Binary black hole spin-orbit resonances: a hint at compact binary formation channels

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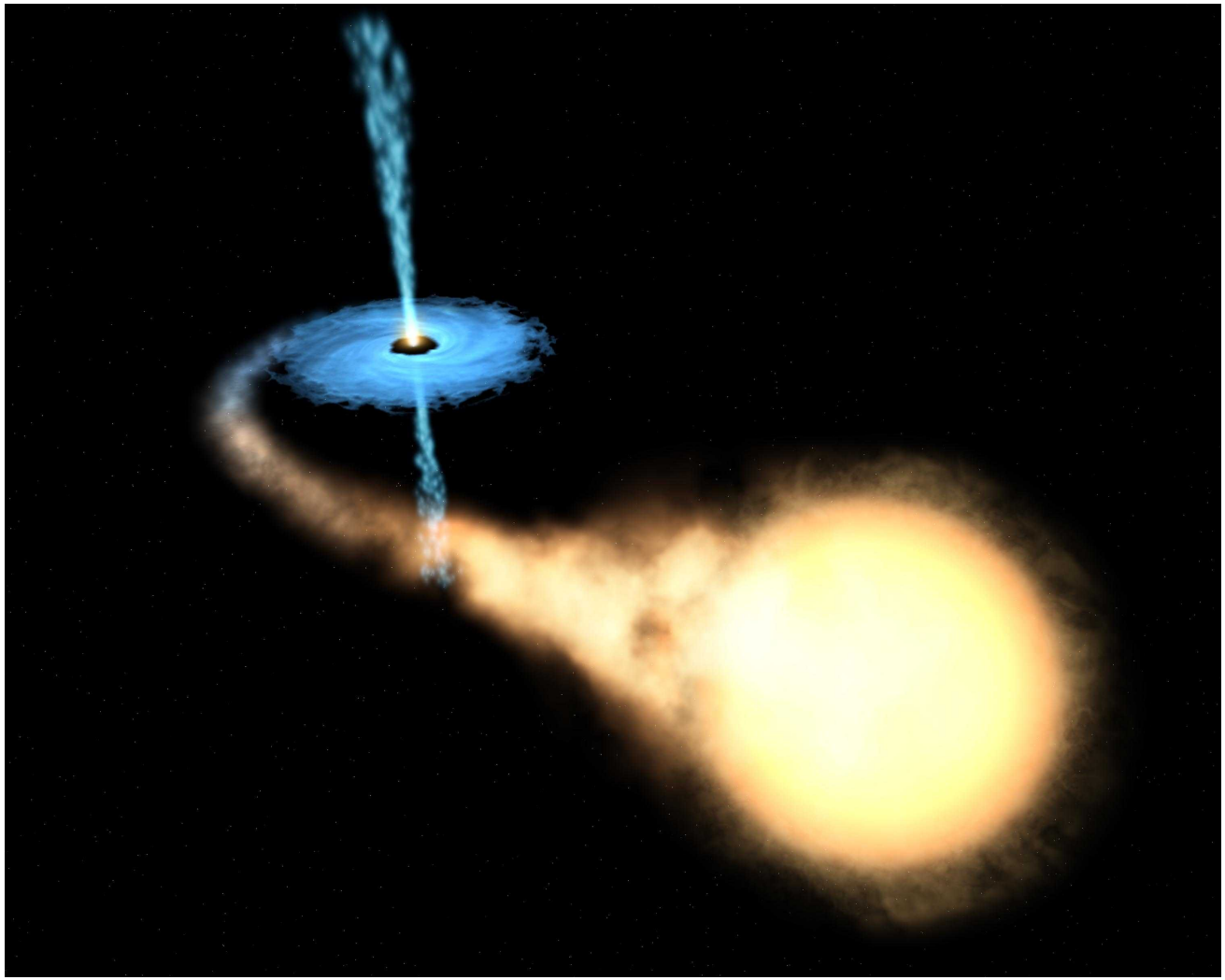
Outline

- Motivation
  - Binaries and compact binary formation
  - Black hole spin misalignment
- Spin precession and resonances
- Models and results
- Conclusions/ Future work

Binaries as modern astrophysical sources



Binary evolution and spins

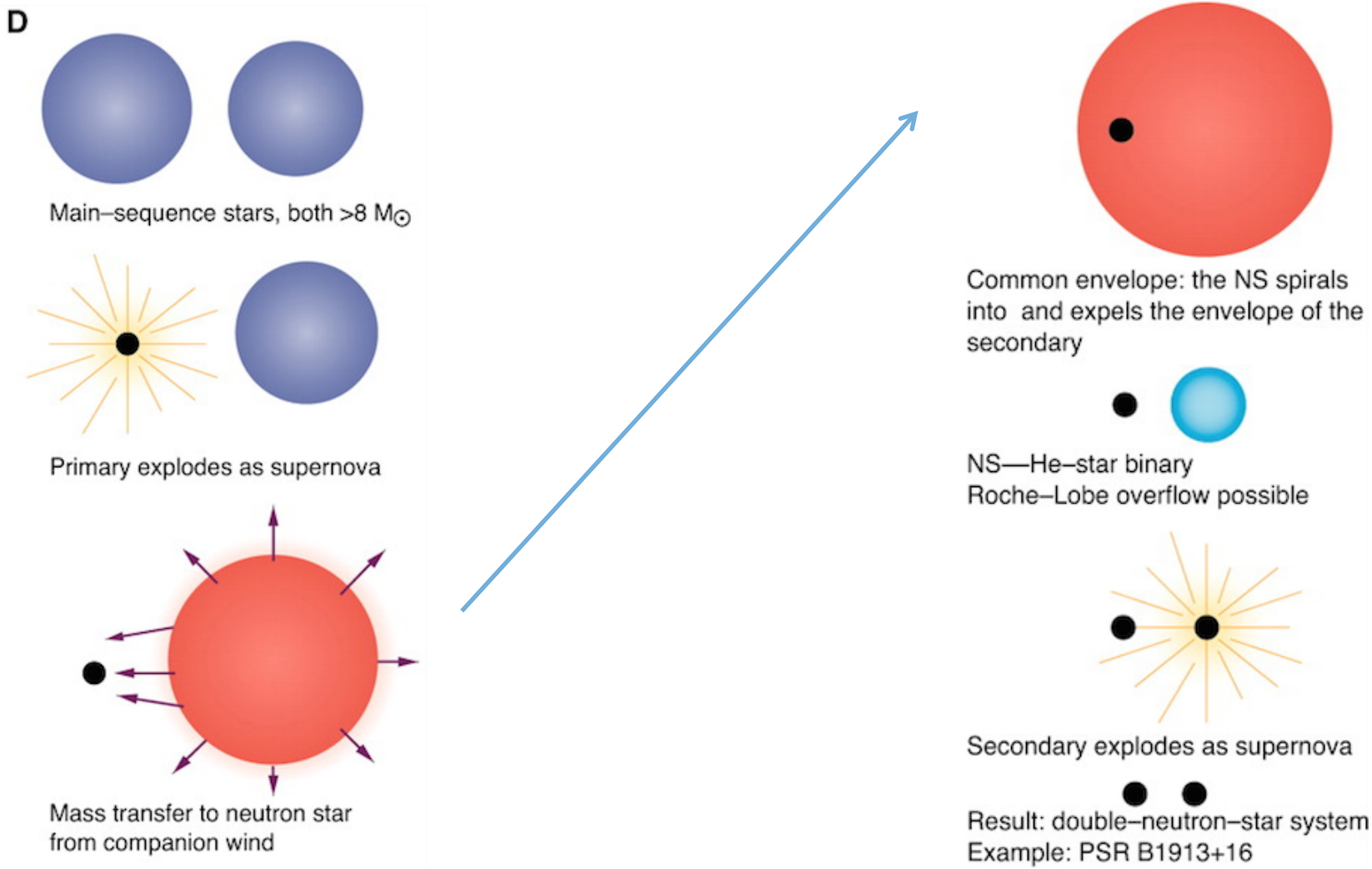


Image + credit http://www.sciencemag.org/content/304/5670/547/F1.expansion

Advanced LIGO

Gravitational-waves from precessing binaries

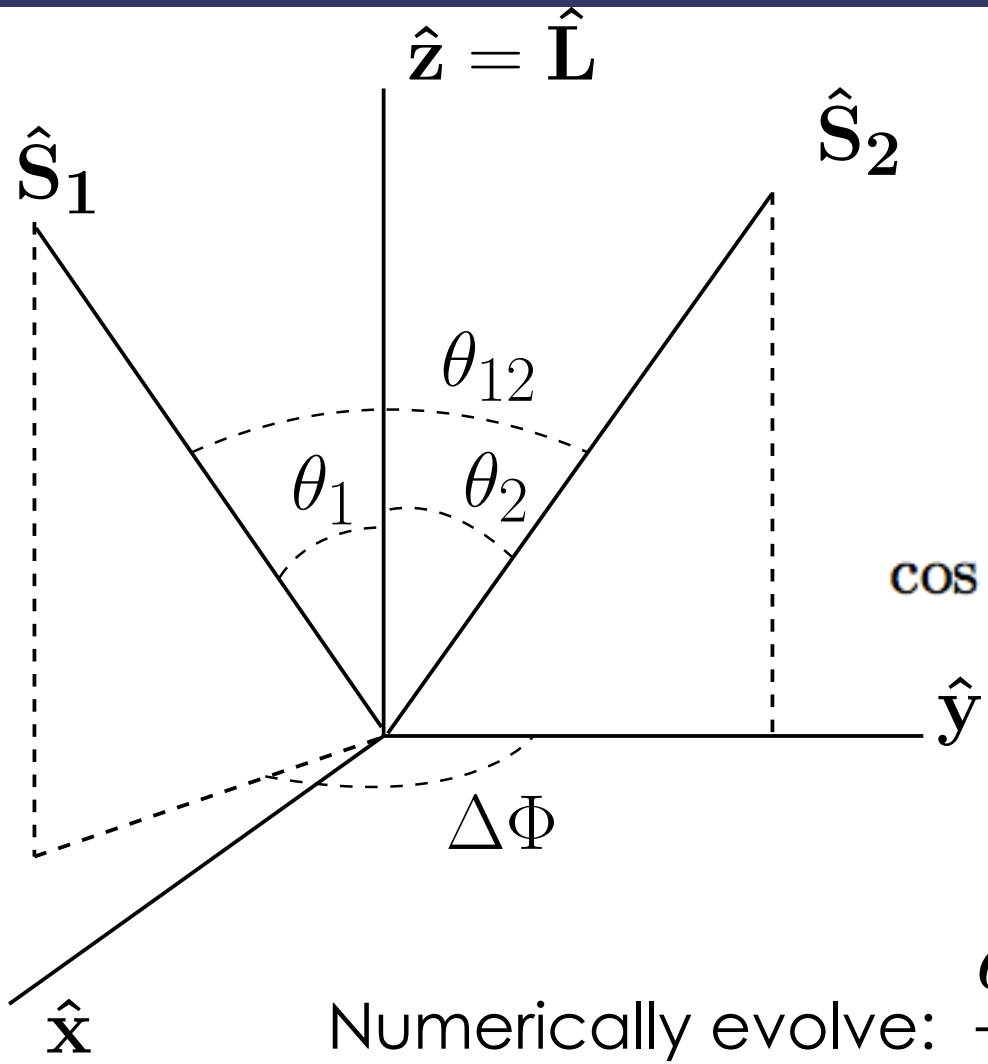
a) Cartoon of non-precessing gravitational waveform

b) Cartoon of precession modulated gravitational waveform

Population synthesis models for spin misalignments in binary black holes

1. Both aligned (e.g. small SN kicks) – no precession
2. Dynamically formed, isotropic distribution – remains isotropic (Schnittman 2004)
3. BH and secondary aligned prior to the second supernova – both BHs equally misaligned afterwards - freely precess (Kalogera 2000)
4. Secondary aligned prior to the second supernova via tides, primary misaligned (as in Gerosa et al 2013) – primary more misaligned by second supernova

Coordinate system



$$\cos\theta_1 = \hat{\mathbf{S}}_1 \cdot \hat{\mathbf{L}},$$

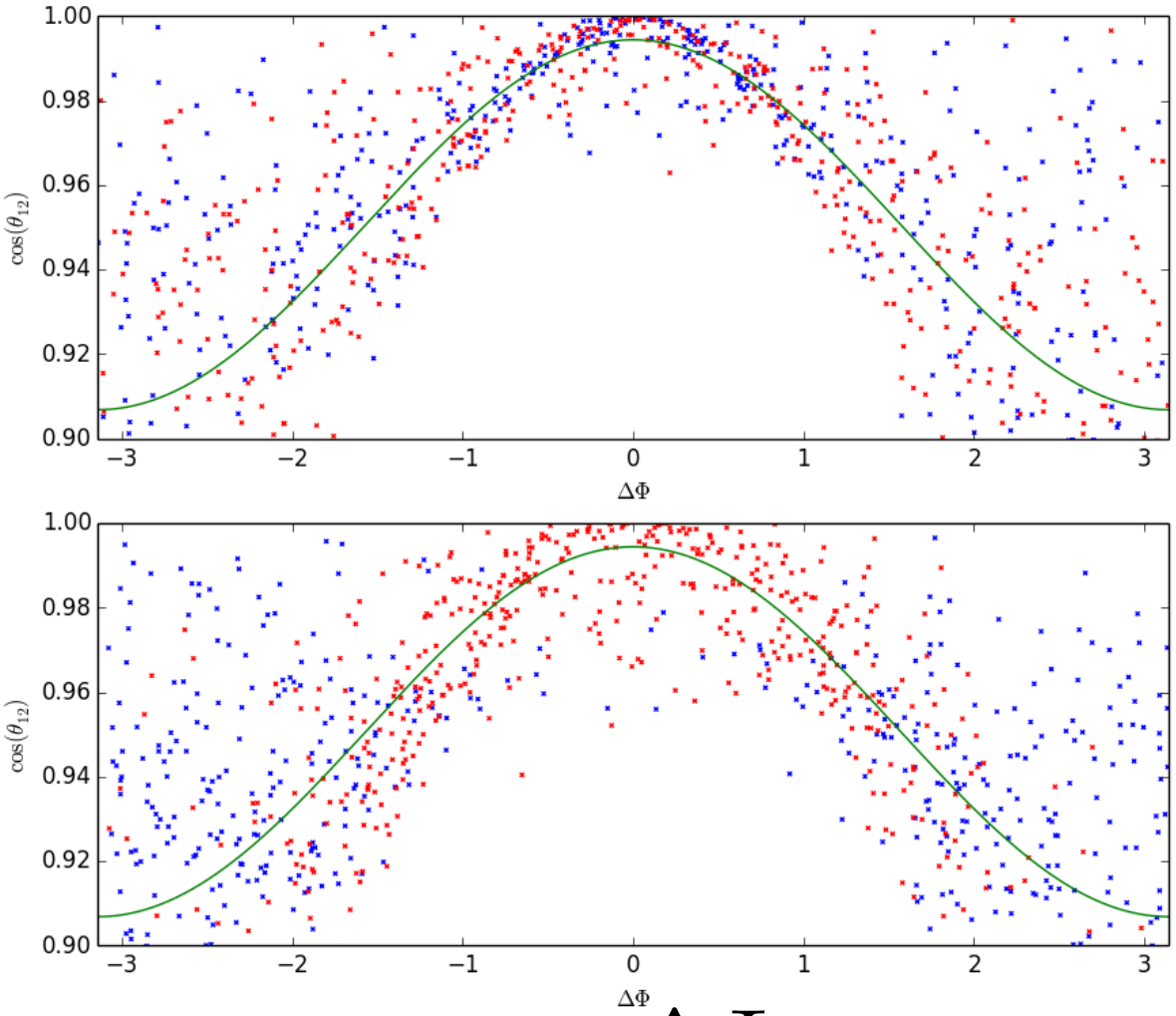
$$\cos\theta_2 = \hat{\mathbf{S}}_2 \cdot \hat{\mathbf{L}},$$

$$\cos\theta_{12} = \hat{\mathbf{S}}_1 \cdot \hat{\mathbf{S}}_2.$$

$$\cos\Delta\Phi = \frac{\mathbf{S}_1 \times \mathbf{L}}{|\hat{\mathbf{S}}_1 \times \hat{\mathbf{L}}|} \cdot \frac{\mathbf{S}_2 \times \mathbf{L}}{|\hat{\mathbf{S}}_2 \times \hat{\mathbf{L}}|}.$$

Numerically evolve: $\frac{d\mathbf{S_1}}{dt}$ $\frac{d\mathbf{S_2}}{dt}$ $\frac{d\nu}{dt}$ $\frac{d\hat{\mathbf{L}}}{dt}$

Spin-orbit resonances



$\cos\theta_{12}$

$\Delta\Phi$

post second supernova

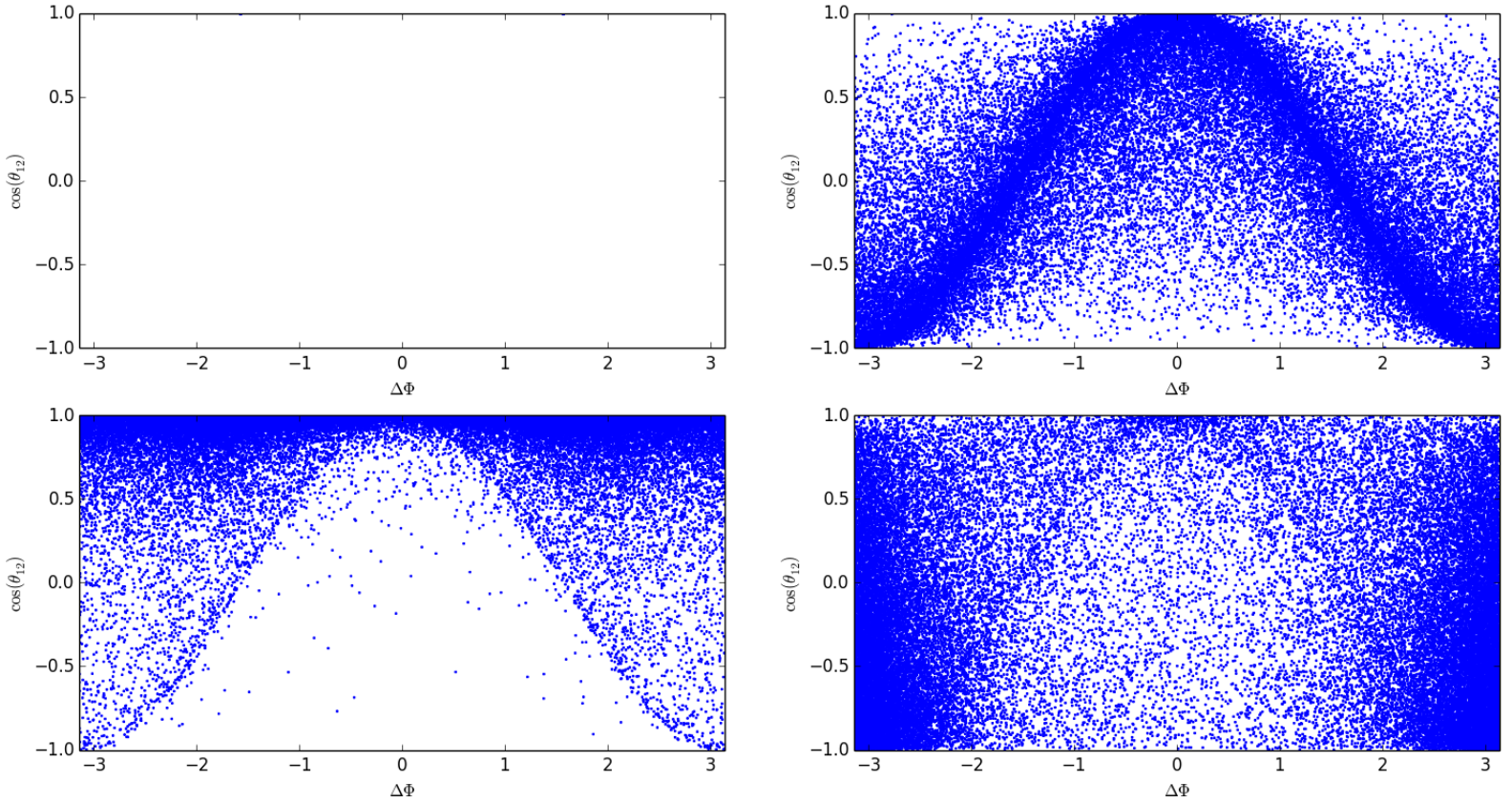
Initially:

$\theta_1 > \theta_2$

$\theta_1 < \theta_2$

$f_{\rm GW} = 10{\rm Hz}$

Results in terms of these weird angles



Conclusions/Future work

- In general, spins in BBH may not be aligned with the orbital angular momentum following a second supernova, leading to precession of the spins
- Spin-orbit resonances are effective in BBH systems with unequal misalignment angles, which may be true for astrophysically formed compact binaries
- Resonances binaries are attracted to depends on the formation mechanism of the binary
- Looking for clustering in well measured angles therefore can tell you about the compact binary channels