Title: Are we already observing inspirals into massive black holes?

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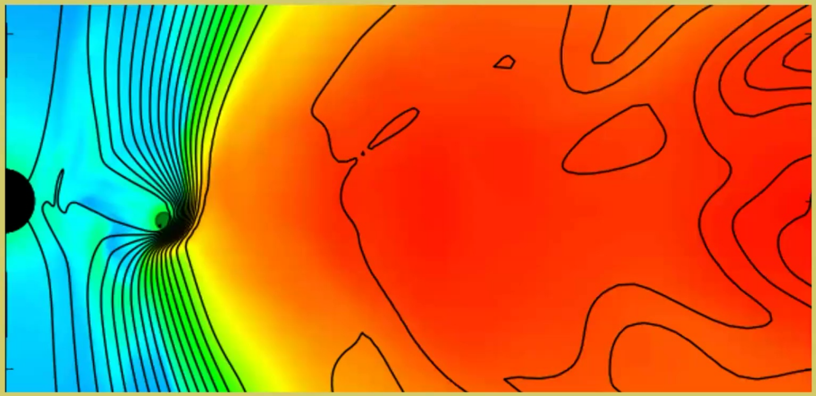
Abstract: Everybody talks about EMRIs and IMRIs in connection with LISA and the 2030s. However, inspirals into massive black holes are happening at this very moment. Would we be able to recognize them with our current electromagnetic observations? Even more, are we maybe observing these inspirals at the very moment without realising it? We simulated accretion-disks perturbed by light perturbers and deduced that the orbital periods show in the disk variability. I present a list of candidate sources that, based on their variability periods and period derivatives, may contain ongoing inspirals into massive black holes.



ARE WE ALREADY OBSERVING INSPIRALS INTO MASSIVE BLACK HOLES?

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Reporting on:

Suková, Zajaček, Witzany, Karas arXiv:2102.08135 (Accepted at ApJ)

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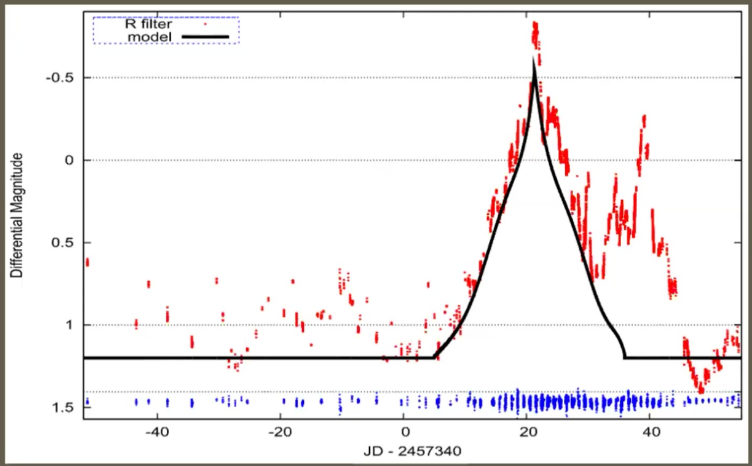
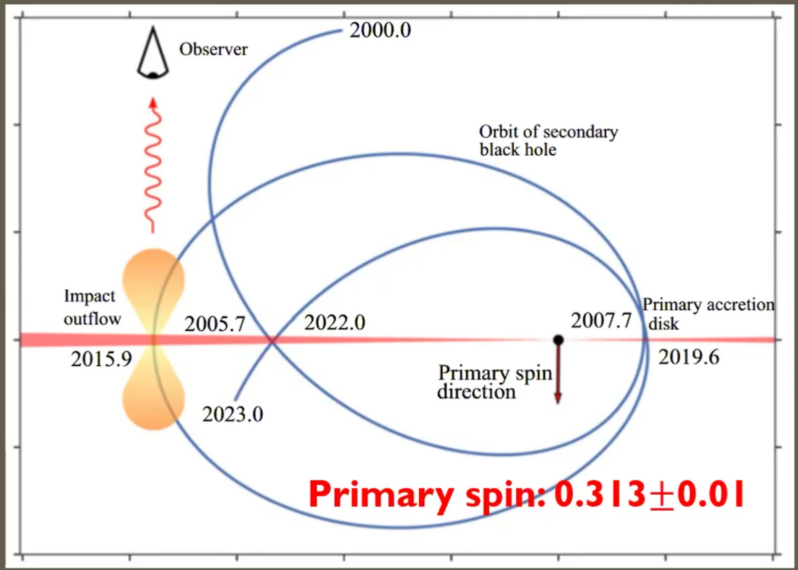
!!!DANGER: SQUIGGLY ZONE!!!

(AKA ASTROPHYSICS)

CASE IN POINT: OJ 287

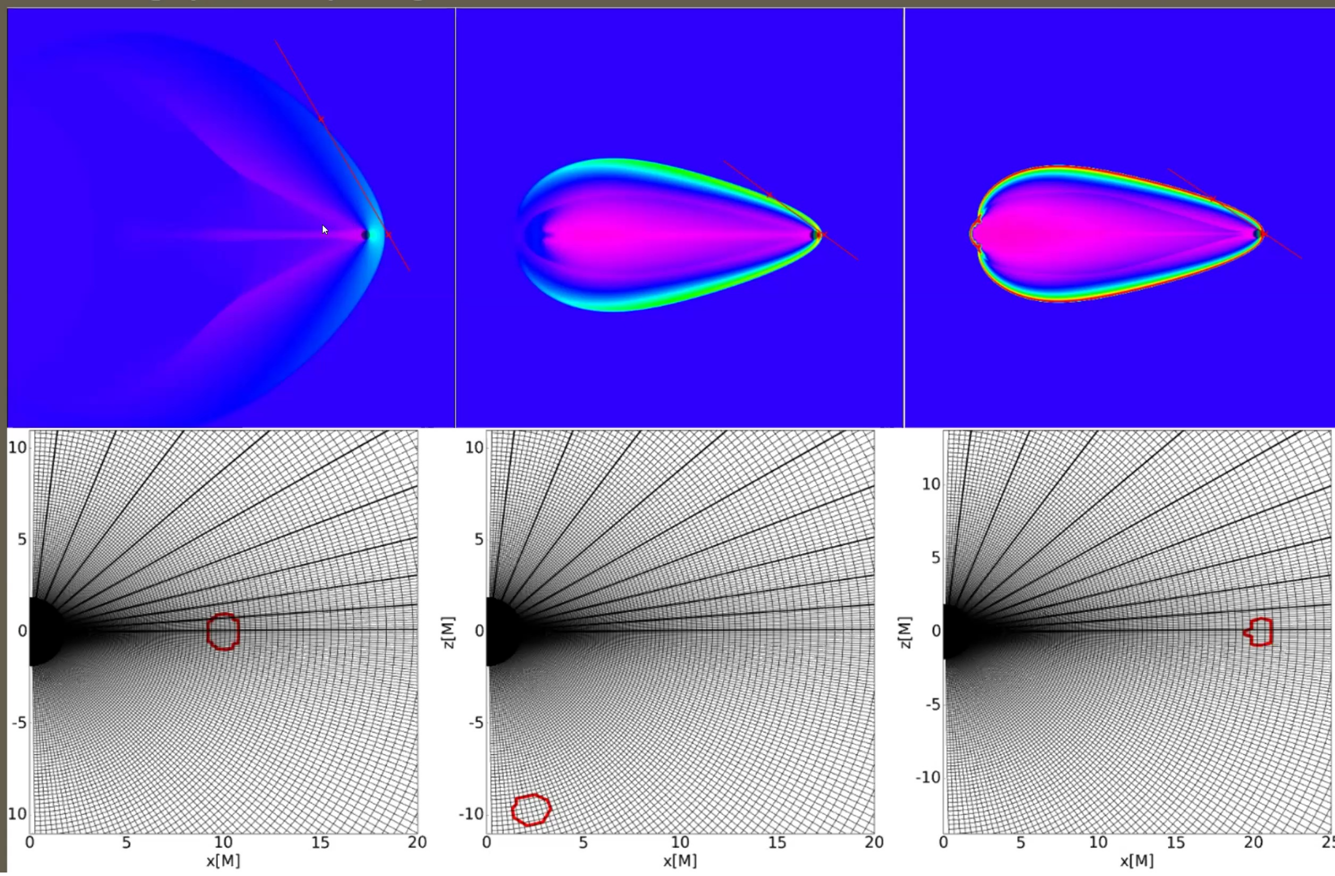
- Quasar observed since 1890s, periodic bursts every ~12 years
- Valtonen+ (2008-2010) took the data, used 2.5PN orbital evolution (including dissipation), interpreted the system as an SMBH binary with $10^{10} M_\odot$ primary, $10^{8} M_\odot$ secondary, predicted next burst in Dec 2015
- What actually happened (Valtonen+ 2016):





TRACTABLE SIMULATION: SYNCHRONIZATION SPHERE

Moving sphere in your grid: whatever enters it must co-move with the „star"



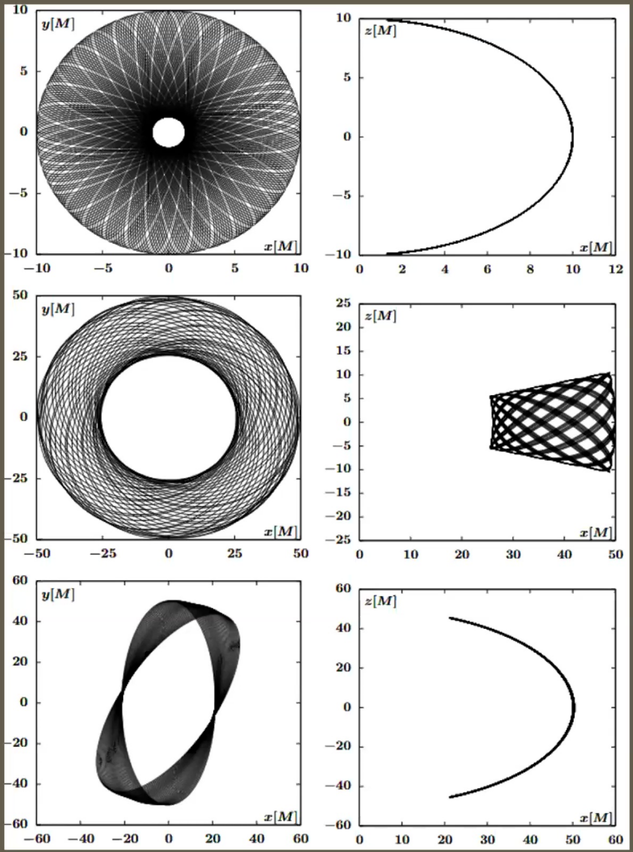
HOW LARGE DO YOU MAKE THE SPHERE?

- The „synchronization sphere" is well motivated for stars with strong winds (Wilkin 1996):

$$R_{stag} \sim \sqrt{\frac{\dot{m}_w v_w}{4\pi\rho[v_{rel.}^2 + (1+\beta_m)c_s^2]}}$$

- Less so for just the gravitational action, but from drag (Ostriker 1999) and momentum balance:

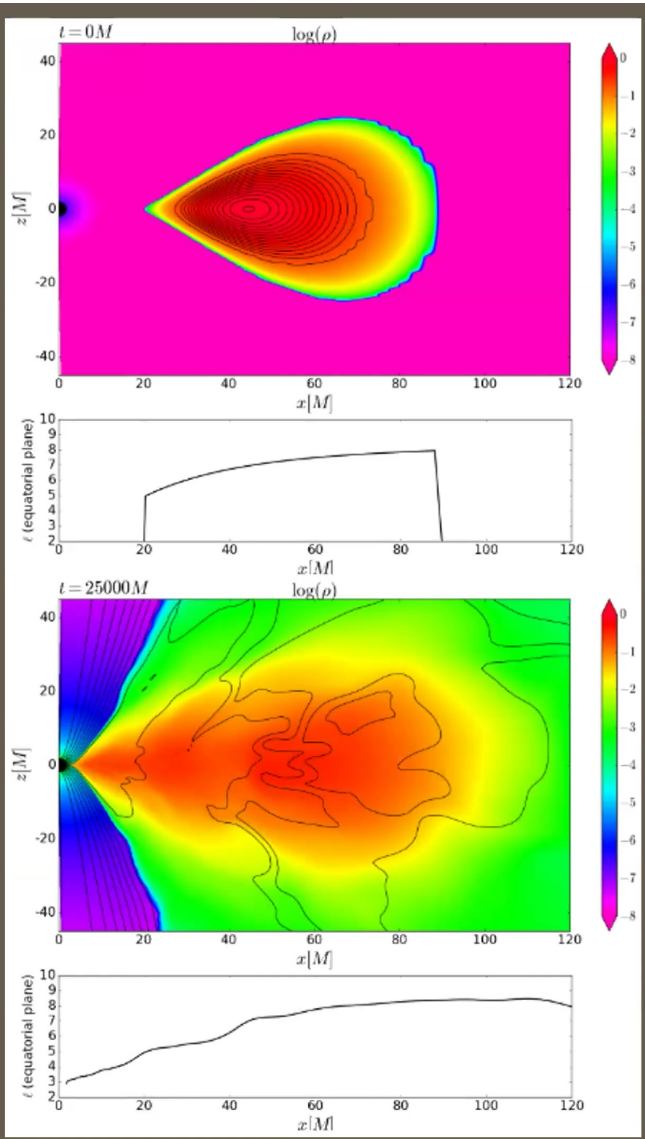
$$R_{sync} \sim \frac{Gm_*}{v_{rel.}^{3/2}\, v_{gas}^{1/2}}$$



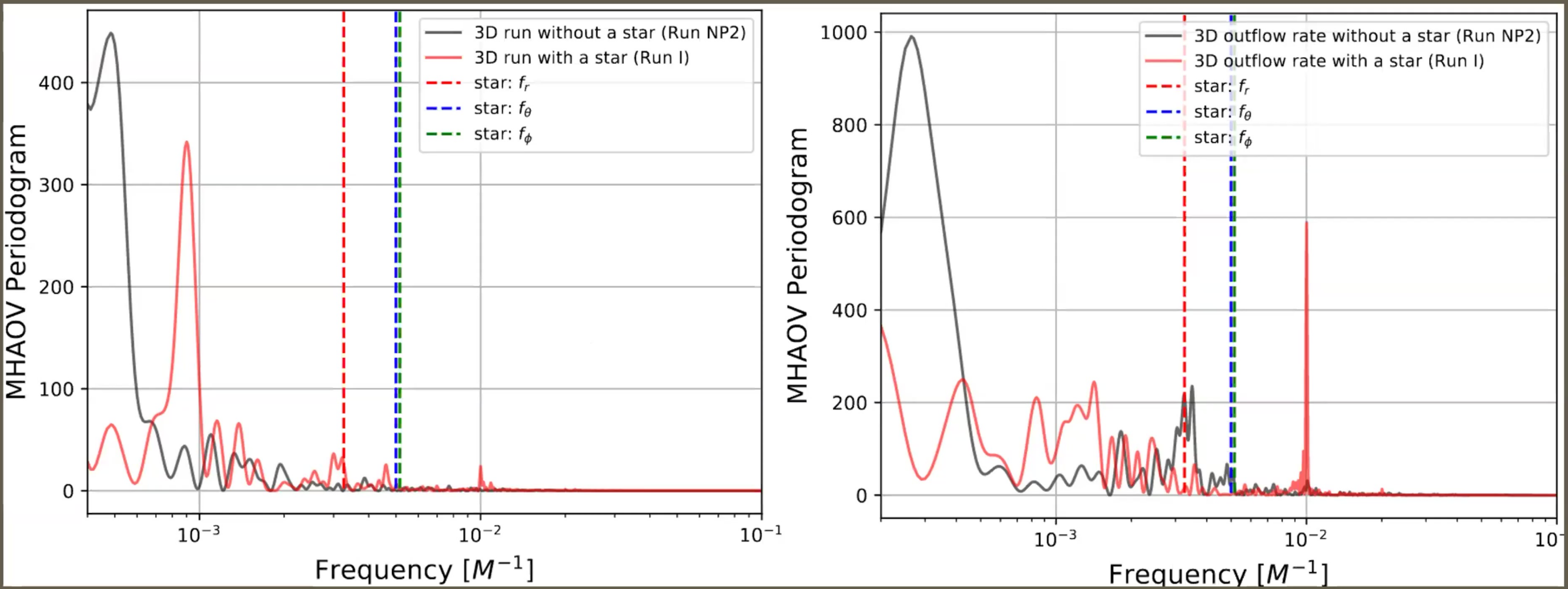
Size of sphere not only „intrinsic", depends on state of gas and orbit wrt gas!

SIMULATION SETUP

- Implemented synchronization sphere in GRMHD code HARMPI (github.com/atchekho/harmpi), made sphere move on Kerr geodesics
- Initial conditions for disk from Witzany & Jefremow (2018)
- A seed magnetic field leading to a „magnetically arrested disk“ (MAD state)
- Let the torus evolve (magneto-rotational instability), turn on perturber later
- Setup corresponds to low-luminosity active galactic nuclei (low accretion rates) when radiative cooling is not too dynamically important



MASS-ACCRETION AND OUTFLOW (JET) PERIODOGRAMS



DO WE SEE THIS?

Source	Perturber	Distance [M]
Sgr A*	stars S4714 and S62	$\sim$ 320–451
OJ287	SMBH $\sim 10^8\ M_\odot$	$\sim$ 144
J0849+5108	SMBH $\sim 5\times10^5 - 2.5\times10^6\ M_\odot$	$\sim$ 536
RE J1034+396	star/IMBH $\gtrsim 100\ M_\odot$	$\sim$ 24
1ES 1927+65	(partial) TDE	$\sim$ 21–152
ESO 253-G003	IMBH $\gtrsim 2\times10^4\ M_\odot$,	$\sim$ 262–415
	partial TDE	$\sim$ 26
GSN 069	IMBH $\sim 10^5\ M_\odot$	$\sim$ 300
	white dwarf $\sim 0.21\ M_\odot$	$\sim 11 - 190$
RX J1301.9+2747	IMBH $\sim (0.8-3)\times10^5\ M_\odot$	$\sim 52 - 121$
eRO-QPE1	SMBH $\sim 10^6 - 10^4\ M_\odot$	$\sim 55 - 1190$
	"S2-type" star	$\sim 55 - 1190$
eRO-QPE2	SMBH $\sim 10^6 - 10^4\ M_\odot$	$\sim 15 - 315$
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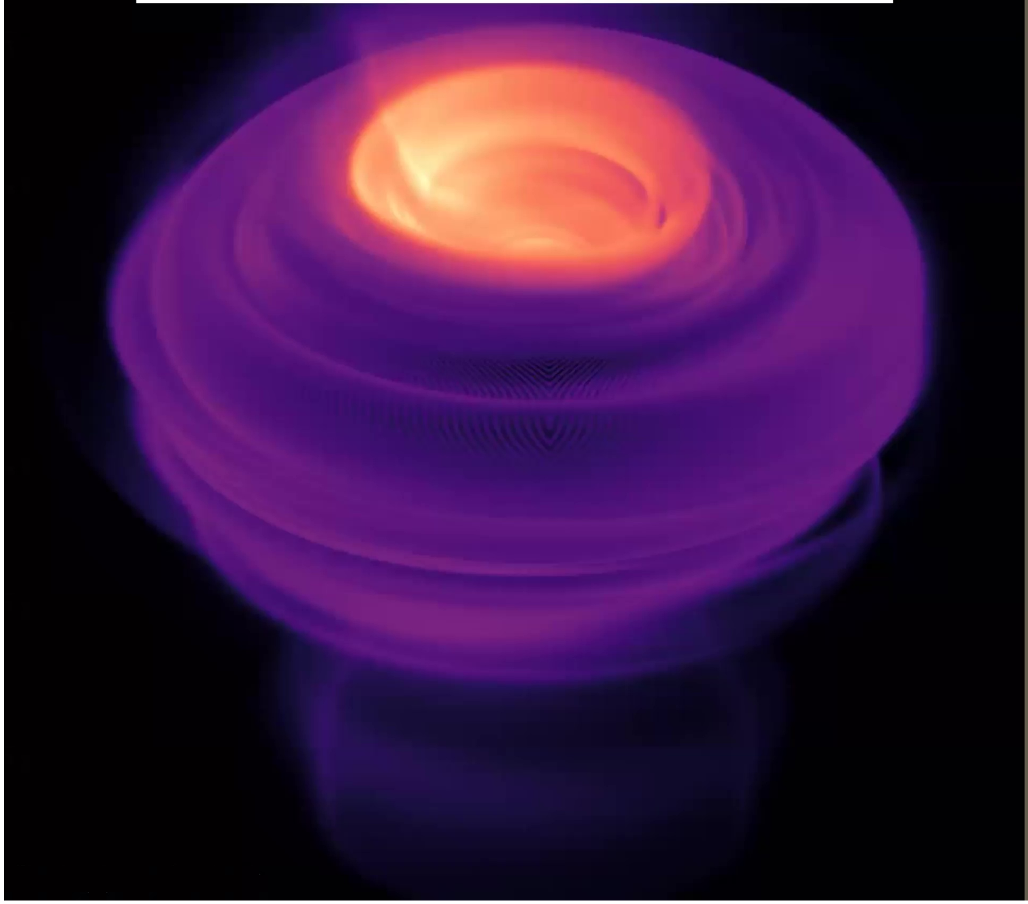
- RE J1034+396: Quasi-periodic oscillation at ~0.1 mHz
- Drifted from 3733 seconds (2007, Gierlinski et al. 2008) to 3550±80 (2018, Jin et al. 2020)
- Interpreting as perturber evolving ***only*** due to radiation-reaction yields (Peters-Mathews 1963)

$$m_* \sim 10^{-3}\,\dot{P}^{\frac{5}{3}} M^{-\frac{2}{3}} G^{-\frac{5}{3}} c^5$$

- Use $M \sim 1 - 4 \cdot 10^6\ M_\odot$ to get $m_* \sim 100\ M_\odot$
- Uncertainty due to the fact that hydrodynamical drag is stronger than radiation-reaction for main-sequence stars (Narayan 2000) → *Could as well be a lighter stellar object!*

CONCLUSIONS/OUTLOOKS



- STAR DESTROYS ACCRETION DISK!!!
- Maybe we can see it, maybe we already are seeing it
- To break drag/GW radiation-reaction degeneracy, more detailed model necessary
- Improve/diversify perturber-disk interaction model
- Get specific observational predictions, e.g. lightcurves (right: output of ray-tracing code RAPTOR for a single radio frequency, github.com/tbronzwaer/raptor)

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