Energetic nuclear transients in luminous infrared galaxies

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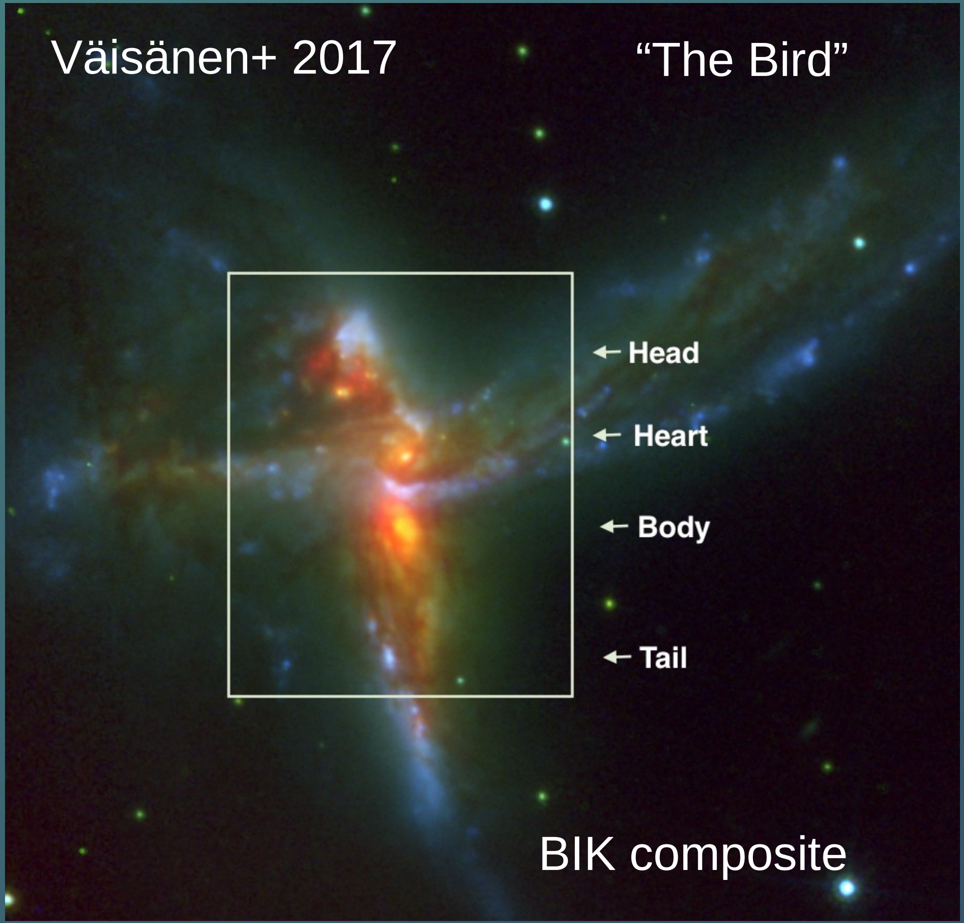
Andreas Efstathiou, Stuart Ryder, Miguel Perez-Torres, et al.

Luminous Infra-red Galaxies (LIRGs)

- Luminous in IR (8-1000 μm): $L_{IR} > 10^{11} L_{\odot}$
- $L_{IR} > 10^{12} L_{\odot}$ => ultraluminous or **ULIRG**
- Radiation from warm dust, heated by a starburst, AGN or both.
- 50% interacting/mergers: connection to TDE rates?
- High star formation rates
  => can produce a few core-collapse supernovae per year!
- Have been subject of SN searches – see Jencson talk yesterday.

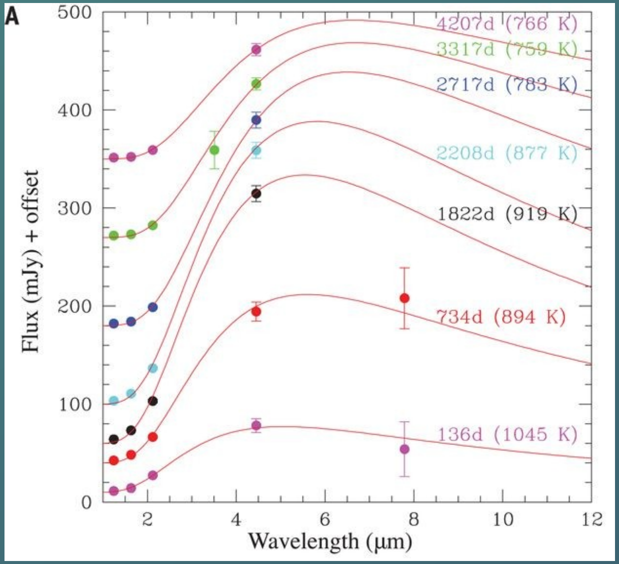
For a review, see Perez-Torres+ 2021

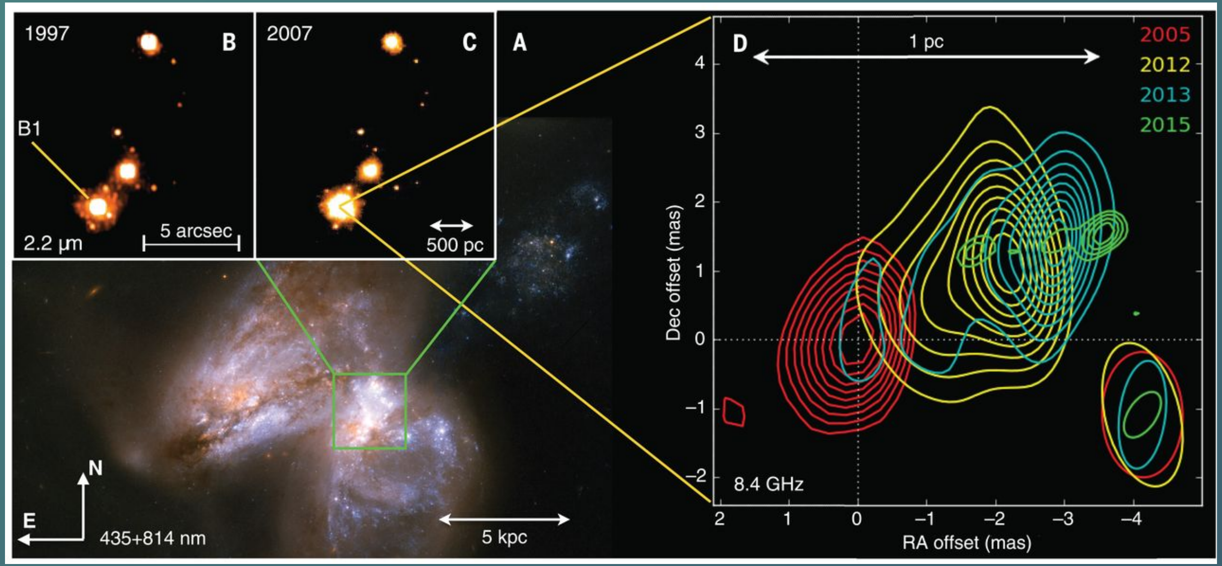


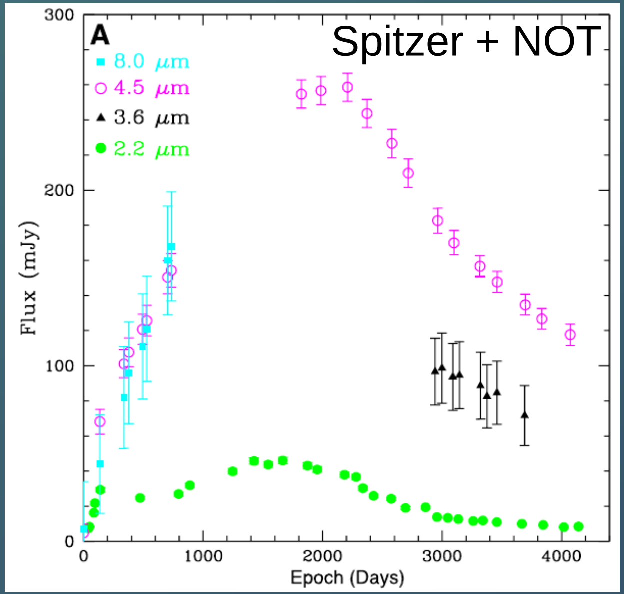
Arp299-B AT1

Mattila+ 2018

- **Discovered in NIR** search for dust obscured (SNe) in LIRGs.
- Long lived: 2005-2022+ => Radiated > 10^{52} erg
- **Not luminous in the optical or X-rays** => heavily obscured.
- Evolution consistent with IR echo from dust (see Van Velzen talk).
- **Resolved radio jet** provides strong case for TDE.
- Member of a population of TDEs hidden in optical, UV and X-rays?

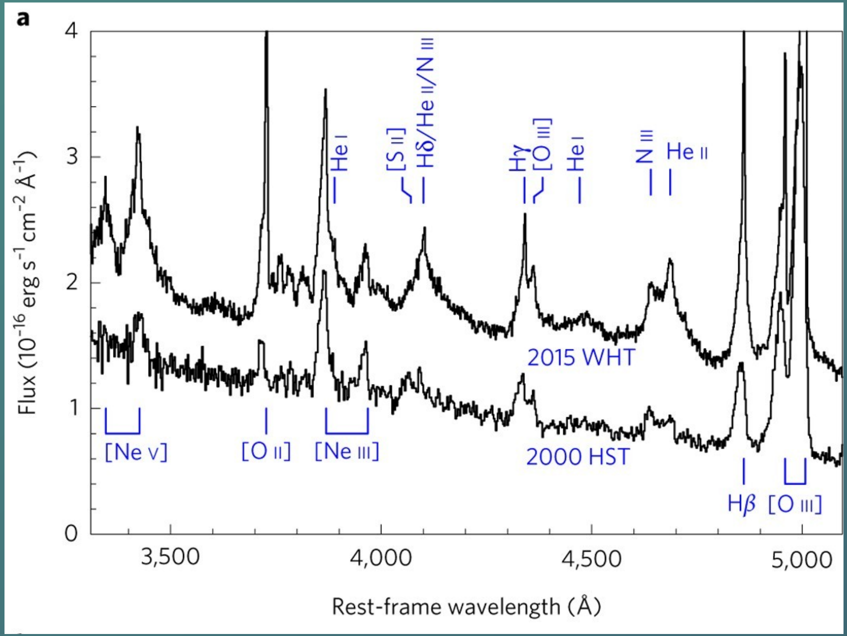






More nuclear outbursts in LIRGs

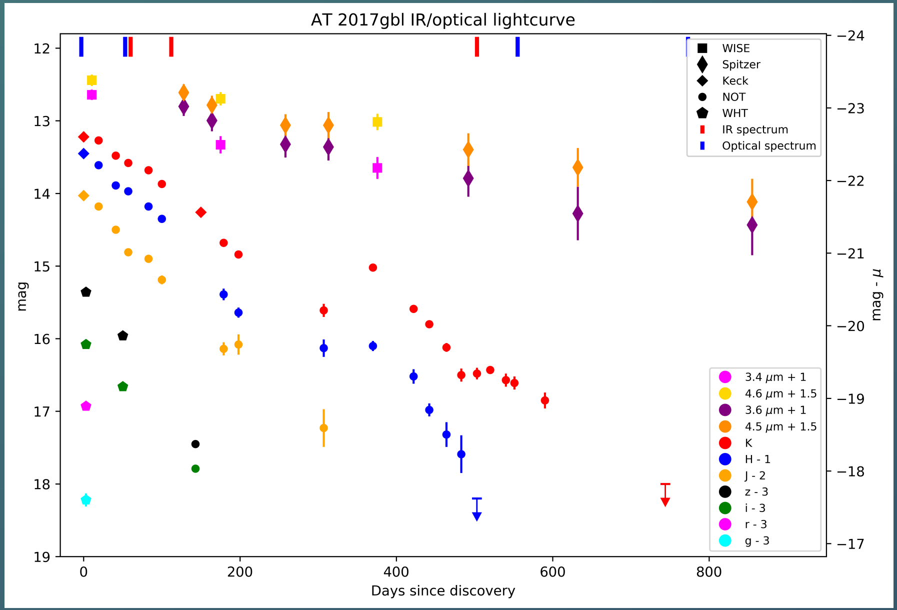
- Luminous transient in ULIRG IRAS F01004-2237
- Discovered in optical spectroscopy.
- AGN related flare or TDE? Debated!
- Evidence for a double AGN - Efstathiou+ 2021.



Tadhunter+ 2017, Dou+ 2017, Trakhtenbrot+ 2019, Frederick+ 2021, Tadhunter+ 2021, Cannizzaro+ 2021

- **AT 2017gbl**: discovered in LIRG with NIR imaging
- Luminous in IR and radio, faint in optical.
- TDE found to be the most plausible explanation
- Part of SN survey so yields rate:

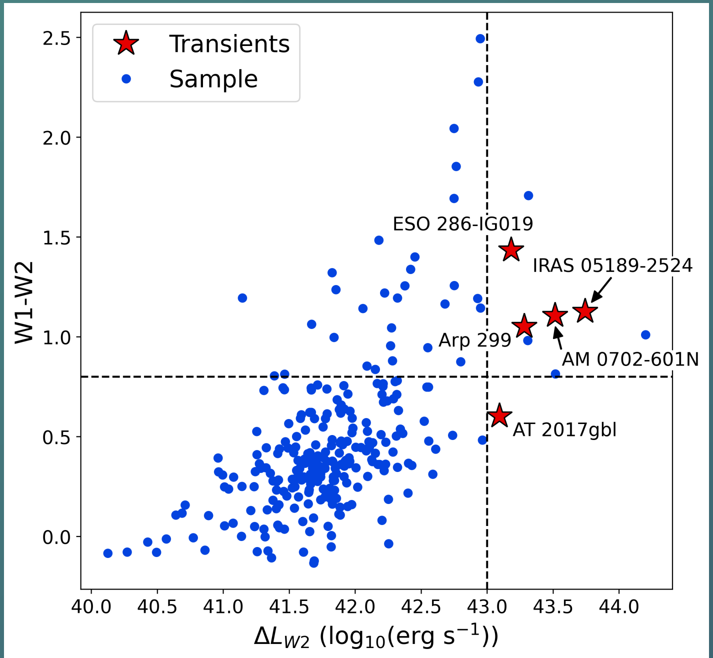
$10^{-1.4}$ – $10^{-2.8}$ events LIRG^{-1} year^{-1}



Kool+ 2020

Survey with NEOWISE

- 6 month cadence from 2013 – 2020+.
- 3.4 μm and 4.6 μm – optimal for detection of IR echos.



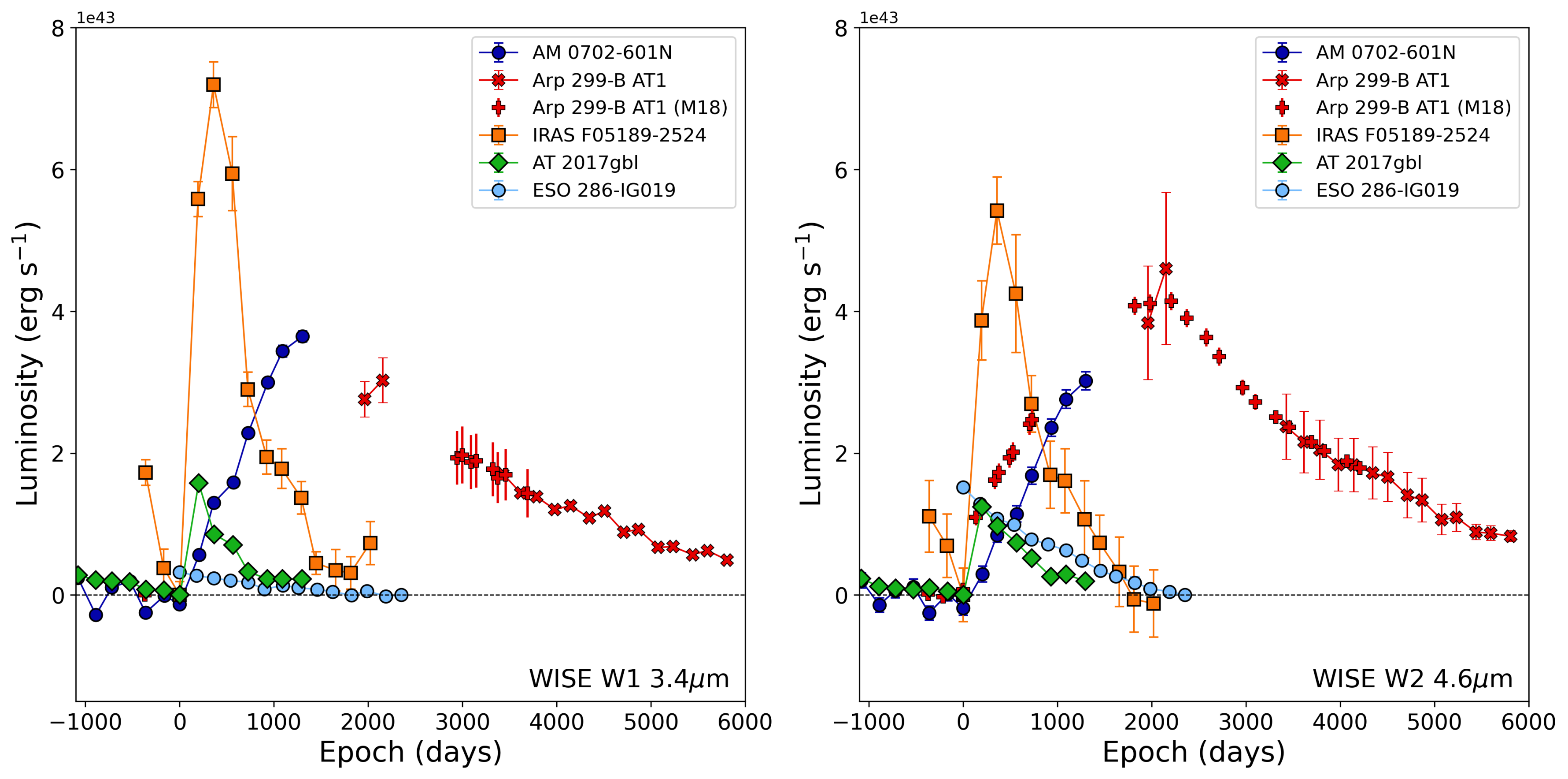
Our Sample

- U/LIRGs in Sanders revised bright galaxy sample:
  215 galaxy systems, 280 nuclei
- Luminosity constraint for selection:
  $L_{max} - L_{min} > 1\times10^{43}$ erg s^{-1}
- Filter out known AGN that show stochastic IR variability.
- Result:
  5 smoothly evolving luminous transients,
  3 new discoveries

Reynolds+ 2022

Luminosity evolution

Variety in light curve properties



Reynolds+, 2022

Luminosity evolution

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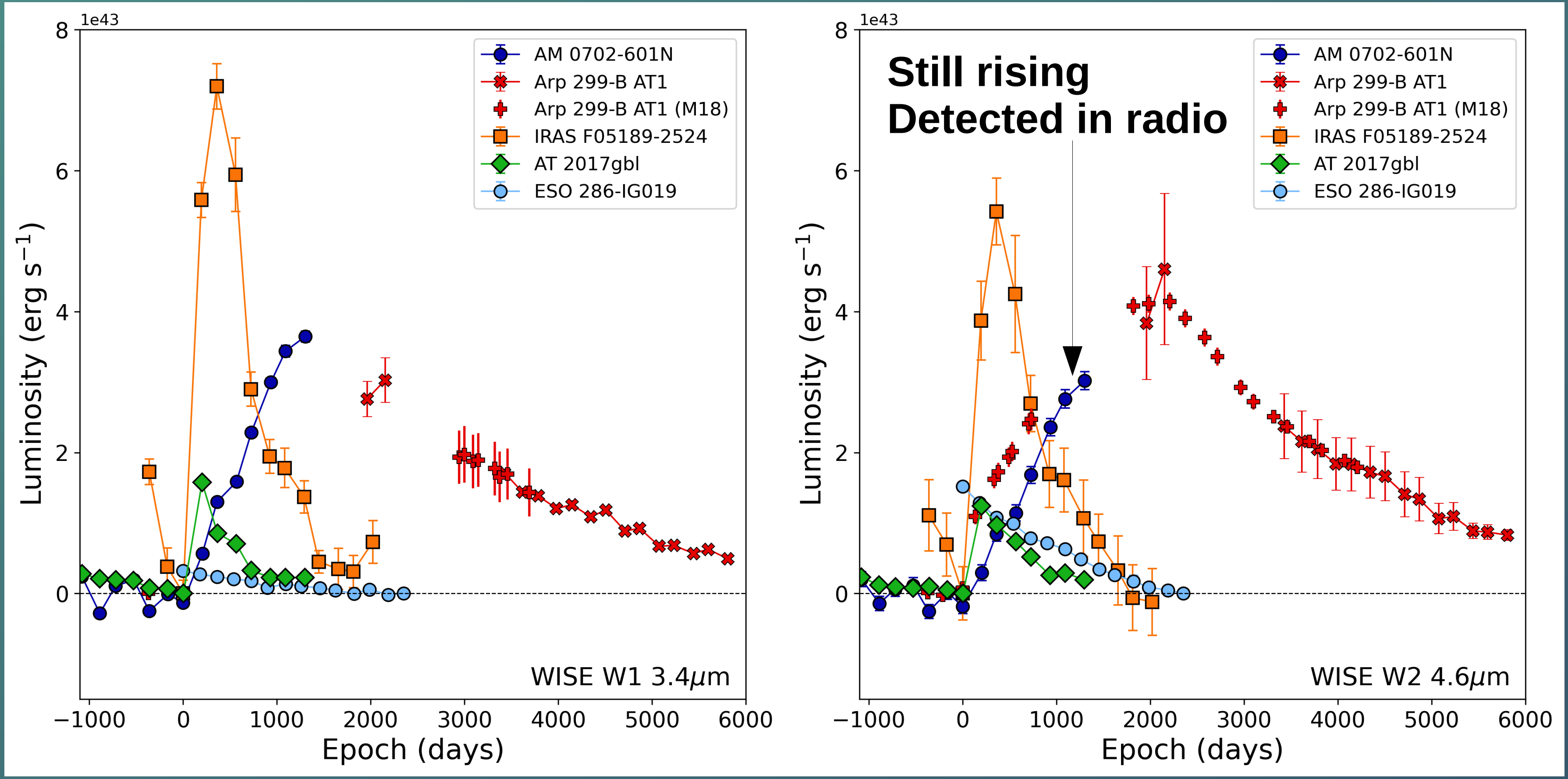
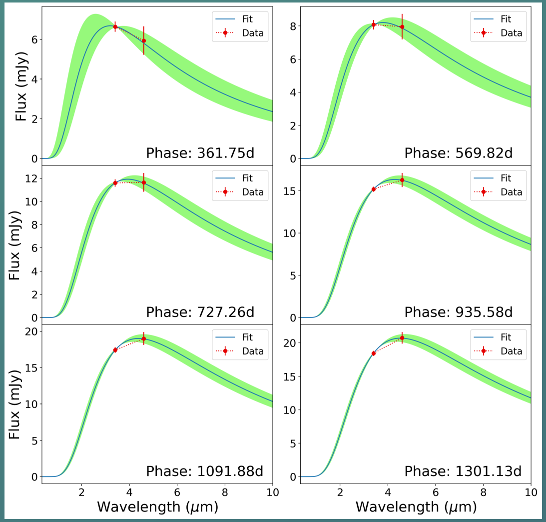


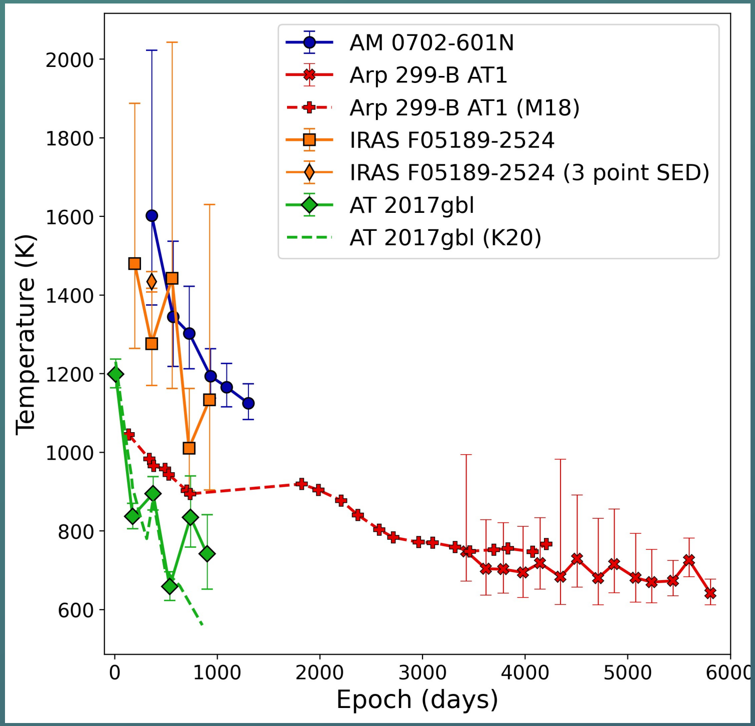
Reynolds+, 2022

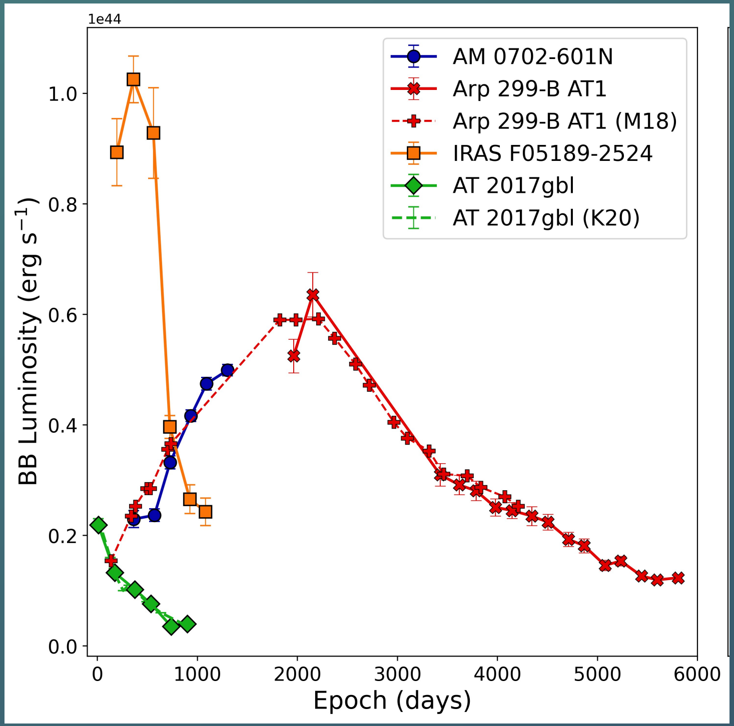
Blackbody fitting

- Crucial for determining the energetics
- Blackbody temperatures consistent with IR echoes from dust

- Fits with two points = large uncertainties







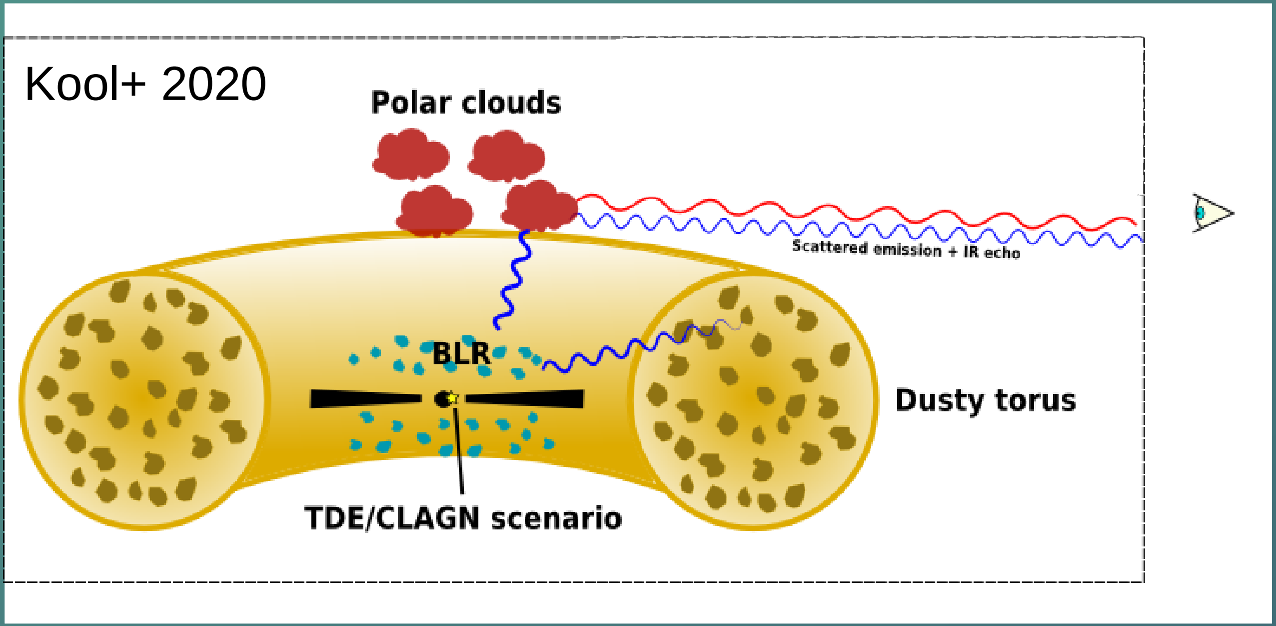
Reynolds+ 2022

- Large total radiated energy – transient bolometer.
- More energetic than supernova or "normal" TDE.
- Dust temperature measurement for IRAS05189 and AM0702 consistent with evaporation temperature.

Transient	Peak $L_{3.4\mu m}$ $\log_{10}(\mathrm{erg\ s^{-1}})$	Peak $L_{4.6\mu m}$ $\log_{10}(\mathrm{erg\ s^{-1}})$	Rise time days	Total Energy $\log_{10}(\mathrm{erg})$	Max dust T K
IRAS F05189−2524	43.9	43.7	360	51.8	1470^{+400}_{-220}
AM 0702-601N	>43.6	>43.5	>1301	>51.6	1590^{+380}_{-230}
ESO 286-IG019	>42.6	>43.2	-	-	-
AT 2017gbl	43.2	43.1	197	50.9	1200^{+40}_{-30}
Arp 299−B AT1	43.5	43.7	2208*	>52.2	1045^{+7*}_{-7}
IRAS F01004−2237	44.2	44.3	>2183	>52.1	850
SN 2010jl	42.3	42.2	~600	50.43	2040
ASASSN-14li	41.3	41.1	<21	49.5	1340^{+276}_{-276}
ASASSN-15lh	43.2	43.2	562	51.4	1360^{+330}_{-330}

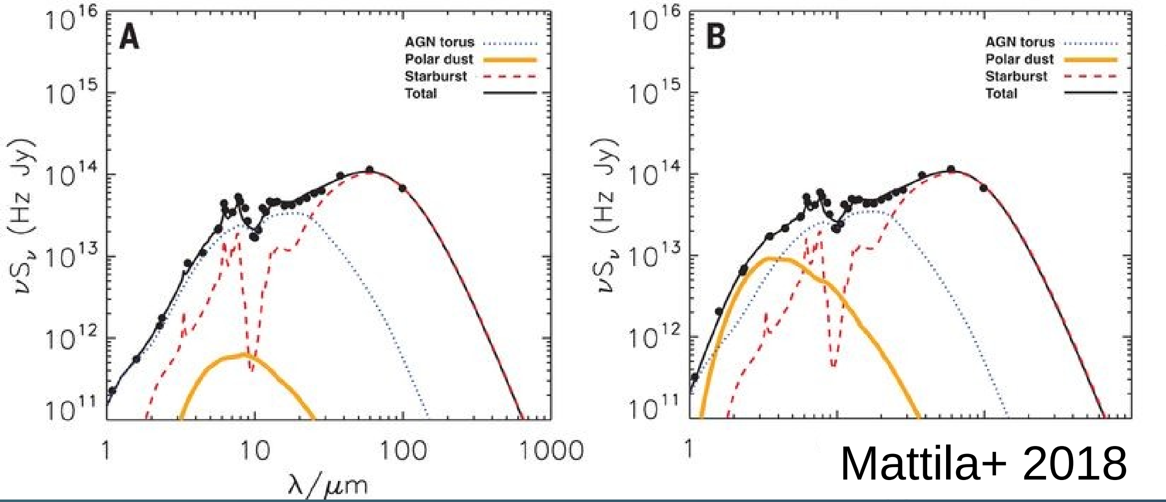
TDEs (ASASSN-14li, ASASSN-15lh)

Reynolds+ 2022, Kool+ 2020, Mattila+ 2018, Dou+ 2017, Fransson+ 2014, Jiang+ 2021



- IR emission consistent with dust in the polar regions of the AGN torus

- Evidence for obscured AGN from SED fitting implies very large extinctions in line of sight.



SED fitting methods:
Efstathiou+ 1995,2000,2009,2013,2021

Rates

- Our survey finds:
  $10^{-2.3}$-$10^{-2.8}$ transients $LIRG^{-1}$ $year^{-1}$ (1σ)

- >2 orders of magnitude higher than MIRONG survey of ~10^6 low-z SDSS spectroscopic galaxies performed by Jiang+ 2021a, who found **5.4×10^{-5}** events $galaxy^{-1}$ $year^{-1}$.

- Lawrence+ 2016 found **0.1 – 0.01% of AGN** show "extreme" optical variability
  ~2% of our sample show transients

- TDE rates in optical are **10^{-4} $galaxy^{-1}$ $year^{-1}$**
  (Van Velzen+ 2021).

- Possible explanations for higher TDE rate:
  - Galaxy mergers => dual SMBHs (Li+ 2019)
  - Enhanced stellar densities in nuclear regions (Stone & Van Velzen 2016)

Are we observing TDEs?

- **Supernova?**
  - Total radiated energy rules out even the most luminous Type IIn SNe such as SN 2010jl. (Szalai+ 2019)
  - Radio properties also inconsistent in cases where we have data.

- **Changing-look AGN (CLAGN)?**
  - Macleod+ 2016 & 2019: CLAGNs exhibit multi-year optical variability – we don’t see this.
  - In cases where optical is obscured, IR LC sets limit on length of underlying optical flare.

- **Tidal Disruption Event?**
  - Radio jet provides compelling evidence in case of Arp299-B AT1 .
  - Multi-wavelength followup required for secure determinations.

A different population of TDEs?

- Optically discovered TDEs have selection bias towards non-AGNs (Van Velzen+ 2020) and dust free galaxies (Jiang+ 2021b).
- Our transients are all occurring in AGNs – they may not look similar to optically discovered TDEs
  - Interaction between AGN disc and TDE can change properties (Chan+ 2019).
- All our transients occurring in regions with lots of dust!
- Elevated TDE rate has implications for galaxy evolution and feedback.
- Optical surveys (even LSST!) will continue to miss these transients in many cases
  - Opportunity for Roman!

Conclusions

1) We are discovering a population of nuclear transients, likely TDEs, that are hidden from optical surveys.

2) The transients are occurring in LIRGs that harbour hidden type 2 AGNs.

3) They are occurring at higher rates than would be expected of normal galaxies.

4) There are implications for galaxy evolution and our understanding of TDE rates.

5) Only IR observations can discover them – Roman will be crucial in the future!

Please read our paper here! → ArXiv: 2202.04019