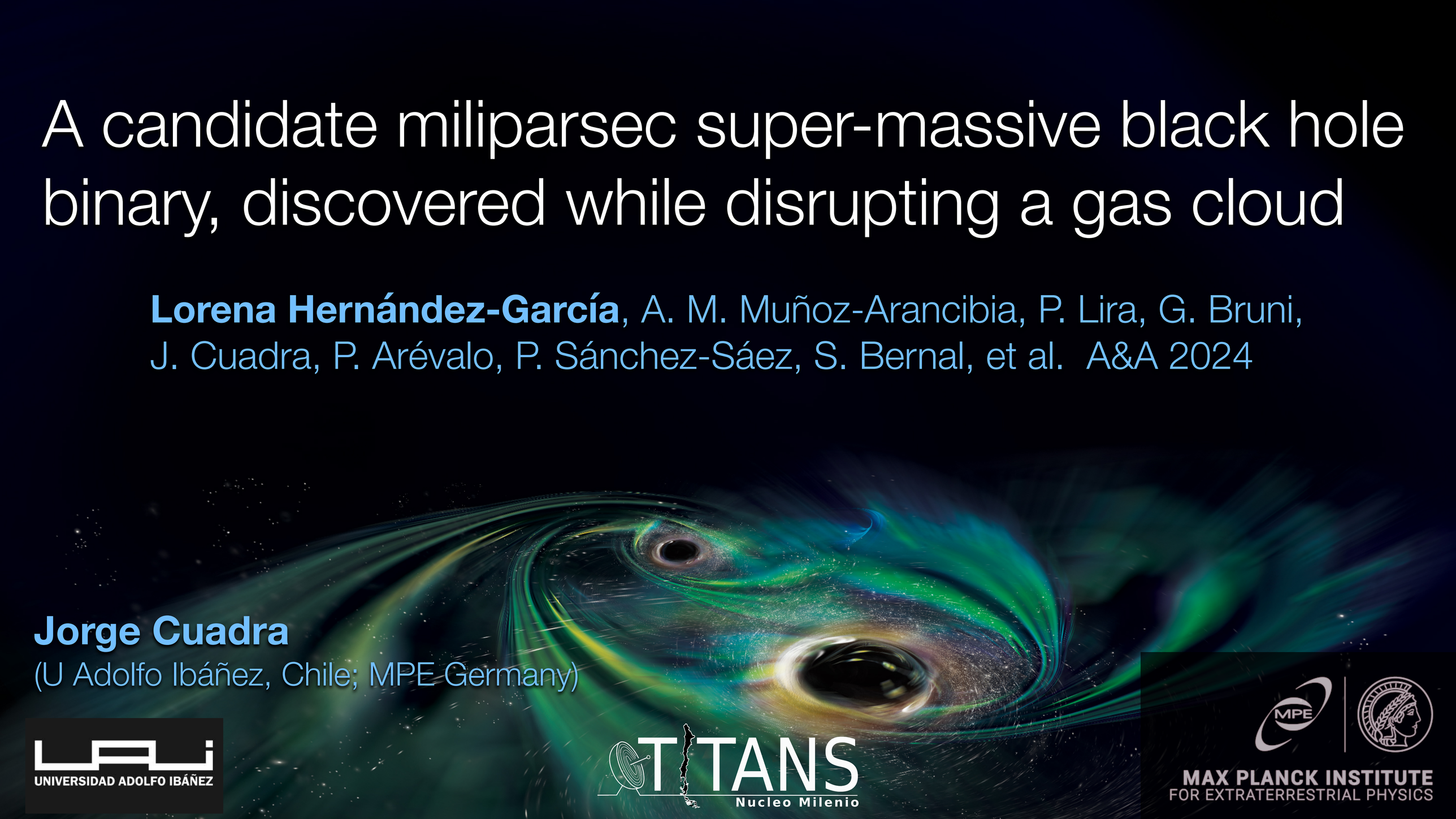
A candidate miliparsec super-massive black hole binary, discovered while disrupting a gas cloud

Lorena Hernández-García, A. M. Muñoz-Arancibia, P. Lira, G. Bruni,
J. Cuadra, P. Arévalo, P. Sánchez-Sáez, S. Bernal, et al. A&A 2024



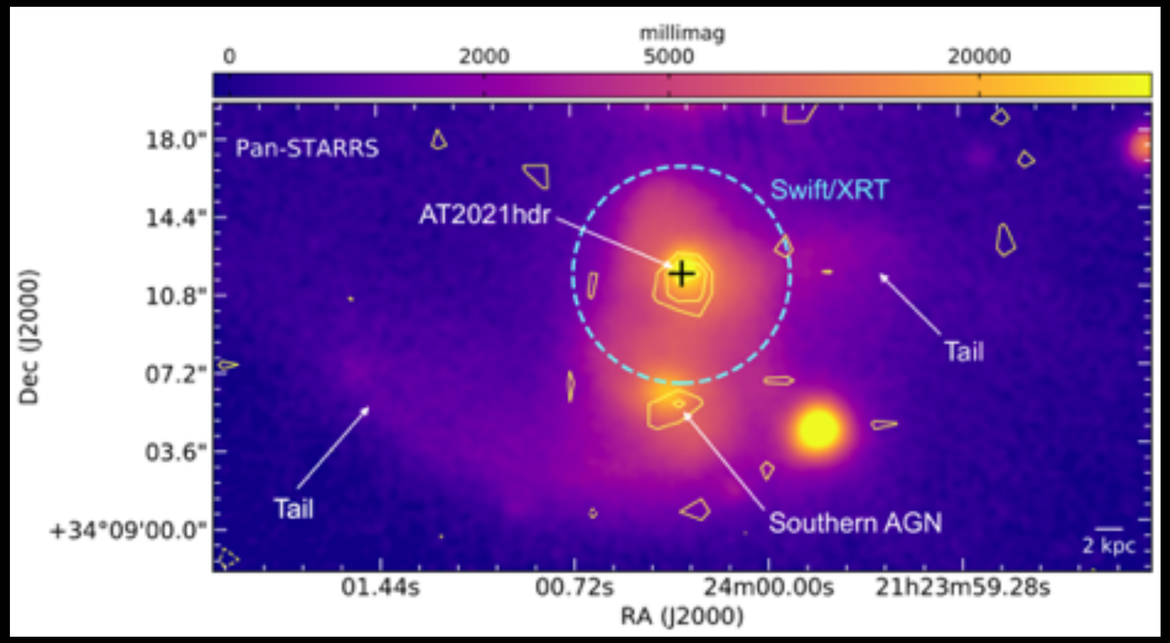
Jorge Cuadra
(U Adolfo Ibáñez, Chile; MPE Germany)

UNIVERSIDAD ADOLFO IBÁÑEZ

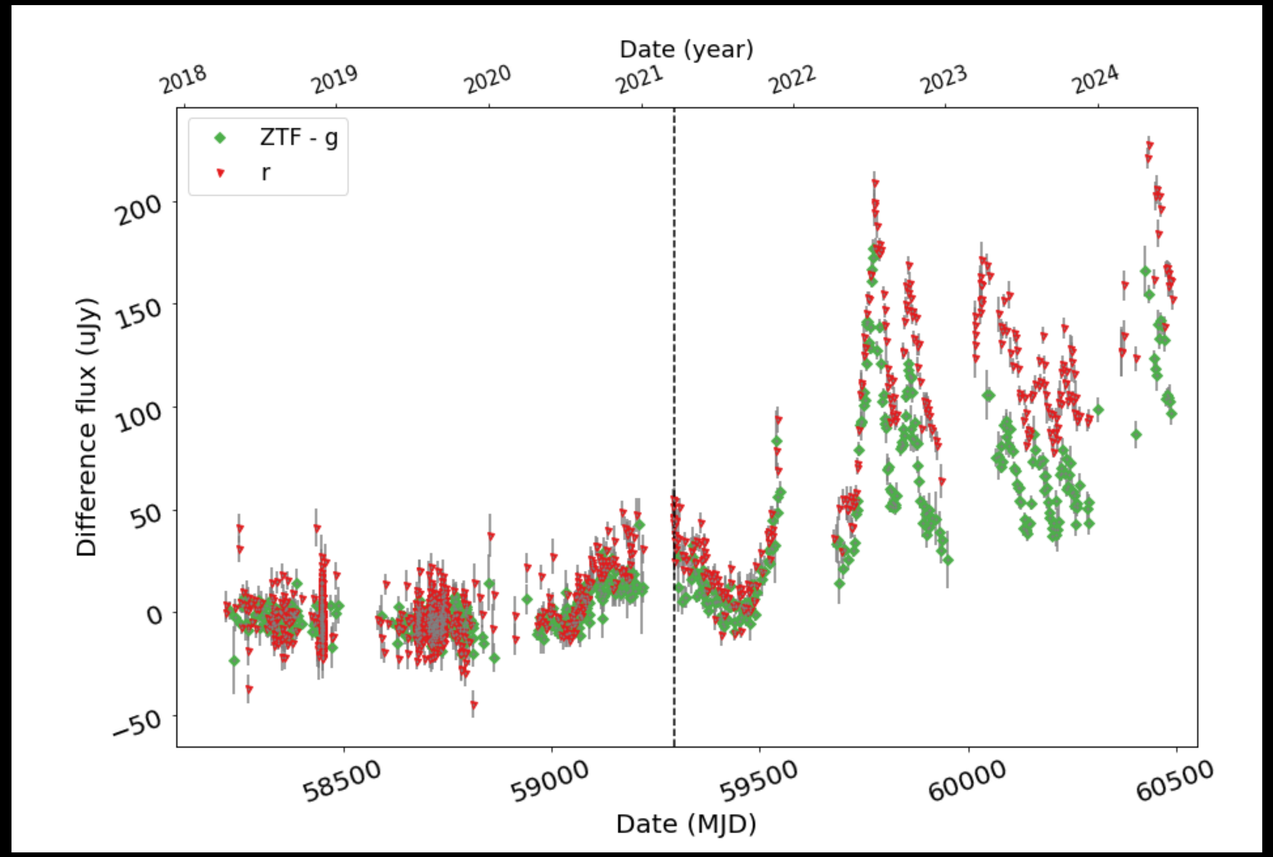
TITANS
Nucleo Milenio

MAX PLANCK INSTITUTE
FOR EXTRATERRESTRIAL PHYSICS

AT2021hdr discovered in the ZTF public alert stream



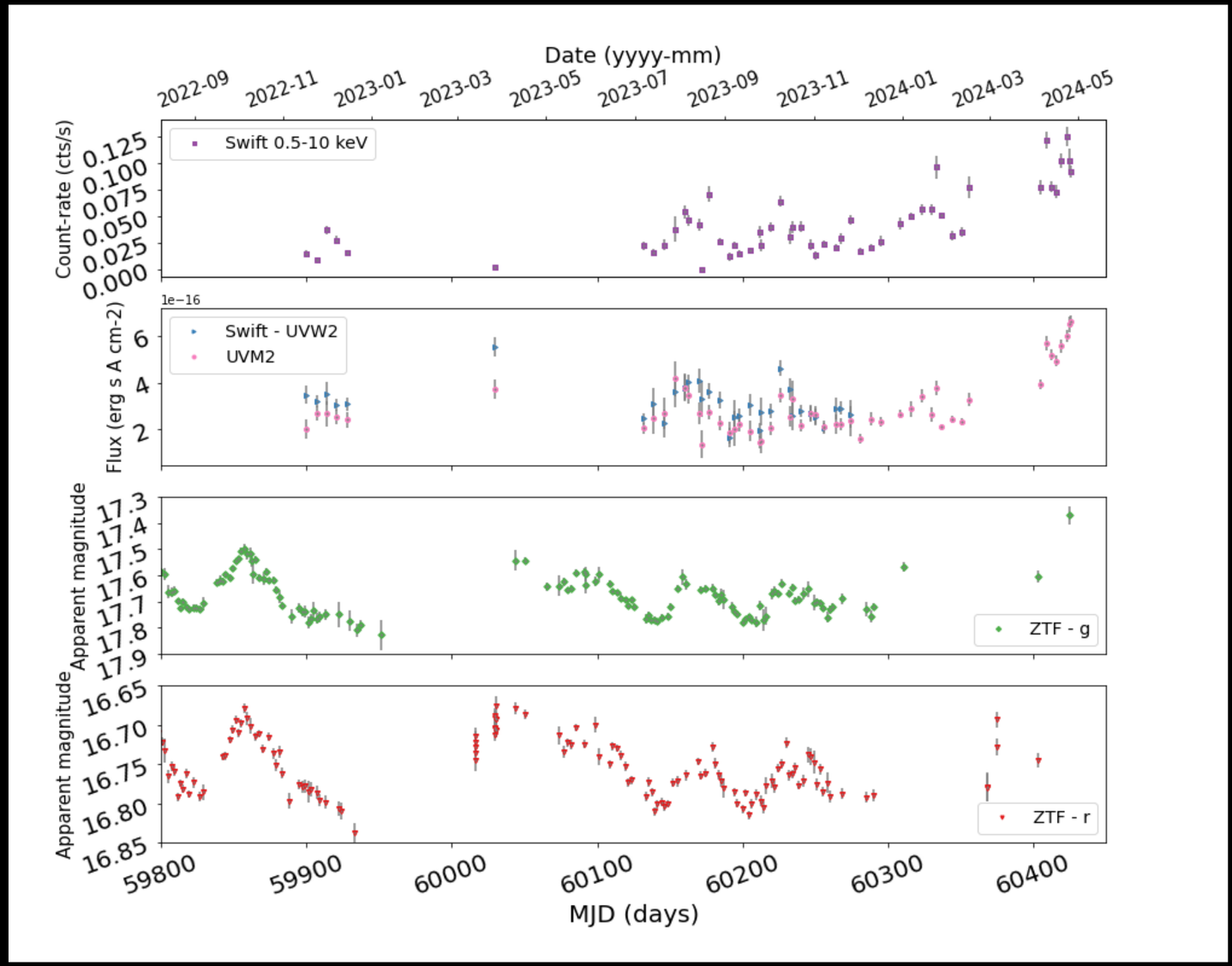
- First alert in March ’21
- z = 0.083 Seyfert 1
- 0.2-mag peaks every ~65 days



ALeRCE
Automatic Learning for the Rapid Classification of Events

Multi-wavelength follow up

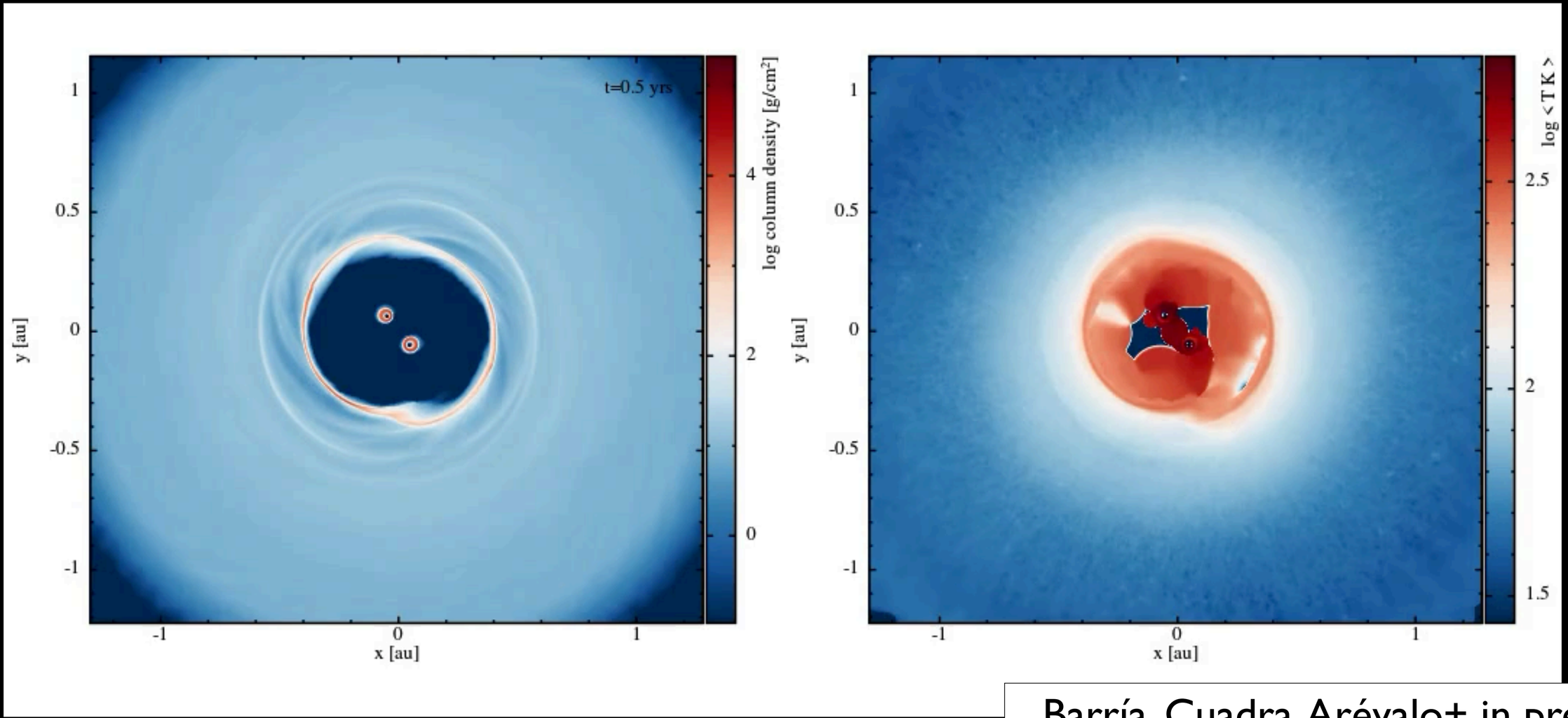
- Oscillations in X-rays and UV also
- No variable radio emission



Which kind of source is this?

- Quasi-periodic eruptions (QPEs)?
  - Too long time-scale, too hard spectrum
- Changing-look AGN?
  - No change in optical spectrum
  - Variability not stochastic
- Tidal disruption event (TDE)?
  - Neither spectrum nor colour match TDE
  - No good fit to the oscillating light curve!

Accretion on to binary produces oscillations, but still need to explain the sudden start

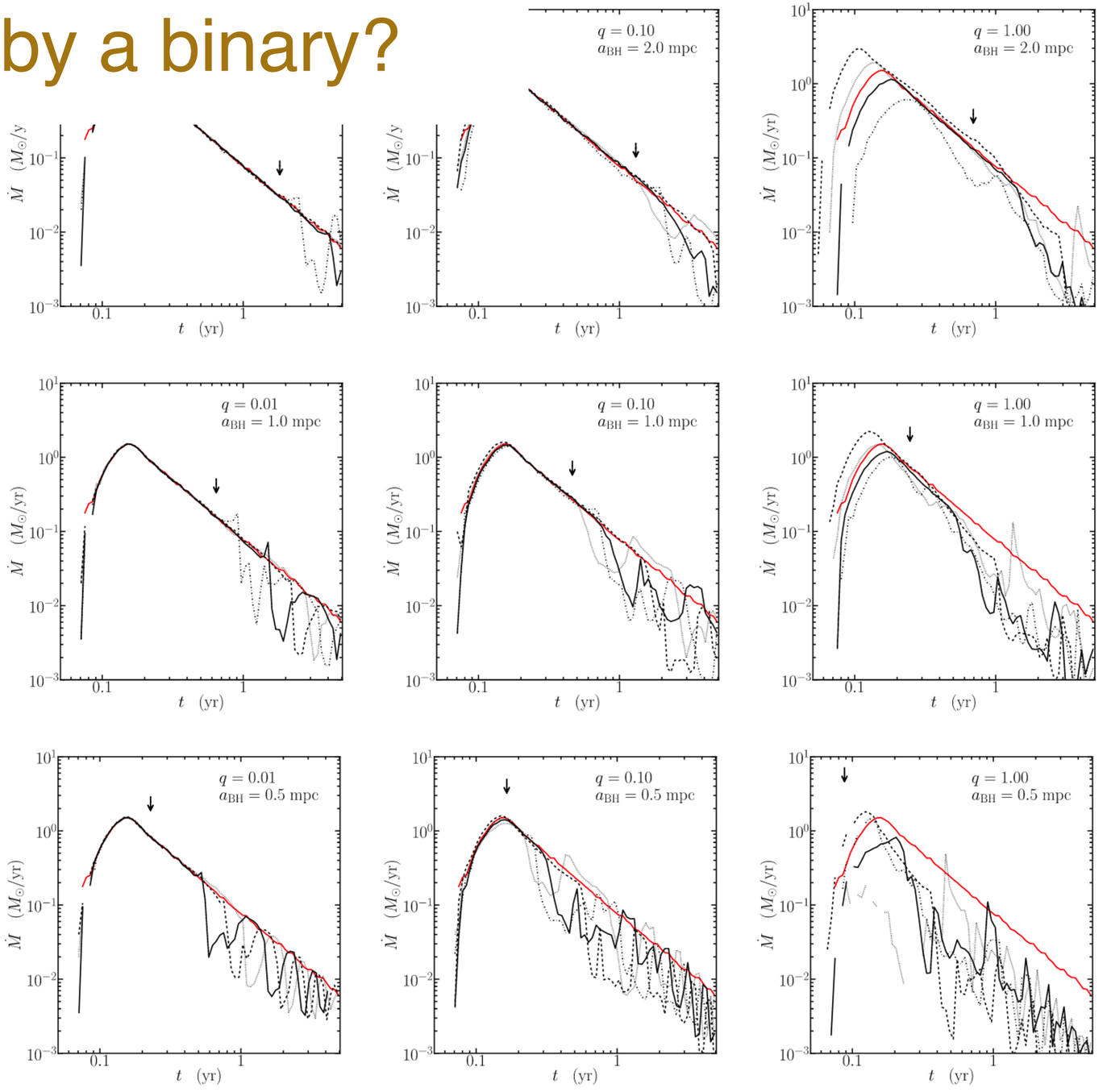


Barría, Cuadra, Arévalo+ in prep

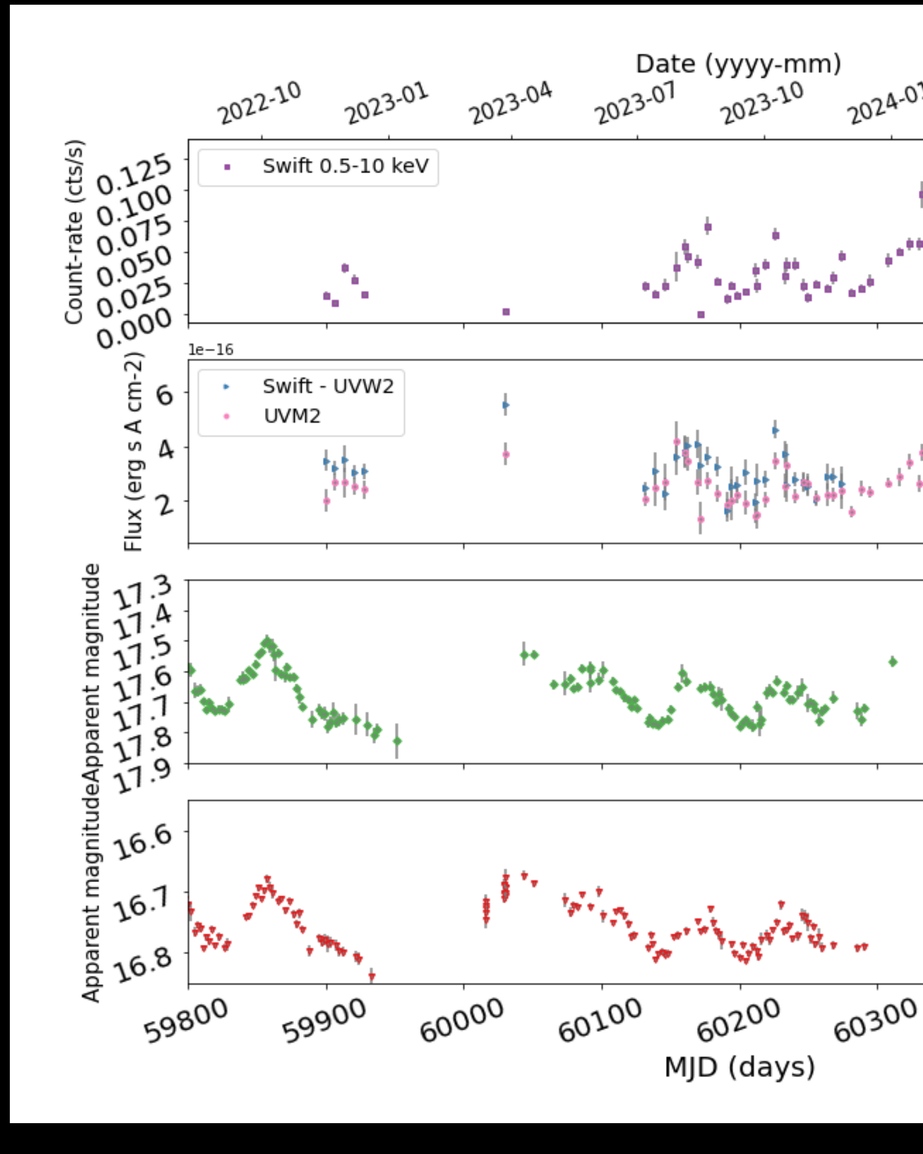
What about a TDE by a binary?

- Overall similar to normal TDE, but with interruptions.
- These can be periodic, depending on system parameters

Vigneron+ 2018



But in none of the binary TDE models the accretion rises again…



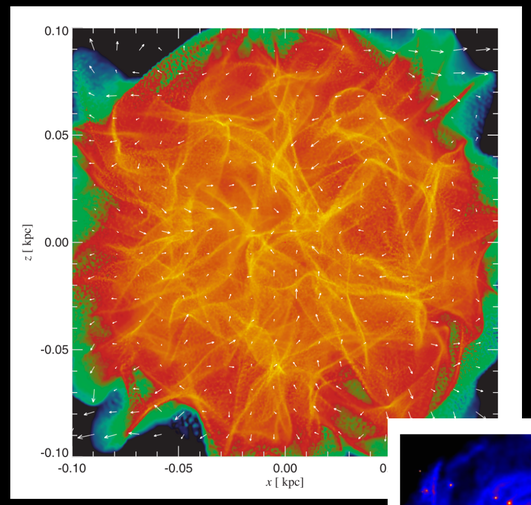
Infalling clouds on to supermassive black hole binaries

Felipe G. Goicovic, Jorge Cuadra, Alberto Sesana, Federico Stasyszyn, Pau Amaro-Seoane and Takamitsu Tanaka

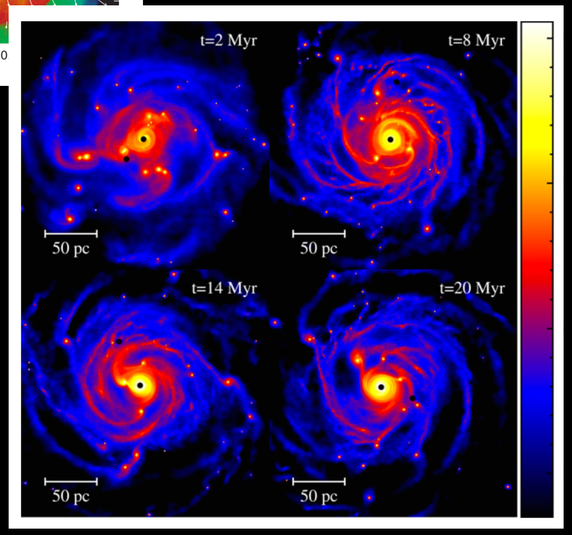
MNRAS 2016

- Formation and infall of gas clumps/molecular clouds can fuel the galactic nuclei, and originate discs.

Hobbs et al. (2011)

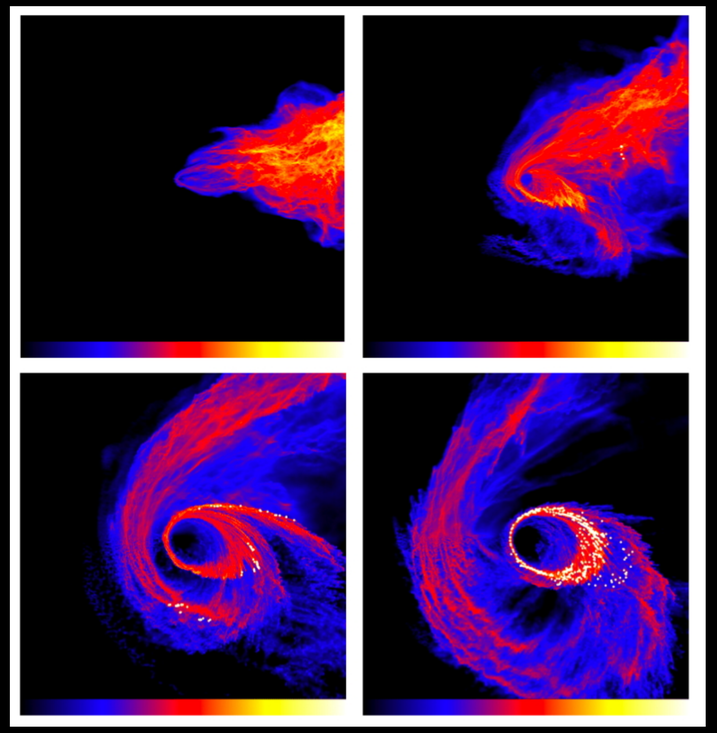


Turbulence

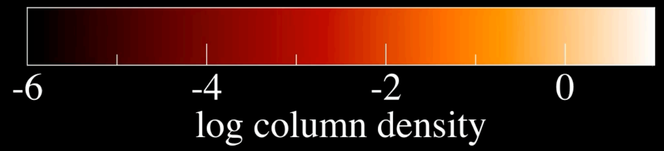


Gravitational instabilities

Fiacconi et al. (2013)

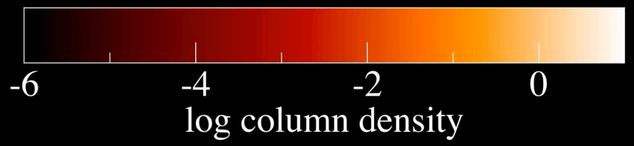


Bonnell & Rice (2008)



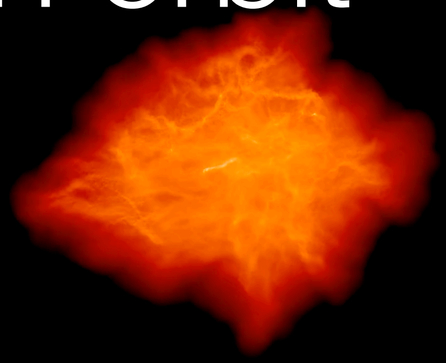
t=3.58 [Pbin]

Aligned orbit

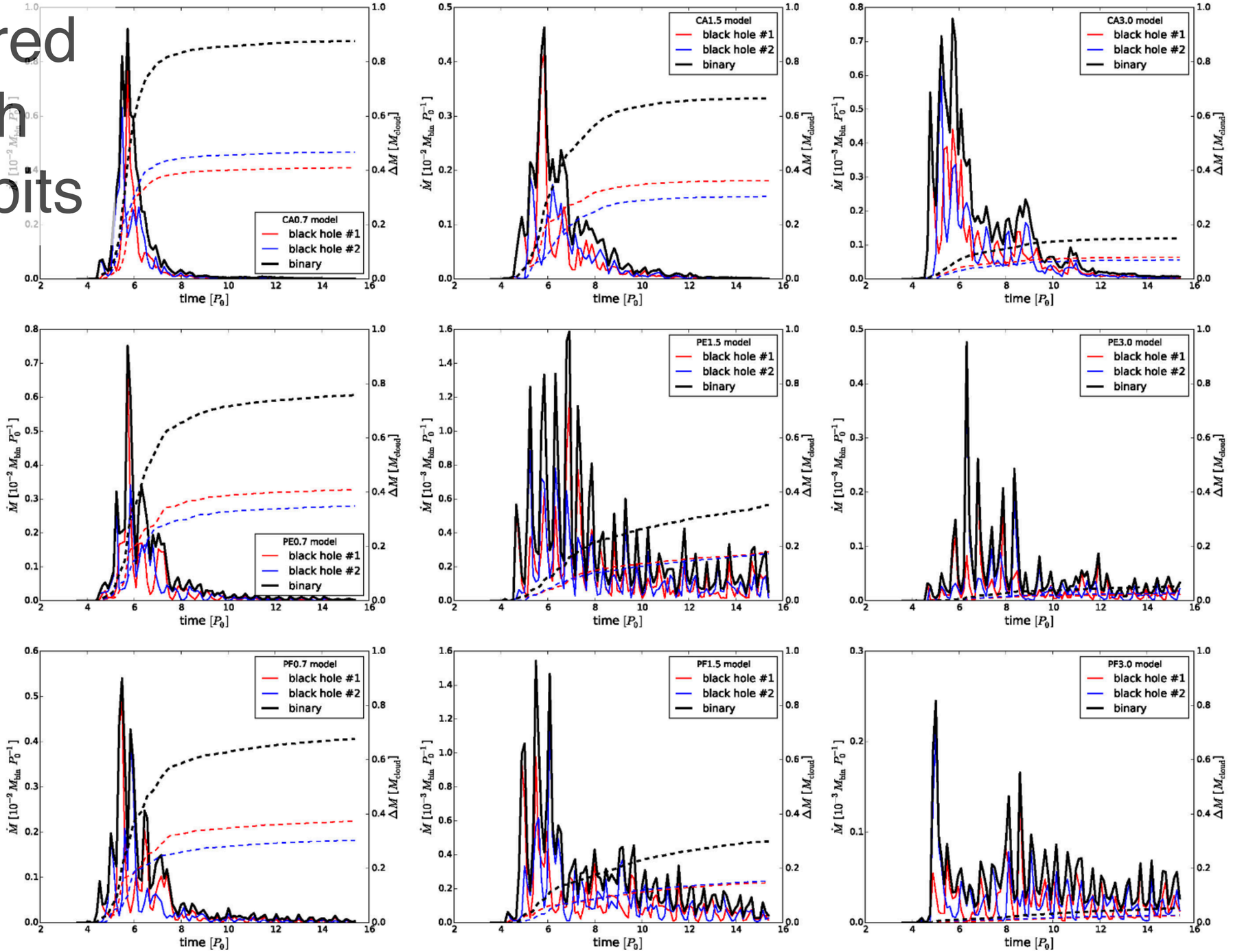


Perpendicular, edge-on orbit

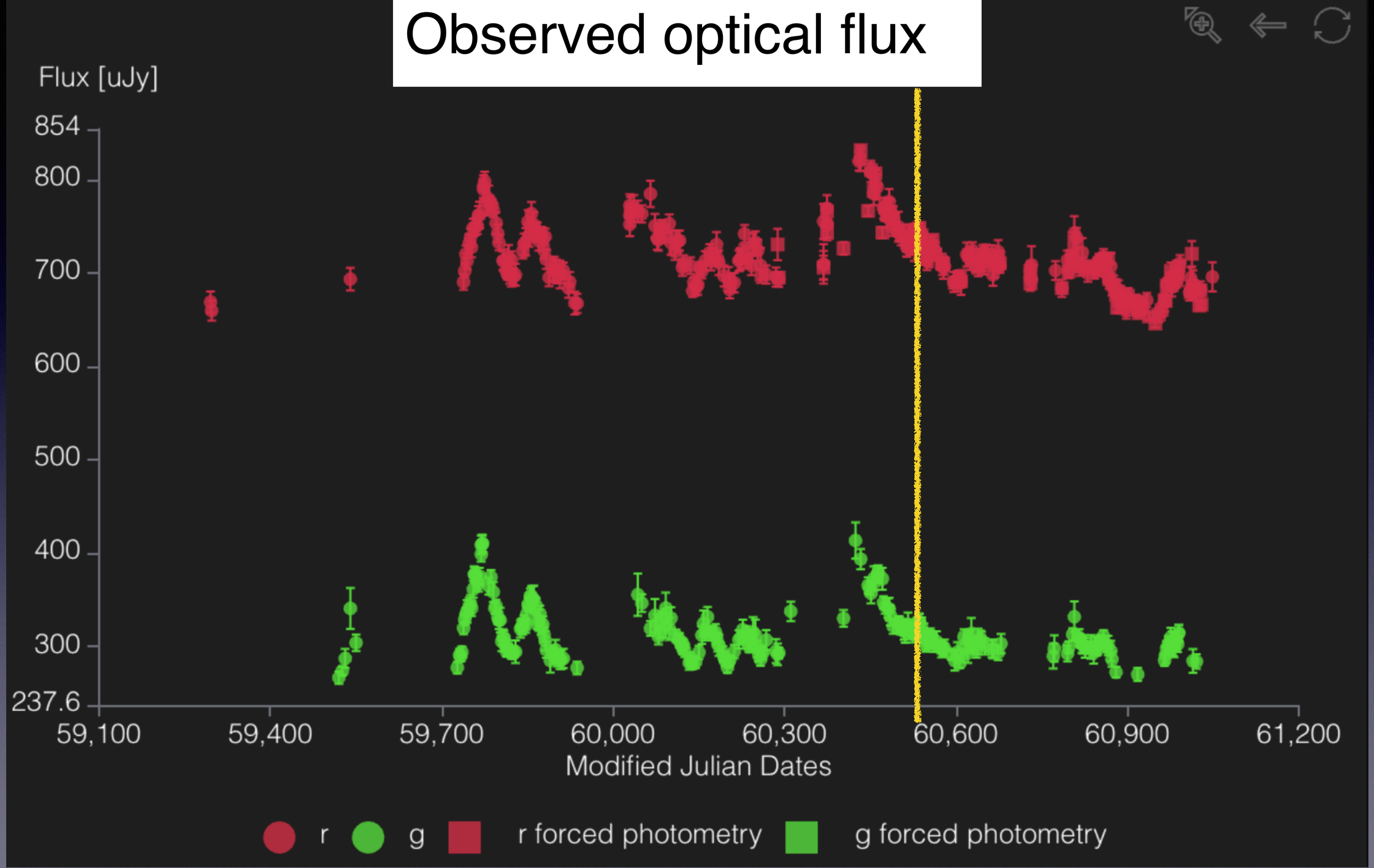
t=3.58 [Pbin]



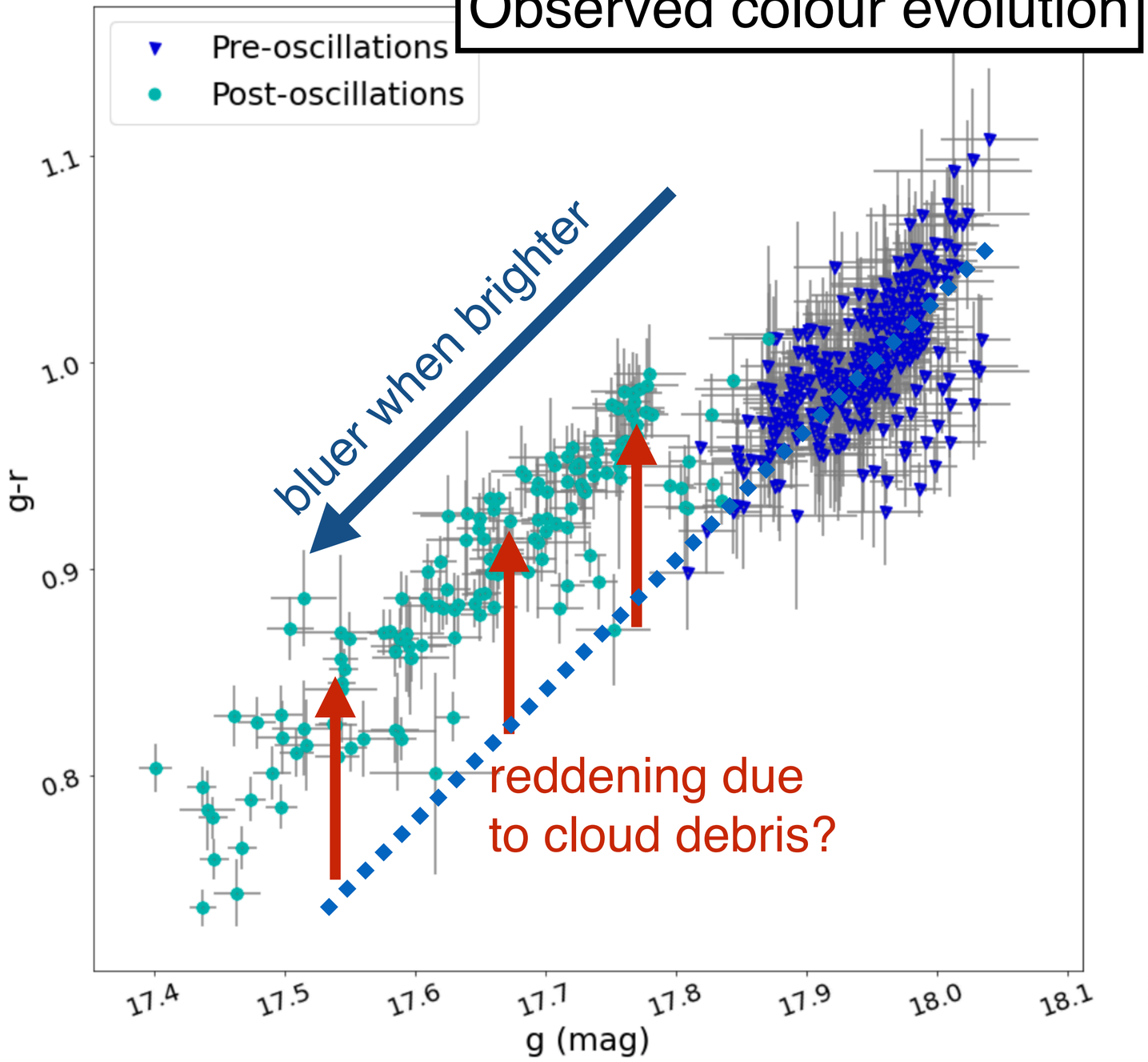
Accretion measured in simulations with different cloud orbits



Observed optical flux



Observed colour evolution



Assuming this is a super-massive BH binary…

- Peaks twice per orbit
  - orbital period ≈ 130 days
- From optical spectrum
  - total black hole mass $\sim 4 \cdot 10^7\ M_{sun}$
- Separation ≈ 0.83 mpc ≈ 220 – 430 R_{Sch} ≈ 0.5 μas :-(
  - smaller than expected broad line region size
  - consistent with regular lines
- Gravitational wave emission
  - Time-scale for merger $\sim 7 \cdot 10^4$ yr

Summary and conclusions

- Oscillating source appeared in a regular Seyfert 1 galaxy
- None of the usual nuclear transients is a good fit
- We propose it’s a binary SMBH accreting a gas cloud
- Ideal case study of black hole mergers
- Expect many interesting sources from Vera Rubin LSST!