At high wave luminosities ($L_w \geq 10^{-3}$), the electron fraction can also be reduced by up to almost 10% as a result of gravito-acoustic wave acceleration of the NDW. This wave-induced reduction in Y_e broadens the regions of L_w-L_ν parameter space over which the r-process occurs and can even cause an r-process to be produced (if conditions are otherwise favorable) in winds with neutrino spectra predicted to result in proton-richness.

The models we have considered are necessarily approximate, given the substantial uncertainties about the properties of long-term PNS convection and wave propagation in these environments. Nevertheless, they suggest that gravito-acoustic waves may have a significant impact on NDW nucleosynthesis, especially at early times when PNS convection is strongest. As advanced, long-term 3D simulations of core-collapse supernovae become available, our results indicate the importance of resolving and examining the impact of PNS convection on wave excitation and possible NDW dynamics. Of course, the production of the r-process requires the NDW to be at least marginally neutron rich, which recent models suggest may or may not be the case. As a result, we intend to examine the impact of the wave effects discussed here in the context of a proton-rich wind in a subsequent paper.

ACKNOWLEDGEMENTS

BN thanks Edward Brown for helpful discussions during this work. BN acknowledges support from a University Distinguished Fellowship and from the College of Natural Sciences at Michigan State University. We thank Brian Metzger for useful comments. LR thanks Stan Woosley for useful discussions during the early stages of this work. This work was supported in part through computational resources and services provided by the Institute for Cyber-Enabled Research at Michigan State University. This work has been assigned a document release number LA-UR-22-33189.

DATA AVAILABILITY

The simulation code and results used in this work are available upon reasonable request to the authors. The SkyNet reaction network used is open-source software publicly available at `https://bitbucket.org/jlippuner/skynet`.

REFERENCES

Arcones A., Thielemann F.-K., 2012, Journal of Physics G: Nuclear and Particle Physics, 40, 013201
Arcones A., Janka H. T., Scheck L., 2007, A&A, 467, 1227
Burrows A., Vartanyan D., 2021, Nature, 589, 29
Cardall C. Y., Fuller G. M., 1997, The Astrophysical Journal, 486, L111
Desai D. K., Siegel D. M., Metzger B. D., 2022, Three-Dimensional General-Relativistic Simulations of Neutrino-Driven Winds from Rotating Proto-Neutron Stars, doi:10.48550/ARXIV.2203.16560, `https://arxiv.org/abs/2203.16560`
Dessart L., Burrows A., Livne E., Ott C. D., 2006, The Astrophysical Journal, 645, 534
Duncan R. C., Shapiro S. L., Wasserman I., 1986, ApJ, 309, 141
Fischer T., Whitehouse S. C., Mezzacappa A., Thielemann F.-K., Liebendörfer M., 2010, A&A, 517, A80
Goldreich P., Kumar P., 1990, ApJ, 363, 694
Gossan S. E., Fuller J., Roberts L. F., 2020, MNRAS, 491, 5376
Hoffman R. D., Woosley S. E., Qian Y.-Z., 1997, The Astrophysical Journal, 482, 951
Hüdepohl L., Müller B., Janka H.-T., Marek A., Raffelt G. G., 2010, Phys. Rev. Lett., 104, 251101
Jacques S. A., 1977, ApJ, 215, 942
Kennedy C., Carpenter M., 2016, Technical report, Diagonally Implicit Runge-Kutta Methods for Ordinary Differential Equations. A Review
Lippuner J., Roberts L. F., 2017, The Astrophysical Journal Supplement Series, 233, 18
Martínez-Pinedo G., Fischer T., Lohs A., Huther L., 2012, Physical Review Letters, 109
Metzger B. D., Thompson T. A., Quataert E., 2007, The Astrophysical Journal, 659, 561–579
Meyer B. S., Mathews G. J., Howard W. M., Woosley S. E., Hoffman R. D., 1992, ApJ, 399, 656
Mihalas D., Mihalas B. W., 1984, Foundations of radiation hydrodynamics. Oxford University Press, Inc.
Nagakura H., Burrows A., Radice D., Vartanyan D., 2020, Monthly Notices of the Royal Astronomical Society, 492, 5764
Nagakura H., Burrows A., Vartanyan D., 2021, MNRAS, 506, 1462
Otsuki K., Tagoshi H., Kajino T., ya Wanajo S., 2000, The Astrophysical Journal, 533, 424
Pllumbi E., Tamborra I., Wanajo S., Janka H.-T., Hüdepohl L., 2015, The Astrophysical Journal, 808, 188
Pons J. A., Reddy S., Prakash M., Lattimer J. M., Miralles J. A., 1999, ApJ, 513, 780
Qian Y., Woosley S. E., 1996, The Astrophysical Journal, 471, 331–351
Roberts L. F., Reddy S., 2017, in Alsabti A. W., Murdin P., eds, , Handbook of Supernovae. p. 1605, doi:10.1007/978-3-319-21846-5_5
Roberts L. F., Reddy S., Shen G., 2012, Physical Review C, 86
Suzuki T. K., Nagataki S., 2005, The Astrophysical Journal, 628, 914–922
Thompson T. A., ud Doula A., 2018, Monthly Notices of the Royal Astronomical Society, 476, 5502
Thompson T. A., Burrows A., Meyer B. S., 2001, The Astrophysical Journal, 562, 887–908
Timmes F. X., Swesty F. D., 2000, The Astrophysical Journal Supplement Series, 126, 501
Vlasov A. D., Metzger B. D., Thompson T. A., 2014, Monthly Notices of the Royal Astronomical Society, 444, 3537
Wanajo S., 2013, ApJ, 770, L22
Witti J., Janka H. T., Takahashi K., 1994, A&A, 286, 841
Woosley S. E., Hoffman R. D., 1992, ApJ, 395, 202
Woosley S. E., Wilson J. R., Mathews G. J., Hoffman R. D., Meyer B. S., 1994, ApJ, 433, 229
Xiong Z., Wu M.-R., Qian Y.-Z., 2019, The Astrophysical Journal, 880, 81

This paper has been typeset from a TEX/LATEX file prepared by the author.