Gravitational Wave Signals from Compact Binary Mergers

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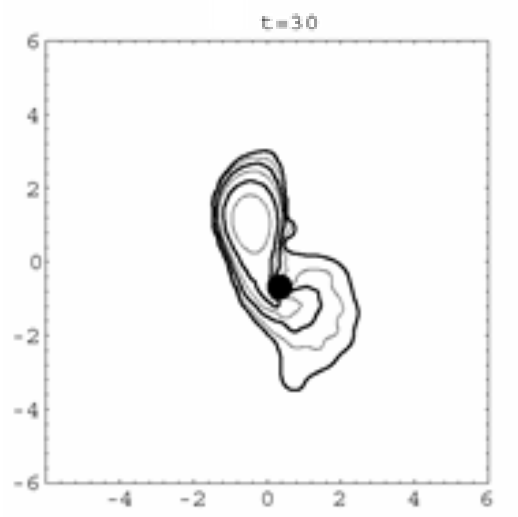
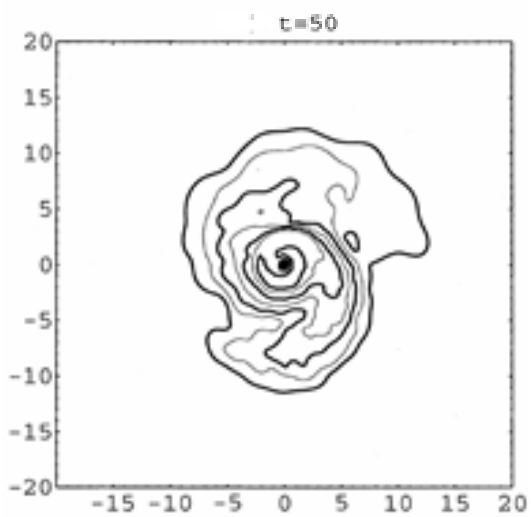
LIGO-G030217-00-Z

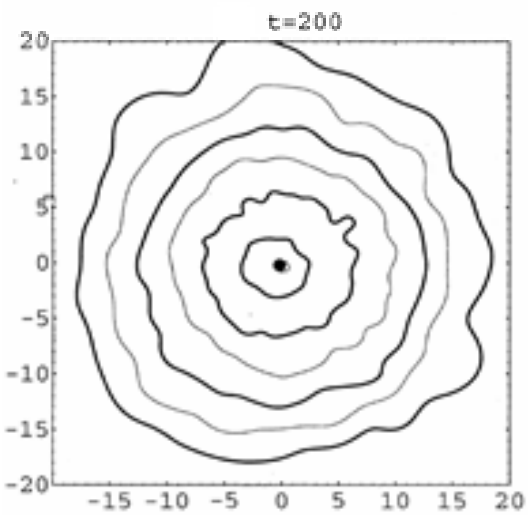
Compact Binary Mergers

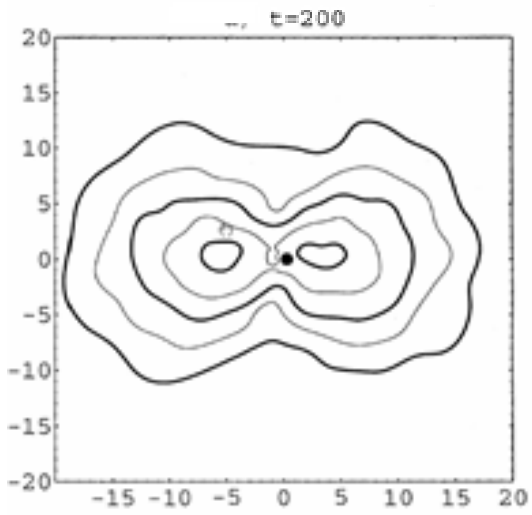
f_{dyn} EM signals	Black Hole	Neutron Star	White Dwarf
Black Hole	300 Hz None	1 kHz GRB?	0.1 Hz GRB? (rare!)
Neutron Star		3 kHz Delayed GRB??	0.1 Hz Delayed GRB?? ULMXB
White Dwarf			0.01 Hz SN Ia AM CVn

NS-WD Binary Mergers





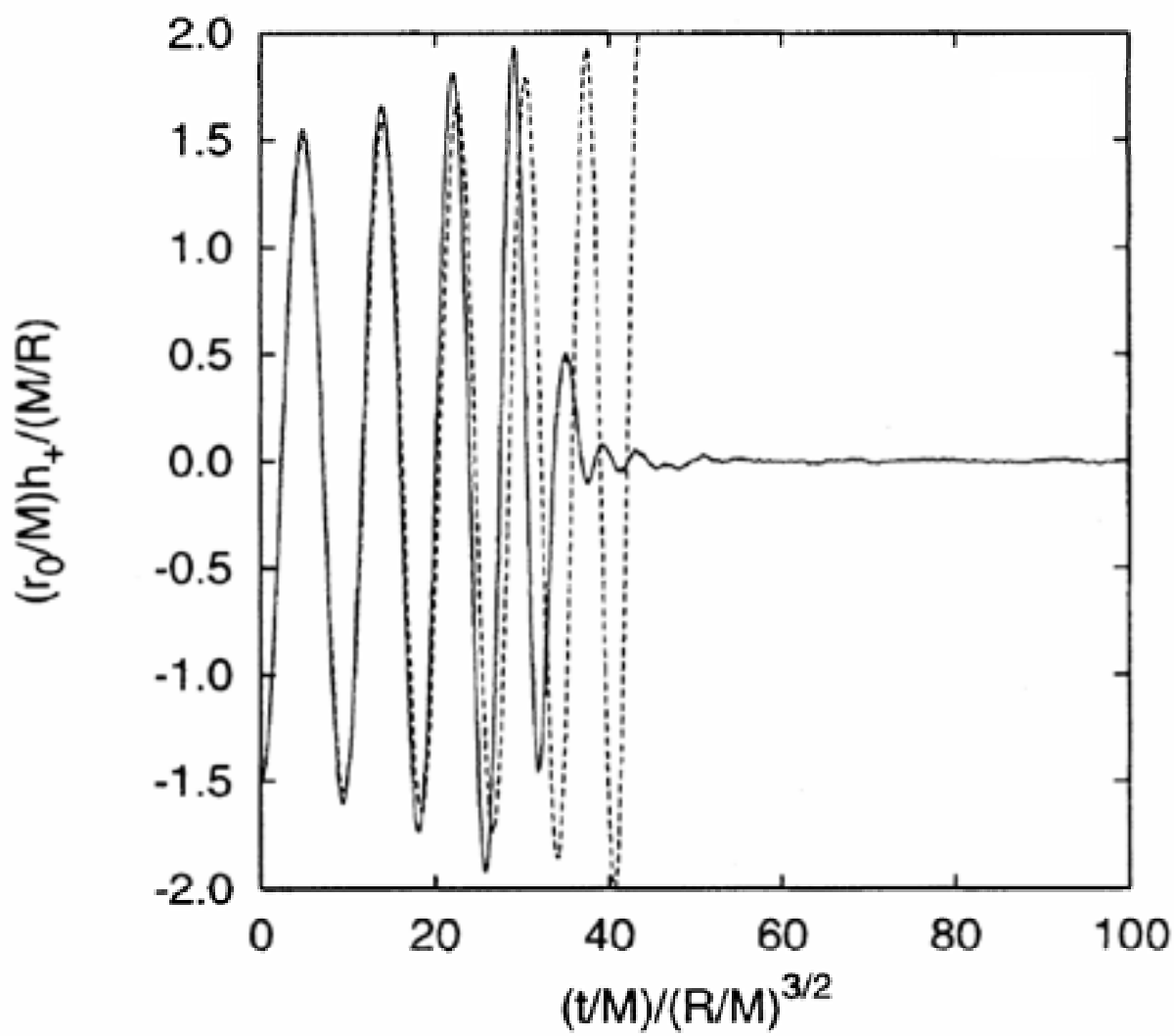




Newtonian q=0.8 point Mass + γ=5/3 polytrope

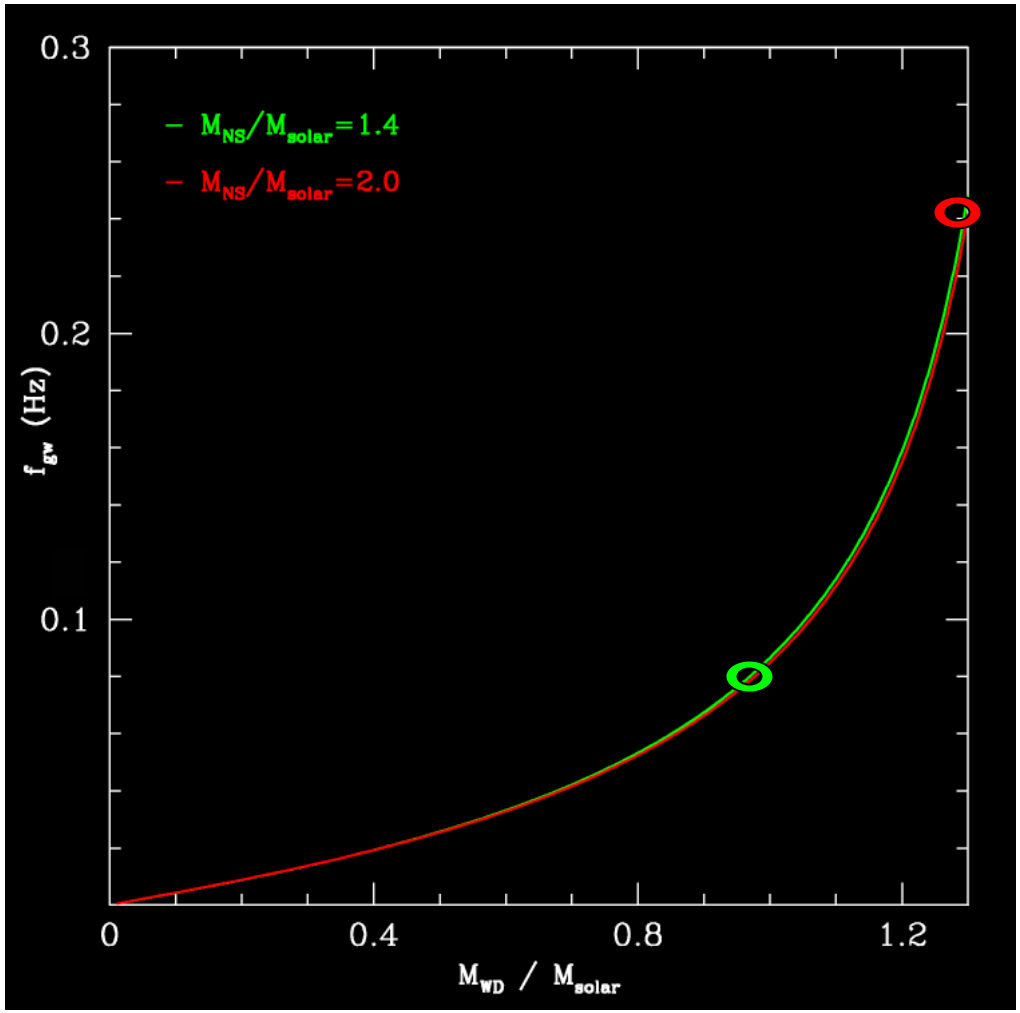
Lee & Kluzniak 2000

GW Signal from NS-WD Merger



Lee & Kluzniak 2000

Stable vs Unstable Mass Transfer



- For $q = M_{wd} / M_{ns} < 2/3$ (??), **stable mass transfer** is expected
- The corresponding GW signal is a **reversed chirp** (the orbit expands during stable mass transfer)
- The maximum GW frequency is still set by the Roche limit

Kim, Kalogera, & Lorimer 2003

Ultracompact X-ray and MSP Binaries

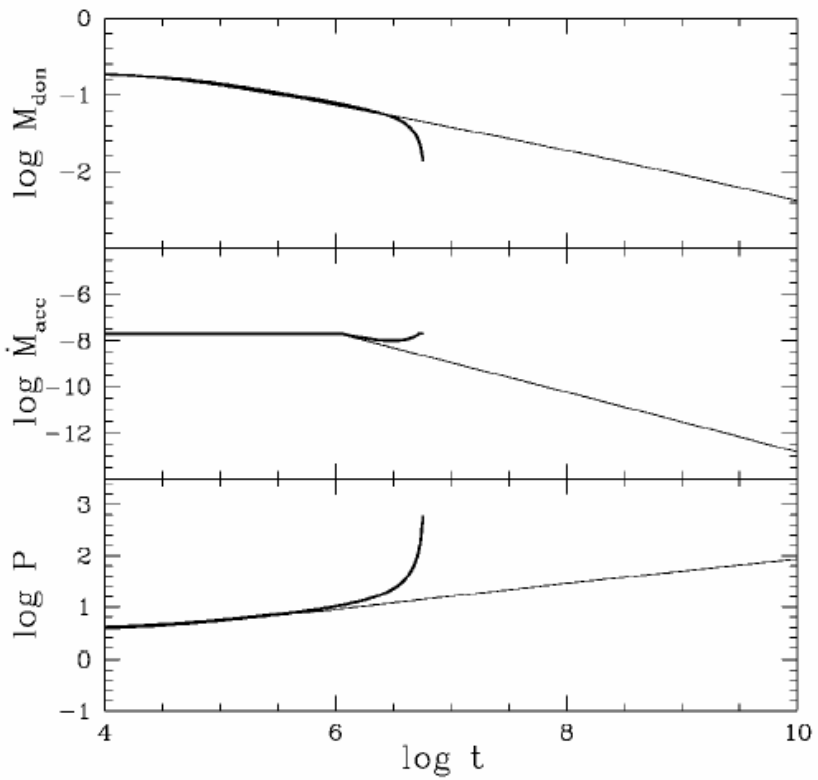


FIG. 1.—Evolution of one representative NS-WD binary driven by gravitational radiation only (*thin lines*) and by a combination of gravitational radiation and tidal heating (*thick lines*). Here time t is in years, the orbital period P is in minutes, the mass accretion rate $\dot{M}_{acc}$ (onto the NS) is in $M_\odot$ yr^{-1}, and the companion (donor) mass M_{don} is in $M_\odot$.

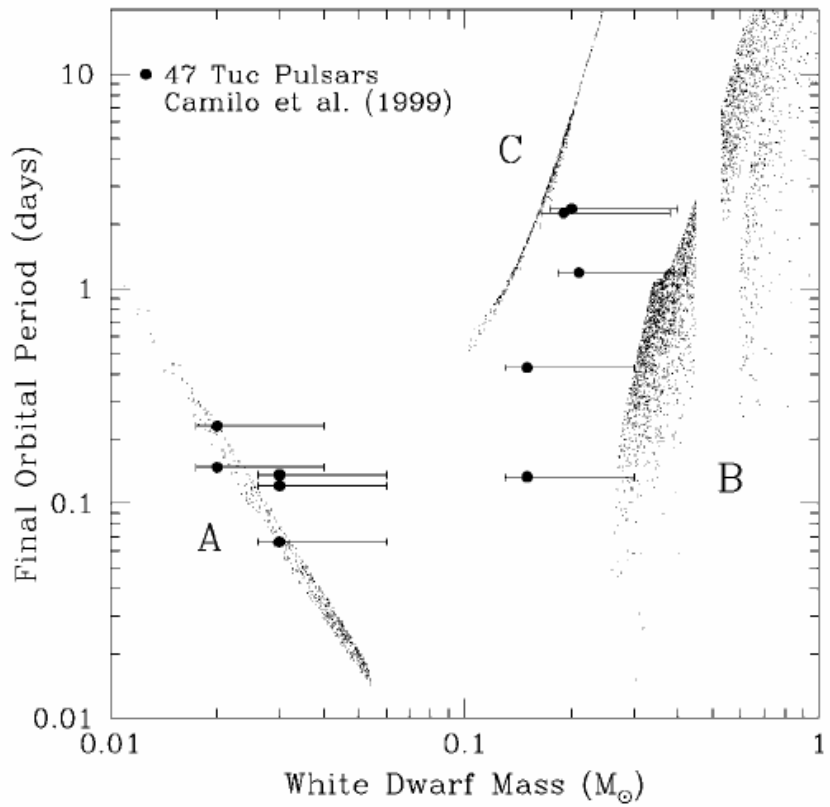
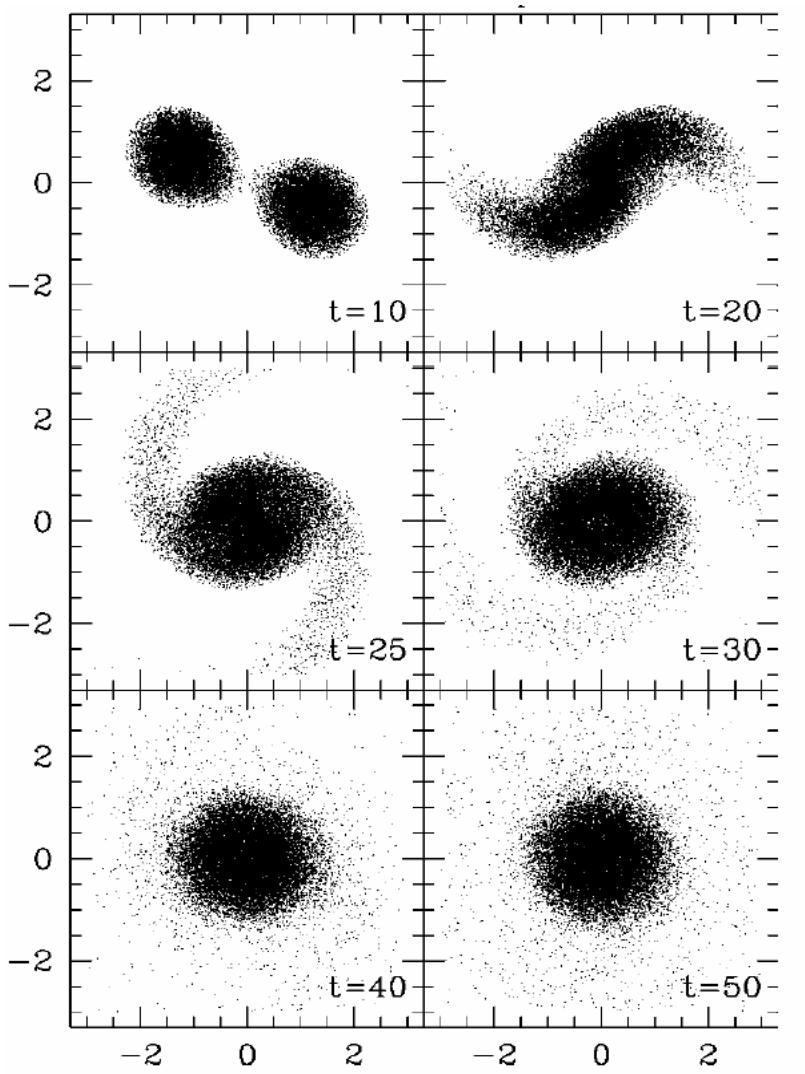


FIG. 2.—Results of our initial population synthesis study for binary millisecond pulsars in 47 Tuc. Each small dot represents a binary system in our simulation, while the circles are the 10 binary pulsars in 47 Tuc with well-measured orbits (the error bars extend from the minimum companion mass to the 90% probability level for random inclinations). There are three principal groups of simulated binaries. Systems in the diagonal band on the left (A) are

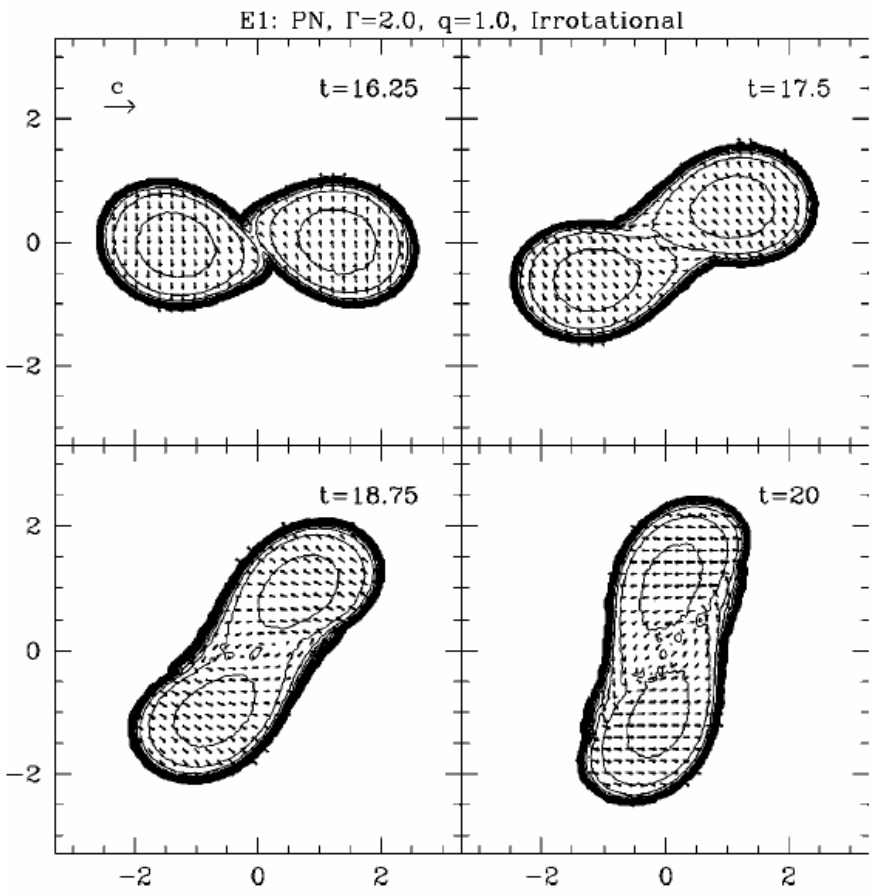
NS-NS Binary Mergers

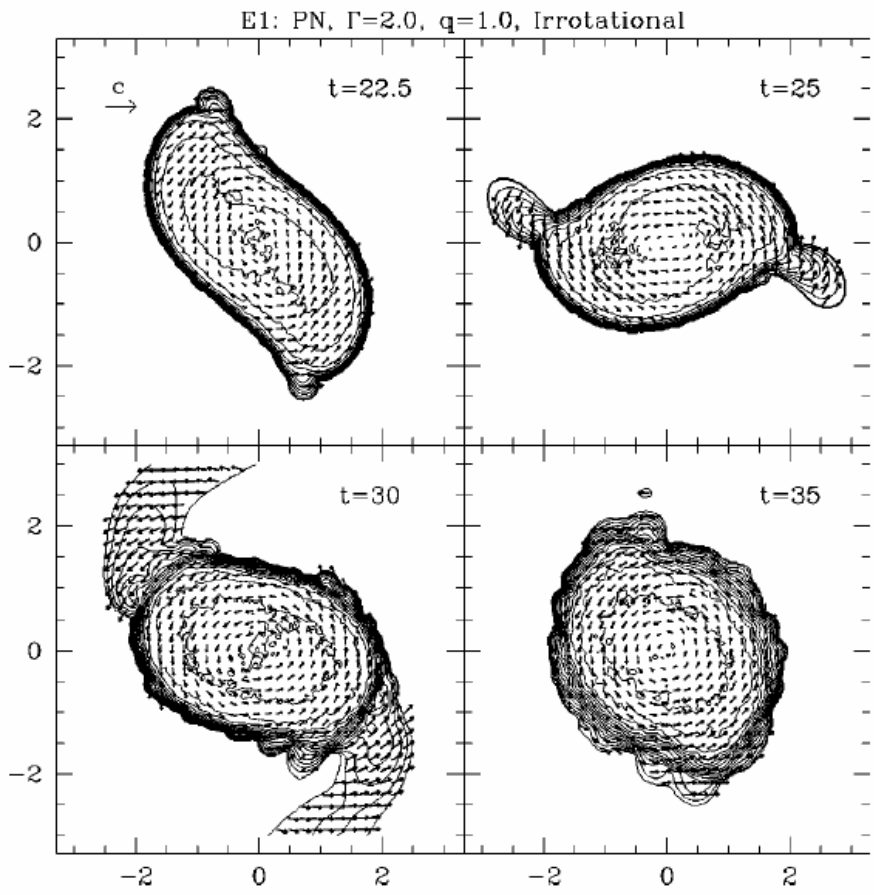
- Well-studied for 15 years with 3D hydro calculations
  - Newtonian + nuclear physics
  - Post-Newtonian
  - Recent full GR attempts
- Main uncertainties
  - NS EOS
  - Initial spins
- Good agreement between different numerical approaches
- Qualitative outcome:
  - NS for stiff EOS
  - BH for soft EOS



Faber, Rasio, & Manor 2001

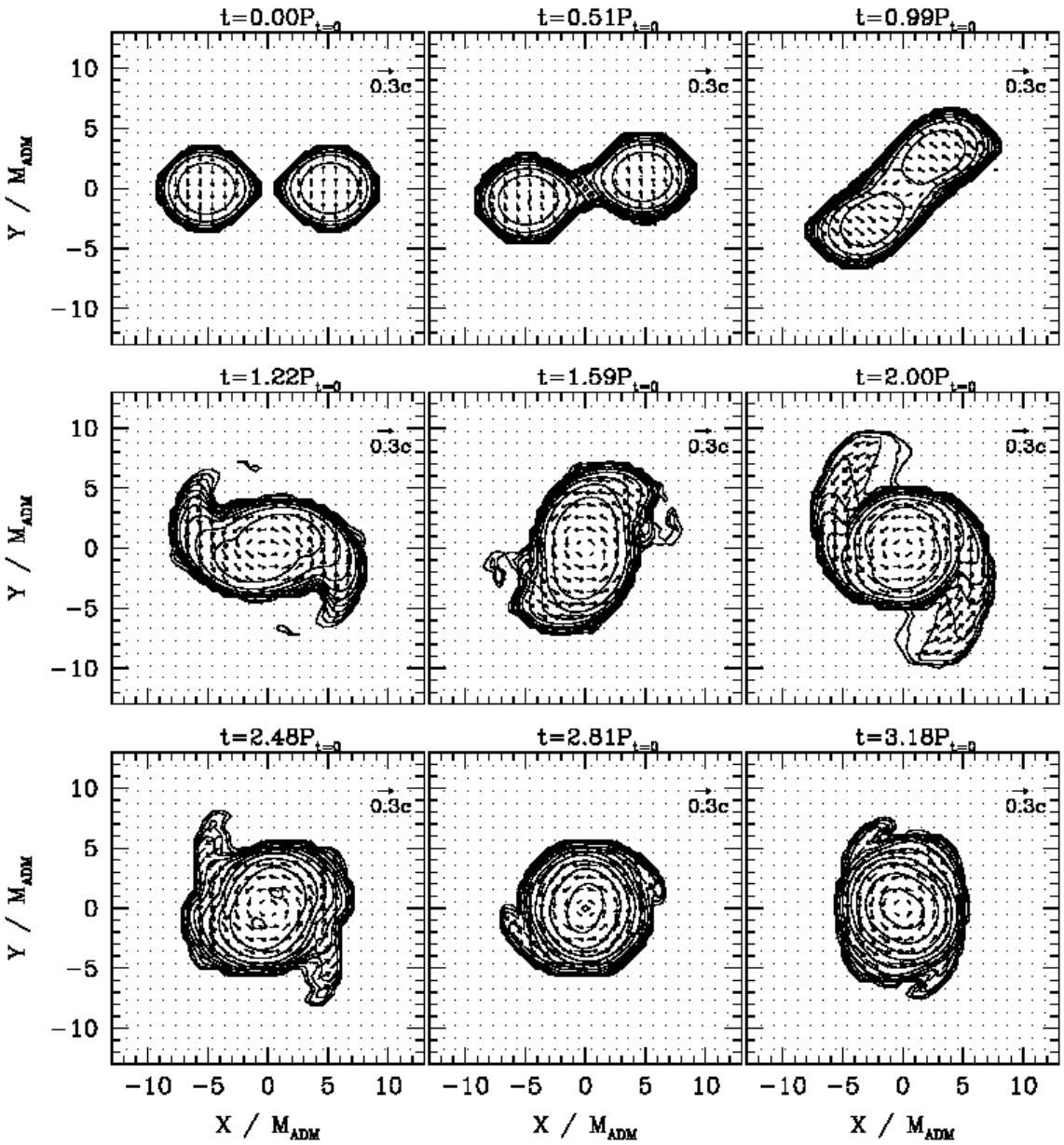
Post-Newtonian SPH Calculations





Faber & Rasio 2002

Compare to full GR…



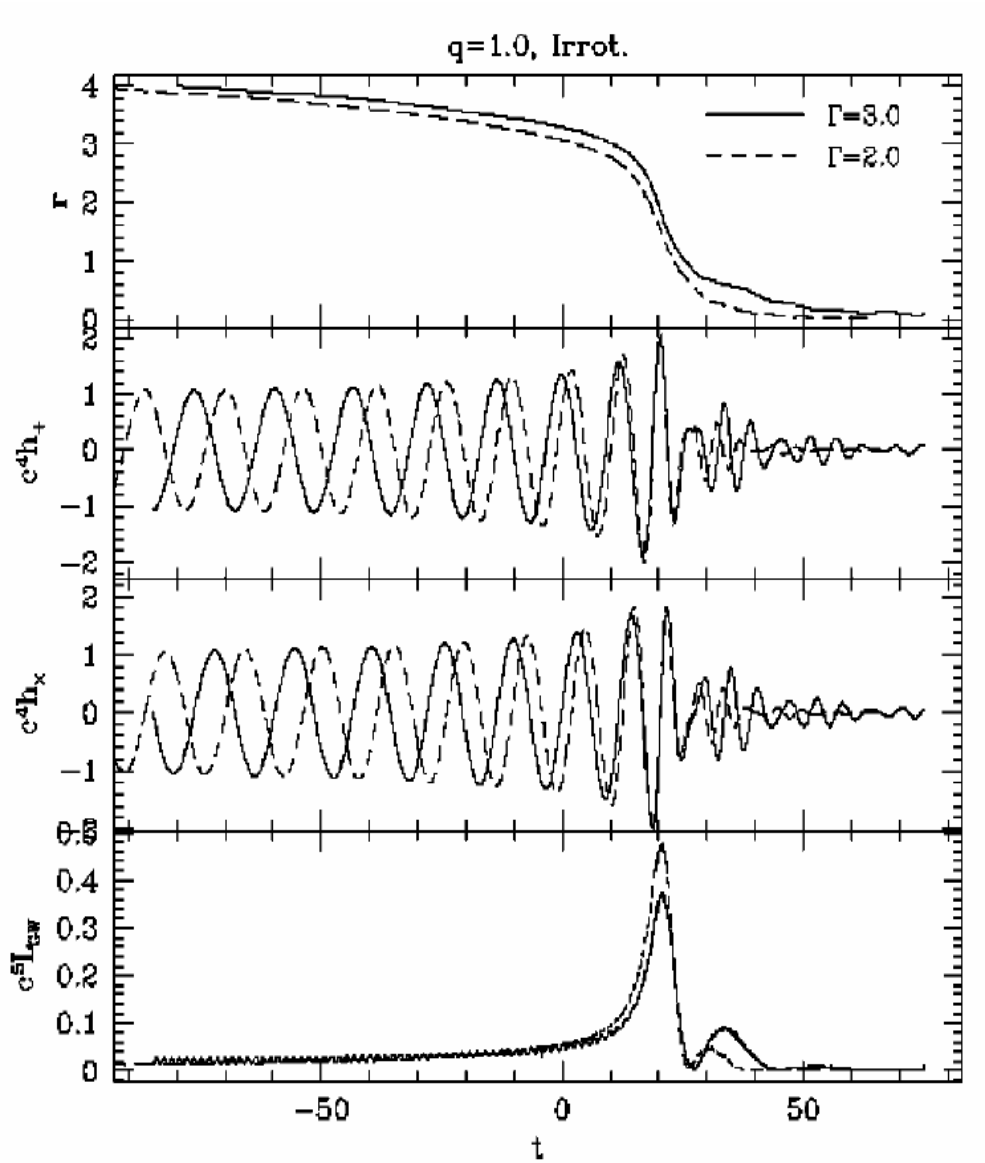
Shibata & Uryu 2002

Movie: NS-NS Binary Merger

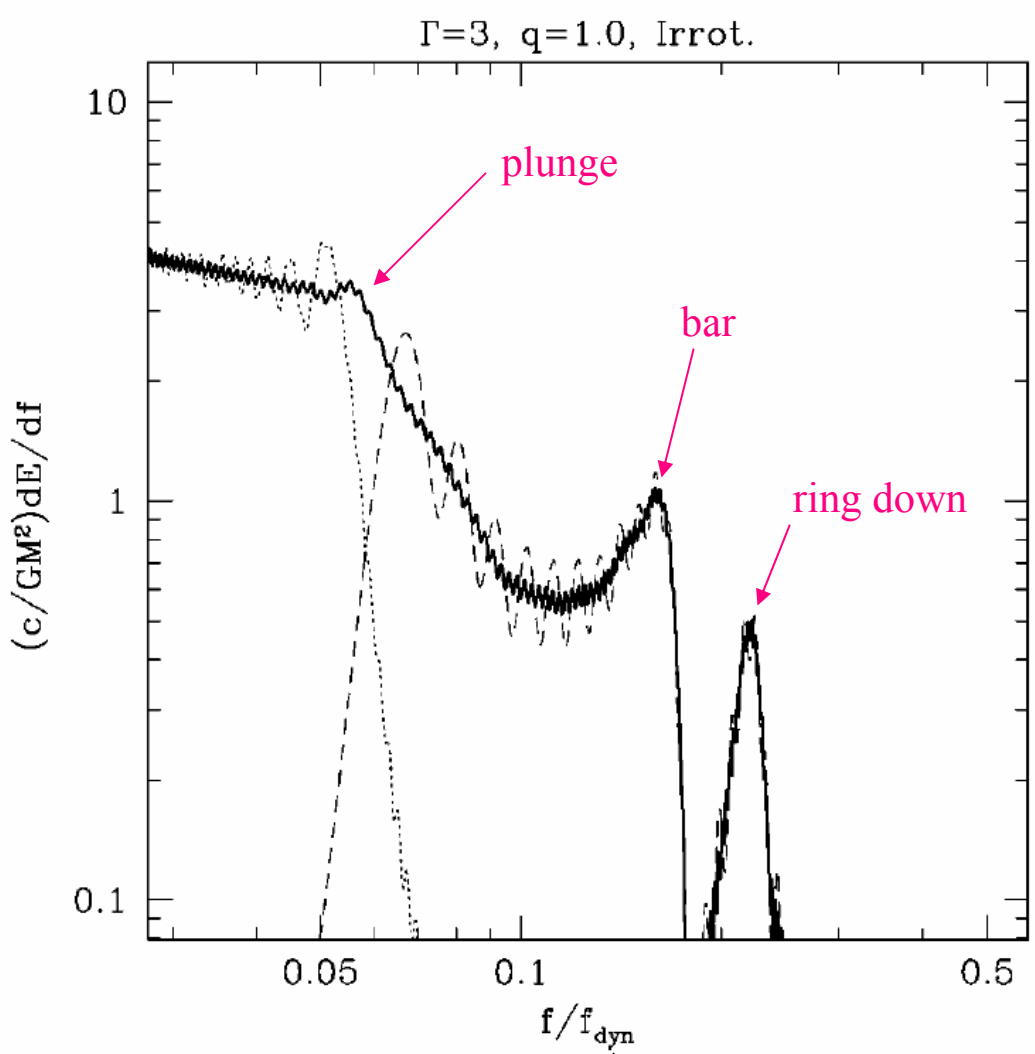
Click here to play (RealMedia)

Visualization by J. Faber & D. Roberts (Northwestern)

GW Signal from NS-NS Merger



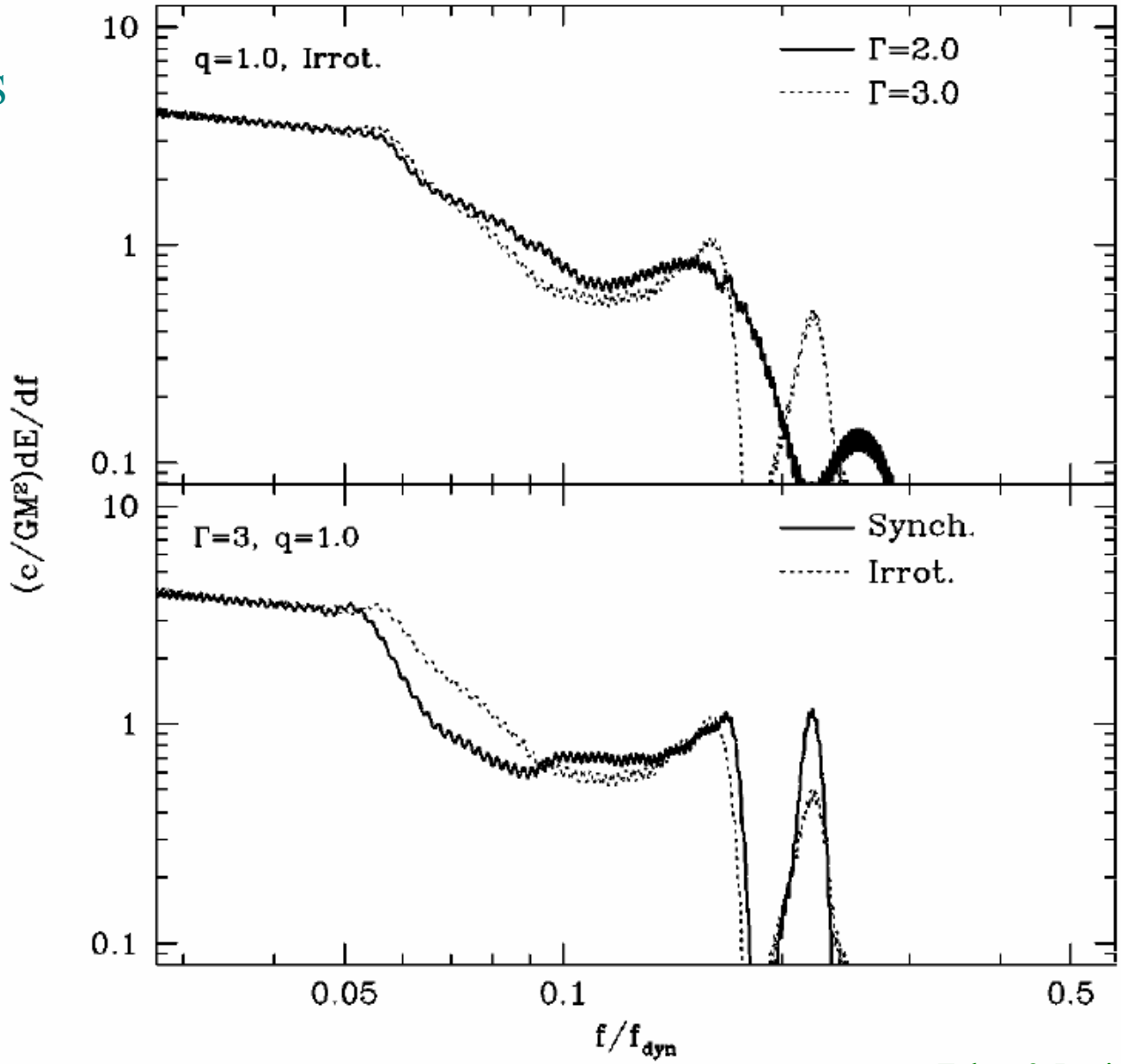
GW Energy Spectrum from NS-NS Merger



Faber & Rasio 2003

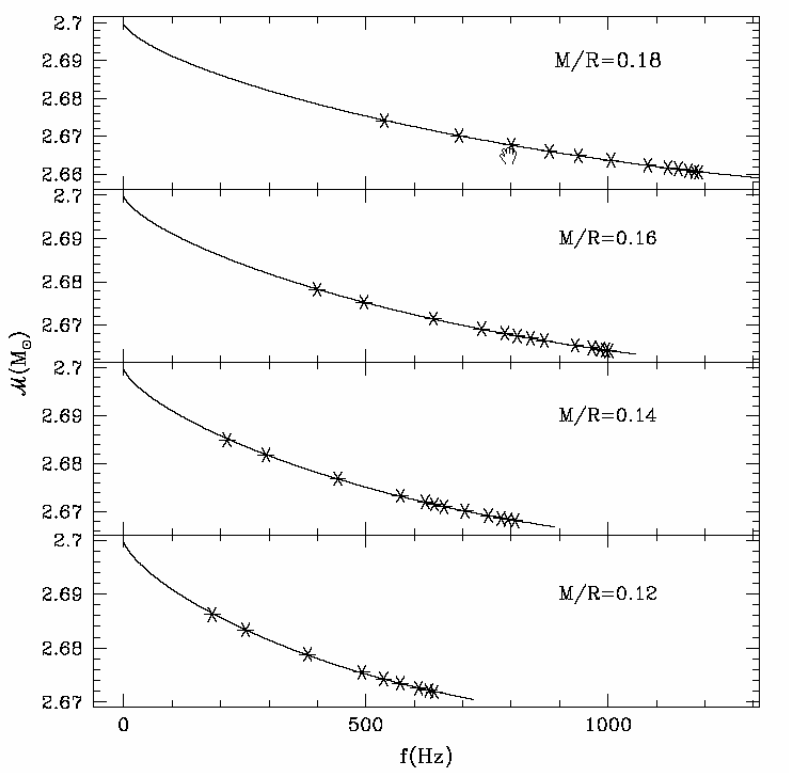
$$f_{\rm dyn} \equiv \left(\frac{GM}{R^3}\right)^{1/2} = 9.2\,{\rm kHz}\left(\frac{M}{1.4\,M_\odot}\right)^{1/2} \times \left(\frac{R}{13\ \ {\rm km}}\right)^{-3/2}$$

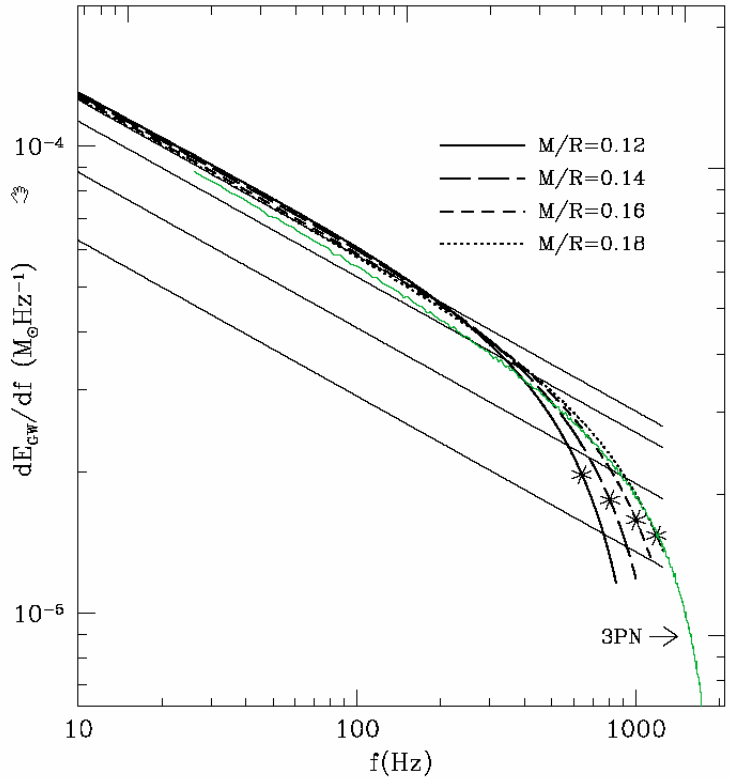
Dependence on EOS and spins…



Faber & Rasio 2002

Closer to reality (perhaps?) …





- Highly accurate, full GR calculations of quasi-equilibrium NS-NS binary sequences
- Semi-analytic derivation of the GW energy spectrum
- See Faber, Grandclément, Rasio, & Taniguchi 2002 PRL