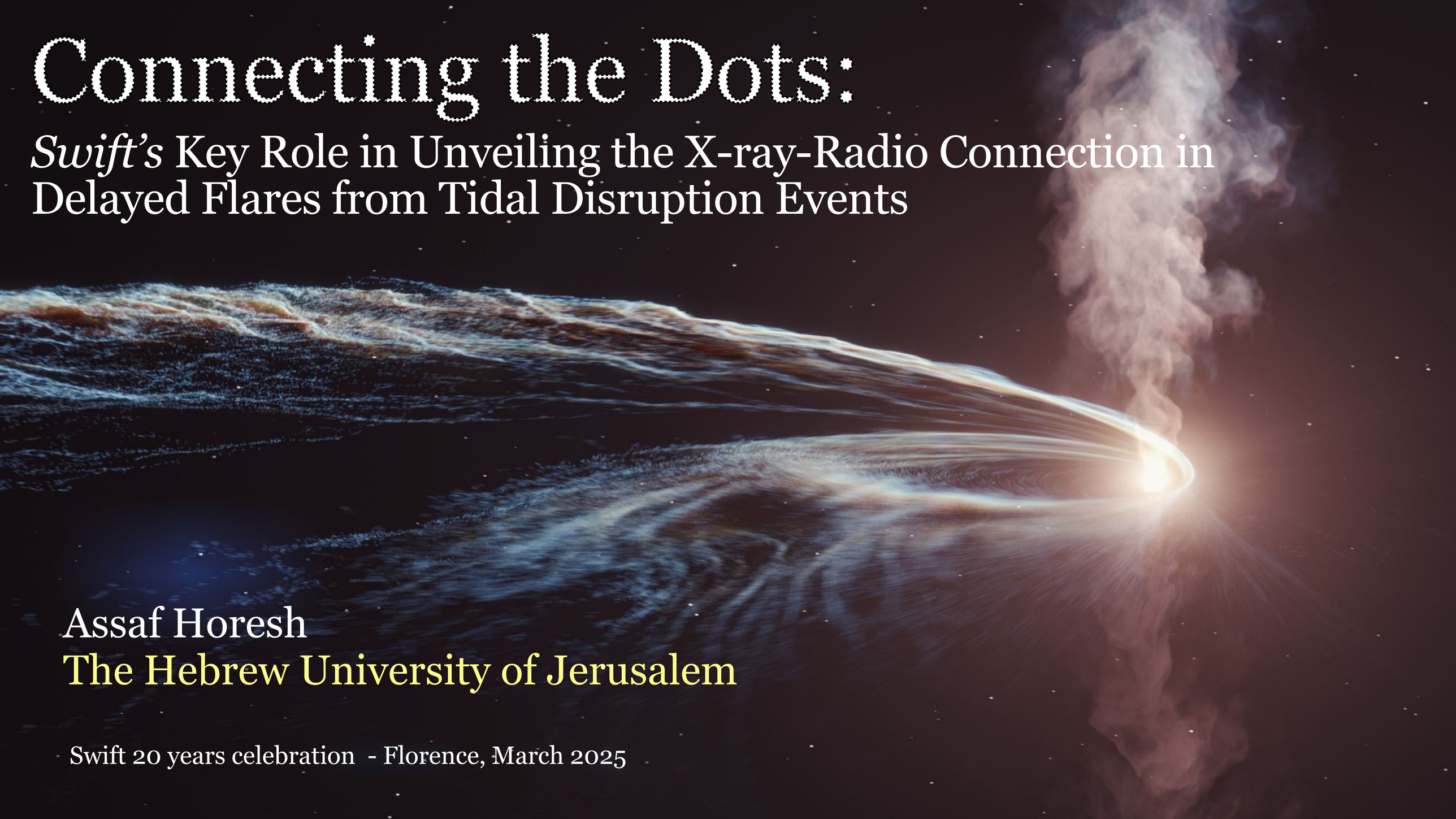
# Connecting the Dots:

## *Swift's* Key Role in Unveiling the X-ray-Radio Connection in Delayed Flares from Tidal Disruption Events

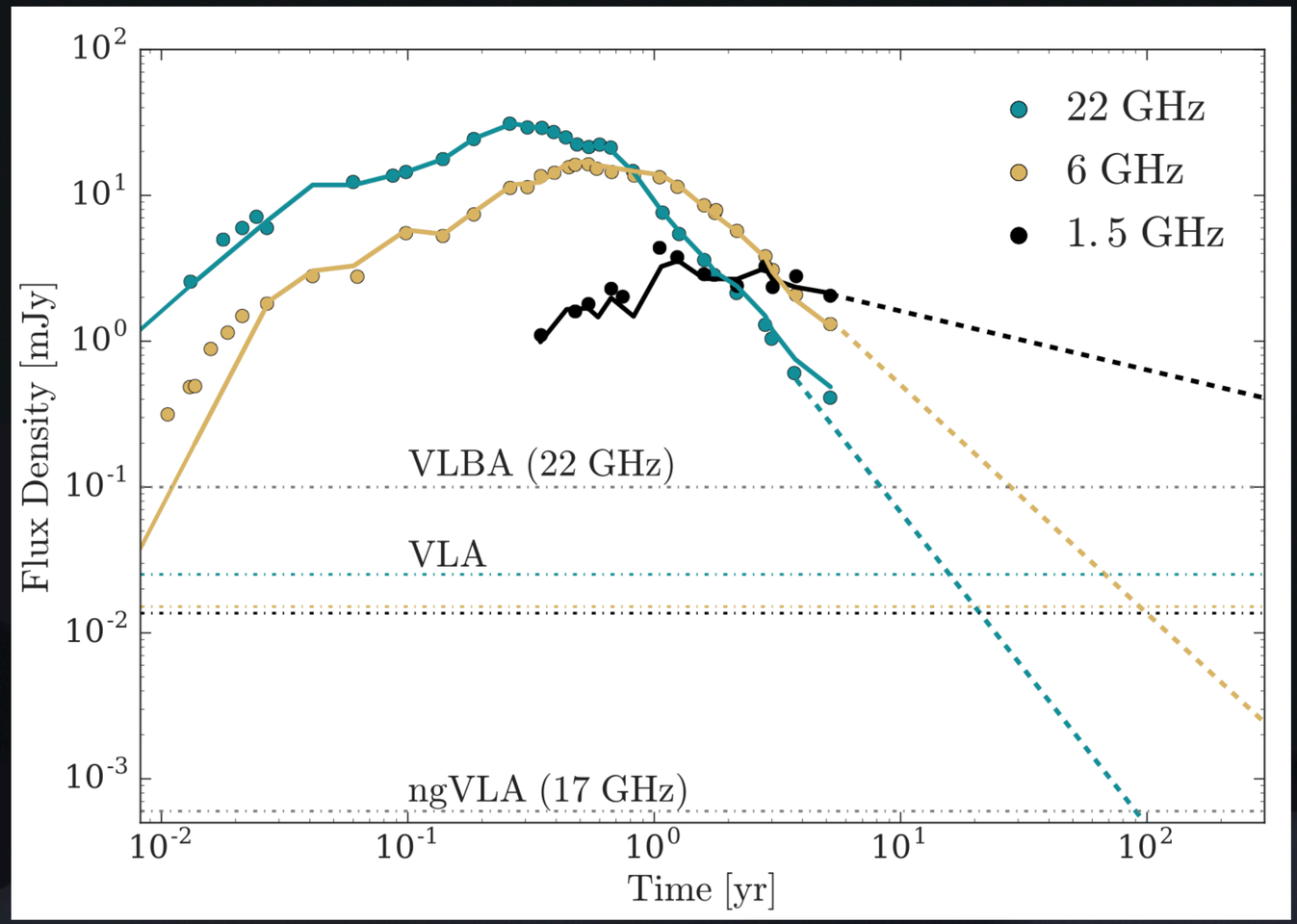


Assaf Horesh
The Hebrew University of Jerusalem

Swift 20 years celebration - Florence, March 2025

# Radio Diagnostics of TDEs

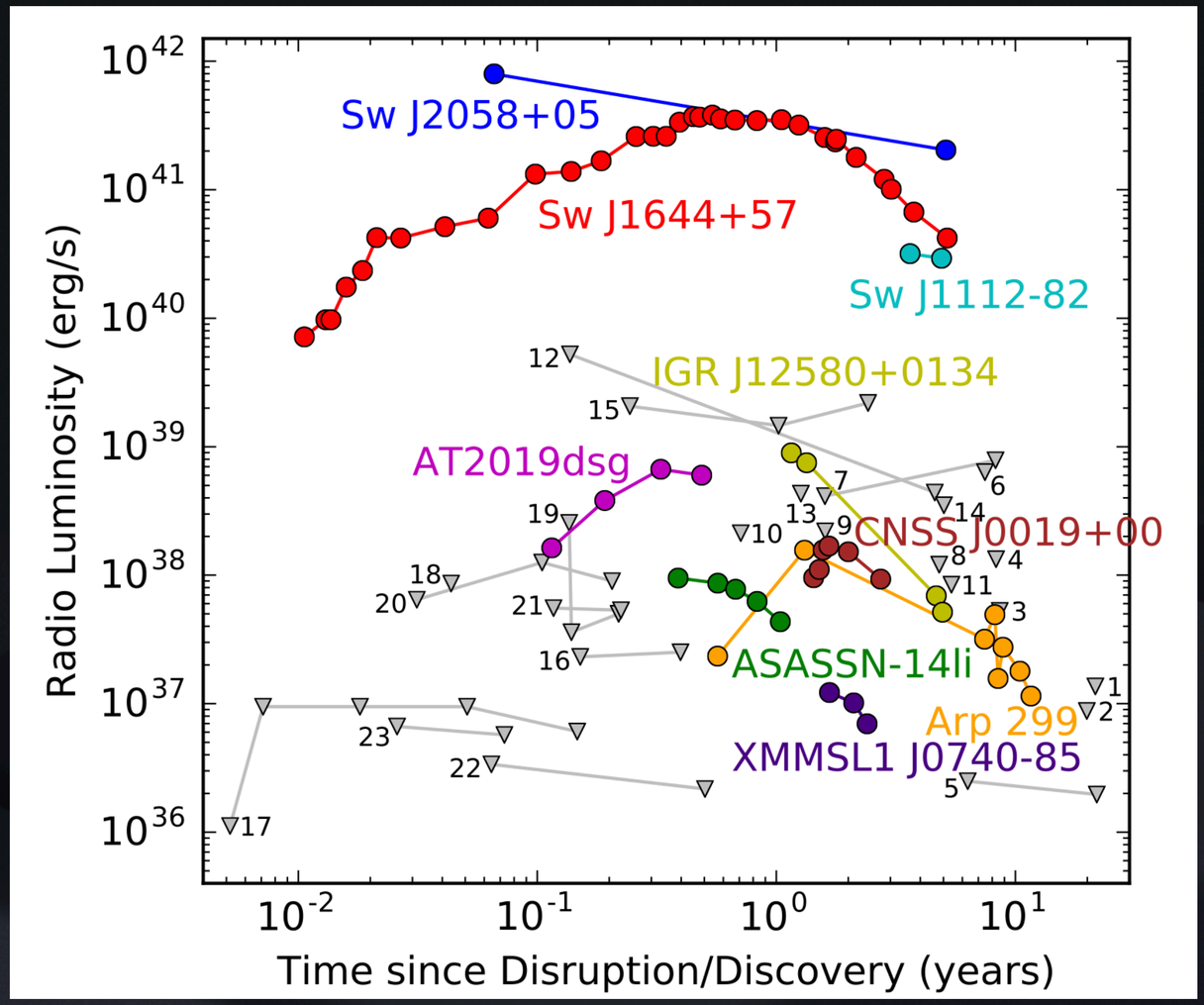
- Track outflows (velocity, Lorentz factor)
- Emission region size (brightness temperature, scintillation)
- Evolution of cooling processes
- Structured Jets
- Energy fraction in magnetic field
- Density variation in the close vicinity of the SMBH




Eftekhari et al. (2018)

# Status of TDE Radio Emission

## Until recently




Alexander, van-Velzen, **Horesh**, Zauderer (2020)

# A New Discovery

## Delayed Radio Flares

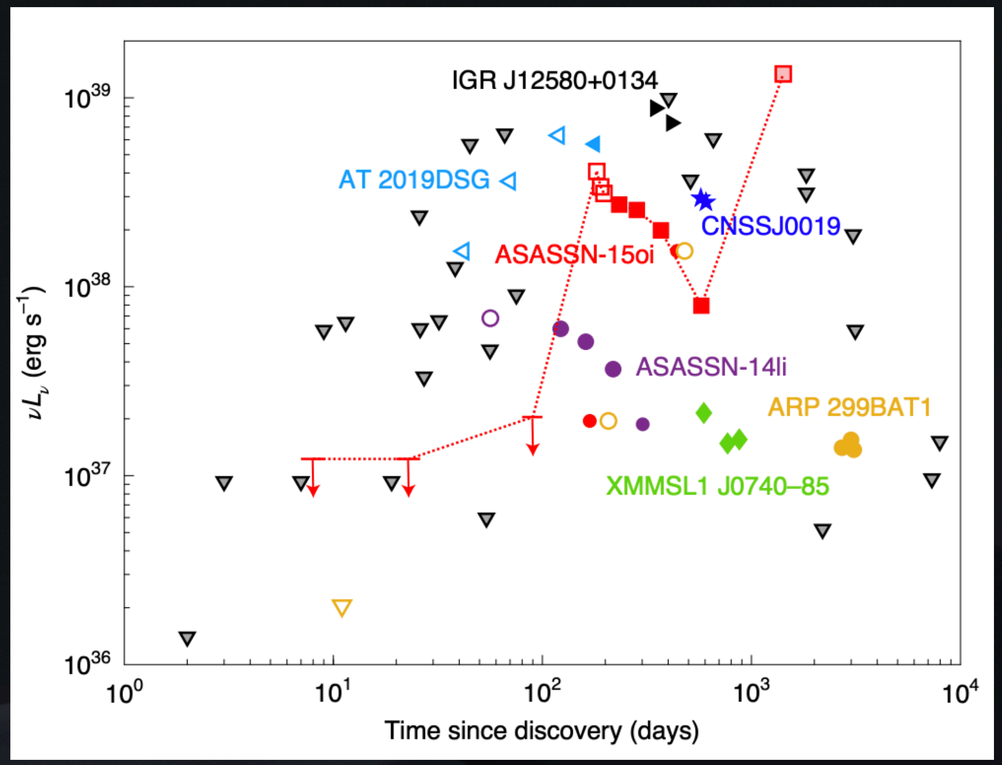
ASTRONOMY

# Radio bursts from ‘zombie’ black holes excite astronomers

Delayed emissions from black holes that fed on stars earlier could help explain the formation of powerful jets

# Delayed Radio Flares

## A new discovery - ASASSN15oi




**Horesh,** Cenko, & Arcavi
Nature Astronomy (2021)

# Delayed Radio Flares

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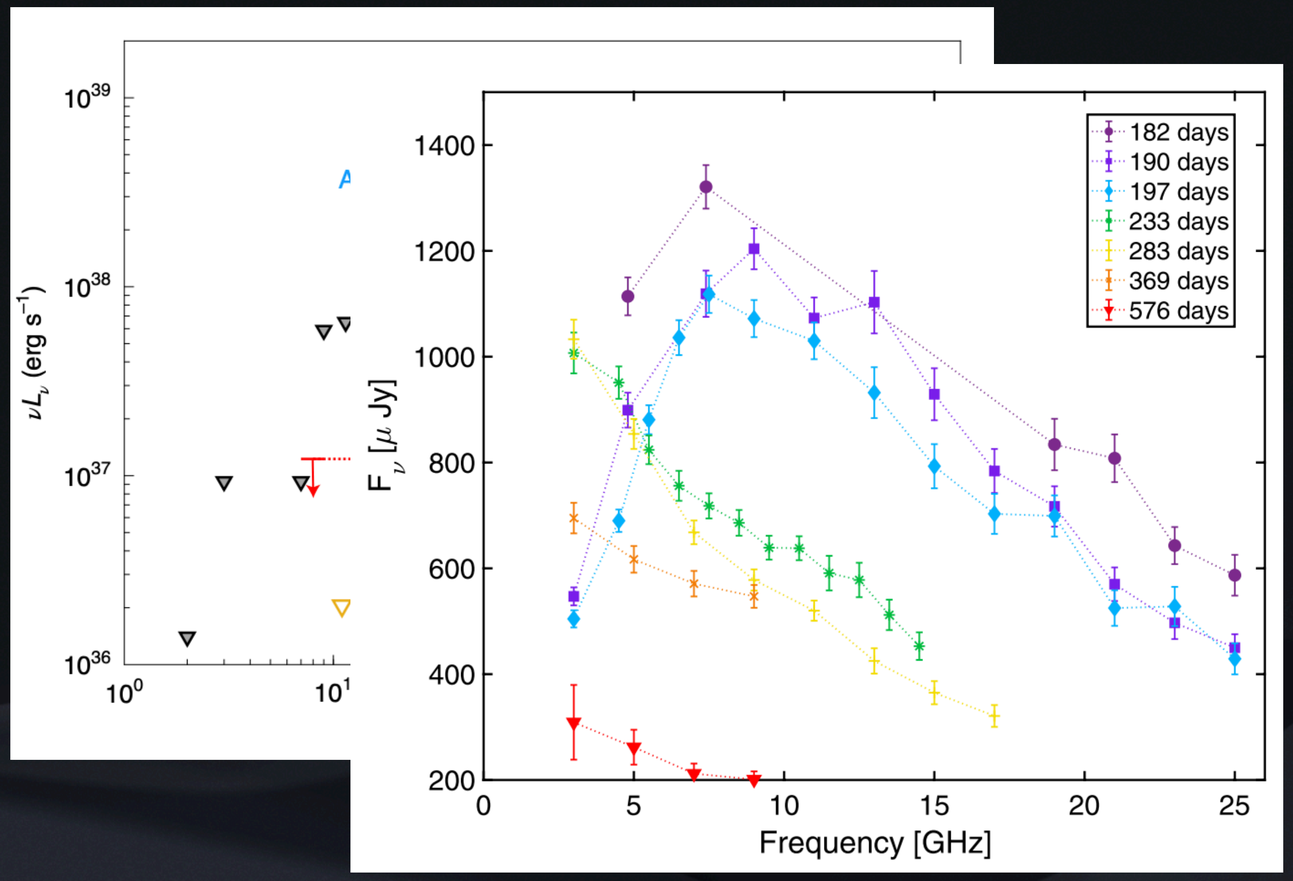
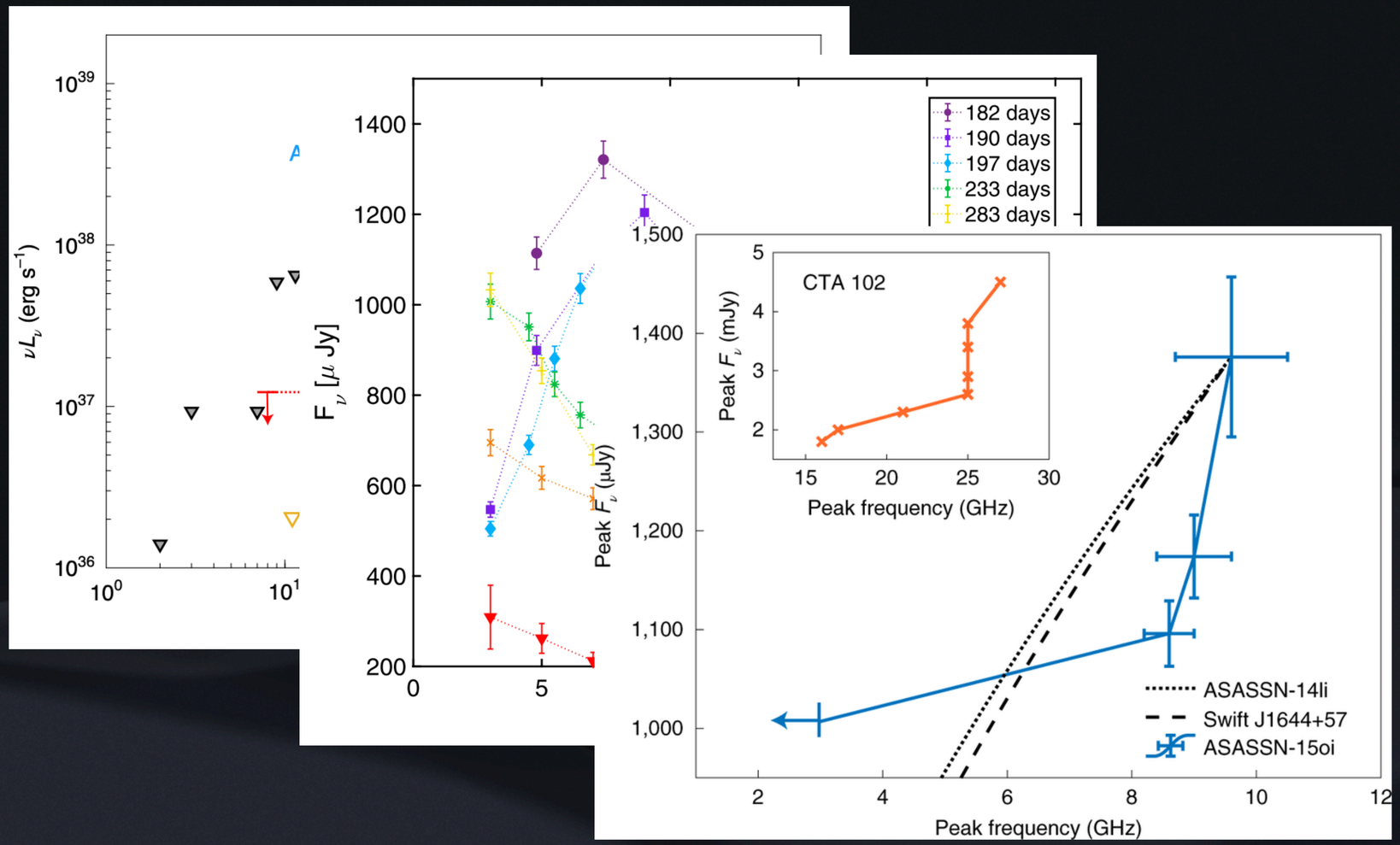



**Horesh,** Cenko, & Arcavi
Nature Astronomy (2021)

# Delayed Radio Flares

## A new discovery - ASASSN15oi

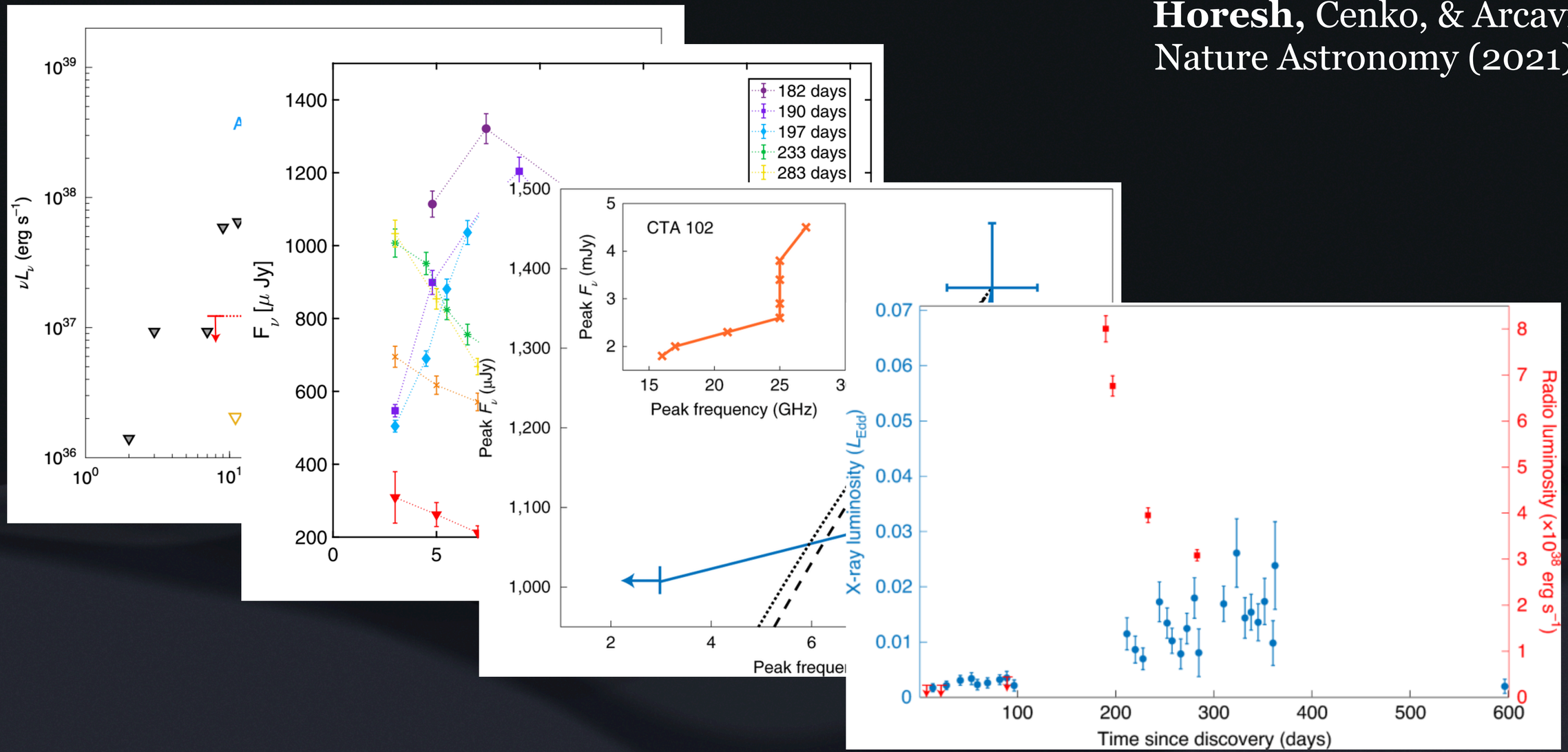
**Horesh,** Cenko, & Arcavi
Nature Astronomy (2021)



# Delayed Radio Flares

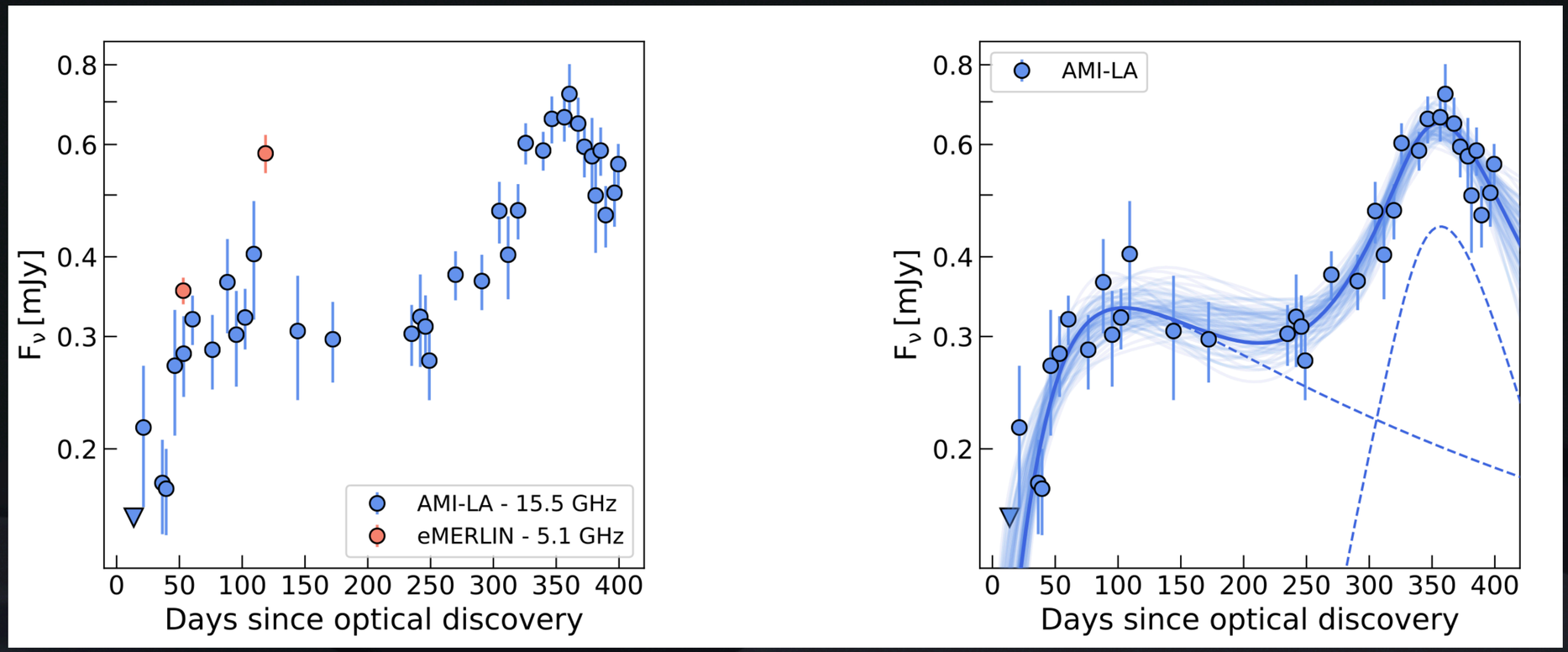
## A new discovery - ASASSN150i

**Horesh,** Cenko, & Arcavi
Nature Astronomy (2021)



# Delayed Radio Flares - Complexity

## A two component flare - AT2019azh

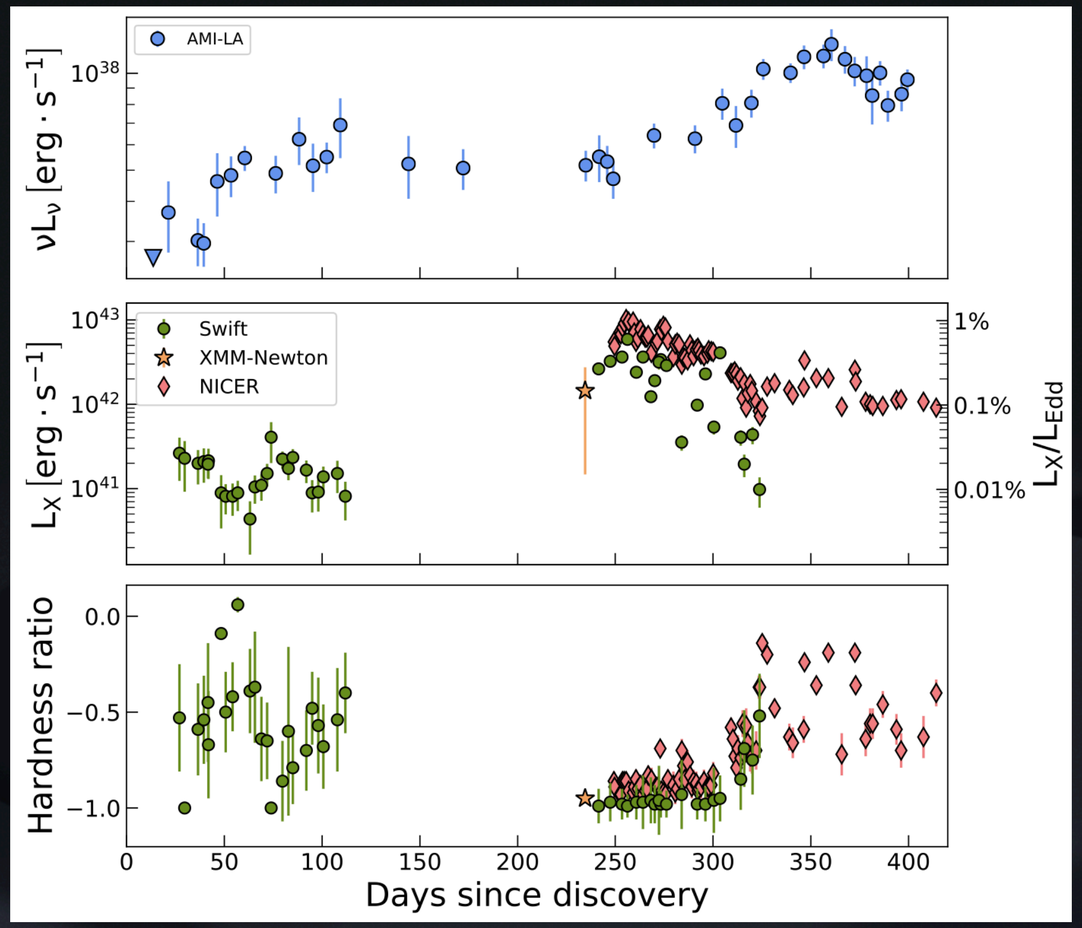



Sfaradi, **Horesh** et al. (2022)

**Crucial Contribution by the AMI Radio Telescope**

# Delayed Radio Flares - Complexity

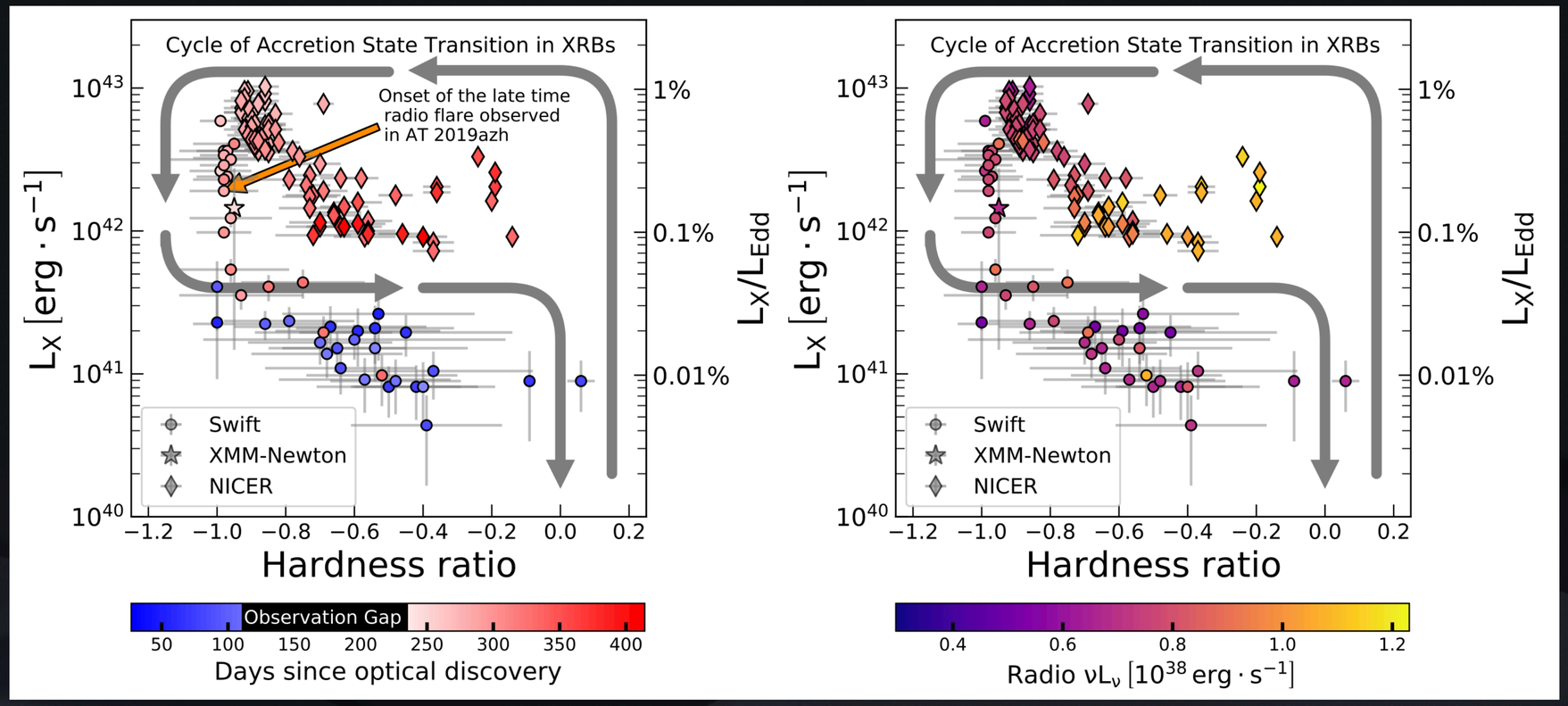
## Both a Delayed X-ray flare and a Delayed Radio flare




Sfaradi, **Horesh** et al. (2022)

# Accretion State Transitions

## A possible explanation (similar to X-ray binary flares)

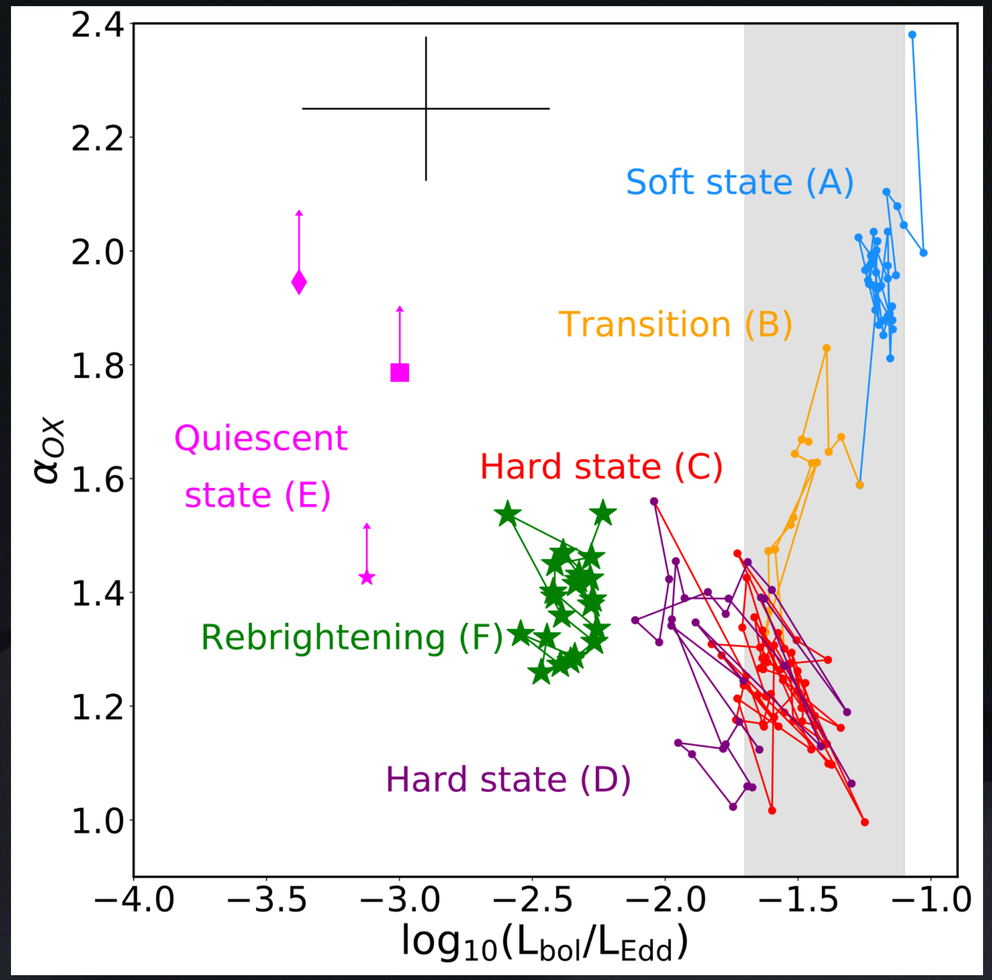



Sfaradi, **Horesh** et al. (2022)

# Indication in previous TDEs

## AT2018fyk

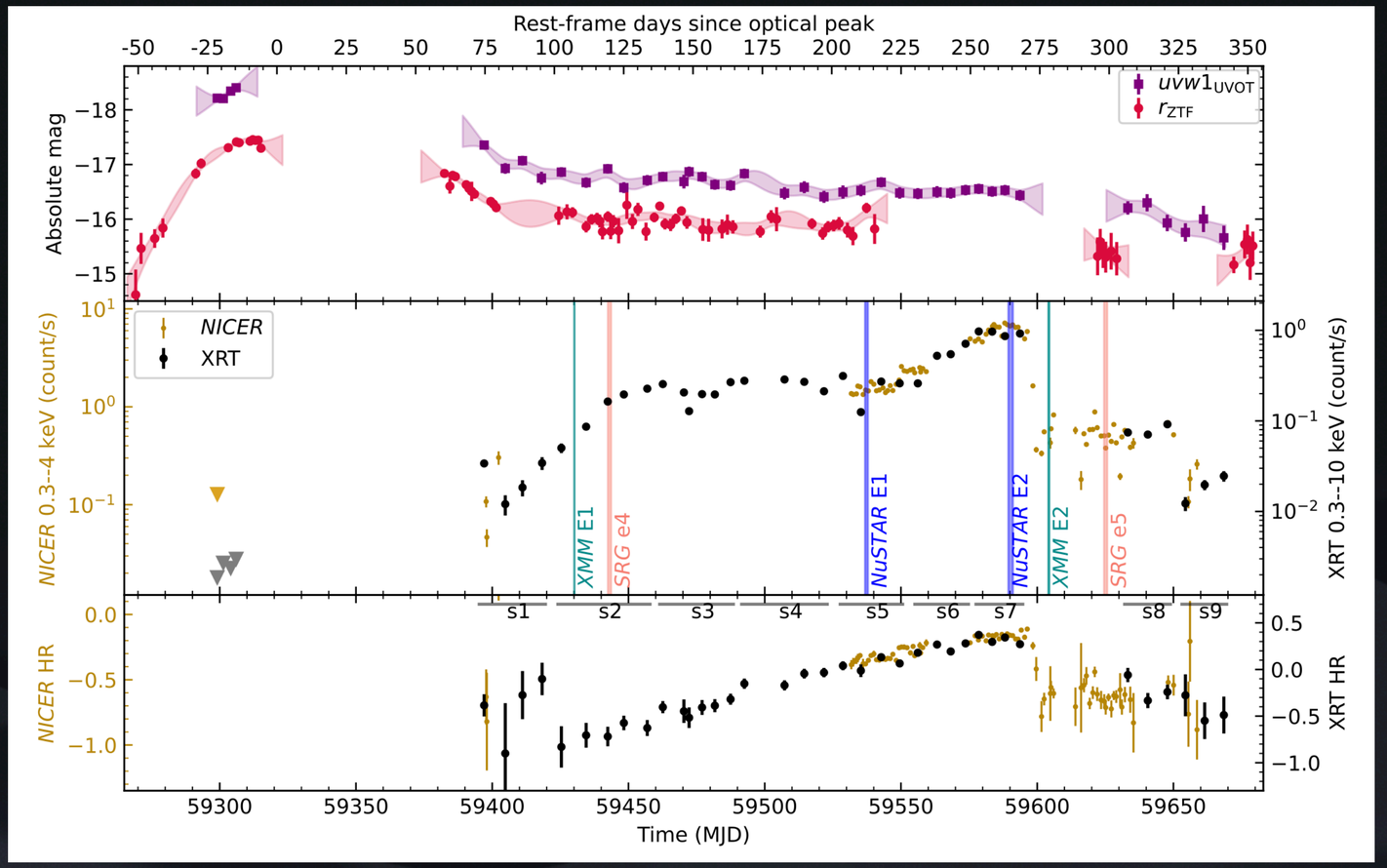
- First rebrightening after ~ 200 days
- Second rebrightening after ~1200 days
- During rebrightening emission transition from soft to hard




Wevers et al. (2021)

# Delayed X-ray flare without radio emission

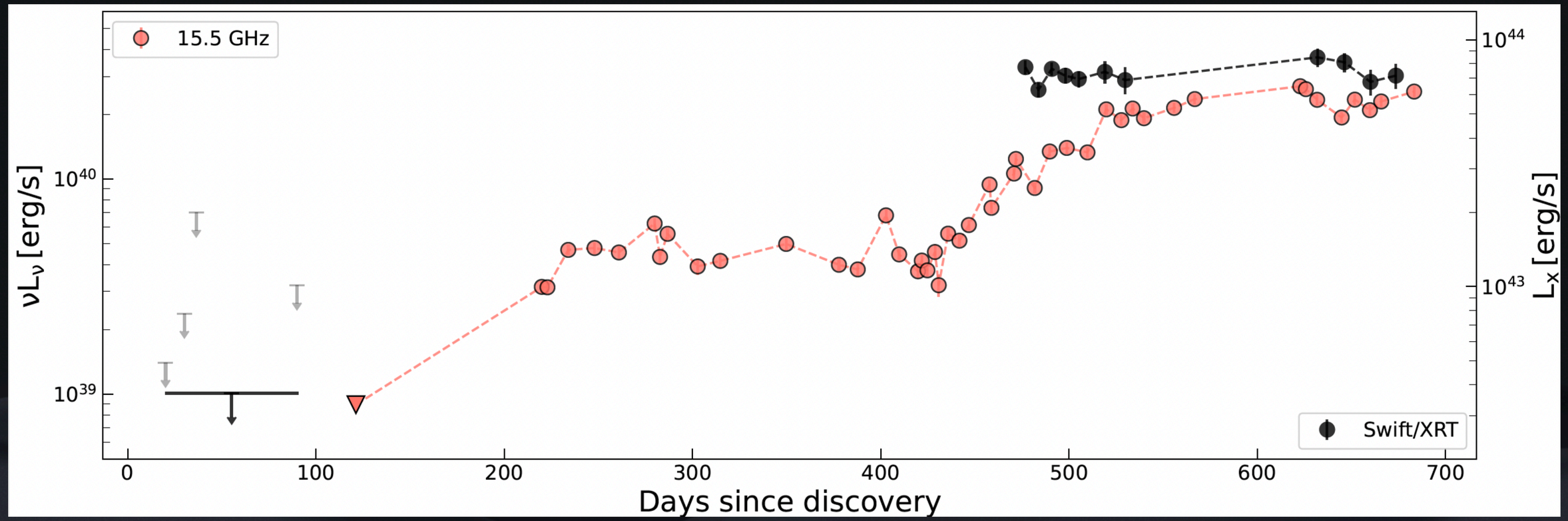
## AT2021ehb




Yao et al. (2022)

# Recent Delayed Flares

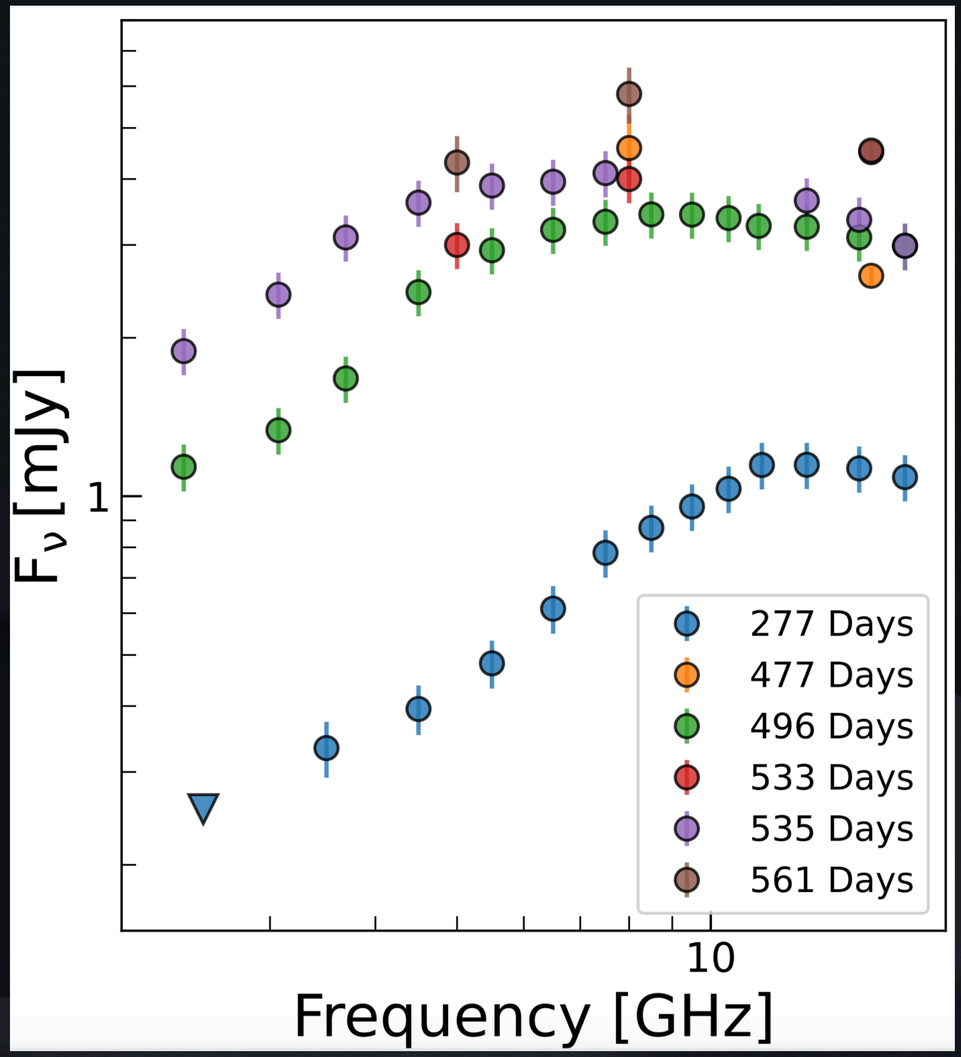
## A common phenomena




**Horesh** et al., in prep

# Recent Delayed Flares

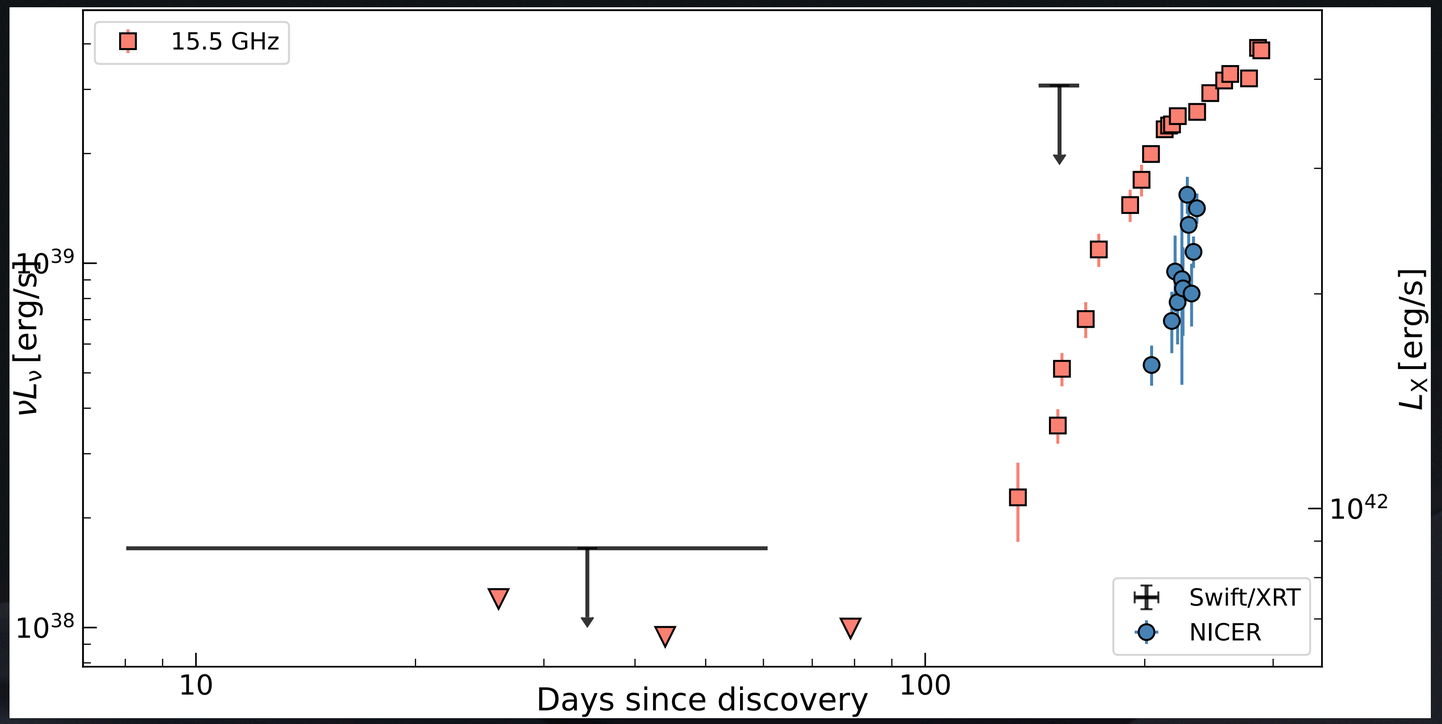
## A common phenomena

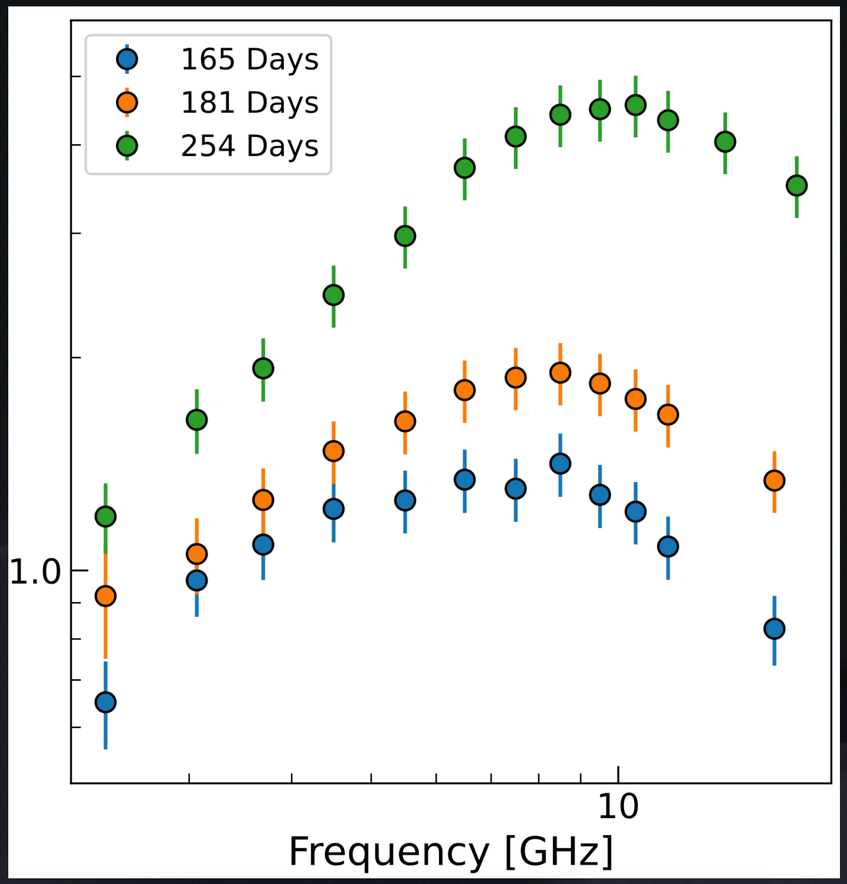



**Horesh** et al., in prep

# Recent Delayed Flares

## A common phenomena



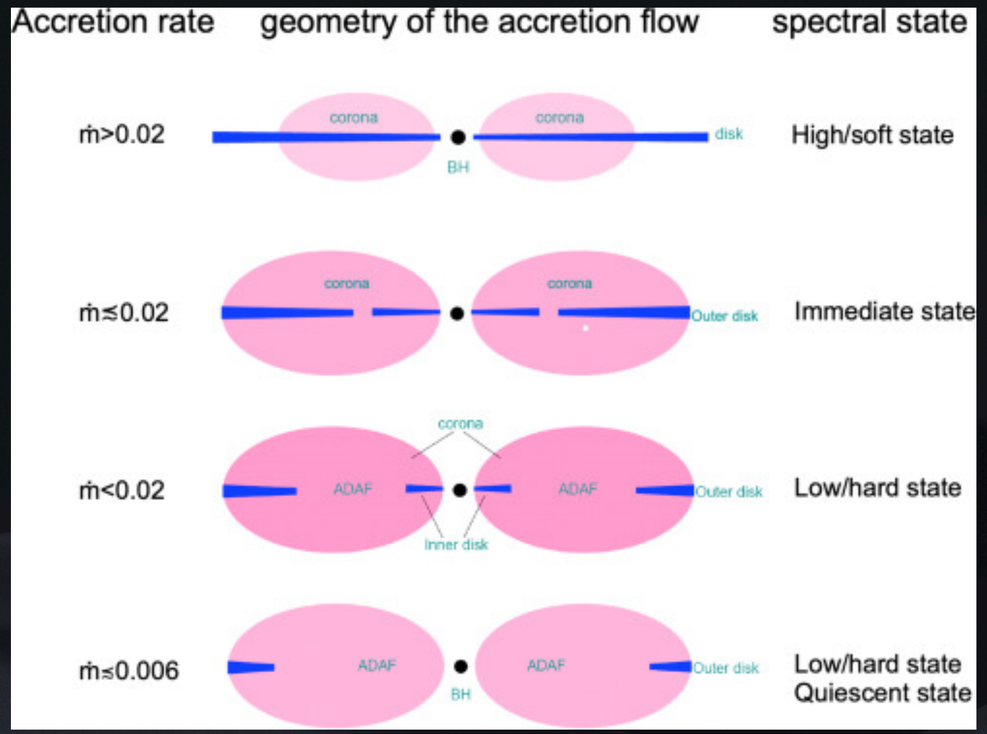




**Horesh** et al., in prep

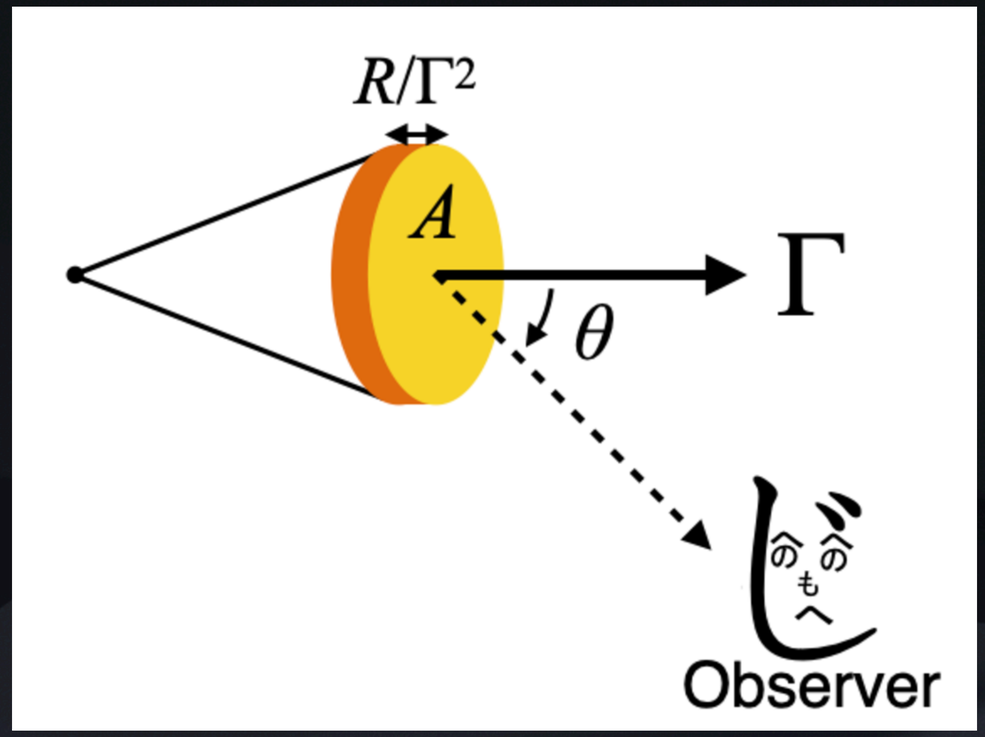
# Possible Explanations

But not limited to…

**Transition in Accretion States**



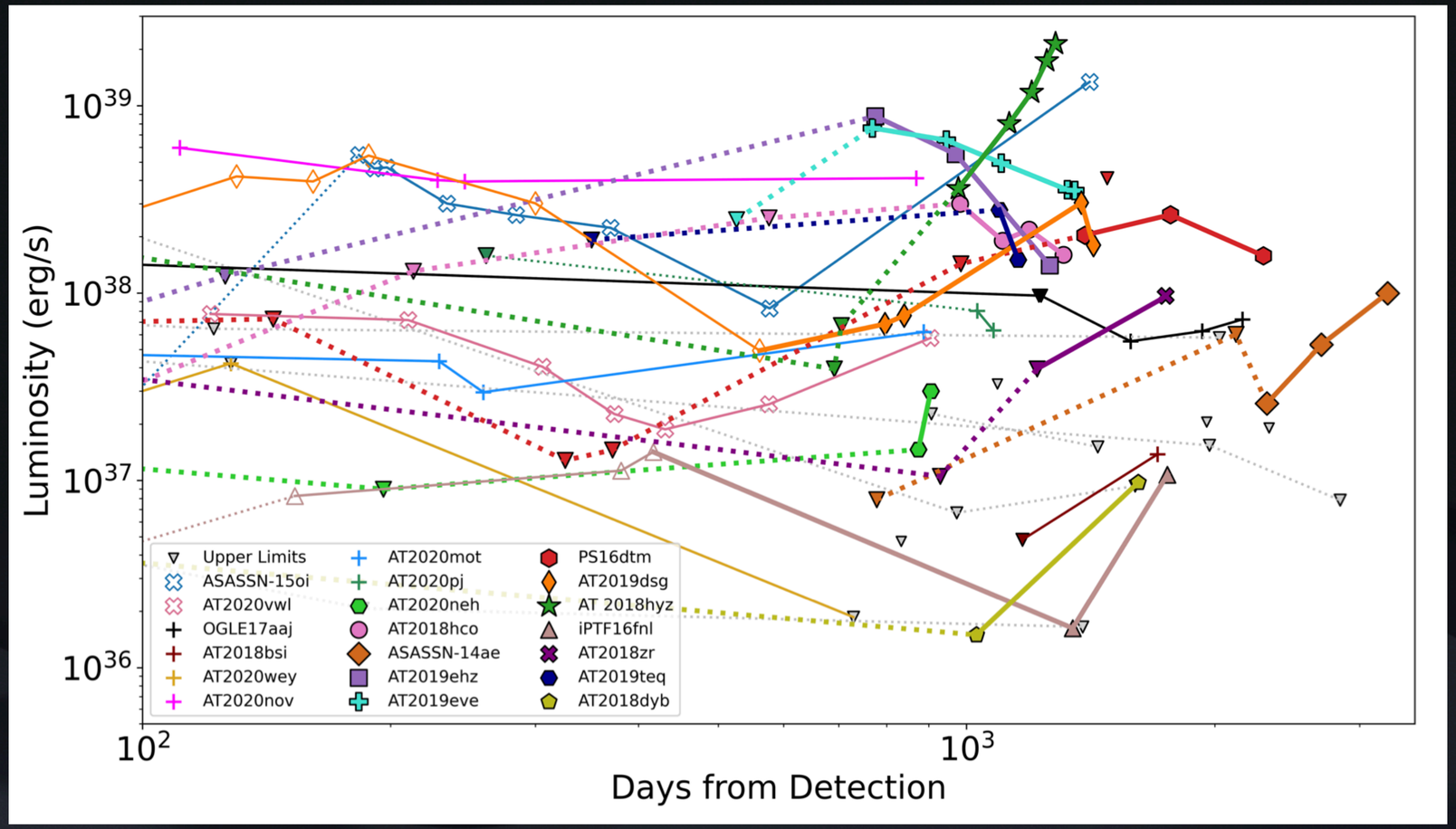

**Large viewing angle off-axis jets**




Matsumoto & Piran (2022)
e.g. AT2018hyz
(Cendes et al. 2022;
Sfaradi, **Horesh**, et al. 2023)

# X-ray rates?

## A common phenomena in radio - Roughly 40% of TDEs




Cendes et al. (2023)

# Summary

Delayed radio flares are a common phenomenon - How common are delayed X-ray flares still remains an open question.

Timescales may range from half a year to a few years.

A zoo of events - diverse properties (light curve, spectral evolution)

Many open questions: accretion related? Jets? Off-axis? Delayed ejecta? Accretion state transition?

Any connection to other late-time phenomenon? Infra-red flares? Neutrinos?

Can we learn something from similarities to AGN knot ejections? X-ray binary flares?

Observational path forward - Combined X-ray and radio monitoring on various time scales and high cadence observations