], A. Moscatello[87], P. Mourier[95], B. Mours[64], C. M. Mow-Lowry[32,101], F. Muciaccia[62,63], Arunava Mukherjee[259], D. Mukherjee[251], Samanwaya Mukherjee[11], Soma Mukherjee[160], Subroto Mukherjee[89], Suvodip Mukherjee[98,169,260], N. Mukund[30], A. Mullavey[61], J. Munch[108], J. Mundi[211], C. L. Mungioli[26], W. R. Munn Oberg[261], Y. Murakami[193], M. Murakoshi[223], P. G. Murray[25], S. Muusse[29], D. Nabari[104,105], S. L. Nadji[39,40], A. Nagar[22,262], N. Nagarajan[25], K. N. Nagler[65], K. Nakagaki[47], K. Nakamura[20], H. Nakano[263], M. Nakano[2], D. Nandi[9], V. Napolano[55], P. Narayan[206], I. Nardecchia[17], T. Narikawa[193], H. Narola[73], L. Naticchioni[62], R. K. Nayak[246], J. Neilson[92,107], A. Nelson[129], T. J. N. Nelson[61], M. Nery[39,40], A. Neunzert[3], S. Ng[51], L. Nguyen Quynh[264], S. A. Nichols[9], A. B. Nielsen[265], G. Nieradka[91], A. Niko[141], Y. Nishino[20,36], A. Nishizawa[266], S. Nissanke[32,98], E. Nitoglia[114], W. Niu[7], F. Nocera[55], M. Norman[18], C. North[18], J. Novak[109,267,268,269], J. F. Nu no Siles[115], L. K. Nuttall[124], K. Obayashi[223], M. Obergaulinger[135], J. Oberling[3], J. O'Dell[219], M. Oertel[109,267,268,269,270], A. Offermans[103], G. Oganesyan[41,116], J. J. Oh[271], K. Oh[220], T. O'Hanlon[61], M. Ohashi[47], M. Ohkawa[217], F. Ohme[39,40], A. S. Oliveira[158], R. Oliveri[109,267,268], B. O'Neal[118], K. Oohara[272,273], B. O'Reilly[61], N. D. Ormsby[118], M. Orselli[48,85], R. O'Shaughnessy[196], S. O'Shea[25], Y. Oshima[36], S. Oshino[47], S. Ossokine[1], C. Osthelder[2], I. Ota[9], D. J. Ottaway[108], A. Ouzriat[114], H. Overmier[61], B. J. Owen[157], A. E. Pace[7], R. Pagano[9], M. A. Page[20], A. Pai[200], A. Pal[274], S. Pal[246], M. A. Palaia[83,84], M. Pálfi[191], P. P. Palma[16,17,63], C. Palomba[62], P. Palud[67], H. Pan[140], J. Pan[26], K. C. Pan[140], R. Panai[87,258], P. K. Panda[225], S. Pandey[7], L. Panebianco[59,60], P. T. H. Pang[32,73], F. Pannarale[62,63], K. A. Pannone[51], B. C. Pant[97], F. H. Panther[26], F. Paoletti[84], A. Paolone[62,275], E. E. Papalexakis[202], L. Papalini[83,84], G. Papigkiotis[276], A. Paquis[35], A. Parisi[48,85], B.-J. Park[238], J. Park[277], W. Parker[61], G. Pascale[39,40], D. Pascucci[90], A. Pasqualetti[55], R. Passaquieti[83,84], L. Passenger[150], D. Passuello[84], O. Patane[3], D. Pathak[11], M. Pathak[108], A. Patra[18], B. Patricelli[83,84], A. S. Patron[9], K. Paul[171], S. Paul[74], E. Payne[2], T. Pearce[18], M. Pedraza[2], R. Pegna[84], A. Pele[2], F. E. Peña Arellano[45], S. Penn[261], M. D. Penuliar[51], A. Perego[104,105], Z. Pereira[134], J. J. Perez[42],

C. Périgois[87,88,152], G. Perna[87], A. Perreca[104,105], J. Perret[67], S. Perriès[114], J. W. Perry[32,101], D. Pesios[276], S. Petracca[168], C. Petrillo[85], H. P. Pfeiffer[1], H. Pham[61], K. A. Pham[93], K. S. Phukon[32,111,231], H. Phurailatpam[209], M. Piarulli[123], L. Piccari[62,63], O. J. Piccinni[38], M. Pichot[46], M. Piendibene[83,84], F. Piergiovanni[59,60], L. Pierini[62], G. Pierra[114], V. Pierro[92,107], M. Pietrzak[91], M. Pillas[46], F. Pilo[84], L. Pinard[165], I. M. Pinto[28,92,107,278], M. Pinto[55], B. J. Piotrzkowski[8], M. Pirello[3], M. D. Pitkin[179,215], A. Placidi[60], E. Placidi[62,63], M. L. Planas[95], W. Plastino[17,279], R. Poggiani[83,84], E. Polini[27], L. Pompili[1], J. Poon[209], E. Porcelli[32], E. K. Porter[67], C. Posnansky[7], R. Poulton[55], J. Powell[153], M. Pracchia[113], B. K. Pradhan[11], T. Pradier[64], A. K. Prajapati[89], K. Prasai[15], R. Prasanna[225], P. Prasia[11], G. Pratten[111], G. Principe[44,183], M. Principe[92,107,168,278], G. A. Prodi[104,105], L. Prokhorov[111], P. Prosposito[16,17], A. Puecher[32,73], J. Pullin[9], M. Punturo[48], P. Puppo[62], M. Pürrer[159], H. Qi[12], J. Qin[29], G. Quéméner[109,164], V. Quetschke[160], C. Quigley[18], P. J. Quinonez[65], F. J. Raab[3], S. S. Raabith[9], G. Raaijmakers[32,98], S. Raja[97], C. Rajan[97], B. Rajbhandari[196], K. E. Ramirez[61], F. A. Ramis Vidal[95], A. Ramos-Buades[32], D. Rana[11], S. Ranjan[56], K. Ransom[61], P. Rapagnani[62,63], B. Ratto[65], S. Rawat[93], A. Ray[8], V. Raymond[18], M. Razzano[83,84], J. Read[51], M. Recaman Payo[103], T. Regimbau[27], L. Rei[53], S. Reid[94], D. H. Reitze[2], P. Relton[18], A. I. Renzini[2], P. Rettegno[22], B. Revenu[67,280], R. Reyes[197], A. S. Rezaei[62,63], F. Ricci[62,63], M. Ricci[62,63], A. Ricciardone[83,84], J. W. Richardson[202], M. Richardson[108], A. Rijal[65], K. Riles[86], H. K. Riley[18], S. Rinaldi[87,253], J. Rittmeyer[82], C. Robertson[219], F. Robinet[35], M. Robinson[3], A. Rocchi[17], L. Rolland[27], J. G. Rollins[2], A. E. Romano[281], R. Romano[4,5], A. Romero[175], I. M. Romero-Shaw[179], J. H. Romie[61], S. Ronchini[41,116], T. J. Roocke[108], L. Rosa[5,28], T. J. Rosauer[202], C. A. Rose[8], D. Rosińska[119], M. P. Ross[50], M. Rossello[95], S. Rowan[25], S. K. Roy[180,181], S. Roy[73], D. Rozza[121,122], P. Ruggi[55], N. Ruhama[229], E. Ruiz Morales[115,282], K. Ruiz-Rocha[143], S. Sachdev[56], T. Sadecki[3], J. Sadiq[126], P. Saffarieh[32,101], M. R. Sah[260], S. S. Saha[140], S. Saha[140], T. Sainrat[64], S. Sajith Menon[62,63,205], K. Sakai[283], M. Sakellariadou[68], S. Sakon[7], O. S. Salafia[121,122,154], F. Salces-Carcoba[2], L. Salconi[55], M. Saleem[93], F. Salemi[62,63], M. Sallé[32], S. Salvador[109,163,164], A. Sanchez[3], E. J. Sanchez[2], J. H. Sanchez[76], L. E. Sanchez[2], N. Sanchis-Gual[135], J. R. Sanders[210], E. M. Sänger[1], F. Santoliquido[41], T. R. Saravanan[11], N. Sarin[150], S. Sasaoka[172], A. Sasli[276], P. Sassi[48,85], B. Sassolas[165], H. Satari[18,26], R. Sato[217], Y. Sato[177], O. Sauter[42], R. L. Savage[3], T. Sawada[47], H. L. Sawant[11], S. Sayah[27], V. Scacco[16,17], D. Schaetzl[2], M. Scheel[147], A. Schiebelbein[178], M. G. Schiworski[108], P. Schmidt[111], S. Schmidt[73], R. Schnabel[82], M. Schneewind[39,40], R. M. S. Schofield[74], K. Schouteden[103], B. W. Schulte[39,40], B. F. Schutz[18,39,40], E. Schwartz[18], M. Scialpi[284], J. Scott[25], S. M. Scott[29], T. C. Seetharamu[25], M. Seglar-Arroyo[38], Y. Sekiguchi[285], D. Sellers[61], A. S. Sengupta[286], D. Sentenac[55], E. G. Seo[25], J. W. Seo[103], V. Sequino[5,28], M. Serra[62], G. Servignat[267], A. Sevrin[175], T. Shaffer[3], U. S. Shah[56], M. A. Shaikh[237], L. Shao[222], A. K. Sharma[81], P. Sharma[97], S. Sharma-Chaudhary[99], M. R. Shaw[18], P. Shawhan[120], N. S. Shcheblanov[248,287], E. Sheridan[143], Y. Shikano[288,289], M. Shikauchi[36], K. Shimode[47], H. Shinkai[290], J. Shiota[223], D. H. Shoemaker[30], D. M. Shoemaker[146], R. W. Short[3], S. ShyamSundar[97], A. Sider[33], H. Siegel[180,181], M. Sieniawska[10], D. Sigg[3], L. Silenzi[48,49], M. Simmonds[108], L. P. Singer[128], A. Singh[206], D. Singh[7], M. K. Singh[81], S. Singh[20,58], A. Singha[31,32], A. M. Sintes[95], V. Sipala[131,162], V. Skliris[18], B. J. J. Slagmolen[29], T. J. Slaven-Blair[26], J. Smetana[111], J. R. Smith[51], L. Smith[25], R. J. E. Smith[150], W. J. Smith[143], J. Soldateschi[60,249,291], K. Somiya[172], I. Song[140], K. Soni[11], S. Soni[30], V. Sordini[114], F. Sorrentino[53], N. Sorrentino[83,84], H. Sotani[292], R. Soulard[46], A. Southgate[18], V. Spagnuolo[31,32], A. P. Spencer[25], M. Spera[44,293], P. Spinicelli[55], J. B. Spoon[9], C. A. Sprague[264], A. K. Srivastava[89], F. Stachurski[25], D. A. Steer[67], J. Steinlechner[31,32], S. Steinlechner[31,32], N. Stergioulas[276], P. Stevens[35], M. StPierre[159], G. Stratta[62,133,294,295], M. D. Strong[9], A. Strunk[3], R. Sturani[296], A. L. Stuver[52,308], M. Suchenek[91], S. Sudhagar[91], N. Sueltmann[82], L. Suleiman[51], K. D. Sullivan[9], L. Sun[29], S. Sunil[89], J. Suresh[10], P. J. Sutton[18], T. Suzuki[217], Y. Suzuki[223], B. L. Swinkels[32], A. Syx[64], M. J. Szczepańczyk[42,297], P. Szewczyk[119], M. Tacca[32], H. Tagoshi[193], S. C. Tait[2], H. Takahashi[298], R. Takahashi[20], A. Takamori[36], T. Takase[47], K. Takatani[194], H. Takeda[299], K. Takeshita[172], C. Talbot[127], M. Tamaki[193], N. Tamanini[123], D. Tanabe[141], K. Tanaka[47], S. J. Tanaka[223], T. Tanaka[299], D. Tang[26], S. Tanioka[75], D. B. Tanner[42], L. Tao[42], R. D. Tapia[7], E. N. Tapia San Martín[32], R. Tarafder[2], C. Taranto[16,17,63], A. Taruya[300], J. D. Tasson[176], M. Teloi[33], R. Tenorio[95], H. Themann[197], A. Theodoropoulos[135], M. P. Thirugnanasambandam[11], L. M. Thomas[2], M. Thomas[61], P. Thomas[3], J. E. Thompson[147], S. R. Thondapu[97], K. A. Thorne[61], E. Thrane[150], J. Tissino[41], A. Tiwari[11], P. Tiwari[41], S. Tiwari[198], V. Tiwari[111], M. R. Todd[75], A. M. Toivonen[93], K. Toland[25], A. E. Tolley[124], T. Tomaru[20], K. Tomita[194], T. Tomura[47], C. Tong-Yu[141], A. Toriyama[223], N. Toropov[111], A. Torres-Forné[135,136], C. I. Torrie[2], M. Toscani[123], I. Tosta e Melo[301], E. Tournefier[27], A. Trapananti[48,49], F. Travasso[48,49], G. Traylor[61], M. Trevor[120], M. C. Tringali[55], A. Tripathee[86], G. Troian[183], L. Troiano[107,302], A. Trovato[44,183], L. Trozzo[5], R. J. Trudeau[2], T. T. L. Tsang[18], R. Tso[147,309], S. Tsuchida[303], L. Tsukada[7], T. Tsutsui[36], K. Turbang[19,175], M. Turconi[46], C. Turski[90], H. Ubach[37,77], N. Uchikata[193], T. Uchiyama[47], R. P. Udall[2], T. Uehara[304], M. Uematsu[194], K. Ueno[36], S. Ueno[223], V. Undheim[265], T. Ushiba[47], M. Vacatello[83,84], H. Vahlbruch[39,40], N. Vaidya[2], G. Vajente[2], A. Vajpeyi[150], G. Valdes[129], J. Valencia[95], M. Valentini[32,101], S. A. Vallejo-Peña[281], S. Vallero[22], V. Valsan[8], N. van Bakel[32], M. van Beuzekom[32], M. van Dael[32,305], J. F. J. van den Brand[31,32,101], C. Van Den Broeck[32,73], D. C. Vander-Hyde[75], M. van der Sluys[32,73], A. Van de Walle[35], J. van Dongen[32,101], K. Vandra[52], H. van Haevermaet[19], J. V. van Heijningen[32,101], P. Van Hove[64], M. VanKeuren[71], J. Vanosky[2], M. H. P. M. van Putten[13], Z. van Ranst[31,32], N. van Remortel[19], M. Vardaro[31,32],

A. F. Vargas[130], J. J. Varghese[65], V. Varma[134], M. Vasúth[79,310], A. Vecchio[111], G. Vedovato[88], J. Veitch[25], P. J. Veitch[108], S. Venikoudis[10], J. Venneberg[39,40], P. Verdier[114], D. Verkindt[27], B. Verma[134], P. Verma[173], Y. Verma[97], S. M. Vermeulen[2], F. Vetrano[59], A. Veutro[62,63], A. M. Vibhute[3], A. Viceré[59,60], S. Vidyant[75], A. D. Viets[80], A. Vijaykumar[178], A. Vilkha[196], V. Villa-Ortega[126], E. T. Vincent[56], J.-Y. Vinet[46], S. Viret[114], A. Virtuoso[44,183], S. Vitale[30], A. Vives[74], H. Vocca[48,85], D. Voigt[82], E. R. G. von Reis[3], J. S. A. von Wrangel[39,40], S. P. Vyatchanin[102], L. E. Wade[71], M. Wade[71], K. J. Wagner[196], A. Wajid[53,54], M. Walker[118], G. S. Wallace[94], L. Wallace[2], H. Wang[36], J. Z. Wang[86], W. H. Wang[160], Z. Wang[141], G. Waratkar[200], J. Warner[3], M. Was[27], T. Washimi[20], N. Y. Washington[2], D. Watarai[36], K. E. Wayt[71], B. R. Weaver[18], B. Weaver[3], C. R. Weaving[124], S. A. Webster[25], M. Weinert[39,40], A. J. Weinstein[2], R. Weiss[30], F. Wellmann[39,40], L. Wen[26], P. Wessels[39,40], K. Wette[29], J. T. Whelan[196], B. F. Whiting[42], C. Whittle[2], J. B. Wildberger[1], O. S. Wilk[71], D. Wilken[39,40], A. T. Wilkin[202], D. J. Willadsen[80], K. Willetts[18], D. Williams[25], M. J. Williams[124], N. S. Williams[111], J. L. Willis[2], B. Willke[39,40], M. Wils[103], J. Winterflood[26], C. C. Wipf[2], G. Woan[25], J. Woehler[31,32], J. K. Wofford[196], N. E. Wolfe[30], H. T. Wong[141], H. W. Y. Wong[209], I. C. F. Wong[209], J. L. Wright[29], M. Wright[25], C. Wu[140], D. S. Wu[39,40], H. Wu[140], E. Wuchner[51], D. M. Wysocki[8], V. A. Xu[30], Y. Xu[198], N. Yadav[91], H. Yamamoto[2], K. Yamamoto[177], T. S. Yamamoto[244], T. Yamamoto[47], S. Yamamura[193], R. Yamazaki[223], S. Yan[15], T. Yan[111], F. W. Yang[190], F. Yang[158], K. Z. Yang[93], Y. Yang[144], Z. Yarbrough[9], H. Yasui[47], S.-W. Yeh[140], A. B. Yelikar[196], X. Yin[30], J. Yokoyama[36,306], T. Yokozawa[47], J. Yoo[148], H. Yu[147], S. Yuan[26], H. Yuzurihara[47], A. Zadrożny[173], M. Zanolin[65], M. Zeeshan[196], T. Zelenova[55], J.-P. Zendri[88], M. Zeoli[10,113], M. Zerrad[34], M. Zevin[76], A. C. Zhang[158], L. Zhang[2], R. Zhang[42], T. Zhang[111], Y. Zhang[29], C. Zhao[26], Yue Zhao[190], Yuhang Zhao[67], Y. Zheng[99], H. Zhong[93], R. Zhou[214], X.-J. Zhu[307], Z.-H. Zhu[201,307], A. B. Zimmerman[146], M. E. Zucker[2,30], J. Zweizig[2], and The LIGO Scientific Collaboration, the Virgo Collaboration, and the KAGRA Collaboration

[1] Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-14476 Potsdam, Germany
[2] LIGO Laboratory, California Institute of Technology, Pasadena, CA 91125, USA
[3] LIGO Hanford Observatory, Richland, WA 99352, USA
[4] Dipartimento di Farmacia, Università di Salerno, I-84084 Fisciano, Salerno, Italy
[5] INFN, Sezione di Napoli, I-80126 Napoli, Italy
[6] University of Warwick, Coventry CV4 7AL, UK
[7] The Pennsylvania State University, University Park, PA 16802, USA
[8] University of Wisconsin-Milwaukee, Milwaukee, WI 53201, USA
[9] Louisiana State University, Baton Rouge, LA 70803, USA
[10] Université catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium
[11] Inter-University Centre for Astronomy and Astrophysics, Pune 411007, India
[12] Queen Mary University of London, London E1 4NS, UK
[13] Department of Physics and Astronomy, Sejong University, 209 Neungdong-ro, Gwangjin-gu, Seoul 143-747, Republic of Korea
[14] Instituto Nacional de Pesquisas Espaciais, 12227-010 São José dos Campos, São Paulo, Brazil
[15] Stanford University, Stanford, CA 94305, USA
[16] Università di Roma Tor Vergata, I-00133 Roma, Italy
[17] INFN, Sezione di Roma Tor Vergata, I-00133 Roma, Italy
[18] Cardiff University, Cardiff CF24 3AA, UK
[19] Universiteit Antwerpen, 2000 Antwerpen, Belgium
[20] Gravitational Wave Science Project, National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka City, Tokyo 181-8588, Japan
[21] Advanced Technology Center, National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka City, Tokyo 181-8588, Japan
[22] INFN Sezione di Torino, I-10125 Torino, Italy
[23] Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, D-07743 Jena, Germany
[24] Dipartimento di Fisica, Università degli Studi di Torino, I-10125 Torino, Italy
[25] SUPA, University of Glasgow, Glasgow G12 8QQ, UK
[26] OzGrav, University of Western Australia, Crawley, Western Australia 6009, Australia
[27] University Savoie Mont Blanc, CNRS, Laboratoire d'Annecy de Physique des Particules - IN2P3, F-74000 Annecy, France
[28] Università di Napoli "Federico II," I-80126 Napoli, Italy
[29] OzGrav, Australian National University, Canberra, Australian Capital Territory 0200, Australia
[30] LIGO Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
[31] Maastricht University, 6200 MD Maastricht, The Netherlands
[32] Nikhef, 1098 XG Amsterdam, The Netherlands
[33] Université Libre de Bruxelles, Brussels 1050, Belgium
[34] Aix Marseille Univ, CNRS, Centrale Med, Institut Fresnel, F-13013 Marseille, France
[35] Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France
[36] University of Tokyo, Tokyo, 113-0033, Japan
[37] Institut de Ciències del Cosmos (ICCUB), Universitat de Barcelona (UB), c. Martí i Franquès, 1, 08028 Barcelona, Spain
[38] Institut de Física d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Campus UAB, E-08193 Bellaterra (Barcelona), Spain
[39] Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-30167 Hannover, Germany
[40] Leibniz Universität Hannover, D-30167 Hannover, Germany
[41] Gran Sasso Science Institute (GSSI), I-67100 L'Aquila, Italy
[42] University of Florida, Gainesville, FL 32611, USA
[43] Dipartimento di Scienze Matematiche, Informatiche e Fisiche, Università di Udine, I-33100 Udine, Italy
[44] INFN, Sezione di Trieste, I-34127 Trieste, Italy
[45] Tecnológico de Monterrey Campus Guadalajara, 45201 Zapopan, Jalisco, Mexico
[46] Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Artemis, F-06304 Nice, France
[47] Institute for Cosmic Ray Research, KAGRA Observatory, The University of Tokyo, 238 Higashi-Mozumi, Kamioka-cho, Hida City, Gifu 506-1205, Japan
[48] INFN, Sezione di Perugia, I-06123 Perugia, Italy
[49] Università di Camerino, I-62032 Camerino, Italy
[50] University of Washington, Seattle, WA 98195, USA

[51] California State University Fullerton, Fullerton, CA 92831, USA
[52] Villanova University, Villanova, PA 19085, USA
[53] INFN, Sezione di Genova, I-16146 Genova, Italy
[54] Dipartimento di Fisica, Università degli Studi di Genova, I-16146 Genova, Italy
[55] European Gravitational Observatory (EGO), I-56021 Cascina, Pisa, Italy
[56] Georgia Institute of Technology, Atlanta, GA 30332, USA
[57] Royal Holloway, University of London, London TW20 0EX, UK
[58] Astronomical course, The Graduate University for Advanced Studies (SOKENDAI), 2-21-1 Osawa, Mitaka City, Tokyo 181-8588, Japan
[59] Università degli Studi di Urbino "Carlo Bo," I-61029 Urbino, Italy
[60] INFN, Sezione di Firenze, I-50019 Sesto Fiorentino, Firenze, Italy
[61] LIG. Livingston Observatory, Livingston, LA 70754, USA
[62] INFN, Sezione di Roma, I-00185 Roma, Italy
[63] Università di Roma "La Sapienza," I-00185 Roma, Italy
[64] Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France
[65] Embry-Riddle Aeronautical University, Prescott, AZ 86301, USA
[66] Dipartimento di Fisica "E.R. Caianiello," Università di Salerno, I-84084 Fisciano, Salerno, Italy
[67] Université Paris Cité, CNRS, Astroparticule et Cosmologie, F-75013 Paris, France
[68] King's College London, University of London, London WC2R 2LS, UK
[69] Korea Institute of Science and Technology Information, Daejeon 34141, Republic of Korea
[70] Université libre de Bruxelles, 1050 Bruxelles, Belgium
[71] Kenyon College, Gambier, OH 43022, USA
[72] International College, Osaka University, 1-1 Machikaneyama-cho, Toyonaka City, Osaka 560-0043, Japan
[73] Institute for Gravitational and Subatomic Physics (GRASP), Utrecht University, 3584 CC Utrecht, The Netherlands
[74] University of Oregon, Eugene, OR 97403, USA
[75] Syracuse University, Syracuse, NY 13244, USA
[76] Northwestern University, Evanston, IL 60208, USA
[77] Departament de Física Quàntica i Astrofísica (FQA), Universitat de Barcelona (UB), c. Martí i Franqués, 1, 08028 Barcelona, Spain
[78] Dipartimento di Medicina, Chirurgia e Odontoiatria "Scuola Medica Salernitana," Università di Salerno, I-84081 Baronissi, Salerno, Italy
[79] HUN-REN Wigner Research Centre for Physics, H-1121 Budapest, Hungary
[80] Concordia University Wisconsin, Mequon, WI 53097, USA
[81] International Centre for Theoretical Sciences, Tata Institute of Fundamental Research, Bengaluru 560089, India
[82] Universität Hamburg, D-22761 Hamburg, Germany
[83] Università di Pisa, I-56127 Pisa, Italy
[84] INFN, Sezione di Pisa, I-56127 Pisa, Italy
[85] Università di Perugia, I-06123 Perugia, Italy
[86] University of Michigan, Ann Arbor, MI 48109, USA
[87] Università di Padova, Dipartimento di Fisica e Astronomia, I-35131 Padova, Italy
[88] INFN, Sezione di Padova, I-35131 Padova, Italy
[89] Institute for Plasma Research, Bhat, Gandhinagar 382428, India
[90] Universiteit Gent, B-9000 Gent, Belgium
[91] Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, 00-716, Warsaw, Poland
[92] Dipartimento di Ingegneria, Università del Sannio, I-82100 Benevento, Italy
[93] University of Minnesota, Minneapolis, MN 55455, USA
[94] SUPA, University of Strathclyde, Glasgow G1 1XQ, UK
[95] IAC3–IEEC, Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain
[96] Departamento de Matemáticas, Universitat Autònoma de Barcelona, 08193 Bellaterra (Barcelona), Spain
[97] RRCAT, Indore, Madhya Pradesh 452013, India
[98] GRAPPA, Anton Pannekoek Institute for Astronomy and Institute for High-Energy Physics, University of Amsterdam, 1098 XH Amsterdam, The Netherlands
[99] Missouri University of Science and Technology, Rolla, MO 65409, USA
[100] Colorado State University, Fort Collins, CO 80523, USA
[101] Department of Physics and Astronomy, Vrije Universiteit Amsterdam, 1081 HV Amsterdam, The Netherlands
[102] Lomonosov Moscow State University, Moscow 119991, Russia
[103] Katholieke Universiteit Leuven, Oude Markt 13, 3000 Leuven, Belgium
[104] Università di Trento, Dipartimento di Fisica, I-38123 Povo, Trento, Italy
[105] INFN, Trento Institute for Fundamental Physics and Applications, I-38123 Povo, Trento, Italy
[106] Bar-Ilan University, Ramat Gan, 5290002, Israel
[107] INFN, Sezione di Napoli, Gruppo Collegato di Salerno, I-80126 Napoli, Italy
[108] OzGrav, University of Adelaide, Adelaide, South Australia 5005, Australia
[109] Centre national de la recherche scientifique, 75016 Paris, France
[110] Univ Rennes, CNRS, Institut FOTON—UMR 6082, F-35000 Rennes, France
[111] University of Birmingham, Birmingham B15 2TT, UK
[112] Washington State University, Pullman, WA 99164, USA
[113] Université de Liège, B-4000 Liège, Belgium
[114] Université Claude Bernard Lyon 1, CNRS, IP2I Lyon/IN2P3, UMR 5822, F-69622 Villeurbanne, France
[115] Instituto de Fisica Teorica UAM-CSIC, Universidad Autonoma de Madrid, 28049 Madrid, Spain
[116] INFN, Laboratori Nazionali del Gran Sasso, I-67100 Assergi, Italy
[117] Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-Université PSL, Collège de France, F-75005 Paris, France
[118] Christopher Newport University, Newport News, VA 23606, USA
[119] Astronomical Observatory, Warsaw University, 00-478 Warsaw, Poland
[120] University of Maryland, College Park, MD 20742, USA
[121] Università degli Studi di Milano-Bicocca, I-20126 Milano, Italy
[122] INFN, Sezione di Milano-Bicocca, I-20126 Milano, Italy
[123] L2IT, Laboratoire des 2 Infinis—Toulouse, Université de Toulouse, CNRS/IN2P3, UPS, F-31062 Toulouse Cedex 9, France
[124] University of Portsmouth, Portsmouth PO1 3FX, UK
[125] Université de Lyon, Université Claude Bernard Lyon 1, CNRS, Institut Lumière Matière, F-69622 Villeurbanne, France
[126] IGFAE, Universidade de Santiago de Compostela, 15782, Spain

[127] University of Chicago, Chicago, IL 60637, USA
[128] NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[129] Texas A&M University, College Station, TX 77843, USA
[130] OzGrav, University of Melbourne, Parkville, Victoria 3010, Australia
[131] INFN, Laboratori Nazionali del Sud, I-95125 Catania, Italy
[132] Niels Bohr Institute, Copenhagen University, 2100 København, Denmark
[133] Istituto di Astrofisica e Planetologia Spaziali di Roma, 00133 Roma, Italy
[134] University of Massachusetts Dartmouth, North Dartmouth, MA 02747, USA
[135] Departamento de Astronomía y Astrofísica, Universitat de València, E-46100 Burjassot, València, Spain
[136] Observatori Astronòmic, Universitat de València, E-46980 Paterna, València, Spain
[137] Niels Bohr Institute, University of Copenhagen, 2100 Kóbenhavn, Denmark
[138] University of British Columbia, Vancouver, BC V6T 1Z4, Canada
[139] Department of Physics, National Cheng Kung University, No.1, University Road, Tainan City 701, Taiwan
[140] National Tsing Hua University, Hsinchu City 30013, Taiwan
[141] National Central University, Taoyuan City 320317, Taiwan
[142] OzGrav, Charles Sturt University, Wagga Wagga, New South Wales 2678, Australia
[143] Vanderbilt University, Nashville, TN 37235, USA
[144] Department of Electrophysics, National Yang Ming Chiao Tung University, 101 University Street, Hsinchu, Taiwan
[145] Kamioka Branch, National Astronomical Observatory of Japan, 238 Higashi-Mozumi, Kamioka-cho, Hida City, Gifu 506-1205, Japan
[146] University of Texas, Austin, TX 78712, USA
[147] CaRT, California Institute of Technology, Pasadena, CA 91125, USA
[148] Cornell University, Ithaca, NY 14850, USA
[149] Northeastern University, Boston, MA 02115, USA
[150] OzGrav, School of Physics & Astronomy, Monash University, Clayton 3800, Victoria, Australia
[151] Dipartimento di Ingegneria Industriale (DIIN), Università di Salerno, I-84084 Fisciano, Salerno, Italy
[152] INAF, Osservatorio Astronomico di Padova, I-35122 Padova, Italy
[153] OzGrav, Swinburne University of Technology, Hawthorn VIC 3122, Australia
[154] INAF, Osservatorio Astronomico di Brera sede di Merate, I-23807 Merate, Lecco, Italy
[155] Departamento de Matemáticas, Universitat de València, E-46100 Burjassot, València, Spain
[156] Montana State University, Bozeman, MT 59717, USA
[157] Texas Tech University, Lubbock, TX 79409, USA
[158] Columbia University, New York, NY 10027, USA
[159] University of Rhode Island, Kingston, RI 02881, USA
[160] The University of Texas Rio Grande Valley, Brownsville, TX 78520, USA
[161] Chennai Mathematical Institute, Chennai 603103, India
[162] Università degli Studi di Sassari, I-07100 Sassari, Italy
[163] Université de Normandie, ENSICAEN, UNICAEN, CNRS/IN2P3, LPC Caen, F-14000 Caen, France
[164] Laboratoire de Physique Corpusculaire Caen, 6 boulevard du maréchal Juin, F-14050 Caen, France
[165] Université Claude Bernard Lyon 1, CNRS, Laboratoire des Matériaux Avancés (LMA), IP2I Lyon/IN2P3, UMR 5822, F-69622 Villeurbanne, France
[166] Dipartimento di Scienze Matematiche, Fisiche e Informatiche, Università di Parma, I-43124 Parma, Italy
[167] INFN, Sezione di Milano Bicocca, Gruppo Collegato di Parma, I-43124 Parma, Italy
[168] University of Sannio at Benevento, I-82100 Benevento, Italy and INFN, Sezione di Napoli, I-80100 Napoli, Italy
[169] Perimeter Institute, Waterloo, ON N2L 2Y5, Canada
[170] Corps des Mines, Mines Paris, Université PSL, 60 Bd Saint-Michel, 75272 Paris, France
[171] Indian Institute of Technology Madras, Chennai 600036, India
[172] Graduate School of Science, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551, Japan
[173] National Center for Nuclear Research, 05-400 Świerk-Otwock, Poland
[174] Institut d'Astrophysique de Paris, Sorbonne Université, CNRS, UMR 7095, 75014 Paris, France
[175] Vrije Universiteit Brussel, 1050 Brussel, Belgium
[176] Carleton College, Northfield, MN 55057, USA
[177] Faculty of Science, University of Toyama, 3190 Gofuku, Toyama City, Toyama 930-8555, Japan
[178] Canadian Institute for Theoretical Astrophysics, University of Toronto, Toronto, ON M5S 3H8, Canada
[179] University of Cambridge, Cambridge CB2 1TN, UK
[180] Stony Brook University, Stony Brook, NY 11794, USA
[181] Center for Computational Astrophysics, Flatiron Institute, New York, NY 10010, USA
[182] Montclair State University, Montclair, NJ 07043, USA
[183] Dipartimento di Fisica, Università di Trieste, I-34127 Trieste, Italy
[184] HUN-REN Institute for Nuclear Research, H-4026 Debrecen, Hungary
[185] Centre de Physique des Particules de Marseille, 163, avenue de Luminy, 13288 Marseille cedex 09, France
[186] CNR-SPIN, I-84084 Fisciano, Salerno, Italy
[187] Scuola di Ingegneria, Università della Basilicata, I-85100 Potenza, Italy
[188] Western Washington University, Bellingham, WA 98225, USA
[189] SUPA, University of the West of Scotland, Paisley PA1 2BE, UK
[190] The University of Utah, Salt Lake City, UT 84112, USA
[191] Eötvös University, Budapest 1117, Hungary
[192] Centro de Física das Universidades do Minho e do Porto, Universidade do Minho, PT-4710-057 Braga, Portugal
[193] Institute for Cosmic Ray Research, KAGRA Observatory, The University of Tokyo, 5-1-5 Kashiwa-no-Ha, Kashiwa City, Chiba 277-8582, Japan
[194] Department of Physics, Graduate School of Science, Osaka Metropolitan University, 3-3-138 Sugimoto-cho, Sumiyoshi-ku, Osaka City, Osaka 558-8585, Japan
[195] Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Lagrange, F-06304 Nice, France
[196] Rochester Institute of Technology, Rochester, NY 14623, USA
[197] California State University, Los Angeles, Los Angeles, CA 90032, USA
[198] University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland
[199] University of Szeged, Dóm tér 9, Szeged 6720, Hungary
[200] Indian Institute of Technology Bombay, Powai, Mumbai 400 076, India
[201] School of Physics and Technology, Wuhan University, Bayi Road 299, Wuchang District, Wuhan, Hubei, 430072, People's Republic of China
[202] University of California, Riverside, CA 92521, USA

[203] INAF, Osservatorio Astronomico di Capodimonte, I-80131 Napoli, Italy
[204] University of Nottingham, Nottingham NG7 2RD, UK
[205] Ariel University, Ramat HaGolan St 65, Ari'el, Israel
[206] The University of Mississippi, University, MS 38677, USA
[207] Institute of Physics, Academia Sinica, 128 Sec. 2, Academia Rd., Nankang, Taipei 11529, Taiwan
[208] Shanghai Astronomical Observatory, Chinese Academy of Sciences, 80 Nandan Road, Shanghai 200030, People's Republic of China
[209] The Chinese University of Hong Kong, Shatin, NT, Hong Kong, People's Republic of China
[210] Marquette University, Milwaukee, WI 53233, USA
[211] American University, Washington, DC 20016, USA
[212] University of Nevada, Las Vegas, NV 89154, USA
[213] Department of Applied Physics, Fukuoka University, 8-19-1 Nanakuma, Jonan, Fukuoka City, Fukuoka 814-0180, Japan
[214] University of California, Berkeley, CA 94720, USA
[215] University of Lancaster, Lancaster LA1 4YW, UK
[216] College of Industrial Technology, Nihon University, 1-2-1 Izumi, Narashino City, Chiba 275-8575, Japan
[217] Faculty of Engineering, Niigata University, 8050 Ikarashi-2-no-cho, Nishi-ku, Niigata City, Niigata 950-2181, Japan
[218] Department of Physics, Tamkang University, No. 151, Yingzhuan Rd., Danshui Dist., New Taipei City 25137, Taiwan
[219] Rutherford Appleton Laboratory, Didcot OX11 0DE, UK
[220] Department of Astronomy and Space Science, Chungnam National University, 9 Daehak-ro, Yuseong-gu, Daejeon 34134, Republic of Korea
[221] Scuola Normale Superiore, I-56126 Pisa, Italy
[222] Kavli Institute for Astronomy and Astrophysics, Peking University, Yiheyuan Road 5, Haidian District, Beijing 100871, People's Republic of China
[223] Department of Physical Sciences, Aoyama Gakuin University, 5-10-1 Fuchinobe, Sagamihara City, Kanagawa 252-5258, Japan
[224] Nambu Yoichiro Institute of Theoretical and Experimental Physics (NITEP), Osaka Metropolitan University, 3-3-138 Sugimoto-cho, Sumiyoshi-ku, Osaka City, Osaka 558-8585, Japan
[225] Directorate of Construction, Services & Estate Management, Mumbai 400094, India
[226] University of Białystok, 15-424 Białystok, Poland
[227] Astronomical Observatory, Jagiellonian University, 31-007 Cracow, Poland
[228] University of Southampton, Southampton SO17 1BJ, UK
[229] Department of Physics, Ulsan National Institute of Science and Technology (UNIST), 50 UNIST-gil, Ulju-gun, Ulsan 44919, Republic of Korea
[230] Institute for Cosmic Ray Research, The University of Tokyo, 5-1-5 Kashiwa-no-Ha, Kashiwa City, Chiba 277-8582, Japan
[231] Institute for High-Energy Physics, University of Amsterdam, 1098 XH Amsterdam, The Netherlands
[232] Chung-Ang University, Seoul 06974, Republic of Korea
[233] University of Washington Bothell, Bothell, WA 98011, USA
[234] Aix Marseille Université, Jardin du Pharo, 58 Boulevard Charles Livon, 13007 Marseille, France
[235] Laboratoire de Physique et de Chimie de l'Environnement, Université Joseph KI-ZERBO, 9GH2+3V5, Ouagadougou, Burkina Faso
[236] Ewha Womans University, Seoul 03760, Republic of Korea
[237] Seoul National University, Seoul 08826, Republic of Korea
[238] Korea Astronomy and Space Science Institute, Daejeon 34055, Republic of Korea
[239] Sungkyunkwan University, Seoul 03063, Republic of Korea
[240] Institute of Particle and Nuclear Studies (IPNS), High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba City, Ibaraki 305-0801, Japan
[241] Division of Science, National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka City, Tokyo 181-8588, Japan
[242] Bard College, Annandale-On-Hudson, NY 12504, USA
[243] Institute of Mathematics, Polish Academy of Sciences, 00656 Warsaw, Poland
[244] Department of Physics, Nagoya University, ES building, Furocho, Chikusa-ku, Nagoya, Aichi 464-8602, Japan
[245] Université de Montréal/Polytechnique, Montreal, Quebec H3T 1J4, Canada
[246] Indian Institute of Science Education and Research, Kolkata, Mohanpur, West Bengal 741252, India
[247] Inje University Gimhae, South Gyeongsang 50834, Republic of Korea
[248] NAVIER, École des Ponts, Univ Gustave Eiffel, CNRS. Marne-la-Vallée, France
[249] Università di Firenze, Sesto Fiorentino I-50019, Italy
[250] National Center for High-performance Computing, National Applied Research Laboratories, No. 7, R&D 6th Rd., Hsinchu Science Park, Hsinchu City 30076, Taiwan
[251] NAS. Marshall Space Flight Center, Huntsville, AL 35811, USA
[252] West Virginia University, Morgantown, WV 26506, USA
[253] Institut fuer Theoretische Astrophysik, Zentrum fuer Astronomie Heidelberg, Universitaet Heidelberg, Albert Ueberle Str. 2, 69120 Heidelberg, Germany
[254] School of Physics Science and Engineering, Tongji University, Shanghai 200092, People's Republic of China
[255] Institut d'Estudis Espacials de Catalunya, c. Gran Capità, 2-4, 08034 Barcelona, Spain
[256] Institucio Catalana de Recerca i Estudis Avançats (ICREA), Passeig de Lluís Companys, 23, 08010 Barcelona, Spain
[257] Tsinghua University, Beijing 100084, People's Republic of China
[258] INFN Cagliari, Physics Department, Università degli Studi di Cagliari, Cagliari 09042, Italy
[259] Saha Institute of Nuclear Physics, Bidhannagar, West Bengal 700064, India
[260] Tata Institute of Fundamental Research, Mumbai 400005, India
[261] Hobart and William Smith Colleges, Geneva, NY 14456, USA
[262] Institut des Hautes Etudes Scientifiques, F-91440 Bures-sur-Yvette, France
[263] Faculty of Law, Ryukoku University, 67 Fukakusa Tsukamoto-cho, Fushimi-ku, Kyoto City, Kyoto 612-8577, Japan
[264] Department of Physics and Astronomy, University of Notre Dame, 225 Nieuwland Science Hall, Notre Dame, IN 46556, USA
[265] University of Stavanger, 4021 Stavanger, Norway
[266] Physics Program, Graduate School of Advanced Science and Engineering, Hiroshima University, 1-3-1 Kagamiyama, Higashihiroshima City, Hiroshima 903-0213, Japan
[267] Laboratoire Univers et Théories, Observatoire de Paris, 92190 Meudon, France
[268] Observatoire de Paris, 75014 Paris, France
[269] Université PSL, 75006 Paris, France
[270] Université de Paris Cité, 75006 Paris, France
[271] National Institute for Mathematical Sciences, Daejeon 34047, Republic of Korea
[272] Graduate School of Science and Technology, Niigata University, 8050 Ikarashi-2-no-cho, Nishi-ku, Niigata City, Niigata 950-2181, Japan
[273] Niigata Study Center, The Open University of Japan, 754 Ichibancho, Asahimachi-dori, Chuo-ku, Niigata City, Niigata 951-8122, Japan
[274] CSIR-Central Glass and Ceramic Research Institute, Kolkata, West Bengal 700032, India
[275] Consiglio Nazionale delle Ricerche - Istituto dei Sistemi Complessi, I-00185 Roma, Italy

[276] Department of Physics, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
[277] Department of Astronomy, Yonsei University, 50 Yonsei-Ro, Seodaemun-Gu, Seoul 03722, Republic of Korea
[278] Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi," I-00184 Roma, Italy
[279] Dipartimento di Ingegneria Industriale, Elettronica e Meccanica, Università degli Studi Roma Tre, I-00146 Roma, Italy
[280] Subatech, CNRS/IN2P3—IMT Atlantique—Nantes Université, 4 rue Alfred Kastler, BP 20722, 44307 Nantes Cédex 03, France
[281] Universidad de Antioquia, Medellín, Colombia
[282] Departamento de Física—ETSIDI, Universidad Politécnica de Madrid, 28012 Madrid, Spain
[283] Department of Electronic Control Engineering, National Institute of Technology, Nagaoka College, 888 Nishikatakai, Nagaoka City, Niigata 940-8532, Japan
[284] Università Degli Studi Di Ferrara, Via Savonarola, 9, 44121 Ferrara FE, Italy
[285] Faculty of Science, Toho University, 2-2-1 Miyama, Funabashi City, Chiba 274-8510, Japan
[286] Indian Institute of Technology, Palaj, Gandhinagar, Gujarat 382355, India
[287] Laboratoire MSME, Cité Descartes, 5 Boulevard Descartes, Champs-sur-Marne, 77454 Marne-la-Vallée Cedex 2, France
[288] Institute of Systems and Information Engineering, University of Tsukuba, 1-1-1, Tennodai, Tsukuba, Ibaraki 305-8573, Japan
[289] Institute for Quantum Studies, Chapman University, 1 University Dr., Orange, CA 92866, USA
[290] Faculty of Information Science and Technology, Osaka Institute of Technology, 1-79-1 Kitayama, Hirakata City, Osaka 573-0196, Japan
[291] INAF, Osservatorio Astrofisico di Arcetri, I-50125 Firenze, Italy
[292] iTHEMS (Interdisciplinary Theoretical and Mathematical Sciences Program), RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
[293] Scuola Internazionale Superiore di Studi Avanzati, Via Bonomea, 265, I-34136, Trieste TS, Italy
[294] Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany
[295] INAF, Osservatorio di Astrofisica e Scienza dello Spazio, I-40129 Bologna, Italy
[296] Universidade Estadual Paulista, 01140-070 São Paulo, Brazil
[297] Faculty of Physics, University of Warsaw, Ludwika Pasteura 5, 02-093 Warszawa, Poland
[298] Research Center for Space Science, Advanced Research Laboratories, Tokyo City University, 3-3-1 Ushikubo-Nishi, Tsuzuki-Ku, Yokohama, Kanagawa 224-8551, Japan
[299] Department of Physics, Kyoto University, Kita-Shirakawa Oiwake-cho, Sakyou-ku, Kyoto City, Kyoto 606-8502, Japan
[300] Yukawa Institute for Theoretical Physics (YITP), Kyoto University, Kita-Shirakawa Oiwake-cho, Sakyou-ku, Kyoto City, Kyoto 606-8502, Japan
[301] University of Catania, Department of Physics and Astronomy, Via S. Sofia, 64, 95123 Catania CT, Italy
[302] Dipartimento di Scienze Aziendali - Management and Innovation Systems (DISA-MIS), Università di Salerno, I-84084 Fisciano, Salerno, Italy
[303] National Institute of Technology, Fukui College, Geshi-cho, Sabae-shi, Fukui 916-8507, Japan
[304] Department of Communications Engineering, National Defense Academy of Japan, 1-10-20 Hashirimizu, Yokosuka City, Kanagawa 239-8686, Japan
[305] Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands
[306] Kavli Institute for the Physics and Mathematics of the Universe, WPI, The University of Tokyo, 5-1-5 Kashiwa-no-Ha, Kashiwa City, Chiba 277-8583, Japan
[307] Department of Astronomy, Beijing Normal University, Xinjiekouwai Street 19, Haidian District, Beijing 100875, People's Republic of China
Received 2024 October 24; revised 2025 March 11; accepted 2025 March 26; published 2025 May 22

Abstract

We present the results of a search for gravitational-wave transients associated with core-collapse supernova SN 2023ixf, which was observed in the galaxy Messier 101 via optical emission on 2023 May 19, during the LIGO–Virgo–KAGRA 15th Engineering Run. We define a five-day on-source window during which an accompanying gravitational-wave signal may have occurred. No gravitational waves have been identified in data when at least two gravitational-wave observatories were operating, which covered ∼14% of this five-day window. We report the search detection efficiency for various possible gravitational-wave emission models. Considering the distance to M101 (6.7 Mpc), we derive constraints on the gravitational-wave emission mechanism of core-collapse supernovae across a broad frequency spectrum, ranging from 50 Hz to 2 kHz, where we assume the gravitational-wave emission occurred when coincident data are available in the on-source window. Considering an ellipsoid model for a rotating proto-neutron star, our search is sensitive to gravitational-wave energy $1 \times 10^{-4}\, M_{\odot} c^2$ and luminosity $2.6 \times 10^{-4}\, M_{\odot} c^2\ \mathrm{s}^{-1}$ for a source emitting at 82 Hz. These constraints are around an order of magnitude more stringent than those obtained so far with gravitational-wave data. The constraint on the ellipticity of the proto-neutron star that is formed is as low as 1.08, at frequencies above 1200 Hz, surpassing past results.

Unified Astronomy Thesaurus concepts: Gravitational waves (678)

1. Introduction

The direct detection of gravitational waves (GWs) from a binary black hole merger (B. P. Abbott et al. 2016a) started the field of GW astronomy and was followed by similar mergers (B. Abbott et al. 2019; R. Abbott et al. 2021a, 2023a, 2024). Two years later, the merger of two neutron stars was observed both with GWs and across the electromagnetic spectrum (B. P. Abbott et al. 2017a, 2017b), leading to the birth of GW multimessenger astronomy. More recently, the observation of mergers of mixed systems (R. Abbott et al. 2021b; A. G. Abac et al. 2024) is allowing measurement of the merger rates of all types of compact binary systems (R. Abbott et al. 2023b).

Core-collapse supernovae (CCSNe) are the explosions of massive stars—masses above $8\, M_{\odot}$ at the end of their evolution—leading to the production of neutron stars and black holes (A. Burrows et al. 1995; K. Kotake et al. 2006; H.-T. Janka 2012). CCSNe are astrophysical sources with multimessenger emission, having historically been observed over the electromagnetic spectrum and, for SN 1987A, also with low-energy neutrinos (R. M. Bionta et al. 1987; K. Hirata et al. 1987; E. N. Alekseev et al. 1987). However, the GW emission of CCSNe is still undetected. The combination of GW and neutrino observations can provide information about the

[308] Deceased, 2024 September.
[309] Deceased, 2023 July.
[310] Deceased, 2024 February.

collapse and the onset of the explosion, since both messengers are emitted from the core very soon after the collapse and have negligible interactions with the surrounding matter (H.-T. Janka 2012). On the other hand, electromagnetic emission is produced in the outer layers of the star and is delayed.

The GW emission from CCSNe is weaker than the emission from compact binary mergers, making it detectable by the advanced generation of detectors only for nearby supernovae (S. E. Gossan et al. 2016; R. Abbott et al. 2021c; M. J. Szczepańczyk et al. 2021). The most likely opportunity for observations are Galactic CCSNe, but the expected rate is of the order of one or two per century (S. V. Bergh & G. A. Tammann 1991; E. Cappellaro et al. 1993; G. A. Tammann et al. 1994; R. Diehl et al. 2006; W. Li et al. 2011; S. M. Adams et al. 2013). However, due to the large uncertainties of the progenitors and GW emission models, we carry out searches for GW emission from CCSNe out to distances of 20 Mpc (B. P. Abbott et al. 2016b, 2020; M. J. Szczepańczyk et al. 2024).

SN 2023ixf was identified in Messier 101 (M101) during its rise, making it one of the closest type II CCSNe observed. The two LIGO observatories were in observing mode during the fifteenth Engineering Run (ER15) of the LIGO–Virgo–KAGRA network (J. Aasi et al. 2015; F. Acernese et al. 2015; T. Akutsu et al. 2021). In this article, we report the results of the search for GWs and the new constraints on GW emission obtained with SN 2023ixf.

2. SN 2023ixf and ER15 Data

2.1. Summary of SN 2023ixf Multimessenger Observations

SN 2023ixf (R.A. = 14:03:38.562, decl. = +54:18:41.94, J2000) was discovered on 2023 May 19 by K. Itagaki (2023) with a clear (unfiltered) magnitude of 14.9 in the host galaxy M101 (NGC 5457, Pinwheel Galaxy). M101 is at a distance of about 6.7 Mpc (see Section 2.3), making SN 2023ixf one of the nearest CCSNe observed in recent years. In addition, this galaxy is a well-observed object with an extensive set of prediscovery observations. SN 2023ixf was quickly classified as a type II supernova a few hours after the discovery (D. A. Perley et al. 2023). Due to its prompt discovery and short distance, SN 2023ixf was the target of extensive electromagnetic coverage. The optical light curve shows a rise to a maximum at about five days, followed by a plateau lasting for about one month, and a slow decline later (D. Hiramatsu et al. 2023; G. Hosseinzadeh et al. 2023; L. A. Sgro et al. 2023; R. S. Teja et al. 2023; M. Yamanaka et al. 2023; G. Li et al. 2024). The early spectroscopic observations show flash ionization features of hydrogen, helium, nitrogen, and carbon, and an increase in temperature not explained by pure shock cooling, suggesting a delayed shock breakout in a dense circumstellar medium (E. Berger et al. 2023; K. A. Bostroem et al. 2023; B. W. Grefenstette et al. 2023; D. Guetta et al. 2023; D. Hiramatsu et al. 2023; G. Hosseinzadeh et al. 2023; W. V. Jacobson-Galan et al. 2023; C. D. Kilpatrick et al. 2023; M. Koenig 2023; Z. Niu et al. 2023; J. L. Pledger & M. M. Shara 2023; N. Smith et al. 2023; R. S. Teja et al. 2023; S. S. Vasylyev et al. 2023; M. Yamanaka et al. 2023; M. C. Bersten et al. 2024; P. Chandra et al. 2024; G. Li et al. 2024; L. Martinez et al. 2024; K. Murase 2024; Y.-J. Qin et al. 2024; S. D. Van Dyk et al. 2024; D. Xiang et al. 2024; E. A. Zimmerman et al. 2024). The earliest detections of X-ray and radio emission occurred four days (B. W. Grefenstette et al. 2023) and one month (D. Matthews et al. 2023) after the discovery, respectively. The hard X-ray (B. W. Grefenstette et al. 2023) and soft X-ray (P. Chandra et al. 2024; S. Panjkov et al. 2024) observations suggest a high and decreasing neutral hydrogen column density close to SN 2023ixf. SN 2023ixf was not detected in gamma rays (G. Marti-Devesa 2023) or in neutrinos (R. Abbasi et al. 2023; M. Nakahata & Super-Kamiokande Collaboration 2023; J. Thwaites et al. 2023).

2.2. Nature and Mass of Progenitor

A large set of M101 prediscovery imaging observations from ground-based telescopes, the Hubble Space Telescope, and the Spitzer Space Telescope suggest the nature of the SN 2023ixf progenitor to be a dusty and variable red supergiant, with an estimated mass ranging from 8 to 20 $M_{\odot}$ (Y. Dong et al. 2023; N. Flinner et al. 2023; D. Hiramatsu et al. 2023; J. E. Jencson et al. 2023; J. M. M. Neustadt et al. 2023; Z. Niu et al. 2023; J. L. Pledger & M. M. Shara 2023; M. D. Soraisam et al. 2023; L. Ferrari et al. 2024; T. J. Moriya & A. Singh 2024; C. L. Ransome et al. 2024; S. D. Van Dyk et al. 2024; D. Xiang et al. 2024).

The circumstellar medium could have been produced by an enhancement in the mass loss before the SN explosion, but several archival investigations did not find any pre-explosion outburst in the years before the discovery (Y. Dong et al. 2023; N. Flinner et al. 2023; J. E. Jencson et al. 2023; J. M. M. Neustadt et al. 2023; M. D. Soraisam et al. 2023; C. L. Ransome et al. 2024), while detecting amplitude pulsations (C. D. Kilpatrick et al. 2023; M. D. Soraisam et al. 2023).

2.3. M101 Distance

The distance of the supernova host galaxy is relevant to constrain the GW energy emitted. Since astronomical distances are estimated using a broad range of methods, we have considered the available published values to estimate the distance to M101. More precisely, we have considered the distance estimations reported in the NASA Extragalactic Database (G. Helou et al. 1991), a total of 115 measurements using 12 different methods: Cepheids, planetary nebulae luminosity function, supernova Ia, tip of the red giant branch, SN II optical, brightest stars, Tully–Fisher relation, M stars, RSV stars, S Dor stars, H II region diameter, and SN II radio. We adopt the median of the remaining 115 data points, 6.7 Mpc, with a standard deviation of 0.9 Mpc, as the estimated distance of SN 2023ixf.

2.4. On-source Window

The on-source window is the time interval containing the core bounce and the following GW emission. We denote the start and end times of this interval as t_1 and t_2, respectively. Due to the availability of well-sampled public photometric data of SN 2023ixf, the on-source window could be estimated using the early photometric observations that include the nondetections before the rise to peak brightness as shown in Figure 1. The first detection is at MJD = 60082.82611, at a CV magnitude of 18.76 ± 0.25 (V. Chufarin et al. 2023), following the last prediscovery observation at MJD = 60082.66041667, clear magnitude > 20.4 (Y. Mao et al. 2023). For SN 2023ixf, t_2 is well approximated by the first detection, while t_1 involves the delay between collapse and shock breakout, which occurs at

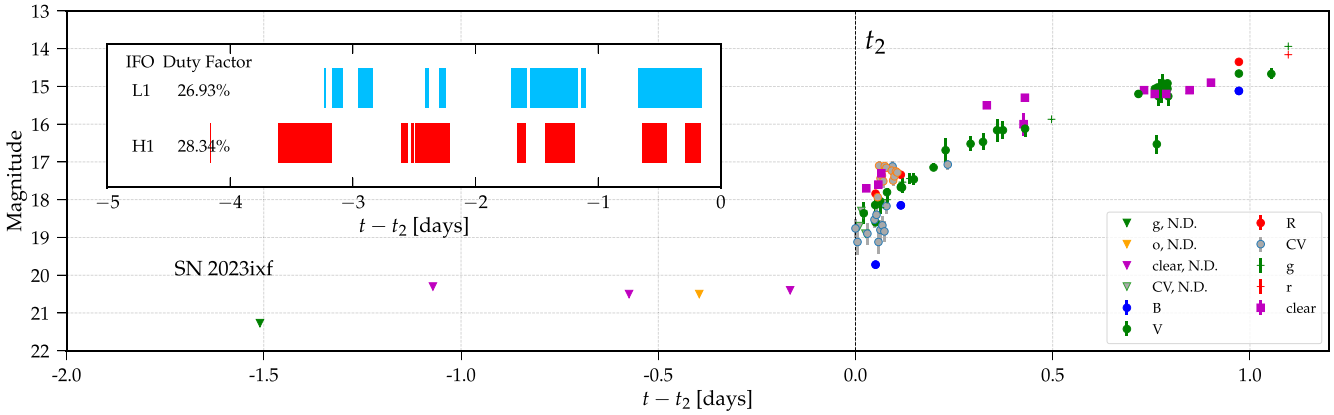

Figure 1. Early evolution of SN 2023ixf covering different photometric bands (*B*, *V*, *R*, *g*, *o*) and unfiltered observations (CV, clear); N.D. marks nondetections; inset: duty cycle of LIGO Hanford (H1) and Livingston (L1) detectors within the on-source window described in the text. Photometric data sources: Transient Name Server Astronotes, Astronomical Telegrams, AAVSO, L. A. Sgro et al. (2023), and G. Li et al. (2024).

a time between t_2 and the latest prediscovery observation. The time delay depends on many properties of the progenitor, including its mass. Considering the large spread in mass estimations and the relation between mass and time delay found by B. L. Barker et al. (2022, Figure 6), we have adopted a conservative maximal on-source window duration of five days, from 2023-05-13T19:49:35 to 2023-05-18T19:49:35 UTC.

2.5. ER15 Data

ER15 took place at the LIG. Livingston and Hanford Observatories from 2023 April 7 to 2023 May 24 following a period of upgrades and commissioning that improved the detectors' sensitivity from the previous observing run. During ER15, the observatories collected data as if it were a normal observing run with the exception that calibration, commissioning, and noise investigations are performed. These studies are concentrated near the beginning of ER15 and taper to an as-needed basis toward the last week. The collapse of SN 2023ixf likely happened during this end period of ER15, as did the time period spanned by this search.

The uncertainty in the strain calibration has been found to be similar to that in previous observing runs (L. Sun et al. 2021). Its effect on the search is marginal and thus ignored. Within the on-source window, the two LIGO observatories were operating jointly for ∼0.8 day.

Transient data artifacts, referred to as glitches, contaminate the data and can affect the confidence estimation of candidate events. The search has been carried out with strain channels `L1:GDS-CALIB_STRAIN_CLEAN_AR` and `H1:GDS-CALIB_STRAIN_CLEAN_AR` where `CLEAN` means some of the well identified noise sources have been removed (R. Abbott et al. 2023c). Data quality studies reveal auxiliary channels that are insensitive to GWs and have a strong correlation to the glitches in the output of the detector. These times of poor data quality are then removed (vetoed) (D. Davis et al. 2021) and represent 15% of the coincident time within the on-source window. This gives the analysis time of ∼0.68 day.

3. Search

3.1. Coherent WaveBurst

We use coherent WaveBurst, a model-agnostic search algorithm, for the detection and reconstruction of transient GW signals (S. Klimenko et al. 2016). The algorithm identifies GW transients by searching for excess power in spectrograms and reconstructs coherent signals in multiple detectors. In previous CCSN searches (M. J. Szczepańczyk et al. 2023), spectrograms were obtained with the Wilson–Daubechies–Meyer wavelet transform (V. Necula et al. 2012). The SN 2023ixf analysis uses the high-resolution wavescan transform (S. Klimenko 2022) that utilizes both the excess-power and cross-power statistics for the identification of GW signals and enables more accurate reconstruction of the signal waveforms T. Mishra et al. (2025). The signal detection statistic η_0 is defined as $\eta_0 = \sqrt{E_c}$ where E_c is the total coherent energy across the detector network (S. Klimenko et al. 2016). To further separate GW signals from the noise, the triggers are then reranked with a reduced statistic $\eta_r = \eta_0 \times W_{\rm XGB}$, where $W_{\rm XGB}$ is the XGBoost classification penalty factor, which ranges between 0 (noiselike) and 1 (signal-like) (T. Mishra et al. 2021; M. J. Szczepańczyk et al. 2023). For this search, the XGBoost algorithm uses the sky location of SN 2023ixf to improve detection sensitivity.

3.2. CCSN Models

To test the sensitivity of the search, we use a range of different waveforms from numerical simulations, which span the expected progenitor parameter space. For nonrotating sources we use the $15\,M_\odot$ SFHx s15 model from T. Kuroda et al. (2016; Kur+16 s15), the $15\,M_\odot$ D15 model from A. Mezzacappa et al. (2023; Mez+23 D15), the $20\,M_\odot$ mesa20_pert model from E. P. O'Connor & S. M. Couch (2018; Oco+18 m20p), the $18\,M_\odot$ s18 model from J. Powell & B. Müller (2019; Pow+19 s18), the $40\,M_\odot$ nonrotating (NR) model from K.-C. Pan et al. (2021; Pan +21 NR), and the $25\,M_\odot$ s25 model from D. Radice et al. (2019; Rad+19 s25). For examples of progenitors at the lower mass end, we include model he3.5 from J. Powell & B. Müller (2019; Pow+19 he3.5), which is an ultrastripped progenitor with a $3.5\,M_\odot$ helium core, and the $13\,M_\odot$ s13 model from D. Radice et al. (2019; Rad+19 s13).

We also include waveforms from more energetic types of explosions. We include the $50\,M_\odot$ s50 model from T. Kuroda et al. (2022; Kur+22 s50), as an example of a CCSN explosion powered by a first-order quantum-chromodynamics phase transition. We include several rotating models, as the rotation can significantly increase the GW amplitude. They are the $40\,M_\odot$ model SR from K.-C. Pan et al. (2021; Pan+21 SR), the $15\,M_\odot$ s15fr model from H. Andresen et al. (2019; And+19 s15fr), and the $39\,M_\odot$ helium star model m39 from J. Powell &

B. Müller (2020; Pow+20 m39). We also include two models that include both rapid rotation and magnetic fields, as this can result in powerful magnetorotational explosions. They are the 39 $M_\odot$ m39_B12 model from J. Powell et al. (2023; Pow+23 B12) and model 3d_signal_O from M. Obergaulinger & M. A. Aloy (2020; Obe+20 signal_O).

We also consider a phenomenological emission model related to the development of long-lasting bar-mode instabilities inside the proto-neutron star (PNS; C. D. Ott 2010; S. E. Gossan et al. 2016). Assuming the PNS is well modeled as a triaxial ellipsoid rotating around the z-axis, one can approximate the GW emission with sine-Gaussian waveforms

$$h_+(t) = \frac{1}{2}h_0[1 + \cos^2\iota]e^{-t^2/\tau^2}\cos(2\pi f_0 t),$$
$$h_\times(t) = h_0 \cos\iota\, e^{-t^2/\tau^2}\sin(2\pi f_0 t), \quad (1)$$

where

$$h_0 = \frac{2}{D}\frac{G}{c^4}\frac{I_{zz}\epsilon}{2}(2\pi f_0)^2, \quad (2)$$

I_{zz} and ϵ are the moment of inertia and ellipticity of the ellipsoid, f_0 is twice the rotation frequency, D is the source distance, and ι is the inclination angle of the z-axis with respect to the line of sight. $I_{zz}\epsilon$ is a free parameter. Throughout the paper, we consider the canonical value for neutron stars $I_{zz} = 10^{45}$ g cm^2 (V. Paschalidis & N. Stergioulas 2017) and keep ϵ as a free parameter.

4. Results

4.1. Search Result and Background Estimation

The detector data contain a variety of transient noise sources that contribute to the search background. To assess the significance of each trigger, we compute the false-alarm rate (FAR), which estimates the frequency of noise triggers mistakenly identified as potential GW events. Within the on-source window, the trigger with the lowest FAR is considered a GW event candidate. In this search, the event candidate with the lowest FAR has a FAR of 2.11 per day, giving a false-alarm probability of $1 - e^{-T_{\rm obs}\times \rm FAR} = 0.75$; i.e., a probability of 0.75 that noise alone would produce a trigger of this FAR or lower ($T_{\rm obs} = 0.68$ day). This suggests that this trigger is likely due to noise.

4.2. Detection Efficiency

To evaluate the search sensitivity, we take the signal models described in Section 3.2 and randomize the source orientation such that it is uniformly distributed over a sphere. Then we add waveforms to the detector coincident data within the on-source window for the sky location of SN 2023ixf. We compute the search detection efficiency, defined as the fraction of detected signals with FAR lower than 1 event in 10 years. This FAR corresponds to a false-alarm probability of 1.9×10^{-4}. At the distance of SN 2023ixf none of the 14 models from numerical simulations are detected. In Table 1 we report the distance at which we recover 90% of the added signals for all 14 CCSN models. The distances reach up to 6.9 kpc for the nonrotating explosions, which means that signals from nonrotating or slowly rotating progenitor CCSNe could be missed within the Galaxy for sources further than the Galactic center. The distances for the more extreme models are around a factor of 4 larger than for the nonrotating explosions, exceeding the Galaxy boundaries—29.9 kpc for model Pow+23 B12—but without reaching the distance of the Large Magellanic Cloud. Finally, for the explosion driven by a first-order quantum-chromodynamics phase transition, a detection of 90% is never achieved because only one polarization is extracted from the 2D numerical simulations.

Table 1
Distance of the 90% Detection Efficiency Reached with CCSN Waveform Models for a FAR of 1 Event in 10 Years

Waveform Models		Distance (kpc)
Nonrotating models	Kur+16 s15	**6.9**
	Mez+23 D15	2.9
	Oco+18 m20p	1.0
	Pow+19 s18	5.5
	Pow+19 he3.5	2.8
	Rad+19 s13	0.6
	Rad+19 s25	5.8
	Pan+21 NR	6.6
Rotating models	And+19 s15fr	1.8
	Obe+20 Signal_O	13.4
	Pan+21 SR	18.2
	Pow+20 m39	19.6
	Pow+23 B12	**29.9**
Phase transition model	Kur+22 s50	8.9*

Note. Values in bold represent the farthest distance reached for each family of models. For the model 2D Kur+22 s50, detection efficiency remains lower than 90% whatever the distance because there is only one polarization. We report the 50% detection efficiency instead, which is marked with *.

Figure 2 shows the detection efficiency for long-lasting bar-mode waveforms with frequencies between 82 Hz and 2 kHz and signal durations between 1 ms and 1 s. The right plot is as a function of $I_{zz}\epsilon$ for a source at the location of SN 2023ixf. The left plot is as a function of distance for $I_{zz}\epsilon \sim 0.1 \times 10^{45}$ g cm^2. The sensitivity increases with the signal's peak frequency and duration. For instance, we could detect at 90% confidence level a signal lasting 1 s at 2 kHz for $I_{zz}\epsilon \sim 10^{45}$ g cm^2. For lower frequencies, if we assume the canonical value $I_{zz} \sim 10^{45}$ g cm^2, the source would need to be highly deformed ($\epsilon \gg 1$).

5. Constraints

Assuming the GW emission occurred when coincident data are available in the on-source window, we establish constraints on several quantities characterizing a core collapse, including emitted GW energy, luminosity, and PNS ellipticity, considering the long-lasting bar-mode model. These bar-mode instabilities are sometimes present in simulations at a low ratio of rotational kinetic energy to gravitational potential energy ($T/|W|$).

5.1. Constraints on GW Energy and Luminosity

Assuming a rotating core, the emitted GW energy is (P. J. Sutton 2013)

$$E_{\rm GW} = \frac{2}{5}\frac{\pi^2 c^3}{G}D^2 f_0^2 \int_{-\infty}^{\infty}[h_+^2(t) + h_\times^2(t)]\quad dt$$
$$= \frac{2}{5}\frac{\pi^2 c^3}{G}\sqrt{\frac{\pi}{2}}\tau D^2 f_0^2 h_0^2 \quad (3)$$

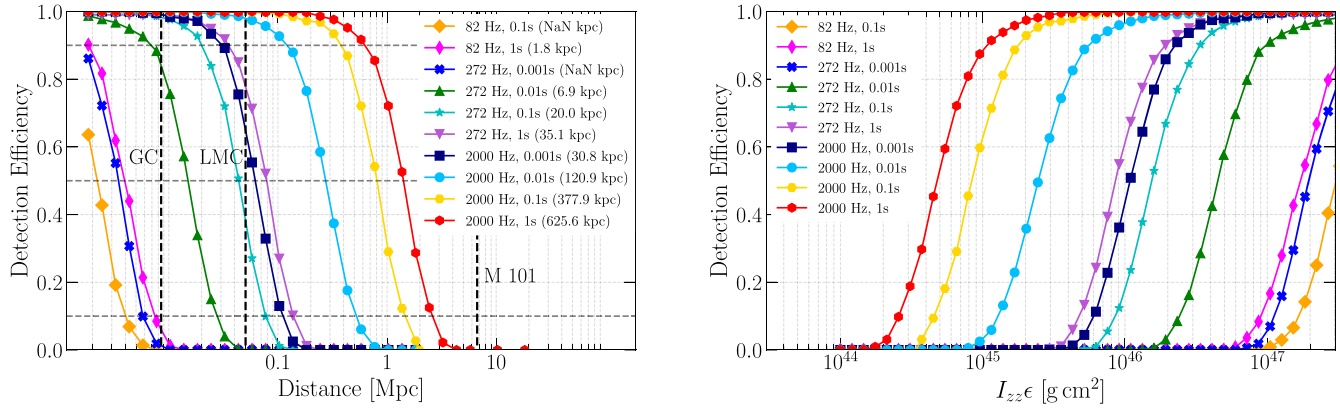

Figure 2. Detection efficiency of a GW source in the direction of M101, and within the on-source window of SN 2023ixf, for a FAR of less than 1 event in 10 years. The long-lasting bar-mode GW emission model is considered for various peak frequencies and durations. In the left panel $I_{zz}\epsilon$ is fixed to 0.1×10^{45} g cm^2 and the detection efficiency is shown as function of the distance to the source. Horizontal dashed lines show 10%, 50%, and 90% detection efficiencies, and the distances of the Galactic center (GC), Large Magellanic Cloud (LMC), and and M101 are shown as references. On the right panel, the distance is fixed to M101 and the detection efficiency is shown as function of $I_{zz}\epsilon$.

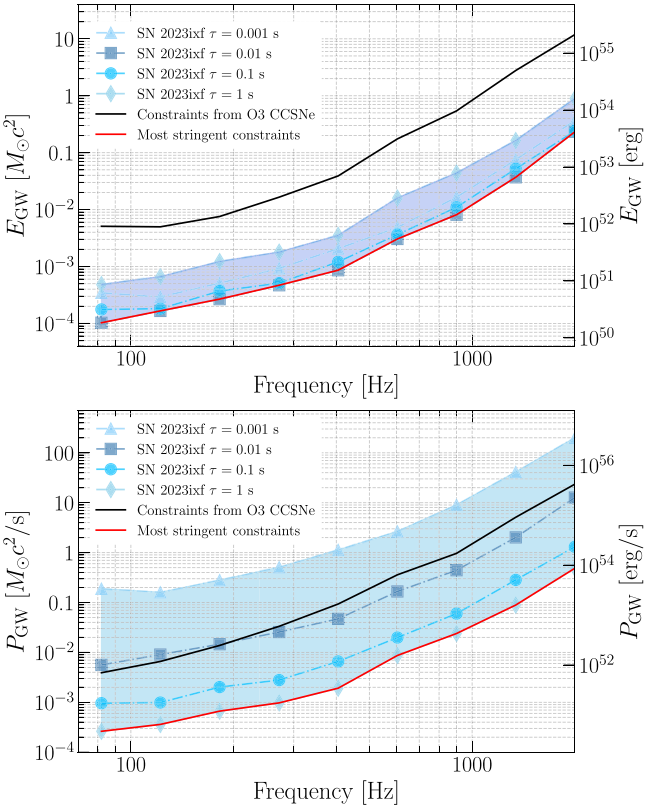

Figure 3. GW energy (E_{GW}) and luminosity (P_{GW}) as a function of the frequency for bar-mode signals with a detection efficiency of 90% and a FAR of 1 event in 10 years. The shaded region contains combined results from all analyzed models for SN 2023ixf.

where the GW strain squared integral is computed for an optimally oriented source.

The GW luminosity is the ratio between the emitted GW energy and the duration of the emission. We define the duration as the time interval τ_{90} that contains 90% of the energy such that the GW average luminosity is given by

$$P_{GW} = \frac{0.9 E_{GW}}{\tau_{90}}. \quad (4)$$

For the sine-Gaussians of Equation (1) $\tau_{90} = 1.65\tau$. Considering the h_0 value corresponding to 90% detection efficiency, we derive constraints on E_{GW} and P_{GW} shown in Figure 3. The shaded region contains results from all long-lasting bar-mode models. At 82 Hz the more stringent energy constraints are $\sim 1 \times 10^{-4} M_\odot c^2$. Figure 3 also shows the constraints derived from GW searches targeting CCSNe during the third observing run (O3) of the LIGO–Virgo–KAGRA network. The constraints with SN 2023ixf are ~49 times more stringent than for O3 CCSNe over the whole frequency range. For the average emitted GW luminosity shown in the bottom panel, the constraints are $2.6 \times 10^{-4} M_\odot c^2$ s^{-1} for signals at 82 Hz and 1 s long. They are a factor of ~36 more stringent than for the O3 CCSNe over the whole frequency range. This upper limit is between two and five orders of magnitude larger than the average GW luminosity predicted by numerical simulations for the different explosion mechanisms (M. J. Szczepańczyk et al. 2021), showing that we could soon exclude some of the most optimistically luminous models with a closer CCSN. It is also ~7 orders of magnitude larger than the bolometric luminosity reported by E. A. Zimmerman et al. (2024).

5.2. Constraints on PNS Ellipticity

As shown in Section 3.2, the amplitude of the GW signal emitted by a rotating PNS can be parameterized by its ellipticity and its moment of inertia given by the relation

$$I_{zz}\,\epsilon = \frac{Dc^4}{G(2\pi f_0)^2} h_0. \quad (5)$$

Figure 4 reports the ellipticity for a range of bar-mode GW signal frequencies and durations for a detection efficiency of 90%. The most stringent constraints on ellipticity are obtained for the signals with $\tau = 1$ s, ranging from 3.6×10^2 at the lowest search frequency to 1.08 at 2 kHz. The ϵ constraints get stricter with longer signals. Over the whole frequency range, the constraints given by SN 2023ixf on the ellipticity are ~6.8× more stringent than for O3 CCSNe.

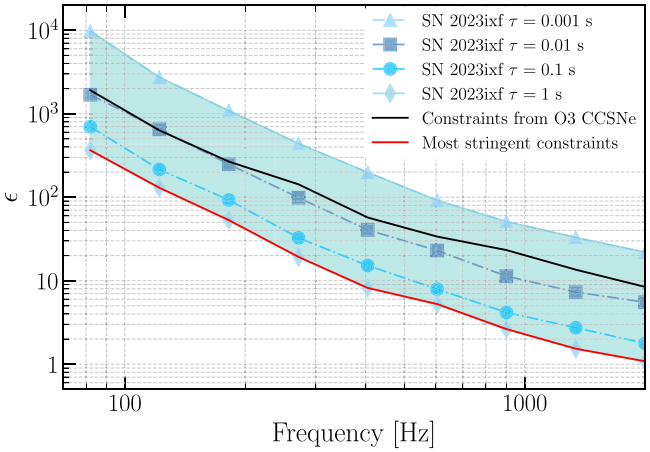

Figure 4. PNS ellipticity as a function of the frequency for bar-mode signals with a detection efficiency of 90% and a FAR of 1 per 10 years. The moment of inertia I_{zz} is fixed to 10^{45} g cm^2. The shaded region contains combined results from all analyzed bar-mode models for SN 2023ixf.

6. Summary and Discussion

We present the results of a search for GW signals coincident with SN 2023ixf, which was observed during the LIGO–Virgo–KAGRA Engineering Run 15, 2023 April 24 to 2023 May 24. No significant GW candidates were identified within the ∼14% of the on-source window where coincident good-quality GW data are available. With different CCSN waveform models, we quantify the search sensitivity by estimating the distances at which 90% of the simulated GW signals are detected. The reported distances are up to 6.9 kpc for nonrotating explosions, and up to 29.9 kpc for rapidly rotating models. These distance sensitivities have been obtained using the FAR of 1 event in 10 years. We derive constraints on the GW energy, luminosity, and PNS ellipticity, which are the most stringent than GW detector data have achieved to date. Assuming the PNS is well modeled as a rotating triaxial ellipsoid whose moment of inertia along the rotation axis is fixed to $I_{zz} = 10^{45}$ g cm^2, we find that the ellipticity should be lower than 1.08. This value, obtained for a hypothetical 1 s long signal at 2 kHz, is one order of magnitude larger than plausible estimates (∼0.1) derived from simulations where bar-mode instabilities are present (M. Obergaulinger & M. A. Aloy 2021; S. Shibagaki et al. 2021; M. Bugli et al. 2023).

Despite the large distance of SN 2023ixf, this event probes regions of the parameter space for bar-mode instabilities that are physically interesting. On the other hand, in the case of a neutrino-driven, magnetorotational or more exotic explosion model such as a first-order quantum-chromodynamics phase transition, we show that for detecting GWs from CCSNe, events within the Local Group are still the best prospect.

Acknowledgments

This material is based upon work supported by NSF's LIGO Laboratory, which is a major facility fully funded by the National Science Foundation. The authors also gratefully acknowledge the support of the Science and Technology Facilities Council (STFC) of the United Kingdom, the Max-Planck-Society (MPS), and the State of Niedersachsen/Germany for support of the construction of Advanced LIGO and construction and operation of the GEO 600 detector. Additional support for Advanced LIGO was provided by the Australian Research Council. The authors gratefully acknowledge the Italian Istituto Nazionale di Fisica Nucleare (INFN), the French Centre National de la Recherche Scientifique (CNRS) and the Netherlands Organization for Scientific Research (NWO), for the construction and operation of the Virgo detector and the creation and support of the EGO consortium. The authors also gratefully acknowledge research support from these agencies as well as by the Council of Scientific and Industrial Research of India, the Department of Science and Technology, India, the Science & Engineering Research Board (SERB), India, the Ministry of Human Resource Development, India, the Spanish Agencia Estatal de Investigación (AEI), the Spanish Ministerio de Ciencia, Innovación y Universidades, the European Union NextGenerationEU/PRTR (PRTR-C17.I1), the ICSC—Centro Nazionale di Ricerca in High Performance Computing, Big Data and Quantum Computing, funded by the European Union NextGenerationEU, the Comunitat Autonòma de les Illes Balears through the Direcció General de Recerca, Innovació i Transformació Digital with funds from the Tourist Stay Tax Law ITS 2017-006, the Conselleria d'Economia, Hisenda i Innovació, the FEDER Operational Program 2021–2027 of the Balearic Islands, the Conselleria d'Innovació, Universitats, Ciència i Societat Digital de la Generalitat Valenciana and the CERCA Programme Generalitat de Catalunya, Spain, the Polish National Agency for Academic Exchange, the National Science Centre of Poland and the European Union—European Regional Development Fund; the Foundation for Polish Science (FNP), the Polish Ministry of Science and Higher Education, the Swiss National Science Foundation (SNSF), the Russian Science Foundation, the European Commission, the European Social Funds (ESF), the European Regional Development Funds (ERDF), the Royal Society, the Scottish Funding Council, the Scottish Universities Physics Alliance, the Hungarian Scientific Research Fund (OTKA), the French Lyon Institute of Origins (LIO), the Belgian Fonds de la Recherche Scientifique (FRS-FNRS), Actions de Recherche Concertées (ARC) and Fonds Wetenschappelijk Onderzoek—Vlaanderen (FWO), Belgium, the Paris Île-de-France Region, the National Research, Development and Innovation Office Hungary (NKFIH), the National Research Foundation of Korea, the Natural Science and Engineering Research Council Canada, Canadian Foundation for Innovation (CFI), the Brazilian Ministry of Science, Technology, and Innovations, the International Center for Theoretical Physics South American Institute for Fundamental Research (ICTP-SAIFR), the Research Grants Council of Hong Kong, the National Natural Science Foundation of China (NSFC), the Leverhulme Trust, the Research Corporation, the National Science and Technology Council (NSTC), Taiwan, the United States Department of Energy, and the Kavli Foundation. The authors gratefully acknowledge the support of the NSF, STFC, INFN and CNRS for provision of computational resources.

This work was supported by MEXT, the JSPS Leading-edge Research Infrastructure Program, JSPS Grant-in-Aid for Specially Promoted Research 26000005, JSPS Grant-in-Aid for Scientific Research on Innovative Areas 2905: JP17H06358, JP17H06361 and JP17H06364, JSPS Core-to-Core Program A, Advanced Research Networks, JSPS Grants-in-Aid for Scientific Research (S) 17H06133 and 20H05639, JSPS Grant-in-Aid for Transformative Research Areas (A) 20A203: JP20H05854, the joint research program of the Institute for Cosmic Ray Research,

the University of Tokyo, the National Research Foundation (NRF), the Computing Infrastructure Project of Global Science experimental Data hub Center (GSDC) at KISTI, the Korea Astronomy and Space Science Institute (KASI), the Ministry of Science and ICT (MSIT) in Korea, Academia Sinica (AS), the AS Grid Center (ASGC) and the National Science and Technology Council (NSTC) in Taiwan under grants including the Rising Star Program and Science Vanguard Research Program, the Advanced Technology Center (ATC) of NAOJ, and the Mechanical Engineering Center of KEK.

We would like to thank all of the essential workers who put their health at risk during the COVID-19 pandemic, without whom we would not have been able to complete this work.

ORCID iDs

A. G. Abac https://orcid.org/0000-0003-4786-2698
K. Ackley https://orcid.org/0000-0002-8648-0767
N. Adhikari https://orcid.org/0000-0002-4559-8427
R. X. Adhikari https://orcid.org/0000-0002-5731-5076
D. Agarwal https://orcid.org/0000-0002-8735-5554
M. Agathos https://orcid.org/0000-0002-9072-1121
M. Aghaei Abchouyeh https://orcid.org/0000-0002-1518-1946
O. D. Aguiar https://orcid.org/0000-0002-2139-4390
L. Aiello https://orcid.org/0000-0003-2771-8816
A. Ain https://orcid.org/0000-0003-4534-4619
T. Akutsu https://orcid.org/0000-0003-0733-7530
S. Albanesi https://orcid.org/0000-0001-7345-4415
R. A. Alfaidi https://orcid.org/0000-0002-6108-4979
A. Al-Jodah https://orcid.org/0000-0003-4536-1240
A. Allocca https://orcid.org/0000-0002-5288-1351
P. A. Altin https://orcid.org/0000-0001-8193-5825
S. Alvarez-Lopez https://orcid.org/0009-0003-8040-4936
A. Amato https://orcid.org/0000-0001-9557-651X
S. B. Anderson https://orcid.org/0000-0003-2219-9383
W. G. Anderson https://orcid.org/0000-0003-0482-5942
M. Andia https://orcid.org/0000-0003-3675-9126
N. Andres https://orcid.org/0000-0002-5360-943X
M. Andrés-Carcasona https://orcid.org/0000-0002-8738-1672
T. Andrić https://orcid.org/0000-0002-9277-9773
S. Ansoldi https://orcid.org/0000-0002-5613-7693
J. M. Antelis https://orcid.org/0000-0003-3377-0813
S. Antier https://orcid.org/0000-0002-7686-3334
K. Arai https://orcid.org/0000-0001-8916-8915
A. Araya https://orcid.org/0000-0002-6884-2875
M. C. Araya https://orcid.org/0000-0002-6018-6447
J. S. Areeda https://orcid.org/0000-0003-0266-7936
F. Armato https://orcid.org/0000-0002-8856-8877
N. Arnaud https://orcid.org/0000-0001-6589-8673
M. Arogeti https://orcid.org/0000-0001-5124-3350
S. M. Aronson https://orcid.org/0000-0001-7080-8177
G. Ashton https://orcid.org/0000-0001-7288-2231
Y. Aso https://orcid.org/0000-0002-1902-6695
P. Astone https://orcid.org/0000-0003-4981-4120
F. Attadio https://orcid.org/0009-0008-8916-1658
F. Aubin https://orcid.org/0000-0003-1613-3142
K. AultONeal https://orcid.org/0000-0002-6645-4473
G. Avallone https://orcid.org/0000-0001-5482-0299
S. Babak https://orcid.org/0000-0001-7469-4250
F. Badaracco https://orcid.org/0000-0001-8553-7904
S. Bae https://orcid.org/0000-0003-2429-3357
S. Bagnasco https://orcid.org/0000-0001-6062-6505
J. G. Baier https://orcid.org/0000-0002-4972-1525
L. Baiotti https://orcid.org/0000-0003-0458-4288
R. Bajpai https://orcid.org/0000-0003-0495-5720
S. Banagiri https://orcid.org/0000-0001-7852-7484
B. Banerjee https://orcid.org/0000-0002-8008-2485
D. Bankar https://orcid.org/0000-0002-6068-2993
P. Baral https://orcid.org/0000-0001-6308-211X
P. Barneo https://orcid.org/0000-0002-8883-7280
F. Barone https://orcid.org/0000-0002-8069-8490
B. Barr https://orcid.org/0000-0002-5232-2736
L. Barsotti https://orcid.org/0000-0001-9819-2562
M. Barsuglia https://orcid.org/0000-0002-1180-4050
D. Barta https://orcid.org/0000-0001-6841-550X
M. A. Barton https://orcid.org/0000-0002-9948-306X
S. Basak https://orcid.org/0000-0002-1824-3292
A. Basalaev https://orcid.org/0000-0001-5623-2853
R. Bassiri https://orcid.org/0000-0001-8171-6833
A. Basti https://orcid.org/0000-0003-2895-9638
M. Bawaj https://orcid.org/0000-0003-3611-3042
J. C. Bayley https://orcid.org/0000-0003-2306-4106
A. C. Baylor https://orcid.org/0000-0003-0918-0864
F. Beirnaert https://orcid.org/0000-0002-4003-7233
M. Bejger https://orcid.org/0000-0002-4991-8213
D. Belardinelli https://orcid.org/0000-0001-9332-5733
A. S. Bell https://orcid.org/0000-0003-1523-0821
W. Benoit https://orcid.org/0000-0003-4750-9413
J. D. Bentley https://orcid.org/0000-0002-4736-7403
S. Bera https://orcid.org/0000-0003-0907-6098
M. Berbel https://orcid.org/0000-0001-6345-1798
F. Bergamin https://orcid.org/0000-0002-1113-9644
B. K. Berger https://orcid.org/0000-0002-4845-8737
S. Bernuzzi https://orcid.org/0000-0002-2334-0935
M. Beroiz https://orcid.org/0000-0001-6486-9897
D. Bersanetti https://orcid.org/0000-0002-7377-415X
J. Betzwieser https://orcid.org/0000-0003-1533-9229
D. Beveridge https://orcid.org/0000-0002-1481-1993
N. Bevins https://orcid.org/0000-0002-4312-4287
U. Bhardwaj https://orcid.org/0000-0003-1233-4174
D. Bhattacharjee https://orcid.org/0000-0001-6623-9506
S. Bhaumik https://orcid.org/0000-0001-8492-2202
G. Billingsley https://orcid.org/0000-0002-4141-2744
A. Binetti https://orcid.org/0000-0001-6449-5493
S. Bini https://orcid.org/0000-0002-0267-3562
O. Birnholtz https://orcid.org/0000-0002-7562-9263
S. Biscoveanu https://orcid.org/0000-0001-7616-7366
M. Bitossi https://orcid.org/0000-0002-9862-4668
M.-A. Bizouard https://orcid.org/0000-0002-4618-1674
J. K. Blackburn https://orcid.org/0000-0002-3838-2986
N. Bode https://orcid.org/0000-0002-7101-9396
G. Boileau https://orcid.org/0000-0002-3576-6968
M. Boldrini https://orcid.org/0000-0001-9861-821X
G. N. Bolingbroke https://orcid.org/0000-0002-7350-5291
L. D. Bonavena https://orcid.org/0000-0002-2630-6724
R. Bondarescu https://orcid.org/0000-0003-0330-2736
F. Bondu https://orcid.org/0000-0001-6487-5197
E. Bonilla https://orcid.org/0000-0002-6284-9769
M. S. Bonilla https://orcid.org/0000-0003-4502-528X
R. Bonnand https://orcid.org/0000-0001-5013-5913
V. Boschi https://orcid.org/0000-0001-8665-2293
V. Boudart https://orcid.org/0000-0001-9923-4154
P. R. Brady https://orcid.org/0000-0002-4611-9387

M. Braglia https://orcid.org/0000-0003-3421-4069
M. Branchesi https://orcid.org/0000-0003-1643-0526
M. Breschi https://orcid.org/0000-0002-3327-3676
T. Briant https://orcid.org/0000-0002-6013-1729
E. Brockmueller https://orcid.org/0000-0002-1489-942X
A. F. Brooks https://orcid.org/0000-0003-4295-792X
M. L. Brozzetti https://orcid.org/0000-0002-5260-4979
R. Bruntz https://orcid.org/0000-0002-0840-8567
O. Bulashenko https://orcid.org/0000-0003-1720-4061
A. Buonanno https://orcid.org/0000-0002-5433-1409
R. Buscicchio https://orcid.org/0000-0002-7387-6754
C. Buy https://orcid.org/0000-0003-2872-8186
G. S. Cabourn Davies https://orcid.org/0000-0002-4289-3439
G. Cabras https://orcid.org/0000-0002-6852-6856
R. Cabrita https://orcid.org/0000-0003-0133-1306
L. Cadonati https://orcid.org/0000-0002-9846-166X
G. Cagnoli https://orcid.org/0000-0002-7086-6550
C. Cahillane https://orcid.org/0000-0002-3888-314X
G. Caneva Santoro https://orcid.org/0000-0002-2935-1600
K. C. Cannon https://orcid.org/0000-0003-4068-6572
E. Capocasa https://orcid.org/0000-0003-3762-6958
E. Capote https://orcid.org/0009-0007-0246-713X
J. B. Carlin https://orcid.org/0000-0001-5694-0809
M. Carpinelli https://orcid.org/0000-0002-8205-930X
J. J. Carter https://orcid.org/0000-0001-8845-0900
G. Carullo https://orcid.org/0000-0001-9090-1862
C. Casentini https://orcid.org/0000-0001-8100-0579
M. Cavaglià https://orcid.org/0000-0002-3835-6729
R. Cavalieri https://orcid.org/0000-0001-6064-0569
G. Cella https://orcid.org/0000-0002-0752-0338
P. Cerdá-Durán https://orcid.org/0000-0003-4293-340X
E. Cesarini https://orcid.org/0000-0001-9127-3167
P. Chakraborty https://orcid.org/0000-0002-0994-7394
S. Chalathadka Subrahmanya https://orcid.org/0000-0002-9207-4669
J. C. L. Chan https://orcid.org/0000-0002-3377-4737
S. Chao https://orcid.org/0000-0003-3853-3593
P. Charlton https://orcid.org/0000-0002-4263-2706
E. Chassande-Mottin https://orcid.org/0000-0003-3768-9908
C. Chatterjee https://orcid.org/0000-0001-8700-3455
Debarati Chatterjee https://orcid.org/0000-0002-0995-2329
Deep Chatterjee https://orcid.org/0000-0003-0038-5468
S. Chaty https://orcid.org/0000-0002-5769-8601
D. Chen https://orcid.org/0000-0003-1433-0716
H. Y. Chen https://orcid.org/0000-0001-5403-3762
J. Chen https://orcid.org/0000-0001-5550-6592
Yitian Chen https://orcid.org/0000-0002-8664-9702
P. Chessa https://orcid.org/0000-0001-9092-3965
F. Chiadini https://orcid.org/0000-0002-9339-8622
A. Chincarini https://orcid.org/0000-0003-4094-9942
M. L. Chiofalo https://orcid.org/0000-0002-6992-5963
A. Chiummo https://orcid.org/0000-0003-2165-2967
S. Choudhary https://orcid.org/0000-0003-0949-7298
N. Christensen https://orcid.org/0000-0002-6870-4202
S. S. Y. Chua https://orcid.org/0000-0001-8026-7597
G. Ciani https://orcid.org/0000-0003-4258-9338
P. Ciecielag https://orcid.org/0000-0002-5871-4730
M. Cieślar https://orcid.org/0000-0001-8912-5587
M. Cifaldi https://orcid.org/0009-0007-1566-7093
R. Ciolfi https://orcid.org/0000-0003-3140-8933
J. A. Clark https://orcid.org/0000-0003-3243-1393
T. A. Clarke https://orcid.org/0000-0002-6714-5429
E. Codazzo https://orcid.org/0000-0001-7170-8733
P.-F. Cohadon https://orcid.org/0000-0003-3452-9415
S. Colace https://orcid.org/0009-0007-9429-1847
M. Colleoni https://orcid.org/0000-0002-7214-9088
A. Colombo https://orcid.org/0000-0002-7439-4773
M. Colpi https://orcid.org/0000-0002-3370-6152
L. Conti https://orcid.org/0000-0003-2731-2656
T. R. Corbitt https://orcid.org/0000-0002-5520-8541
I. Cordero-Carrión https://orcid.org/0000-0002-1985-1361
N. J. Cornish https://orcid.org/0000-0002-7435-0869
A. Corsi https://orcid.org/0000-0001-8104-3536
S. Cortese https://orcid.org/0000-0002-6504-0973
M. W. Coughlin https://orcid.org/0000-0002-8262-2924
S. T. Countryman https://orcid.org/0000-0003-0613-2760
P. Couvares https://orcid.org/0000-0002-2823-3127
R. Coyne https://orcid.org/0000-0002-5243-5917
J. D. E. Creighton https://orcid.org/0000-0003-3600-2406
P. Cremonese https://orcid.org/0000-0001-6472-8509
A. W. Criswell https://orcid.org/0000-0002-9225-7756
J. R. Cudell https://orcid.org/0000-0002-2003-4238
T. J. Cullen https://orcid.org/0000-0001-8075-4088
A. Cumming https://orcid.org/0000-0003-4096-7542
M. Cusinato https://orcid.org/0000-0003-4075-4539
T. Dal Canton https://orcid.org/0000-0001-5078-9044
S. Dall'Osso https://orcid.org/0000-0003-4366-8265
S. Dal Pra https://orcid.org/0000-0002-1057-2307
G. Dálya https://orcid.org/0000-0003-3258-5763
B. D'Angelo https://orcid.org/0000-0001-9143-8427
S. Danilishin https://orcid.org/0000-0001-7758-7493
S. D'Antonio https://orcid.org/0000-0003-0898-6030
S. Datta https://orcid.org/0000-0001-9200-8867
D. Davis https://orcid.org/0000-0001-5620-6751
M. C. Davis https://orcid.org/0000-0001-7663-0808
P. J. Davis https://orcid.org/0009-0004-5008-5660
M. Dax https://orcid.org/0000-0001-8798-0627
J. De Bolle https://orcid.org/0000-0002-5179-1725
J. Degallaix https://orcid.org/0000-0002-1019-6911
M. De Laurentis https://orcid.org/0000-0002-3815-4078
S. Deléglise https://orcid.org/0000-0002-8680-5170
F. De Lillo https://orcid.org/0000-0003-4977-0789
D. Dell'Aquila https://orcid.org/0000-0001-5895-0664
W. Del Pozzo https://orcid.org/0000-0003-3978-2030
F. De Marco https://orcid.org/0000-0002-5411-9424
F. De Matteis https://orcid.org/0000-0001-7860-9754
V. D'Emilio https://orcid.org/0000-0001-6145-8187
T. Dent https://orcid.org/0000-0003-1354-7809
A. Depasse https://orcid.org/0000-0003-1014-8394
R. De Pietri https://orcid.org/0000-0003-1556-8304
R. De Rosa https://orcid.org/0000-0002-4004-947X
C. De Rossi https://orcid.org/0000-0002-5825-472X
R. DeSalvo https://orcid.org/0000-0002-4818-0296
M. C. Díaz https://orcid.org/0000-0002-7555-8856
M. Di Cesare https://orcid.org/0009-0003-0411-6043
T. Dietrich https://orcid.org/0000-0003-2374-307X
C. Di Fronzo https://orcid.org/0000-0002-2693-6769
M. Di Giovanni https://orcid.org/0000-0003-4049-8336
T. Di Girolamo https://orcid.org/0000-0003-2339-4471
A. Di Michele https://orcid.org/0000-0002-0357-2608
J. Ding https://orcid.org/0000-0003-1693-3828
S. Di Pace https://orcid.org/0000-0001-6759-5676

I. Di Palma https://orcid.org/0000-0003-1544-8943
F. Di Renzo https://orcid.org/0000-0002-5447-3810
Divyajyoti https://orcid.org/0000-0002-2787-1012
A. Dmitriev https://orcid.org/0000-0002-0314-956X
Z. Doctor https://orcid.org/0000-0002-2077-4914
L. D'Onofrio https://orcid.org/0000-0001-9546-5959
K. L. Dooley https://orcid.org/0000-0002-1636-0233
S. Doravari https://orcid.org/0000-0001-8750-8330
M. Drago https://orcid.org/0000-0002-3738-2431
J. C. Driggers https://orcid.org/0000-0002-6134-7628
L. Dunn https://orcid.org/0000-0002-1769-6097
D. D'Urso https://orcid.org/0000-0002-8215-4542
H. Duval https://orcid.org/0000-0002-2475-1728
M. Ebersold https://orcid.org/0000-0003-4631-1771
T. Eckhardt https://orcid.org/0000-0002-1224-4681
G. Eddolls https://orcid.org/0000-0002-5895-4523
B. Edelman https://orcid.org/0000-0001-7648-1689
O. Edy https://orcid.org/0000-0001-9617-8724
A. Effler https://orcid.org/0000-0001-8242-3944
J. Eichholz https://orcid.org/0000-0002-2643-163X
A. Ejlli https://orcid.org/0000-0002-4149-4532
M. Emma https://orcid.org/0000-0001-7943-0262
L. Errico https://orcid.org/0000-0003-2112-0653
R. C. Essick https://orcid.org/0000-0001-8196-9267
H. Estellés https://orcid.org/0000-0001-6143-5532
D. Estevez https://orcid.org/0000-0002-3021-5964
M. Evans https://orcid.org/0000-0001-8459-4499
J. M. Ezquiaga https://orcid.org/0000-0002-7213-3211
F. Fabrizi https://orcid.org/0000-0002-3809-065X
V. Fafone https://orcid.org/0000-0003-1314-1622
S. Fairhurst https://orcid.org/0000-0001-8480-1961
A. M. Farah https://orcid.org/0000-0002-6121-0285
B. Farr https://orcid.org/0000-0002-2916-9200
W. M. Farr https://orcid.org/0000-0003-1540-8562
G. Favaro https://orcid.org/0000-0002-0351-6833
M. Favata https://orcid.org/0000-0001-8270-9512
M. Fays https://orcid.org/0000-0002-4390-9746
R. Felicetti https://orcid.org/0009-0005-6263-5604
E. Fenyvesi https://orcid.org/0000-0003-2777-3719
D. L. Ferguson https://orcid.org/0000-0002-4406-591X
S. Ferraiuolo https://orcid.org/0009-0005-5582-2989
I. Ferrante https://orcid.org/0000-0002-0083-7228
F. Fidecaro https://orcid.org/0000-0002-6189-3311
P. Figura https://orcid.org/0000-0002-8925-0393
A. Fiori https://orcid.org/0000-0003-3174-0688
I. Fiori https://orcid.org/0000-0002-0210-516X
M. Fishbach https://orcid.org/0000-0002-1980-5293
V. Fiumara https://orcid.org/0000-0003-3644-217X
S. M. Fleischer https://orcid.org/0000-0001-7884-9993
J. A. Font https://orcid.org/0000-0001-6650-2634
B. Fornal https://orcid.org/0000-0003-3271-2080
F. Frasconi https://orcid.org/0000-0003-4204-6587
A. Frattale Mascioli https://orcid.org/0000-0002-0155-3833
Z. Frei https://orcid.org/0000-0002-0181-8491
A. Freise https://orcid.org/0000-0001-6586-9901
O. Freitas https://orcid.org/0000-0002-2898-1256
R. Frey https://orcid.org/0000-0003-0341-2636
G. G. Fronzé https://orcid.org/0000-0003-0966-4279
M. Fuentes-Garcia https://orcid.org/0000-0003-3390-8712
B. Gadre https://orcid.org/0000-0002-1534-9761
J. R. Gair https://orcid.org/0000-0002-1671-3668
S. Galaudage https://orcid.org/0000-0002-1819-0215
R. Gamba https://orcid.org/0000-0001-7239-0659
A. Gamboa https://orcid.org/0000-0001-8391-5596
D. Ganapathy https://orcid.org/0000-0003-3028-4174
A. Ganguly https://orcid.org/0000-0001-7394-0755
B. Garaventa https://orcid.org/0000-0003-2490-404X
J. García-Bellido https://orcid.org/0000-0002-9370-8360
C. García-Quirós https://orcid.org/0000-0002-8059-2477
J. W. Gardner https://orcid.org/0000-0002-8592-1452
J. Gargiulo https://orcid.org/0000-0002-3507-6924
A. Garron https://orcid.org/0000-0002-1601-797X
F. Garufi https://orcid.org/0000-0003-1391-6168
C. Gasbarra https://orcid.org/0000-0001-8335-9614
V. Gayathri https://orcid.org/0000-0002-7167-9888
G. Gemme https://orcid.org/0000-0002-1127-7406
A. Gennai https://orcid.org/0000-0003-0149-2089
V. Gennari https://orcid.org/0000-0002-0190-9262
R. George https://orcid.org/0000-0002-7797-7683
O. Gerberding https://orcid.org/0000-0001-7740-2698
L. Gergely https://orcid.org/0000-0003-3146-6201
Archisman Ghosh https://orcid.org/0000-0003-0423-3533
Shaon Ghosh https://orcid.org/0000-0001-9901-6253
Suprovo Ghosh https://orcid.org/0000-0002-1656-9870
Tathagata Ghosh https://orcid.org/0000-0001-9848-9905
J. A. Giaime https://orcid.org/0000-0002-3531-817X
C. Gier https://orcid.org/0000-0003-0897-7943
P. Giri https://orcid.org/0000-0002-4628-2432
S. Gkaitatzis https://orcid.org/0000-0001-9420-7499
N. L. Goebbels https://orcid.org/0000-0002-3923-5806
E. Goetz https://orcid.org/0000-0003-2666-721X
S. Gomez Lopez https://orcid.org/0000-0002-9557-4706
B. Goncharov https://orcid.org/0000-0003-3189-5807
G. González https://orcid.org/0000-0003-0199-3158
A. W. Goodwin-Jones https://orcid.org/0000-0002-0395-0680
A. S. Göttel https://orcid.org/0000-0002-6215-4641
R. Gouaty https://orcid.org/0000-0001-5372-7084
S. Goyal https://orcid.org/0000-0002-4225-010X
B. Grace https://orcid.org/0009-0009-9349-9317
A. Grado https://orcid.org/0000-0002-0501-8256
V. Graham https://orcid.org/0000-0003-3633-0135
A. E. Granados https://orcid.org/0000-0003-2099-9096
M. Granata https://orcid.org/0000-0003-3275-1186
V. Granata https://orcid.org/0000-0003-2246-6963
R. Gray https://orcid.org/0000-0002-5556-9873
A. C. Green https://orcid.org/0000-0002-6287-8746
S. R. Green https://orcid.org/0000-0002-6987-6313
W. L. Griffiths https://orcid.org/0000-0001-8366-0108
H. L. Griggs https://orcid.org/0000-0001-5018-7908
A. Grimaldi https://orcid.org/0000-0002-6956-4301
H. Grote https://orcid.org/0000-0002-0797-3943
D. Guerra https://orcid.org/0000-0003-0029-5390
D. Guetta https://orcid.org/0000-0002-7349-1109
G. M. Guidi https://orcid.org/0000-0002-3061-9870
F. Gulminelli https://orcid.org/0000-0003-4354-2849
H. Guo https://orcid.org/0000-0002-3777-3117
W. Guo https://orcid.org/0000-0002-4320-4420
Y. Guo https://orcid.org/0000-0002-6959-9870
Anchal Gupta https://orcid.org/0000-0002-1762-9644
Anuradha Gupta https://orcid.org/0000-0002-5441-9013
Ish Gupta https://orcid.org/0000-0001-6932-8715
T. Gupta https://orcid.org/0000-0003-2692-5442
F. Guzman https://orcid.org/0000-0001-9136-929X

M. Haberland https://orcid.org/0000-0001-9816-5660
E. D. Hall https://orcid.org/0000-0001-9018-666X
G. Hammond https://orcid.org/0000-0002-1414-3622
W.-B. Han https://orcid.org/0000-0002-2039-0726
M. Haney https://orcid.org/0000-0001-7554-3665
O. A. Hannuksela https://orcid.org/0000-0002-3887-7137
A. G. Hanselman https://orcid.org/0000-0002-8304-0109
T. Harmark https://orcid.org/0000-0002-2795-7035
J. Harms https://orcid.org/0000-0002-7332-9806
G. M. Harry https://orcid.org/0000-0002-8905-7622
I. W. Harry https://orcid.org/0000-0002-5304-9372
C.-J. Haster https://orcid.org/0000-0001-8040-9807
K. Haughian https://orcid.org/0000-0002-1223-7342
A. Heffernan https://orcid.org/0000-0003-3355-9671
A. Heidmann https://orcid.org/0000-0002-0784-5175
J. Heinze https://orcid.org/0000-0001-8692-2724
H. Heitmann https://orcid.org/0000-0003-0625-5461
F. Hellman https://orcid.org/0000-0002-9135-6330
A. F. Helmling-Cornell https://orcid.org/0000-0002-7709-8638
G. Hemming https://orcid.org/0000-0001-5268-4465
O. Henderson-Sapir https://orcid.org/0000-0002-1613-9985
M. Hendry https://orcid.org/0000-0001-8322-5405
E. Hennes https://orcid.org/0000-0002-2246-5496
C. Henshaw https://orcid.org/0000-0002-4206-3128
M. Heurs https://orcid.org/0000-0002-5577-2273
A. L. Hewitt https://orcid.org/0000-0002-1255-3492
Y. Himemoto https://orcid.org/0000-0002-6856-3809
Z. J. Holmes https://orcid.org/0000-0003-1311-4691
D. E. Holz https://orcid.org/0000-0002-0175-5064
J. Hough https://orcid.org/0000-0003-3242-3123
E. J. Howell https://orcid.org/0000-0001-7891-2817
C. G. Hoy https://orcid.org/0000-0002-8843-6719
H.-F. Hsieh https://orcid.org/0000-0002-8947-723X
W.-F. Hsu https://orcid.org/0000-0001-5234-3804
Q. Hu https://orcid.org/0000-0002-3033-6491
H. Y. Huang https://orcid.org/0000-0002-1665-2383
Y.-J. Huang https://orcid.org/0000-0002-2952-8429
D. C. Y. Hui https://orcid.org/0000-0003-1753-1660
V. Hui https://orcid.org/0000-0002-0233-2346
S. Husa https://orcid.org/0000-0002-0445-1971
L. Iampieri https://orcid.org/0009-0004-1161-2990
G. A. Iandolo https://orcid.org/0000-0003-1155-4327
A. Iess https://orcid.org/0000-0001-9658-6752
K. Inayoshi https://orcid.org/0000-0001-9840-4959
G. Iorio https://orcid.org/0000-0003-0293-503X
J. Irwin https://orcid.org/0000-0002-2364-2191
M. Isi https://orcid.org/0000-0001-8830-8672
M. A. Ismail https://orcid.org/0000-0001-9340-8838
Y. Itoh https://orcid.org/0000-0003-2694-8935
B. R. Iyer https://orcid.org/0000-0002-4141-5179
V. JaberianHamedan https://orcid.org/0000-0003-3605-4169
P.-E. Jacquet https://orcid.org/0000-0001-9552-0057
S. P. Jadhav https://orcid.org/0000-0003-0554-0084
A. L. James https://orcid.org/0000-0001-9165-0807
K. Janssens https://orcid.org/0000-0001-8760-4429
S. Jaraba https://orcid.org/0000-0002-4759-143X
P. Jaranowski https://orcid.org/0000-0001-8085-3414
R. Jaume https://orcid.org/0000-0001-8691-3166
J. Jiang https://orcid.org/0000-0002-0154-3854
J. Kubisz https://orcid.org/0000-0001-7258-8673
M. C. Johnston https://orcid.org/0000-0002-0663-9193
D. H. Jones https://orcid.org/0000-0003-3987-068X
L. Ju https://orcid.org/0000-0002-7951-4295
K. Jung https://orcid.org/0000-0003-4789-8893
J. Junker https://orcid.org/0000-0002-3051-4374
T. Kajita https://orcid.org/0000-0003-1207-6638
V. Kalogera https://orcid.org/0000-0001-9236-5469
M. Kamiizumi https://orcid.org/0000-0001-7216-1784
N. Kanda https://orcid.org/0000-0001-6291-0227
S. Kandhasamy https://orcid.org/0000-0002-4825-6764
G. Kang https://orcid.org/0000-0002-6072-8189
S. J. Kapadia https://orcid.org/0000-0001-5318-1253
D. P. Kapasi https://orcid.org/0000-0001-8189-4920
C. Karathanasis https://orcid.org/0000-0002-0642-5507
R. Kashyap https://orcid.org/0000-0002-5700-282X
M. Kasprzack https://orcid.org/0000-0003-4618-5939
R. Kaushik https://orcid.org/0000-0003-4888-5154
D. Keitel https://orcid.org/0000-0002-2824-626X
J. Kennington https://orcid.org/0000-0002-6899-3833
J. S. Key https://orcid.org/0000-0003-0123-7600
F. Y. Khalili https://orcid.org/0000-0001-7068-2332
F. Khan https://orcid.org/0000-0001-6176-853X
W. Kiendrebeogo https://orcid.org/0000-0002-9108-5059
N. Kijbunchoo https://orcid.org/0000-0002-2874-1228
K. Kim https://orcid.org/0000-0003-1653-3795
S. Kim https://orcid.org/0000-0003-1437-4647
Y.-M. Kim https://orcid.org/0000-0001-8720-6113
C. Kimball https://orcid.org/0000-0001-9879-6884
M. Kinley-Hanlon https://orcid.org/0000-0002-7367-8002
J. S. Kissel https://orcid.org/0000-0002-1702-9577
A. M. Knee https://orcid.org/0000-0003-0703-947X
N. Knust https://orcid.org/0000-0002-5984-5353
S. M. Koehlenbeck https://orcid.org/0000-0002-3842-9051
K. Kohri https://orcid.org/0000-0003-3764-8612
K. Kokeyama https://orcid.org/0000-0002-2896-1992
S. Koley https://orcid.org/0000-0002-5793-6665
P. Kolitsidou https://orcid.org/0000-0002-6719-8686
M. Kolstein https://orcid.org/0000-0002-5482-6743
K. Komori https://orcid.org/0000-0002-4092-9602
A. K. H. Kong https://orcid.org/0000-0002-5105-344X
A. Kontos https://orcid.org/0000-0002-1347-0680
M. Korobko https://orcid.org/0000-0002-3839-3909
N. Kouvatsos https://orcid.org/0000-0002-5497-3401
N. V. Krishnendu https://orcid.org/0000-0002-3483-7517
A. Królak https://orcid.org/0000-0003-4514-7690
P. Kuijer https://orcid.org/0000-0002-6987-2048
S. Kulkarni https://orcid.org/0000-0001-8057-0203
A. Kulur Ramamohan https://orcid.org/0000-0003-3681-1887
Praveen Kumar https://orcid.org/0000-0002-2288-4252
Prayush Kumar https://orcid.org/0000-0001-5523-4603
J. Kume https://orcid.org/0000-0003-3126-5100
K. Kuns https://orcid.org/0000-0003-0630-3902
S. Kuroyanagi https://orcid.org/0000-0001-6538-1447
S. Kuwahara https://orcid.org/0009-0009-2249-8798
K. Kwak https://orcid.org/0000-0002-2304-7798
D. Laghi https://orcid.org/0000-0001-7462-3794
M. Lalleman https://orcid.org/0000-0002-2254-010X
R. N. Lang https://orcid.org/0000-0002-4804-5537
B. Lantz https://orcid.org/0000-0002-7404-4845
A. La Rana https://orcid.org/0000-0001-8755-9322
I. L. Rosa https://orcid.org/0000-0003-0107-1540

A. Lartaux-Vollard https://orcid.org/0000-0003-1714-365X
P. D. Lasky https://orcid.org/0000-0003-3763-1386
M. Laxen https://orcid.org/0000-0001-7515-9639
A. Lazzarini https://orcid.org/0000-0002-5993-8808
P. Leaci https://orcid.org/0000-0002-3997-5046
Y. K. Lecoeuche https://orcid.org/0000-0002-9186-7034
H. M. Lee https://orcid.org/0000-0003-4412-7161
H. W. Lee https://orcid.org/0000-0002-1998-3209
K. Lee https://orcid.org/0000-0003-0470-3718
R.-K. Lee https://orcid.org/0000-0002-7171-7274
S. Lee https://orcid.org/0000-0001-6034-2238
M. Le Jean https://orcid.org/0009-0003-8047-3958
M. Lenti https://orcid.org/0000-0002-2765-3955
M. Leonardi https://orcid.org/0000-0002-7641-0060
N. Leroy https://orcid.org/0000-0002-2321-1017
M. Lethuillier https://orcid.org/0000-0001-6185-2045
K. Leyde https://orcid.org/0000-0001-7661-2810
K. L. Li https://orcid.org/0000-0001-8229-2024
X. Li https://orcid.org/0000-0002-3780-7735
C-Y. Lin https://orcid.org/0000-0002-7489-7418
E. T. Lin https://orcid.org/0000-0002-0030-8051
L. C.-C. Lin https://orcid.org/0000-0003-4083-9567
Y.-C. Lin https://orcid.org/0000-0003-4939-1404
A. Liu https://orcid.org/0000-0003-1081-8722
G. C. Liu https://orcid.org/0000-0001-5663-3016
Jian Liu https://orcid.org/0000-0001-6726-3268
J. Llobera-Querol https://orcid.org/0000-0003-3322-6850
R. K. L. Lo https://orcid.org/0000-0003-1561-6716
A. Longo https://orcid.org/0000-0003-4254-8579
D. Lopez https://orcid.org/0000-0003-3342-9906
M. Lorenzini https://orcid.org/0000-0002-2765-7905
A. Lorenzo-Medina https://orcid.org/0009-0006-0860-5700
G. Losurdo https://orcid.org/0000-0003-0452-746X
T. P. Lott IV https://orcid.org/0009-0002-2864-162X
J. D. Lough https://orcid.org/0000-0002-5160-0239
C. O. Lousto https://orcid.org/0000-0002-6400-9640
N. Lu https://orcid.org/0000-0002-8861-9902
D. Lumaca https://orcid.org/0000-0002-3628-1591
A. W. Lussier https://orcid.org/0000-0002-4507-1123
L.-T. Ma https://orcid.org/0009-0000-0674-7592
M. Ma'arif https://orcid.org/0000-0001-8472-7095
R. Macas https://orcid.org/0000-0002-6096-8297
A. Macedo https://orcid.org/0009-0001-7671-6377
D. M. Macleod https://orcid.org/0000-0002-1395-8694
I. A. O. MacMillan https://orcid.org/0000-0002-6927-1031
A. Macquet https://orcid.org/0000-0001-5955-6415
S. Maenaut https://orcid.org/0000-0003-1464-2605
C. Magazzù https://orcid.org/0000-0002-9913-381X
R. M. Magee https://orcid.org/0000-0001-9769-531X
E. Maggio https://orcid.org/0000-0002-1960-8185
M. Magnozzi https://orcid.org/0000-0003-4512-8430
U. Mali https://orcid.org/0009-0003-1285-2788
V. Mandic https://orcid.org/0000-0001-6333-8621
V. Mangano https://orcid.org/0000-0001-7902-8505
G. L. Mansell https://orcid.org/0000-0003-4736-6678
M. Manske https://orcid.org/0000-0002-7778-1189
M. Mantovani https://orcid.org/0000-0002-4424-5726
M. Mapelli https://orcid.org/0000-0001-8799-2548
D. Marín Pina https://orcid.org/0000-0001-6482-1842
F. Marion https://orcid.org/0000-0002-8184-1017
S. Márka https://orcid.org/0000-0002-3957-1324
Z. Márka https://orcid.org/0000-0003-1306-5260
S. Marsat https://orcid.org/0000-0001-9449-1071
F. Martelli https://orcid.org/0000-0003-3761-8616
I. W. Martin https://orcid.org/0000-0001-7300-9151
R. M. Martin https://orcid.org/0000-0001-9664-2216
V. Martinez https://orcid.org/0000-0001-5852-2301
J. C. Martins https://orcid.org/0000-0002-6099-4831
M. Masso-Reid https://orcid.org/0000-0001-6177-8105
S. Mastrogiovanni https://orcid.org/0000-0003-1606-4183
M. Matiushechkina https://orcid.org/0000-0002-9957-8720
N. Mavalvala https://orcid.org/0000-0003-0219-9706
D. E. McClelland https://orcid.org/0000-0001-6210-5842
L. McCuller https://orcid.org/0000-0003-0851-0593
J. McIver https://orcid.org/0000-0003-0316-1355
A. McLeod https://orcid.org/0000-0001-5424-8368
D. Meacher https://orcid.org/0000-0001-5882-0368
S. Mellaerts https://orcid.org/0000-0002-6715-3066
A. Menendez-Vazquez https://orcid.org/0000-0002-0828-8219
C. S. Menoni https://orcid.org/0000-0001-9185-2572
R. A. Mercer https://orcid.org/0000-0001-8372-3914
J. R. Mérou https://orcid.org/0000-0002-5776-6643
C. Messenger https://orcid.org/0000-0001-7488-5022
M. Meyer-Conde https://orcid.org/0000-0003-2230-6310
F. Meylahn https://orcid.org/0000-0002-9556-142X
A. Miani https://orcid.org/0000-0001-7737-3129
I. Michaloliakos https://orcid.org/0000-0003-2980-358X
C. Michel https://orcid.org/0000-0003-0606-725X
Y. Michimura https://orcid.org/0000-0002-2218-4002
H. Middleton https://orcid.org/0000-0001-5532-3622
A. L. Miller https://orcid.org/0000-0002-4890-7627
M. Millhouse https://orcid.org/0000-0002-8659-5898
E. Milotti https://orcid.org/0000-0001-7348-9765
V. Milotti https://orcid.org/0000-0003-4732-1226
Ll. M. Mir https://orcid.org/0000-0002-4276-715X
L. Mirasola https://orcid.org/0009-0004-0174-1377
M. Miravet-Tenés https://orcid.org/0000-0002-8766-1156
C.-A. Miritescu https://orcid.org/0000-0002-7716-0569
C. Mishra https://orcid.org/0000-0002-8115-8728
T. Mishra https://orcid.org/0000-0002-7881-1677
S. Mitra https://orcid.org/0000-0002-0800-4626
V. P. Mitrofanov https://orcid.org/0000-0002-6983-4981
O. Miyakawa https://orcid.org/0000-0002-9085-7600
S. Miyoki https://orcid.org/0000-0002-1213-8416
G. Mo https://orcid.org/0000-0001-6331-112X
S. R. Mohite https://orcid.org/0000-0003-1356-7156
M. Molina-Ruiz https://orcid.org/0000-0003-4892-3042
A. More https://orcid.org/0000-0001-7714-7076
S. More https://orcid.org/0000-0002-2986-2371
S. Morisaki https://orcid.org/0000-0002-8445-6747
Y. Moriwaki https://orcid.org/0000-0002-4497-6908
G. Morras https://orcid.org/0000-0002-9977-8546
A. Moscatello https://orcid.org/0000-0001-5480-7406
P. Mourier https://orcid.org/0000-0001-8078-6901
B. Mours https://orcid.org/0000-0002-6444-6402
C. M. Mow-Lowry https://orcid.org/0000-0002-0351-4555
F. Muciaccia https://orcid.org/0000-0003-0850-2649
D. Mukherjee https://orcid.org/0000-0001-7335-9418
Suvodip Mukherjee https://orcid.org/0000-0002-3373-5236
N. Mukund https://orcid.org/0000-0002-8666-9156
P. G. Murray https://orcid.org/0000-0002-8218-2404
D. Nabari https://orcid.org/0009-0006-8500-7624
N. Nagarajan https://orcid.org/0000-0003-3695-0078

K. Nakamura https://orcid.org/0000-0001-6148-4289
H. Nakano https://orcid.org/0000-0001-7665-0796
I. Nardecchia https://orcid.org/0000-0001-5558-2595
L. Naticchioni https://orcid.org/0000-0003-2918-0730
R. K. Nayak https://orcid.org/0000-0002-6814-7792
A. Neunzert https://orcid.org/0000-0003-0323-0111
L. Nguyen Quynh https://orcid.org/0000-0002-1828-3702
A. B. Nielsen https://orcid.org/0000-0001-8694-4026
A. Niko https://orcid.org/0009-0007-4502-9359
A. Nishizawa https://orcid.org/0000-0003-3562-0990
E. Nitoglia https://orcid.org/0000-0001-8906-9159
J. Novak https://orcid.org/0000-0002-6029-4712
J. F. Nu no Siles https://orcid.org/0000-0001-8304-8066
L. K. Nuttall https://orcid.org/0000-0002-8599-8791
M. Obergaulinger https://orcid.org/0000-0002-5552-7681
J. Oberling https://orcid.org/0009-0001-4174-3973
M. Oertel https://orcid.org/0000-0002-1884-8654
K. Oh https://orcid.org/0000-0002-9672-3742
M. Ohashi https://orcid.org/0000-0001-8072-0304
M. Ohkawa https://orcid.org/0000-0002-1380-1419
F. Ohme https://orcid.org/0000-0003-0493-5607
A. S. Oliveira https://orcid.org/0000-0001-5755-5865
R. Oliveri https://orcid.org/0000-0002-7497-871X
K. Oohara https://orcid.org/0000-0002-7518-6677
B. O'Reilly https://orcid.org/0000-0002-3874-8335
M. Orselli https://orcid.org/0000-0003-3563-8576
R. O'Shaughnessy https://orcid.org/0000-0001-5832-8517
Y. Oshima https://orcid.org/0000-0002-1868-2842
S. Oshino https://orcid.org/0000-0002-2794-6029
S. Ossokine https://orcid.org/0000-0002-2579-1246
I. Ota https://orcid.org/0000-0001-5045-2484
D. J. Ottaway https://orcid.org/0000-0001-6794-1591
B. J. Owen https://orcid.org/0000-0003-3919-0780
R. Pagano https://orcid.org/0000-0001-8362-0130
M. A. Page https://orcid.org/0000-0002-5298-7914
A. Pai https://orcid.org/0000-0003-3476-4589
S. Pal https://orcid.org/0000-0003-2172-8589
M. A. Palaia https://orcid.org/0009-0007-3296-8648
C. Palomba https://orcid.org/0000-0002-4450-9883
P. Palud https://orcid.org/0000-0002-5850-6325
K. C. Pan https://orcid.org/0000-0002-1473-9880
R. Panai https://orcid.org/0009-0003-3282-1970
F. Pannarale https://orcid.org/0000-0002-7537-3210
F. Paoletti https://orcid.org/0000-0001-8898-1963
L. Papalini https://orcid.org/0000-0002-5219-0454
A. Parisi https://orcid.org/0000-0003-0251-8914
J. Park https://orcid.org/0000-0002-7510-0079
W. Parker https://orcid.org/0000-0002-7711-4423
D. Pascucci https://orcid.org/0000-0003-1907-0175
R. Passaquieti https://orcid.org/0000-0003-4753-9428
O. Patane https://orcid.org/0000-0002-4850-2355
B. Patricelli https://orcid.org/0000-0001-6709-0969
K. Paul https://orcid.org/0000-0002-8406-6503
S. Paul https://orcid.org/0000-0002-4449-1732
E. Payne https://orcid.org/0000-0003-4507-8373
R. Pegna https://orcid.org/0000-0002-6532-671X
A. Pele https://orcid.org/0000-0002-1873-3769
F. E. Peña Arellano https://orcid.org/0000-0002-8516-5159
S. Penn https://orcid.org/0000-0003-4956-0853
A. Perego https://orcid.org/0000-0002-0936-8237
C. Périgois https://orcid.org/0000-0002-9779-2838
G. Perna https://orcid.org/0000-0002-7364-1904
A. Perreca https://orcid.org/0000-0002-6269-2490
S. Perriès https://orcid.org/0000-0003-2213-3579
H. P. Pfeiffer https://orcid.org/0000-0001-9288-519X
K. A. Pham https://orcid.org/0000-0002-7650-1034
K. S. Phukon https://orcid.org/0000-0003-1561-0760
L. Piccari https://orcid.org/0009-0000-0247-4339
O. J. Piccinni https://orcid.org/0000-0001-5478-3950
M. Pichot https://orcid.org/0000-0002-4439-8968
M. Piendibene https://orcid.org/0000-0003-2434-488X
F. Piergiovanni https://orcid.org/0000-0001-8063-828X
L. Pierini https://orcid.org/0000-0003-0945-2196
G. Pierra https://orcid.org/0000-0003-3970-7970
V. Pierro https://orcid.org/0000-0002-6020-5521
M. Pillas https://orcid.org/0000-0003-3224-2146
F. Pilo https://orcid.org/0000-0003-4967-7090
I. M. Pinto https://orcid.org/0000-0002-2679-4457
B. J. Piotrzkowski https://orcid.org/0000-0001-8919-0899
M. D. Pitkin https://orcid.org/0000-0003-4548-526X
A. Placidi https://orcid.org/0000-0001-8032-4416
E. Placidi https://orcid.org/0000-0002-3820-8451
M. L. Planas https://orcid.org/0000-0001-8278-7406
W. Plastino https://orcid.org/0000-0002-5737-6346
R. Poggiani https://orcid.org/0000-0002-9968-2464
E. Polini https://orcid.org/0000-0003-4059-0765
L. Pompili https://orcid.org/0000-0002-0710-6778
R. Poulton https://orcid.org/0000-0003-2049-520X
J. Powell https://orcid.org/0000-0002-1357-4164
B. K. Pradhan https://orcid.org/0000-0002-2526-1421
G. Pratten https://orcid.org/0000-0003-4984-0775
G. Principe https://orcid.org/0000-0003-0406-7387
G. A. Prodi https://orcid.org/0000-0001-5256-915X
L. Prokhorov https://orcid.org/0000-0002-0869-185X
J. Pullin https://orcid.org/0000-0001-8248-603X
M. Punturo https://orcid.org/0000-0001-8722-4485
M. Pürrer https://orcid.org/0000-0002-3329-9788
H. Qi https://orcid.org/0000-0001-6339-1537
J. Qin https://orcid.org/0000-0002-7120-9026
G. Quéméner https://orcid.org/0000-0001-6703-6655
F. J. Raab https://orcid.org/0009-0005-5872-9819
B. Rajbhandari https://orcid.org/0000-0001-7568-1611
K. E. Ramirez https://orcid.org/0000-0003-2194-7669
F. A. Ramis Vidal https://orcid.org/0000-0001-6143-2104
A. Ramos-Buades https://orcid.org/0000-0002-6874-7421
S. Ranjan https://orcid.org/0000-0001-7480-9329
P. Rapagnani https://orcid.org/0000-0002-1865-6126
A. Ray https://orcid.org/0000-0002-7322-4748
V. Raymond https://orcid.org/0000-0003-0066-0095
M. Razzano https://orcid.org/0000-0003-4825-1629
L. Rei https://orcid.org/0000-0002-8690-9180
D. H. Reitze https://orcid.org/0000-0002-5756-1111
P. Relton https://orcid.org/0000-0003-2756-3391
P. Rettegno https://orcid.org/0000-0001-8088-3517
B. Revenu https://orcid.org/0000-0002-7629-4805
A. S. Rezaei https://orcid.org/0000-0002-1674-1837
M. Ricci https://orcid.org/0009-0008-7421-4331
A. Ricciardone https://orcid.org/0000-0002-5688-455X
J. W. Richardson https://orcid.org/0000-0002-1472-4806
K. Riles https://orcid.org/0000-0002-6418-5812
S. Rinaldi https://orcid.org/0000-0001-5799-4155
A. Rocchi https://orcid.org/0000-0002-1382-9016
L. Rolland https://orcid.org/0000-0003-0589-9687
J. G. Rollins https://orcid.org/0000-0002-9388-2799

A. E. Romano https://orcid.org/0000-0002-0314-8698
R. Romano https://orcid.org/0000-0002-0485-6936
A. Romero https://orcid.org/0000-0003-2275-4164
S. Ronchini https://orcid.org/0000-0003-0020-687X
T. J. Roocke https://orcid.org/0000-0003-2640-9683
D. Rosińska https://orcid.org/0000-0002-3681-9304
M. P. Ross https://orcid.org/0000-0002-8955-5269
M. Rossello https://orcid.org/0000-0002-3341-3480
S. Rowan https://orcid.org/0000-0002-0666-9907
S. K. Roy https://orcid.org/0000-0001-9295-5119
D. Rozza https://orcid.org/0000-0002-7378-6353
E. Ruiz Morales https://orcid.org/0000-0002-0995-595X
S. Sachdev https://orcid.org/0000-0002-0525-2317
J. Sadiq https://orcid.org/0000-0001-5931-3624
M. R. Sah https://orcid.org/0009-0005-9881-1788
S. Saha https://orcid.org/0000-0002-3333-8070
S. Sajith Menon https://orcid.org/0009-0008-4985-1320
M. Sakellariadou https://orcid.org/0000-0002-2715-1517
S. Sakon https://orcid.org/0000-0002-5861-3024
O. S. Salafia https://orcid.org/0000-0003-4924-7322
F. Salces-Carcoba https://orcid.org/0000-0001-7049-4438
M. Saleem https://orcid.org/0000-0002-3836-7751
F. Salemi https://orcid.org/0000-0002-9511-3846
M. Sallé https://orcid.org/0000-0002-6620-6672
S. Salvador https://orcid.org/0000-0003-3444-7807
J. H. Sanchez https://orcid.org/0000-0001-7080-4176
N. Sanchis-Gual https://orcid.org/0000-0001-5375-7494
E. M. Sänger https://orcid.org/0009-0003-6642-8974
S. Sasaoka https://orcid.org/0000-0002-2155-8092
A. Sasli https://orcid.org/0000-0001-7357-0889
P. Sassi https://orcid.org/0000-0002-4920-2784
B. Sassolas https://orcid.org/0000-0002-3077-8951
O. Sauter https://orcid.org/0000-0003-2293-1554
R. L. Savage https://orcid.org/0000-0003-3317-1036
T. Sawada https://orcid.org/0000-0001-5726-7150
M. G. Schiworski https://orcid.org/0000-0001-9298-004X
P. Schmidt https://orcid.org/0000-0003-1542-1791
S. Schmidt https://orcid.org/0000-0002-8206-8089
R. Schnabel https://orcid.org/0000-0003-2896-4218
E. Schwartz https://orcid.org/0000-0001-8922-7794
J. Scott https://orcid.org/0000-0001-6701-6515
S. M. Scott https://orcid.org/0000-0002-9875-7700
M. Seglar-Arroyo https://orcid.org/0000-0001-8654-409X
Y. Sekiguchi https://orcid.org/0000-0002-2648-3835
A. S. Sengupta https://orcid.org/0000-0002-3212-0475
E. G. Seo https://orcid.org/0000-0002-8588-4794
J. W. Seo https://orcid.org/0000-0003-4937-0769
M. Serra https://orcid.org/0000-0002-6093-8063
G. Servignat https://orcid.org/0000-0003-0057-922X
U. S. Shah https://orcid.org/0000-0001-8249-7425
M. A. Shaikh https://orcid.org/0000-0003-0826-6164
L. Shao https://orcid.org/0000-0002-1334-8853
P. Shawhan https://orcid.org/0000-0002-8249-8070
N. S. Shcheblanov https://orcid.org/0000-0001-8696-2435
Y. Shikano https://orcid.org/0000-0003-2107-7536
K. Shimode https://orcid.org/0000-0002-5682-8750
H. Shinkai https://orcid.org/0000-0003-1082-2844
D. H. Shoemaker https://orcid.org/0000-0002-4147-2560
D. M. Shoemaker https://orcid.org/0000-0002-9899-6357
H. Siegel https://orcid.org/0000-0001-5161-4617
D. Sigg https://orcid.org/0000-0003-4606-6526
L. Silenzi https://orcid.org/0000-0001-7316-3239
L. P. Singer https://orcid.org/0000-0001-9898-5597
D. Singh https://orcid.org/0000-0001-9675-4584
M. K. Singh https://orcid.org/0000-0001-8081-4888
A. Singha https://orcid.org/0000-0002-9944-5573
A. M. Sintes https://orcid.org/0000-0001-9050-7515
V. Skliris https://orcid.org/0000-0003-0902-9216
B. J. J. Slagmolen https://orcid.org/0000-0002-2471-3828
J. R. Smith https://orcid.org/0000-0003-0638-9670
L. Smith https://orcid.org/0000-0002-3035-0947
R. J. E. Smith https://orcid.org/0000-0001-8516-3324
W. J. Smith https://orcid.org/0009-0003-7949-4911
J. Soldateschi https://orcid.org/0000-0002-5458-5206
K. Somiya https://orcid.org/0000-0003-2601-2264
I. Song https://orcid.org/0000-0002-4301-8281
K. Soni https://orcid.org/0000-0001-8051-7883
S. Soni https://orcid.org/0000-0003-3856-8534
N. Sorrentino https://orcid.org/0000-0002-1855-5966
H. Sotani https://orcid.org/0000-0002-3239-2921
A. P. Spencer https://orcid.org/0000-0003-4418-3366
M. Spera https://orcid.org/0000-0003-0930-6930
F. Stachurski https://orcid.org/0000-0002-8658-5753
D. A. Steer https://orcid.org/0000-0002-8781-1273
S. Steinlechner https://orcid.org/0000-0003-4710-8548
N. Stergioulas https://orcid.org/0000-0002-5490-5302
G. Stratta https://orcid.org/0000-0003-1055-7980
S. Sudhagar https://orcid.org/0000-0001-8578-4665
L. Suleiman https://orcid.org/0000-0003-3783-7448
L. Sun https://orcid.org/0000-0001-7959-892X
P. J. Sutton https://orcid.org/0000-0003-1614-3922
T. Suzuki https://orcid.org/0000-0003-3030-6599
B. L. Swinkels https://orcid.org/0000-0002-3066-3601
M. J. Szczepańczyk https://orcid.org/0000-0002-6167-6149
P. Szewczyk https://orcid.org/0000-0002-1339-9167
M. Tacca https://orcid.org/0000-0003-1353-0441
H. Tagoshi https://orcid.org/0000-0001-8530-9178
S. C. Tait https://orcid.org/0000-0003-0327-953X
H. Takahashi https://orcid.org/0000-0003-0596-4397
R. Takahashi https://orcid.org/0000-0003-1367-5149
A. Takamori https://orcid.org/0000-0001-6032-1330
H. Takeda https://orcid.org/0000-0001-9937-2557
N. Tamanini https://orcid.org/0000-0001-8760-5421
S. J. Tanaka https://orcid.org/0000-0002-8796-1992
T. Tanaka https://orcid.org/0000-0001-8406-5183
S. Tanioka https://orcid.org/0000-0003-3321-1018
L. Tao https://orcid.org/0000-0003-4382-5507
E. N. Tapia San Martín https://orcid.org/0000-0002-4817-5606
A. Taruya https://orcid.org/0000-0002-4016-1955
J. D. Tasson https://orcid.org/0000-0002-4777-5087
R. Tenorio https://orcid.org/0000-0002-3582-2587
L. M. Thomas https://orcid.org/0000-0003-3271-6436
J. E. Thompson https://orcid.org/0000-0002-0419-5517
J. Tissino https://orcid.org/0000-0003-2483-6710
S. Tiwari https://orcid.org/0000-0003-1611-6625
V. Tiwari https://orcid.org/0000-0002-1602-4176
A. M. Toivonen https://orcid.org/0009-0008-9546-2035
K. Toland https://orcid.org/0000-0001-9537-9698
A. E. Tolley https://orcid.org/0000-0001-9841-943X
T. Tomaru https://orcid.org/0000-0002-8927-9014
T. Tomura https://orcid.org/0000-0002-7504-8258
N. Toropov https://orcid.org/0000-0002-0297-3661
A. Torres-Forné https://orcid.org/0000-0001-8709-5118

M. Toscani https://orcid.org/0000-0001-5997-7148
I. Tosta e Melo https://orcid.org/0000-0001-5833-4052
E. Tournefier https://orcid.org/0000-0002-5465-9607
A. Trapananti https://orcid.org/0000-0001-7763-5758
F. Travasso https://orcid.org/0000-0002-4653-6156
M. C. Tringali https://orcid.org/0000-0001-5087-189X
A. Tripathee https://orcid.org/0000-0002-6976-5576
A. Trovato https://orcid.org/0000-0002-9714-1904
T. T. L. Tsang https://orcid.org/0000-0003-3666-686X
S. Tsuchida https://orcid.org/0000-0001-8217-0764
T. Tsutsui https://orcid.org/0000-0002-2909-0471
K. Turbang https://orcid.org/0000-0002-9296-8603
M. Turconi https://orcid.org/0000-0001-9999-2027
H. Ubach https://orcid.org/0000-0002-0679-9074
N. Uchikata https://orcid.org/0000-0003-0030-3653
T. Uchiyama https://orcid.org/0000-0003-2148-1694
R. P. Udall https://orcid.org/0000-0001-6877-3278
T. Uehara https://orcid.org/0000-0003-4375-098X
K. Ueno https://orcid.org/0000-0003-3227-6055
V. Undheim https://orcid.org/0000-0003-4028-0054
T. Ushiba https://orcid.org/0000-0002-5059-4033
M. Vacatello https://orcid.org/0009-0006-0934-1014
H. Vahlbruch https://orcid.org/0000-0003-2357-2338
N. Vaidya https://orcid.org/0000-0003-1843-7545
G. Vajente https://orcid.org/0000-0002-7656-6882
G. Valdes https://orcid.org/0000-0001-5411-380X
J. Valencia https://orcid.org/0000-0003-2648-9759
M. Valentini https://orcid.org/0000-0003-1215-4552
S. A. Vallejo-Peña https://orcid.org/0000-0002-6827-9509
V. Valsan https://orcid.org/0000-0003-0315-4091
M. van Beuzekom https://orcid.org/0000-0002-0500-1286
M. van Dael https://orcid.org/0000-0002-6061-8131
J. F. J. van den Brand https://orcid.org/0000-0003-4434-5353
M. van der Sluys https://orcid.org/0000-0003-1231-0762
J. van Dongen https://orcid.org/0000-0003-0964-2483
H. van Haevermaet https://orcid.org/0000-0003-2386-957X
J. V. van Heijningen https://orcid.org/0000-0002-8391-7513
P. Van Hove https://orcid.org/0000-0002-2431-3381
M. H. P. M. van Putten https://orcid.org/0000-0002-9212-411X
Z. van Ranst https://orcid.org/0000-0002-0460-6224
N. van Remortel https://orcid.org/0000-0003-4180-8199
V. Varma https://orcid.org/0000-0002-9994-1761
A. Vecchio https://orcid.org/0000-0002-6254-1617
J. Veitch https://orcid.org/0000-0002-6508-0713
P. J. Veitch https://orcid.org/0000-0002-2597-435X
J. Venneberg https://orcid.org/0000-0002-2508-2044
P. Verdier https://orcid.org/0000-0003-3090-2948
D. Verkindt https://orcid.org/0000-0003-4344-7227
Y. Verma https://orcid.org/0000-0003-4147-3173
S. M. Vermeulen https://orcid.org/0000-0003-4227-8214
A. Veutro https://orcid.org/0009-0002-9160-5808
A. M. Vibhute https://orcid.org/0000-0003-1501-6972
A. Viceré https://orcid.org/0000-0003-0624-6231
A. D. Viets https://orcid.org/0000-0002-4241-1428
A. Vijaykumar https://orcid.org/0000-0002-4103-0666
V. Villa-Ortega https://orcid.org/0000-0001-7983-1963
E. T. Vincent https://orcid.org/0000-0002-0442-1916
A. Virtuoso https://orcid.org/0000-0003-1837-1021
S. Vitale https://orcid.org/0000-0003-2700-0767
H. Vocca https://orcid.org/0000-0002-1200-3917
D. Voigt https://orcid.org/0000-0001-9075-6503
S. P. Vyatchanin https://orcid.org/0000-0002-6823-911X
M. Wade https://orcid.org/0000-0002-5703-4469
K. J. Wagner https://orcid.org/0000-0002-7255-4251
H. Wang https://orcid.org/0000-0002-6589-2738
G. Waratkar https://orcid.org/0000-0003-3630-9440
M. Was https://orcid.org/0000-0002-1890-1128
T. Washimi https://orcid.org/0000-0001-5792-4907
A. J. Weinstein https://orcid.org/0000-0002-0928-6784
K. Wette https://orcid.org/0000-0002-4394-7179
J. T. Whelan https://orcid.org/0000-0001-5710-6576
B. F. Whiting https://orcid.org/0000-0002-8501-8669
C. Whittle https://orcid.org/0000-0002-8833-7438
D. Wilken https://orcid.org/0000-0002-7290-9411
D. Williams https://orcid.org/0000-0003-3772-198X
M. J. Williams https://orcid.org/0000-0003-2198-2974
J. L. Willis https://orcid.org/0000-0002-9929-0225
B. Willke https://orcid.org/0000-0003-0524-2925
M. Wils https://orcid.org/0000-0002-1544-7193
G. Woan https://orcid.org/0000-0003-0381-0394
J. K. Wofford https://orcid.org/0000-0002-4301-2859
H. T. Wong https://orcid.org/0000-0003-4145-4394
H. W. Y. Wong https://orcid.org/0000-0002-4027-9160
I. C. F. Wong https://orcid.org/0000-0003-2166-0027
M. Wright https://orcid.org/0000-0003-1829-7482
C. Wu https://orcid.org/0000-0003-3191-8845
D. S. Wu https://orcid.org/0000-0003-2849-3751
H. Wu https://orcid.org/0000-0003-4813-3833
D. M. Wysocki https://orcid.org/0000-0001-9138-4078
V. A. Xu https://orcid.org/0000-0002-3020-3293
Y. Xu https://orcid.org/0000-0001-8697-3505
N. Yadav https://orcid.org/0000-0002-1423-8525
H. Yamamoto https://orcid.org/0000-0001-6919-9570
K. Yamamoto https://orcid.org/0000-0002-3033-2845
T. S. Yamamoto https://orcid.org/0000-0002-8181-924X
T. Yamamoto https://orcid.org/0000-0002-0808-4822
R. Yamazaki https://orcid.org/0000-0002-1251-7889
F. W. Yang https://orcid.org/0000-0001-9873-6259
K. Z. Yang https://orcid.org/0000-0001-8083-4037
Y. Yang https://orcid.org/0000-0002-3780-1413
Z. Yarbrough https://orcid.org/0000-0002-9825-1136
A. B. Yelikar https://orcid.org/0000-0002-8065-1174
J. Yokoyama https://orcid.org/0000-0001-7127-4808
J. Yoo https://orcid.org/0000-0002-3251-0924
H. Yu https://orcid.org/0000-0002-6011-6190
H. Yuzurihara https://orcid.org/0000-0002-3710-6613
M. Zeeshan https://orcid.org/0000-0002-6494-7303
M. Zevin https://orcid.org/0000-0002-0147-0835
R. Zhang https://orcid.org/0000-0001-8095-483X
Y. Zhang https://orcid.org/0000-0002-5756-7900
C. Zhao https://orcid.org/0000-0001-5825-2401
Yuhang Zhao https://orcid.org/0000-0003-2542-4734
Y. Zheng https://orcid.org/0000-0002-5432-1331
H. Zhong https://orcid.org/0000-0001-8324-5158
X.-J. Zhu https://orcid.org/0000-0001-7049-6468
Z.-H. Zhu https://orcid.org/0000-0002-3567-6743
A. B. Zimmerman https://orcid.org/0000-0002-7453-6372
J. Zweizig https://orcid.org/0000-0002-1521-3397

References

Aasi, J., Abbott, B. P., Abbott, R., et al. 2015, CQGra, 32, 074001
Abac, A. G., Abbott, R., Abouelfettouh, I., et al. 2024, ApJL, 970, L34
Abbasi, R., Ackermann, M., Adams, J., et al. 2023, ICRC (Nagoya), 38, 1096

Abbott, B., Abbott, R., Abbott, T. D., et al. 2019, PhRvX, 9, 031040
Abbott, B. P., Abbott, R., Abbott, T. D., et al. 2016a, PhRvL, 116, 061102
Abbott, B. P., Abbott, R., Abbott, T. D., et al. 2016b, PhRvD, 94, 102001
Abbott, B. P., Abbott, R., Abbott, T. D., et al. 2017a, PhRvL, 119, 161101
Abbott, B. P., Abbott, R., Abbott, T. D., et al. 2017b, ApJL, 848, L12
Abbott, B. P., Abbott, R., Abbott, T. D., et al. 2020, PhRvD, 101, 084002
Abbott, R., Abbott, T. D., Abraham, S., et al. 2021a, PhRvX, 11, 021053
Abbott, R., Abbott, T. D., Abraham, S., et al. 2021b, ApJL, 915, L5
Abbott, R., Abbott, T. D., Acernese, F., et al. 2021c, PhRvD, 104, 122004
Abbott, R., Abbott, T. D., Acernese, F., et al. 2023a, PhRvX, 13, 041039
Abbott, R., Abbott, T. D., Acernese, F., et al. 2023b, PhRvX, 13, 011048
Abbott, R., Abe, H., Acernese, F., et al. 2023c, ApJS, 267, 29
Abbott, R., Abbott, T. D., Acernese, F., et al. 2024, PhRvD, 109, 022001
Acernese, F., Agathos, M., Agatsuma, K., et al. 2015, CQGra, 32, 024001
Adams, S. M., Kochanek, C. S., Beacom, J. F., Vagins, M. R., & Stanek, K. Z. 2013, ApJ, 778, 164
Akutsu, T., Ando, M., Arai, K., et al. 2021, PTEP, 2021, 05A101
Alekseev, E. N., Alekseeva, L. N., Krivosheina, I. V., & Volchenko, V. I. 1987, ESOC, 26, 237
Andresen, H., Müller, E., Janka, H. T., et al. 2019, MNRAS, 486, 2238
Barker, B. L., Harris, C. E., Warren, M. L., O'Connor, E. P., & Couch, S. M. 2022, ApJ, 934, 67
Berger, E., Keating, G. K., Margutti, R., et al. 2023, ApJL, 951, L31
Bergh, S. V., & Tammann, G. A. 1991, ARA&A, 29, 363
Bersten, M. C., Orellana, M., Folatelli, G., et al. 2024, A&A, 681, L18
Bionta, R. M., Blewitt, G., Bratton, C. B., et al. 1987, PhRvL, 58, 1494
Bostroem, K. A., Pearson, J., Manisha, S., et al. 2023, ApJL, 956, L5
Bugli, M., Guilet, J., Foglizzo, T., & Obergaulinger, M. 2023, MNRAS, 520, 5622
Burrows, A., Hayes, J., & Fryxell, B. A. 1995, ApJ, 450, 830
Cappellaro, E., Turatto, M., Benetti, et al. 1993, A&A, 273, 383
Chandra, P., Chevalier, R. A., Maeda, K., Ray, A. K., & Nayana, A. J. 2024, ApJL, 963, L4
Chufarin, V., Potapov, N., Ionov, I., et al. 2023, TNSAN, 150, 1
Davis, D., Areeda, J. S., Berger, B. K., et al. 2021, CQGra, 38, 135014
Diehl, R., Halloin, H., Kretschmer, K., et al. 2006, Natur, 439, 45
Dong, Y., Sand, D. J., Valenti, S., et al. 2023, ApJ, 957, 28
Ferrari, L., Folatelli, G., Ertini, K., Kuncarayakti, H., & Andrews, J. E. 2024, A&A, 687, L20
Flinner, N., Tucker, M. A., Beacom, J. F., & Shappee, B. J. 2023, RNAAS, 7, 174
Gossan, S. E., Sutton, P., Stuver, A., et al. 2016, PhRvD, 93, 042002
Grefenstette, B. W., Brightman, M., Earnshaw, H. P., Harrison, F. A., & Margutti, R. 2023, ApJL, 952, L3
Guetta, D., Langella, A., Gagliardini, S., & Della Valle, M. 2023, ApJL, 955, L9
Helou, G., Madore, B. F., Schmitz, M., et al. 1991, in Databases and On-line Data in Astronomy, ed. M. A. Albrecht & D. Egret (Berlin: Springer), 89
Hiramatsu, D., Tsuna, D., Berger, E., et al. 2023, ApJL, 955, L8
Hirata, K., Kajita, T., Koshiba, M., et al. 1987, PhRvL, 58, 1490
Hosseinzadeh, G., Farah, J., Shrestha, M., et al. 2023, ApJL, 953, L16
Itagaki, K. 2023, TNSTR, 1158, 1
Jacobson-Galan, W. V., Dessart, L., Margutti, R., et al. 2023, ApJL, 954, L42
Janka, H.-T. 2012, ARNPS, 62, 407
Jencson, J. E., Pearson, J., Beasor, E. R., et al. 2023, ApJL, 952, L30
Kilpatrick, C. D., Foley, R. J., Jacobson-Galán, W. V., et al. 2023, ApJL, 952, L23
Klimenko, S. 2022, arXiv:2201.01096
Klimenko, S., Vedovato, G., Drago, M., et al. 2016, PhRvD, 93, 042004
Koenig, M. 2023, RNAAS, 7, 169
Kotake, K., Sato, K., & Takahashi, K. 2006, RPPh, 69, 971
Kuroda, T., Fischer, T., Takiwaki, T., & Kotake, K. 2022, ApJ, 924, 38
Kuroda, T., Kotake, K., & Takiwaki, T. 2016, ApJL, 829, L14
Li, G., Hu, M., Li, W., et al. 2024, Natur, 627, 754
Li, W., Leaman, J., Chornock, R., et al. 2011, MNRAS, 412, 1441
Mao, Y., Zhang, M., Cai, G., et al. 2023, TNSAN, 130, 1
Marti-Devesa, G. 2023, ATel, 16075, 1
Martinez, L., Bersten, M. C., Folatelli, G., Orellana, M., & Ertini, K. 2024, A&A, 683, A154
Matthews, D., Margutti, R., AJ, N., et al. 2023, ATel, 16091, 1
Mezzacappa, A., Marronetti, P., Landfield, R. E., et al. 2023, PhRvD, 107, 043008
Mishra, T., Bhaumik, S., Gayathri, V., et al. 2025, PhRvD, 111, 023054
Mishra, T., O'Brien, B., Gayathri, V., et al. 2021, PhRvD, 104, 023014
Moriya, T. J., & Singh, A. 2024, PASJ, 76, 1050
Murase, K. 2024, PhRvD, 109, 103020
Nakahata, M. & Super-Kamiokande Collaboration 2023, ATel, 16070, 1
Necula, V., Klimenko, S., & Mitselmakher, G. 2012, JPhCS, 363, 012032
Neustadt, J. M. M., Kochanek, C. S., & Smith, M. R. 2023, MNRAS, 527, 5366
Niu, Z., Sun, N.-C., Maund, J. R., et al. 2023, ApJL, 955, L15
Obergaulinger, M., & Aloy, M. A. 2020, MNRAS, 492, 4613
Obergaulinger, M., & Aloy, M. A. 2021, MNRAS, 503, 4942
O'Connor, E. P., & Couch, S. M. 2018, ApJ, 865, 81
Ott, C. D. 2010, GWs from Bar-mode Instabilities, Tech. Rep. LIGO-T1000553-v2, LIGO Scientific Collaboration, https://dcc.ligo.org/LIGO-T1000553-v2/public
Pan, K.-C., Liebendörfer, M., Couch, S. M., & Thielemann, F.-K. 2021, ApJ, 914, 140
Panjkov, S., Auchettl, K., Shappee, B. J., et al. 2024, PASA, 41, e059
Paschalidis, V., & Stergioulas, N. 2017, LRR, 20, 7
Perley, D. A., Gal-Yam, A., Irani, I., & Zimmerman, E. 2023, TNSAN, 119, 1
Pledger, J. L., & Shara, M. M. 2023, ApJL, 953, L14
Powell, J., & Müller, B. 2019, MNRAS, 487, 1178
Powell, J., & Müller, B. 2020, MNRAS, 494, 4665
Powell, J., Müller, B., Aguilera-Dena, D. R., & Langer, N. 2023, MNRAS, 522, 6070
Qin, Y.-J., Zhang, K., Bloom, J., et al. 2024, MNRAS, 534, 271
Radice, D., Morozova, V., Burrows, A., Vartanyan, D., & Nagakura, H. 2019, ApJL, 876, L9
Ransome, C. L., Villar, V. A., Tartaglia, A., et al. 2024, ApJ, 965, 93
Sgro, L. A., Esposito, T. M., Blaclard, G., et al. 2023, RNAAS, 7, 141
Shibagaki, S., Kuroda, T., Kotake, K., & Takiwaki, T. 2021, MNRAS, 502, 3066
Smith, N., Pearson, J., Sand, D. J., et al. 2023, ApJ, 956, 46
Soraisam, M. D., Szalai, T., Van Dyk, S. D., et al. 2023, ApJ, 957, 64
Sun, L., Goetz, E., Kissel, J. S., et al. 2021, arXiv:2107.00129
Sutton, P. J. 2013, arXiv:1304.0210
Szczepańczyk, M. J., Antelis, J. M., Benjamin, M., et al. 2021, PhRvD, 104, 102002
Szczepańczyk, M. J., Salemi, F., Bini, S., et al. 2023, PhRvD, 107, 062002
Szczepańczyk, M. J., Zheng, Y., Antelis, J. M., et al. 2024, PhRvD, 110, 042007
Tammann, G. A., Loeffler, W., & Schroder, A. 1994, ApJS, 92, 487
Teja, R. S., Singh, A., Basu, J., et al. 2023, ApJL, 954, L12
Thwaites, J., Vandenbroucke, J., Santander, M. & IceCube Collaboration 2023, ATel, 16043, 1
Van Dyk, S. D., Srinivasan, S., Andrews, J. E., et al. 2024, ApJ, 968, 27
Vasylyev, S. S., Yang, Y., Filippenko, A. V., et al. 2023, ApJL, 955, L37
Xiang, D., Mo, J., Wang, L., et al. 2024, SCPMA, 67, 219514
Yamanaka, M., Fujii, M., & Nagayama, T. 2023, PASJ, 75, L27
Zimmerman, E. A., Irani, I., Chen, P., et al. 2024, Natur, 627, 759