Bosonic stars in their astrophysical environment

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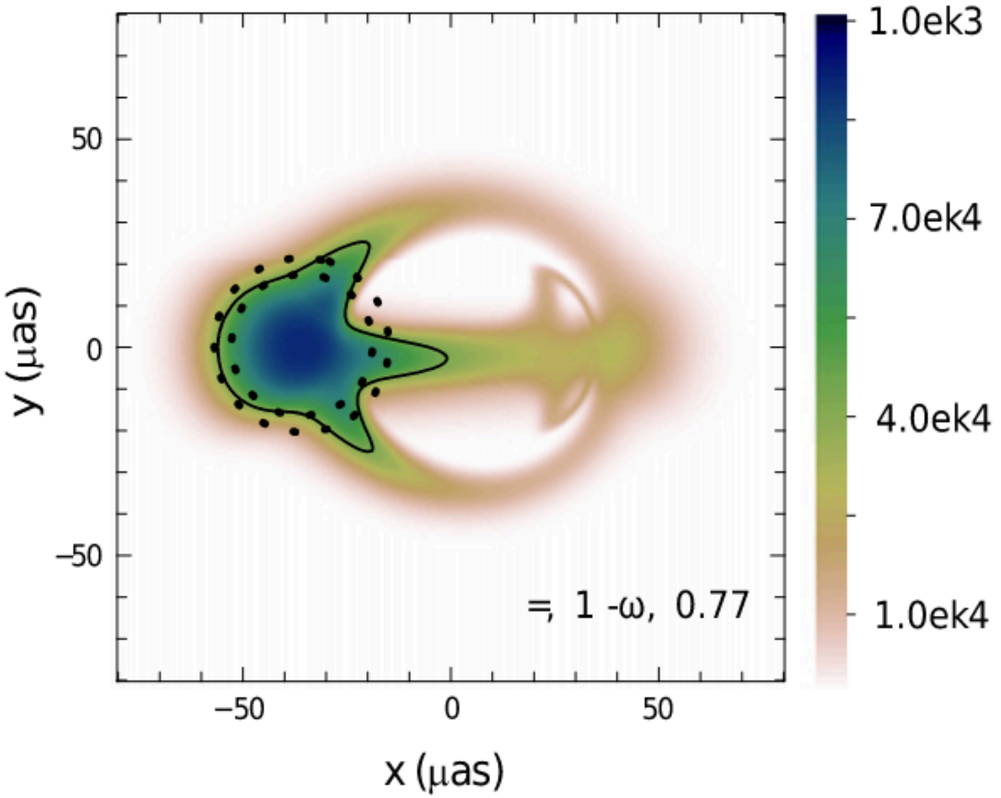
Bosonic stars as black hole mimickes

- Bosonic stars: among the most theoretically-developed exotic compact objects (ECOs).

- This talk: recent developments on their possibilities as BH mimickers in the electromagnetic channel.

- Complementary to gravitational waves: sampling regimes such as isolated supermassive BH candidates

Vincent+ 2016



- General assumptions:
  - 'Dark matter' compact objects, i.e., only gravitational interaction
  - Plasma described by general relativistic magnetohydrodynamics (GRMHD)

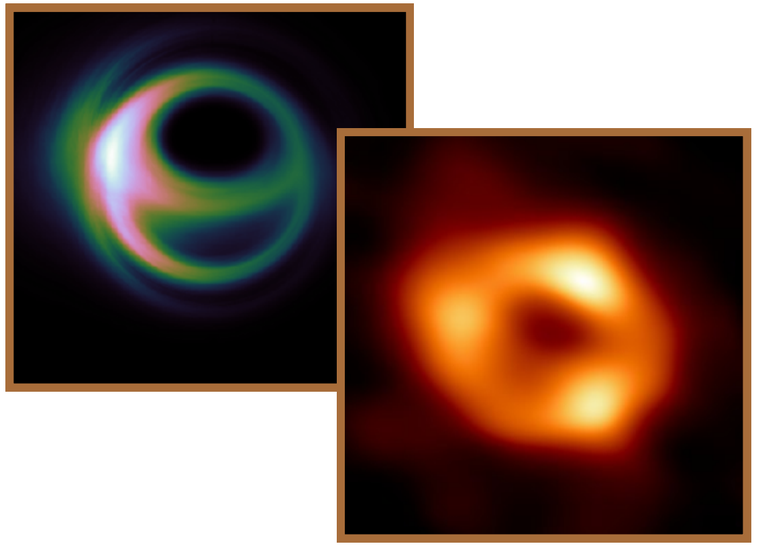
'Fake shadows' from bosonic stars

- Boson stars can produce ring-like images with a central brightness depression (CBD), as those observed by the Event Horizon Telescope (EHT).

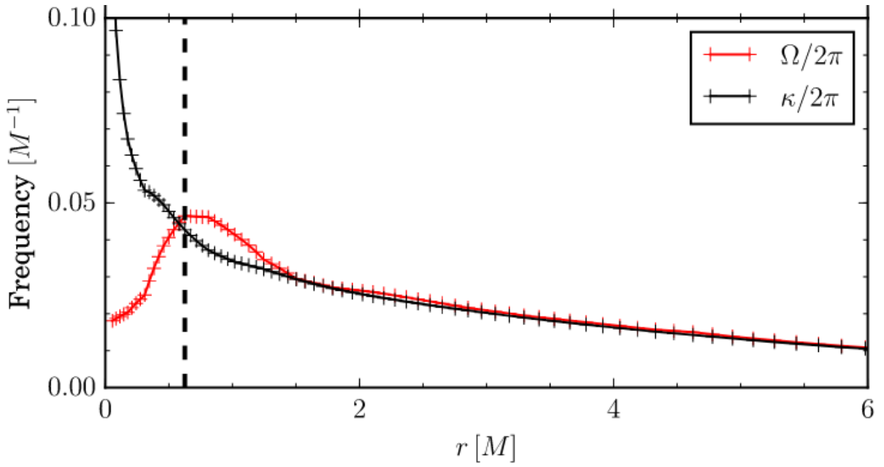
- Requirements (Olivares+2020):
  - Angular momentum transported by the magnetorotational instability (MRI)
  - Maximum in the angular velocity profile

- Possible to approximately predict the size of the CBD for a given metric.

Olivares+ 2020

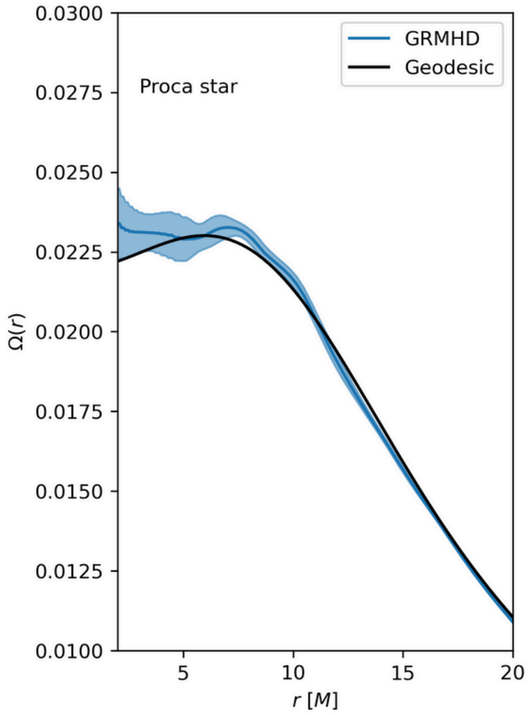


EHT+ 2022

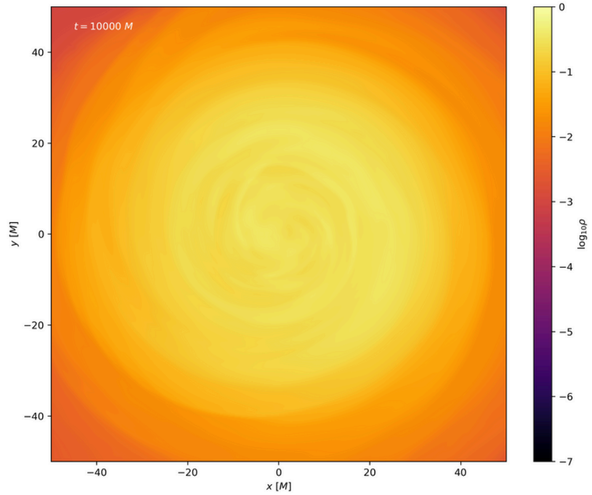


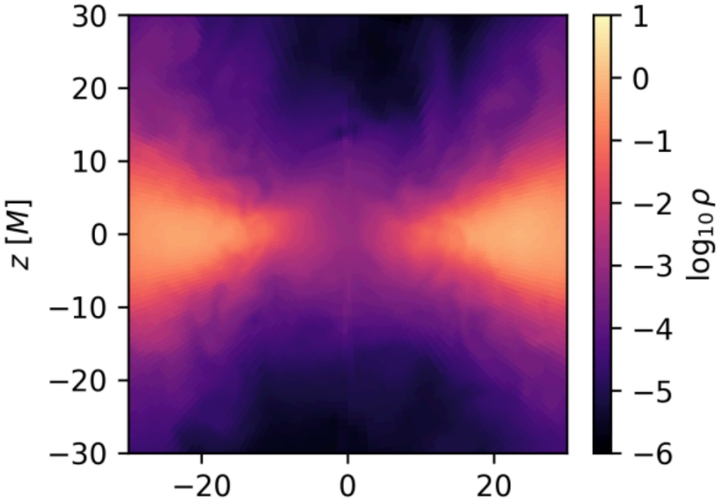
Olvera-Meneses+ 2026

How robust is it?



- Simulated magnetized accretion onto an object with a very large ring size ~6 M from Herdeiro+ (2021)
- The ring formed in 2D simulations, but not in 3D!





- The maximum of Ω is too small compared to local fluctuations.
- Reducing fluctuations, the ring forms.

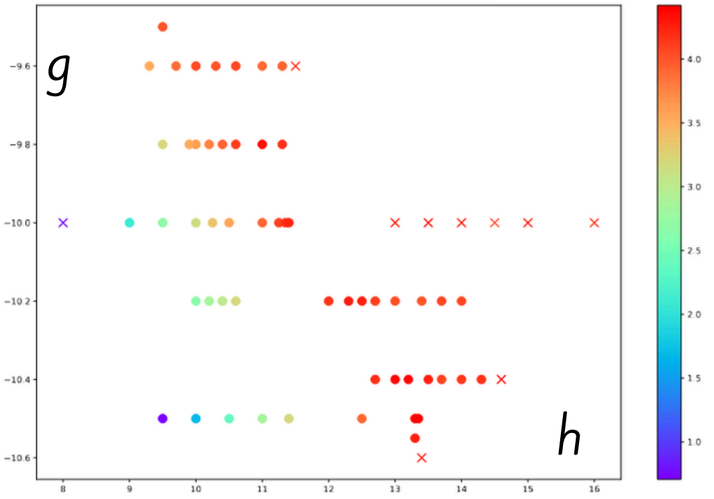
⇒ The simulation setup (i.e. astrophysics) matters

Solitonic stars

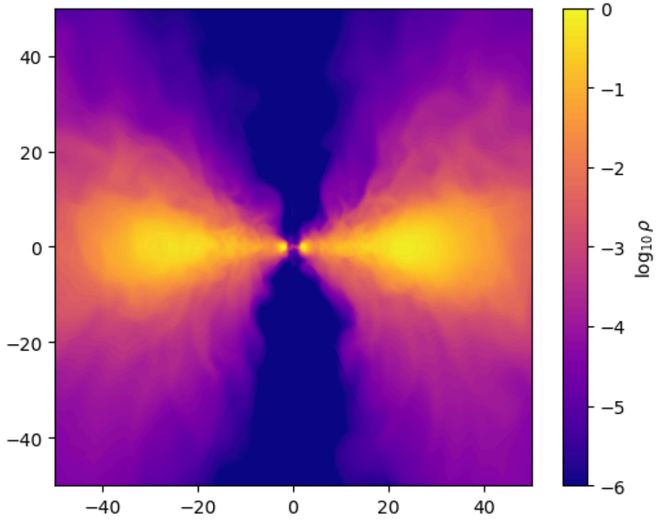
Meneses, Jaramillo+ 2026

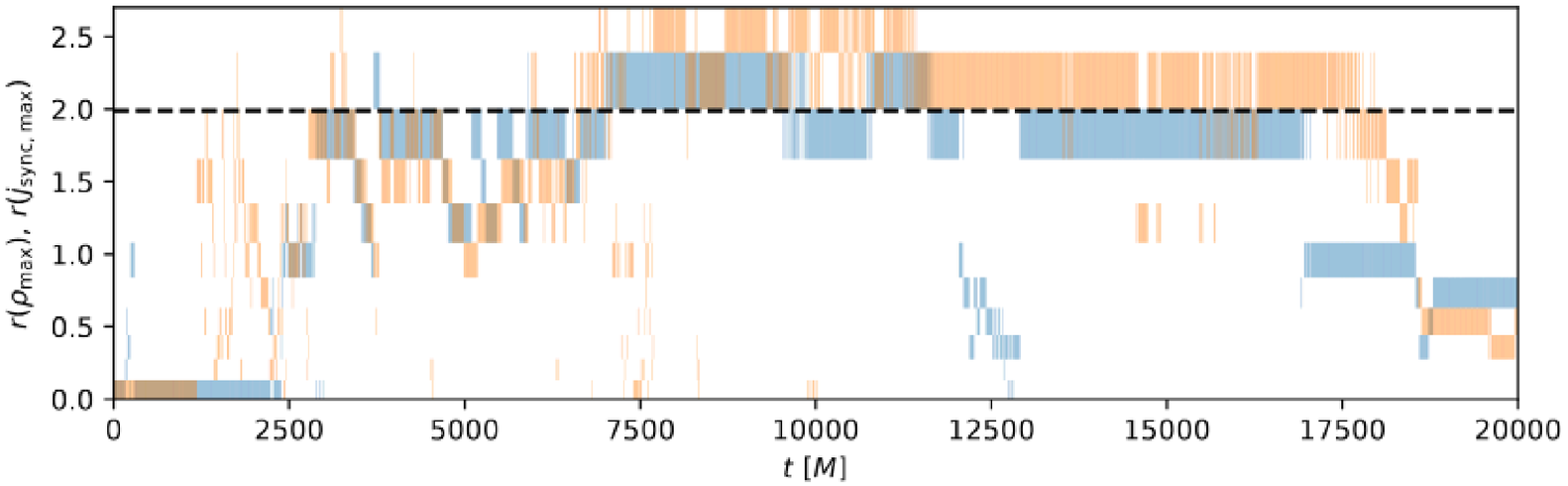
$$V(\Phi) = |\Phi|^2 + \frac{1}{2}g|\Phi|^4 + \frac{1}{3}h|\Phi|^6$$

- Sampling the parameter space to produce a more robust ring of the desired size



- The ring forms and survives a long time before numerical viscosity starts to dominate!

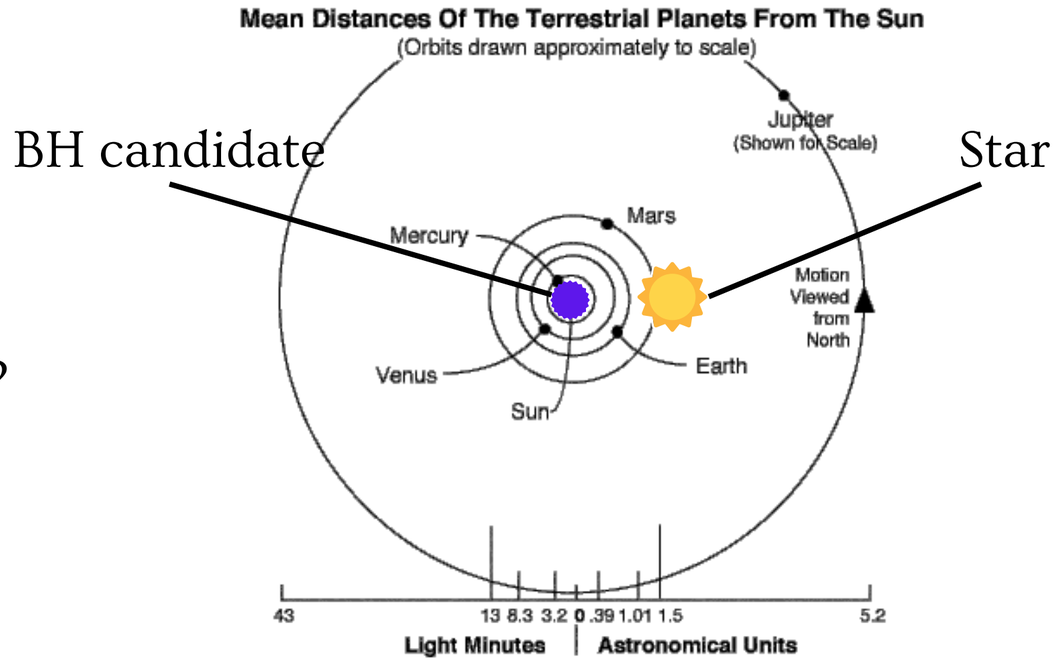




A boson star in a binary system?

Passos+ 2025
arXiv:2505.07544

- Gaia BH1: a BH candidate in a binary with a sun-like star with no detectable X-ray emission
- Pombo & Saltas (2025): can we use orbital motions to distinguish a BH from a bosonic star?
- Passos+ 2025: can we use constraints on the EM emission?



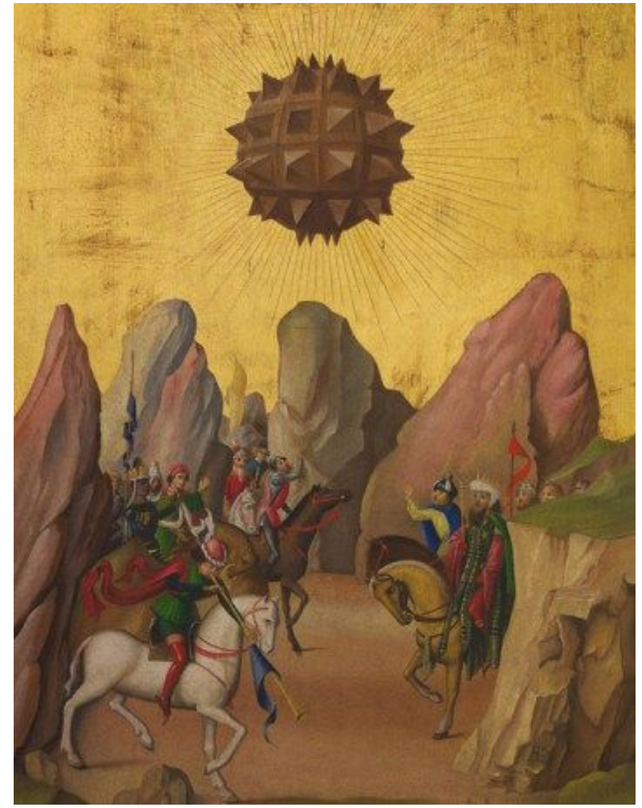
- Qualitative differences: shallower gravitational potential, absence of event horizon.
- From semi-analytic wind accretion model: X-ray emission from the BS interior would exceed that of a BH and be detectable, if the star had been accreting for > 100 years

Conclusion

- Bosonic stars can produce ring-like images, but the effectiveness of the mechanism depends on astrophysics.

- In some regimes, black holes and bosonic stars' qualitative differences can help us distinguishing them even for unresolved observations.

- Understanding the interactions between bosonic stars and their environment is crucial for assessing their feasibility as black hole mimickers.



Laurent Grasso (?)
Studies into the past

Supporting Slides

Geodesic rotation profiles