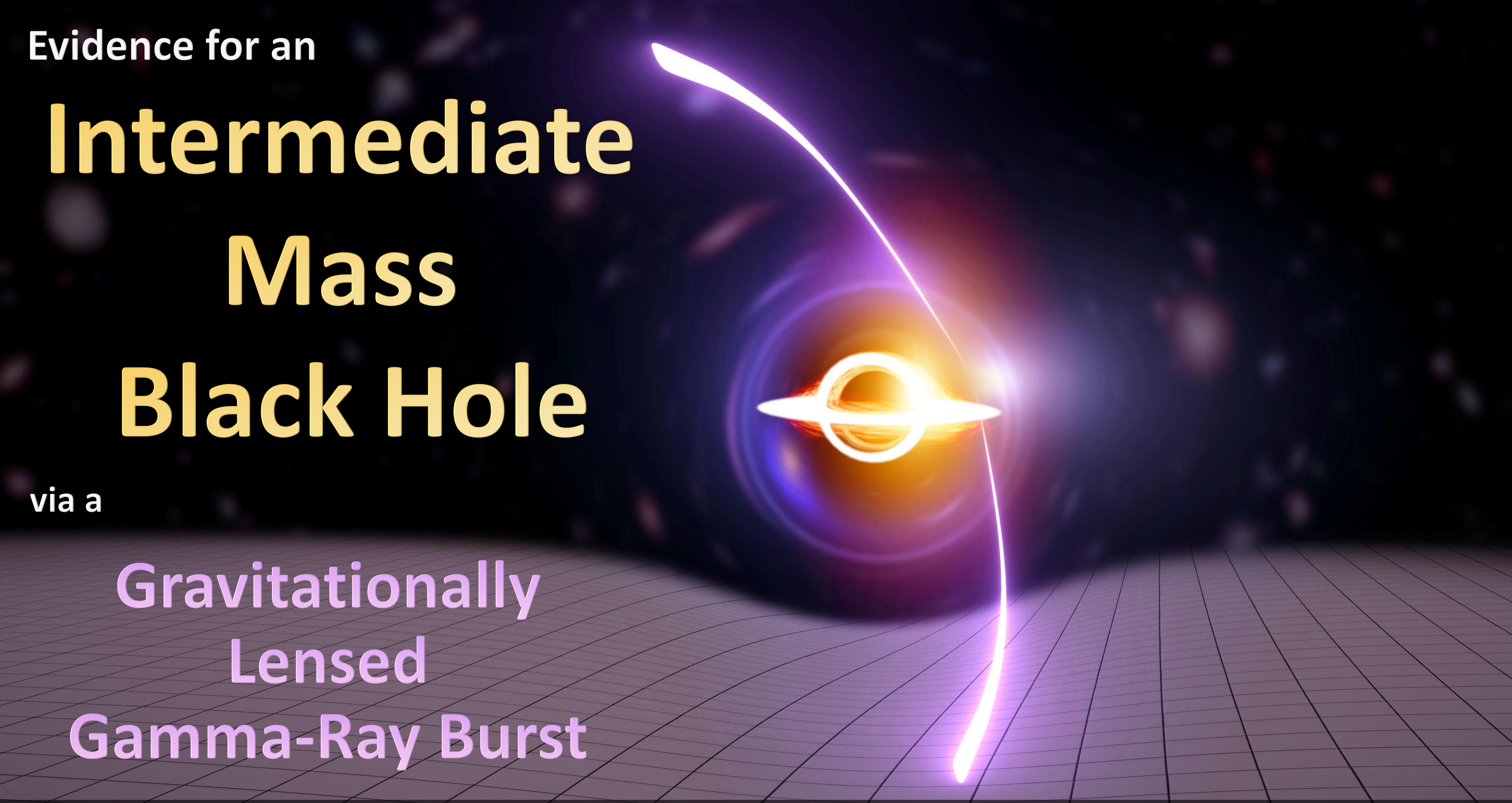
Evidence for an Intermediate Mass Black Hole via a Gravitationally Lensed Gamma-Ray Burst



Artist's impression (credit Carl Knox, Swinburne/OzGrav):
The strong gravitational field of an intermediate mass black hole (orange, centre) distorts the distant gamma-ray burst (purple), focusing the light paths on both sides of the black hole towards the observer.

We find evidence for an intermediate mass black hole (IMBH), **with mass** $(1+z_l)M_l = 5.5^{+1.7}_{-0.9} \times 10^4\ M_\odot$.

Our detection method, gravitational lensing, allows us to infer a dimensionless energy density of $\Omega_{IMBH} \approx 4.6^{+9.8}_{-3.3} \times 10^{-4}$ for black holes of this mass. We calculate a present day number density of $n_{IMBH} \approx 2.3^{+4.9}_{-1.6} \times 10^3\ \mathrm{Mpc}^{-3}$. This is consistent with the stellar mass black hole density if number density scales as $\sim M^{-1}$.

Why is this result significant? Supermassive black holes lurk within the hearts of most galaxies. A stellar mass black hole accreting at the Eddington (theoretical maximum) rate would not be able to grow to this size within the age of the universe. A cosmological population of IMBHs could provide seeds for the growth of supermassive black holes in the early universe.

How can we detect an intermediate mass black hole? Direct observational signatures for the existence of IMBHs are elusive. A quiescent black hole is difficult to detect since by definition it does not emit light. Its gravitational field is one of the few ways to infer its presence. The gravitational lensing of a background source by a black hole betrays both its presence and mass.

Gravitational lensing is the distortion of null geodesics by gravitational fields. Strong gravitational lensing creates multiple pathways for light to travel from a source to an observer. Gamma-ray detectors have great temporal resolution but poor spatial resolution, so we detect the multiple images as delayed "echoes".

Quoted uncertainties are 90%.
To calculate the energy density we assume a source redshift of $z_s = 2$.
To calculate the number density we assume a lens redshift of $z_l = 1$.

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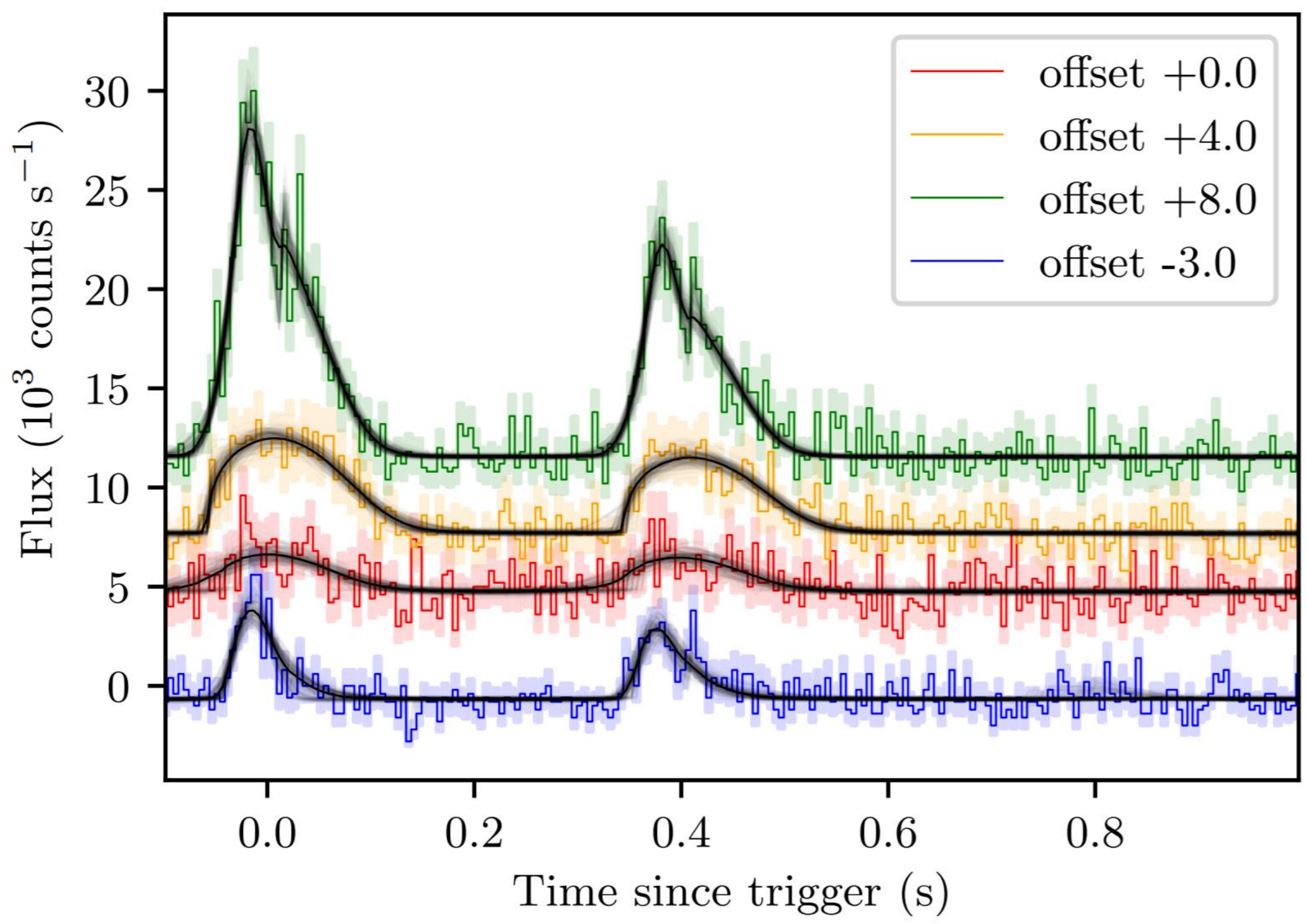
Gamma-ray bursts (GRBs) are short (10ms – 10^3s) and intense ($\sim 10^4$ photons s^{-1}) bursts of low energy (keV – MeV) gamma radiation that signify the birth of a black hole. Generated by core-collapse supernovae, and neutron star mergers. Rapid infall of supernova/merger debris onto the nascent black hole launches the ultra-relativistic bipolar jets that are responsible for γ-ray emission. We search for *strong* gravitational lensing in 2,700 Burst and Transient Source Experiment (BATSE) GRB light-curves.



GRB 950830
PyGRB fits to the light-curve of the gravitationally lensed GRB 950830. We argue that the second pulse is an identical copy of the first based on the similarity of the pulse profiles, indicative of gravitational lensing. Each colour represents a different energy channel, red: 20–60 keV, yellow: 60–110 keV, green: 110–320 keV, blue: 320–2,000 keV.
PyGRB: https://pygrb.readthedocs.io/

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