Evolution of massive black hole binaries in gaseous environments

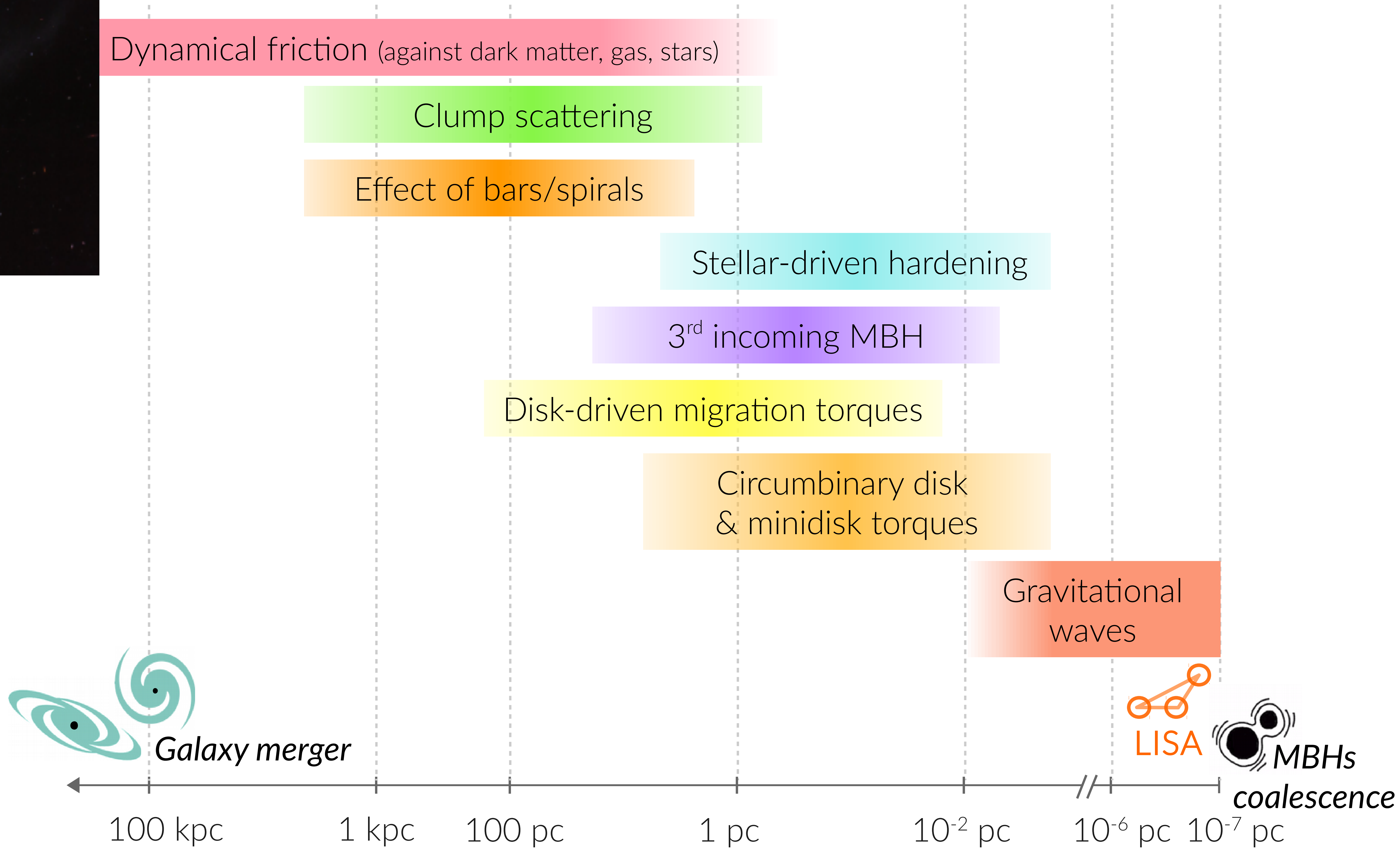
Universität Zürich[UZH]

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

Alessia Franchini October 10th 2024 @ V Gravi-Gamma-Nu Workshop, Bari (IT)

Massive black hole binaries path to coalescence

Credit: NASA/ESA/Hubble



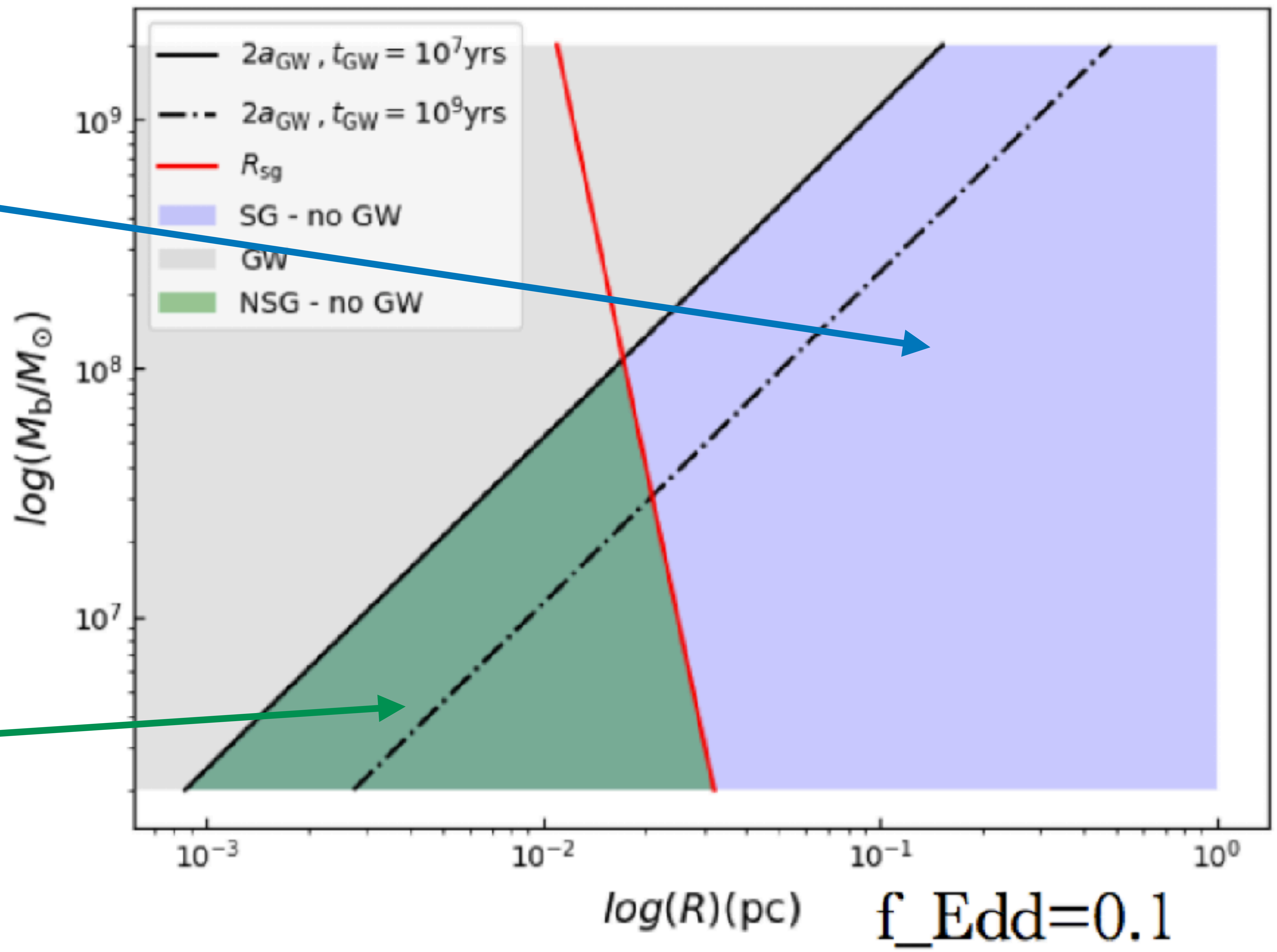
Credit: E. Bortolas

Massive black hole binaries in gaseous environments

After a successful dynamical friction driven inspiral, a bound binary in the central parsec of the remnant host galaxy evolves through the interaction with gas before diving into the GW dominated phase

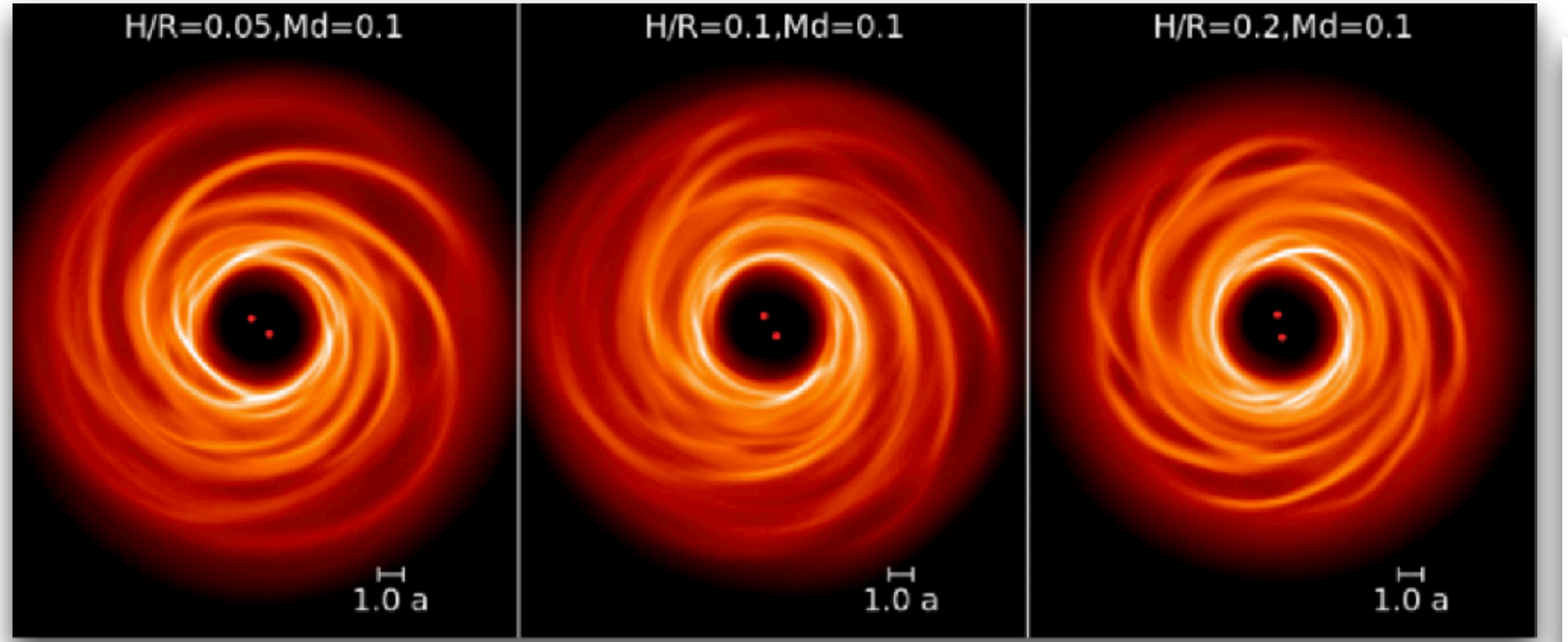
Pulsar Timing Array (PTA) binaries may reside in massive discs whose self-gravity cannot be neglected

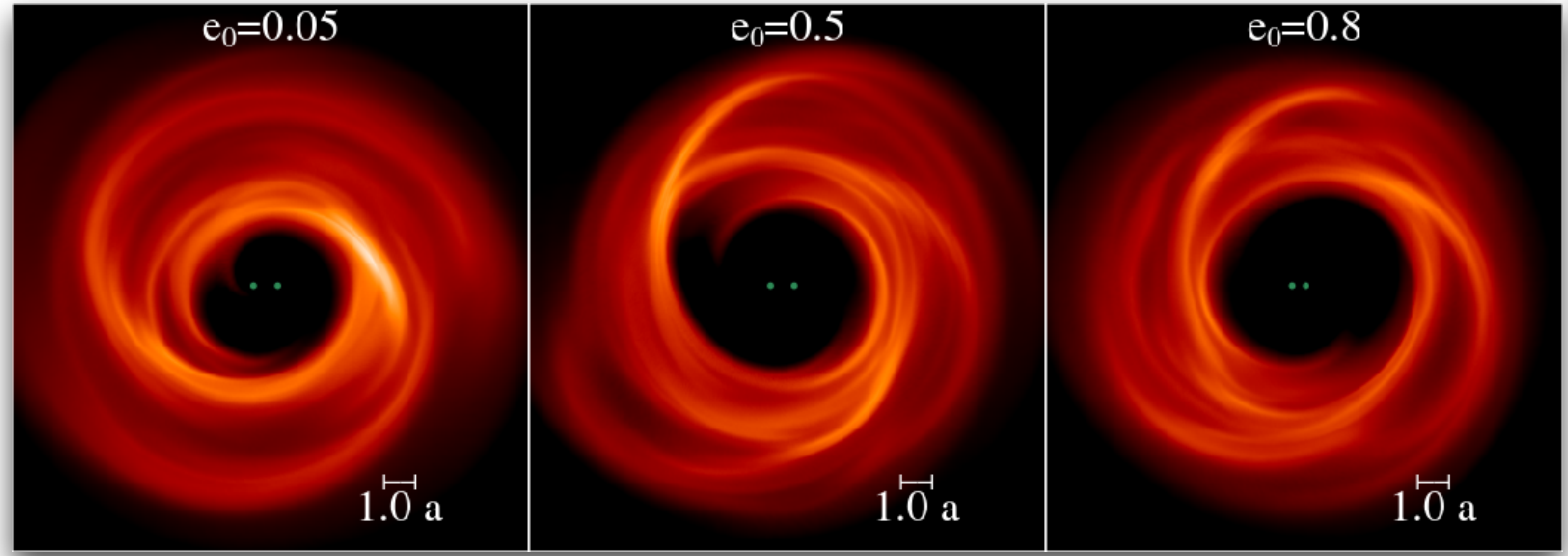
LISA binaries evolve within gaseous discs where the gas self-gravity can be neglected

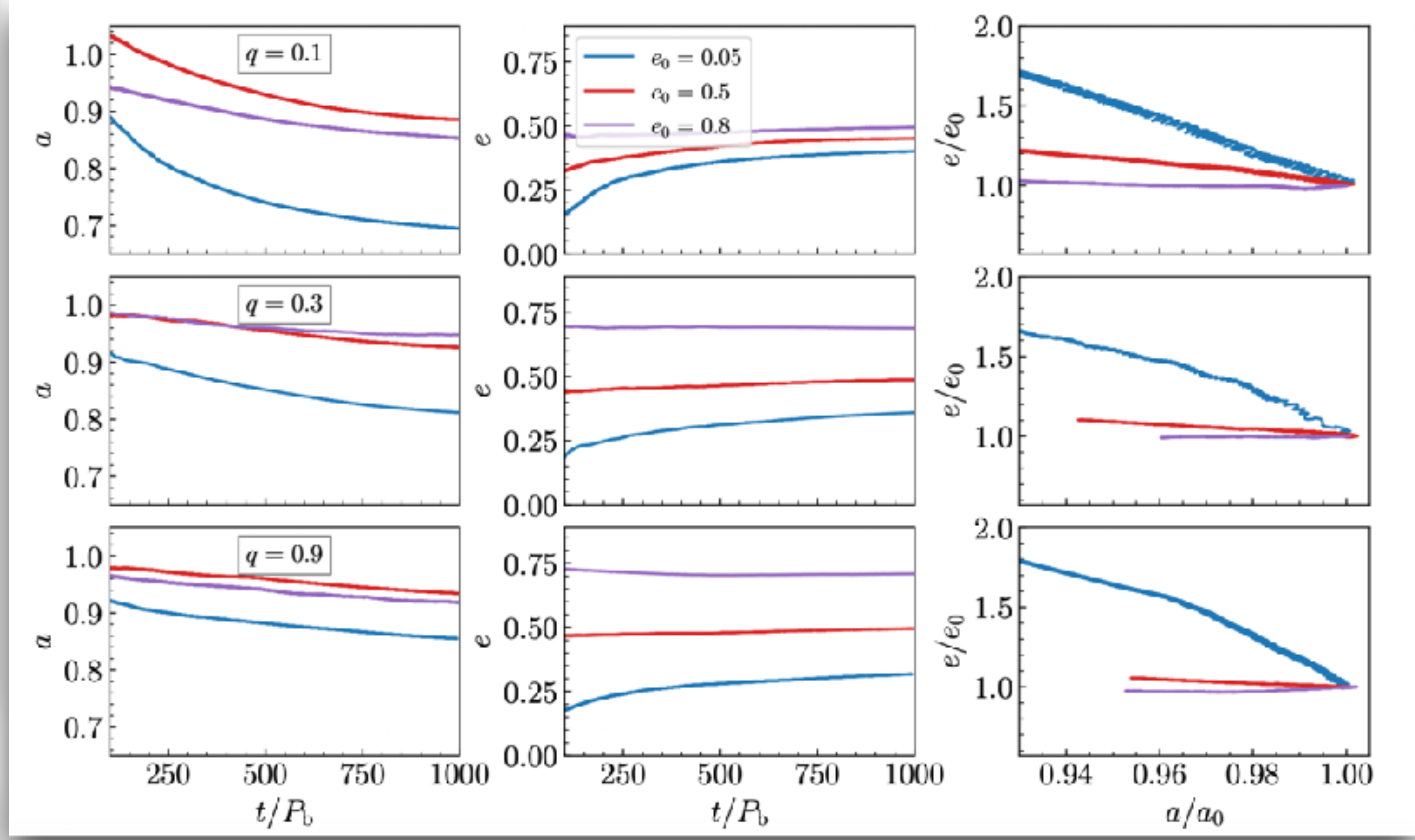


Franchini A., Sesana A. & Dotti M., MNRAS 507 (2021)

PTA Massive black hole binaries in gaseous environments





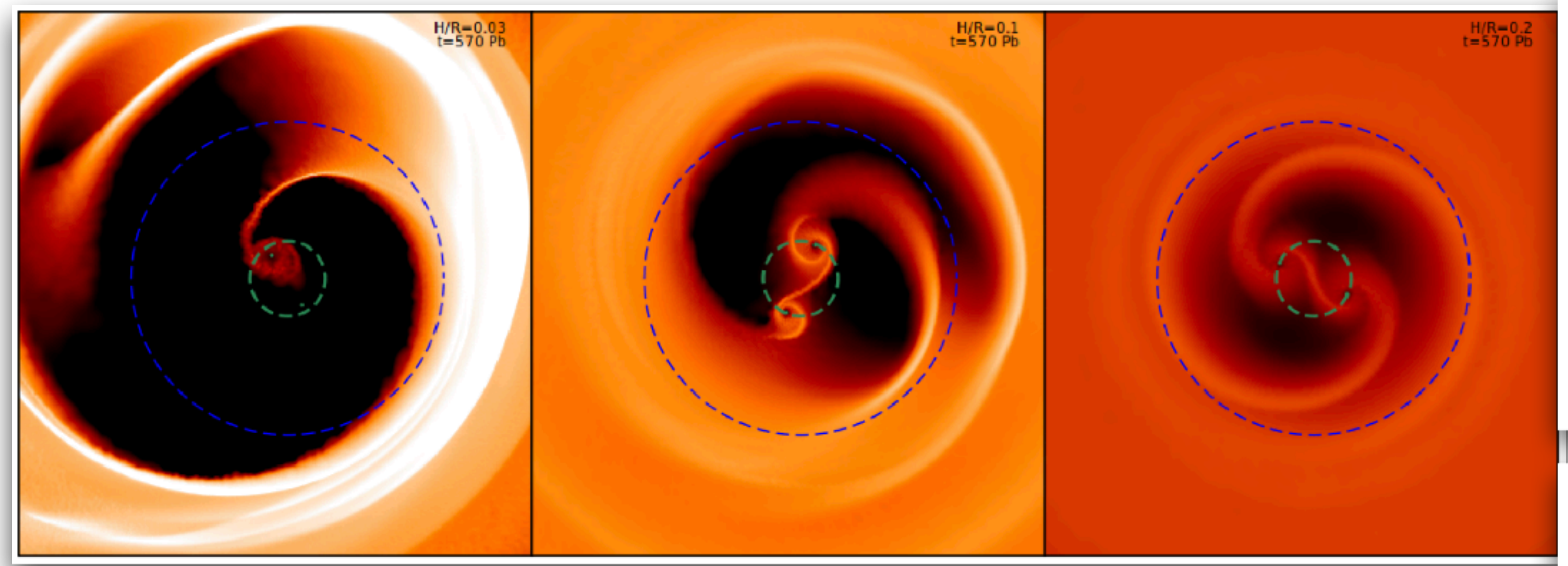


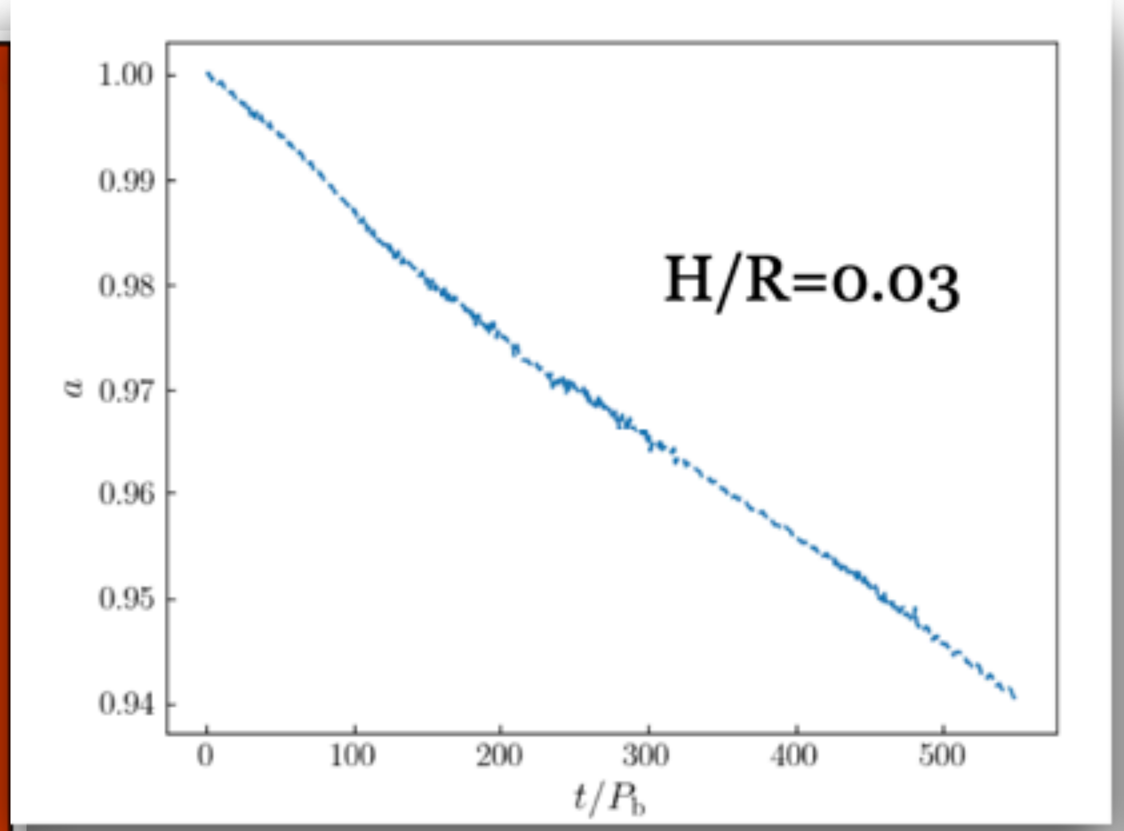
We find binaries embedded in massive self-gravitating discs to always in-spiral while reaching an orbital eccentricity which depends on the initial value and on the initial mass ratio.

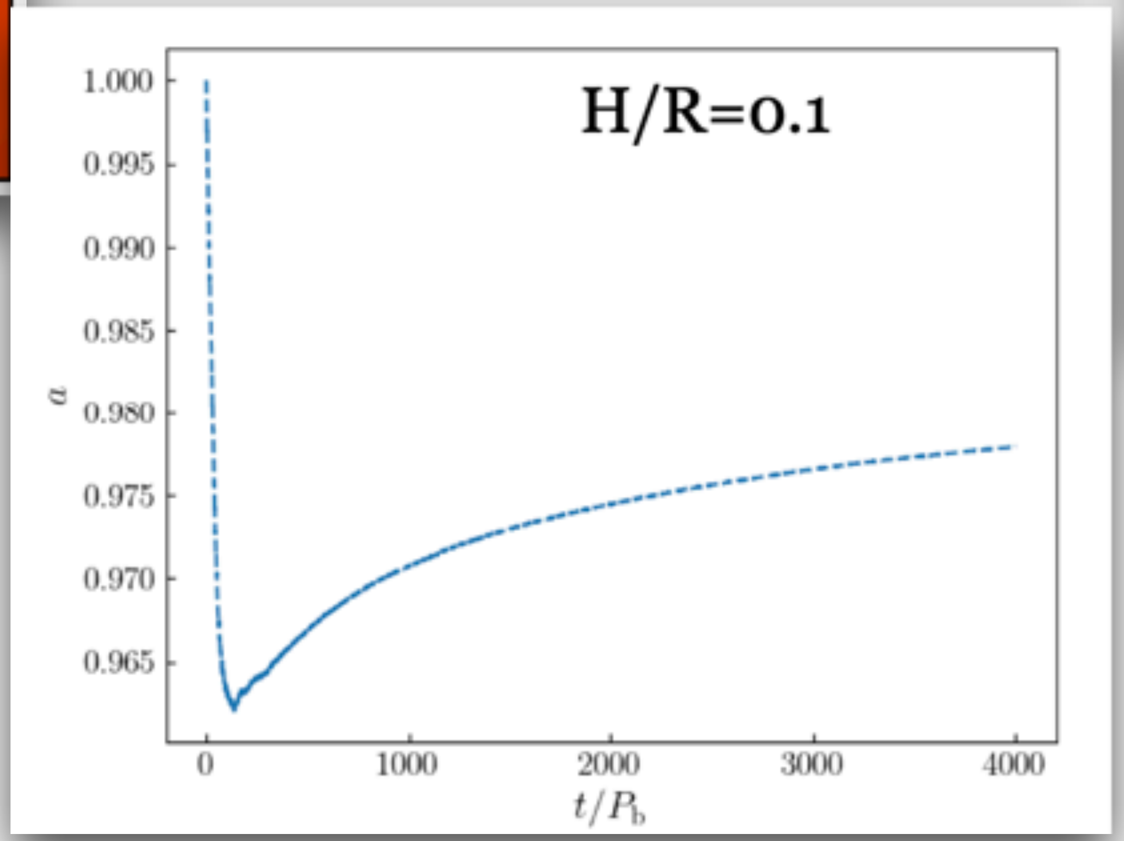
Franchini A., Sesana A. & Dotti M., MNRAS 507 (2021)
Franchini A. et al. A&A 688 A174 (2024)

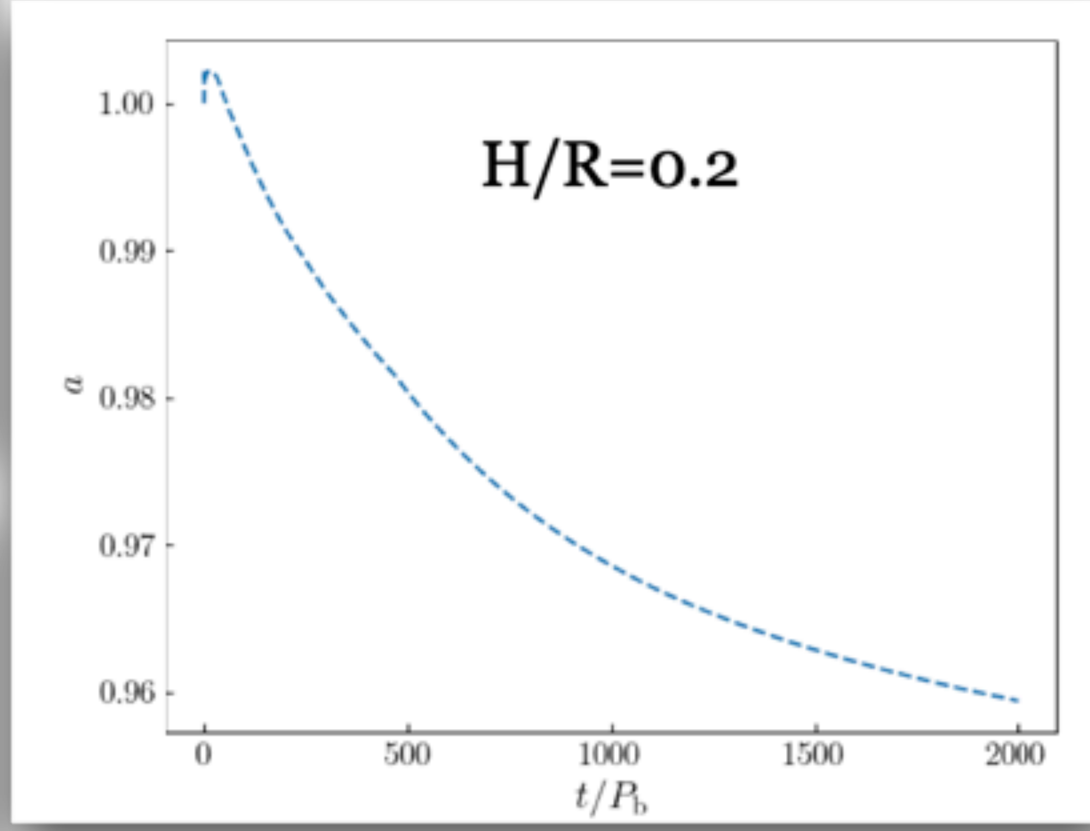
LISA Massive black hole binaries in gaseous environments

We use hyper-Lagrangian refinement to investigate the effect of the disc temperature during the interaction between an equal mass circular binary and an isothermal circumbinary disc.







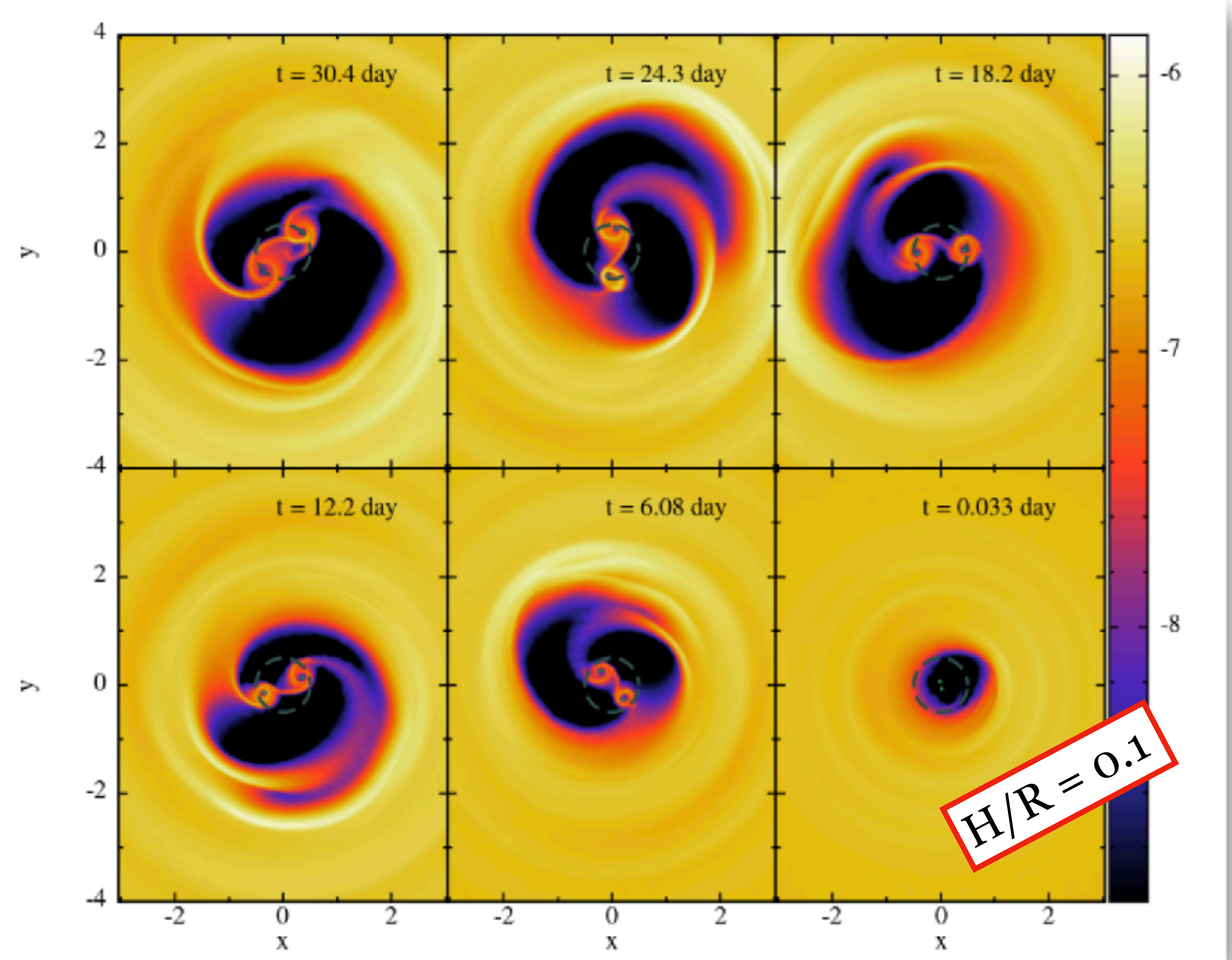


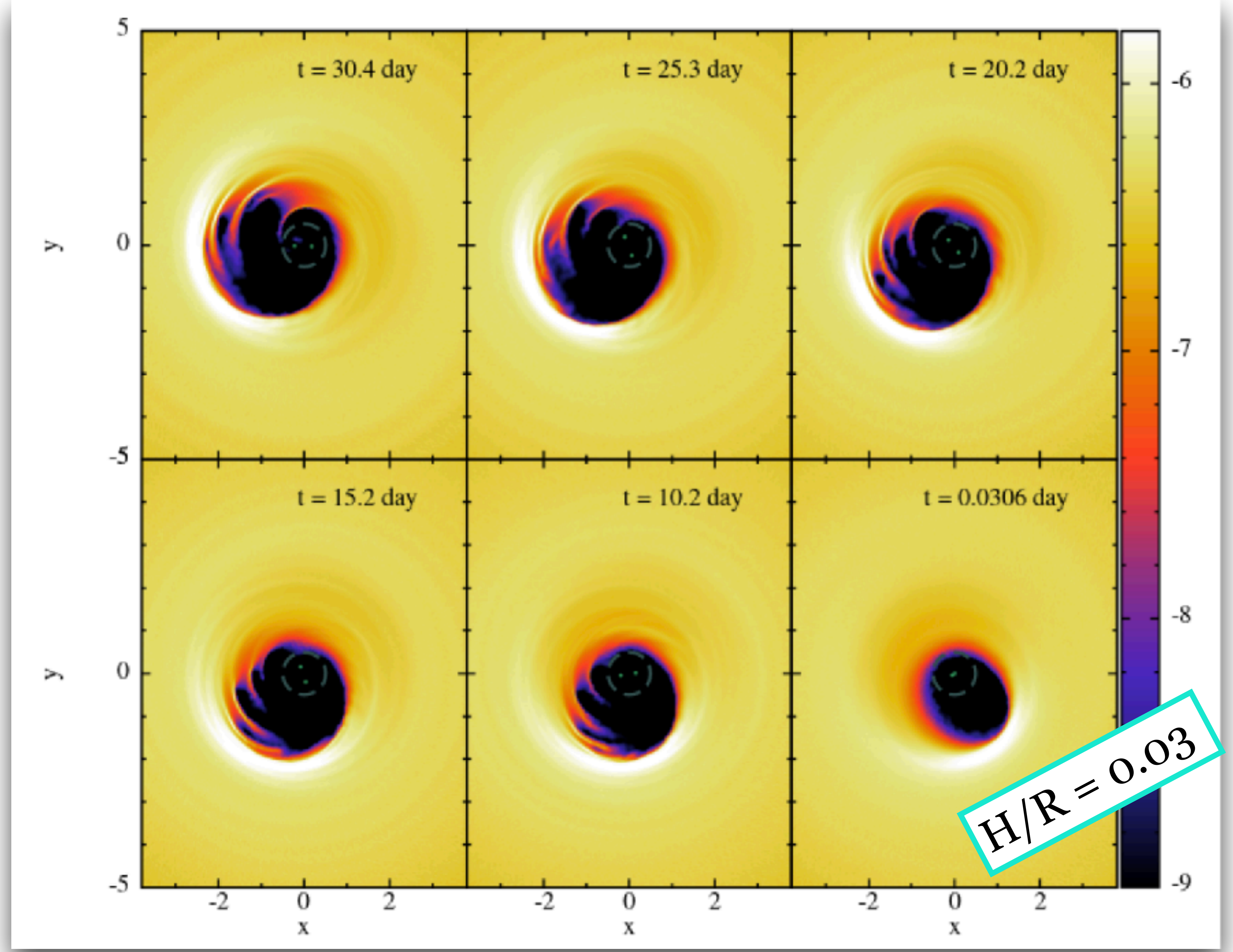
We find binary out-spiral for intermediate values of the disc temperature

Franchini A., Lupi A. & Sesana A., ApJL 929 L13 (2022)
Franchini A. et al. MNRAS 552 (2023)

LISA Massive black hole binaries electromagnetic counterparts

We use hyper-Lagrangian refinement coupled with 2.5PN corrections to the binary orbit to investigate electromagnetic counterparts of LISA binaries.

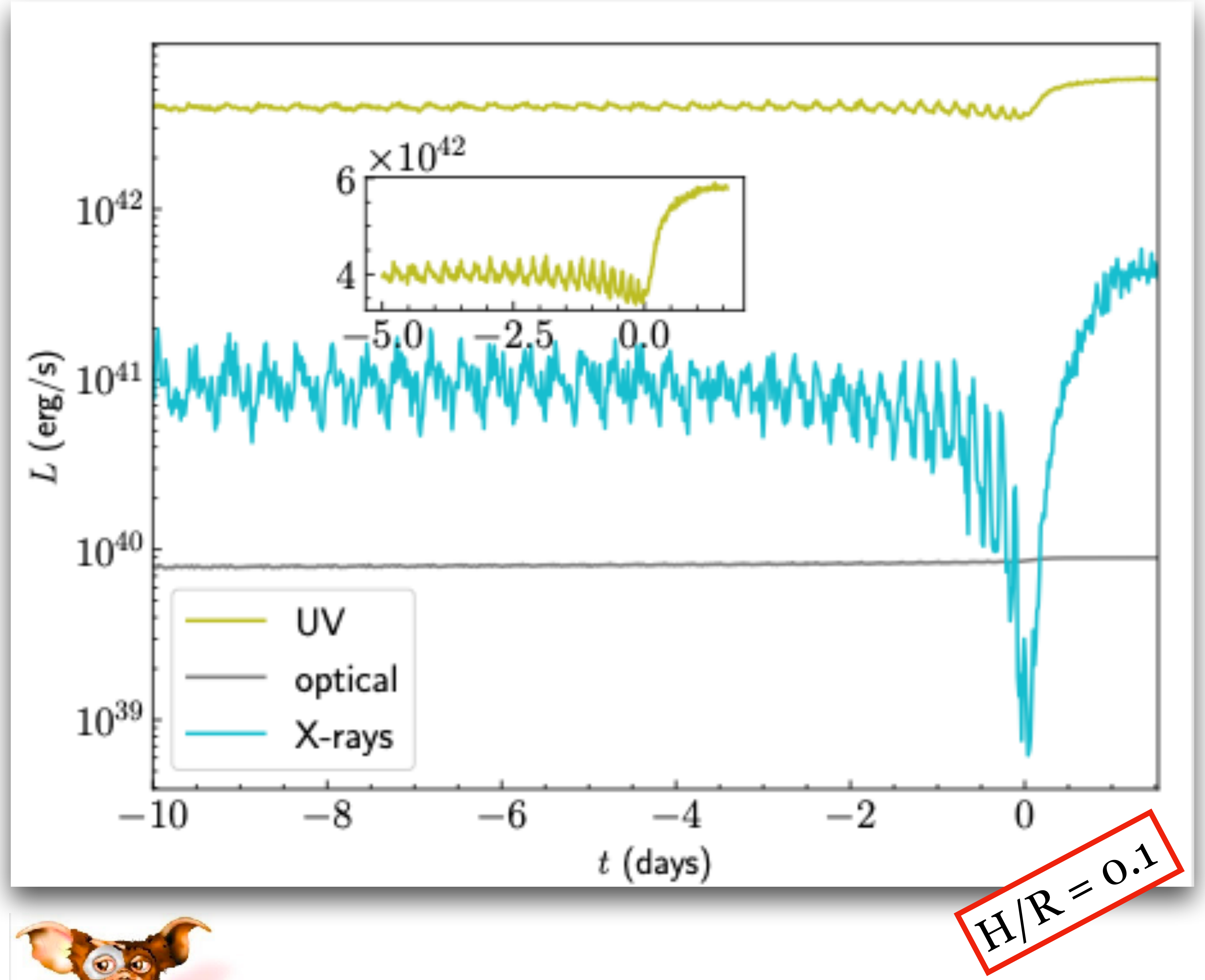


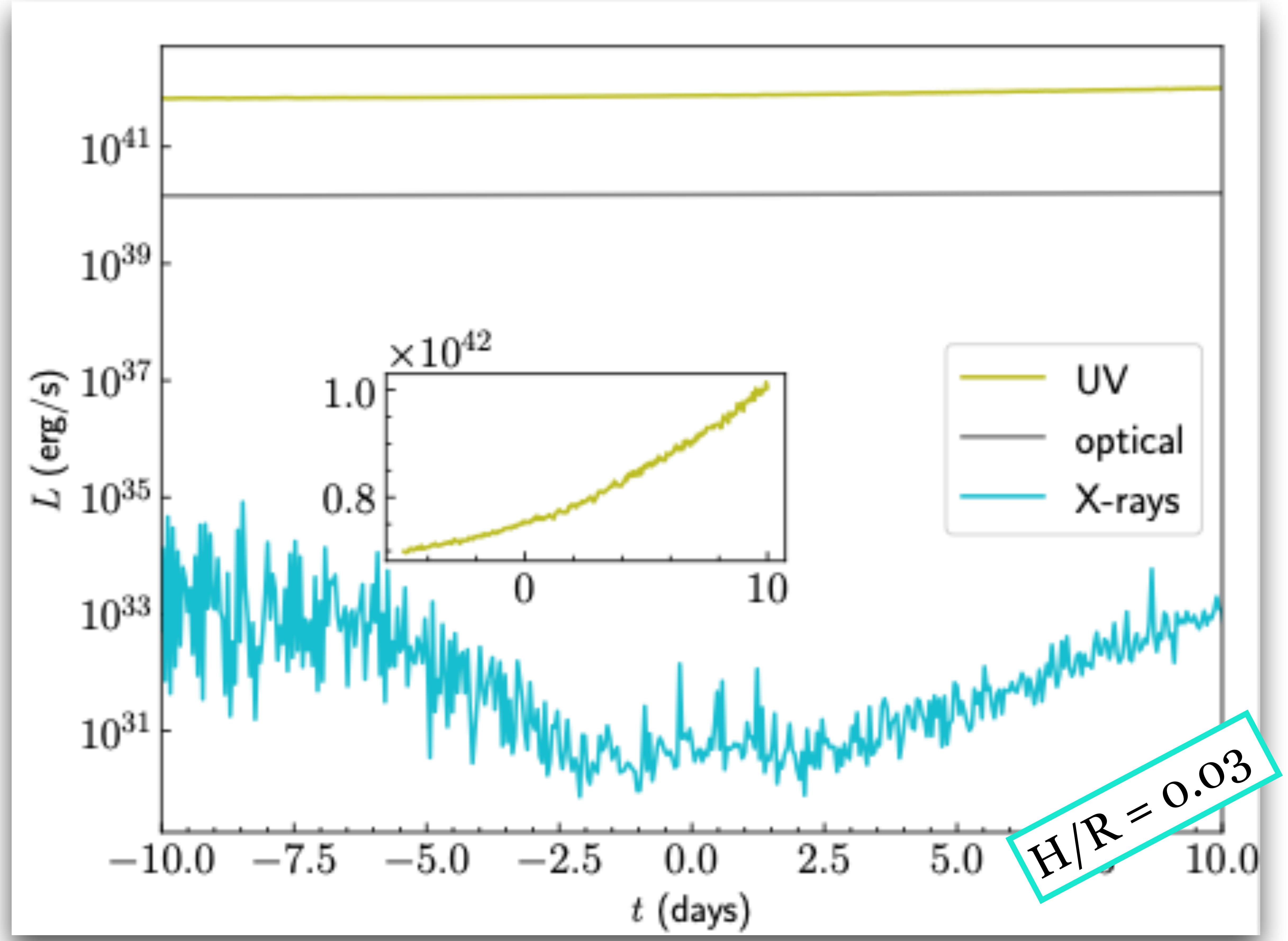


Franchini A., Bonetti M., Lupi A. & Sesana A., A&A 686 A288 (2024)

LISA Massive black hole binaries multi band light curves

We use hyper-Lagrangian refinement coupled with 2.5PN corrections to the binary orbit to investigate electromagnetic counterparts of LISA binaries prior, during and post merger.

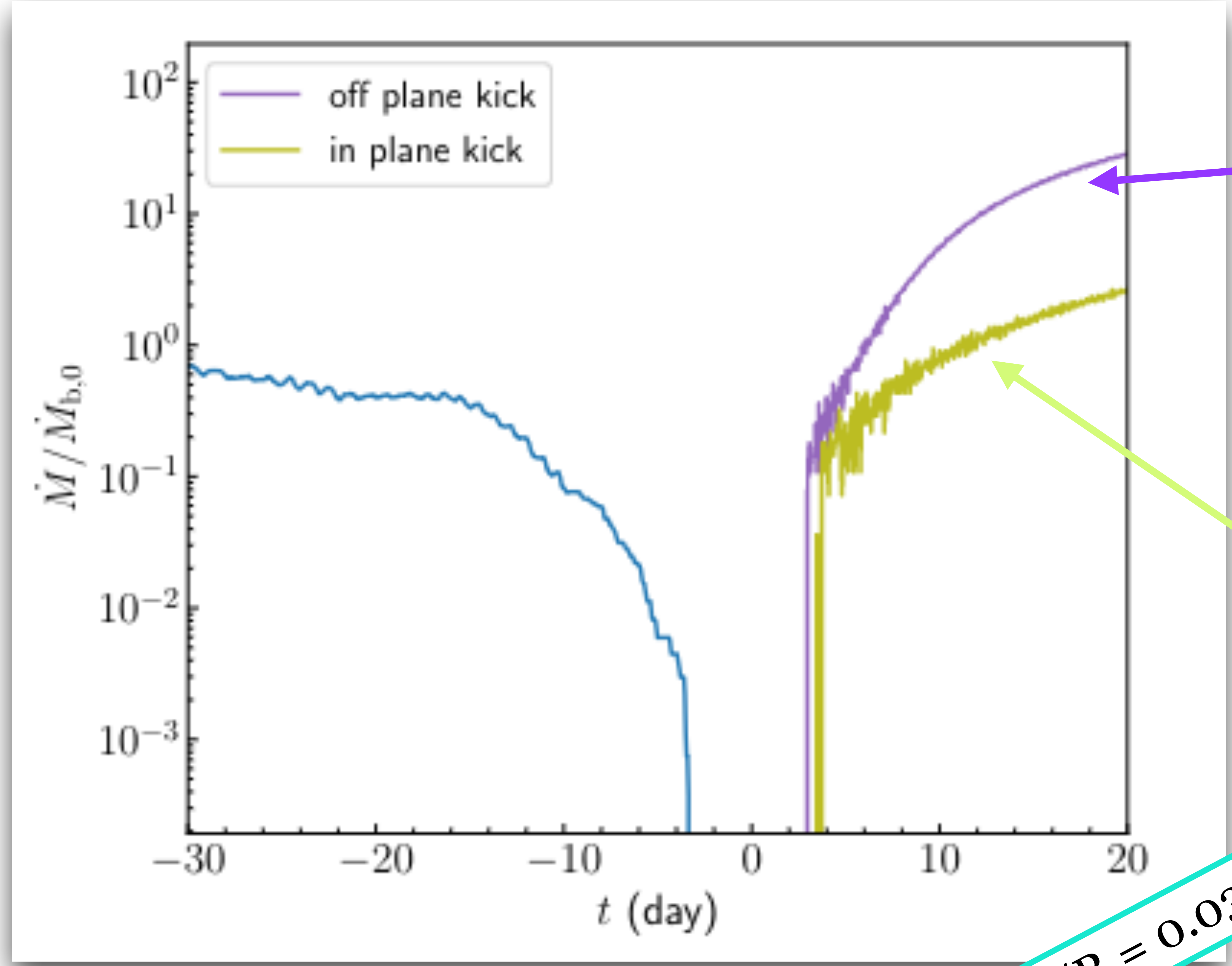




Franchini A., Bonetti M., Lupi A. & Sesana A., A&A 686 A288 (2024)

Post merger signatures of LISA massive black hole binaries

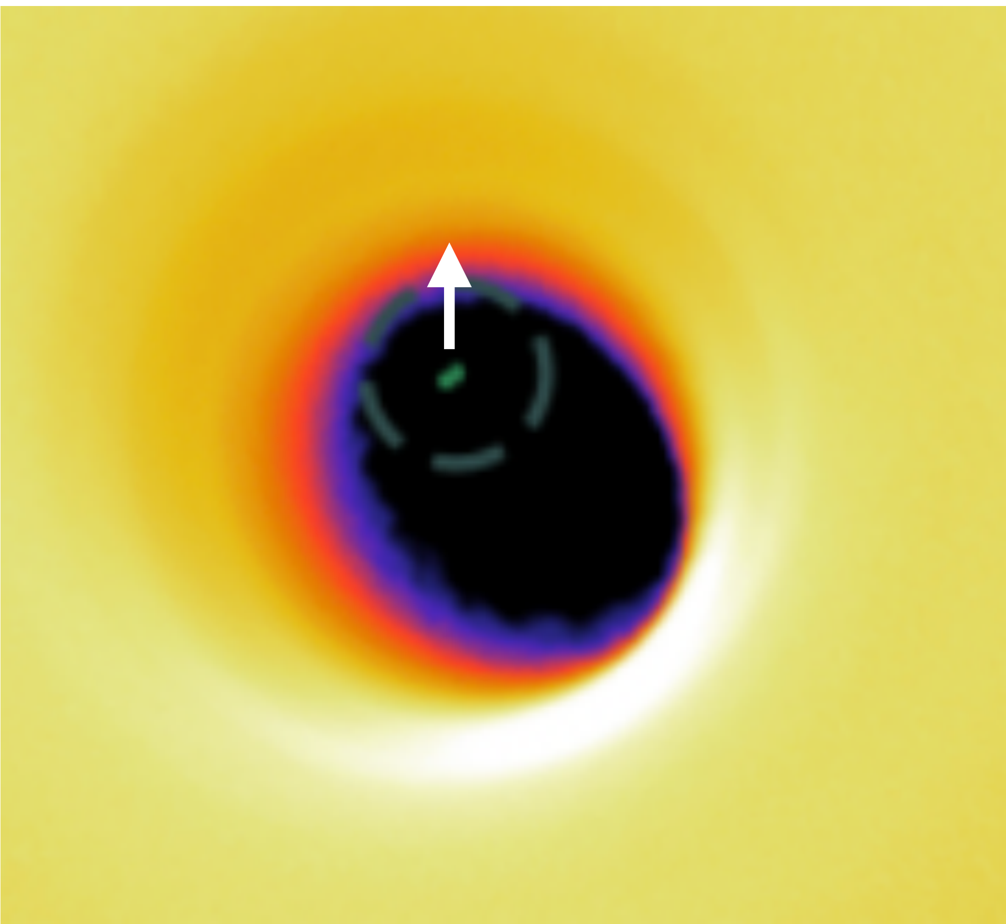
We investigated the accretion rate onto the merger remnant in two kick scenarios.



H/R = 0.03

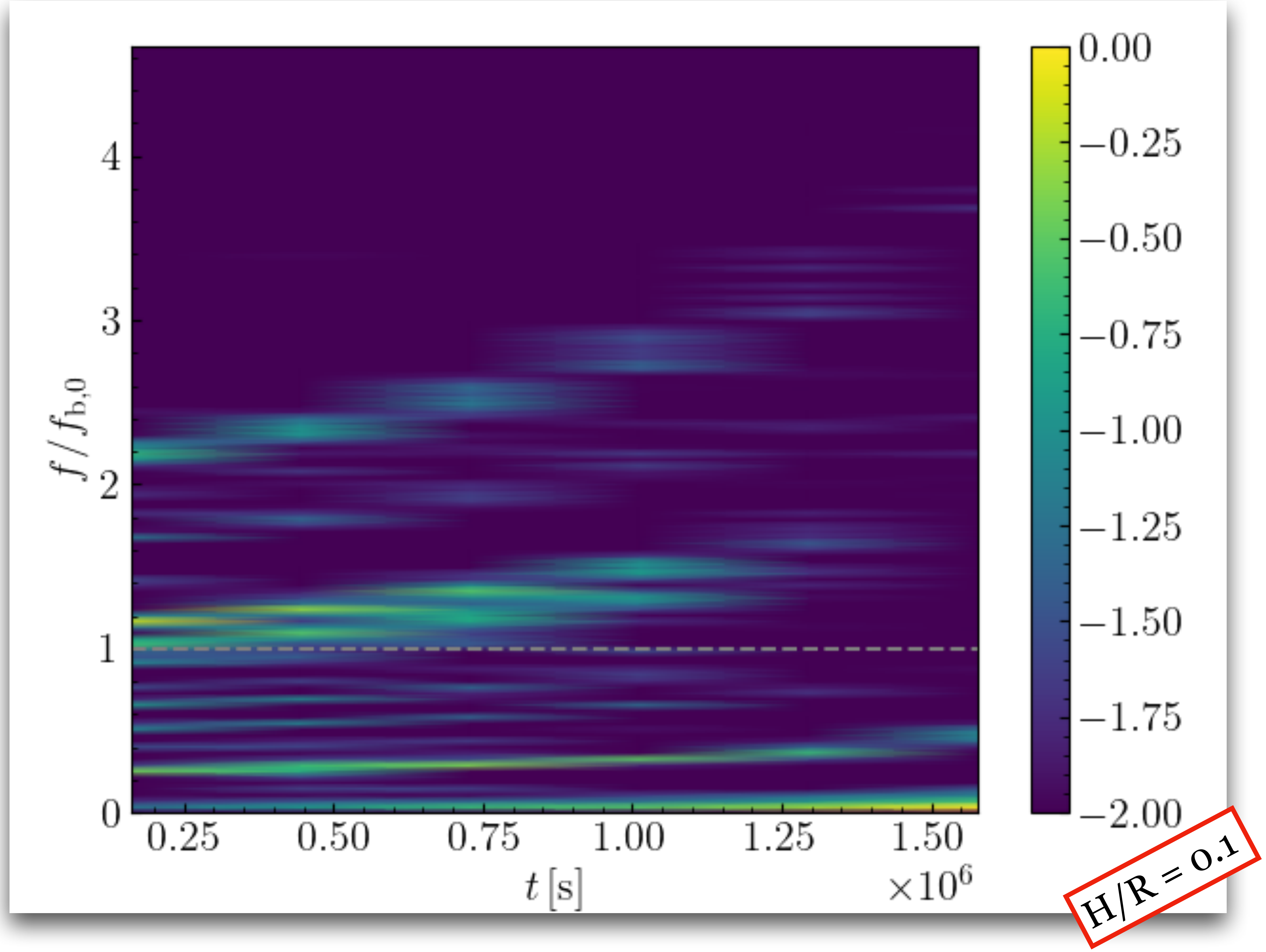
Remnant moves along the z-axis, dragging the disc outside its initial orbital plane

Remnant moves along the y-axis, towards the cavity pericentre



Franchini A., Bonetti M., Lupi A. & Sesana A., A&A 686 A288 (2024)

Chirping of massive black hole binaries in the optical band

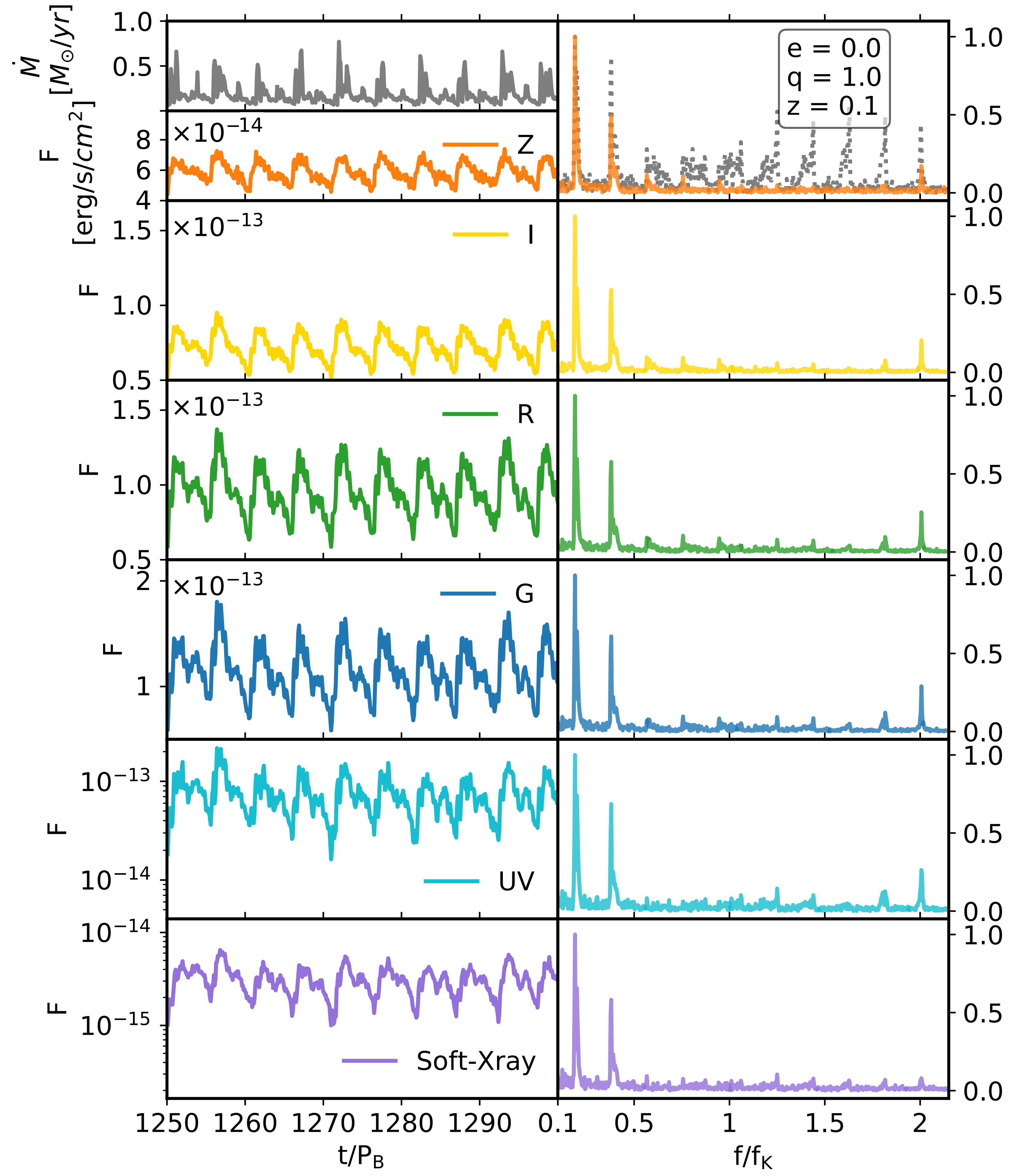


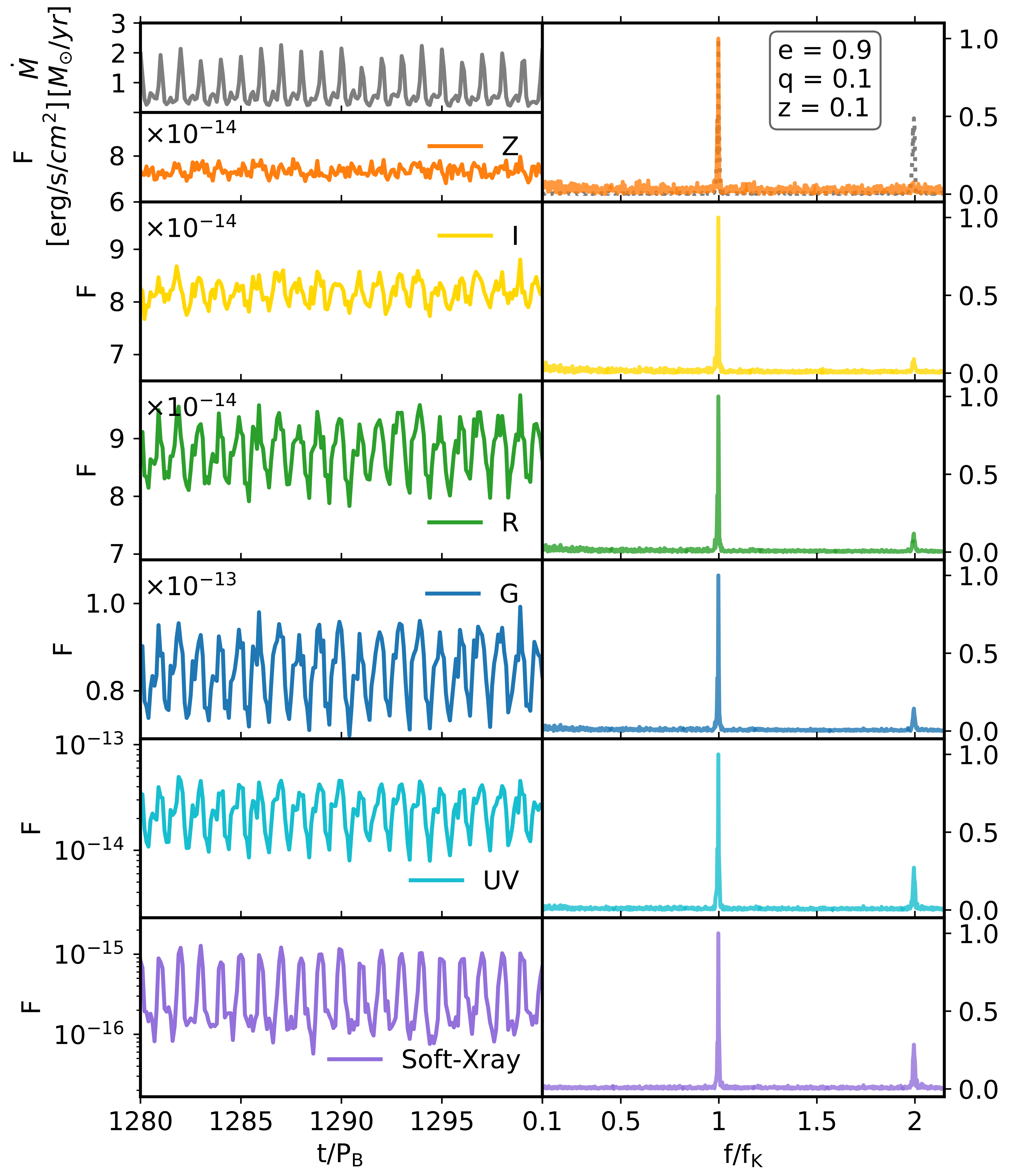
Spectrogram of in-spiral electromagnetic signal in the optical band for circular equal mass binaries.

Franchini A., Bonetti M., Lupi A. & Sesana A., A&A 686 A288 (2024)

Periodicities from massive black hole binaries accretion rates

- We find stronger modulation on the <u>binary orbital period</u> for higher mass ratios
- We find modulation on the <u>cavity edge</u> (i.e. lump) to be stronger for equal mass binaries

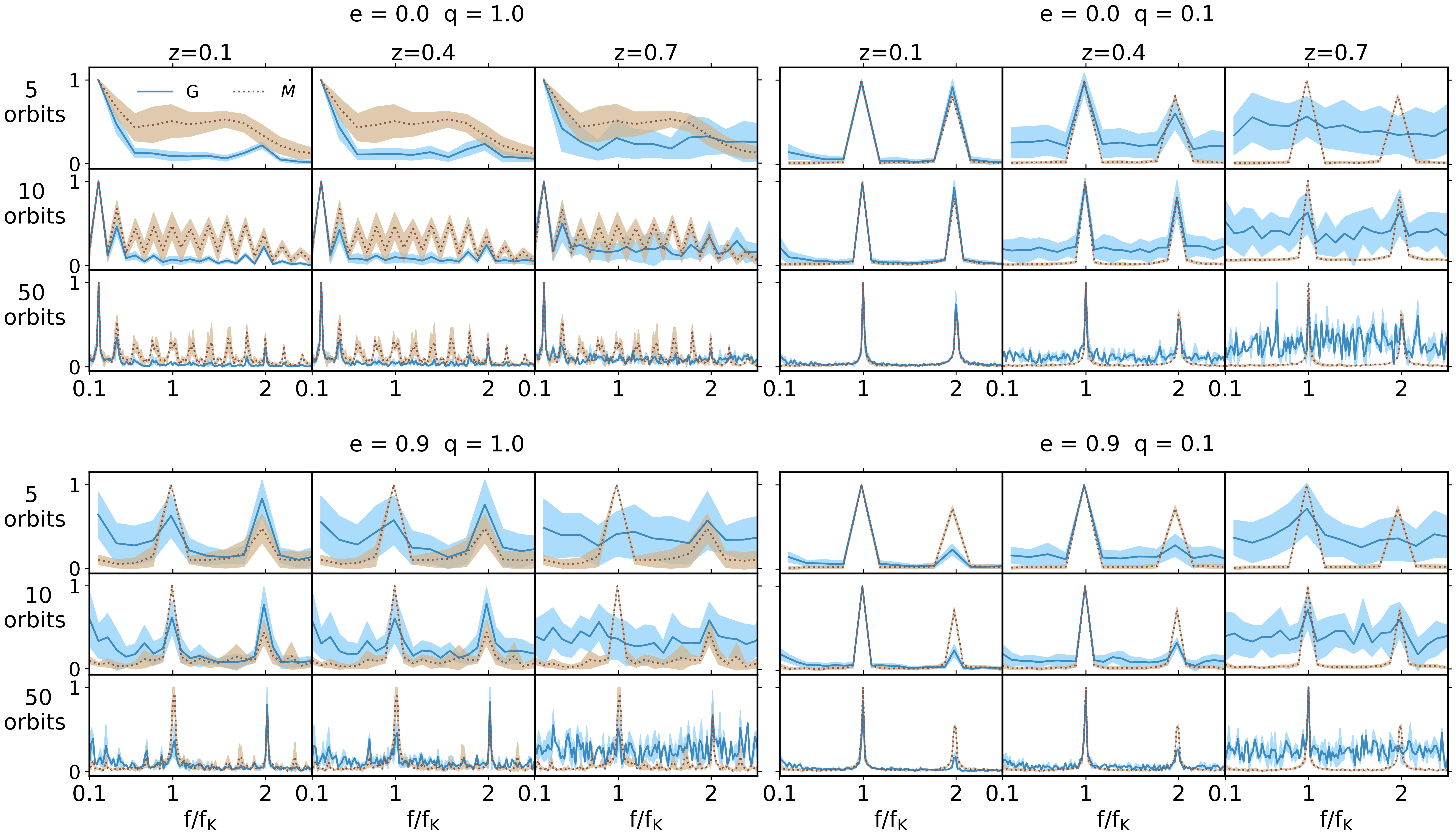




Franchini A., Bonetti M., Lupi A. & Sesana A., A&A 686 A288 (2024)
Cocchiararo F., Franchini A., Lupi A. & Sesana A., A&A (2024)

Periodicities predictions for Vera Rubin Observatory

Equal mass, circular binaries are unlikely to be identified due to the lack of prominent peaks when considering few binary orbits. Conversely, unequal mass and/or eccentric binaries can be singled out up to z ~ 0.5



Cocchiararo F., Franchini A., Lupi A. & Sesana A., A&A (2024)

Conclusions

- Binary semi-major axis decreases with time as a result of its interaction with a circumbinary disc in a vast region of the parameter space
- PN corrections to the binary dynamics allow us to extract electromagnetic signatures prior, during and after the merger
- We find significant orbital phase deviation with respect to the evolution of the binary in vacuum
- Merger characterised by a ~ 2 orders of magnitude decrease in the X-ray flux followed by an increase in the UV flux
- Off plane kicks are characterised by a very fast increase of the accretion rate post merger
- Periodicity on the binary orbital period and lump modulation strength depends on the binary parameters but it is difficult to detect with a handful of binary orbits
- The chirping signal can in principle be detected also in the optical band