A tidal disruption event in Arp 299 with much of its emission reradiated at infrared wavelengths

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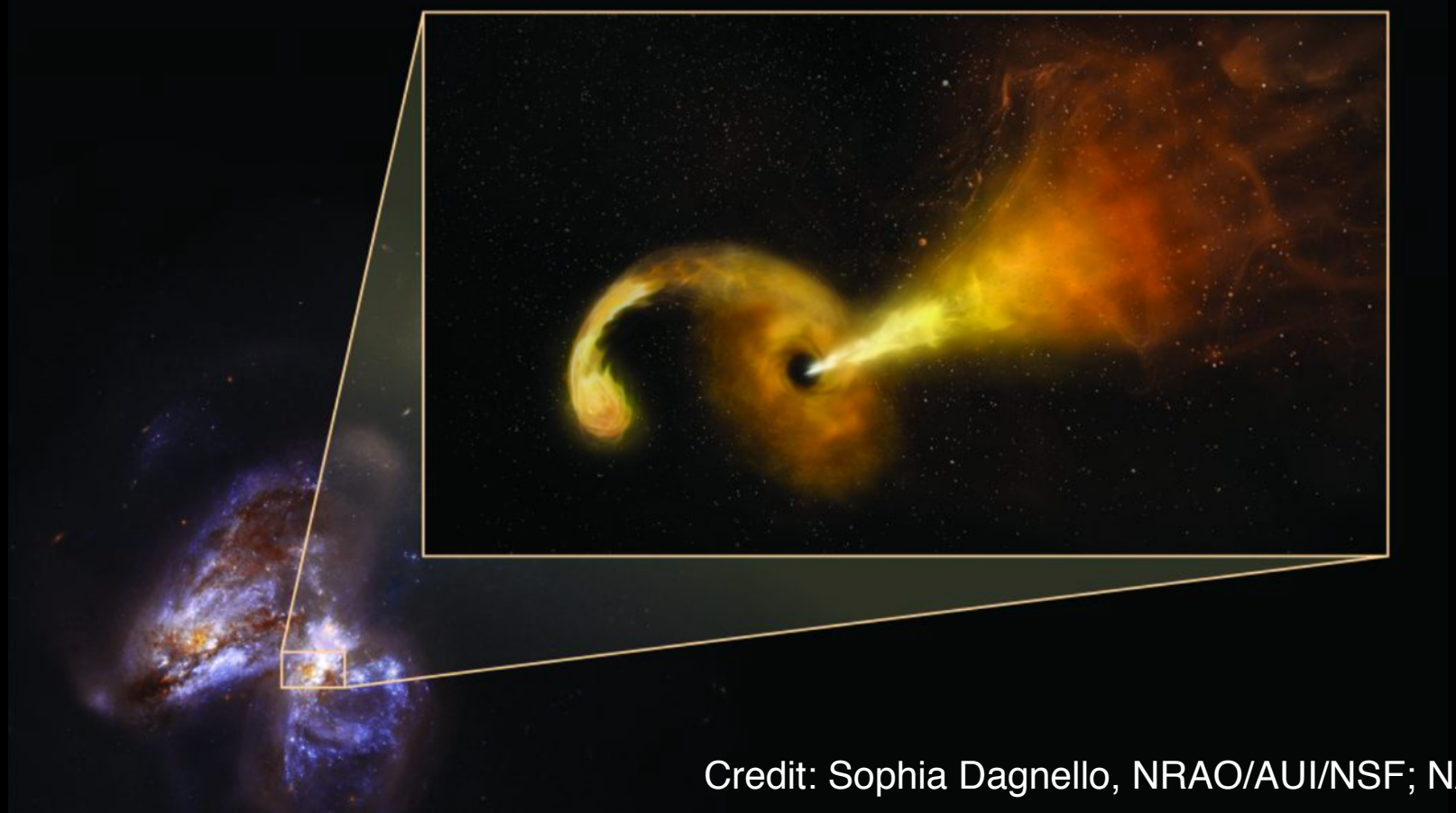
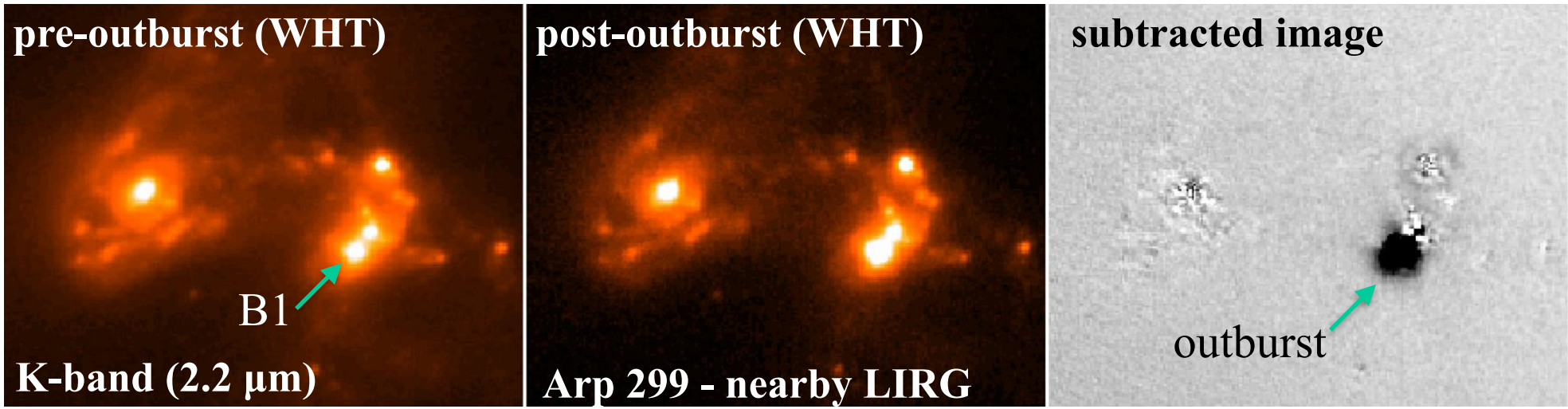
Miguel Perez-Torres, Andreas Efstathiou, Petar Mimica,
Morgan Fraser, Erkki Kankare, Almudena Alonso-Herrero et al.



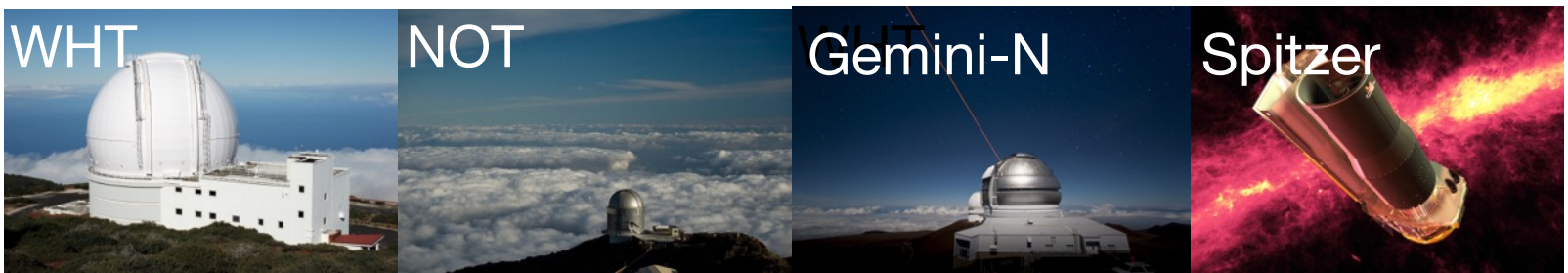
Credit: Sophia Dagnello, NRAO/AUI/NSF; NASA, STScI

Infrared discovery and follow-up

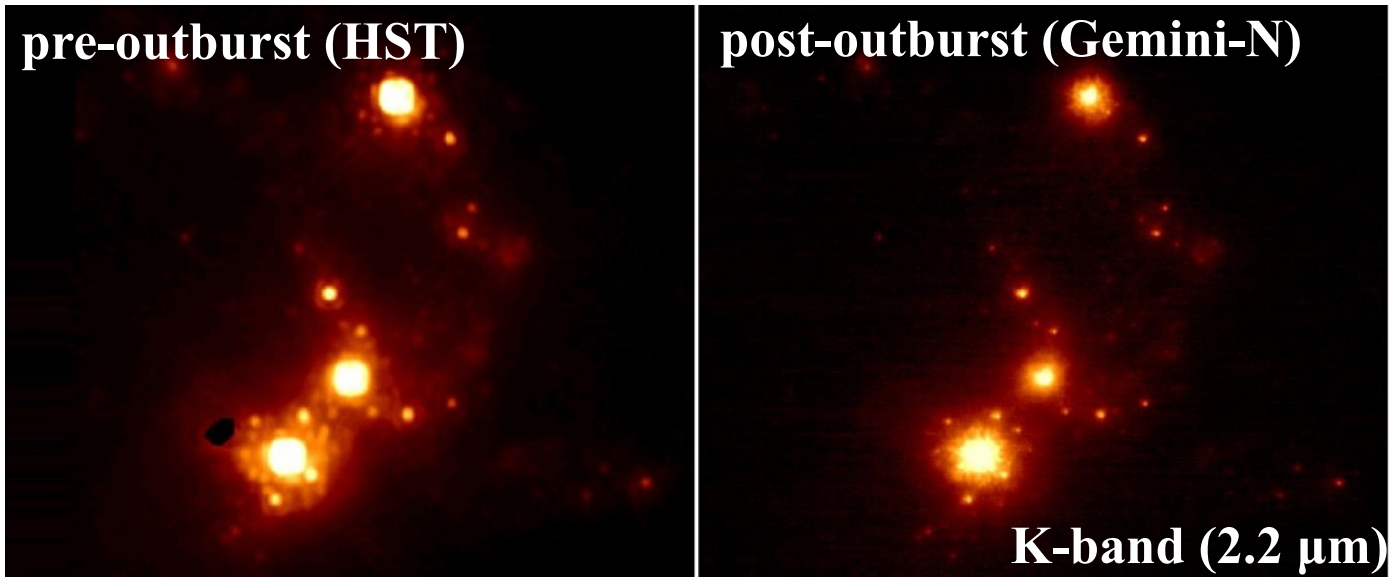


- A systematic near-IR search for nuclear supernovae in starburst galaxies using the WHT
- Discovery of an extremely luminous nuclear outburst in the near-IR (2.2µm) in Jan. 2005
- That time only detected in the IR, in the optical completely obscured by interstellar dust

Mattila+2005, IAU Circ. 8477

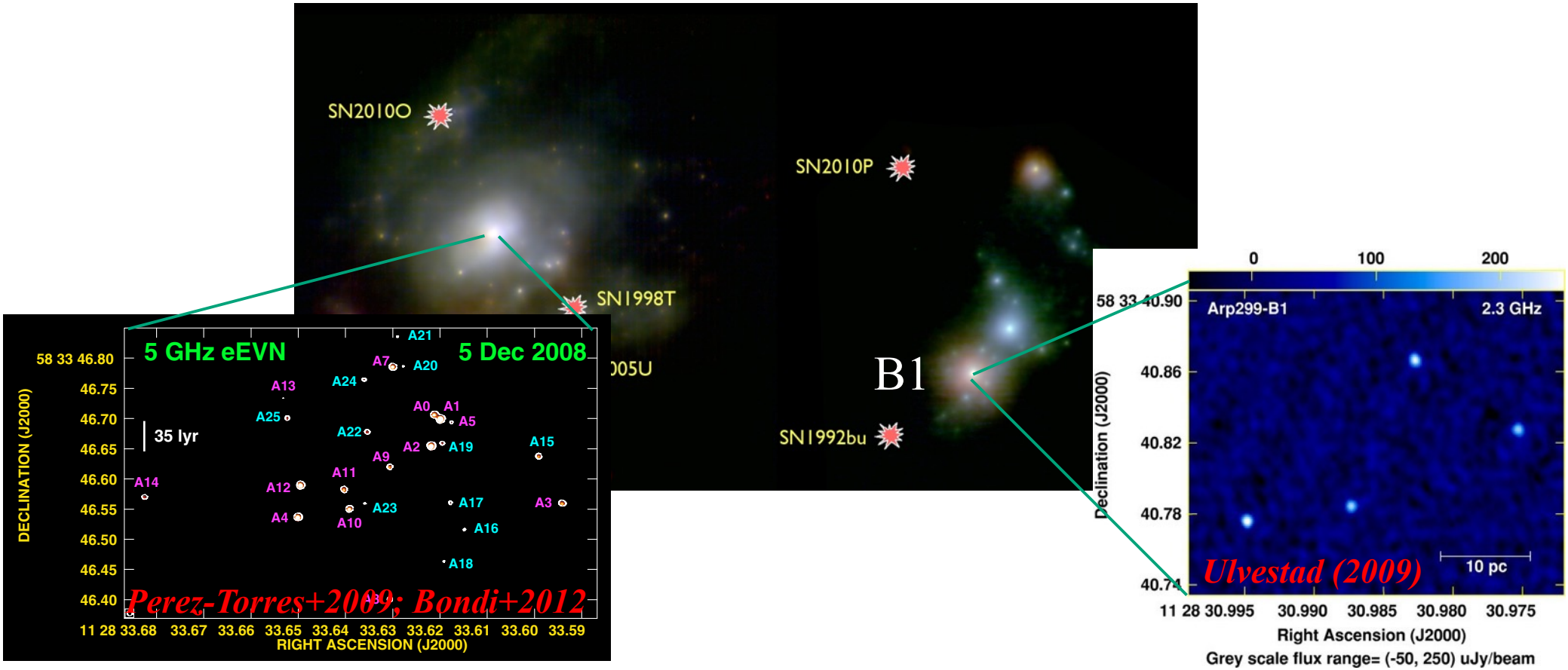


Nuclear location from Adaptive Optics imaging

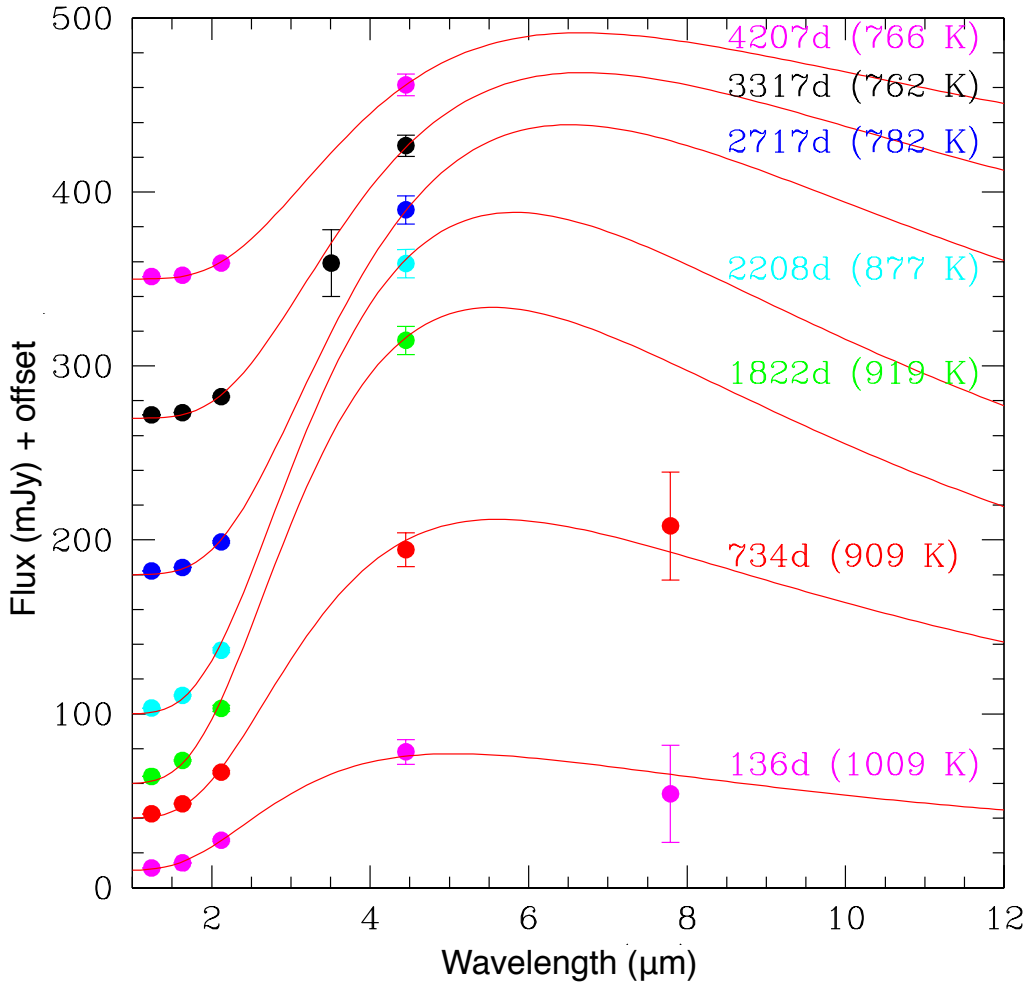


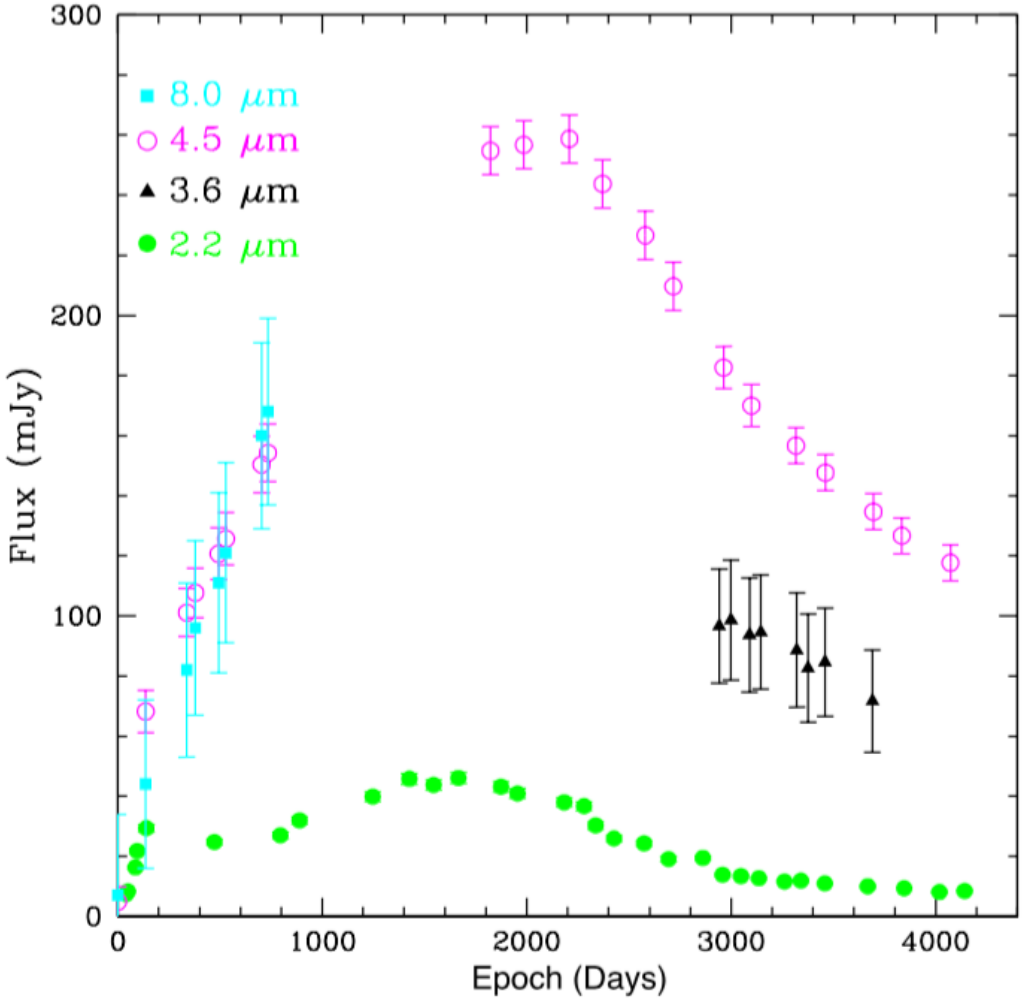
- Adaptive Optics (AO) assisted near-IR imaging with 0.1” spatial resolution compared with pre-explosion HST imaging
- The outburst is co-incident with the *K*-band nucleus within 0.030” (~6 pc), and its position stable in 10 epochs of AO observations in 2007 - 2012

Mattila, Perez-Torres et al. 2018, Science



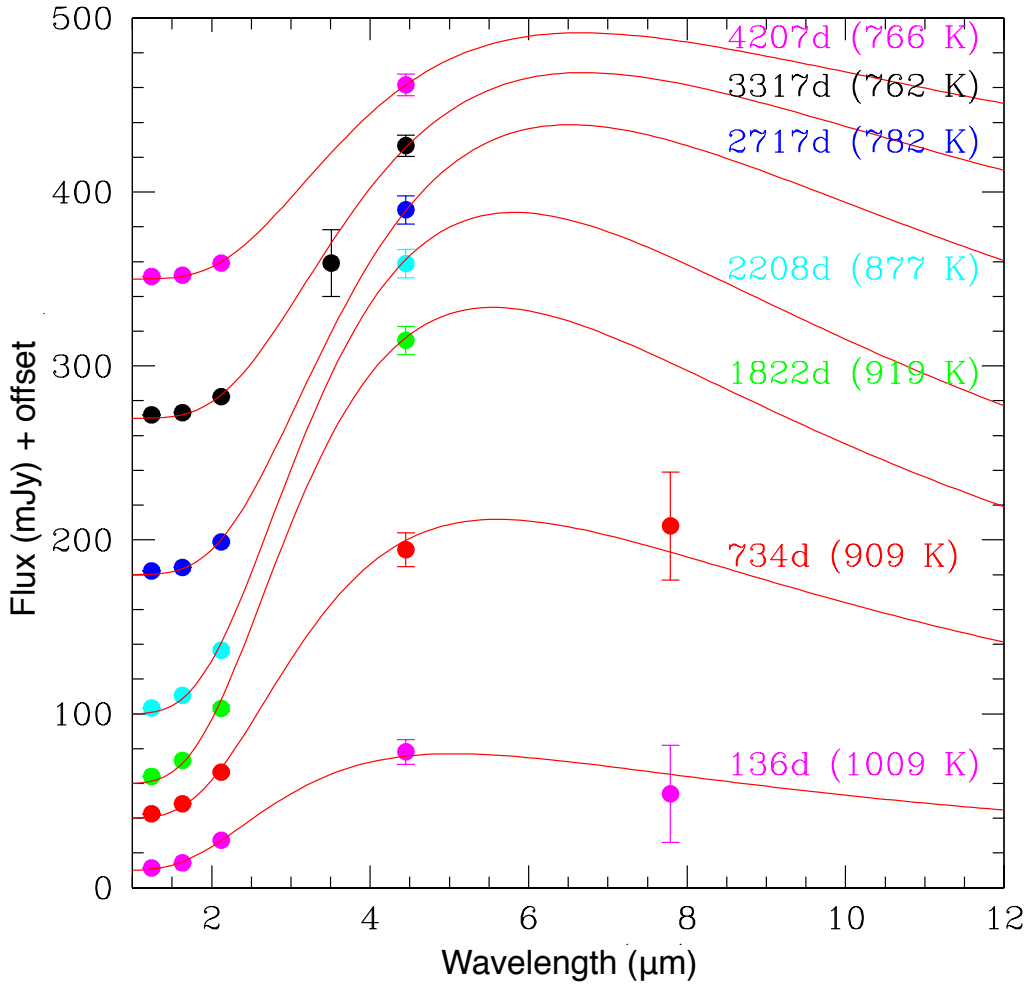
- The merging pair Arp 299 is one of the brightest (L_{IR} = 7x10^{11} $L_\odot$) nearby (45 Mpc) luminous infrared galaxies with SFR ~150-200 $M_\odot$ yr^{-1} and expected core-collapse SN rate ~2 SN/yr and hosting a Compton thick AGN (N_H = 3x10^{24} cm^{-2}) in the B1 nucleus
- Consider two broad scenarios: *(i)* event unrelated to the SMBH (e.g. a supernova) or *(ii)* SMBH related event (e.g. an AGN flare or a tidal disruption event)

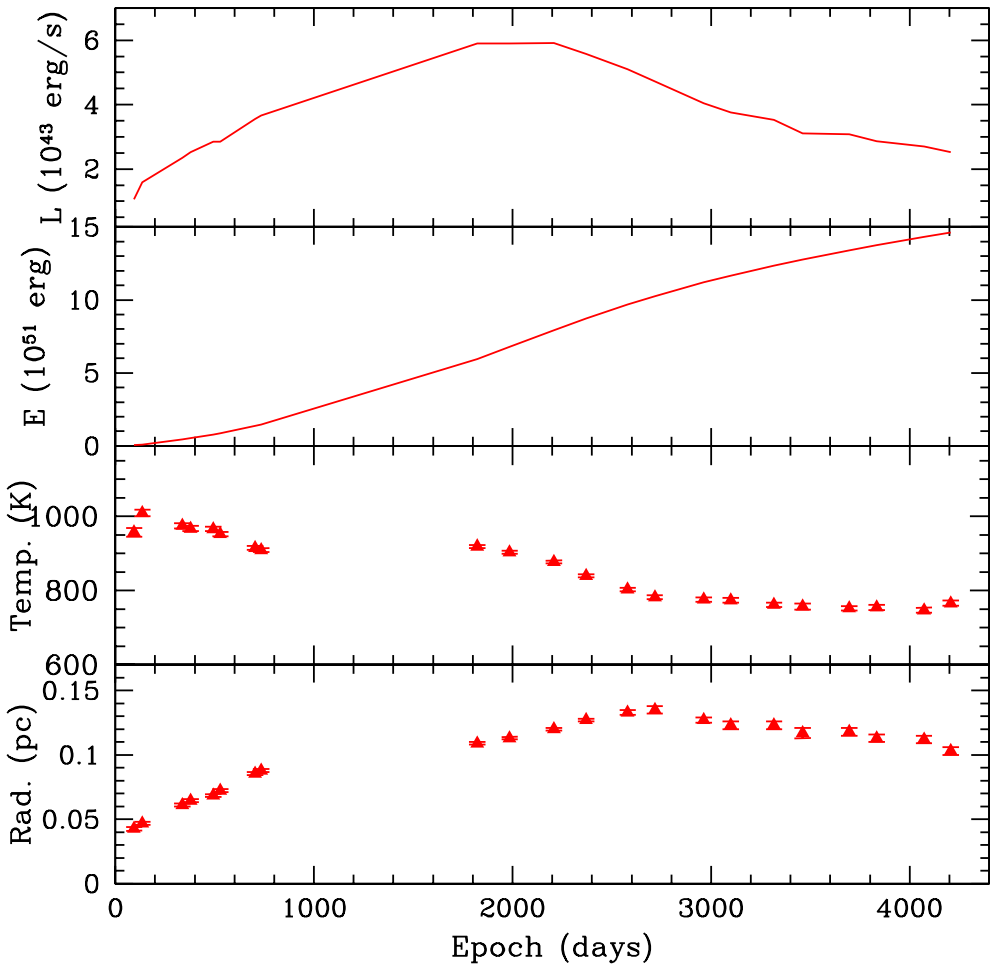




- The shape of the IR SED very close to a single component blackbody, indicating a narrow range of dust temperatures and relatively low foreground extinction

Mattila, Perez-Torres et al. 2018, Science



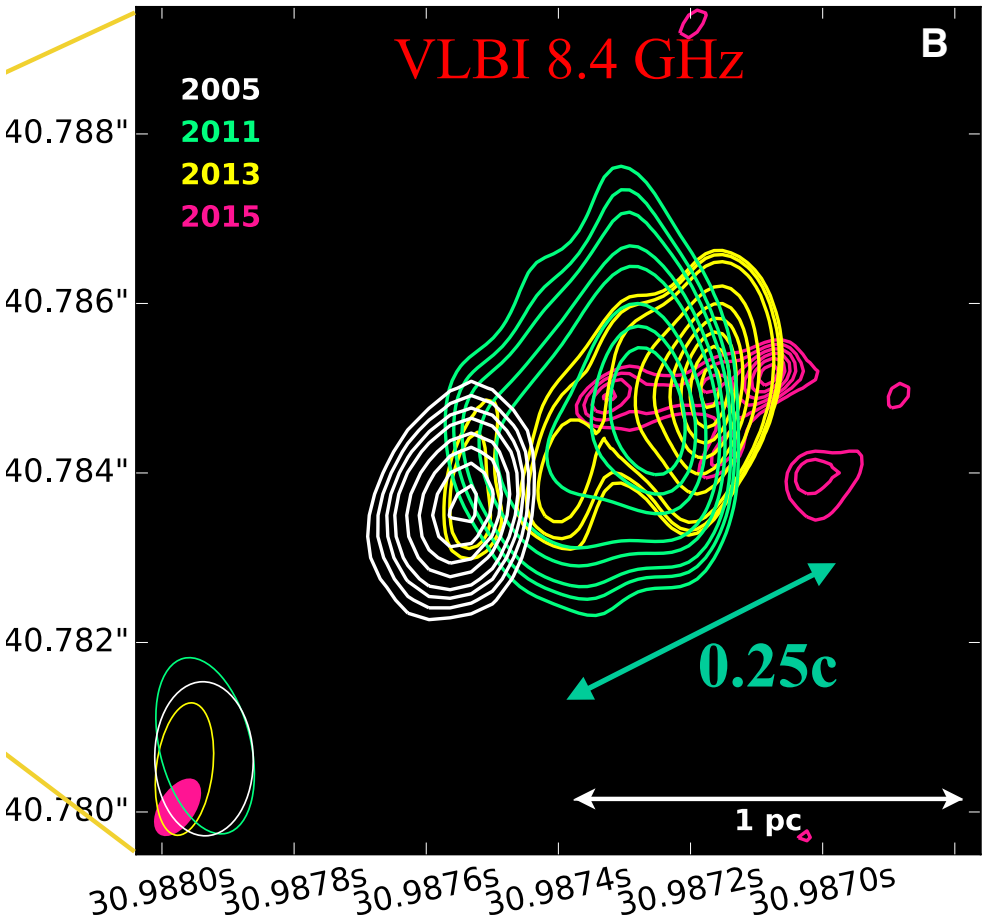


- The shape of the IR SED very close to a single component blackbody, indicating a narrow range of dust temperatures and relatively low foreground extinction
- Blackbody radius expands from 0.04 to 0.13 pc while temperature cools from 1000 to 750 K, peak luminosity of ~6×10^{43} erg, and total radiated energy of ~1.5×10^{52} erg

Mattila, Perez-Torres et al. 2018, Science

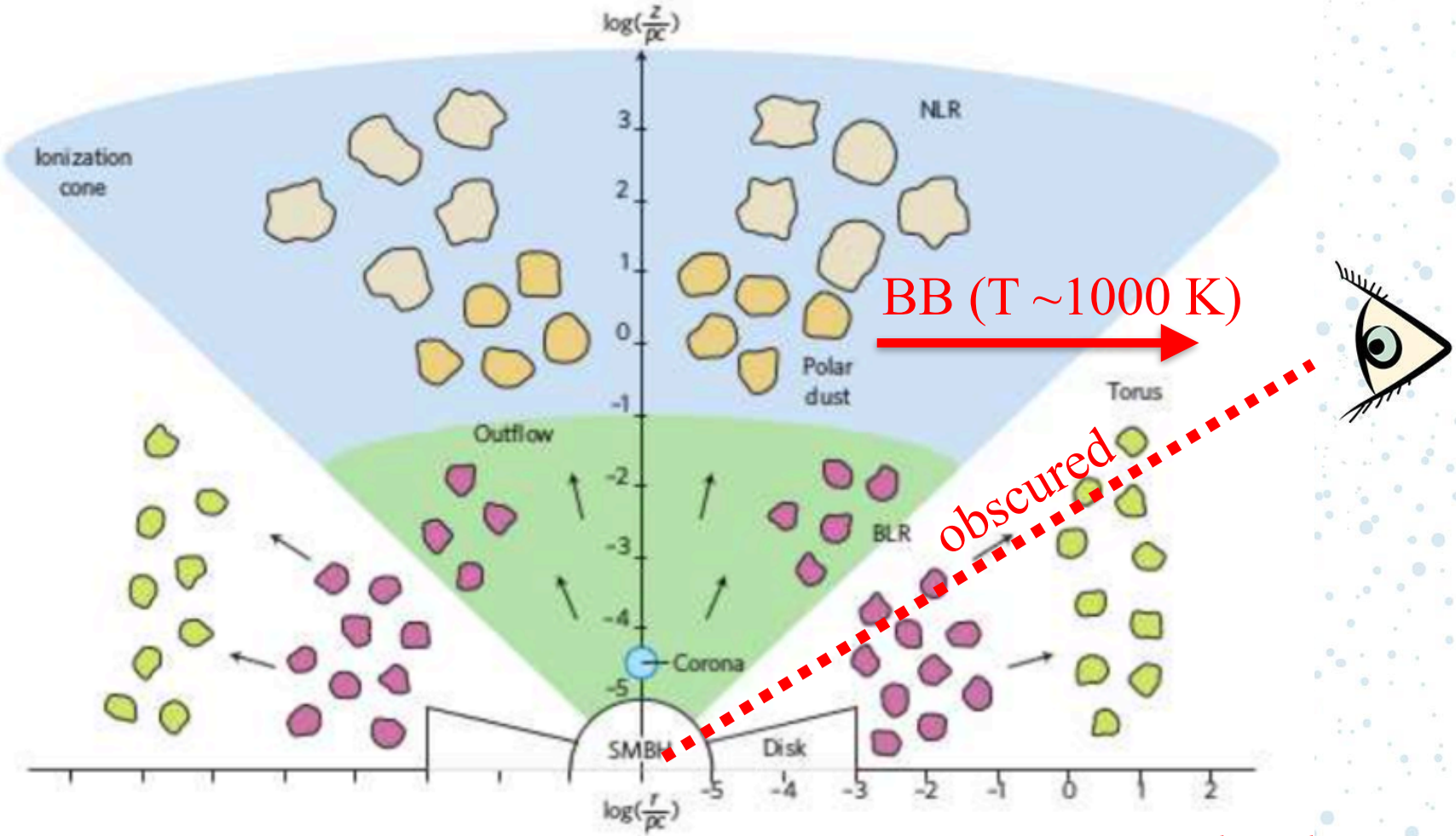
Radio evolution from the VLBI at milliarcsec resolution

- A new compact radio source detected in July 2005 at 8.4 GHz; developed a prominent extended jet-like structure by 2011
- Radio jets commonly observed in AGN but also expected in TDEs and tentatively seen in the case of a couple of events so far !



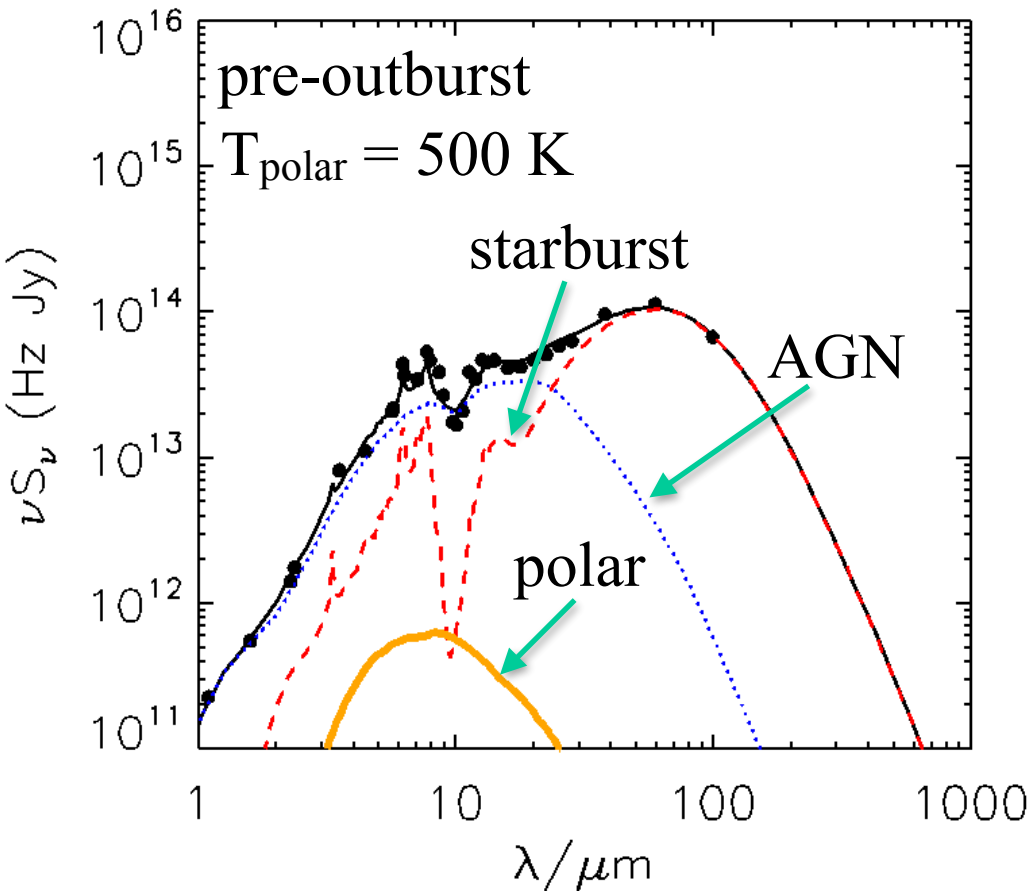
Mattila, Perez-Torres et al. 2018, Science

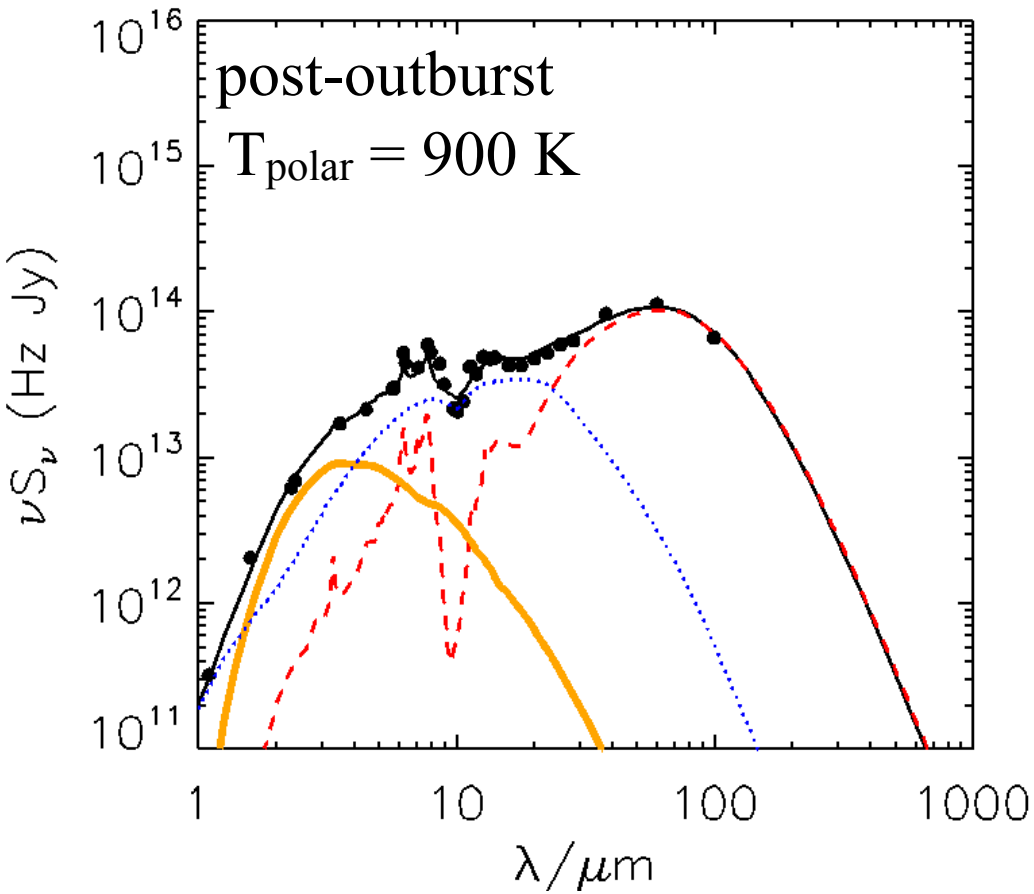
- The AGN torus observed almost edge-on with $N_H = 3x10^{24}$ cm^{-2} towards the AGN
- Observed IR emission re-radiation by optically thick dust clouds in the polar regions of the torus, which suffer from a relatively low foreground extinction within Arp 299



Ramos Almeida & Ricci (2017)

- Fit the IR SED using radiative transfer models for starburst, AGN and polar dust

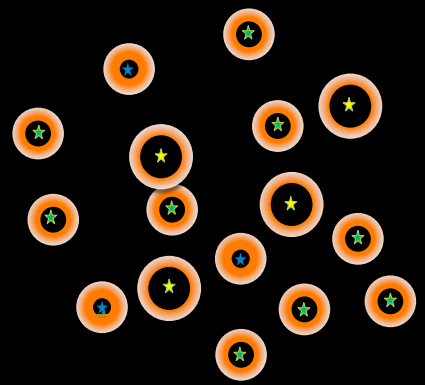




Efstathiou et al. starburst model

- Simple model for the evolution of an ensemble of giant molecular clouds illuminated by recently formed stars
- The stellar population synthesis model of Bruzual & Charlot gives the spectrum of the stars as a function of age
- Radiative transfer including the effect of transiently heated grains/PAHs

Efstathiou, Rowan-Robinson & Siebenmorgen (2000)
revised by Efstahiou & Siebenmorgen (2009)



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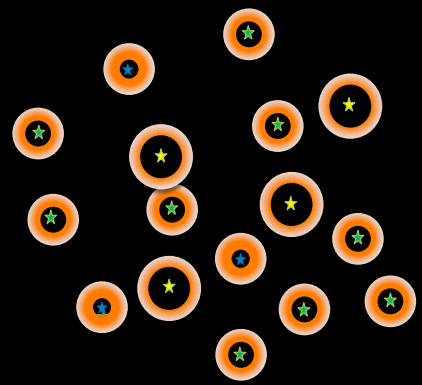
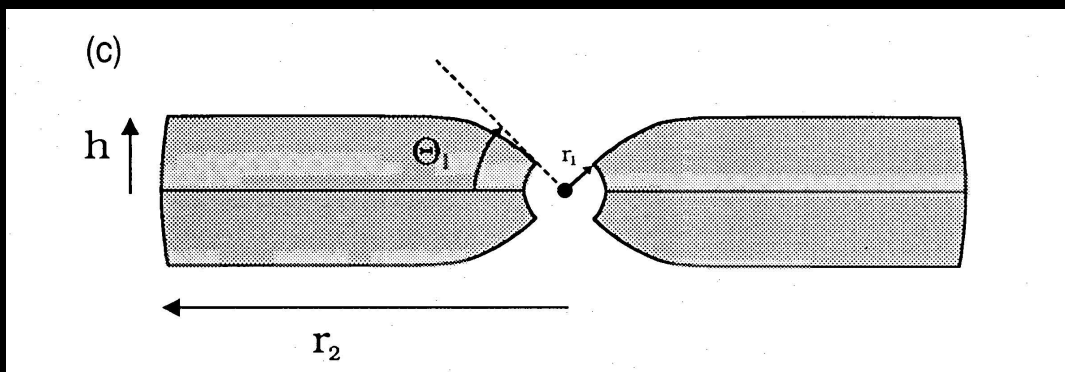


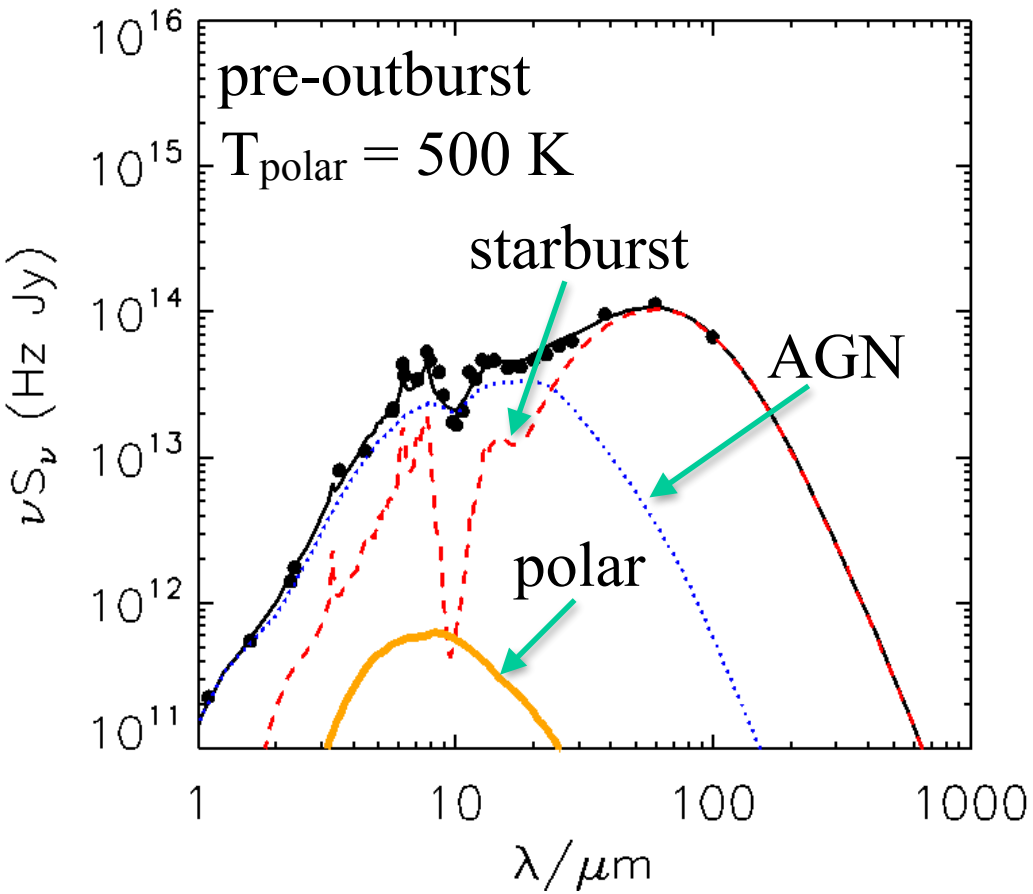
Tapered disc of Efstathiou & Rowan-Robinson + polar dust

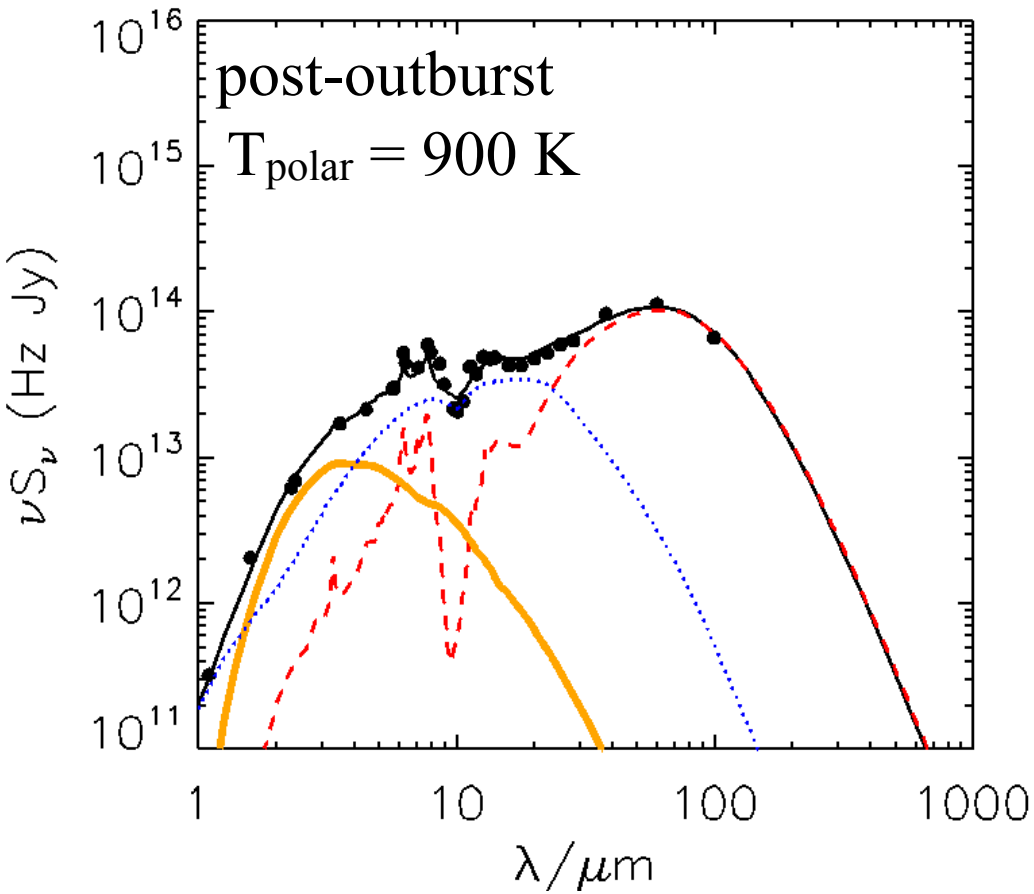
- Large grid of tapered smooth disc models with the ratio of outer to inner radius, equatorial UV optical depth, opening angle and inclination of the torus as the free parameters
- Solve the radiative transfer problem to determine the dust temperature distribution taking into account absorption of emission from hot inner torus by the outer torus
- Separate polar dust component

Efstathiou & Rowan-Robinson (1995)
Efstathiou (2006)
Efstathiou et al. (2013)

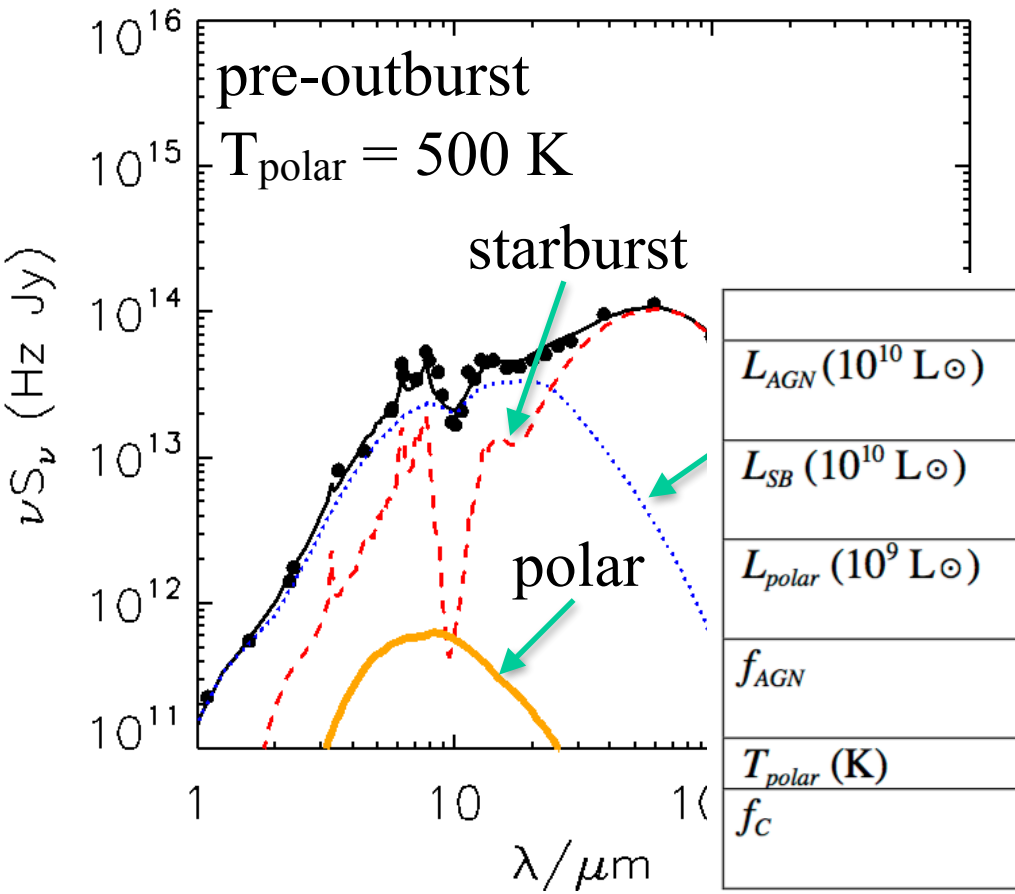


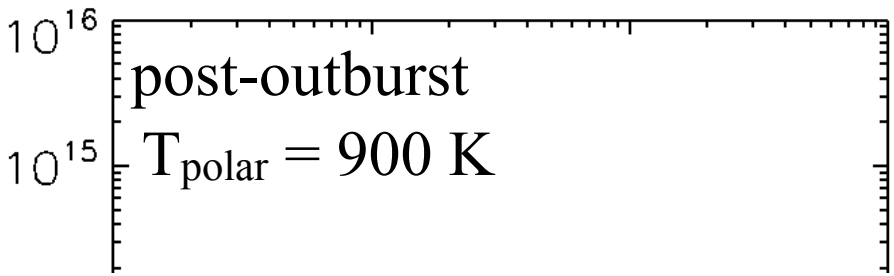
- Fit the IR SED using radiative transfer models for starburst, AGN and polar dust
- Starbursts and AGN components remain constant but the polar dust component found to increase by a factor of ~15 after the outburst with temperature increasing to 900 K





- Fit the IR SED using radiative transfer models for starburst, AGN and polar dust
- Starbursts and AGN components remain constant but the polar dust component found to increase by a factor of ~15 after the outburst with temperature increasing to 900 K
- Estimated covering factor of 23-78% for the polar dust implies a total radiated energy ~2.0-6.5x10^{52} erg
- Opportunity to probe the dusty nuclear environment and constrain the torus models

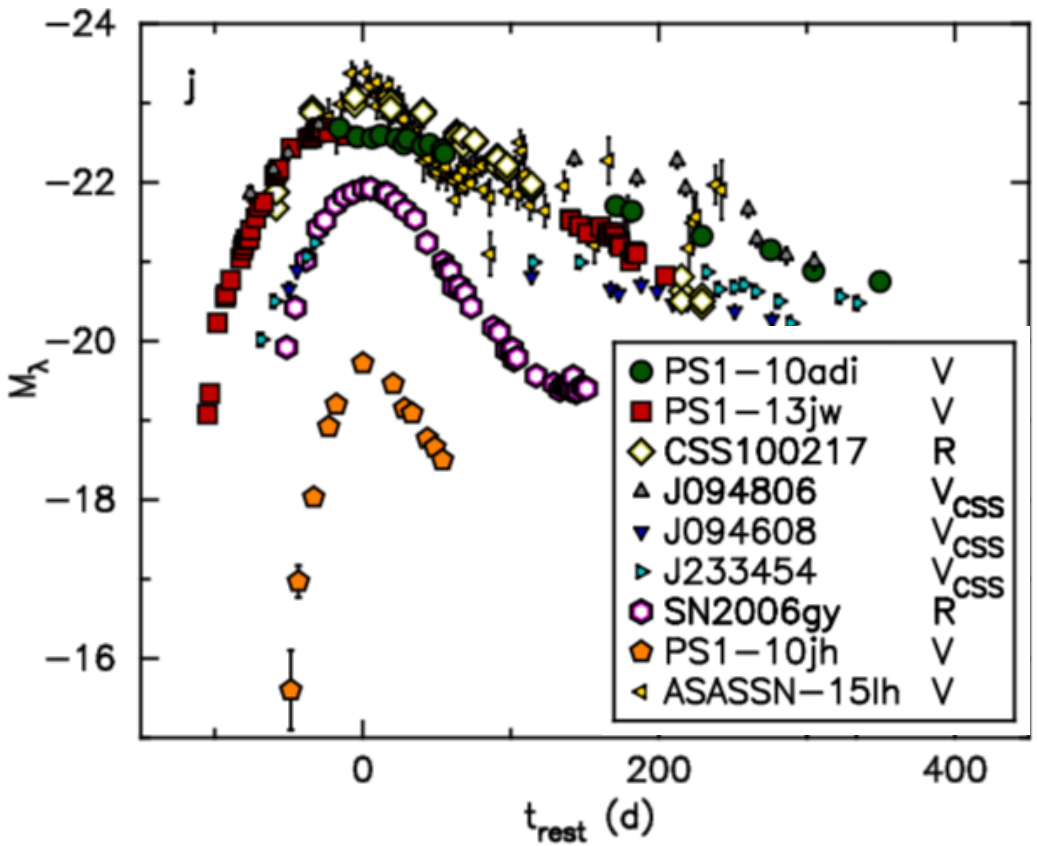


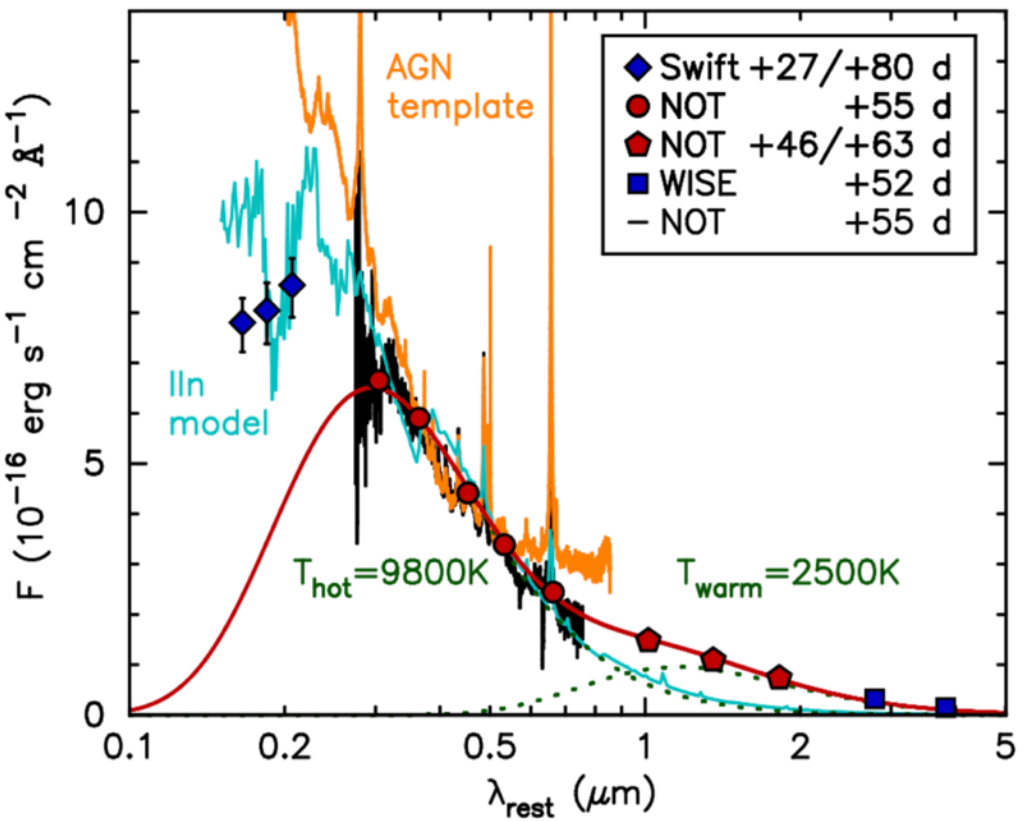


	Pre-outburst	**Post-outburst**
L_{AGN} (10^{10} L⊙)	$3.18^{+0.77}_{-0.87}$	$3.02^{+1.31}_{-0.66}$
L_{SB} (10^{10} L⊙)	$9.84^{+1.15}_{-0.79}$	$9.91^{+0.07}_{-0.16}$
L_{polar} (10^{9} L⊙)	$0.52^{+4.68}_{-0.52}$	$7.78^{+4.05}_{-4.07}$
f_{AGN}	$0.24^{+0.04}_{-0.06}$	$0.23^{+0.07}_{-0.04}$
T_{polar} (K)	500	900
f_C	$0.03^{+0.40}_{-0.03}$	$0.52^{+0.26}_{-0.29}$

Energetic nuclear transient PS1-10adi

- Host galaxy with AGN characteristics, SN-like smooth light curve evolution
- Blackbody temperature 2500-1200 K, radius 0.02-0.04 pc, radiated energy ~2×10^{52} erg (40% in the IR), $A_V \sim 0$ for the optical emission
- Evidence for dust evaporation and reprocessing of UV/optical emission by dust

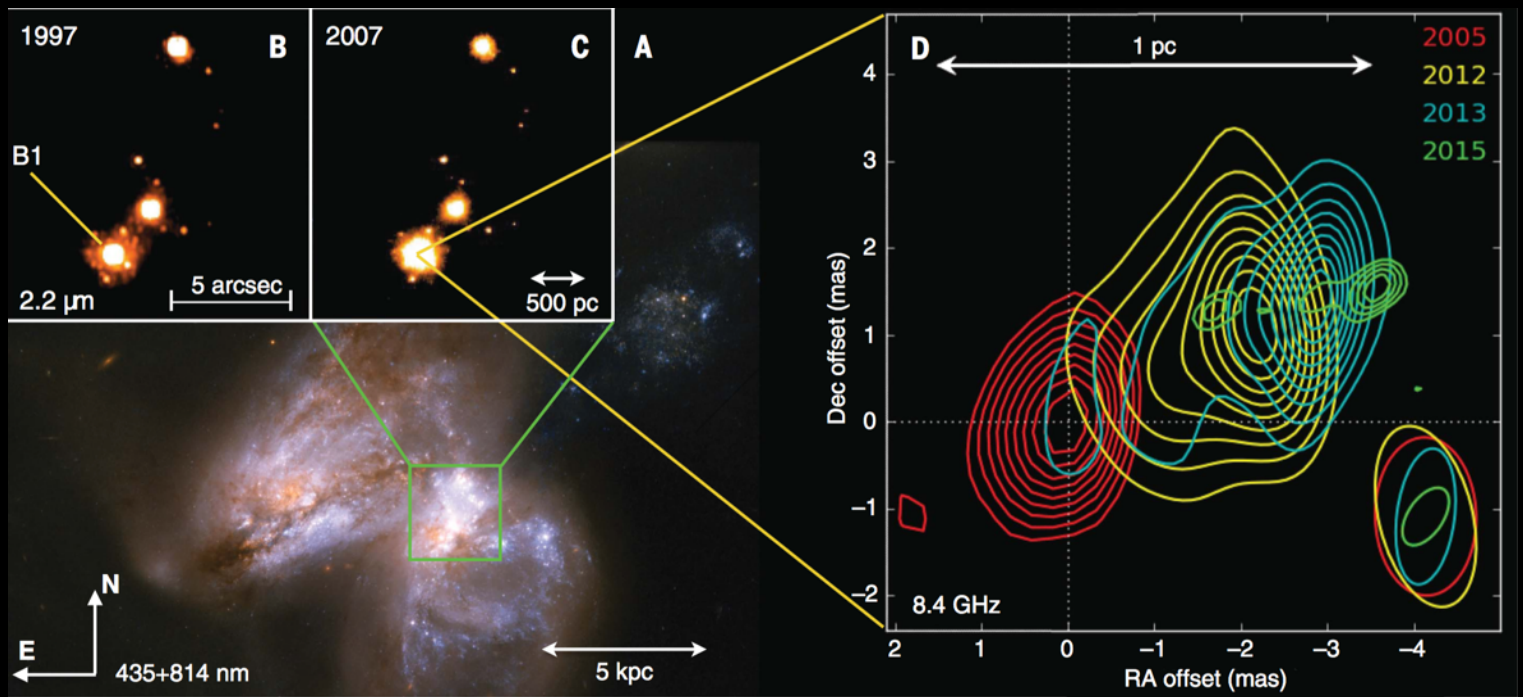




Kankare, Kotak, Mattila...Ward et al. 2017, Nature Astron.

Summary

- The nuclear transient in Arp 299 radiated at least 1.5×10^{52} erg in the IR and showed a resolved radio jet but remained elusive in the optical and X-rays
- Consistent with a tidal disruption event with an efficient reprocessing of soft X-ray photons to UV-optical range by dense gas and further to IR by dust in the nuclear regions
- Offers an opportunities to probe the dusty nuclear environment in Arp 299 and constrain torus models: polar dust with low foreground extinction arguing against obscuration by galaxy-scale dust or unobscured "keyhole" view through the obscuring nuclear medium

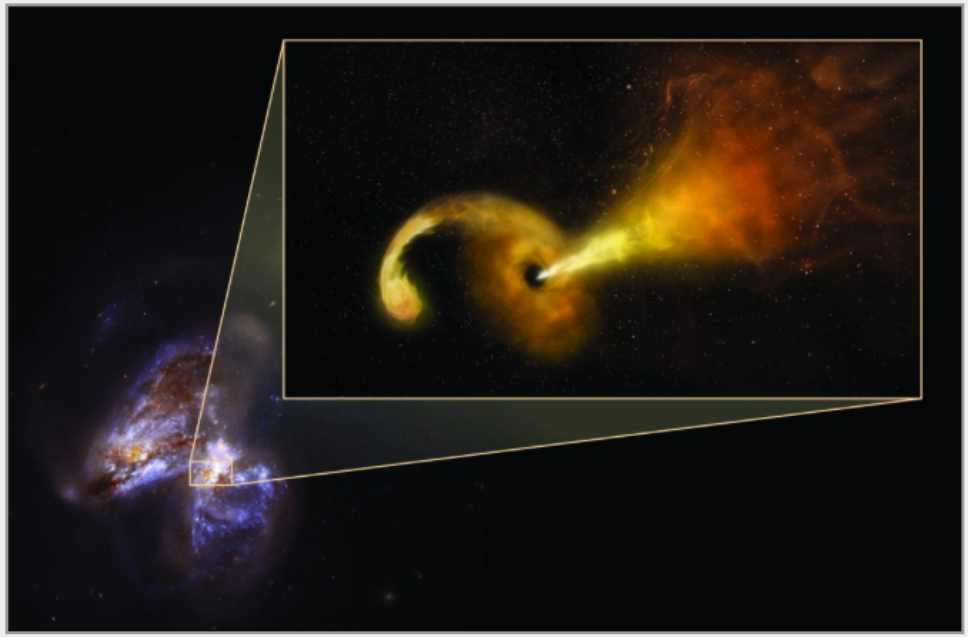


Special Session SS4 24 June 2019

as a part of the European Week of Astronomy and Space Science (EWASS)

Multi-wavelength view of transient events in galactic nuclei

Aims and scope



The Special Session on multi-wavelength view of transient events in galactic nuclei aims at gathering together researchers with expertise of phenomena including supernovae (SNe), tidal disruption events (TDEs) and changing look active galactic nuclei (AGN) over a range of wavelengths from radio, infrared, optical, UV and X-rays. This will include experts on a range of techniques from optical spectroscopy to interferometric radio observations providing high angular-resolution, as well as theoreticians to explain the state of the art of current models. The session will therefore consist of presentations and posters providing a multi-wavelength view of nuclear transients, highlighting some intriguing individual cases and also possible explanations for the recently discovered extremely energetic nuclear outbursts. In preparation for the next generation of telescopes, the session will address current observational challenges and needs, such as increasing the number of nearby well studied events, new techniques (e.g. spatially resolved radio observations) and clues for resolving the true nature of the nuclear activity.

Programme

- Nuclear supernovae (SNe)
- Tidal disruption events (TDE)
- Extremely energetic nuclear transients
- Changing look AGN