

RISING TIDES IN ACTIVE GALAXIES

Nuclear Transients and Episodic Activity in NGC 7213, AT 2021hdr, and Ansky

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Future Prospects (LSST, SKA)

NUCLEAR TRANSIENTS: A GROWING POPULATION

Time-domain surveys (ZTF, soon LSST) are revealing nuclear transients that trace rapid changes in SMBH accretion state:

TDE

Tidal Disruption Events – star or gas cloud disrupted by SMBH

CS-AGN

Changing-State / Changing-Look AGNs – dramatic accretion changes

QPE

Quasi-Periodic Eruptions – repeating X-ray bursts from disk interactions

ANT

Ambiguous Nuclear Transients – new class, unclear origin

Turn-on

AGN Ignition Events – previously quiescent galaxies turning active

IGNITE

Tracing the Onset of Radio Emission in Newborn and Flaring AGN

Using VLBI arrays to detect the emergence of compact parsec-scale radio emission in newly activated and flaring AGN.

Target Sources

Ansky

Turn-on AGN + Extreme QPEs

AT2021hdr

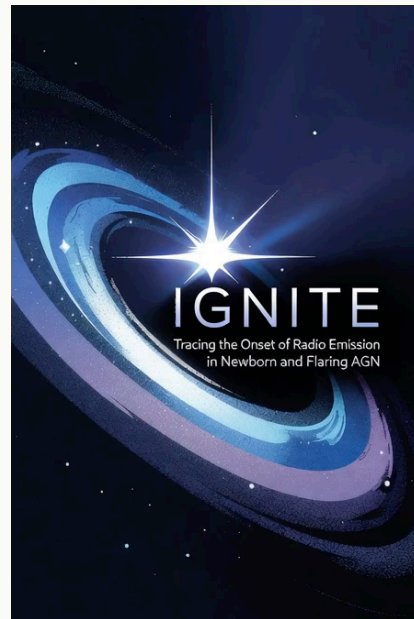
QPO - candidate SMBH binary

AT2023zgo

Bowen Flare Transient

ZTF20aaglfpy

Newborn Type 1 AGN



Instruments: Italian VLBI Network + Effelsberg @ K-band • Expanding to other VLBI arrays

Why Trace the Radio Phase?

The Importance of Detecting Compact Radio Emission in Newly Activated AGN

Accretion–Jet Connection

Observe in real time how and when a relativistic jet forms following a sudden increase in accretion rate.

Time Delays

Measure possible delays between high-energy activity (optical/X-ray/UV) and the appearance of a compact radio core.

Discriminate Physical Scenarios

Presence/absence of parsec-scale radio emission helps distinguish between turn-on AGN, TDE, and EMRI+disk models.

QPE Sources (e.g. Ansky)

Rapid evolution in recurrence time and energetics makes radio monitoring crucial to test models.

Unique Laboratory

These transients allow us to study disk–jet coupling while it happens, on human timescales.

NGC 7213: RECURRENT JET ACTIVITY IN A NEARBY LLGN



NGC 7213: RECURRENT JET ACTIVITY IN A NEARBY LINER

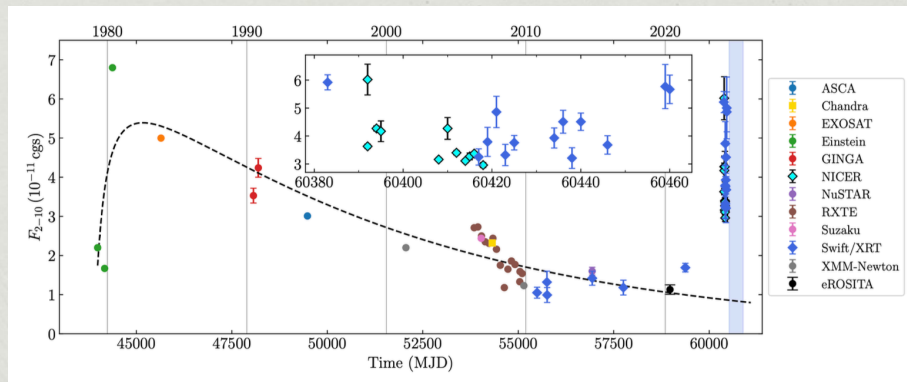
Key Properties

- Distance: ~20 Mpc (one of the closest LLAGNs)
- $MBH \approx 8 \times 10^7 M_{\odot}$
- Low Eddington ratio accretion
- Seyfert 1 + LINER spectrum
- Known X-ray/radio correlated variability

Open Question Before This Work

- Could this LLAGN launch collimated outflows beyond the nuclear region?
- Previous radio observations only showed a compact, flat-spectrum VLBI core.
- No clear evidence of kpc-scale jet structures.

NGC 7213: DISCOVERY OF SYMMETRIC kpc-SCALE RADIO KNOTS

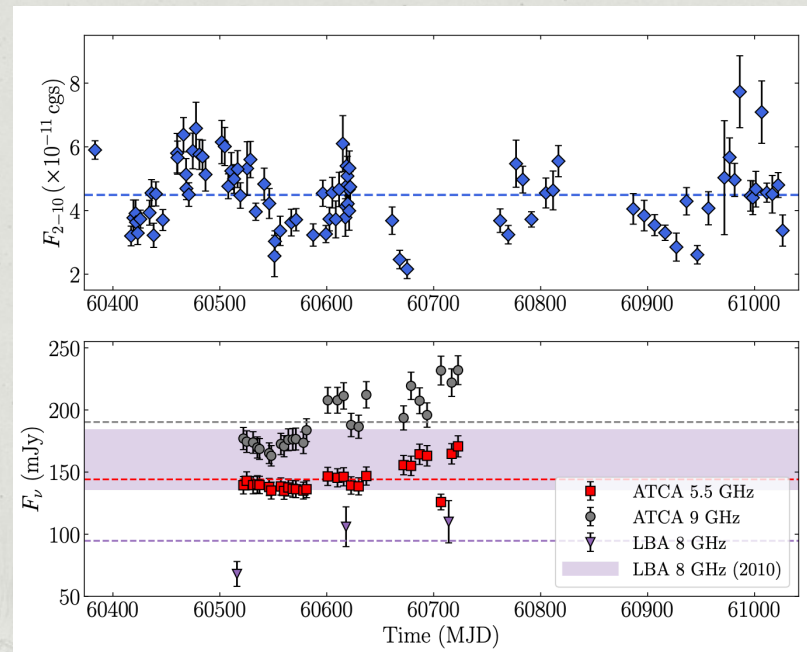


ATCA Monitoring

6-month campaign at 5.5 & 9 GHz shows significant variability, stronger at higher frequency

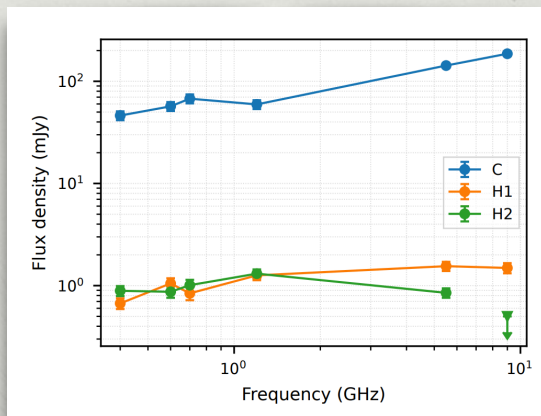
LBA (pc-scale)

Core remains unresolved (< 0.3 pc); strong variability on months and decade timescales (~ 40 mJy rise in 6 months)

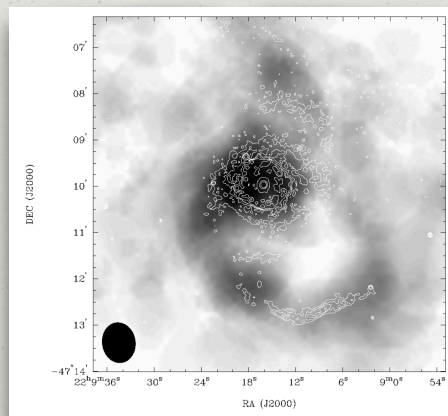


Bruni+26, in press

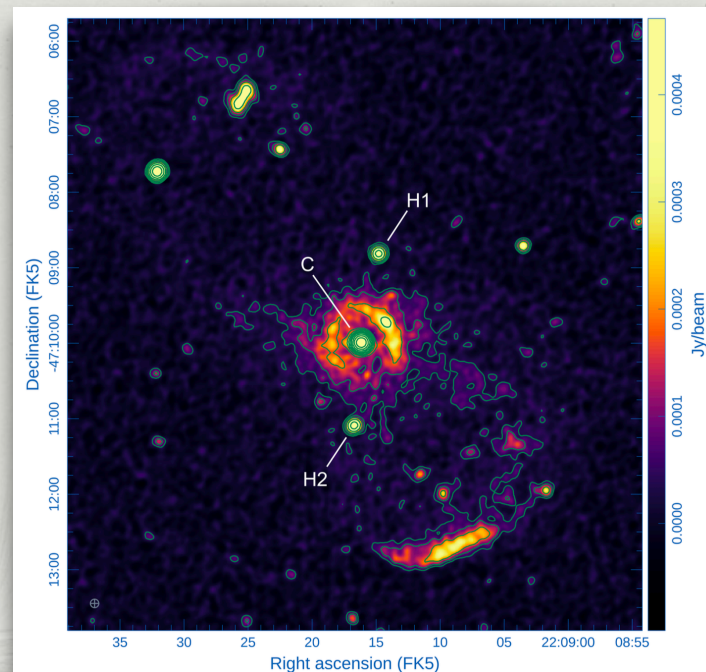
NGC 7213: DISCOVERY OF SYMMETRIC kpc-SCALE RADIO KNOTS



Bruni+26, in press



Hameed+01



Bruni+26, in press

MeerKAT + uGMRT

Two compact radio knots at ~ 5 kpc N and S of nucleus, nearly identical flux densities (~ 1 – 1.6 mJy) and flat spectra ($\alpha \approx 0$)

Symmetry

Projected distances almost identical; position angle difference $< 10^\circ$; aligned with nuclear axis

NGC 7213: EVIDENCE FOR A CONFINED WEAK JET

Interpretation

The symmetric kiloparsec-scale knots are best explained as compact termination shocks of a weak or intermittent jet launched by the LLAGN and confined by the dense, disturbed interstellar medium of the host galaxy.

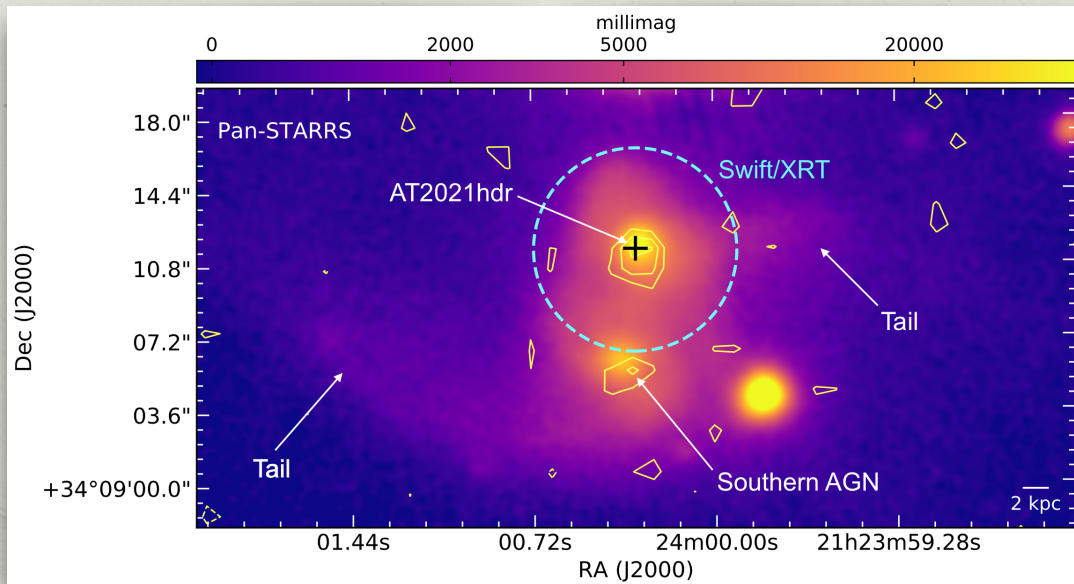
- 1 Symmetry + flat spectra → compact synchrotron emission at termination shocks
- 2 LBA variability on months/decades → originates in innermost jet region
- 3 Connection to recent X-ray flare (Kammoun et al. 2025) → enhanced nuclear activity
- 4 Host shows signs of past merger (H α filament, HI tail) → disturbed ISM helps confine the jet

NGC 7213 provides a nearby laboratory for how weak jets in low-accretion AGN interact with complex galactic environments.

AT 2021hdr: AN OSCILLATING NUCLEAR TRANSIENT



AT 2021hdr: OSCILLATING NUCLEAR TRANSIENT



Discovery

ZTF alert March 2021 (ZTF21aaqqwsa);
classified as SN candidate initially

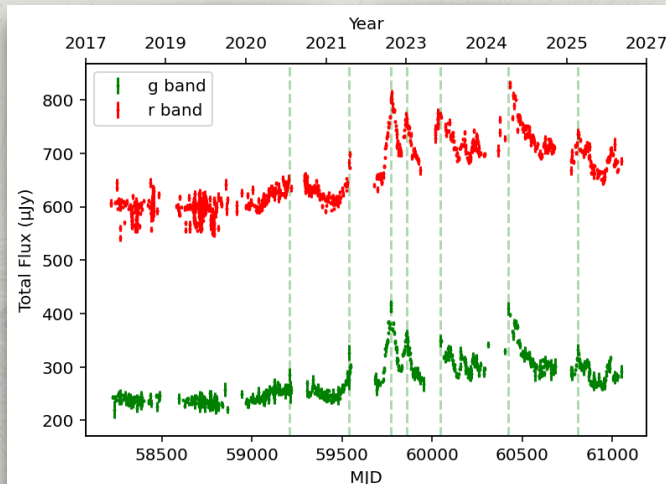
Variability

Multiple re-brightenings with ~60–90
day quasi-periodic oscillations

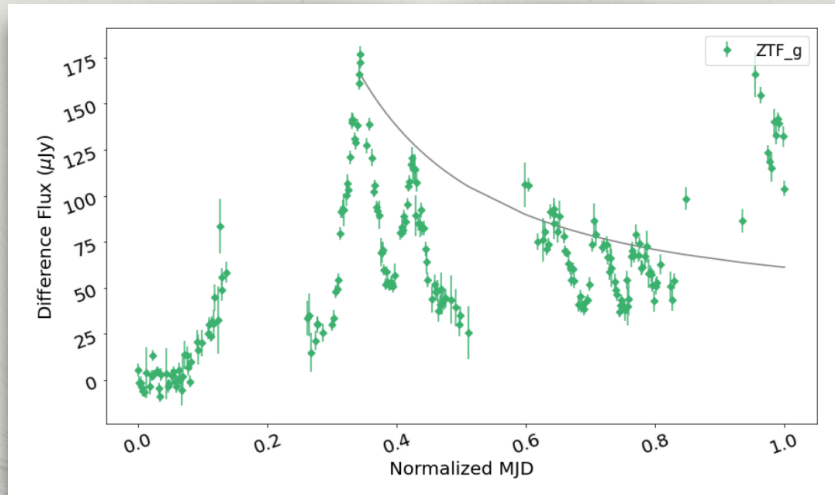
Host

Early-stage merger: Seyfert + LINER
nuclei separated by 9 kpc

Hernandez-Garcia+24

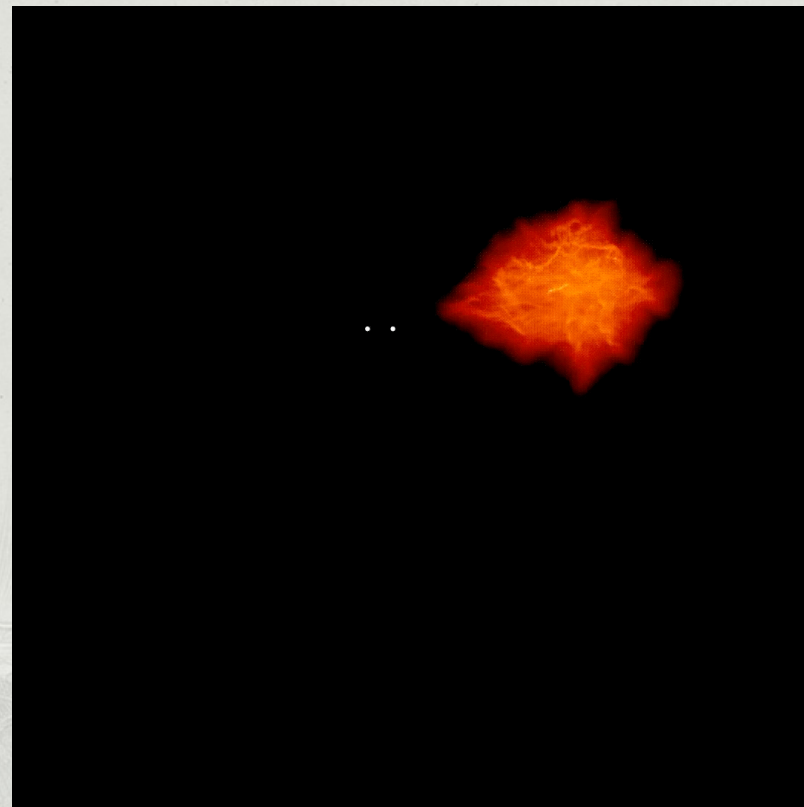


AT 2021hdr: OSCILLATING NUCLEAR TRANSIENT



Proposed Scenario

Tidal disruption of a gas cloud by a binary supermassive black hole system (separation ~ 0.83 mpc, merger in $\sim 7 \times 10^4$ yr). The oscillations may arise from the orbital dynamics or disk interactions in the binary system.



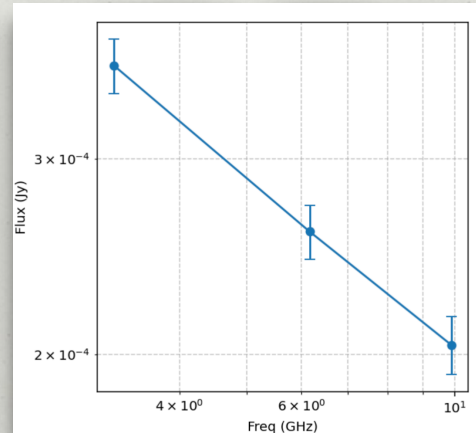
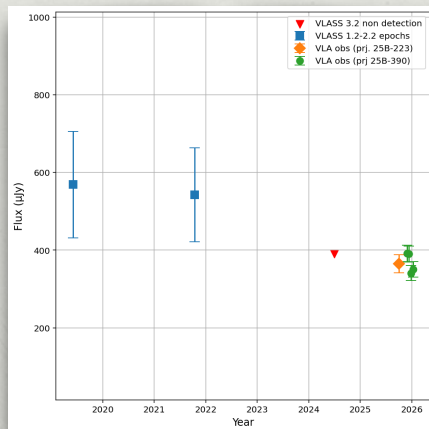
AT 2021hdr: NOT A STANDARD TDE OR CLAGN

Why standard interpretations fail:

- ✗ Light curve shows repeated oscillations, not a single $t^{-5/3}$ decay typical of TDEs
- ✗ No broad emission lines or Bowen fluorescence lines expected in many TDEs/flaring AGNs
- ✗ Radio properties inconsistent with strong jet or new compact core
- ✗ Oscillations correlated across optical/UV/X-ray – points to central engine origin

AT 2021hdr: OSCILLATING NUCLEAR TRANSIENT

Check out Edoardo's poster!



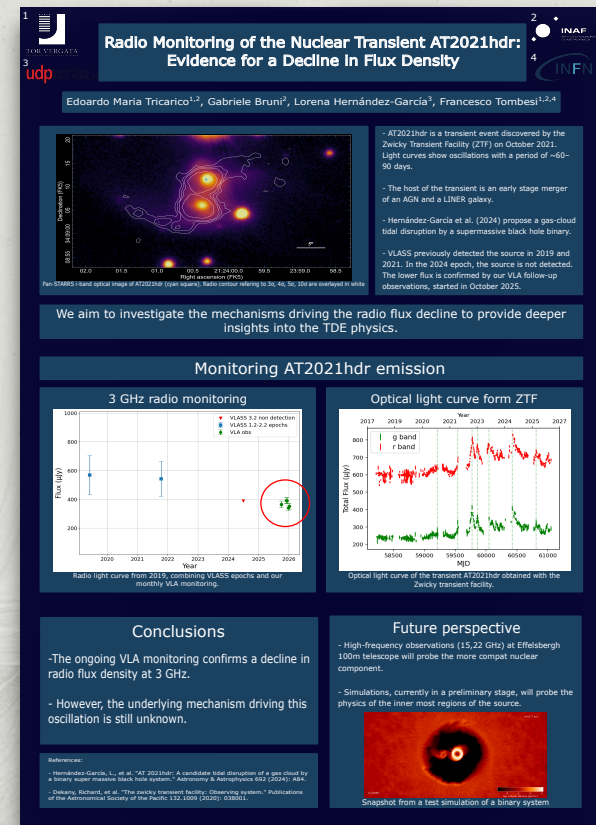
Tricarico et al. (in prep)

Radio

kpc-scale emission detected (VLASS), but no pc-scale core or jet (VLBA upper limits)

Flux decline

Detected in the first 2 VLASS epochs but not in the third one, VLA monitoring revealed flux decline



SDSS J1335+0728 (ANSKY): A TURNING-ON AGN



SDSS J1335+0728 (ANSKY): A TURNING-ON AGN

A galaxy that was completely quiescent for >20 years suddenly 'wakes up'.

Pre-2019

No optical variability for two decades;
classified as composite / star-forming

Dec 2019

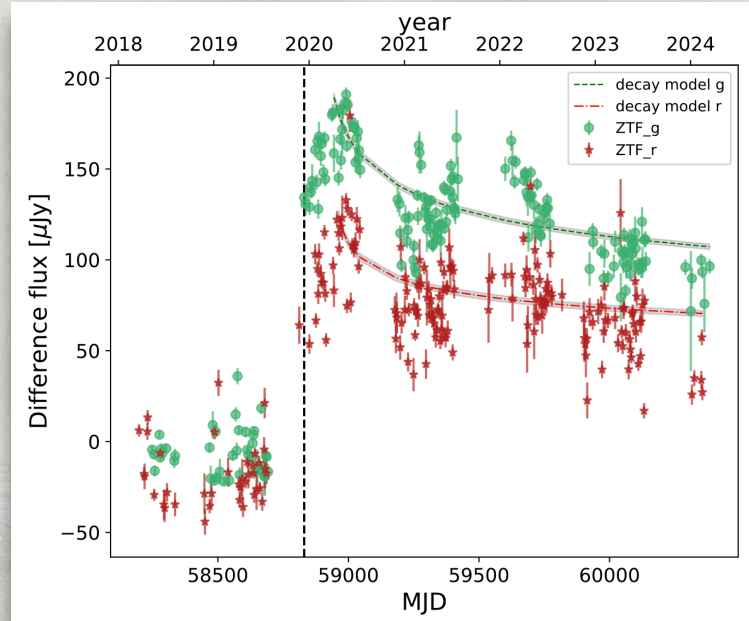
ZTF detects first nuclear flare
(ZTF19acnskyj / ZTF22abyhaut)

2020–2021

UV flux $\times 4$ brighter than GALEX 2004;
optical stochastic variability

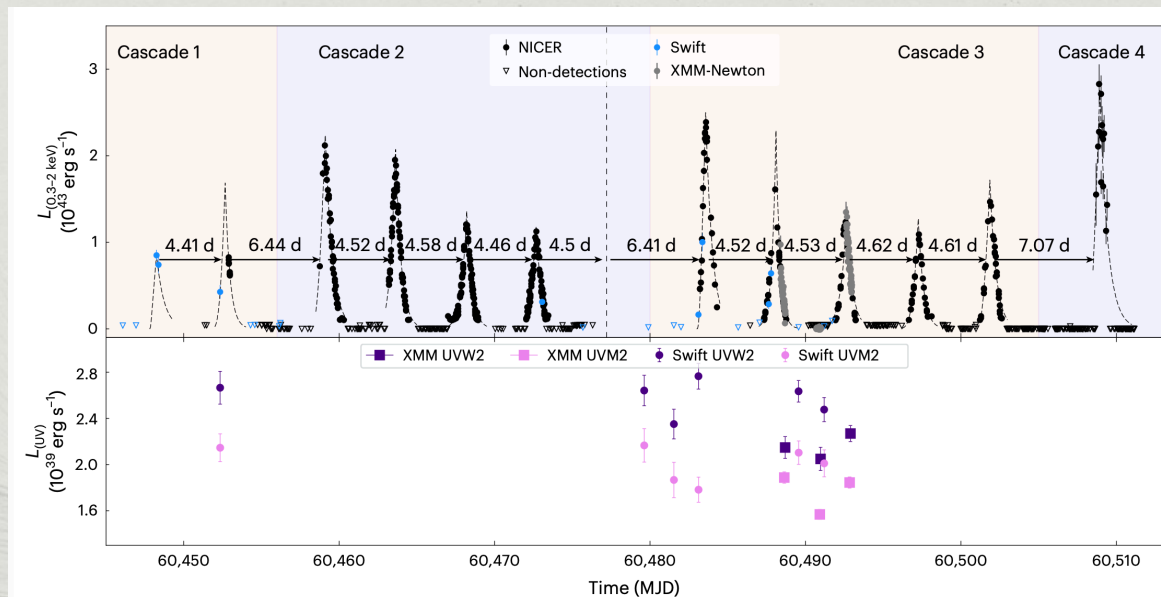
2022–2023

MIR flux doubles; W1–W2 becomes
redder; [O III] flux increases $\times 3.6$



Sanchez-Saez+24

SDSS J1335+0728 (ANSKY): A TURNING-ON AGN



*Hernandez-Garcia+25,
Nature Astronomy*

Feb 2024+

Soft X-ray emission appears → extreme ~4.5-day QPEs discovered with NICER

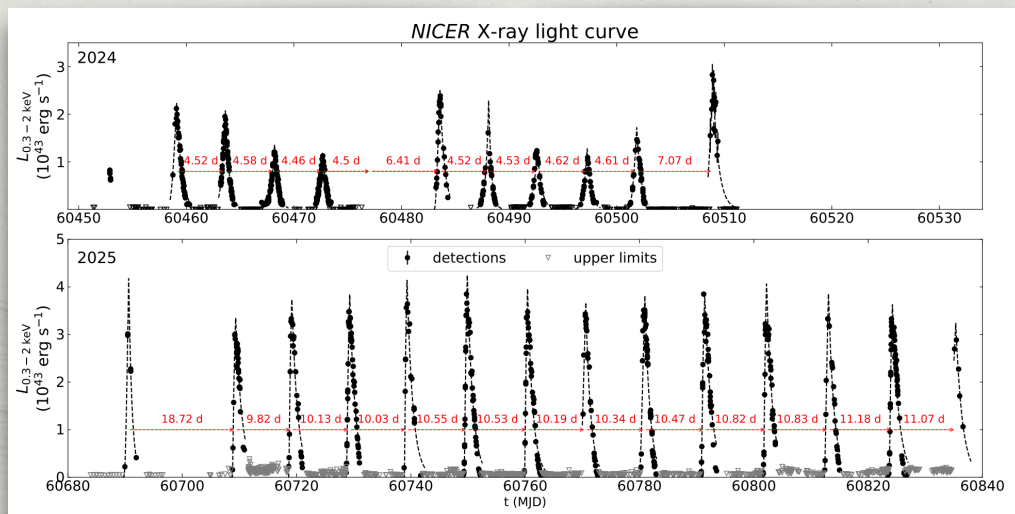
Recurrence

~4.5 days (peak-to-peak); super-period ~25 days with 5+1 pattern
~1.5 days per burst – longest among known QPEs

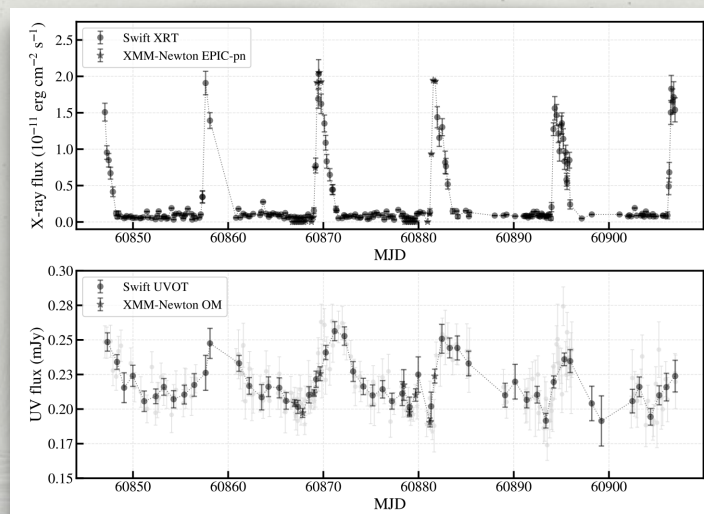
ANSKY: EXTREME QUASI-PERIODIC ERUPTIONS

QPE slowing down x2 from 2024 to 2025...

...and recently detected in UV as well!



Hernandez-Garcia+25



Guo+26

ANSKY: IMPLICATIONS FOR QPEs AND TURN-ON AGNs

Ansky extends the QPE population to longer timescales and higher energies, and shows that QPEs can appear in a newly forming accretion flow – not only after classical TDEs.

- 1 First QPEs witnessed emerging in real time after an optical transient that is NOT a standard TDE (no broad lines, flatter decay)
- 2 Host shows clear signs of activating AGN: rising MIR, evolving narrow lines, compact NLR
- 3 Supports EMRI + newly formed disk scenario: newborn AGN provides rich environment for stellar captures
- 4 Super-periodic pattern (~ 25 d) may indicate precessing eccentric disk cavity
- 5 Broadens QPE formation channels beyond post-TDE disks to any newly formed accretion flow

FUTURE PROSPECTS

Vera C. Rubin Observatory (LSST)

Will discover thousands of nuclear transients per year, enabling statistical studies of turn-on AGNs and QPE rates

Square Kilometre Array (SKA)

Revolutionize studies of weak jets and recurrent activity in LLAGNs through sensitive, high-resolution radio imaging

XRISM, New Athena, AXIS

High-resolution X-ray spectroscopy of QPEs and changing-look events to probe disk–corona physics

Multi-messenger synergies

Combination of time-domain + VLBI + X-ray timing will be key to understanding EMRI candidates and binary SMBHs

SUMMARY

- 1 **NGC 7213** shows clear evidence of recurrent, confined weak jet activity on kpc scales – a nearby template for LLAGN feedback
- 2 **AT 2021hdr** displays unusual quasi-periodic optical/UV/X-ray oscillations best explained by a gas cloud TDE in a binary SMBH system
- 3 **Ansky** (SDSS J1335+0728) is one of the best cases of a $\sim 10^6 M_{\odot}$ BH turning on in real time, now exhibiting extreme long-timescale QPEs
- 4 These objects illustrate the rich, time-variable phenomenology of SMBHs **switching between quiescent and active states**
- 5 Time-domain + multiwavelength monitoring is essential; LSST + SKA will transform the field in the coming decade

Thank you! Questions?