GWPAW 2021

The Gravitational Wave Physics and Astronomy Workshop

Is GW190521 Precessing?

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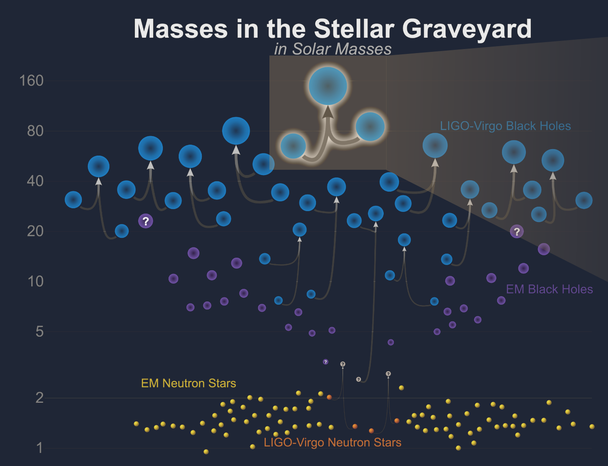
The most massive confirmed event



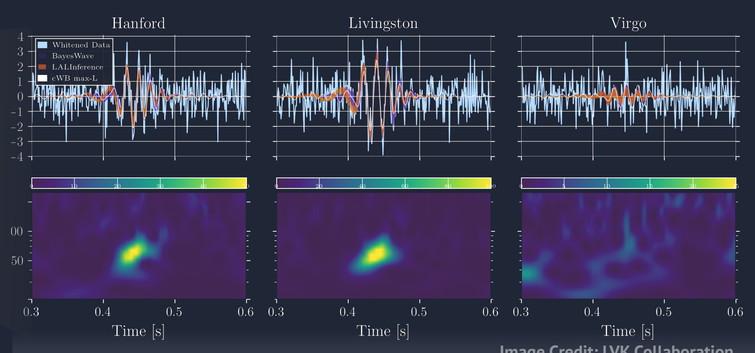
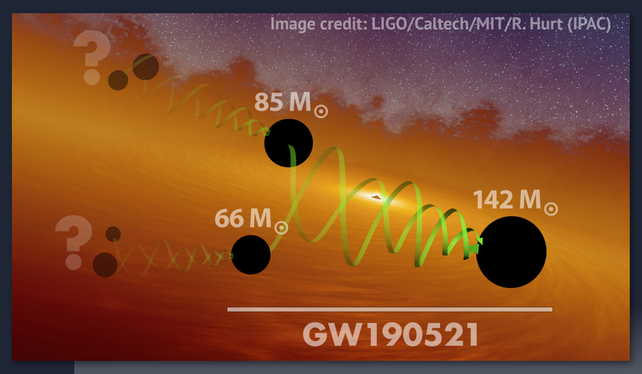


Image Credit: LVK Collaboration

GW190521 is detected with 14.7 network SNR. It is a very short event (approximately 0.1s), and only has around 4 cycles in the frequency band 30-80Hz. The frequency is 60Hz at the signal peak.

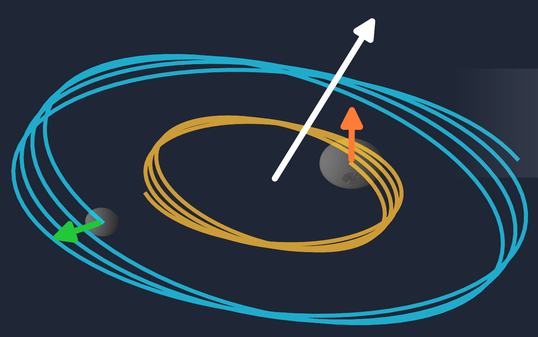
Astrophysical property



The mass of the primary black hole in this event is in the range of the Pair-instability supernova(PISN) mass gap (65 – 120M⊙), The final black hole is the first ever detection of an intermediate mass black hole.

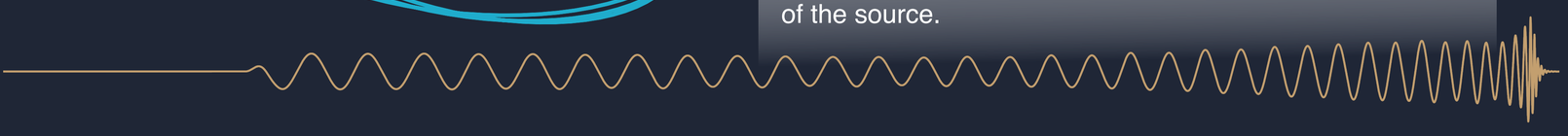
What is precession?

When spins do not align with orbit angular momentum…



Spin-induced precession occurs when the spins are not aligned with the orbital angular momentum.

Precession will introduce modulation into gravitational wave amplitude and phase, and encode useful information of the source.



Waveform model

We used NRSur7dq4 (a waveform model calibrated to numerical relativity of precessing systems) to simulate the possible signals responsible for this event.

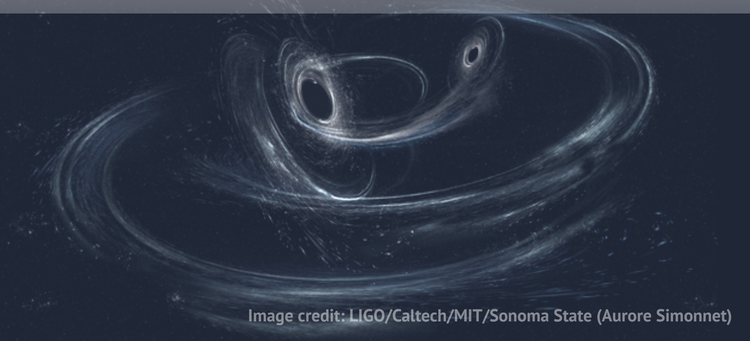
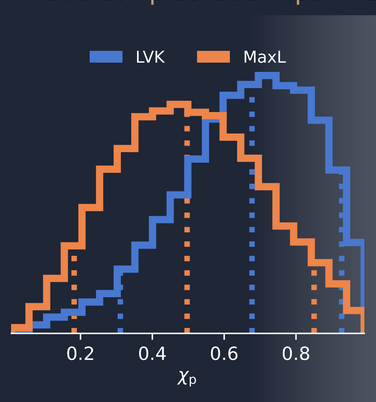


Image credit: LIGO/Caltech/MIT/Sonoma State (Aurore Simonnet)

Is GW190521 precessing?

Max LogLikelihood injection

Can the signal from most probable source reproduce the effective precession spin in LVK results?

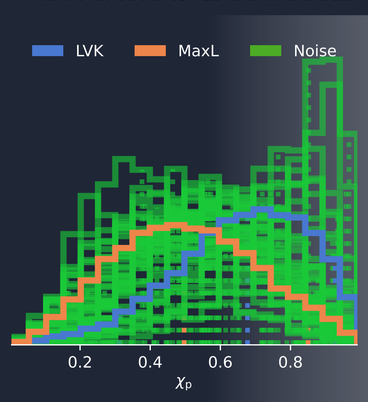


The peak and 90% confidence interval of effective precession spin from maxL injection is shifted to lower values.

The max likelihood injection with zero noise can not reproduce the effective spin magnitude.

Bias from noise?

30 signals were injected with gaussian noise generated from different random seeds to explore the bias from noise.

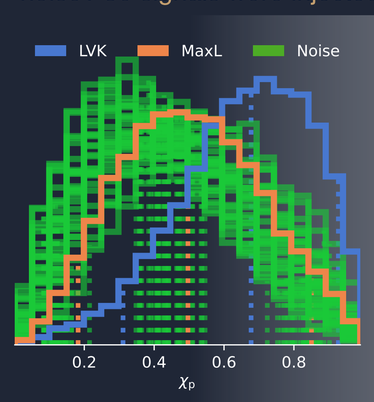


Some of the noise make the inferred parameter much closer to the LVK results.

Higher precessing spins seen in the PE for the event may be the effect of noise fluctuations on such a short signal.

Pure noise without spin?

Could this large effective precession come from pure noise? 30 signals were injected with noise and zero-spin.

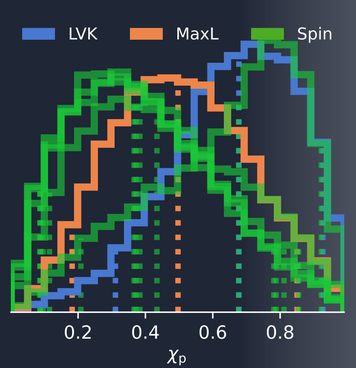


Without spin, the noise can cause deviation from prior.

However they cannot reproduce high enough inferred effective precession.

Minimal spin magnitude required?

What's the minimal spin required for inferring that large precession spin? We injected with different spin magnitude.

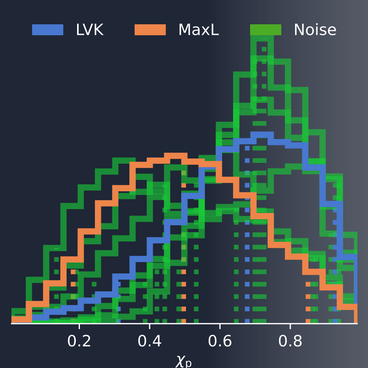


Only when injected effective precession spin is larger than 0.62, we can start to see deviation from its prior.

For zero noise injection, it requires total spin of ~ 0.8, which is at edge of calibration range for NRSur7dq4.

…with noise?

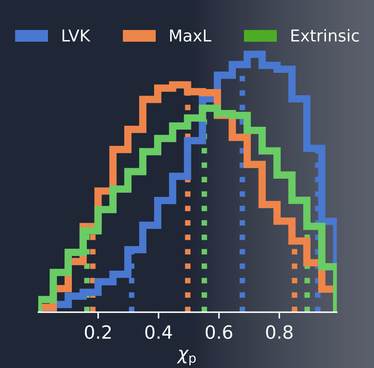
We injected the different spin magnitude with noise which cause the largest inferred effective precession spin.



We find that only when the effective precession spin is larger than 0.4 for this kind of event, the noise can reproduce the large precession.

Extrinsic parameter

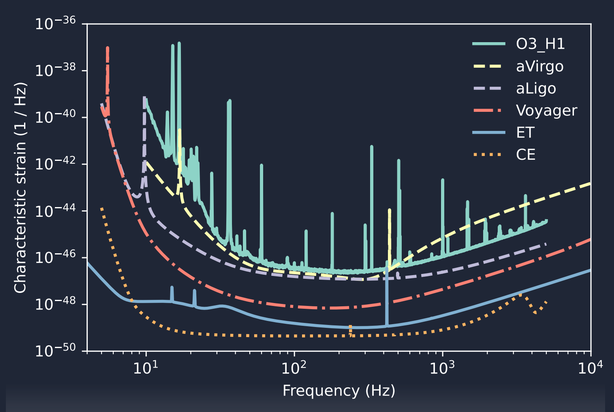
The inclination has a big effect on precession. We injected the extrinsic parameter which maximize the precession.



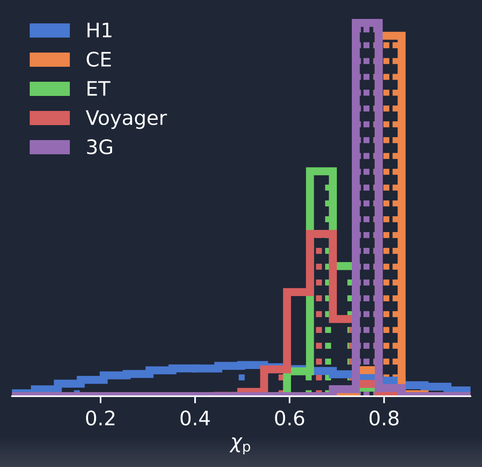
We choose inclination ι = 1.7593 and polarisation ψ = 1.0053 which maximise the precession.

The inferred posterior does not have the same high effective precession spin.

Future detectability

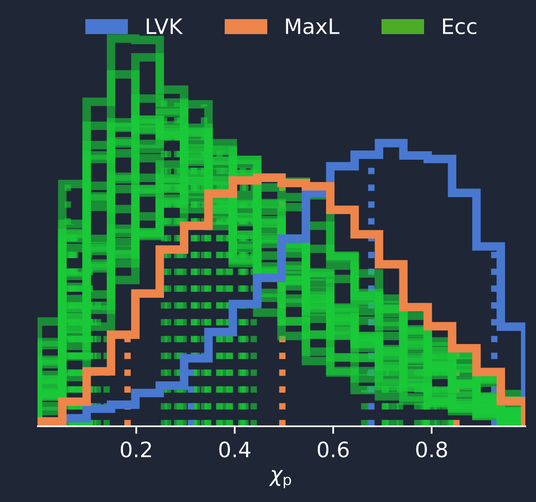


Will the future ground based detectors can detect precession from this kind of binary? We use the sensitivity curve of third generation detectors to investigate.



The higher sensitivity, the narrow distribution. However, single detector may not detect the right precession.

Degeneracy with eccentricity



Eccentricity might have degeneracy with precession. Here we use SXS data with eccentricity to explore the possible degeneracy.

We injected the SXS data which have eccentricity and mass-ratio 1. The injection data have eccentricity below 0.2.

We can see for eccentricities lower than 0.2 the eccentricity does not have a noticeable impact on the measurement of precession in the waveform.