A Sun-like star orbiting a black-hole

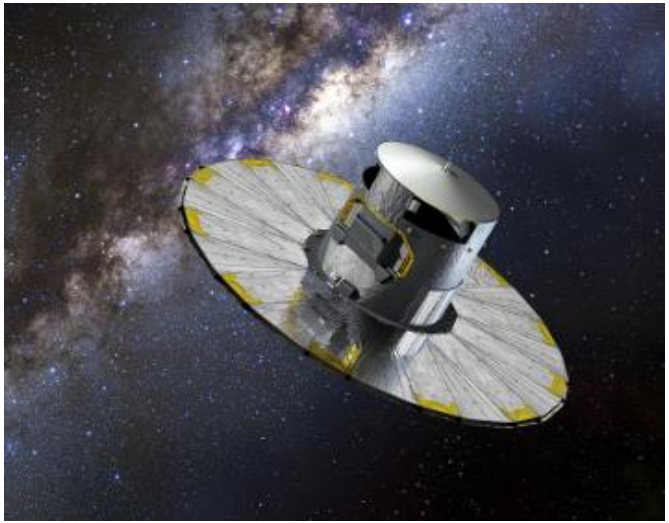
Authors : El-Badry et al (2022)

- Kent Barbey

- PHYS-643 : Astrophysics V
- November 2022

Context

- We only know a tiny fraction of galactic stellar mass BHs.
- Detection
  - Mass transfer(X emission)
  - Sometimes dynamical grounds
  - Or microlensing
- Where are the others ?
- Gaia DR3 to the (first) help.

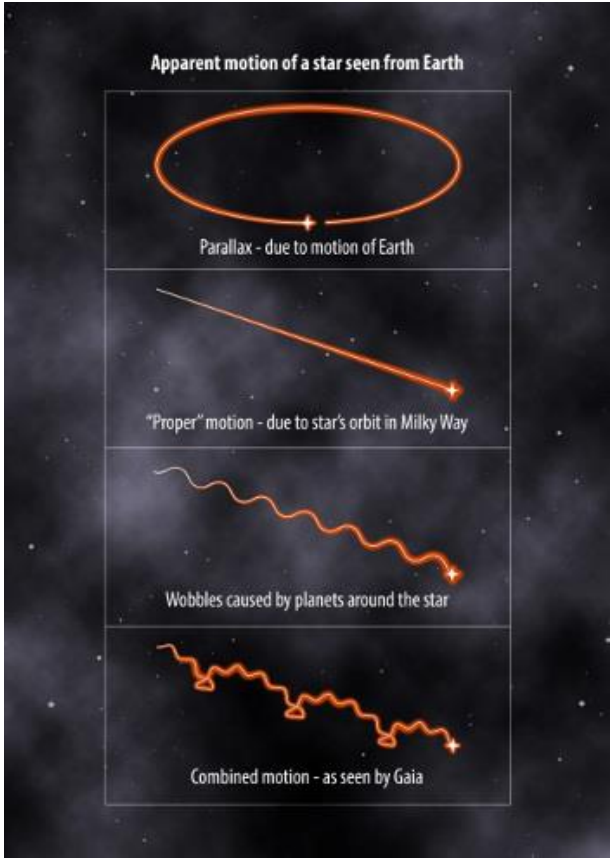


Main goal(s)

- Find a compact object companion to a «normal» star using Gaia’s DR3, hopefully a BH.
- Characterise the properties of this system.
- Find a formation channel.
- Estimate the number of these systems in our galaxy.

Methods

- Measurement techniques :
  - Astrometry : Position, parallax and proper motion
    ⟶ *Gaia*
  - Spectroscopy : Radial velocities and abundances
    ⟶ *Gaia*, LAMOST, MagE, GMOS, HIRES, FEROS and ESI.
  - Photometry : Spectral energy distribution
    ⟶ GALEX, PanSTARRS and WISE
- Statistical methods :
  - Bayesian inference : MCMC.

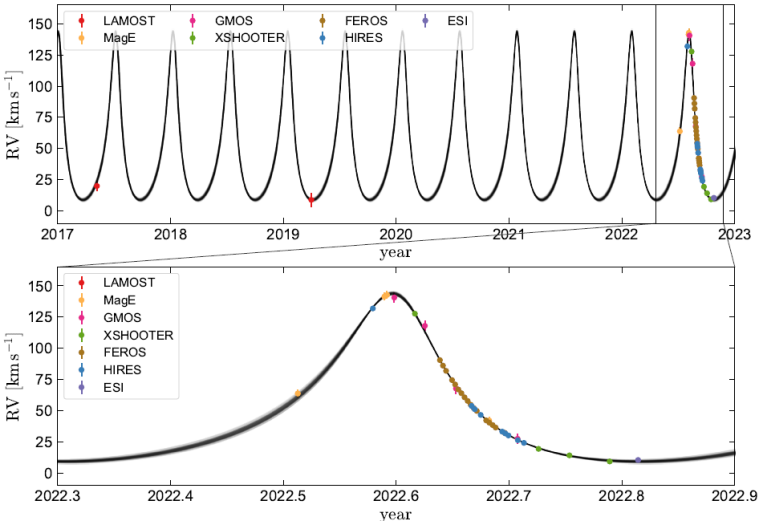


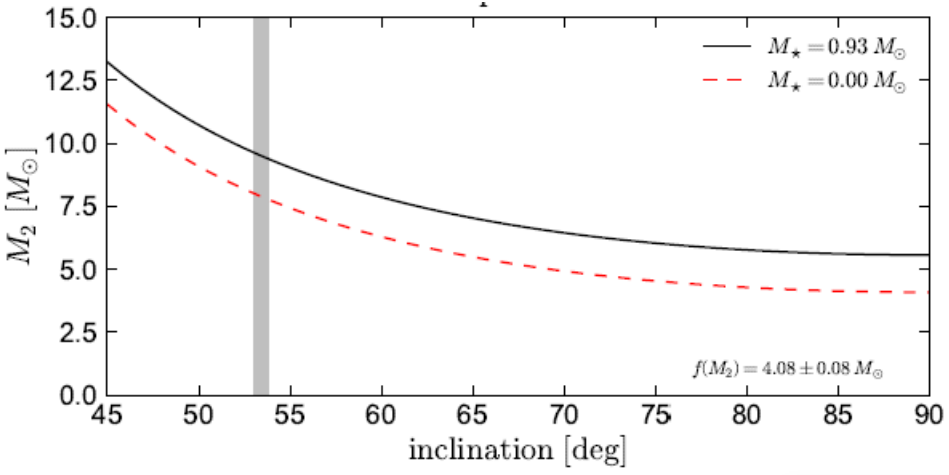
Discovering the system

- Selecting the right data : unusually large photocenter ellipses.
- Deduce the properties of the luminous source : first guess of the mass, SED ⟶ Temperature and radius of the star.
- Radial velocities : fit the orbit better and confirm Gaia's astrometry.
  - Find the companion's mass
- Star's spectrum : abundances, metallicity, age and other luminous companion
- Galactic orbit and X-Ray/radio upper limits.
- Nature of the companion
- Evolutionary history : formation channels.

Results

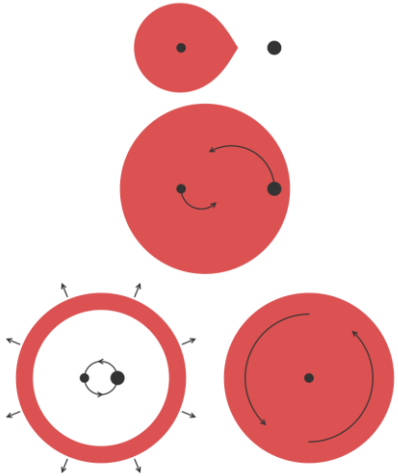
- Orbit:
  - P = 185.59 days
  - a = 1.40 a.u.
  - e = 0.45
- G-star :
  - M = 0.93 Msol
  - T=5850 K
  - [Fe/H] = -0.20
  - No pollution
- Companion : M = 9.62 Msol. Most probably a BH.
- Many differences with BH imposters.
- No measurable radio or X-ray emission
- Formation : isolated binary but then ?

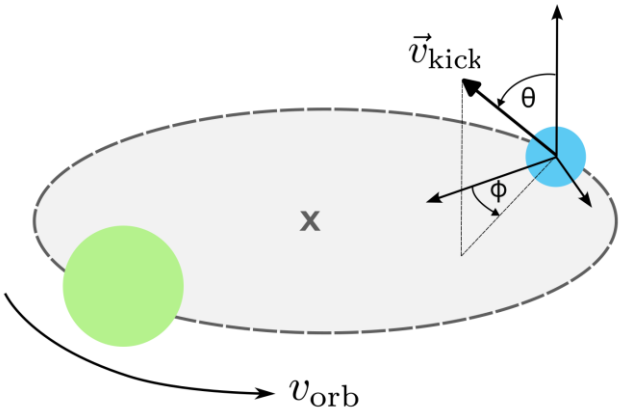




Formation channels

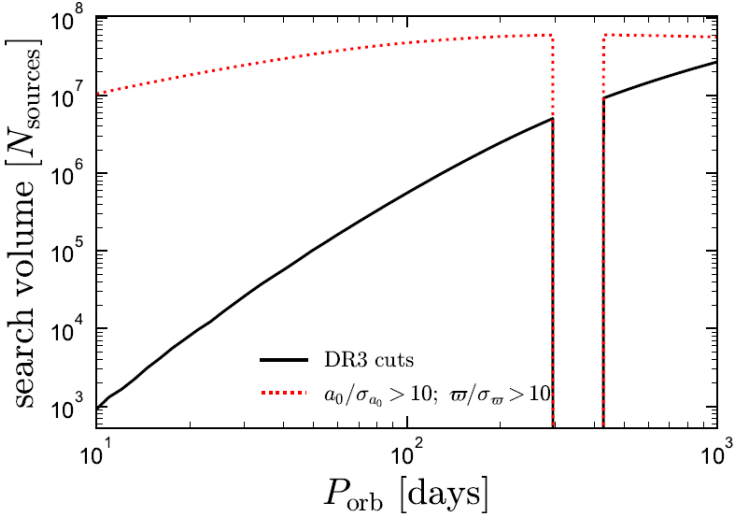
- Common envelope(CE)
  - Can a 1Msol star survive a CE event ?
  - Orbital energy needed for E ejection too high.
  - Cannot explain the current configuration.
- Progenitor that never became a giant
  - G-star formation would have been too close.
  - Can be avoided but : low metallicity only scenario
- 3B dynamics
  - Periastron distance is too large.
- Dense cluster
  - Maybe in an open cluster.
- Hierarchal triple
  - Maybe too but surprising





What's next ?

- Follow-up of the system to further confirm the presence of a BH
- DR4, DR5 : epoch-level, lower SNR cut so less constrained especially on the parallax parameter ⟶ dozens more expected.
- Spectroscopy and photometry.
- Find a new formation channel for such systems or improve the existing ones.



Conclusion

- First reasonably confident observation of a Sun-like star orbiting a BH(no mass transfer) thanks to *Gaia.*
- Closest BH to us : 0.48 kpc
- Formation channel uncertain
- Next steps : *Gaia* DR4 and DR5 for epoch-level astrometry, interferometric follow-up, ellipsoidal variation through self-lensing(photometry), longer time baseline thanks to time-domain spectroscomic surveys with better cadence and more epoch per source etc…

Thank you for your attention !

References :

1. *A Sun-like star orbiting a black-hole(2022)*, El-Badry et al.
2. https://galaxiesbook.org/
3. Wikipedia