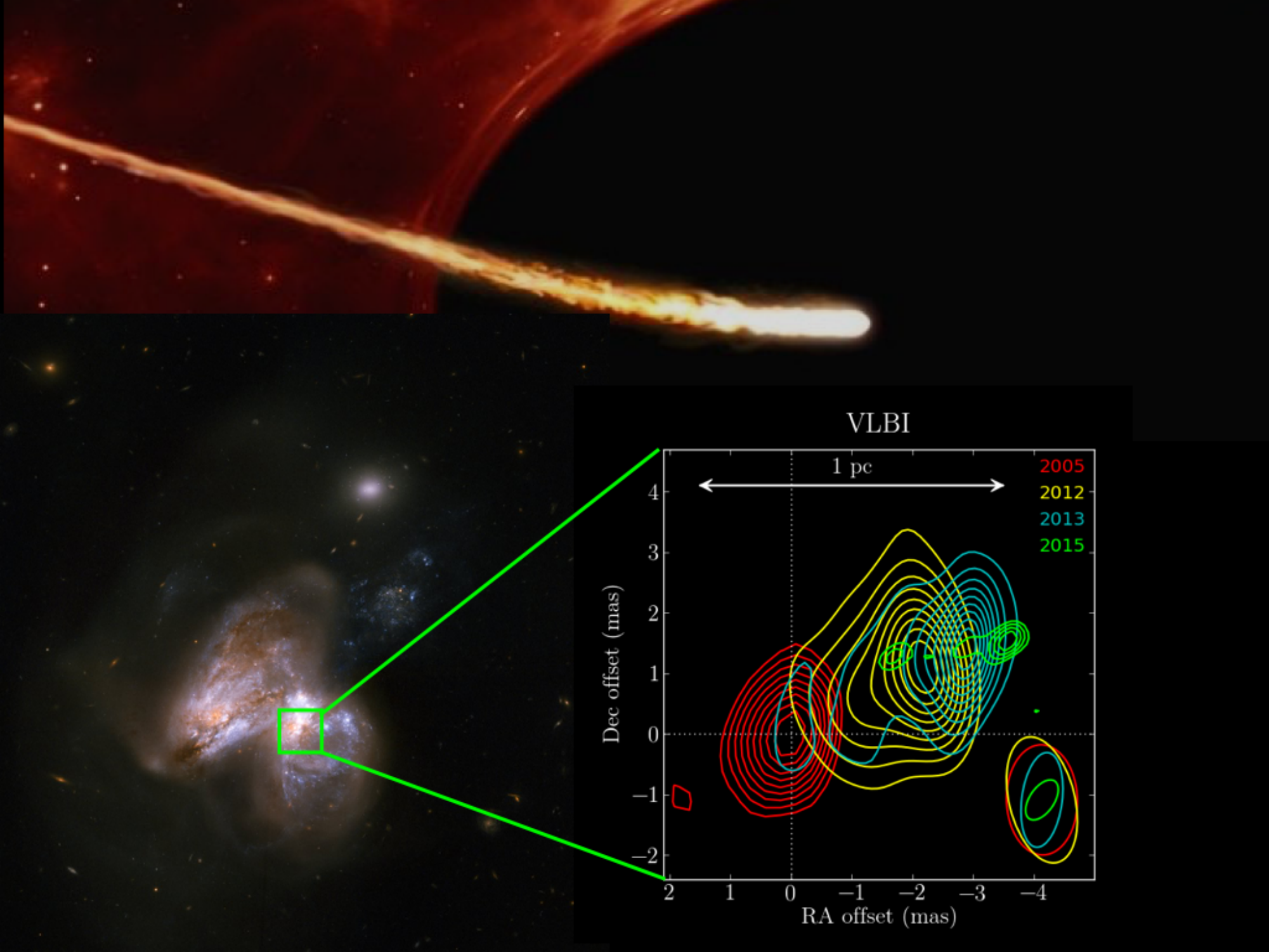
Instituto de Astrofísica de Andalucía (IAA-CSIC), Granada

A luminous, dust-enshrouded TDE in a galaxy merger

Miguel Pérez-Torres (torres@iaa.es)
(On behalf ofthe "Arp299" team:
S. Mattila, M. Pérez-Torres et al.,
Science, **361**, 482, 3 Aug 2018)

14th EVN Symposium
Granada, 9 Oct 2018


VLBI
1 pc
2005
2012
2013
2015
Dec offset (mas)
RA offset (mas)
4
3
2
1
0
−1
−2
2
1
0
−1
−2
−3
−4

article

Nature **254**, 295 - 298 (27 March 1975); doi:10.1038/254295a0

Possible power source of Seyfert galaxies and QSOs

J. G. HILLS

Department of Astronomy, University of Michigan, Ann Arbor, Michigan 48104

The possible presence of massive black holes in the nuclei of galaxies has been suggested many times. In addition, there is considerable observational evidence for high stellar densities in these nuclei. I show that the tidal breakup of stars passing within the Roche limit of a black hole initiates a chain of events that may explain many of the observed principal characteristics of QSOs and the nuclei of Seyfert galaxies.

article

Nature **333**, 523 - 528 (09 June 1988); doi:10.1038/333523a0

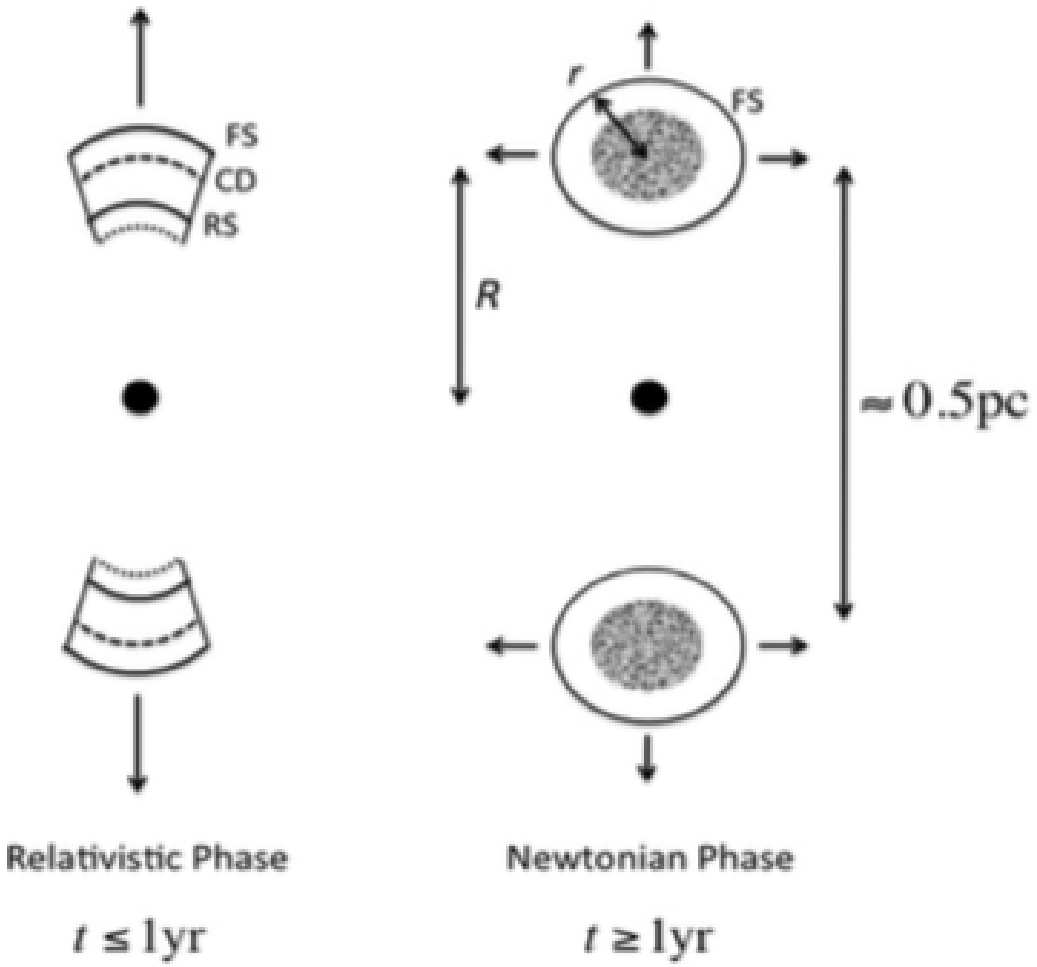
Tidal disruption of stars by black holes of 10^6–10^8 solar masses in nearby galaxies

MARTIN J. REES

Institute of Astronomy, Madingley Road, Cambridge CB3 OHA, UK

Stars in galactic nuclei can be captured or tidally disrupted by a central black hole. Some debris would be ejected at high speed', the remainder would be swallowed by the hole, causing a bright flare lasting at most a few years. Such phenomena are compatible with the presence of 10^6–10^8 $M_\odot$ holes in the nuclei of many nearby galaxies. Stellar disruption may have interesting consequences in our own Galactic Centre if a ~10^6 $M^\odot$ hole lurks there.

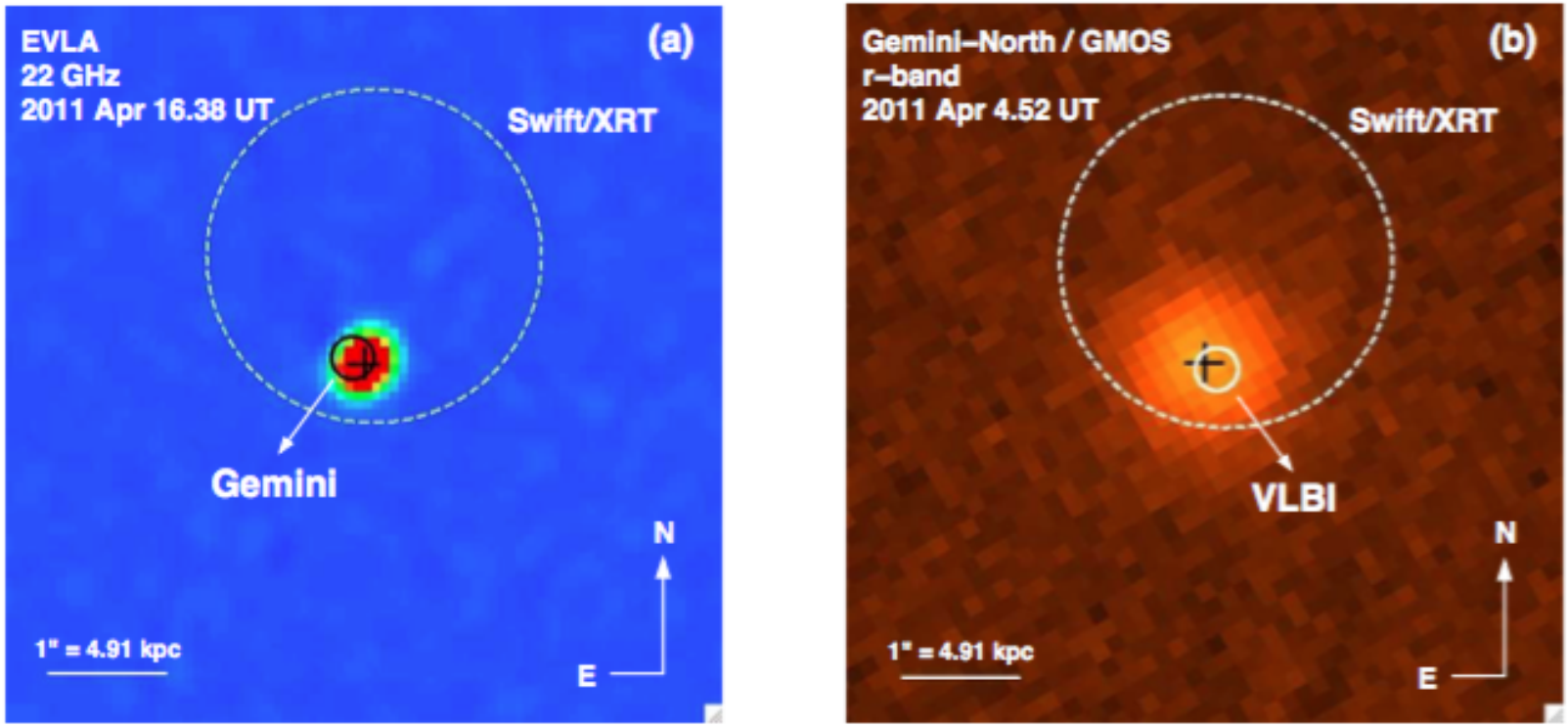
Radio transients from TDEs



(Giannios & Metzger 2011)

- Production of relativistic jet
- Significant deceleration due to interaction with surroundings
- Synchrotron radiation powers the transient
- Timescale of $\sim$ years
- Non-thermal emission from TDE probes physics of jet formation

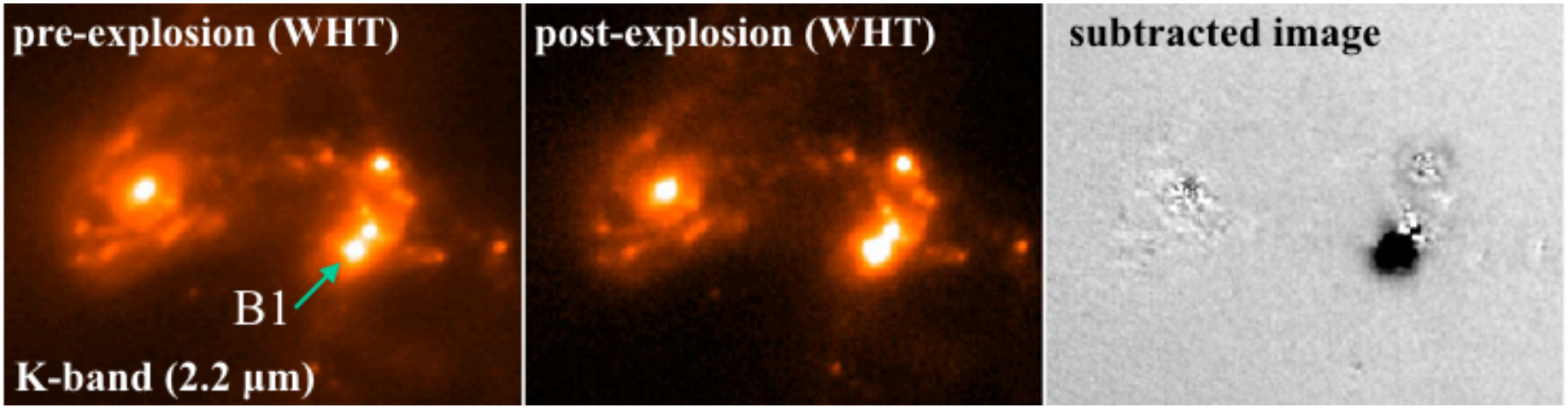
The unusual γ – *ray* transient Swift J1644+57



(Zauderer+2011)

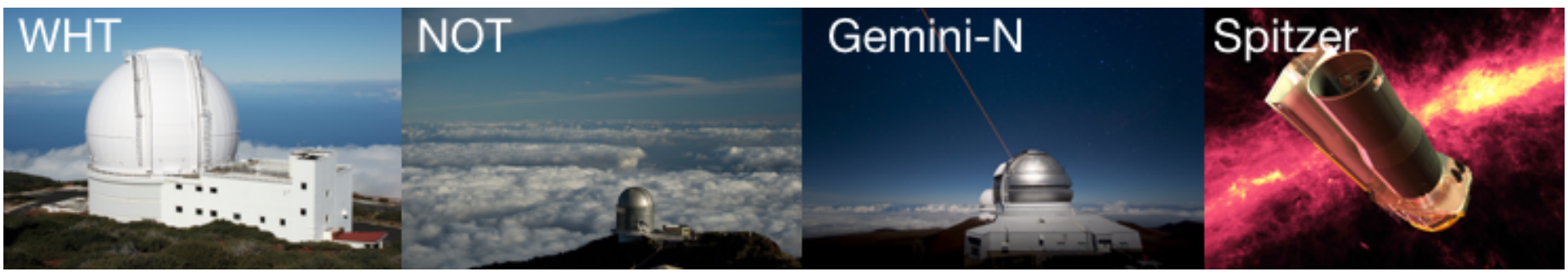
Discovery of a radio transient and mm- properties interpreted as being due to a relativistic outflow. Unresolved observations!

IR discovery of a transient in Arp299-B1

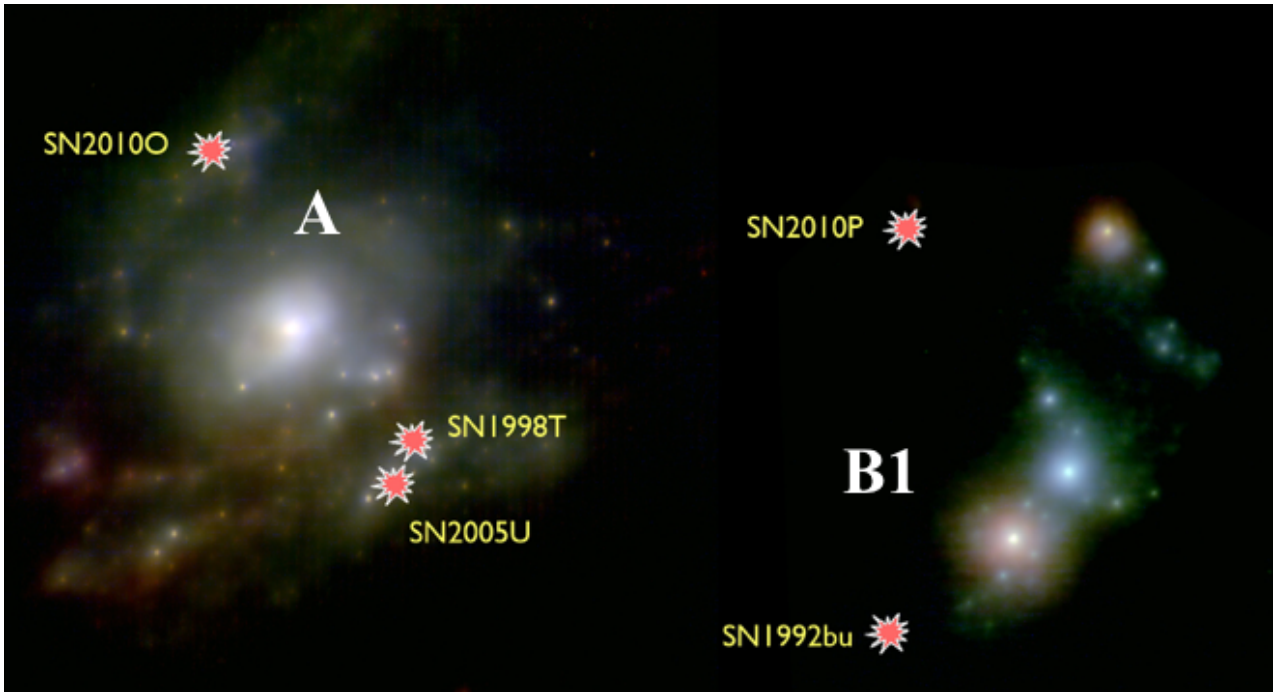


Mattila+2005, IAU Circ. 8477

- A systematic near-IR search for nuclear SNe in SB gals
- Discovery of a nuclear outburst in the near-IR in Jan 2005
- Only detected in the IR at that time

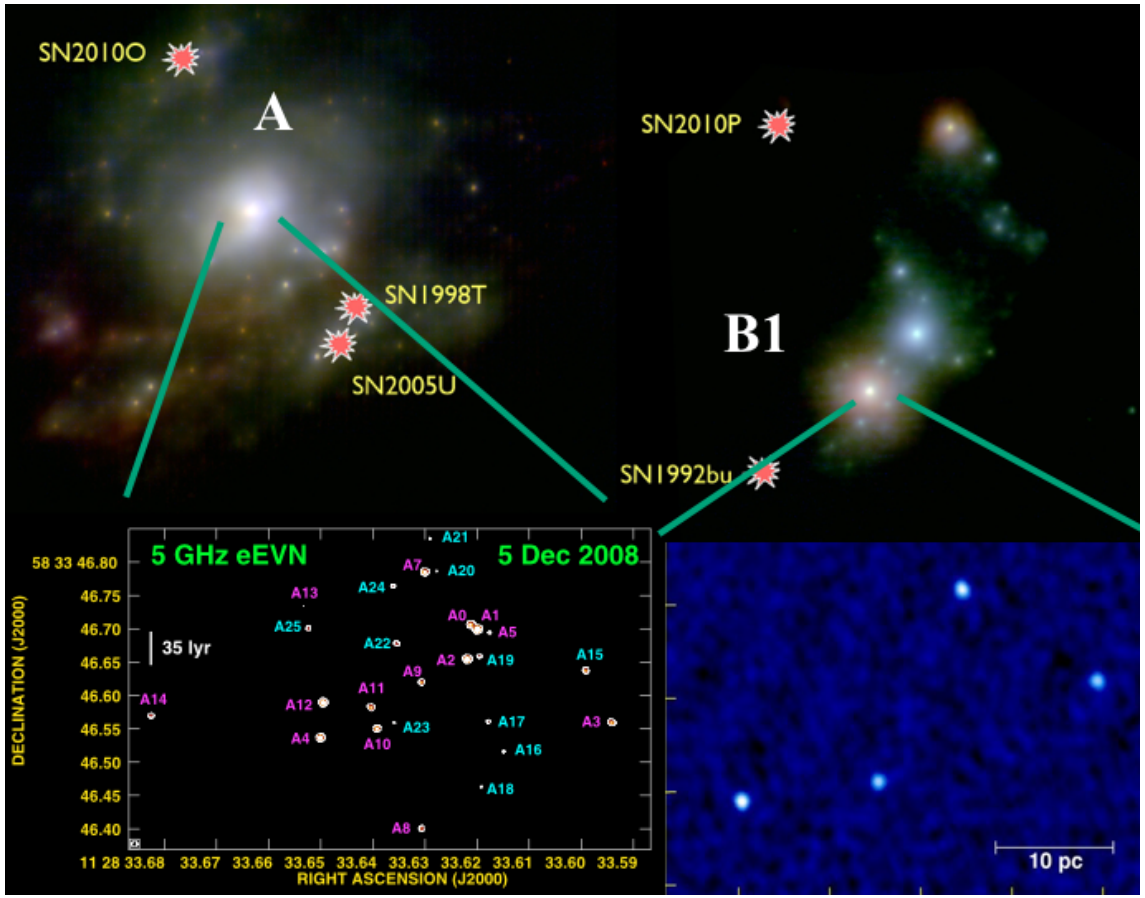


The galaxy merger Arp299



- Luminous Infrared Galaxy (LIRG)[$\log(L/L_\odot) = 11.7$]
- Nearby ($D = 45$ Mpc)

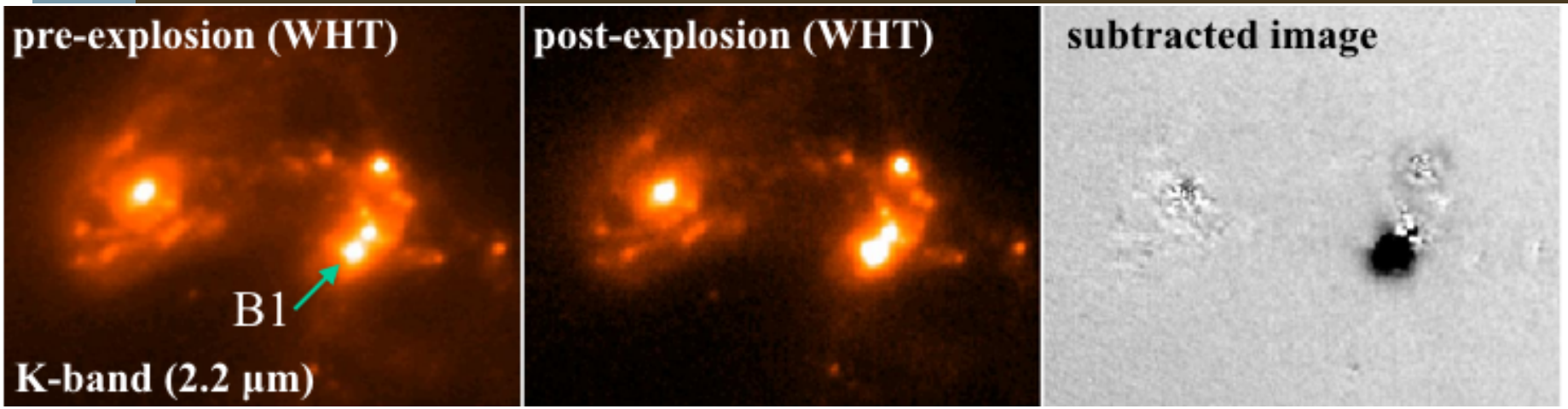
Arp299: A prolific SN factory



(Pérez-Torres+2009) (Ulvestad 2009)

- SFR $\simeq$ (150 - 200) $M_\odot\ yr^{-1}$
- CCSN rate $\sim 2\ yr^{-1}$

The AGN in B1 and its transient

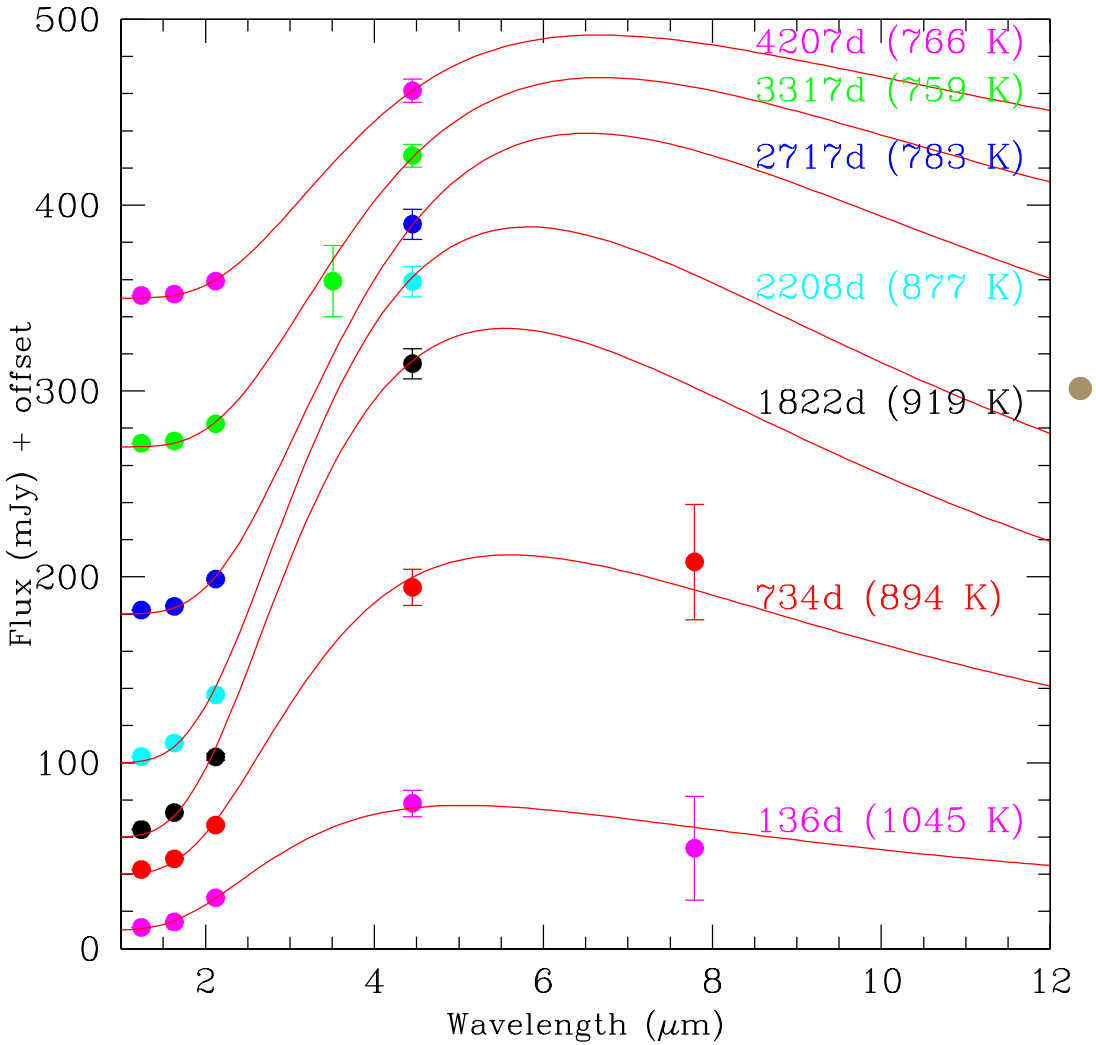


AGN in B1

- Strongly obscured ($N_H \sim 3 \times 10^{24}$ cm^{-2}); $A_V \gtrsim 460$ mag
- AGN torus viewed almost edge-on
- $M_{\rm SMBH}$(B1) $\approx 2 \times 10^7$ M$_\odot$

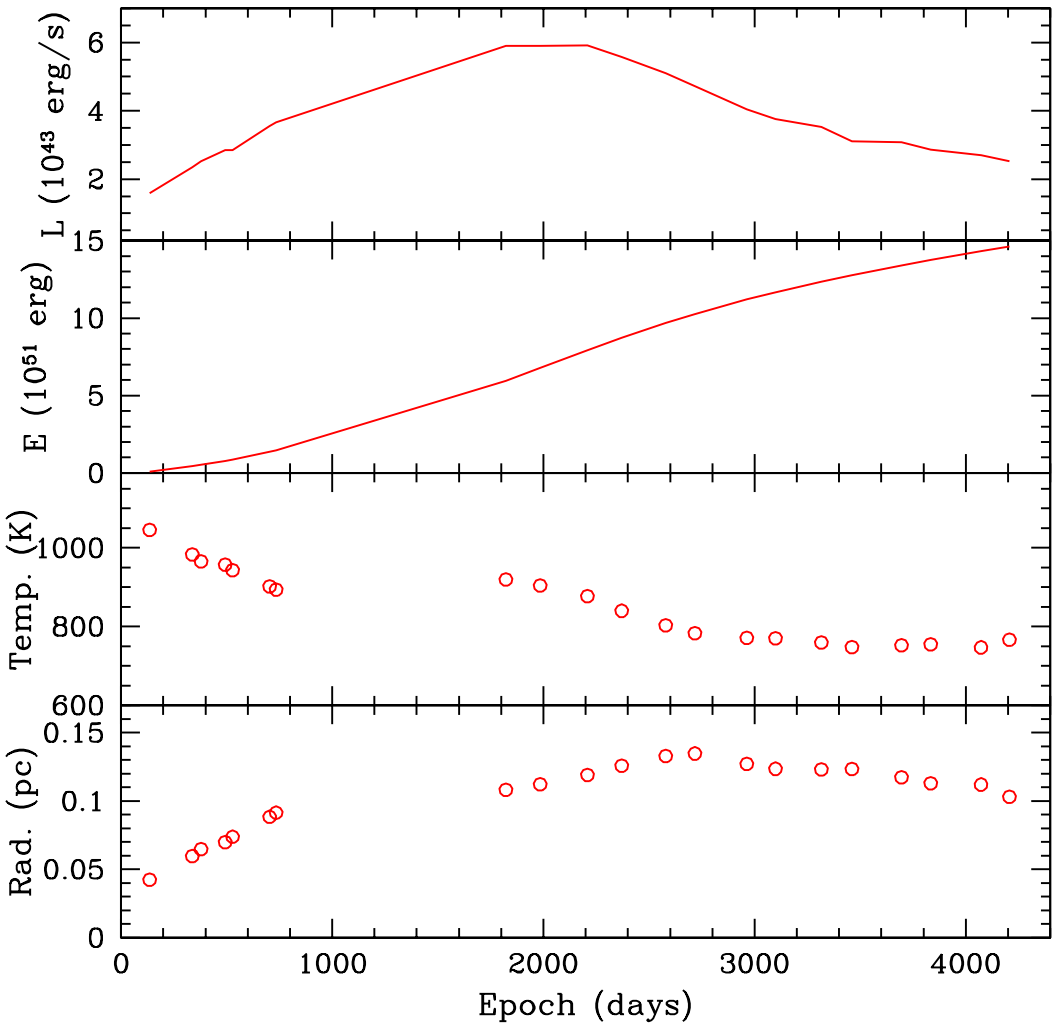
- Event unrelated to the SMBH (e.g., supernova or GRB)
- Event related to the SMBH (e.g., AGN flare or TDE)

near-IR properties of Arp299B-AT1



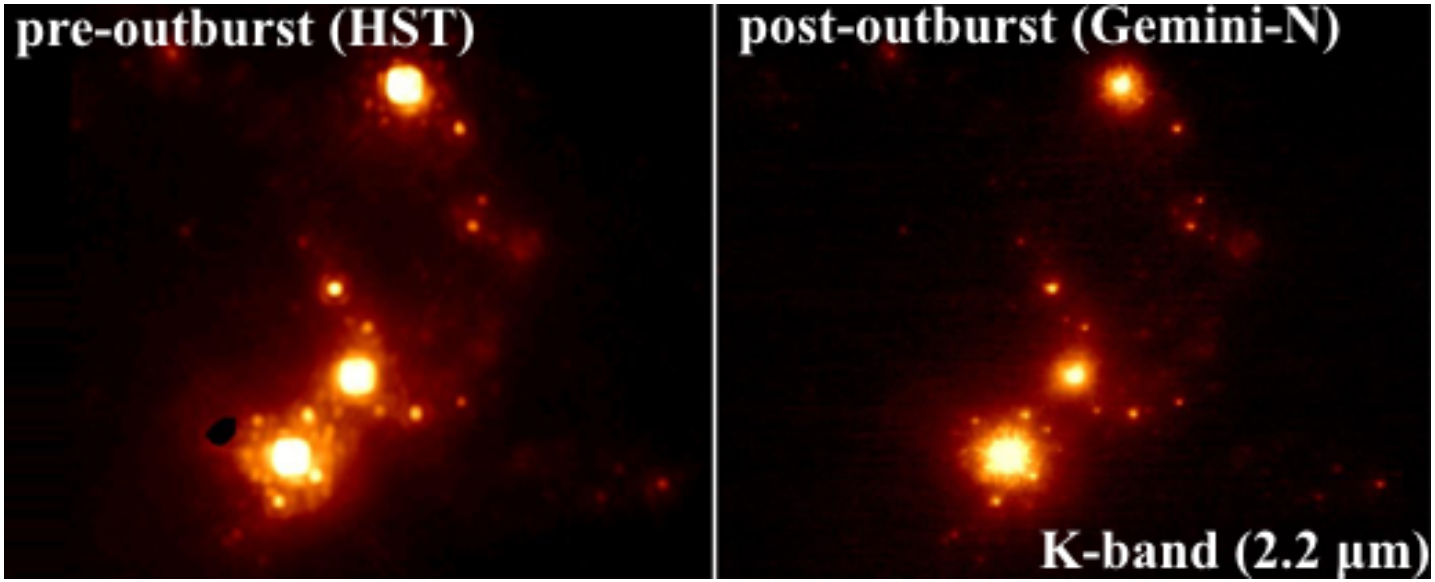
- Near- to mid-IR SED described by single blackody function

near-IR properties of Arp299B-AT1



- Expansion from ~0.04 to ~0.13 pc
- Source cools from ~1050 to ~750 K
- Extremely energetic: $E_{\rm rad} \gtrsim 1.5 \times 10^{52}$ erg

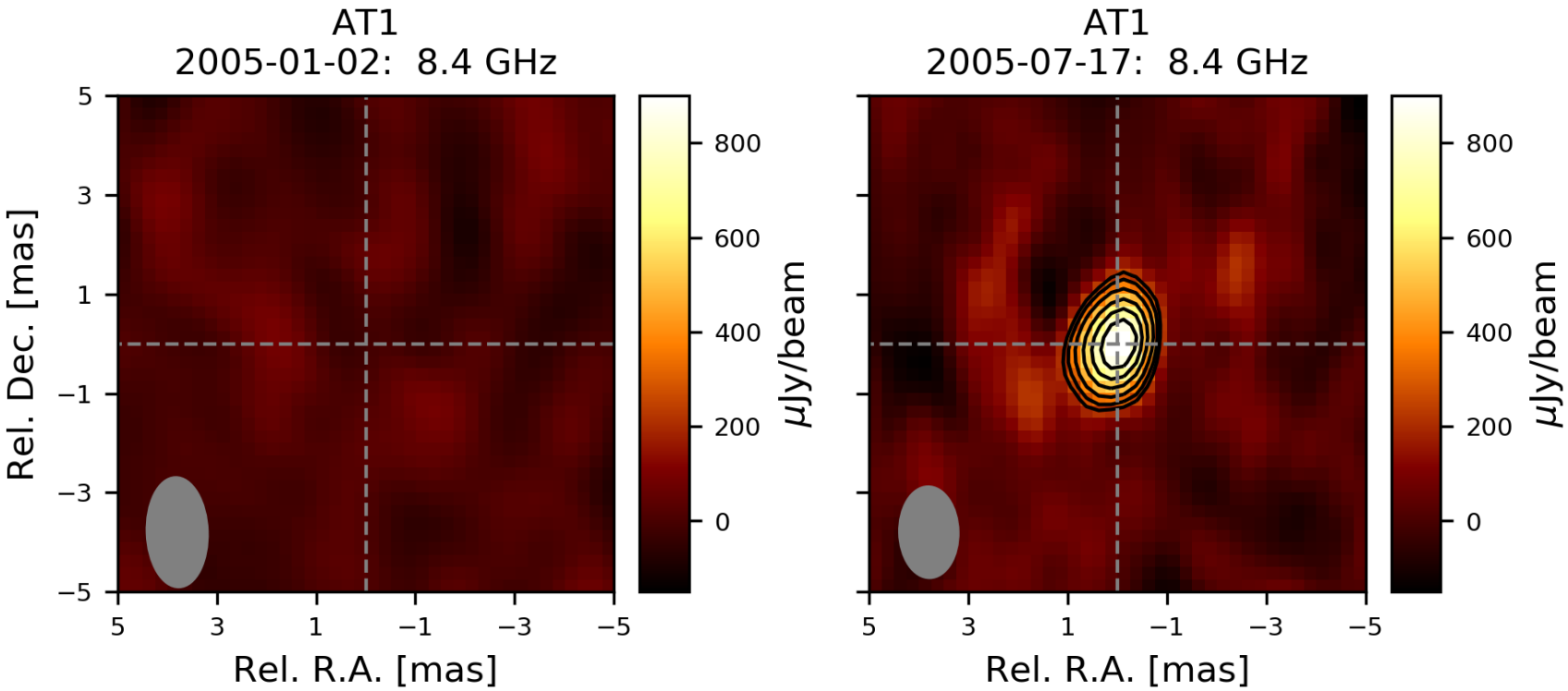
IR nuclear location from Adaptive Optics



- AO near-IR imaging with 0.1" angular resolution
- AO imaging compared with pre-explosion HST imaging
- Outburst coincident with IR nucleus within 0.030"
- Position stable in all AO epochs (2007-2012)

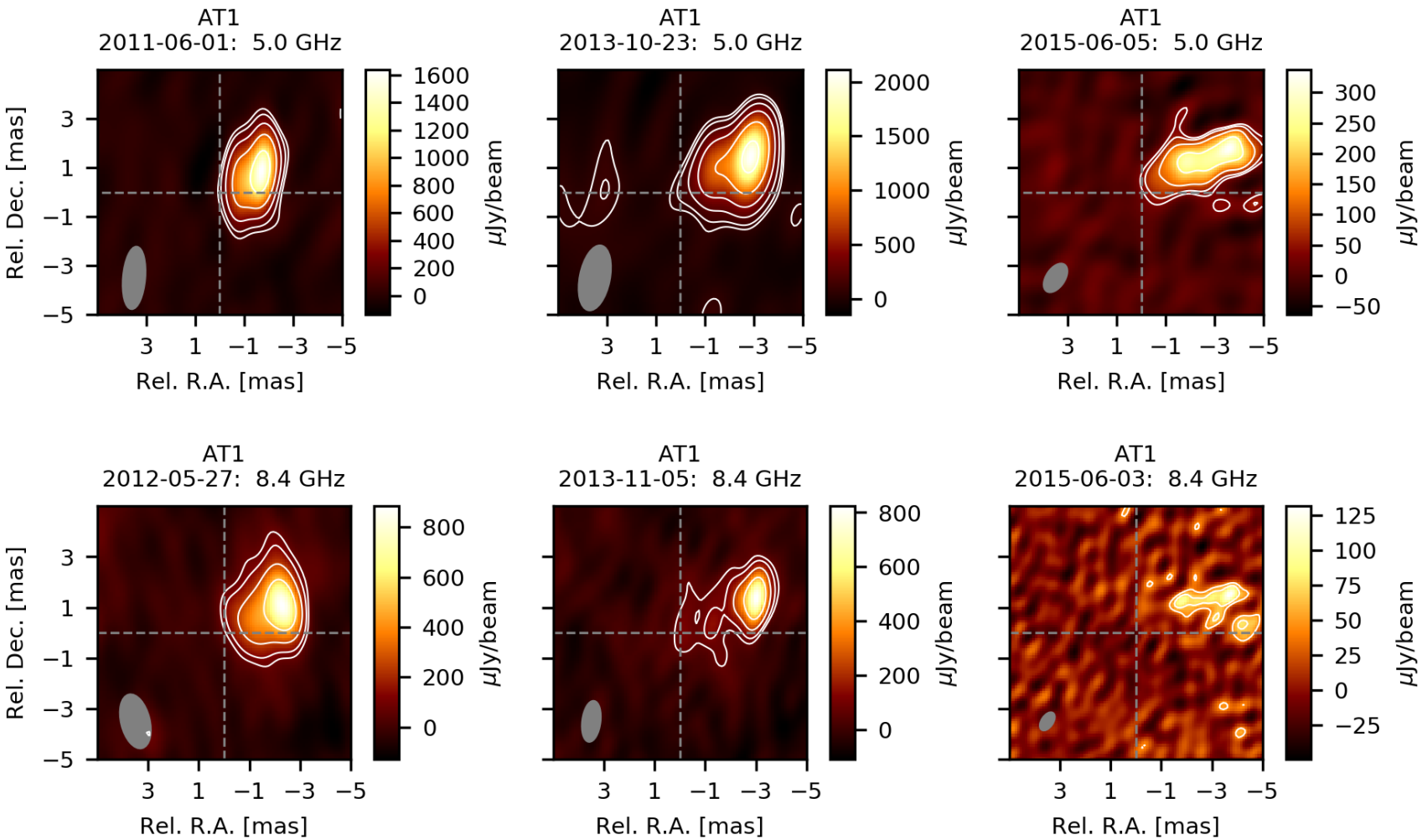
Transient connected to the SMBH at the centre of B1?

The radio counterpart of Arp299B-AT1



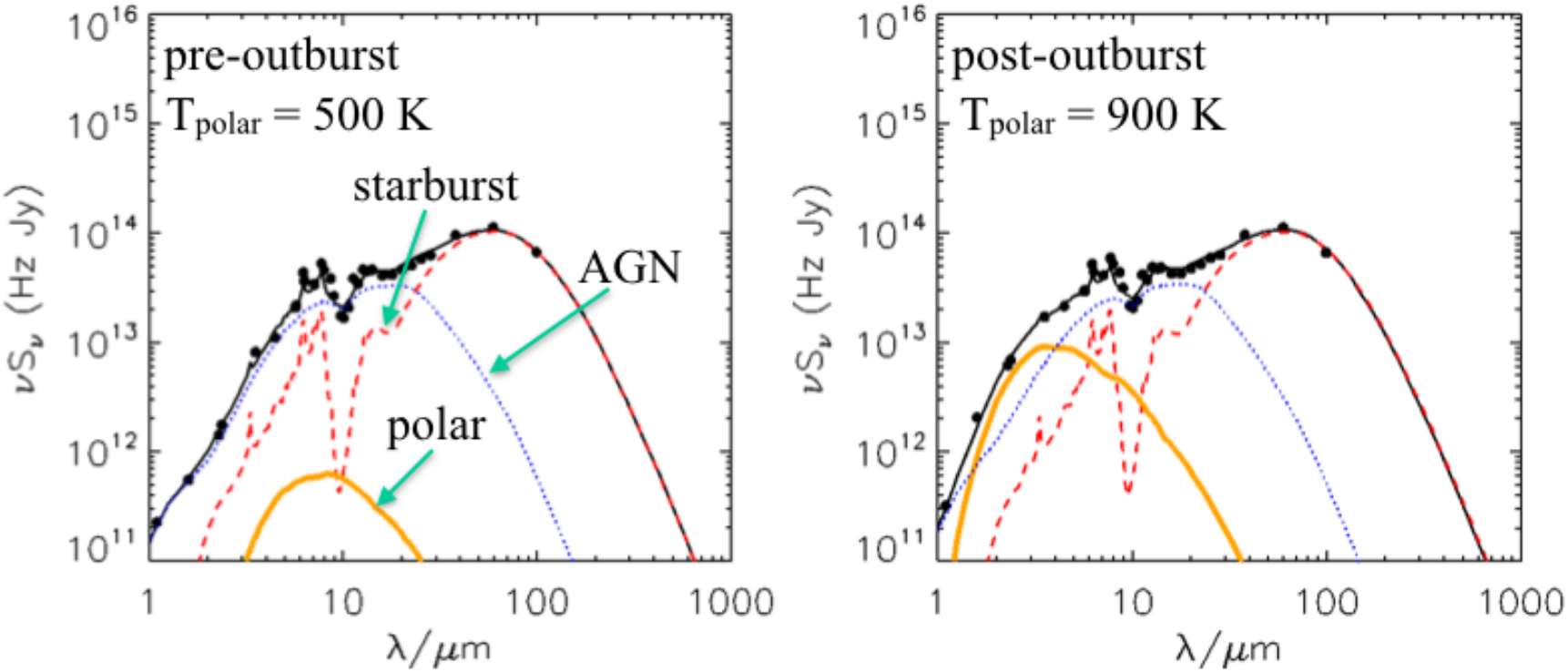
- VLBI observations showed the appearance of a new source
- milliarcsecond accuracy; near-IR position coincident ⇒ Transient connected to the SMBH in B1! (initially taken as a nuclear SN; Ulvestad 2009)

An expanding radio jet unveiled by the EVN



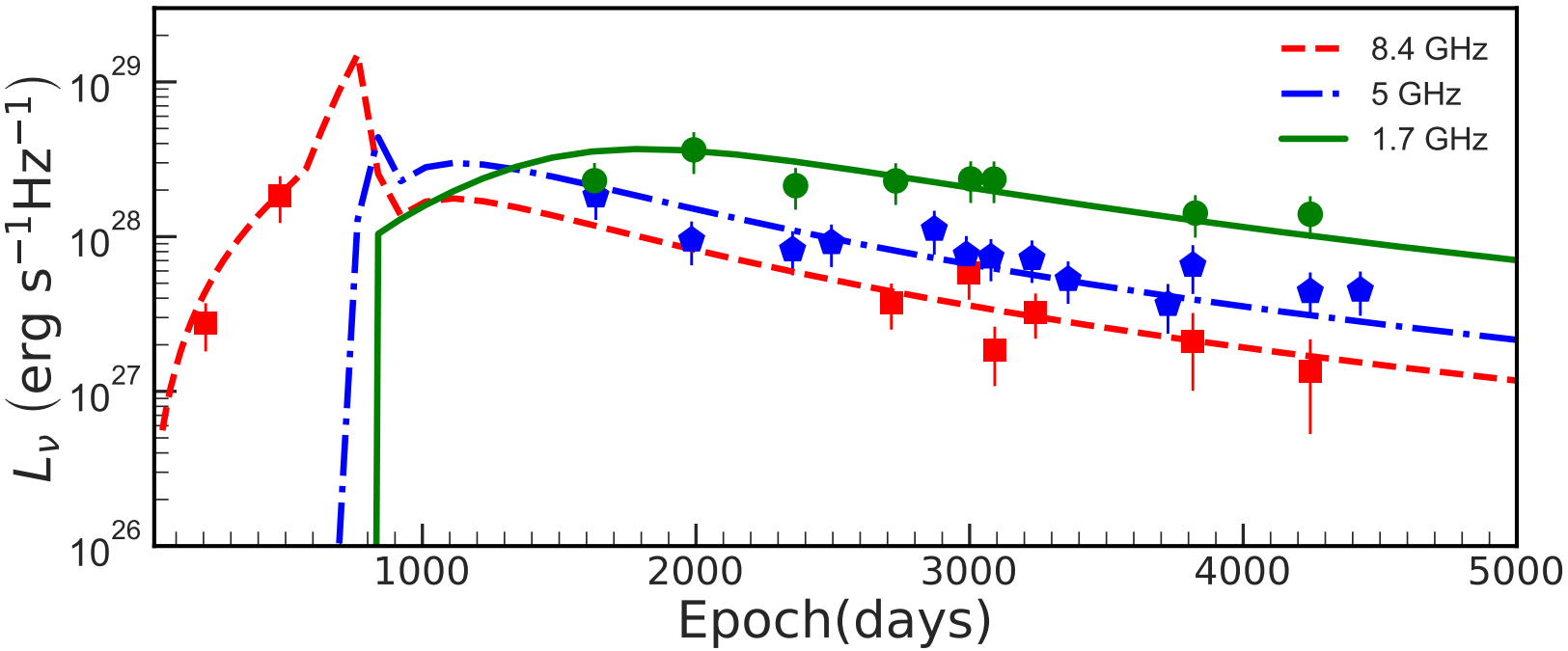
- European VLBI Network obs-ns with ∼mas resolution
- VLBI obs-ns rule out either a SN, or a GRB, origin

Infra-red SED modelling



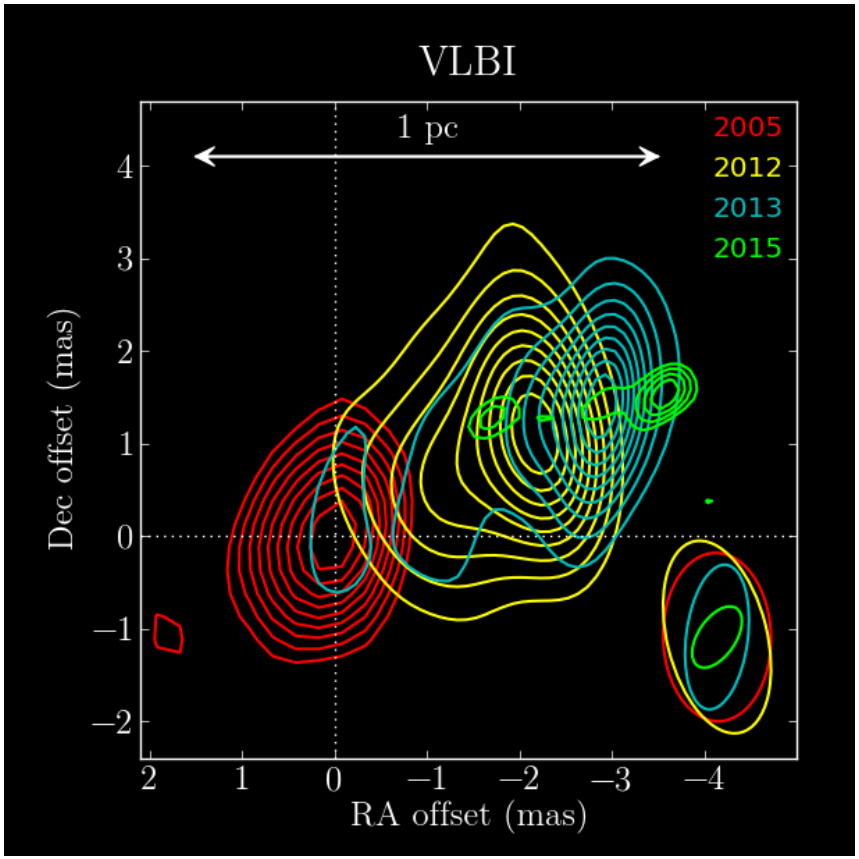
- Evidence for Polar dust in the surroundings of the AGN
- Radiative transfer models for both AGN and starbursts
- Covering factor of dust: $f_{cov} = 23\% - 78\%$
- Huge radiated energy: $E_{rad} \simeq (2.0 - 6.5) \times 10^{52}$ erg

Radio light curve modelling of Arp299B-AT1



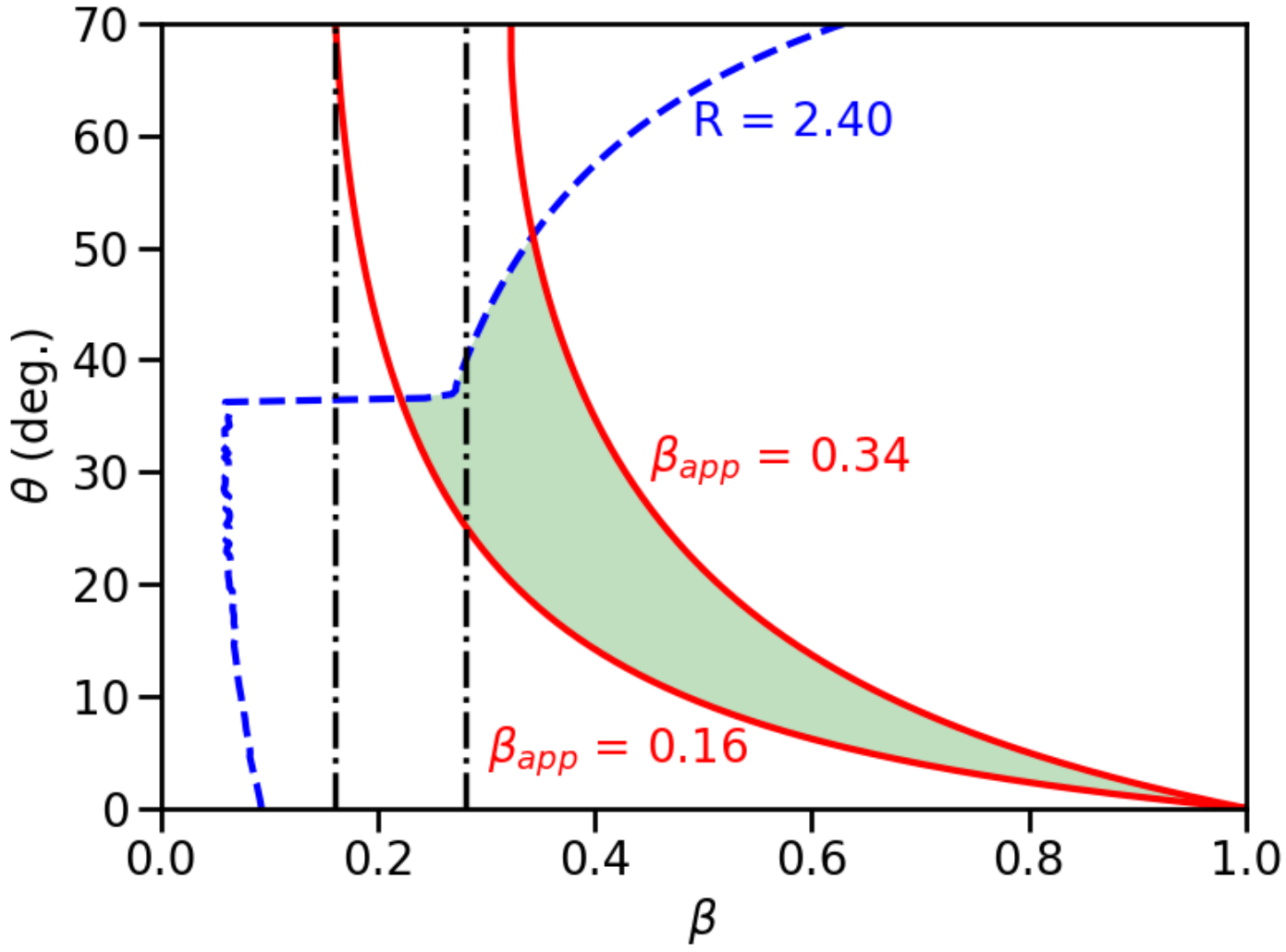
- TDE: radio transient expected, including relativistic jet
- Light curves well reproduced by TDE-driven jet
- $E_{\rm K} \sim 2 \times 10^{51}$ erg
- $n_{\rm nuclear} \sim 4 \times 10^{4}$ cm^{-3}
- Jet initially relativistic ($v \simeq 0.997\,c$), but soon decelerates.

The radio jet of Arp299B-AT1



- From point-like in 2005 to jet-like by 2011
- Average apparent speed, $\beta_{\rm app} = 0.25 \pm 0.03$
- Jets are common in AGN; but also expected in TDEs

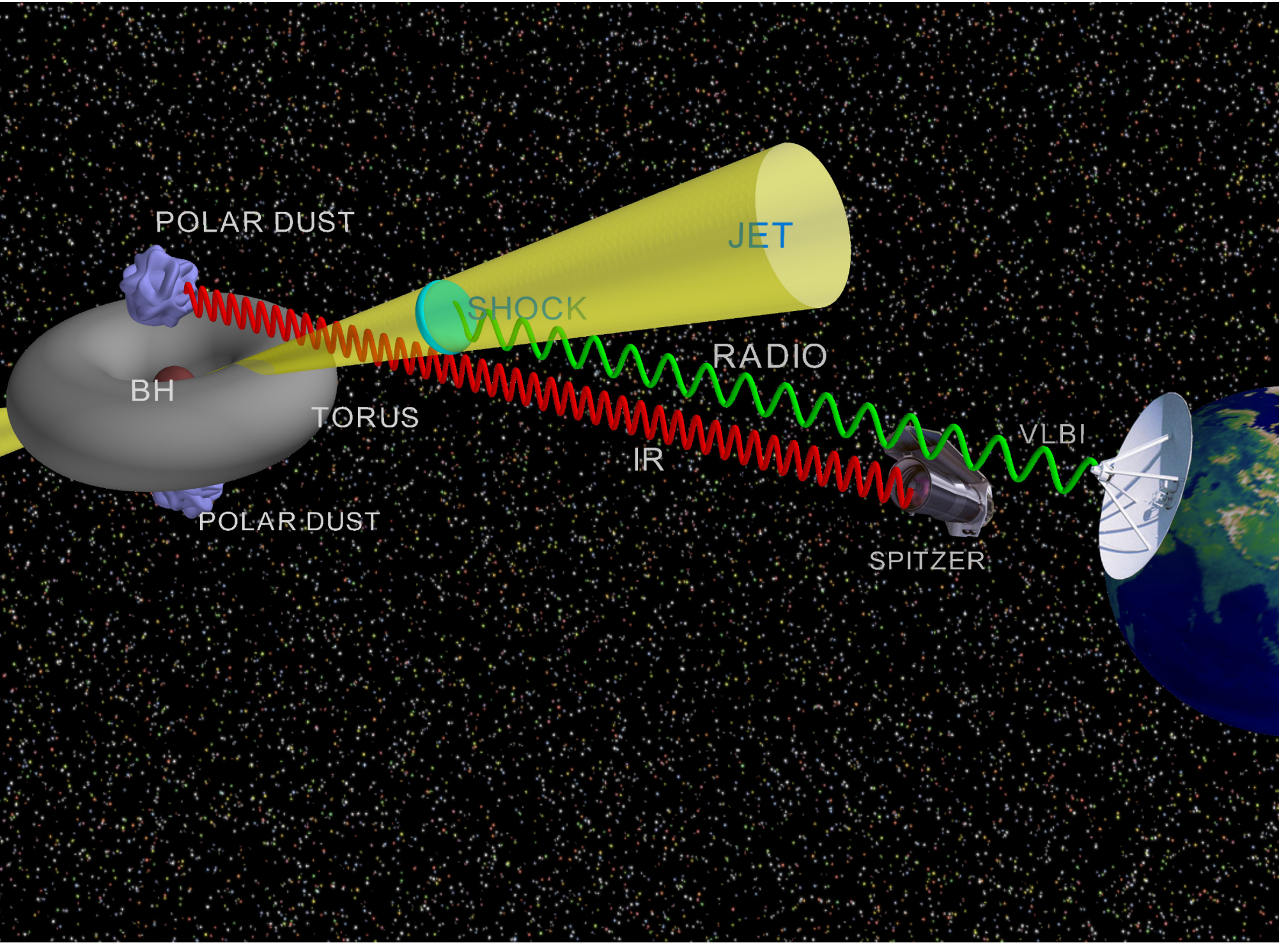
VLBI obs-ns rule out a normal AGN jet



Jet viewing angle, $\theta \simeq 25^\circ - 35^\circ$

$\Rightarrow$ A TDE-launched radio jet!!

A TDE-launched jet unveiled by the EVN


POLAR DUST
JET
SHOCK
RADIO
BH
TORUS
IR
VLBI
POLAR DUST
SPITZER

Science

REPORTS

Cite as: S. Mattila *et al.*, *Science* 10.1126/science. aao4669 (2018).

A dust-enshrouded tidal disruption event with a resolved radio jet in a galaxy merger

S. Mattila[1,2*†], M. Pérez-Torres[3,4*†], A. Efstathiou[5], P. Mimica[6], M. Fraser[7,8], E. Kankare[9], A. Alberdi[3], M. Á. Aloy[6], T. Heikkilä[1], P. G. Jonker[10,11], P. Lundqvist[12], I. Martí-Vidal[13], W. P. S. Meikle[14], C. Romero-Cañizales[15,16], S. J. Smartt[9], S. Tsygankov[1], E. Varenius[13,17], A. Alonso-Herrero[18], M. Bondi[19], C. Fransson[12], R. Herrero-Illana[20], T. Kangas[1,21], R. Kotak[1,9], N. Ramírez-Olivencia[3], P. Väisänen[22,23], R. J. Beswick[17], D. L. Clements[14], R. Greimel[24], J. Harmanen[1], J. Kotilainen[2,1], K. Nandra[25], T. Reynolds[1], S. Ryder[26], N. A. Walton[8], K. Wiik[1], G. Östlin[12]

[1]Tuorla Observatory, Department of Physics and Astronomy, FI-20014 University of Turku, Finland. [2]Finnish Centre for Astronomy with ESO (FINCA), FI-20014 University of Turku, Finland. [3]Instituto de Astrofísica de Andalucía - Consejo Superior de Investigaciones Científicas (CSIC), PO Box 3004, 18008, Granada, Spain. [4]Departamento de Física Teórica, Facultad de Ciencias, Universidad de Zaragoza, 50019, Zaragoza, Spain. [5]School of Sciences, European University Cyprus, Diogenes Street, Engomi, 1516 Nicosia, Cyprus. [6]Departament d'Astronomia i Astrofisica, Universitat de València Estudi General, 46100 Burjassot, València, Spain. [7]School of Physics, O'Brien Centre for Science North, University College Dublin, Belfield, Dublin 4, Ireland. [8]Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK. [9]Astrophysics Research Centre, School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, UK. [10]SRON, Netherlands Institute for Space Research, Sorbonnelaan 2, NL-3584 CA Utrecht, the Netherlands. [11]Department of Astrophysics/Institute for Mathematics, Astrophysics and Particle Physics, Radboud University, P.O. Box 9010, 6500GL Nijmegen, Netherlands. [12]Department of Astronomy and The Oskar Klein Centre, AlbaNova University Center, Stockholm University, SE-106 91 Stockholm, Sweden. [13]Department of Space, Earth and Environment, Chalmers University of Technology, Onsala Space Observatory, SE-439 92 Onsala, Sweden. [14]Astrophysics Group, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2AZ, UK. [15]Chinese Academy of Sciences South America Center for Astronomy, National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China. [16]Núcleo de Astronomía de la Facultad de Ingeniería y Ciencias, Universidad Diego Portales, Av. Ejército 441, 8370191 Santiago, Chile. [17]Jodrell Bank Centre for Astrophysics, The University of Manchester, Oxford Rd, Manchester M13 9PL, UK. [18]Centro de Astrobiología (CSIC-INTA), ESAC Campus, E-28692 Villanueva de la Cañada, Madrid, Spain. [19]Istituto di Radioastronomia - Istituto Nazionale di Astrofisica (INAF), Bologna, via P. Gobetti 101, 40129, Bologna, Italy. [20]European Southern Observatory, Alonso de Córdova 3107, Vitacura, Casilla 19001, Santiago de Chile, Chile. [21]Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA. [22]South African Astronomical Observatory, PO Box 9, Observatory 7935, Cape Town, South Africa. [23]Southern African Large Telescope, PO Box 9 Observatory 7935, Cape Town, South Africa. [24]Institute of Physics, Department for Geophysics, Astrophysics, and Meteorology, NAWI Graz, Universitätsplatz 5, 8010 Graz, Austria. [25]Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstraße, 85748, Garching, Germany. [26]Australian Astronomical Observatory, 105 Delhi Rd, North Ryde, NSW 2113, Australia.

***These authors contributed equally to this work.**

[†]Corresponding author. Email: sepmat@utu.fi (S.M.); torres@iaa.es (M.P.-T.)

Summary

- First ever resolved TDE radio jet
- Extremely luminous ($E_{\rm rad} \gtrsim 1.5 \times 10^{52}$ erg)
- Disruption of a star with $2 \lesssim M/\mathrm{M}_\odot \lesssim 6.5$
- Efficient reprocessing: X-rays to UV-optical (dense gas), and to IR (dust)

Outlook

- Dust reprocessing may explain the difference betw/ theo predictions and observed luminosities of TDEs.
- AT1-like TDEs not detectable by OPT/UV/X-rays
  $\Rightarrow$ IR and radio to the rescue
- Tip of the iceberg of a hidden TDE population?
  Could be much more numerous at high-z
- Radiative feedback might be significant
  $\Rightarrow$ Important for modelling AGN-SF feedback in galaxies

A luminous, dust-enshrouded TDE jet in a