WEEK 10: GW'S FROM NEUTRON-STAR ROTATION AND PULSATION; NUMERICAL RELATIVITY AND SIMULATIONS OF GRAVITATIONAL-WAVE SOURCES

Lectures 17 by Lee Lindblom, and 18 by Mark Scheel

Recommended Reading:

There are no textbook treatments of the material covered in this week's lectures. The following materials may be useful. There is far more material here than any one person should try to read. Choose a reasonable amount, in the area of greatest interest or relevance to you, and read or browse it.

GW's from Neutron-Star Rotation and Pulsation

1. Gravitational waves from structurally deformed, spinning neutron stars.

- **a.** The brief summary in **Sections 2.2 and 2.7 of C. Cutler and K.S. Thorne, "An overview of gravitational wave sources", in Proceedings of the GR16 Conference on General Relativity and Gravitation, ed. N. Bishop (World Scientific, 2002), in press; available at http://xxx.lanl.gov/abs/gr-qc/0204090 .**
- **b.** References cited in this Cutler-Thorne review.

2. Gravitational waves from dynamical, bar-mode instabilities in spinning, deformed neutron stars:

- **a.** The classic 19'th century theory of equilibria and pulsations of homogeneous, spinning perfect fluids: S. Chandrasekhar, *Ellipsoidal Figures of Equilibrium* (Yale University Press, New Haven, CN, 1969).
- **b.** Dynamical, bar-mode instability in realistic models of rapidly spinning neutron stars:
  - **i.** The survey paper, discussed in Lindblom's lecture, by **K.C.B. New, J.M. Centrella, and J.E. Tohline, "Gravitational waves from long-duration simulations of the dynamical bar instability", Physical Review D, 62, 064019 (2000); also available at http://xxx.lanl.gov/abs/astro-ph/9911525 .**
  - **ii.** Surveys of the fact that only modest amounts of rotation are needed, if the rotation is strongly differential, to trigger the bar-mode instability: M. Shibata, S. Karino and Y. Eriguchi, "Dynamical instability of differentially rotating stars," *Monthly Notices of the Royal Astronomical Socieity*, in press; also available at http://xxx.lanl.gov/abs/gr-qc/0206002 ; and J.M. Centrella, K.C.B. New, L.L. Lowe and J.D. Brown, "Dynamical rotational instability at low T/W", *Astrophysical Journal letters*, **550**, L193–L196 (2001).
  - **iii.** A studies of the bar-mode instability in the context of the accretion-induced collapse of white dwarf stars: Y.-T. Liu, "Dynamical instability of newborn neutron stars as sources of gravitational radiation", *Physical Review D*, **65**, 124003 (2002); available at http://xxx.lanl.gov/abs/gr-qc/0109078

iv. A 3+1 dimensional simulations of the collapse of rapildly spinning stars which show the dynamical instabilities develop: M. Rampp, E. Mueller and M. Ruffert, "Simulations of nonaxisymmetric rotational core collapse", *Astronomy and Astrophysics*, **332**, 969–983 (1998); available at http://xxx.lanl.gov/abs/astro-ph/9711122 .

c. R-modes (modes whose restoring force is due to the Coriolis effect) –

i. The summary emphasizing connections to LIGO, in B.J. Owen and L. Lindblom, "Gravitational radiation from the r-mode instability," *Classical and Quantum Gravity*, **19**, 1247–1254 (2002); also available at http://xxx.lanl.gov/abs/gr-qc/0111024 .

ii. An analysis that shows with fairly high confidence that mode-mode coupling will limit the amplitude of the r-mode oscillations at such a small level that LIGO will probably not be able to detect any: P. Arras, E.E. Flanagan, S.M. Morskink, A.K. Schenk, S.A. Teukolsky, and I. Wasserman, "Saturation of the r-mode instability," *Astrophysical Journal*, in press; available at http://xxx.lanl.gov/abs/astro-ph/0202345 .

iii. An analysis that shows that hyperon bulk viscosity is very likely to damp out the r-modes in newborn neutron stars, making them undetectable by LIGO: L. Lindblom and B..J. Owen, "Effect of hyperon bulk viscosity on neutron-star r-modes", *Physical Review D*, **65**, 063006 (2002); also available at http://xxx.lanl.gov/abs/astro-ph/0110558 .

Numerical Relativity and Numerical Simulations of GW Sources

3. Motivations:

a. Binary black hole mergers: Event rates and science to be learned: Sections 2.3, 2.5 and 3.3 of C. Cutler and K.S. Thorne, "An Overview of Gravitational Waves Sources", in *Proceedings of the GR16 Conference on General Relativity and Gravitation*, edited by Nigel Bishop (World Scientific, 2002), in press; available at http://xxx.lanl.gov/abs/gr-qc/0204090 .

b. Tidal disruption of a neutron star by a black hole: M. Vallisneri, *Physical Review Letters*, **84**, 3519 (2000); also available at http://xxx.lanl.gov/abs/gr-qc/9912026 .

c. Merger of neutron-star binaries: J.A. Faber, P. Grandclement, F.A. Rasio and K. Taniguchi, "Measuring neutron-star radii with gravitational wave detectors," *Physical Review Letters*, submitted; available at http://xxx.lanl.gov/abs/astro-ph/0204397 .

4. Numerical Relativity:

a. A recent review, of modest length and not much technical detail: **L. Lehner, "Numerical Relativity: Status and Prospects," in Proceedings of the 16'th International Conference on General Relativity and Gravitation, N. Bishop ed., (World Scientific, 2002), in press; available at http://xxx.lanl.gov/abs/gr-qc/0202055.**

b. A long review by the same author, including much technical detail: L. Lehner, "Numerical Relativity: A Review," *Classical and Quantum Gravity*,. **18**, R25–R86 (2001); also available at http://xxx.lanl.gov/abs/gr-qc/0106072 .