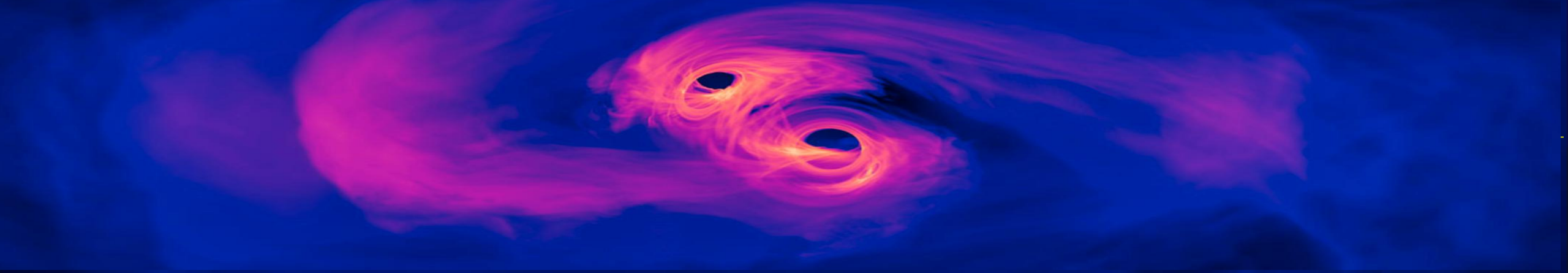


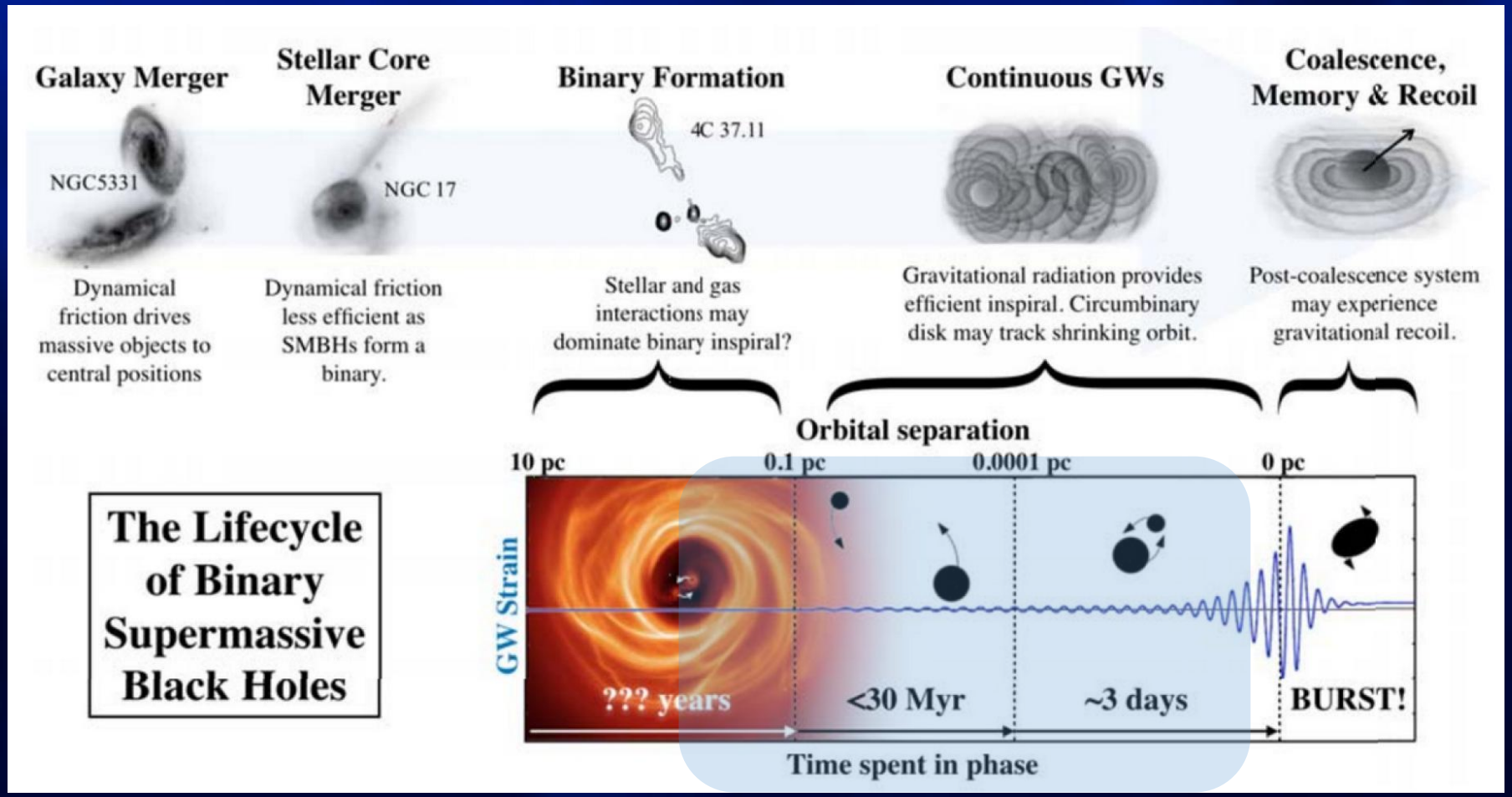
Discovery and Follow-ups of a SMBH binary candidate predicted to merge within three years

蒋 凝（USTC）

Colaborators: Huan Yang, Tinggui Wang, Jiazheng Zhu, Zhenwei Lyu, Liming Dou, Yibo Wang, Zhen Pan, Jian-Guo Wang, Ji-an Jiang, Xinwen Shu, Zhen-Ya Zheng, Hui Liu, Norio Narita, Akihiko Fukui, Masahiro Ikoma, Motohide Tamura

2022-06-17@“X射线天文学60周年及中国X射线天文研究”研讨会

From galaxy merger to SMBH binary coalescence

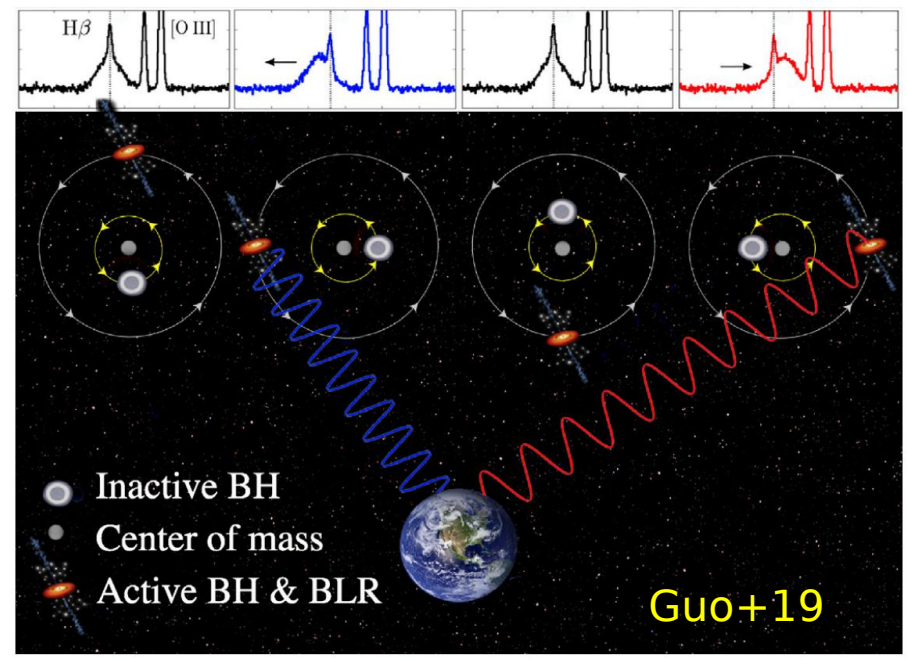


Witt+2022

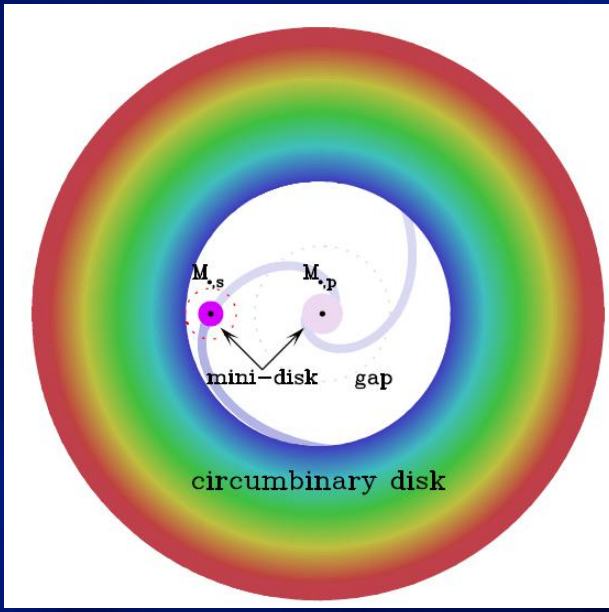
spatially unresolvable (even VLBI)

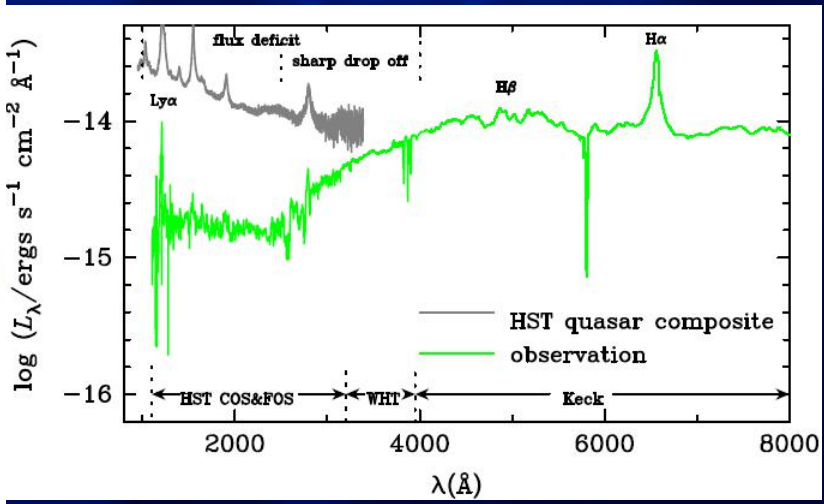
Indirect indicators of sub-pc SMBHB

- Broad-line velocity shift



- deficits in the optical-to-UV continuum

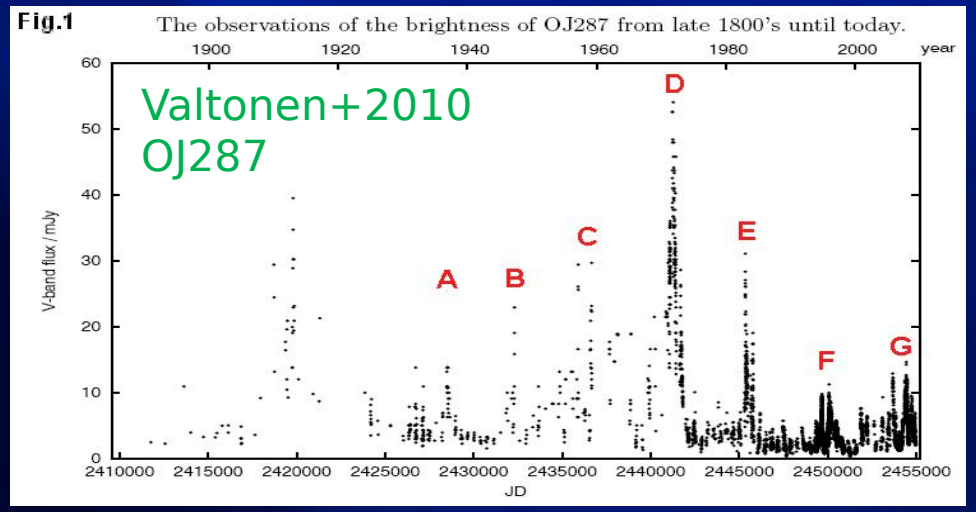


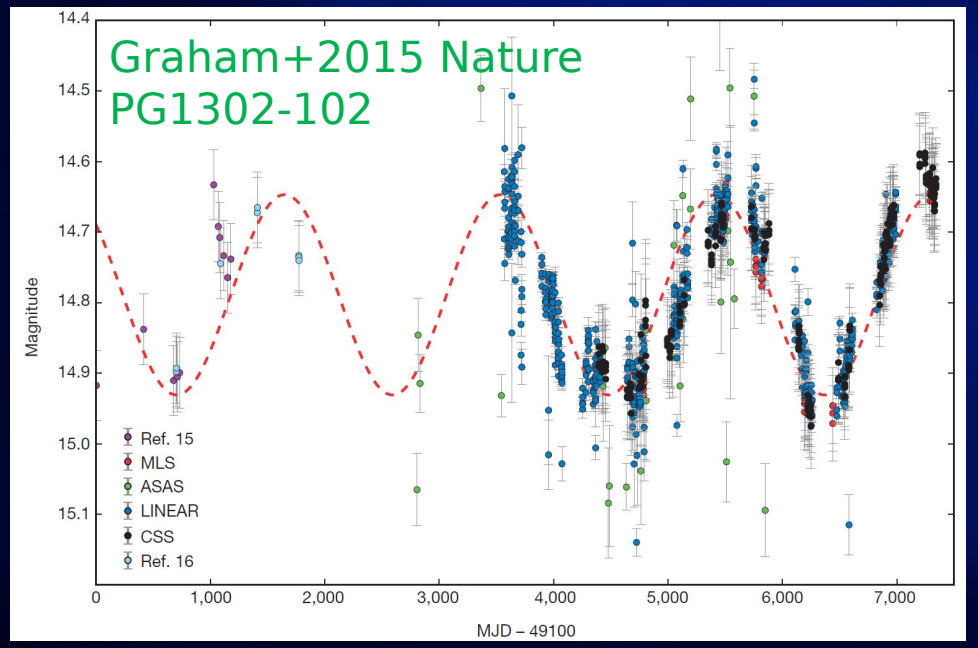


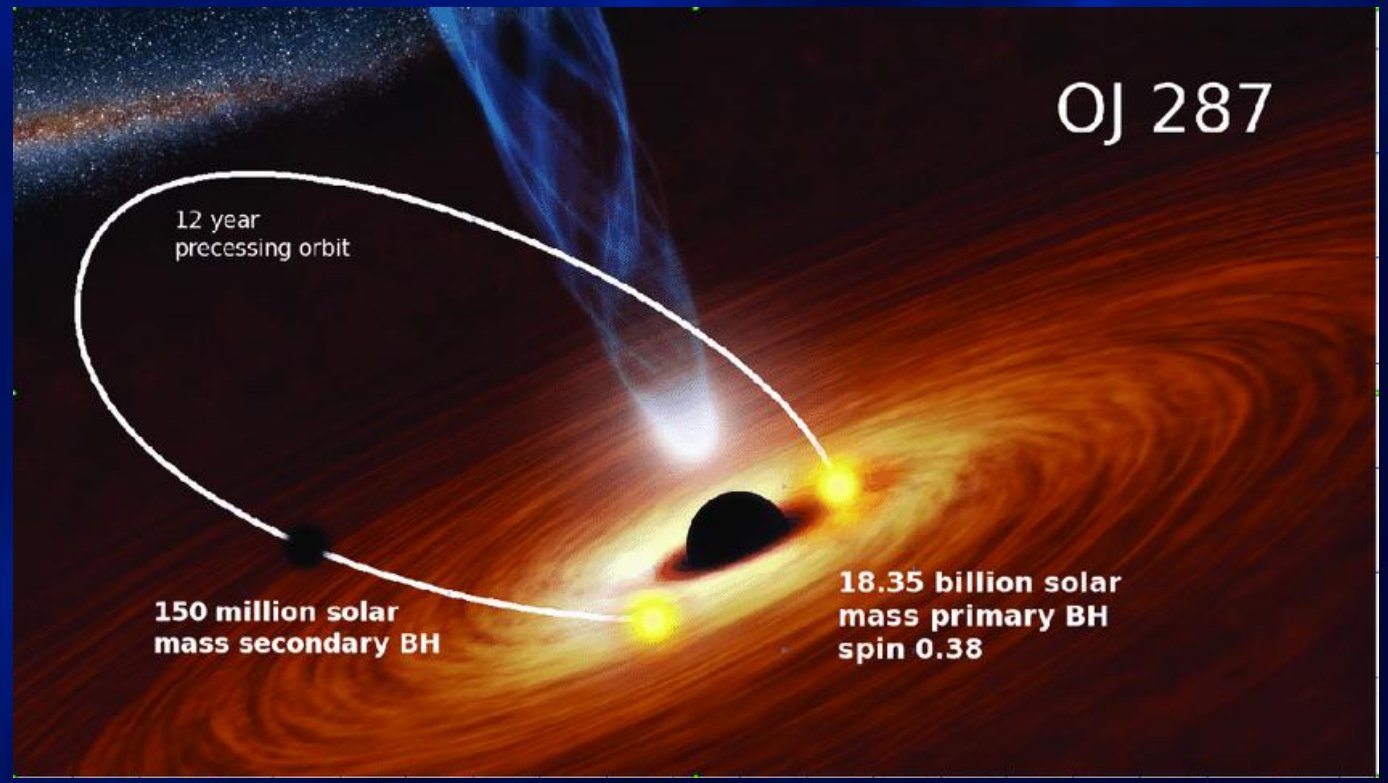
Yan+15

many candidates, but no confirmed sub-pc SMBHB yet

Periodicity as evidence for SMBH binary



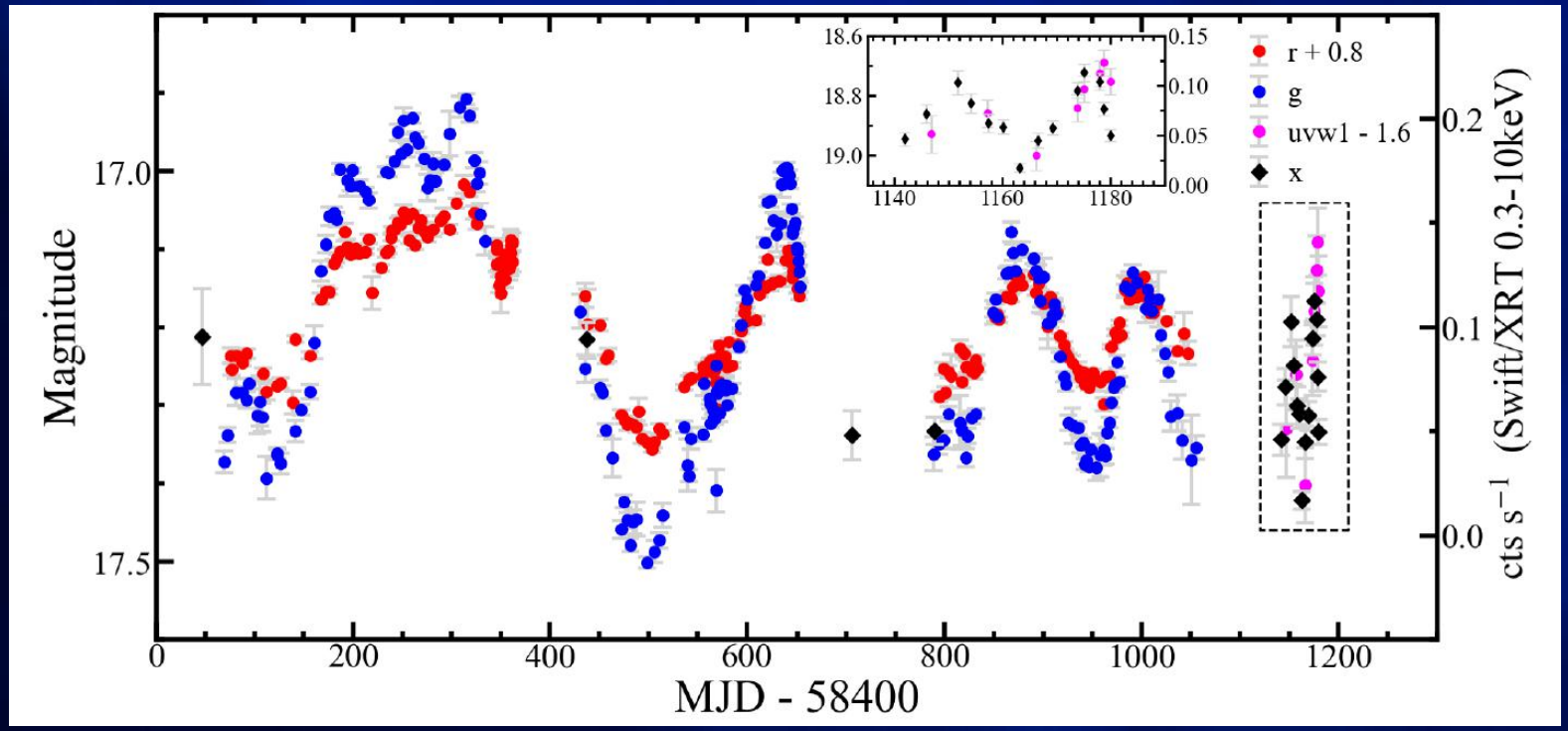


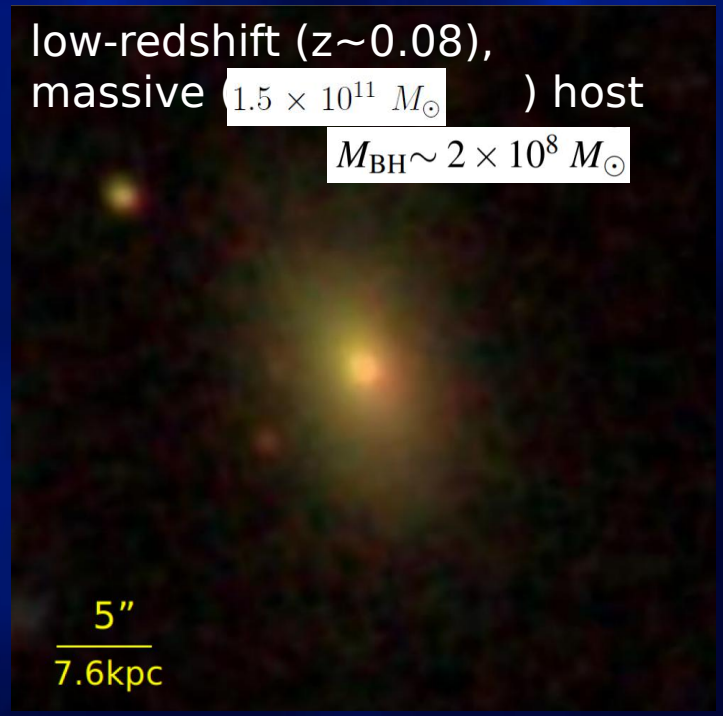


Graham2015b,Liu2016,Charisi2016,Zheng2016,Chen2020...

Still no candidates close to final coalescence with decreasing period

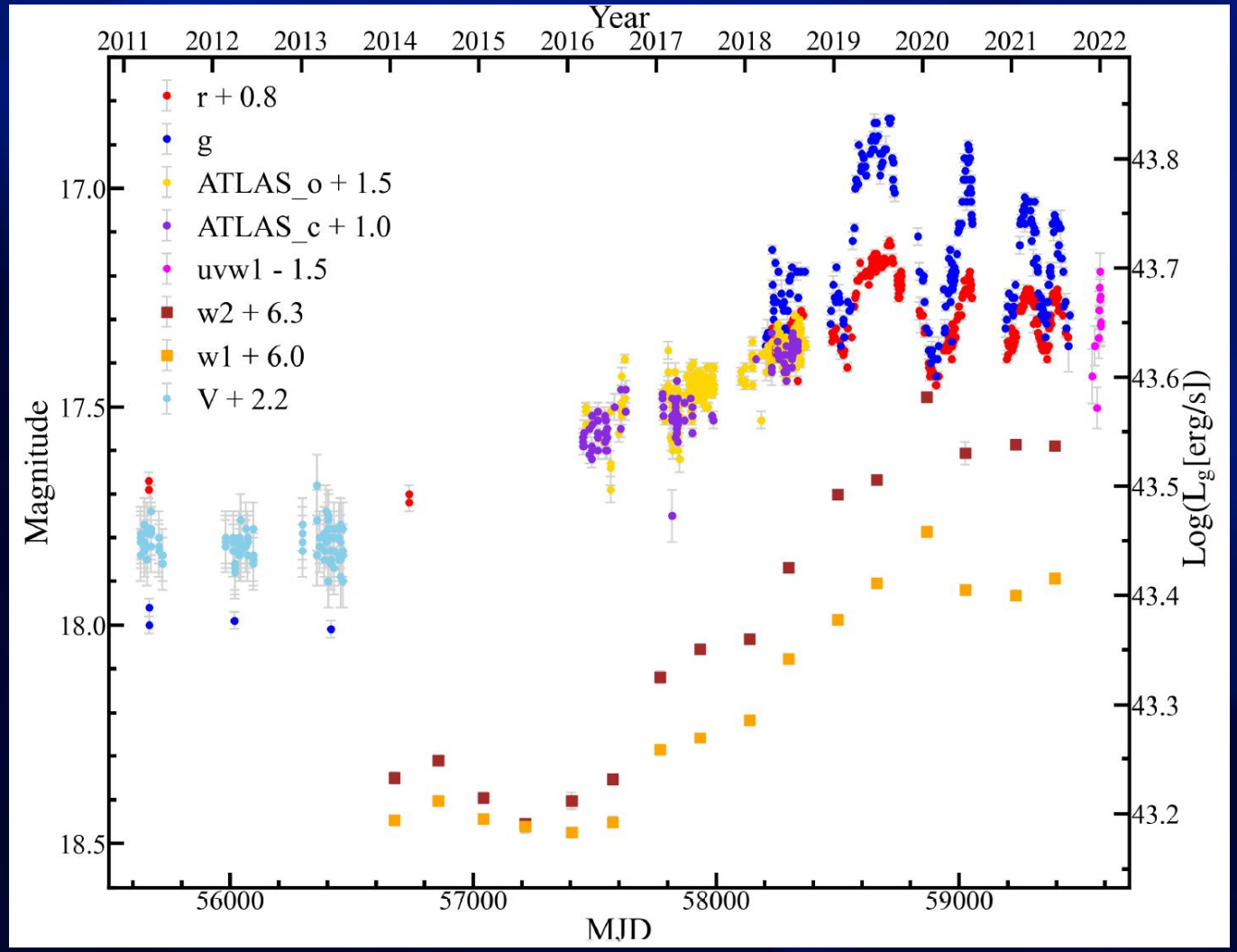
Chirping flares in SDSSJ1430+2303



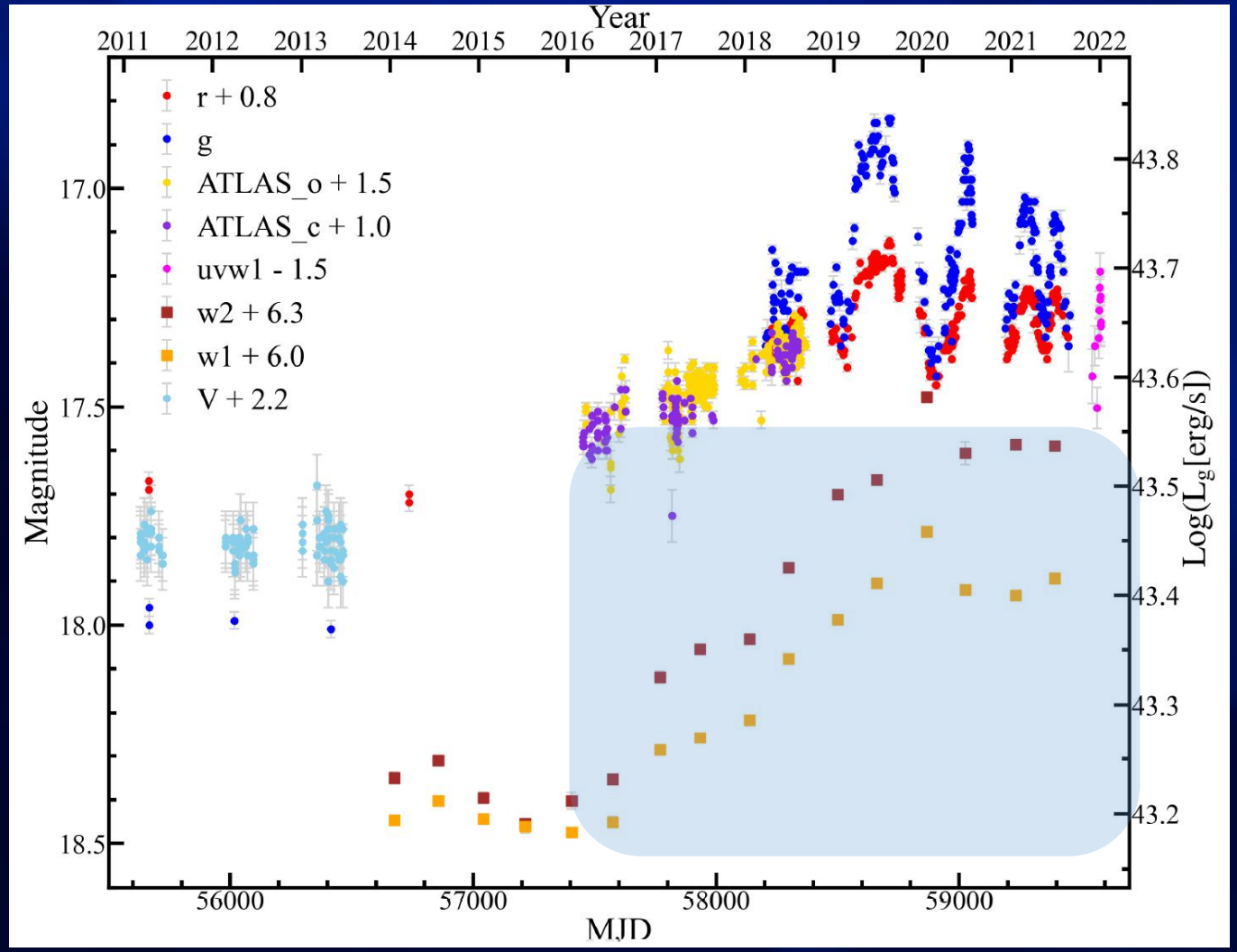


period decreasing from ~1 yr to ~3(or 1) month within 3 years,
a SMBH binary approaching merger?

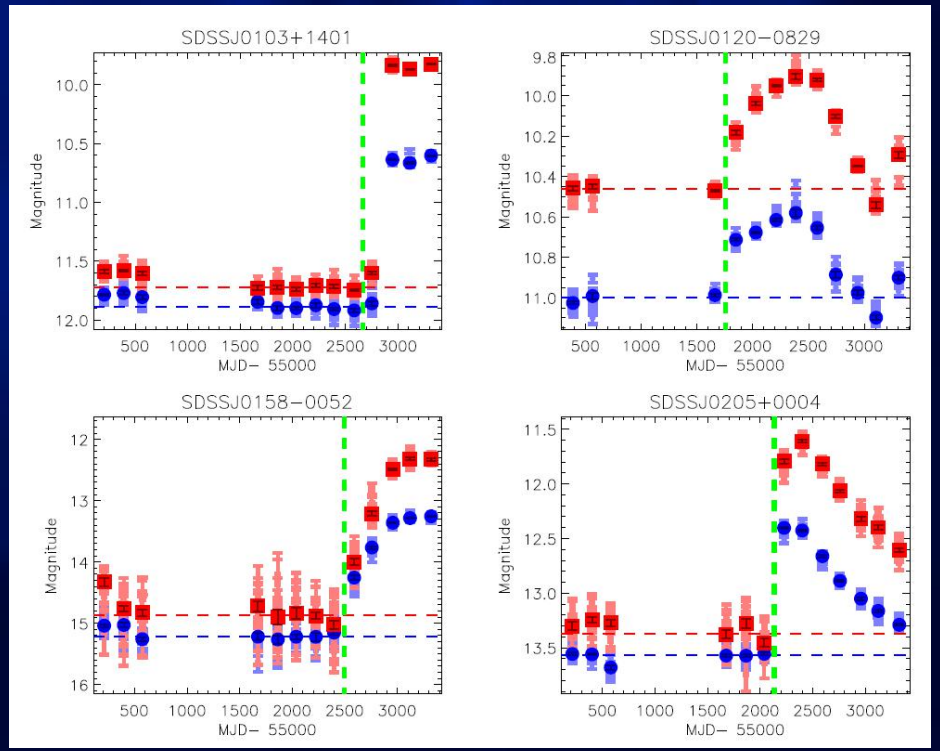
Chirping flares in SDSSJ1430+2303



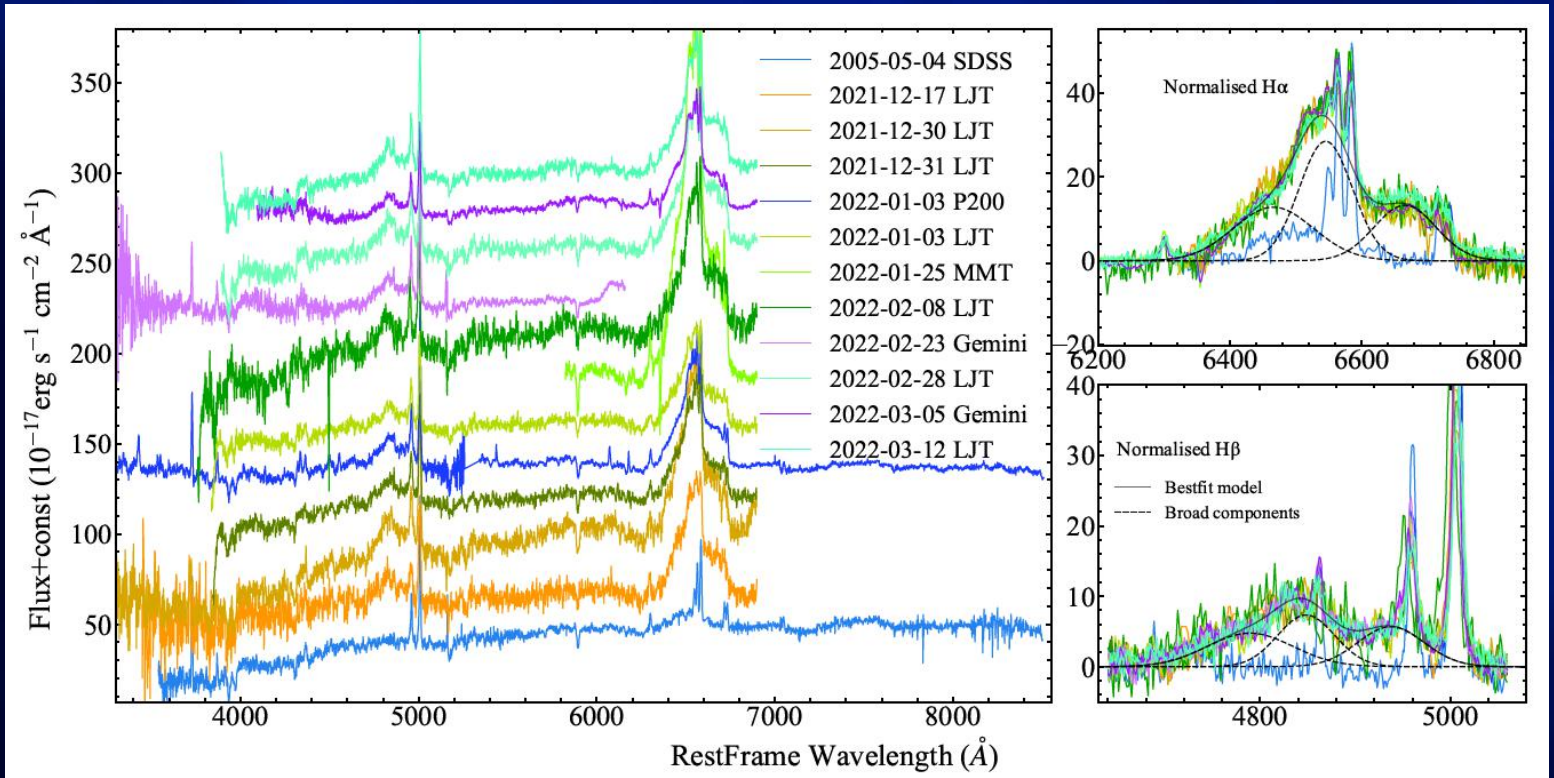
Chirping flares in SDSSJ1430+2303

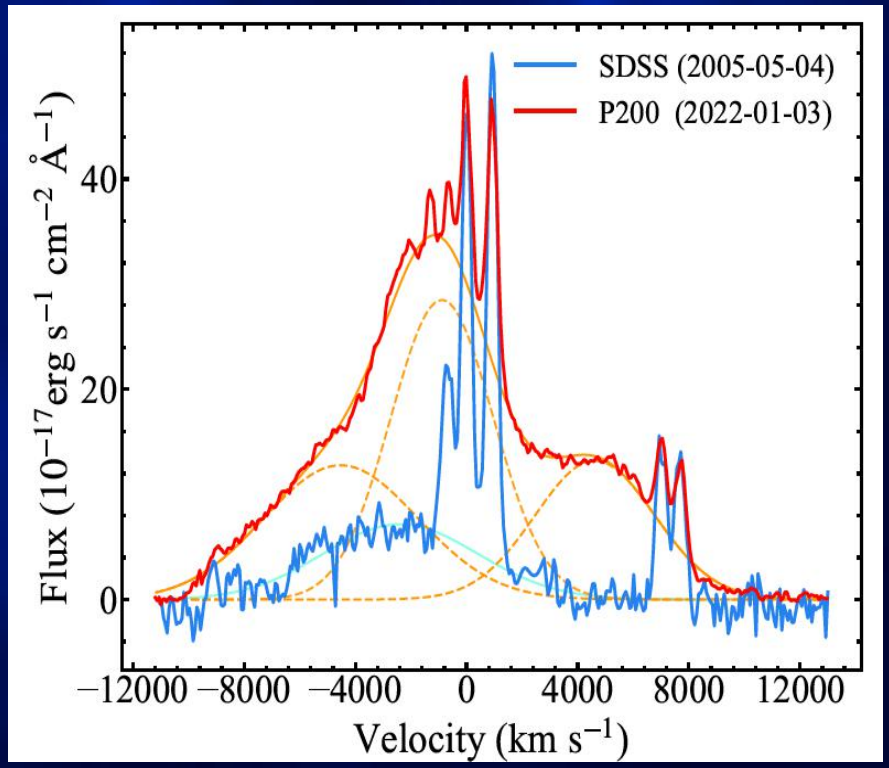


initially noticed due to its mid-infrared outburst (MIRONG, Jiang+21)



spectral evolution: changing-look AGN



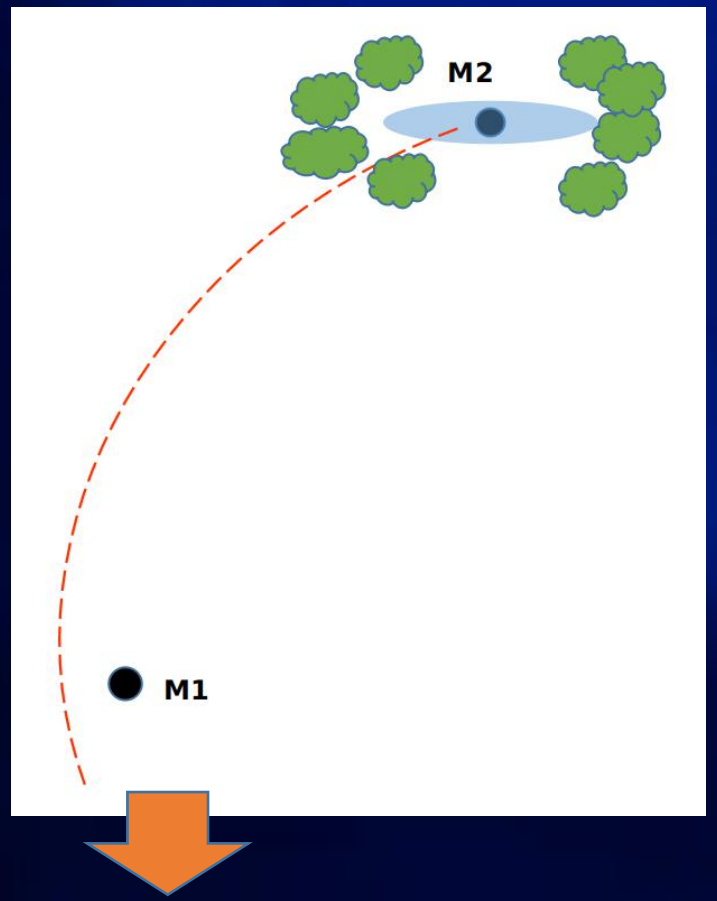


2005: blueshifted (-2400km/s) broad H $M_{\rm BH} \sim 4 \times 10^7\ M_\odot$

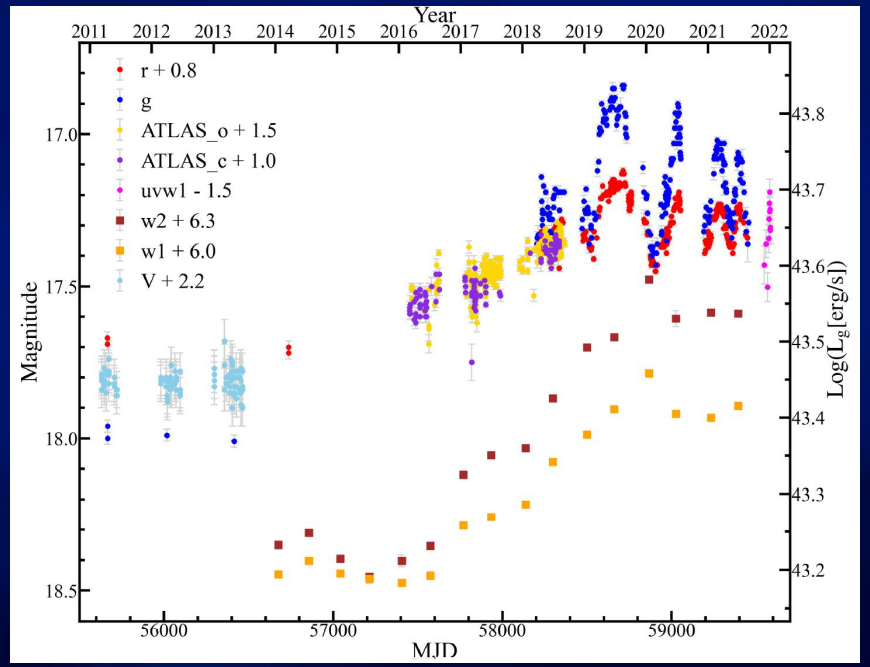
2022: double-peaked (-4000 and 4600km/s)

as an independent evidence

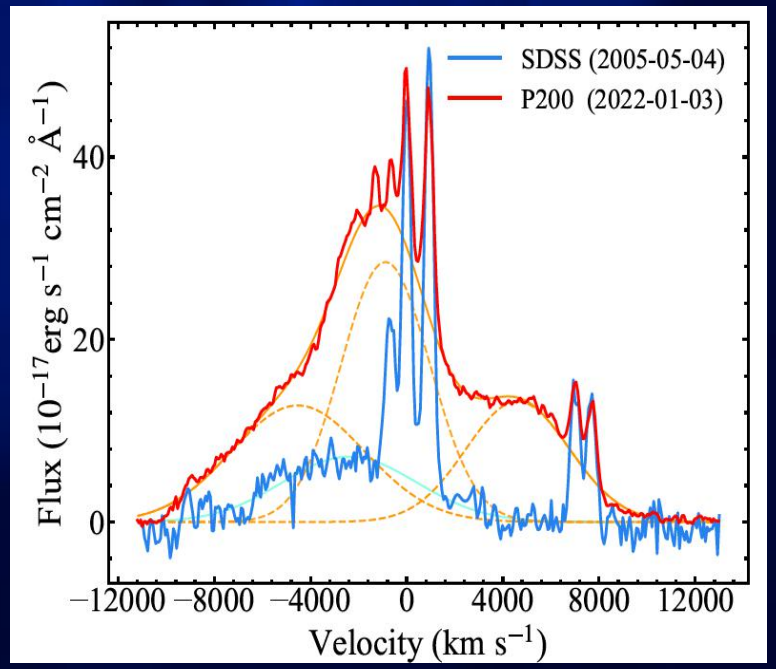
First encounter around 2014-2016



outburst: the gas captured by primary BH and being accreted

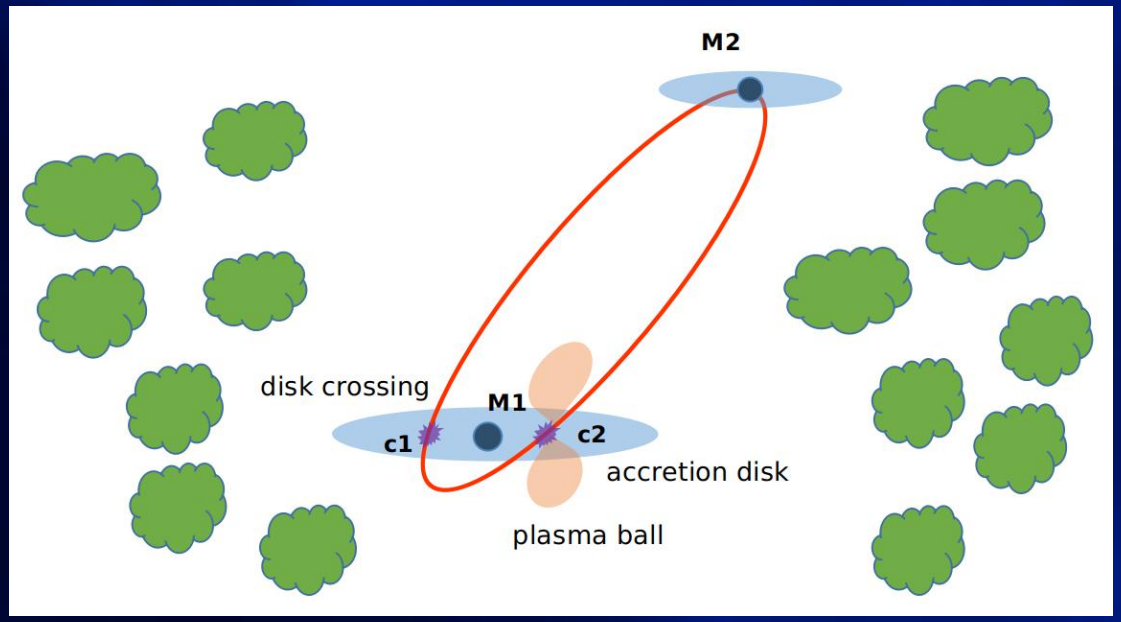


high-velocity Ha component: unbounded gas



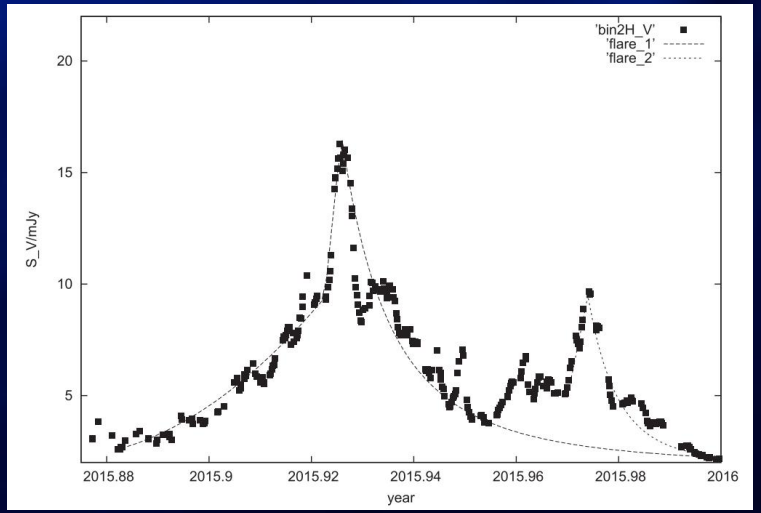
BLR clouds tidally disturbed and scattered by the primary SMBH

Flare model: accretion disk impact



- The secondary SMBH crosses the accretion disk shortly before and after the pericenter passages
- ejected plasma balls induced by disk crossing produce observed optical flares (similar to SNe)
- significant energy and angular momentum radiated away through GWs, leading to orbit decay

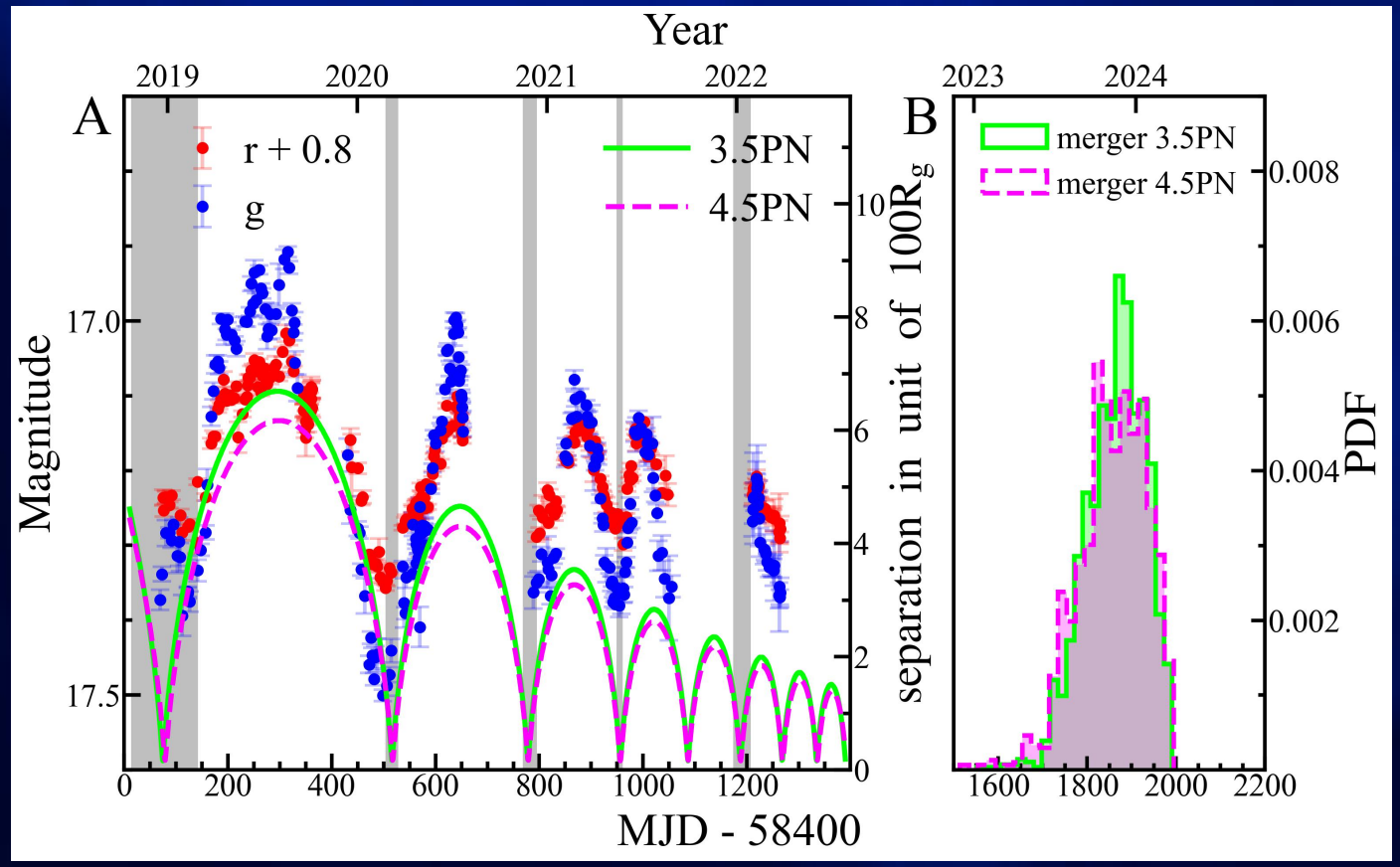
an uneven mass-ratio (5:1), highly eccentric (e>0.9) SMBH binary



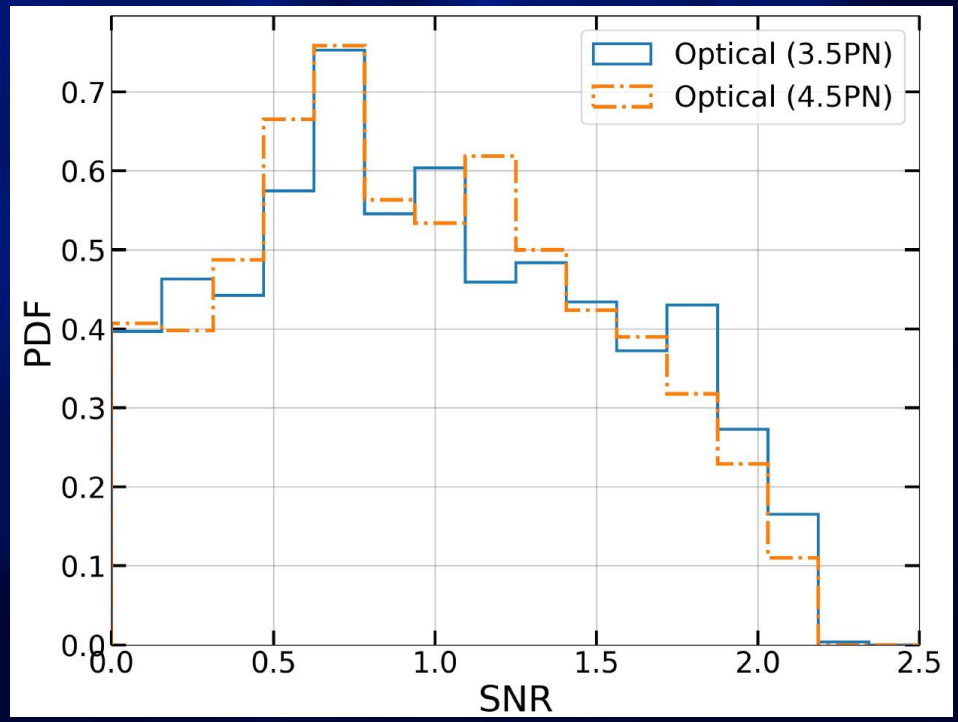
OJ287 flare model (Lehto+96, Ivanov+98, Pihajoki+2016...)

Valtonen+2019

predicted merger time

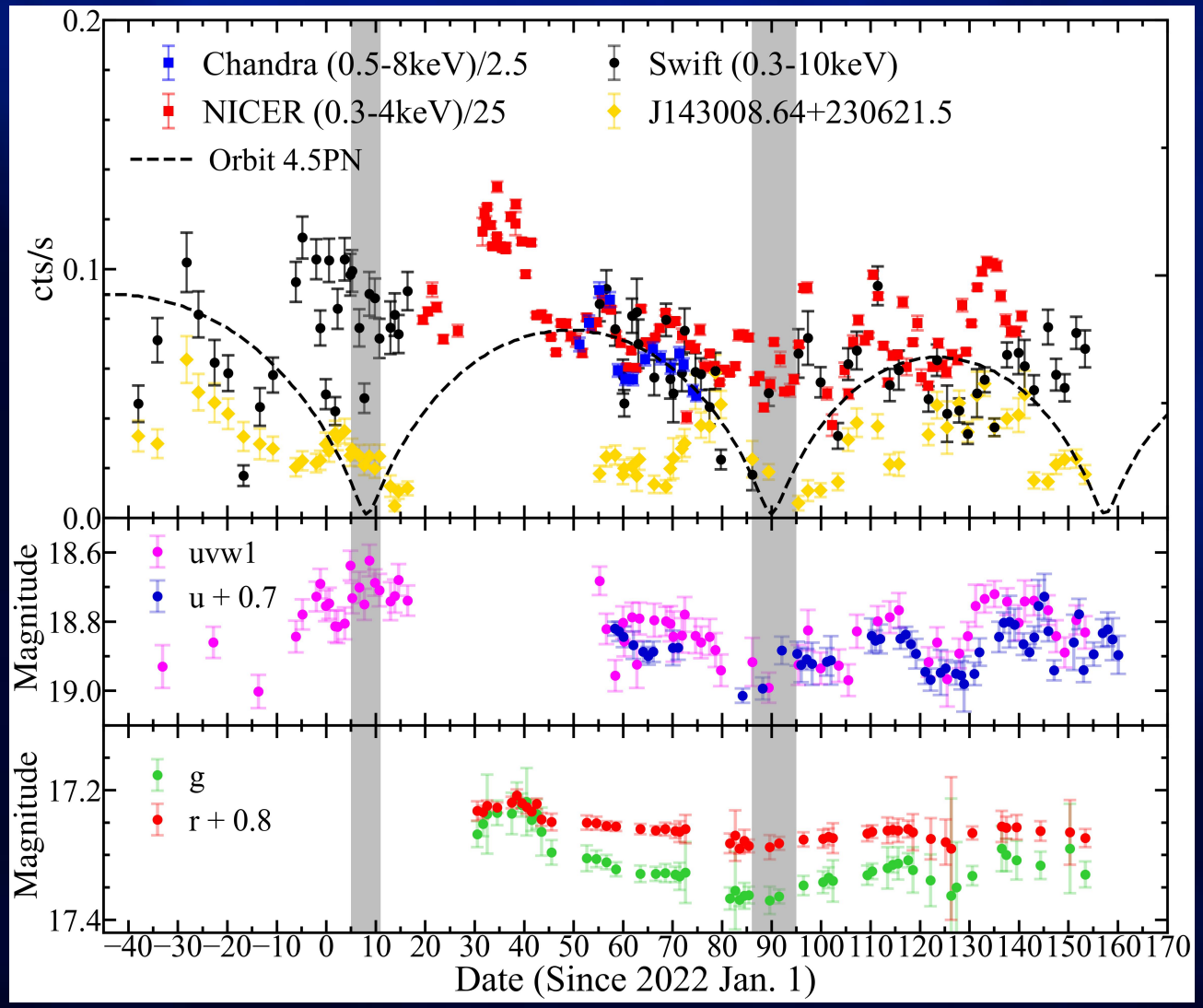


expected SNR for the gravitational memory effect as observed using PTA



see Chen+2022 (arxiv:2204.00749) for a more realistic calculation

Multi-wavelength light curves



Swift: every 1-3 day since 2021 Nov.23

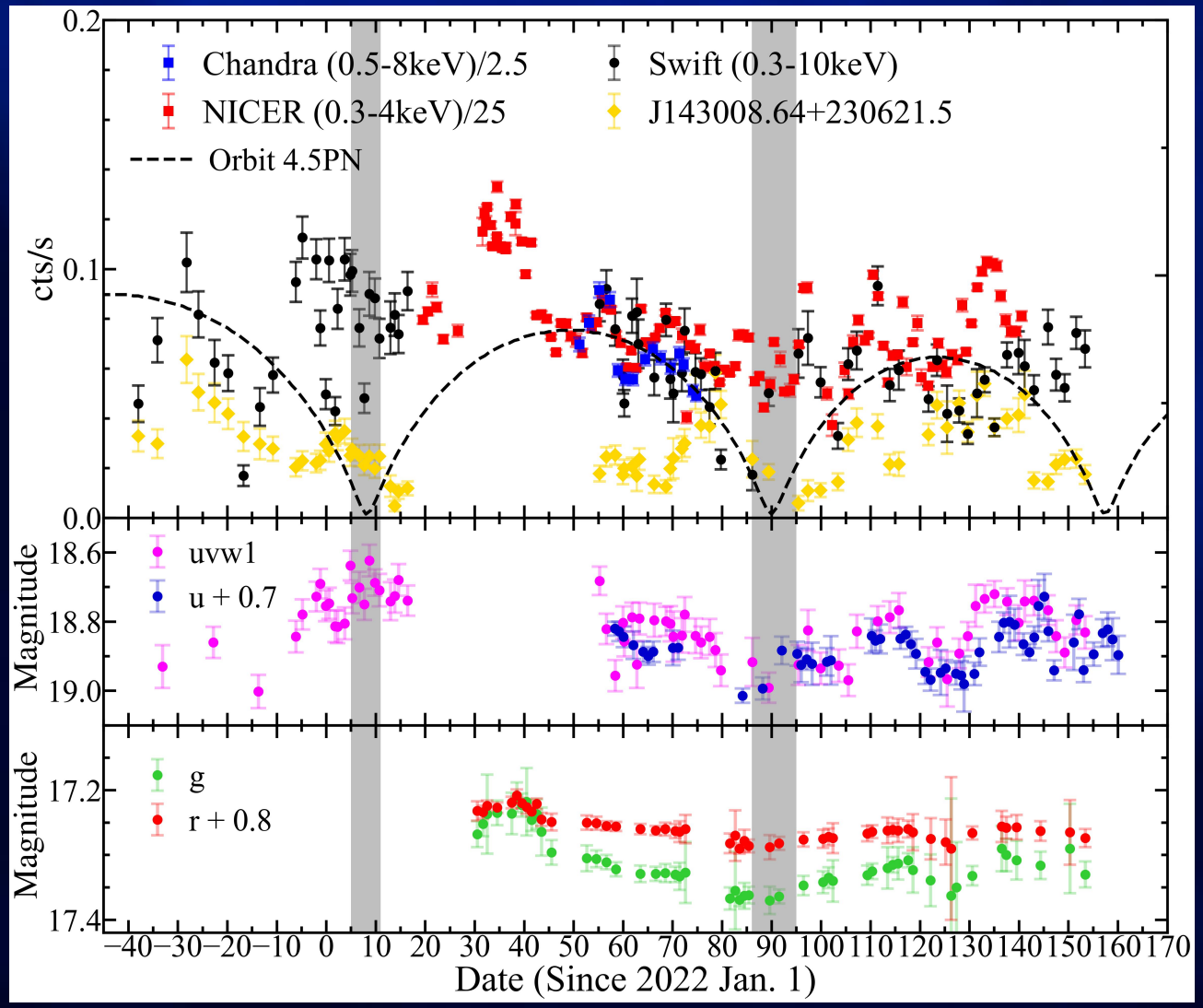
NICER: daily since Jan.20

Chandra: 15*4ks (Feb.21-Mar.16)

XMM-Newton: 50ks (Dec.31)+75ks (Jan.19) +100ks (June 29)

NuSTAR: 100ks (Feb.2-6)

Multi-wavelength light curves



AT2019cuk/SDSSJ1430/ZTF18aarippg: High-cadence NICER and NuSTAR X-ray observations of the potential supermassive black hole binary with imminent merger (the tick-tock source)

ATel #15225; *Dheeraj Pasham (MIT), Andrew Fabian (U. Cambridge), Dom Walton (U. Hertfordshire), Keith Gendreau (NASA/GSFC), Zaven Arzoumanian (NASA/GSFC), Megan Masterson (MIT), Erin Kara (MIT), Ron Remillard (MIT)*

*on **17 Feb 2022; 03:59 UT***

Distributed as an Instant Email Notice Transients

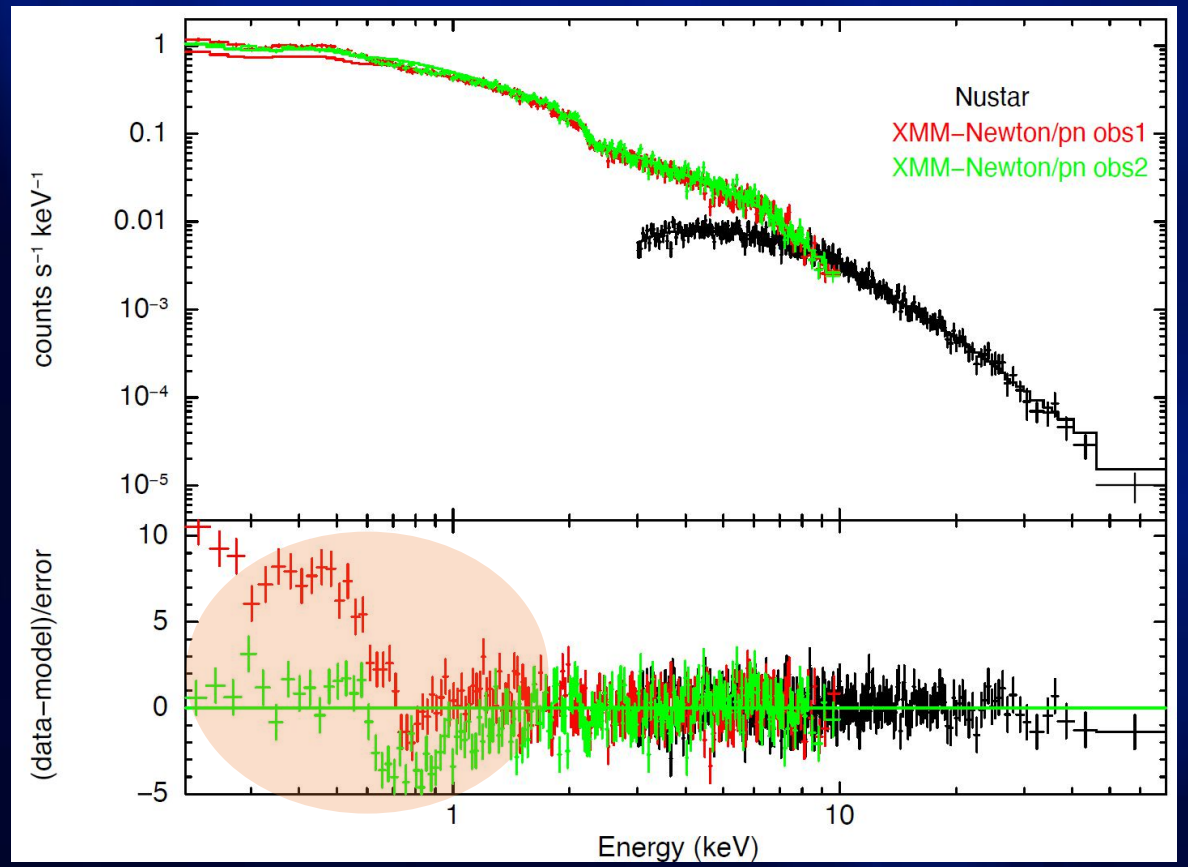
Credential Certification: Dheeraj Pasham (drreddy@mit.edu)

Subjects: X-ray, AGN, Transient

"While the probability of finding such a system within <1 Gpc is very low, the scientific potential of studying a bonafide SMBH binary close to coalescence is large"

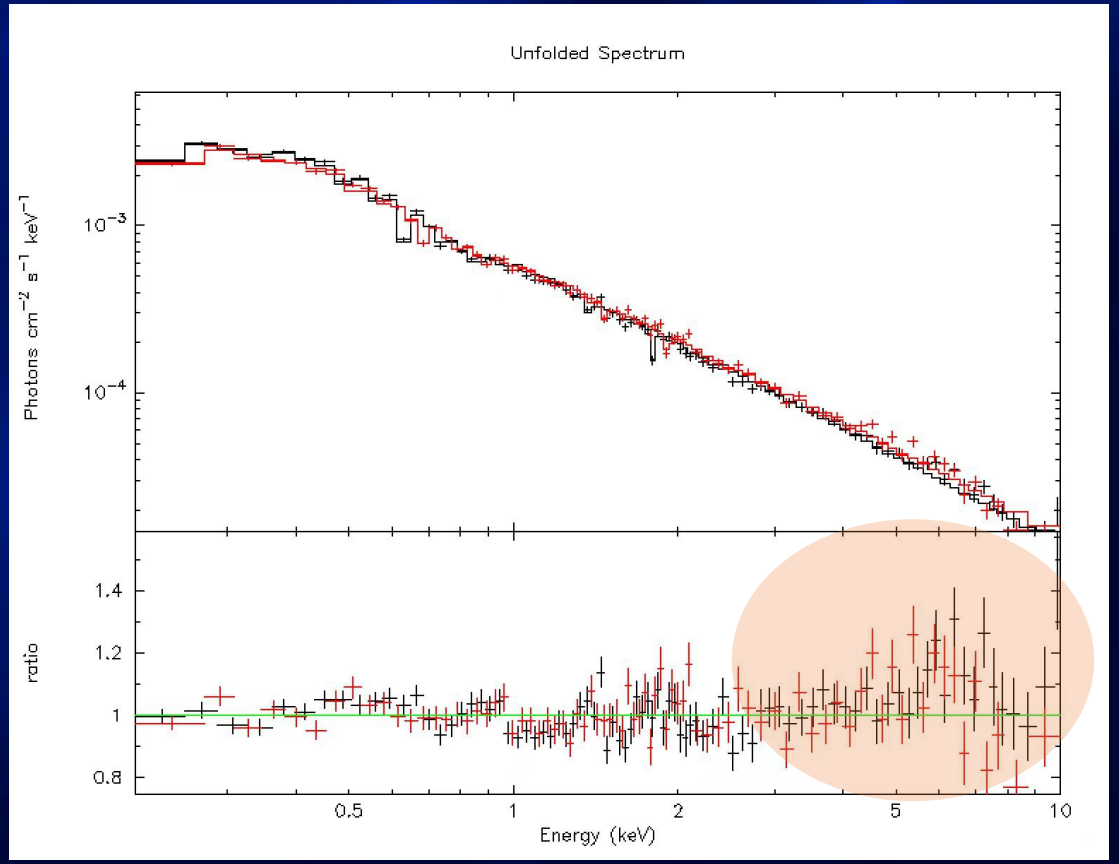
XMM-Newton + NuSTAR

powerlaw fitting



warm absorber

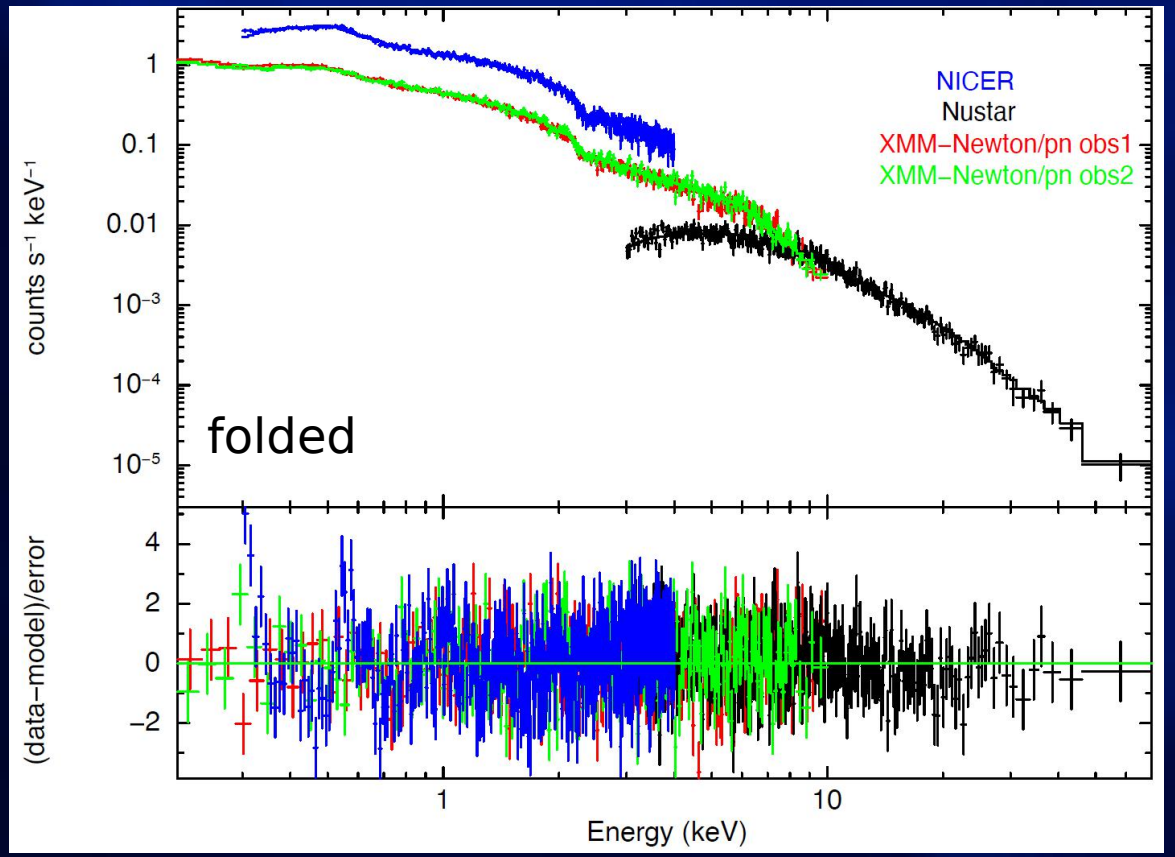
+warm absorber

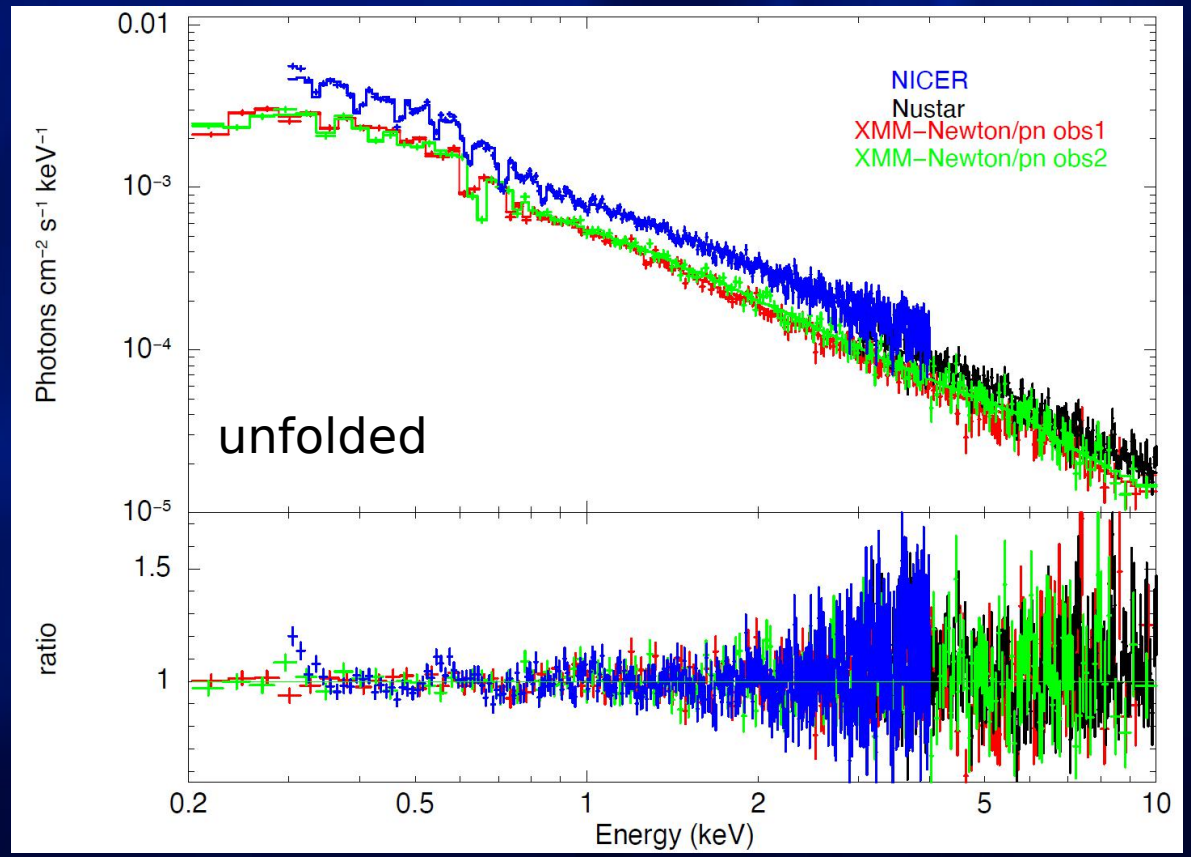


slight excess in 5-8 keV: broad Fe Ka?

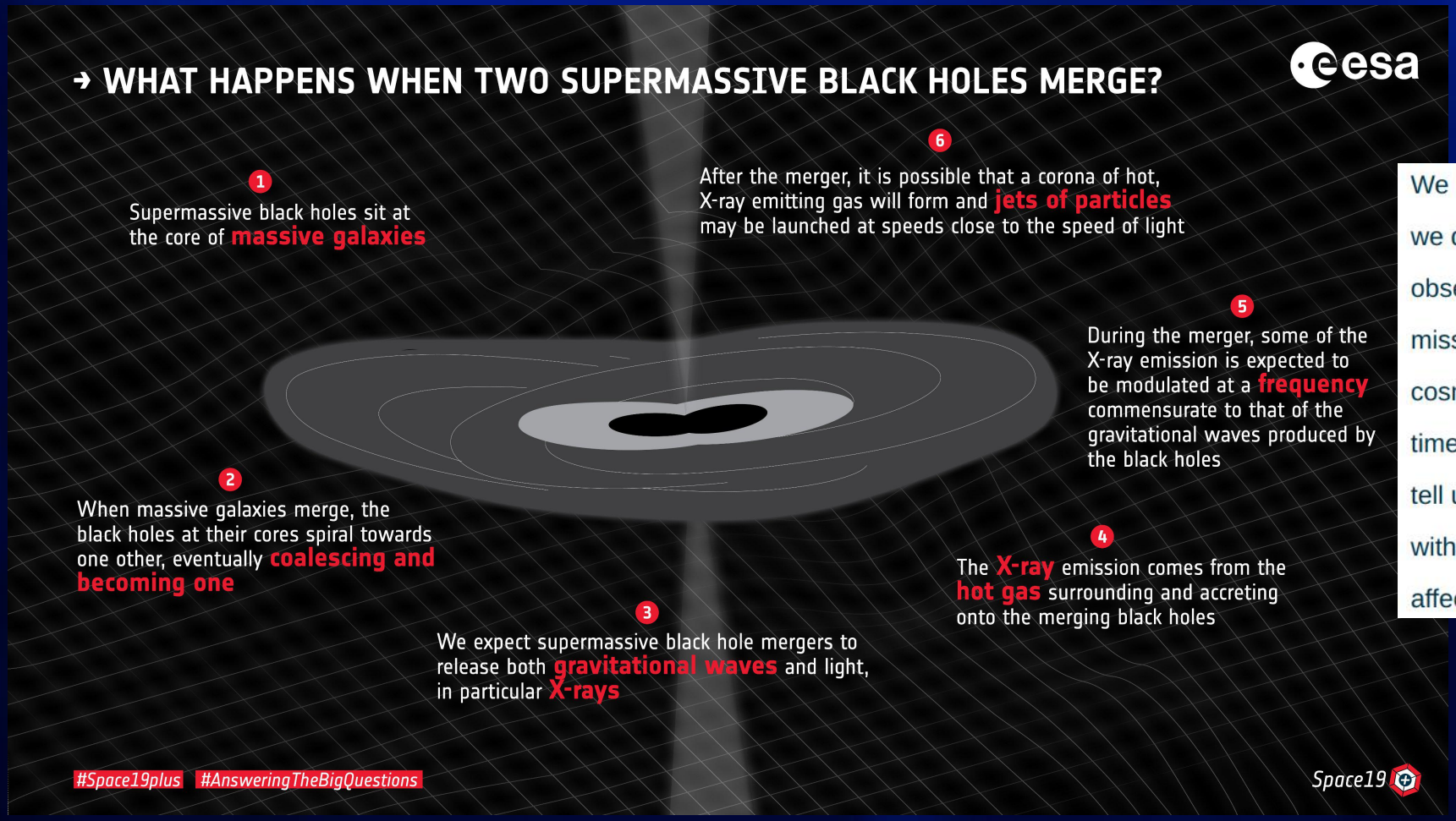
warm absorbed relativistic reflection disk model

phabs*(partcov*((zmshift*warmabs)*relxill))





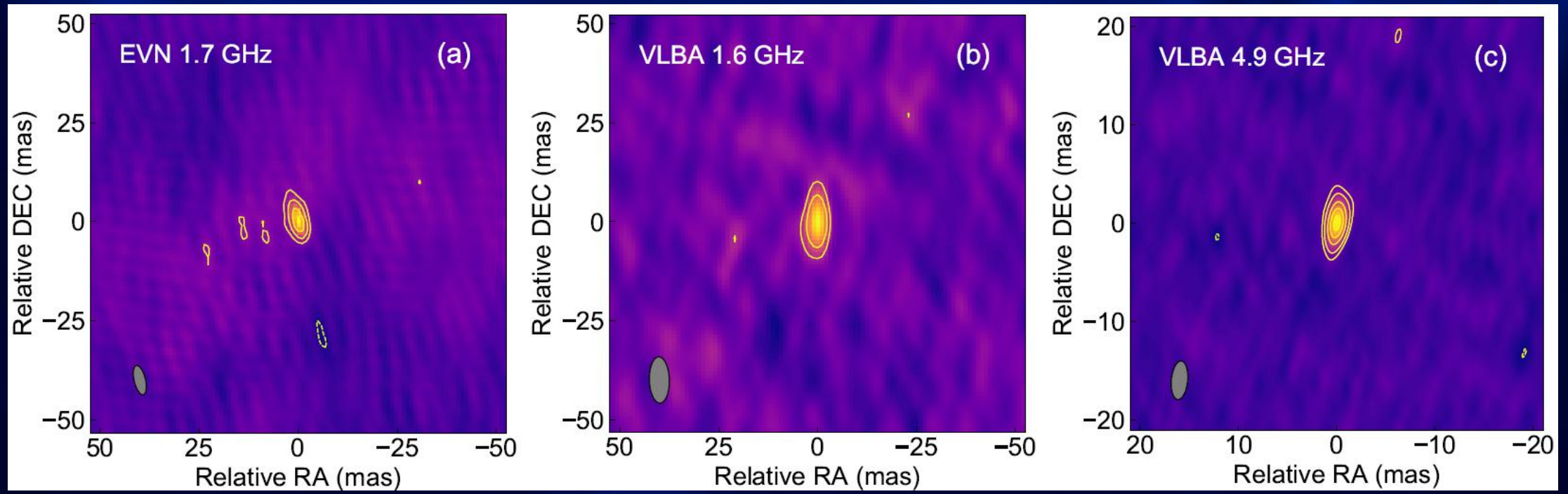
X-ray signals expected upon the final coalescence



We have never observed merging supermassive black holes – we do not yet have the facilities for such observations. Combining the observing power of two future ESA missions, Athena and LISA, would allow us to study these cosmic clashes and their mysterious aftermath for the first time. First, we need LISA to detect the gravitational waves and tell us where to look in the sky; then we need Athena to observe with high precision in X-rays to see how the mighty collision affects the gas surrounding the black holes.

Radio follow-ups

radio-quiet unresolved(<0.8pc) emission, still no outburst



An+22 (arXiv:2205.03208)

Summary

- a unprecedented SMBH binary candidate has been found by its chirping flares in a low-redshift (z~0.08), radio-quiet elliptical galaxy, predicted to merge within 3 years
- Multi-wavelength follow-ups are encouraging but also challenging to confirm (or rule out) SMBH binary scenario: optical flare amplitude is decreasing yet X-ray is chaotic
- X-ray spectra reveal rapid evolving warm absorber and broad FeKa, further observation is planned

We regard the proposition that the source is a pair of in-spiraling SMBHs to be extremely intriguing, but also less likely than a scenario in which a TDE or some other variability in a quasar system is at play. In any case, the behavior is sufficiently interesting to warrant further study.
—— Patrick Slane (Chandra director)

Thanks for your attention!