Multi-Messenger Constraint on H_0 with Tidal Disruption Events

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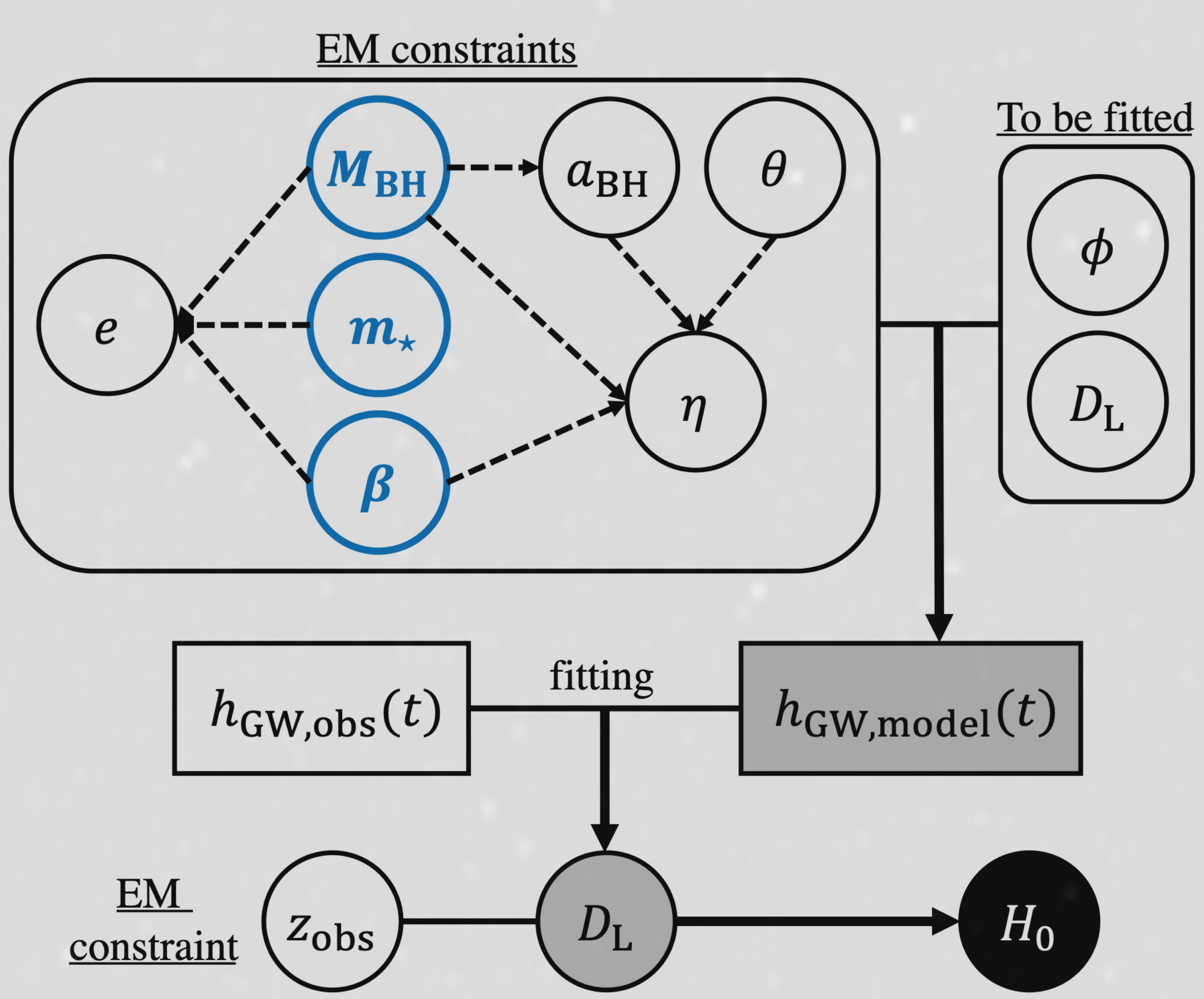
Abstract

Gravitational waves are intrinsically produced in Tidal Disruption Events (TDEs). We propose a methodology to measure the Hubble constant H_0 by incorporating the TDE parameters measured by **electromagnetic observations** into the observed TDE GW waveforms. An accurate knowledge of the *black hole spin* could help disentangle the well-known *distance-inclination degeneracy* in waveform fitting, hence yielding a self-contained measurement via **Hubble's law**.

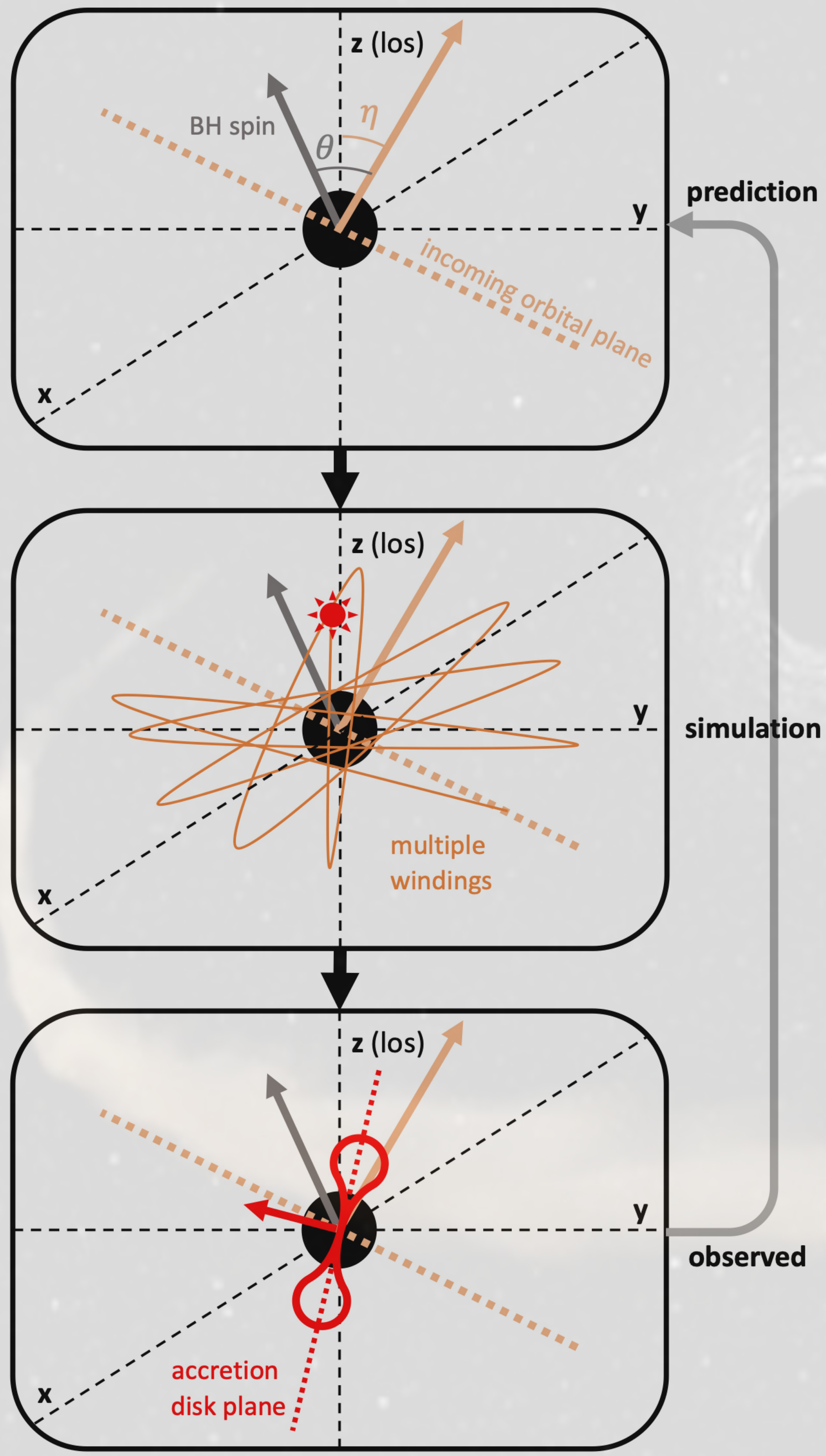
Main Methodology

Luminosity distance D_L is mainly yielded by GW waveform fitting, however, full disruption events only produce peak signals which challenge accurate multi-parameter fitting. EM observations could then be used to **fix most parameters, leaving D_L to the waveform fitting**. The dominant uncertainty comes from the penetration parameter β given how significantly it contributes to determining the incoming orbital plane.



Breaking Distance-inclination Degeneracy with Black Hole Spin

A significant offset between the BH spin and the incoming orbital plane would result in the **debris stream missing itself** via Lense-Thirring effect. The new stream-crossing point could potentially **determine the plane of the accretion disk**.



The usefulness of connecting the **incoming orbital plane** and the **accretion disk plane** via **BH spin** is to utilize the multi-wavelength observation of TDEs to determine the inclination angle of the disk, hence **backward modelling** the initial incoming stellar orbit.

Since the overall amplitude of the GW signal is most sensitive towards $D_{\rm L}$ and the initial incoming orbital inclination η, having a scientific way of constraining one of them would yield a potential constraint of the other.

Multiple sources of error are introduced in this analysis: **BH spin $a_{\rm BH}$** and **orbital penetration parameter β**. Either a large $a_{\rm BH}$ and/or a large β could result in multiple windings of the stream, and given the non-linear dependence of the shifting from orbital plane to disk plane by the system parameters, any large uncertainties in determining the parameters via EM observation would propagate onto the constraining power of the initial η, hence the desired distance $D_{\rm L}$.

Summary and Future Work

The ultimate aim of this methodology is not to constrain most parameters with GW, but only the luminosity distance. Quantitative prediction on how and where the stream-crossing point happens, and the accuracy in forming the desired accretion disk plane is still needed. Once completed, this could serve as a fully **independent manner to constrain H_0** by exploiting the multi-messenger nature of TDE.

Key References
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