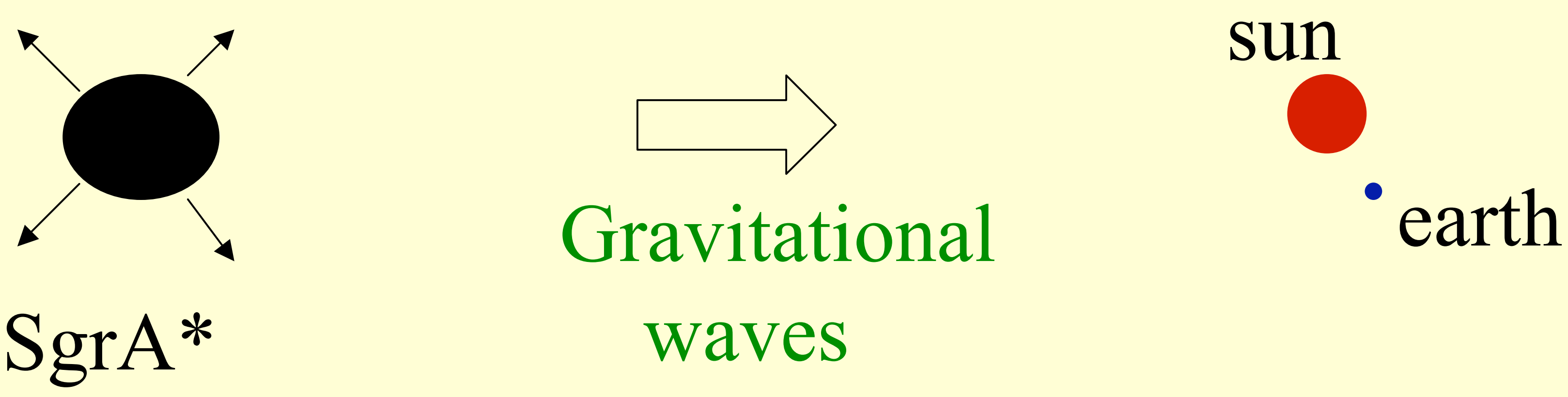
Gravitational waves in Astrophysics.

Yuri Levin, CITA

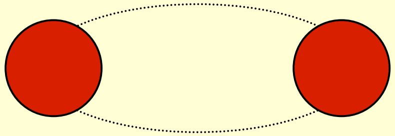
1. Nature and strength of gravitational waves
2. Sources for LIGO
3. Sources for LISA
4. GWs from rapidly rotating neutron stars
    a. Steady-state quadrupole
    b. R-modes
    c. What can we learn?



$$h = \frac{\text{Black hole radius}}{\text{distance}} = 10^{-10}$$

More realistic signal: 10^{-23}

What we expect from gods for LIGO:



NS NS

waveform is known, rate 10-10000/yr

Kalogera et. al. 04

Physics:

a. in LIGO band NS are point masses

b. test GR to 5.5 PN order

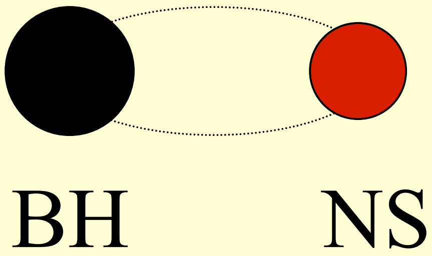
Astronomy:

a. certain to exist

b. tell us about binary evolution

c. cross-correlate with short GRBs.

What we expect from gods for LIGO:



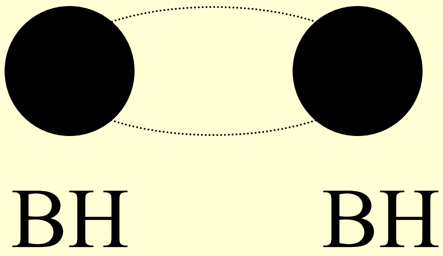
Waveform needs work, rate highly uncertain (pure theory)

Physics: tidal disruption of NS may tell us about equation of state

Astronomy:

a. Unknown whether exist
b. tell us about binary evolution
c. cross-correlate with short GRBs.

What we expect from gods for LIGO:



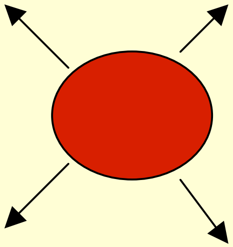
Waveform needs work, rate highly uncertain (pure theory)

Physics: full GR! need simulations.

Astronomy:

a. unknown whether exist
b. tell us about binary evolution
c. tell us about dynamics in .globular clusters

Supernovae: vibration, rapid rotation, bars.

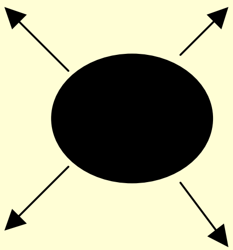


Burrows et. al.,
Centrella et. al.

Everything very uncertain!

Vibrating Intermediate-mass BHs

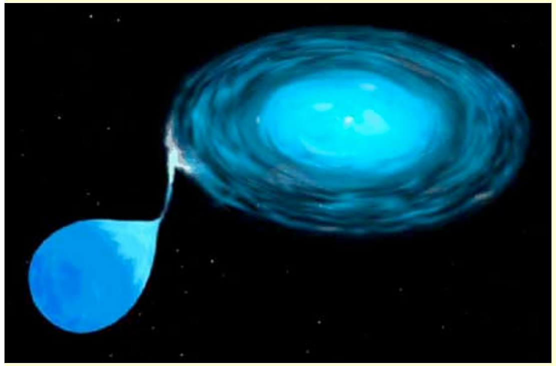
Wyithe and Loeb



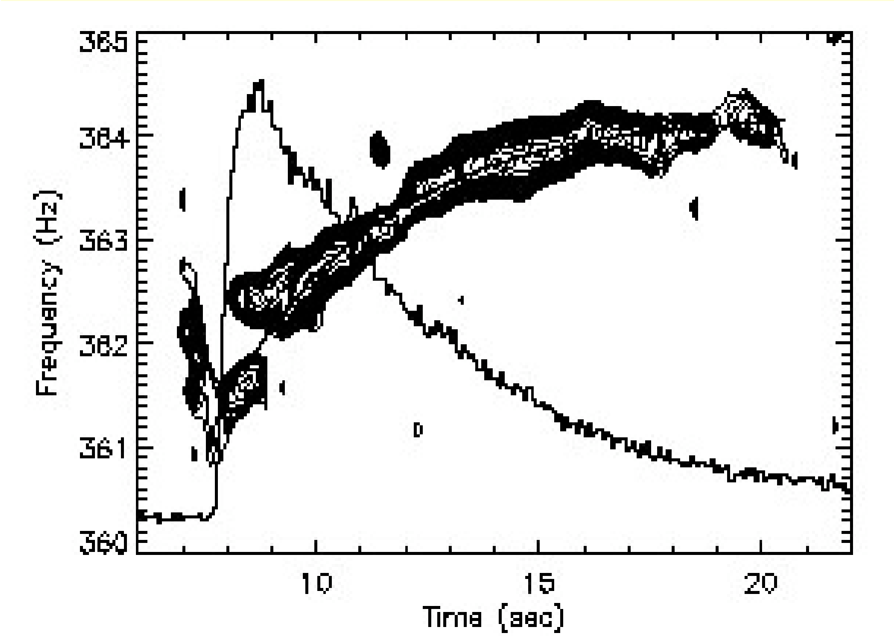
Physics: pretty well modeled

Astronomy: high-z mergers;
rate highly uncertain.

Accreting Neutron Stars in LMXBs



- About 60 in the Galaxy
- 10 bursters with pulsations
- 3 millisecond pulsars

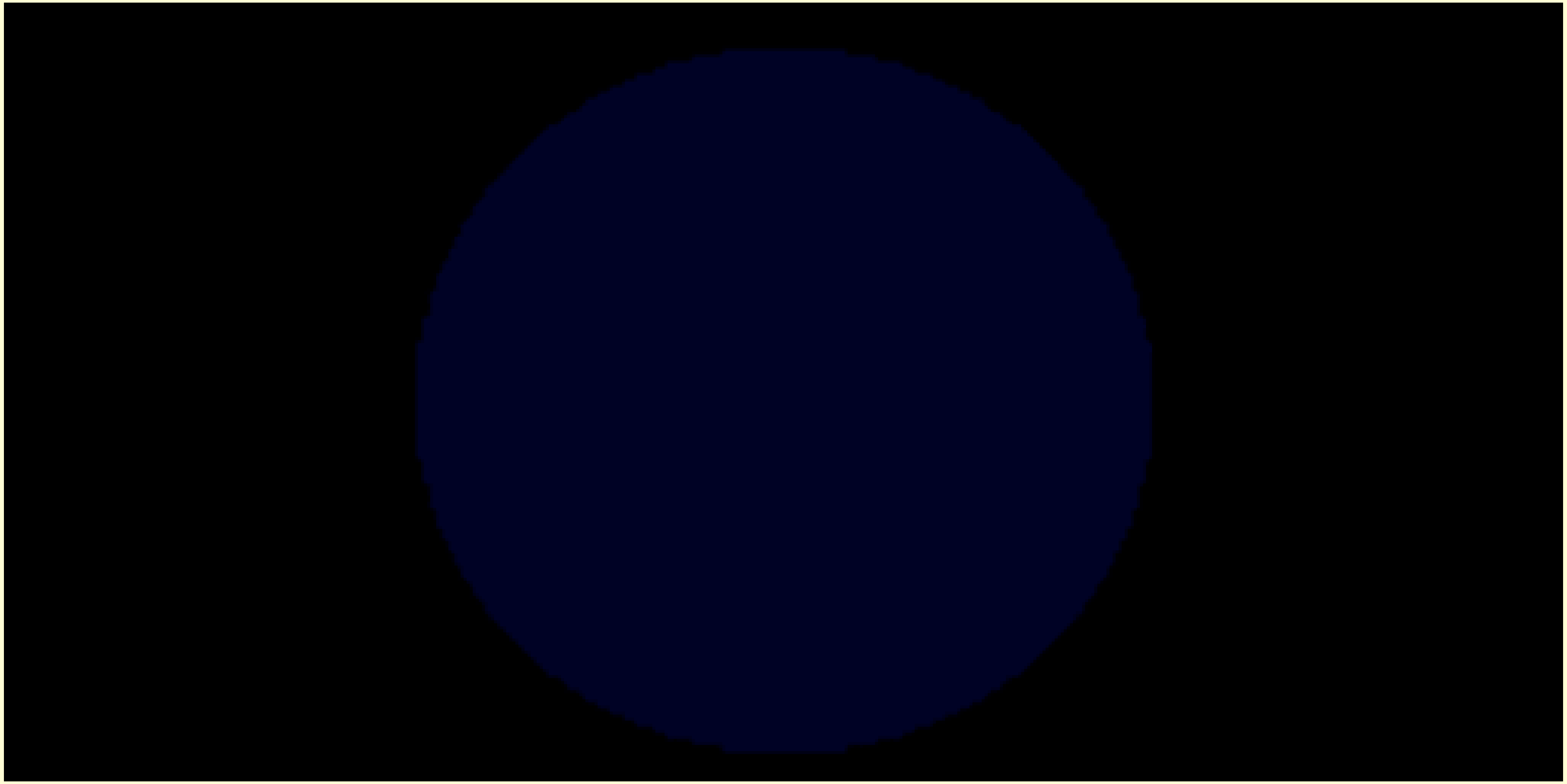


- all spins between 240 and 700 Hz
- NSs non-magnetic or weakly magnetic
- Consistent with radio pulsars

No bias!! What sets the spin?

Simulations of type-I burst

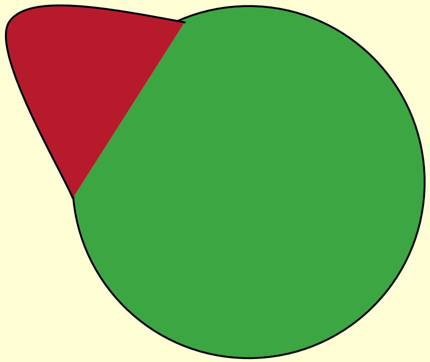
Spitkovsky, Levin, Ushomirsky 02



Rossby soliton (Boyd)

Gravitational waves! Bildsten 98

way 1: build a mountain



In the crust due to

a. non-uniform temperature or chemical composition of 5% (Bildsten, Ushomirsky et al)

b. Magnetic tutu (Melatos, Payne)

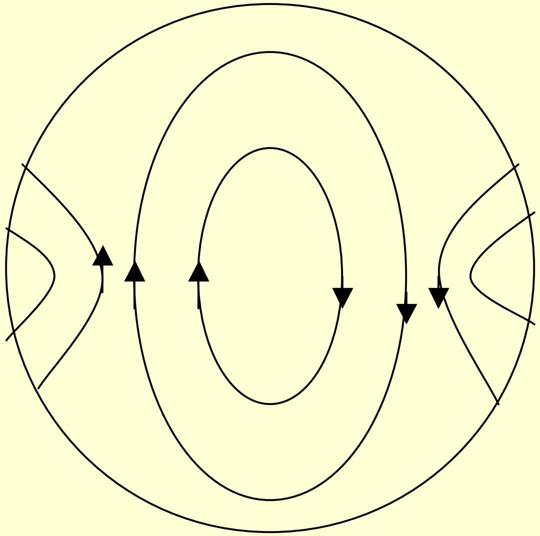
In the core due to

a. Toroidal B-field (Cutler 01)

Frequency 2_spin, LIGO will see a few in the Galaxy

Way 2: R-mode instability.

Andersson 98
Lindblom et. al. 98



- Vorticity wave driven by gravitational radiation - certain.
- damped by viscosity - uncertain!
- GW frequency (4/3)_spin

Nature of GW signal is sensitive to _(T): YL 99

“normal fluid” d_/dT<0

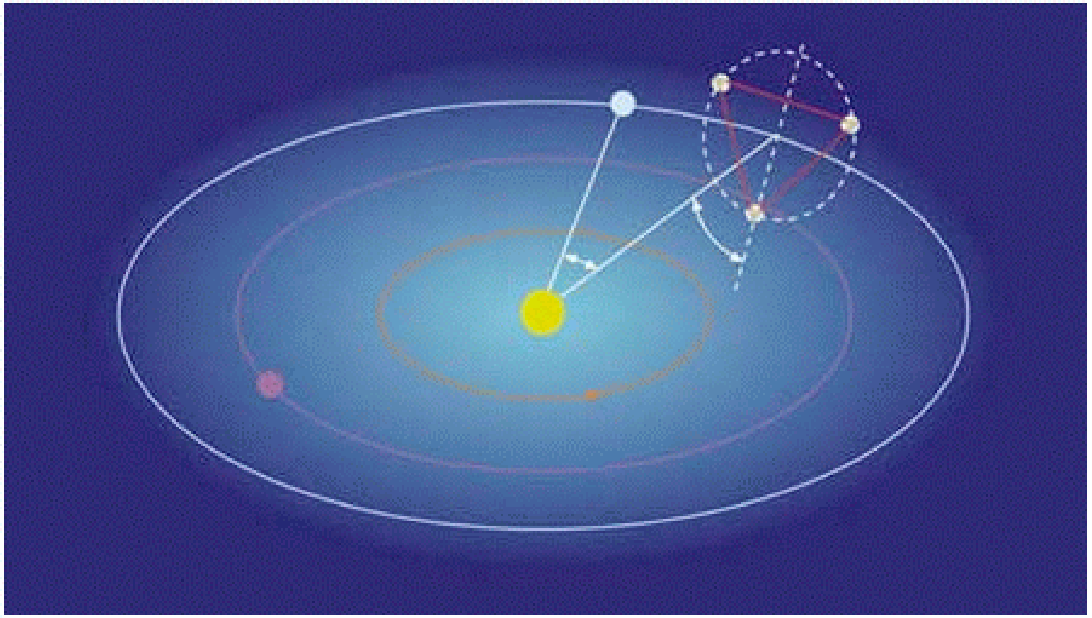
GWs come in cyclic flashes, last about 1000yr, duty cycle .0001
Marginal detection in nearby Galaxies.

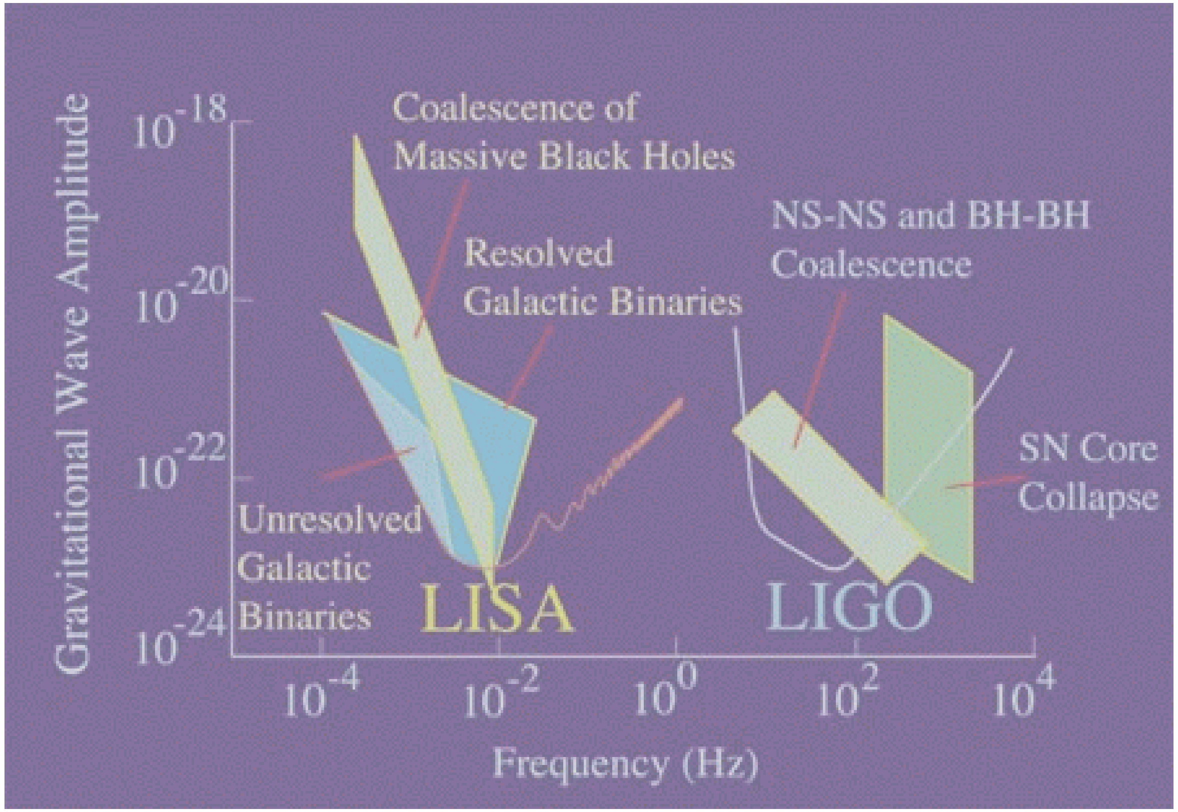
hyperons: d_/dT>0

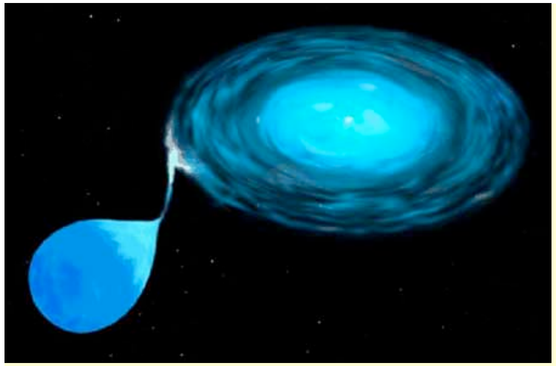
Owen 04

GWs are steady,
LIGO will see a few in Our Galaxy

LISA – space interferometer







Close binaries

a. 18 known close binaries – verification highest priority, test of weak GR.

b. 10000 detectable binaries in the Galaxy.

Astronomy

- binary star map of the Galaxy
- exotic hard-to-see binaries (eg, BH-BH)
- white dwarf mergers: SN 1a, AIC ?
- Galactic Background_binary history of the Galaxy
- chirp masses and freq. derivatives_ constrain binary evolution theories

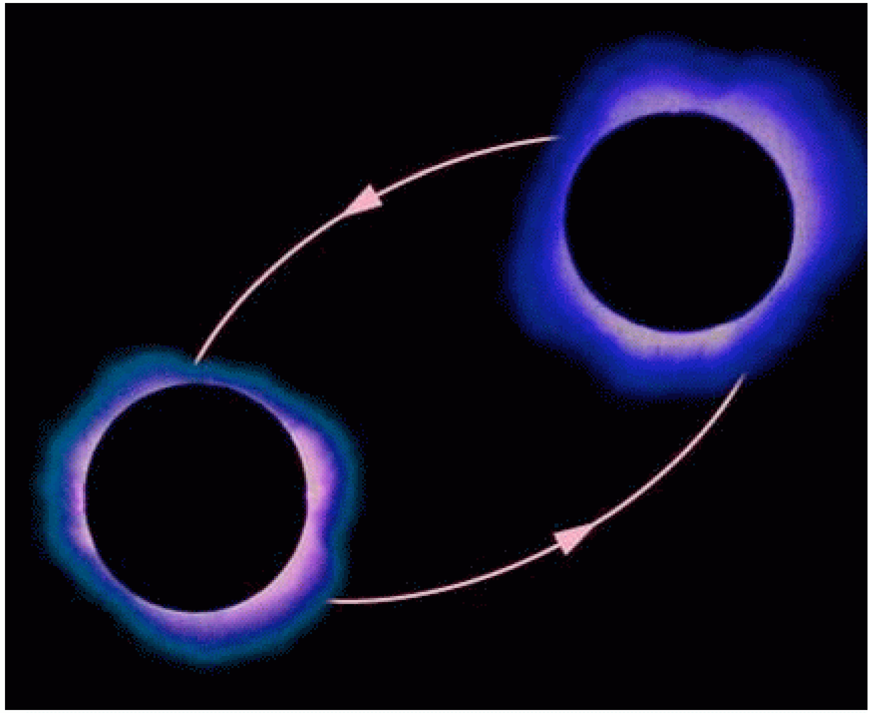
Physics:

Weak-field GR

Binary black holes:

a. major mergers

b. extreme mass-ratio mergers.

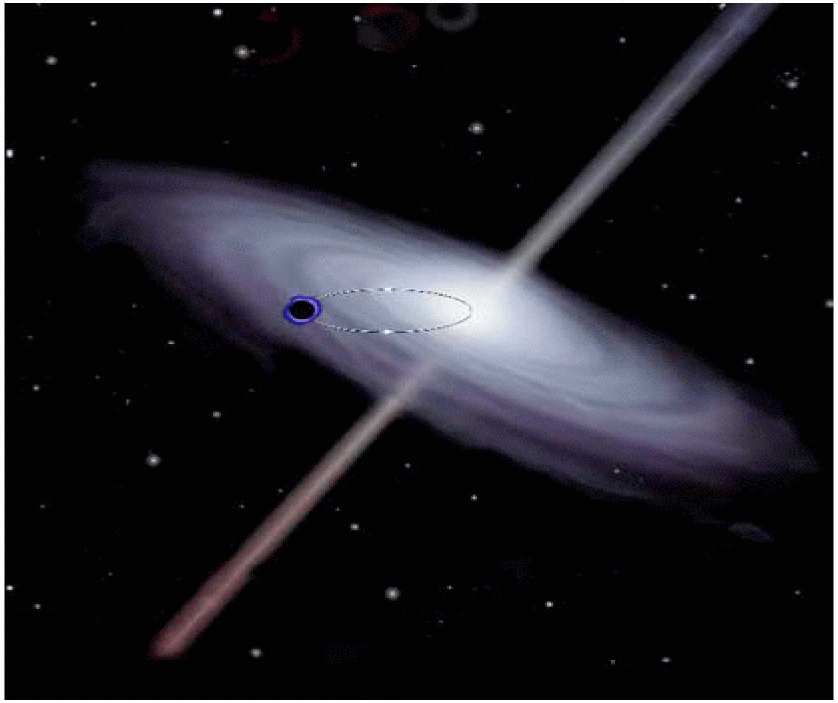


Astronomy:

- Black-hole cosmogony
- Galactic Nuclei

Physics:

Strong GR!!!!!!!!!!



Final remarks:

a. Gravitational waves are great for astrophysics

b. Close collaboration exists between experimentalists and theorists in designing the GW observatories