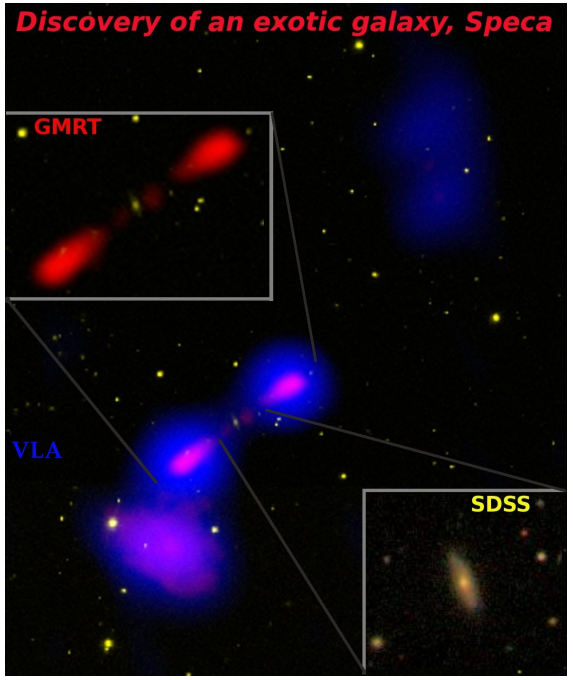
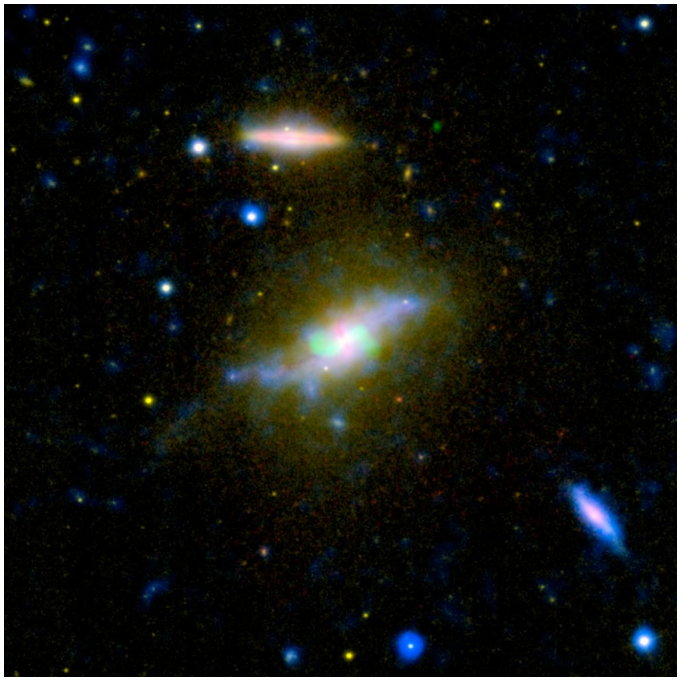




UM-DAE CBS

University Grants Commission

NGC6764, NGC3801 and Speca: Effects of AGN-jets at kpc to Mpc scales, observed in low frequency radio to X-ray bands

Ananda Hota

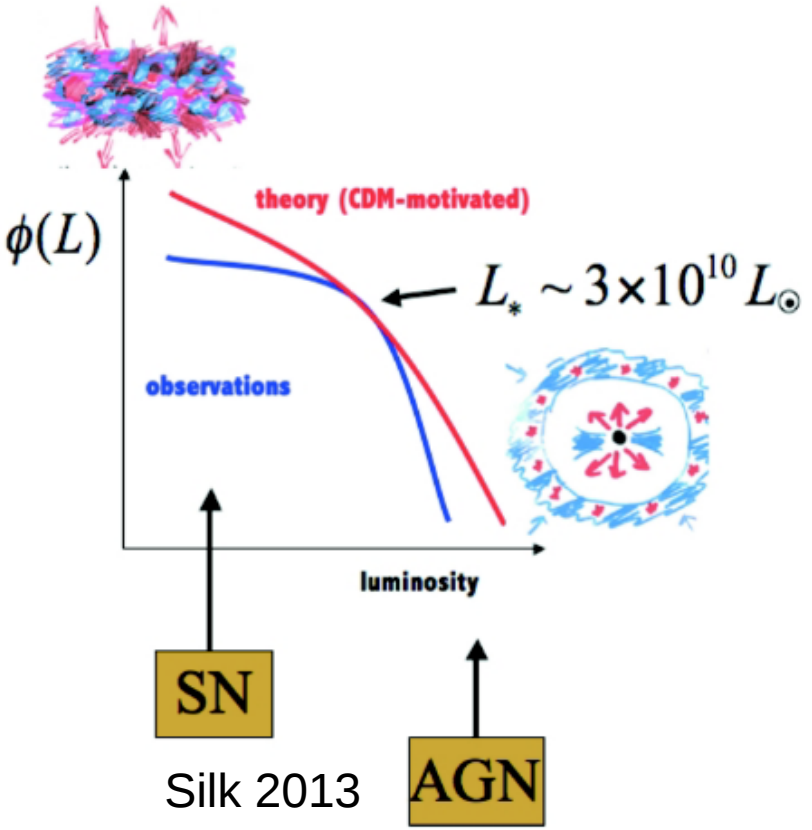
UM-DAE Centre for Excellence in Basic Sciences

***RAD@home* Astronomy Collaboratory, India**

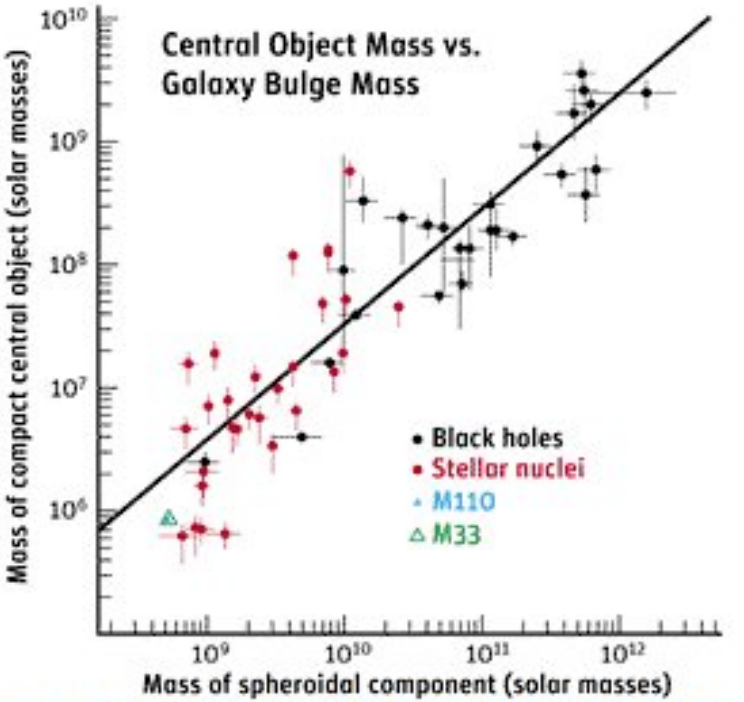
#ABCDresearch #RADathomeindia

RAD@home

Galaxy- Black hole co-evolution via Feedback

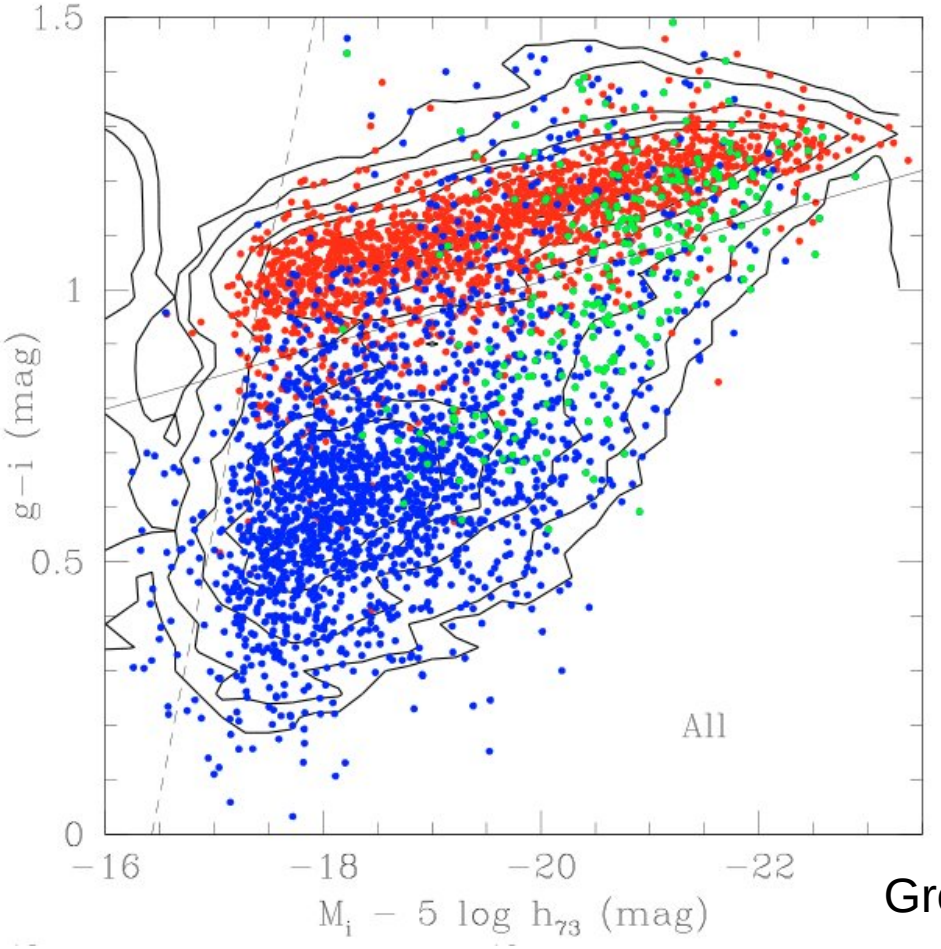


Silk 2013

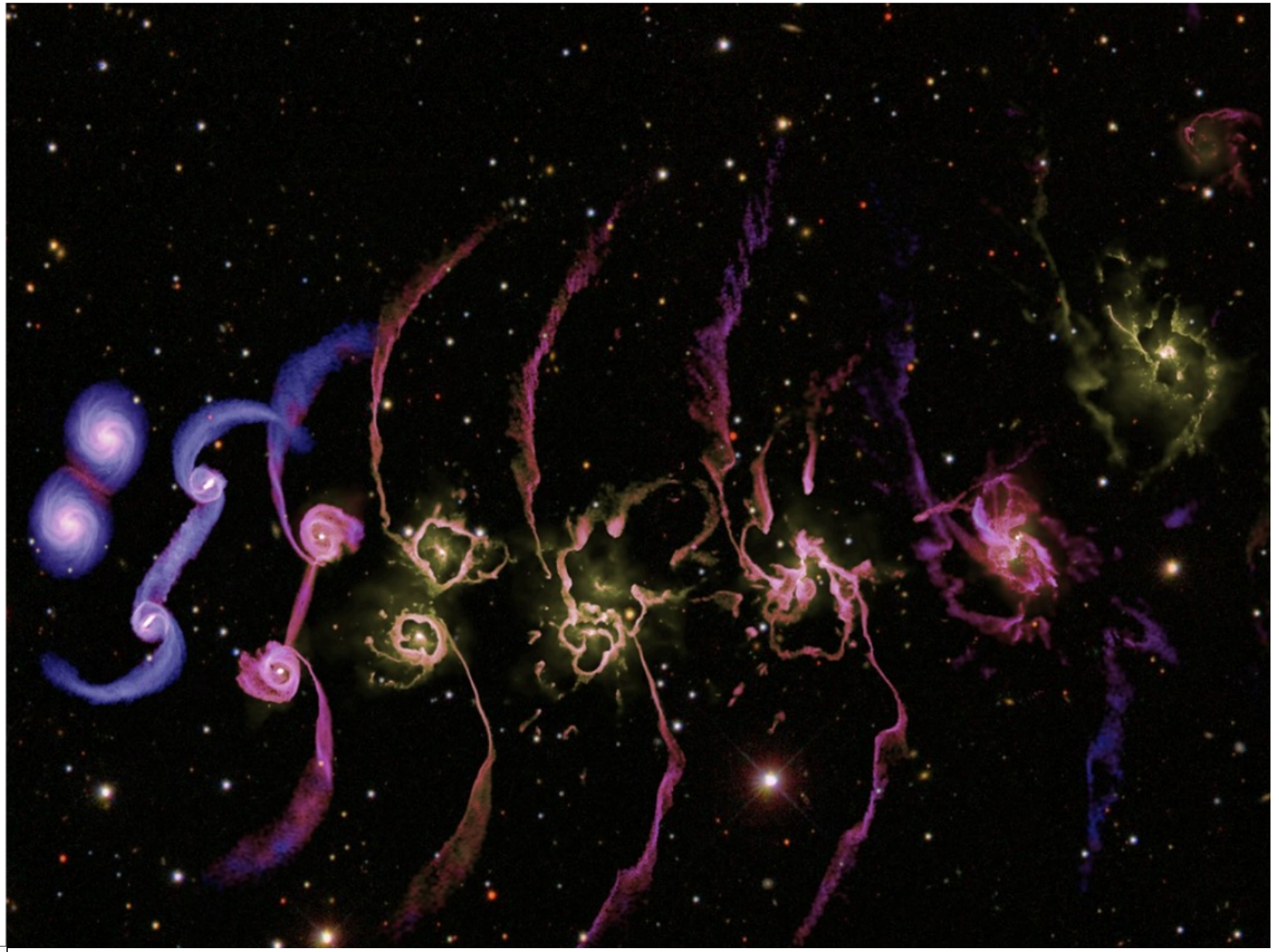


Robert Naeye, Sky & Telescope, May 31, 2006
Ferrarese et al. 2006, ApJL, 644, 21

Infall & Feedback key to Galacy Evolution



Great Wall: Gavazzi et al. 2010



Feedback during merger (Springel et al. 2005)

Teacher finds new cosmic object

By Paul Rincon

Science reporter, BBC News

Ms Van Arkel was an astronomy novice before taking part in Galaxy Zoo

The object is lit up by a long-dead quasar

Hanny Voorwerp in spiral galaxy IC 2497

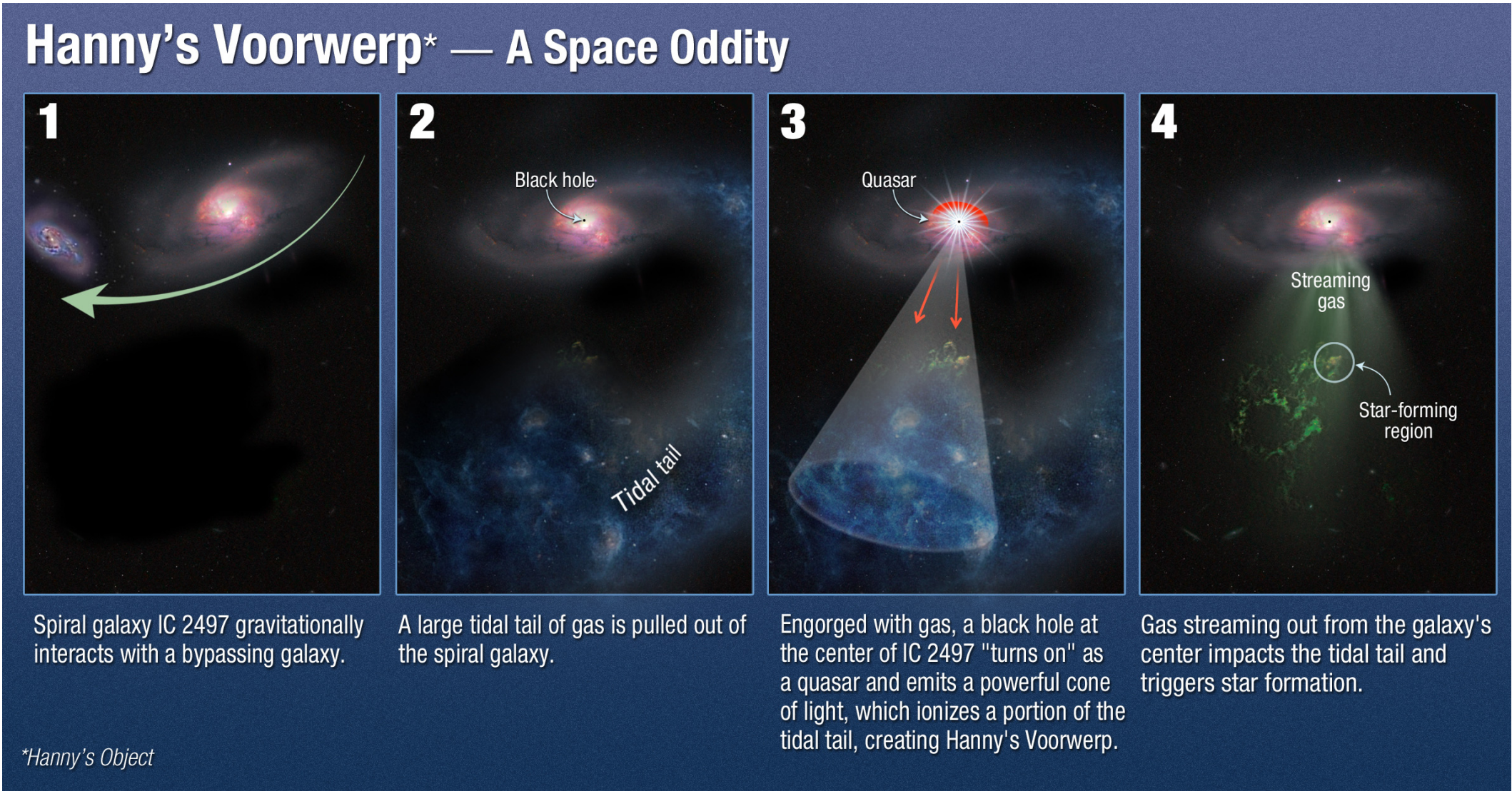
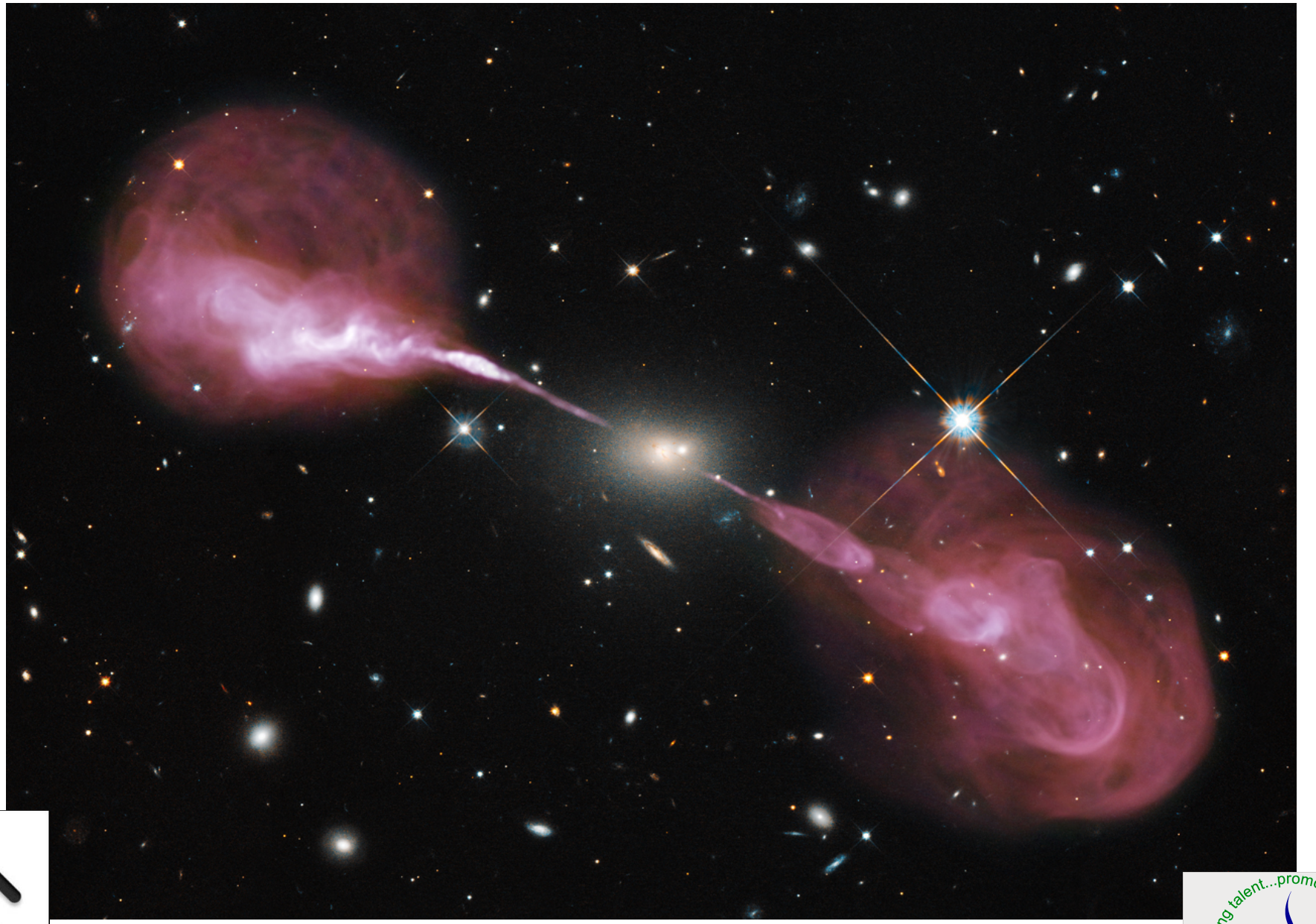


Image: wikipedia

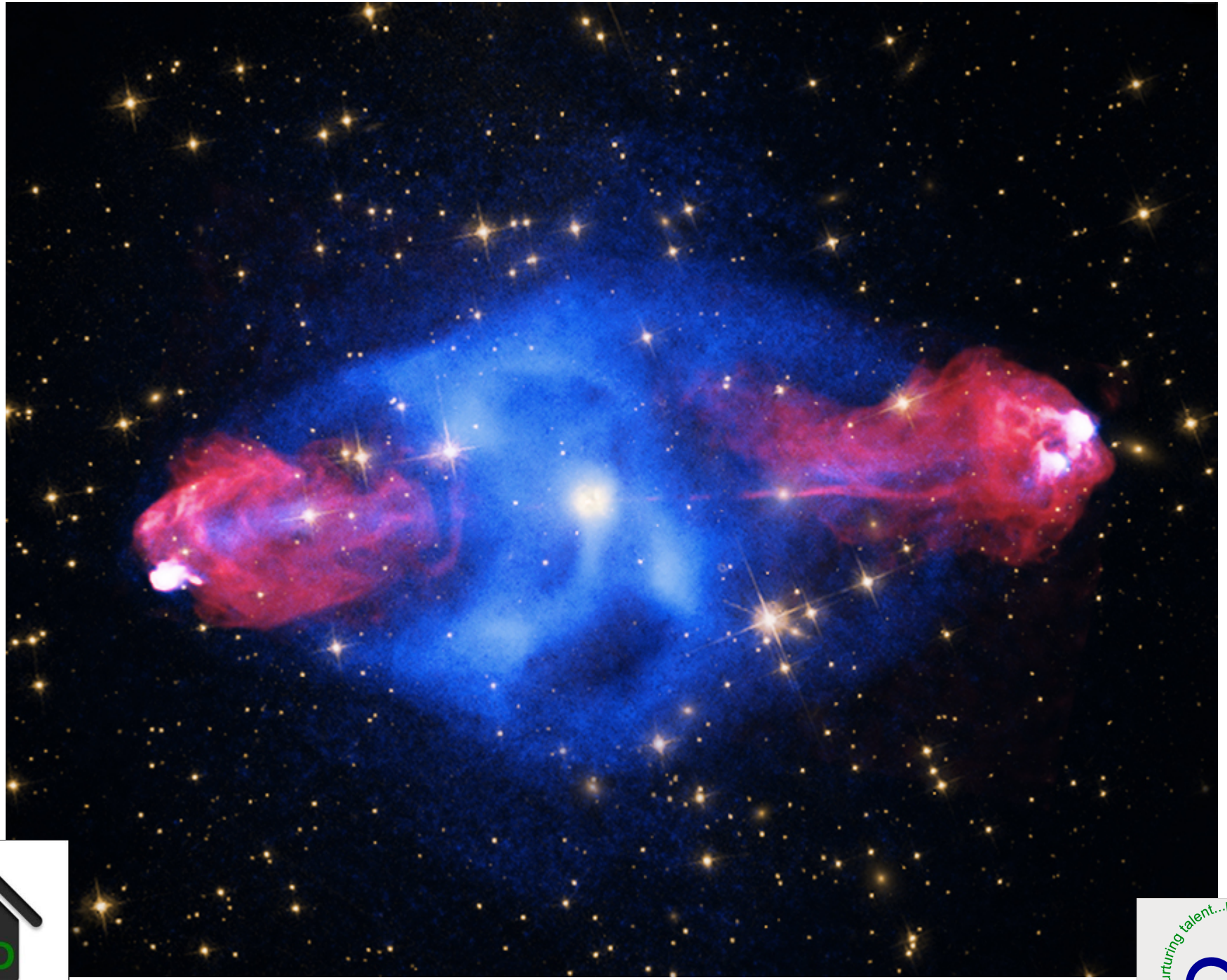
Time scales: Quasar relic

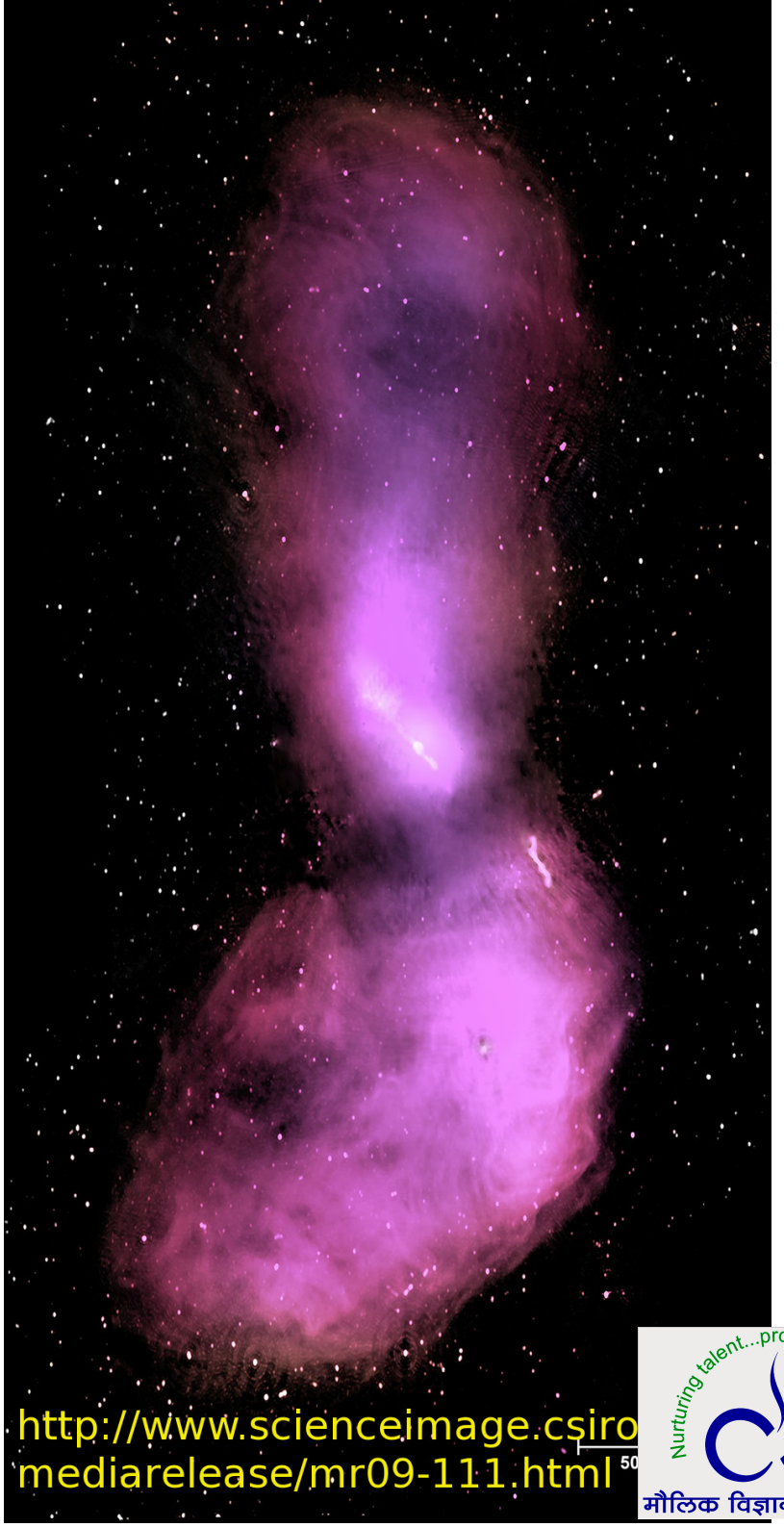
20,000 – 70,000 years

Time scale or relics of Radio Galaxy Activity ???

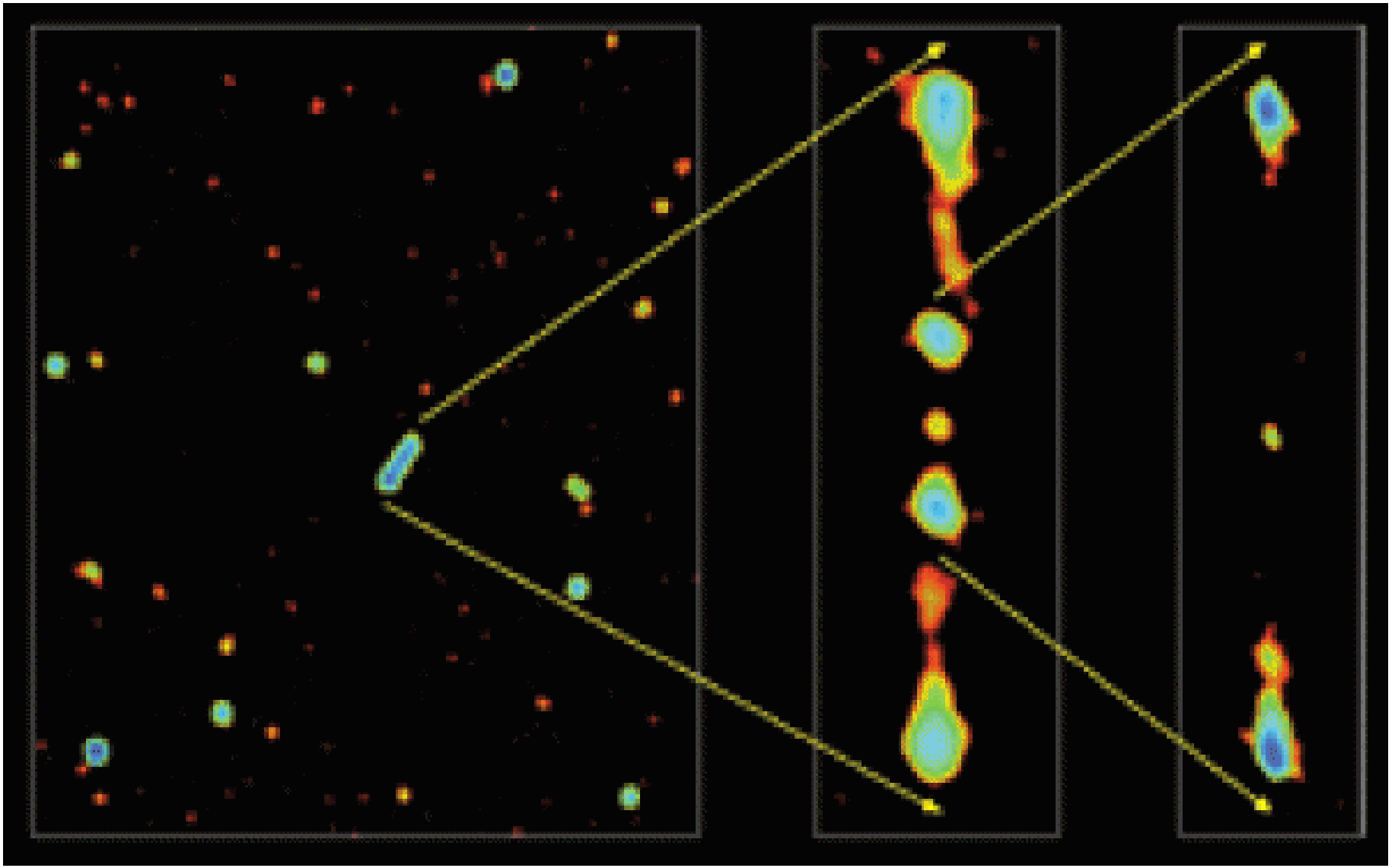


Jet @ ICTS

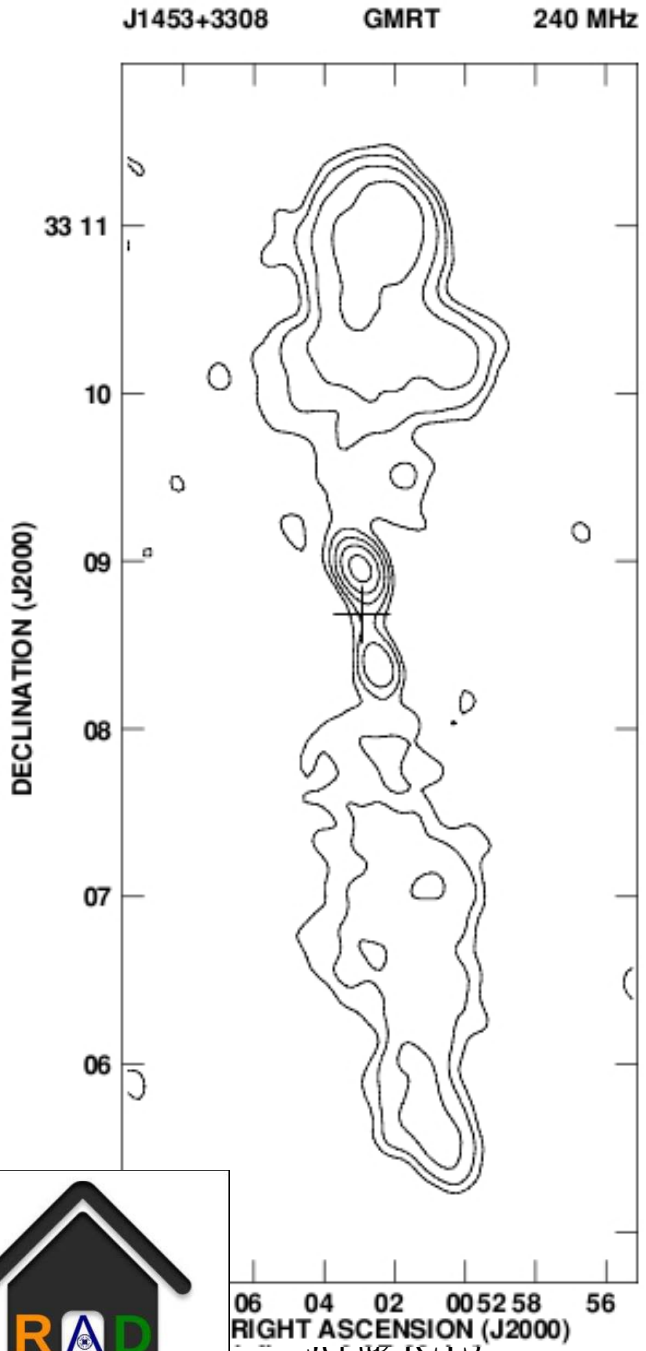


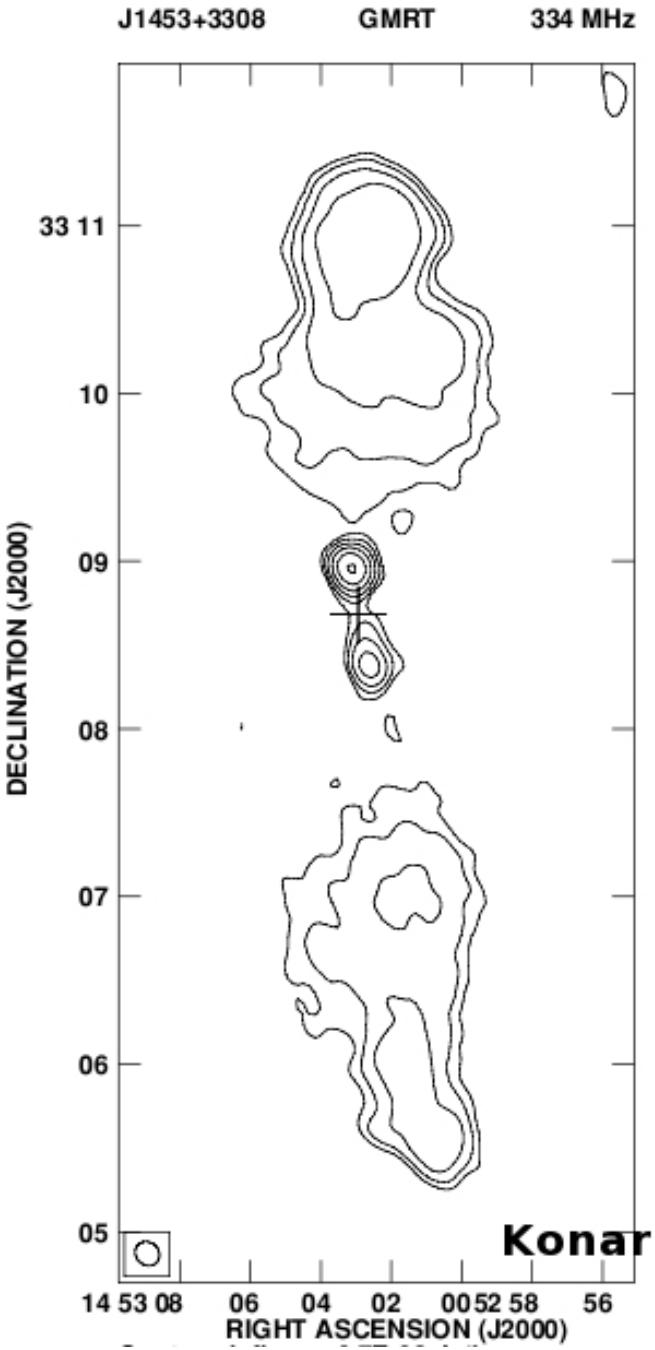


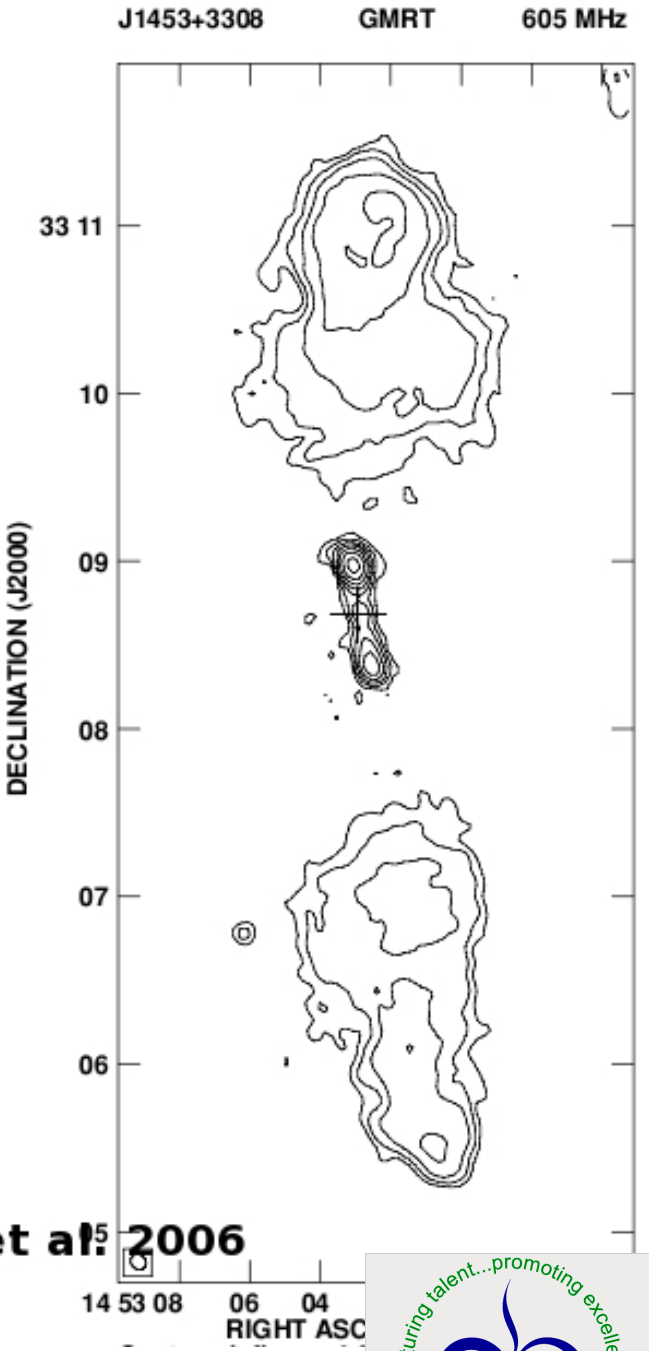
Fealin et al 2011



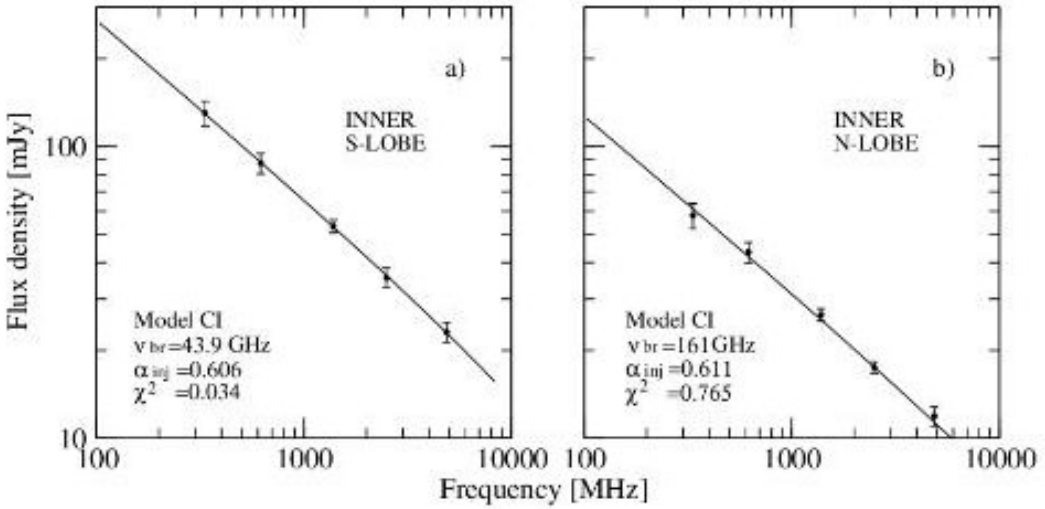
Double-double radio galaxy Schoenmakers 2000

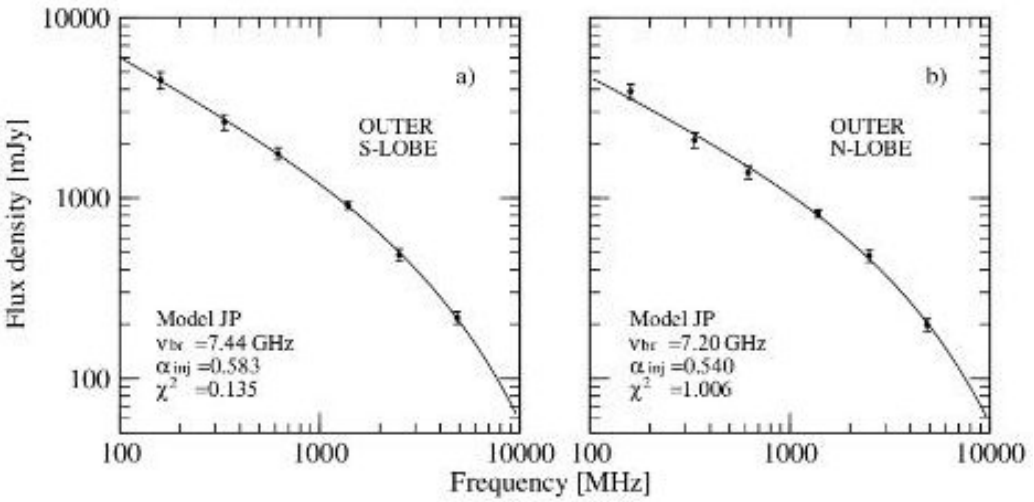






Konar et al. 2006





Double-double radio galaxy J1548-3216 from Machalski, Jamrozy & Konar 2010

$$\tau_{\rm rad} = 50.3 \frac{B^{1/2}}{B^2 + B_{\rm iC}^2} [\nu_{\rm br}(1+z)]^{-1/2} \ {\rm Myr},$$

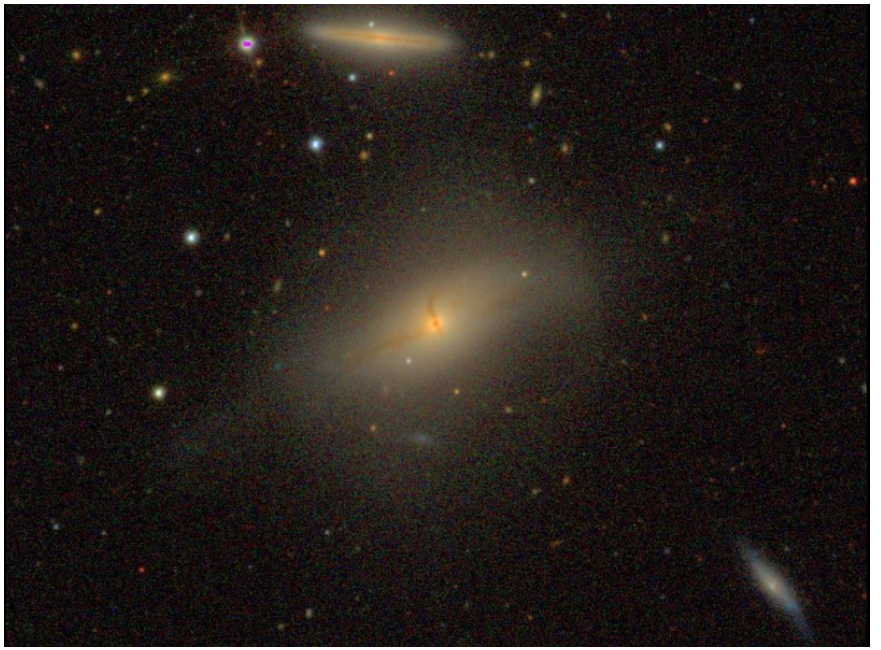
where $B_{\rm iC} = 0.318(1+z)^2$ is the magnetic field strength equivalent to the inverse-Compton microwave background radiation; B and $B_{\rm iC}$ are expressed in units of nT, while $\nu_{\rm br}$ is in GHz.

Konar et al 2006

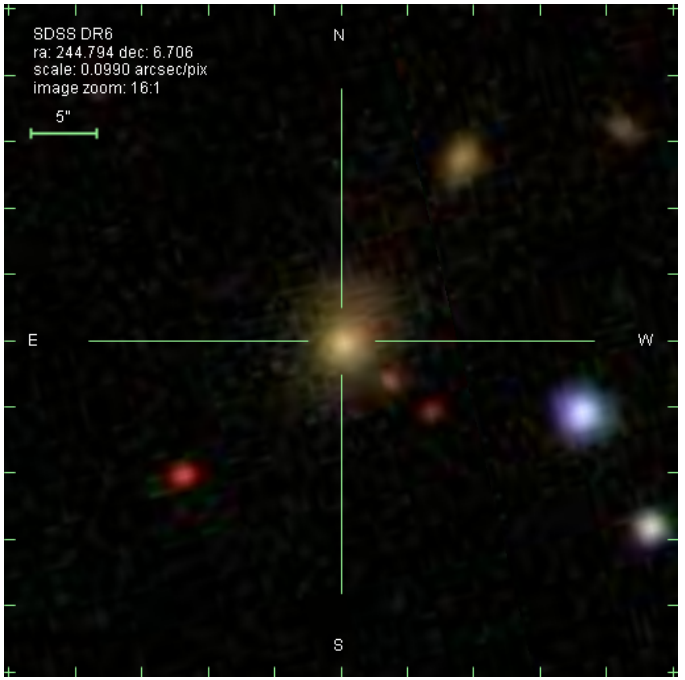
Finally, we use our theoretical machinery to provide a recipe for calculating the age of the most recent star formation event (t_2) in nearby ($z \lesssim 0.1$) red early-type galaxies: $\log t_2({\rm Gyrs}) \sim 0.6^{\pm 0.03} [({\rm NUV} - u) - (g - z) - 1.73^{\pm 0.03}]$, where NUV, u, g and z are the observed photometric magnitudes of the galaxies in the *GALEX*/SDSS filter sets.

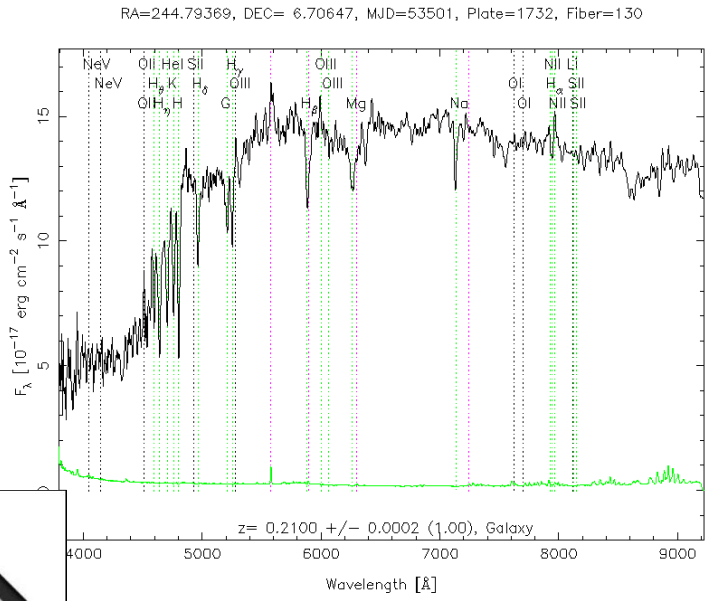
Kaviraj 2010

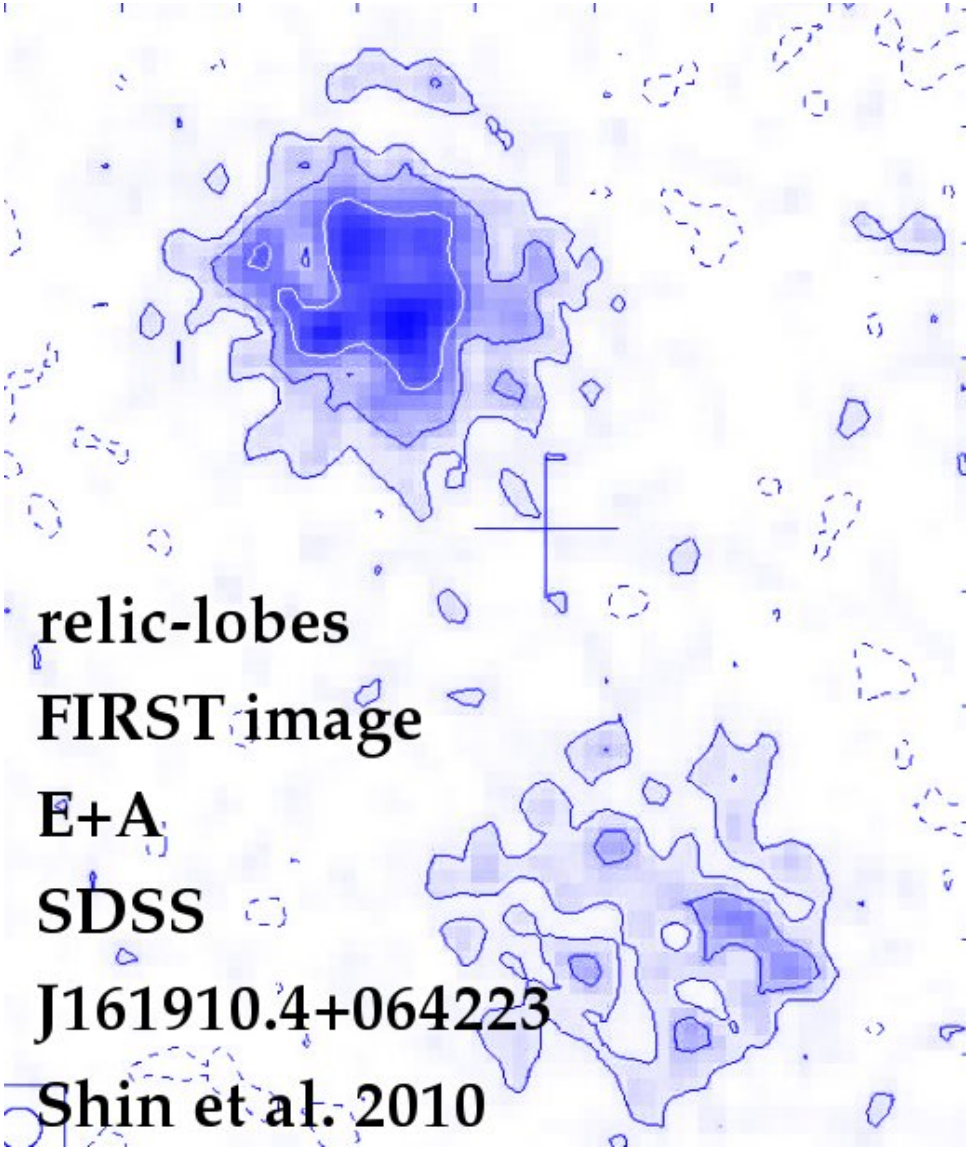
Smoking gun Evidence of AGN-feedback
Wait.....Timescle has to match
Need to push the limit a few Myr to 100s to billion yrs.
Only radio seems to be capable of....



1, 2, 3, three bullets fired, that is Speca







Jet @ ICTS

Observed with GMRT at 50cm 90cm and 120cm bands

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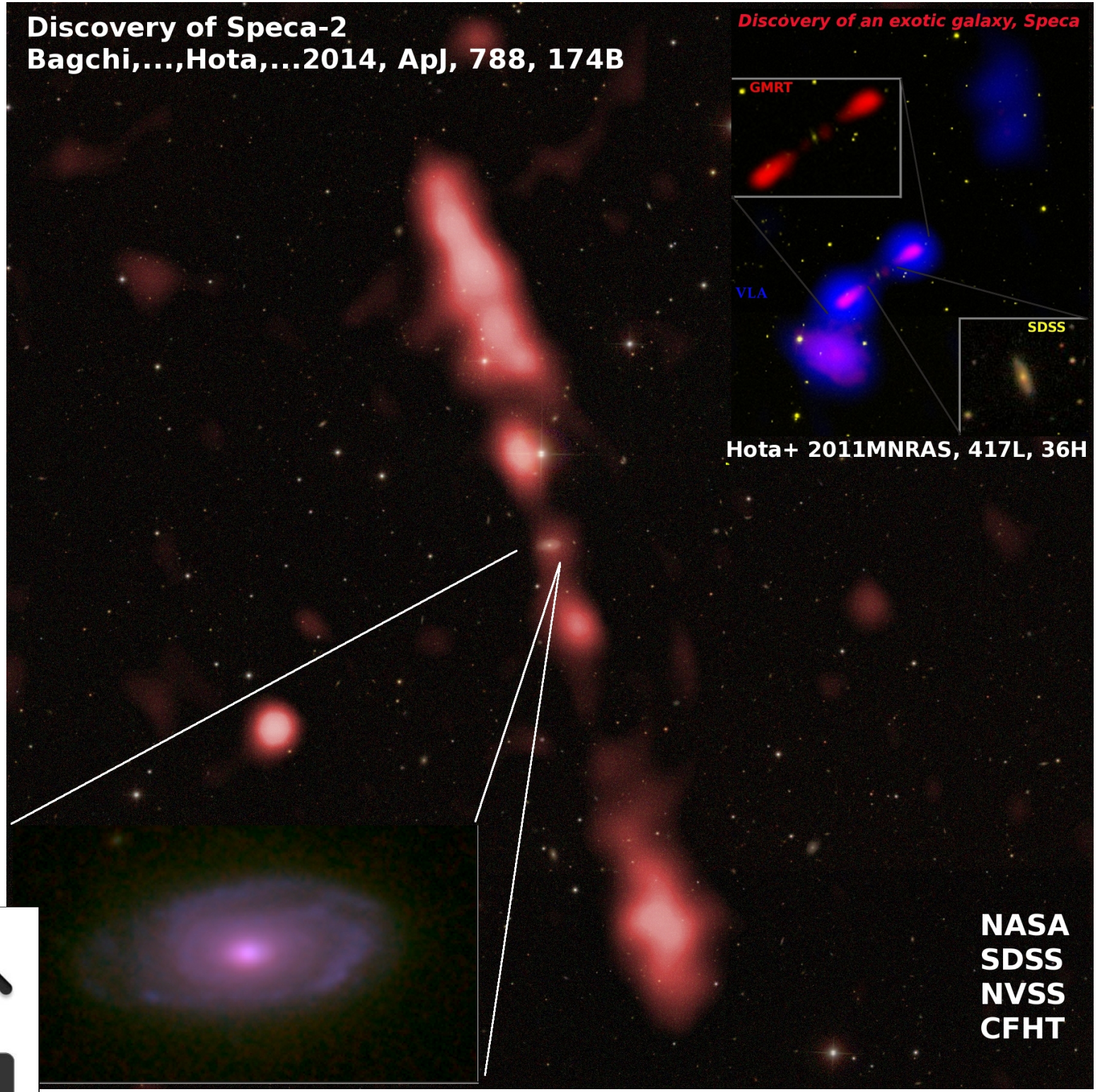
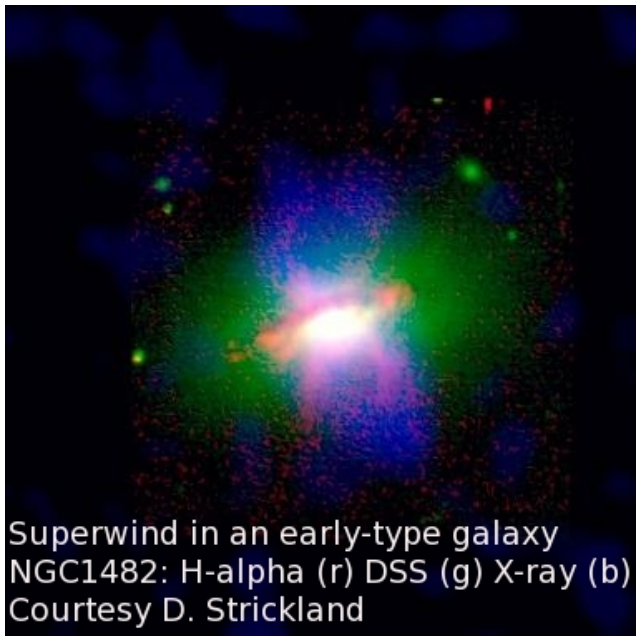
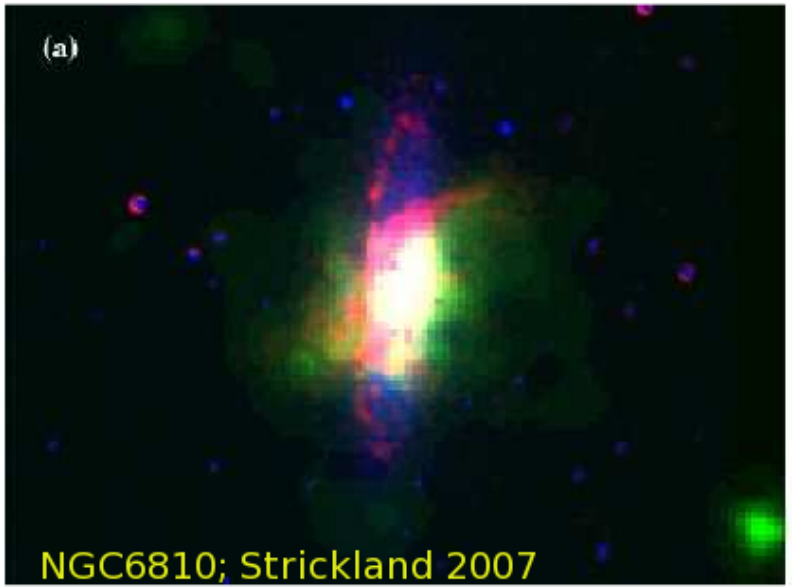




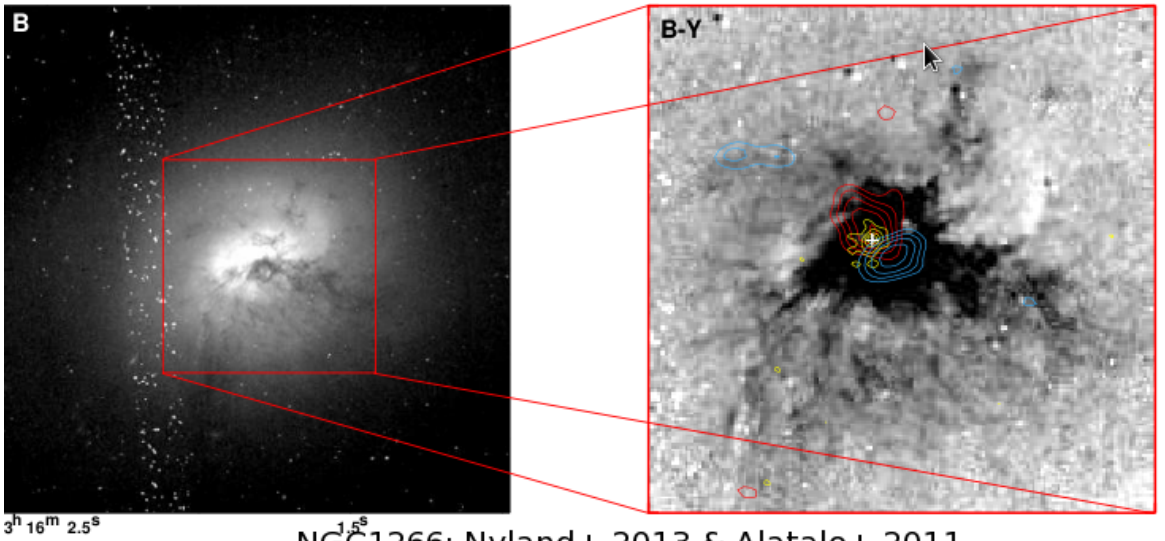
NGC1482: 25 Mpc



NGC6810 27Mpc

Near-by

ETGs In Transition



NGC1266: Nyland+ 2013 & Alatalo+ 2011

NGC1266:
30 Mpc

Jet @ ICTS

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY LETTERS

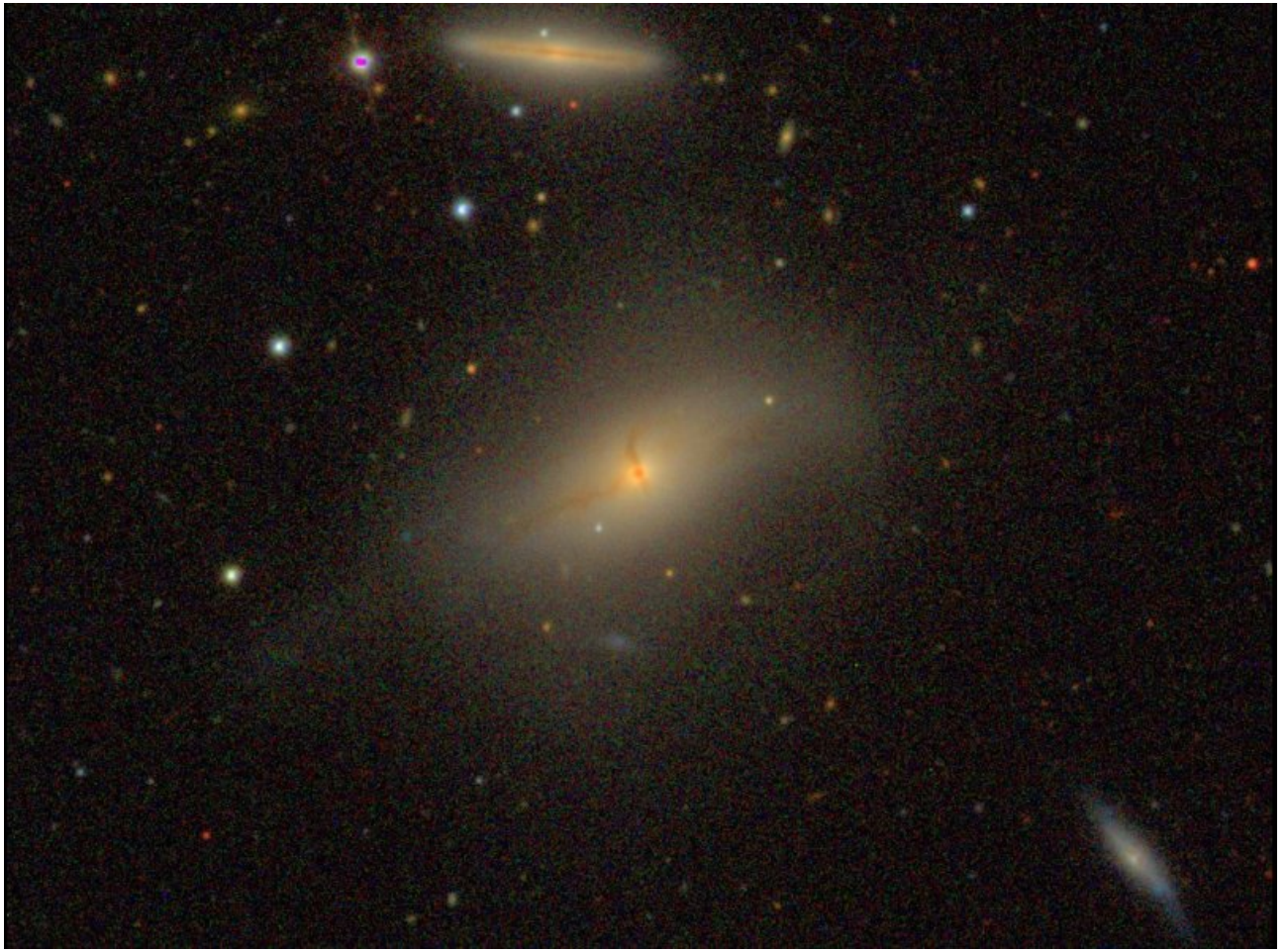
Mon. Not. R. Astron. Soc. **422,** L38–L42 (2012) doi:10.1111/j.1745-3933.2012.01231.x

NGC 3801 caught in the act: a post-merger star-forming early-type galaxy with AGN–jet feedback

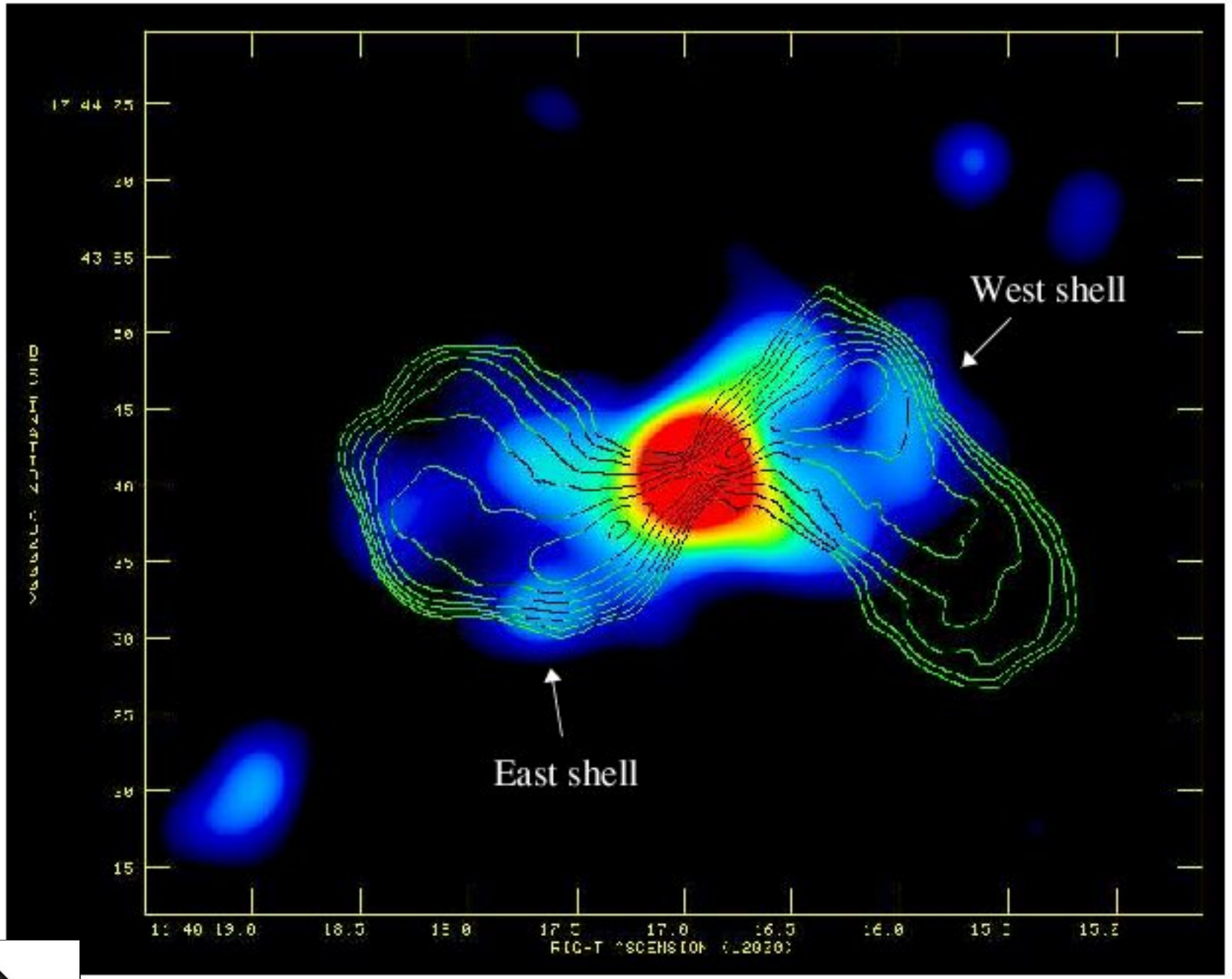
Ananda Hota,[1]★ Soo-Chang Rey,[2]★ Yongbeom Kang,[2,3] Suk Kim,[2] Satoki Matsushita[1] and Jiwon Chung[2]

[1] *Academia Sinica Institute of Astronomy and Astrophysics, PO Box 23-141, Taipei 106, Taiwan*
[2] *Department of Astronomy and Space Science, Chungnam National University, Daejeon 305-764, Republic of Korea*
[3] *Department of Physics and Astronomy, Johns Hopkins University, Baltimore, MD 21218, USA*

Accepted 2012 February 1. Received 2012 February 1; in original form 2011 November 22

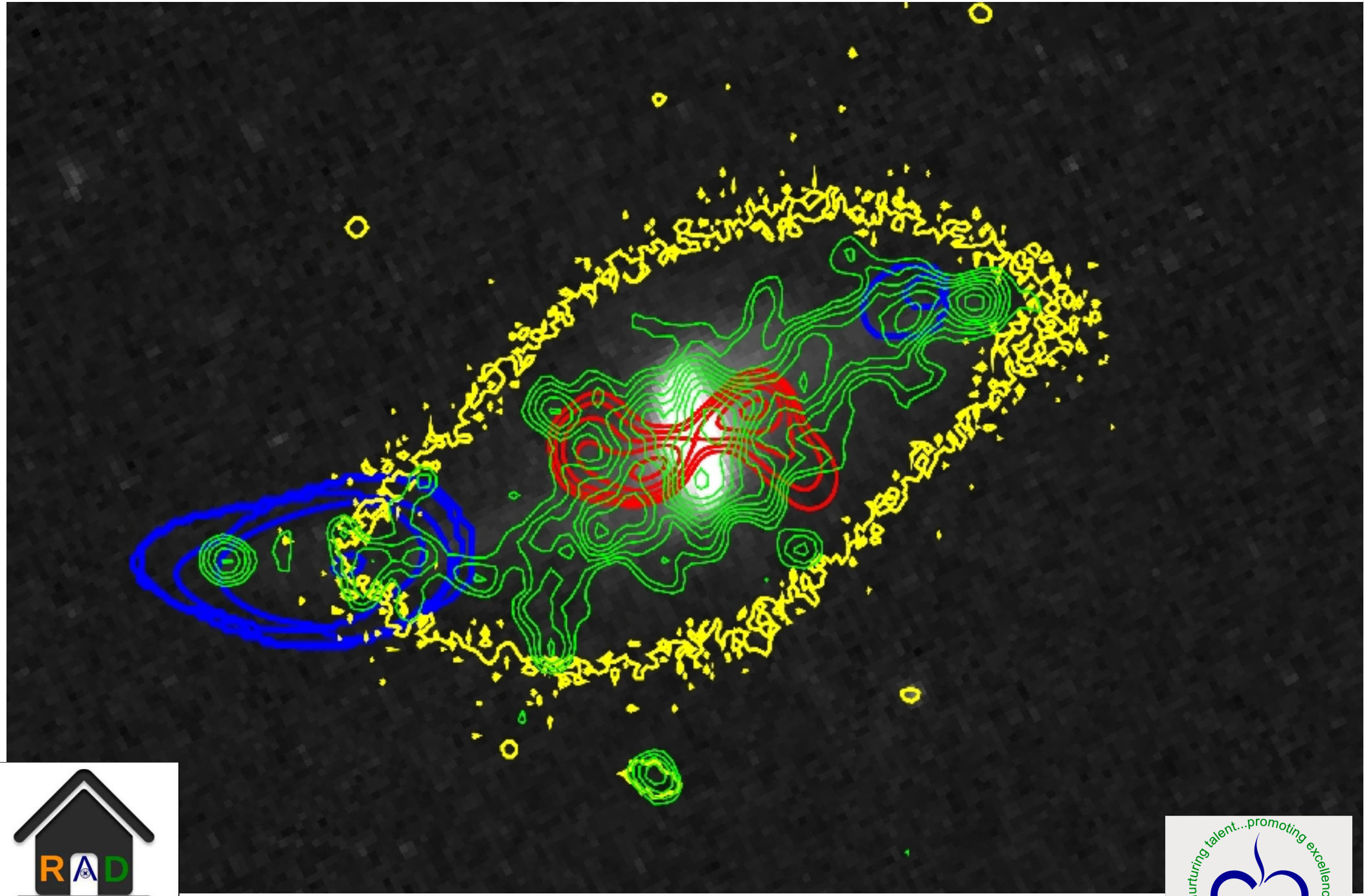


Cosmic Leaf-blower galaxy -- NGC3801



2.— Gaussian smoothed (σ = 1.97 arcsec) 0.5 – 5 keV image of the *Chandra* data, wit
Hz radio contours overlaid to illustrate the relationship between the X-ray shells and radi
nology.

Croston et al. 2007ApJ...660..191



RAD @

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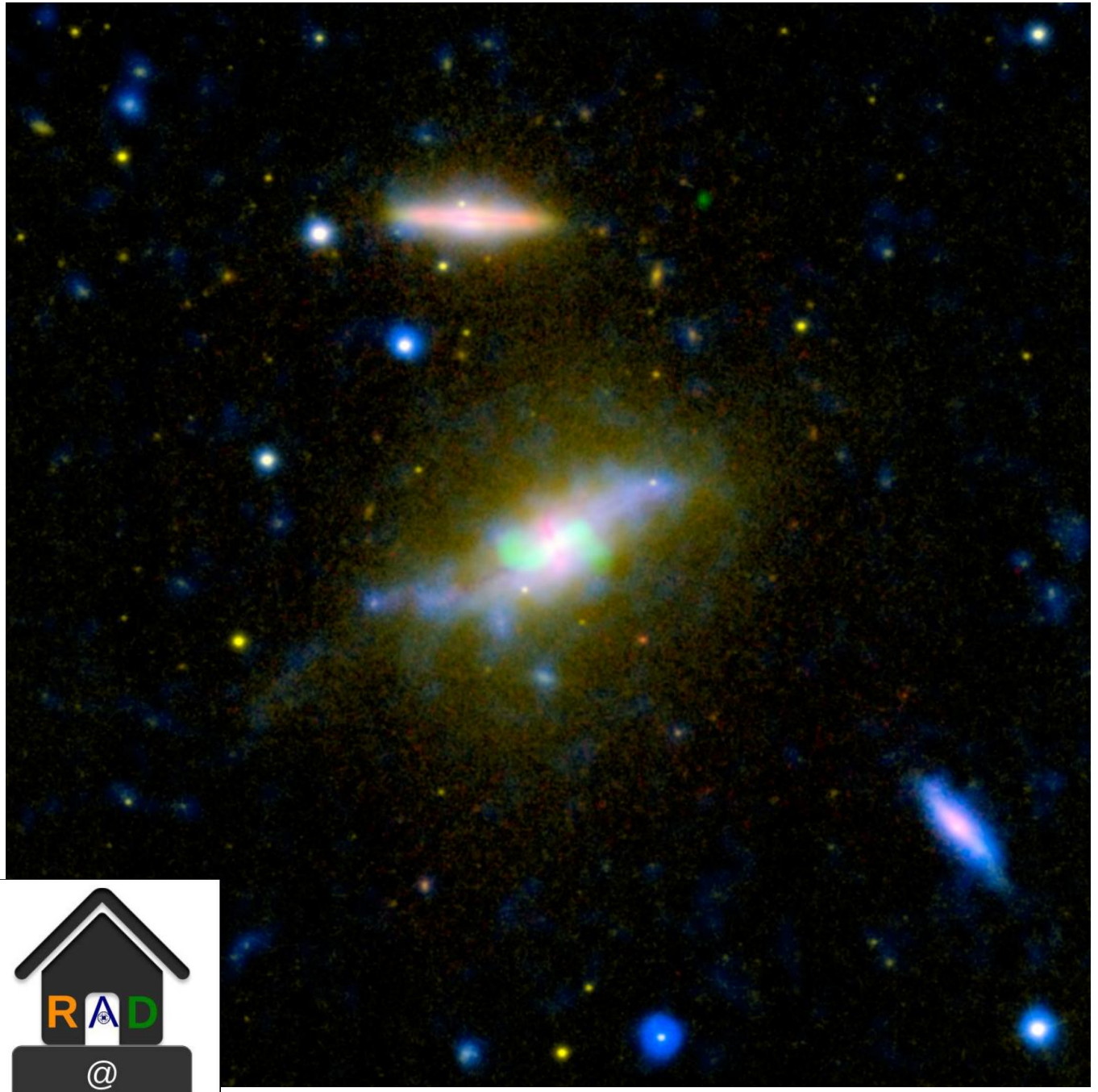
NGC 3801 caught in the act: A post-merger starforming early-type galaxy with AGN-jet feedback



NGC3801

SDSS -stellar light

Spitzer 8micron dust/PAH

GALEX NUV young stars

VLA 20m radio bent jets

NASA-JPL-CalTech news release,
TIME magazine site
Times of India
~ 3 lakhs peak google hits

Cosmic Leaf Blower

Hota et al. 2012
MNRAS, Letters

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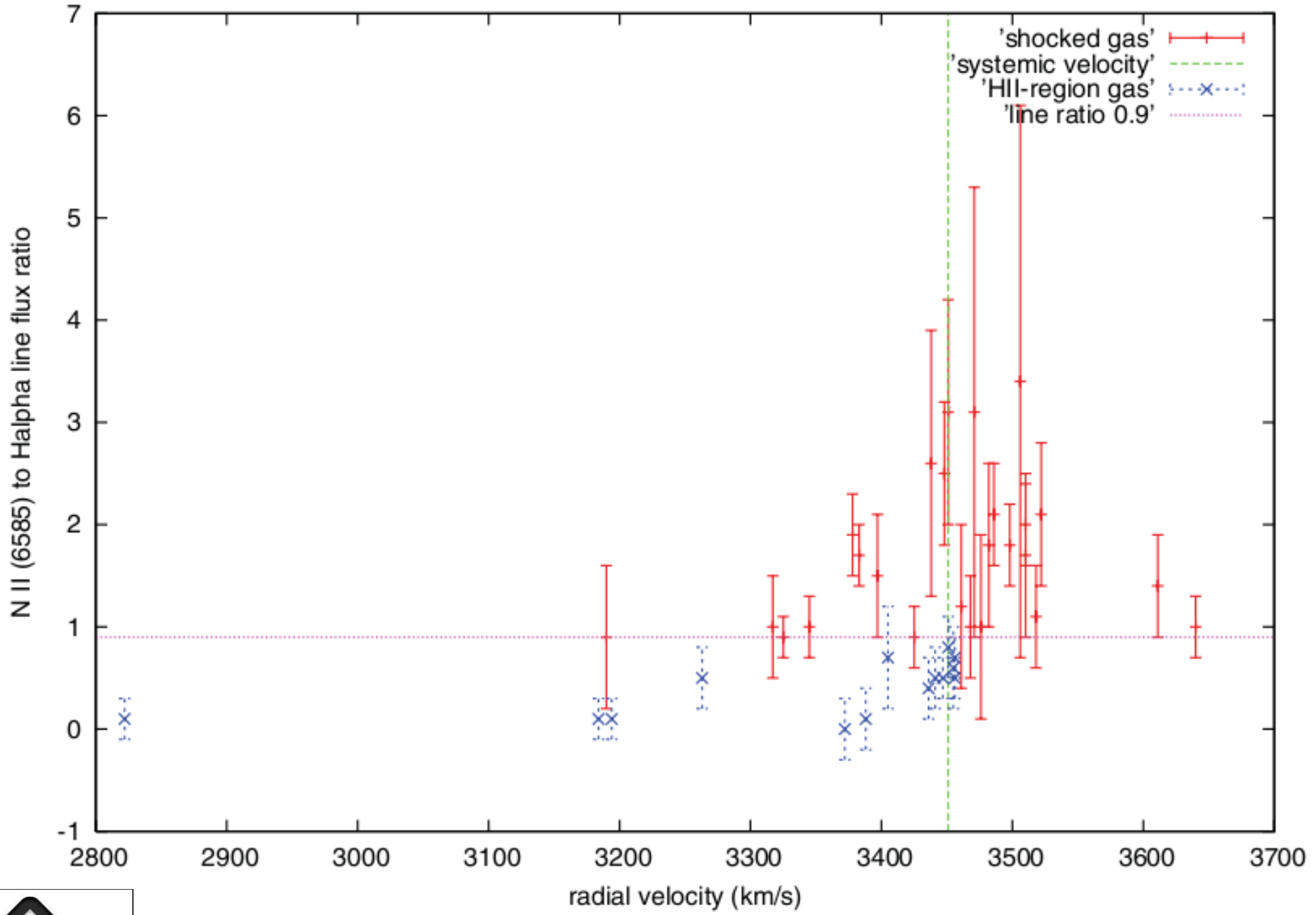
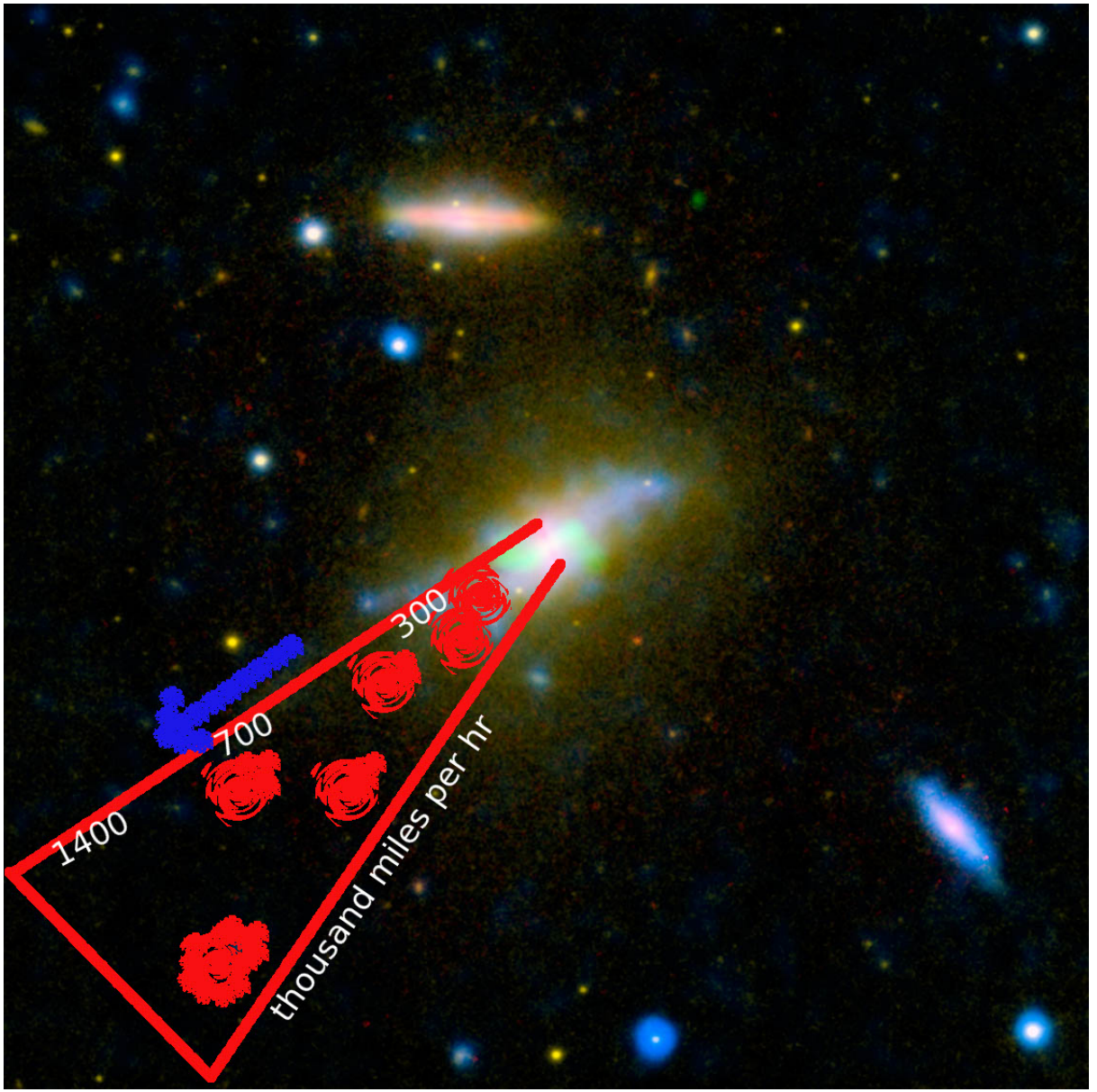
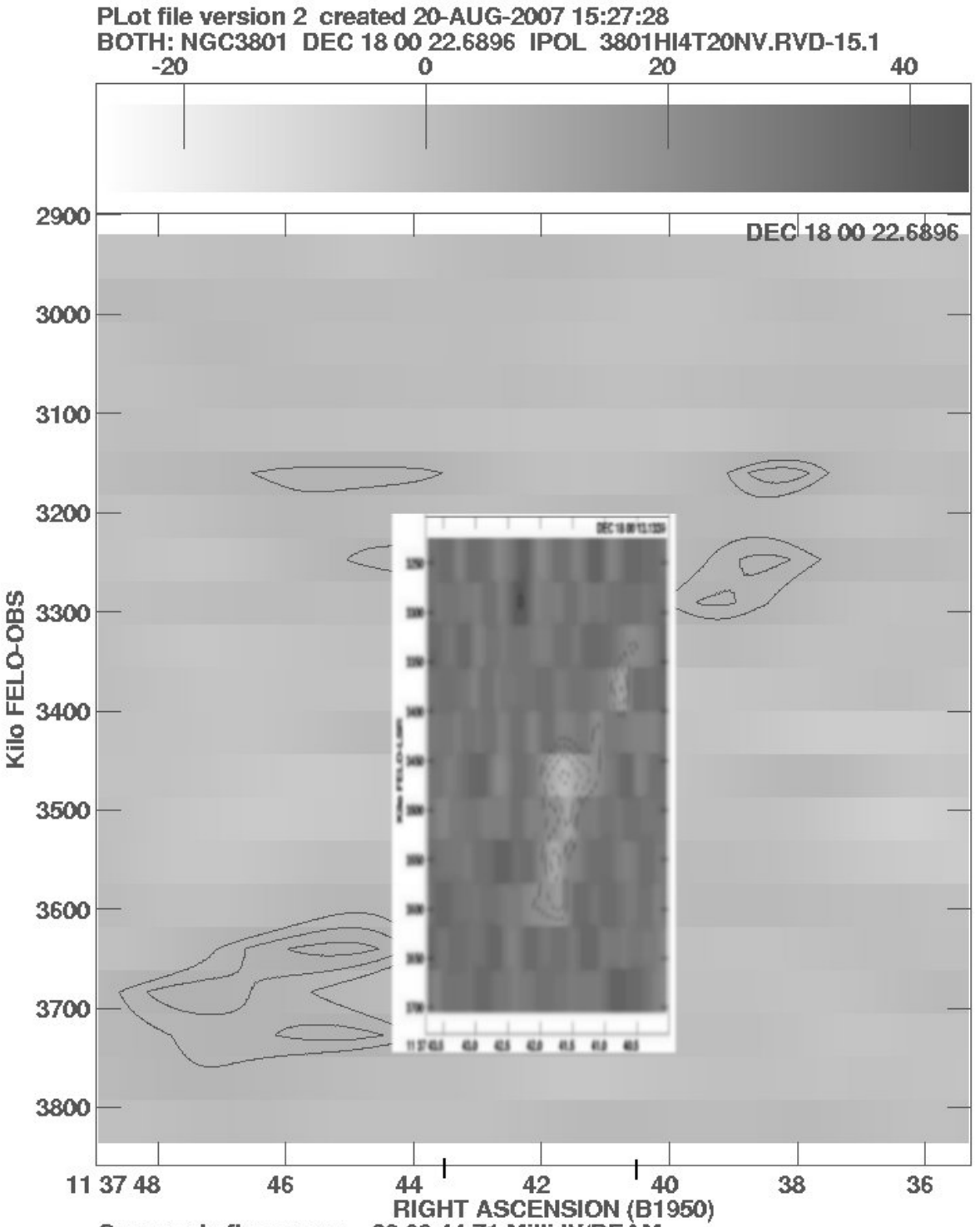

'shocked gas'
'systemic velocity'
'HII-region gas'
'line ratio 0.9'
N II (6585) to Halpha line flux ratio
radial velocity (km/s)
7
6
5
4
3
2
1
0
-1
2800
2900
3000
3100
3200
3300
3400
3500
3600
3700



Jet @ ICTS



Jet @ I

Nurturing talent...promoting excellence

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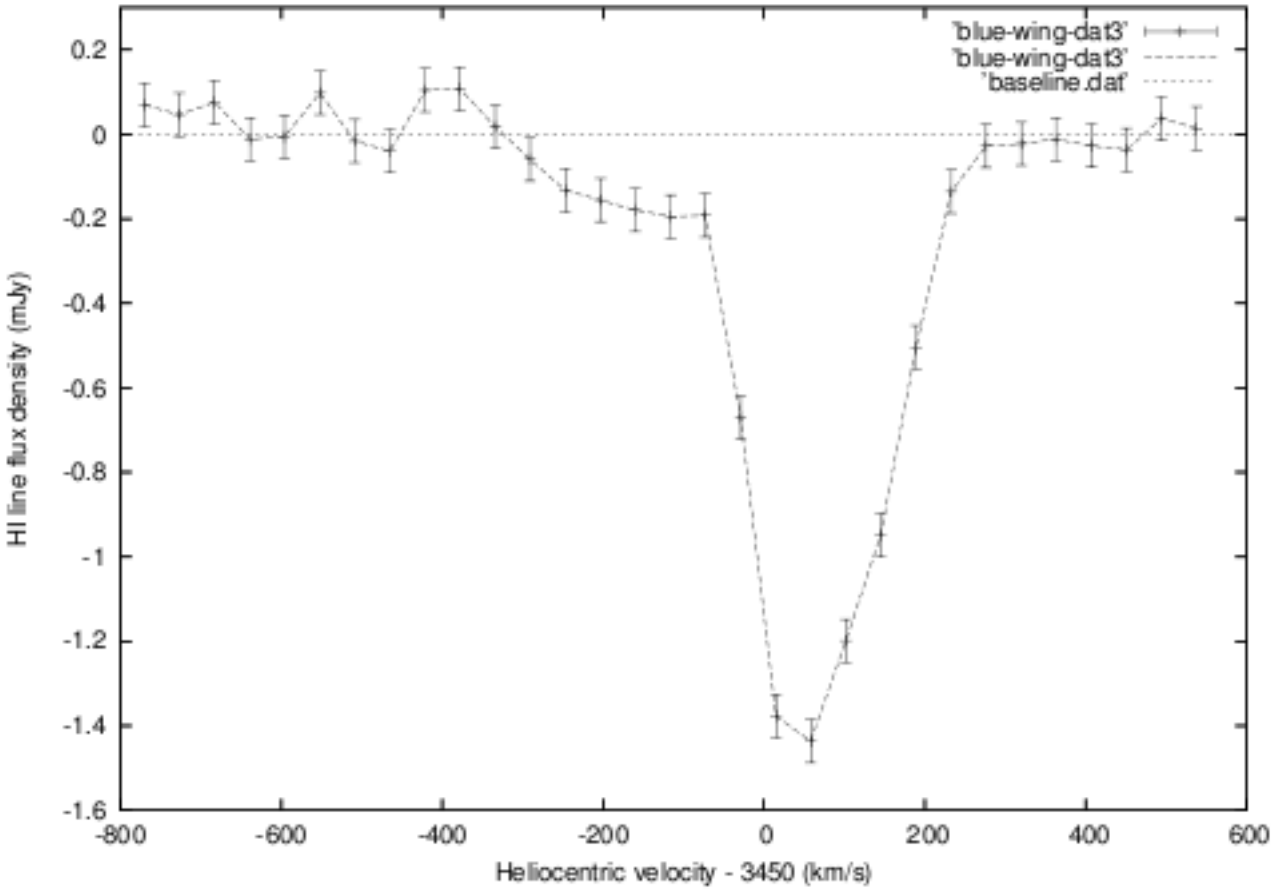
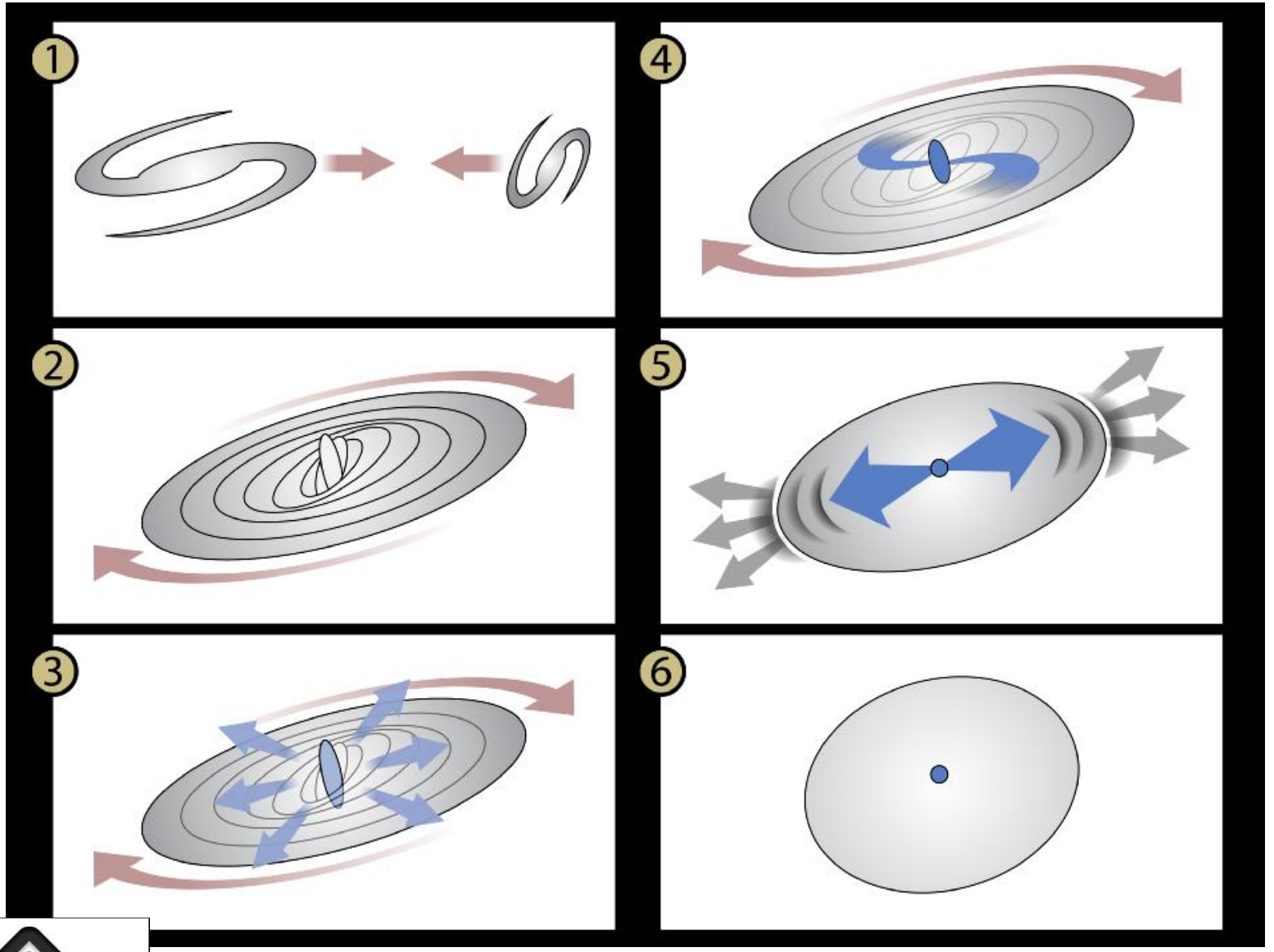


FIG. 14.— HI-absorption spectra against the eastern radio continuum peak taken from a square region of double the size of beam ($8''$). Noise estimated from the spectrum 1σ=0.05 mJy has also been plotted.

Hota, Lim, Ohyama ... (????)

A evolutionary sequence..



Observed with the GMRT for

HI sign of Multiple Feedbacks

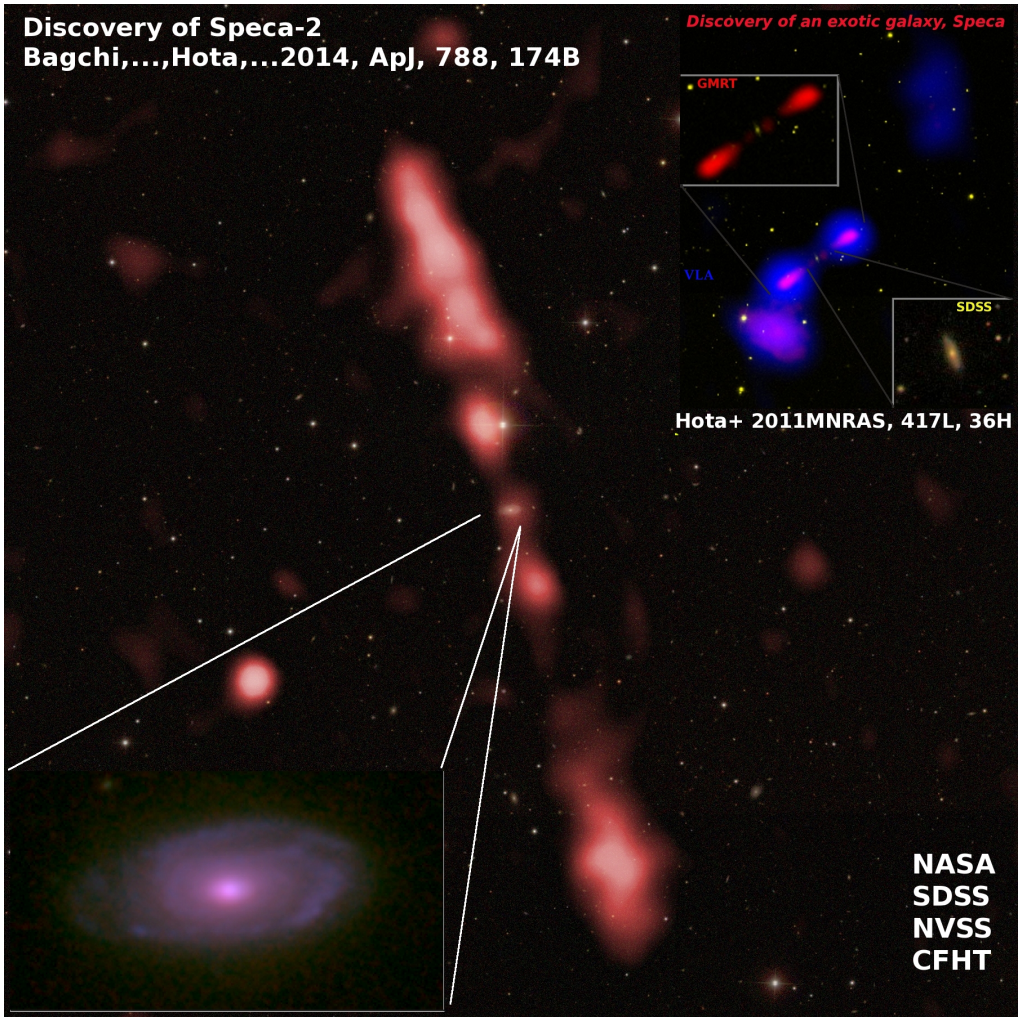
Event before this S-shaped jet

NASA-JPL-CalTech (Ananda Hota & Tim Pyle

NOW Future

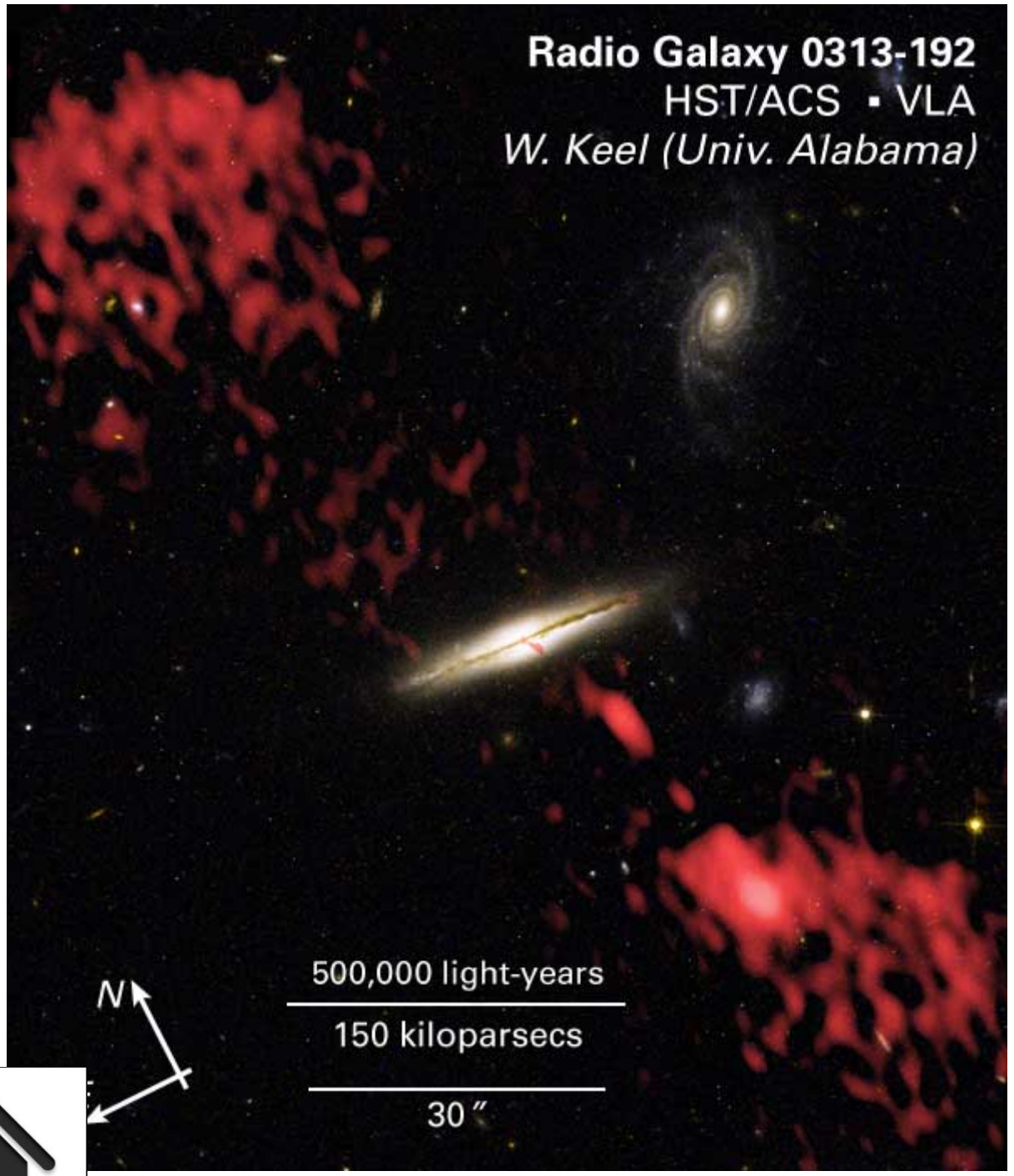
~ 10 Millin years

Jet @ ICTS



Discovery of a spiral-host episodic radio galaxy
Hota, Sirothia, Ohyama, Konar, Kim, Rey, Saikia, Croston, Matsushita 2011

Megaparsec Relativistic Jets Launched from an Accreting Supermassive Black Hole in an Extreme Spiral Galaxy
Bagchi, Vivek, Vikram, Hota, Biju, Sirothia, Srianand, Gopal-Krishna, Jacob 2014

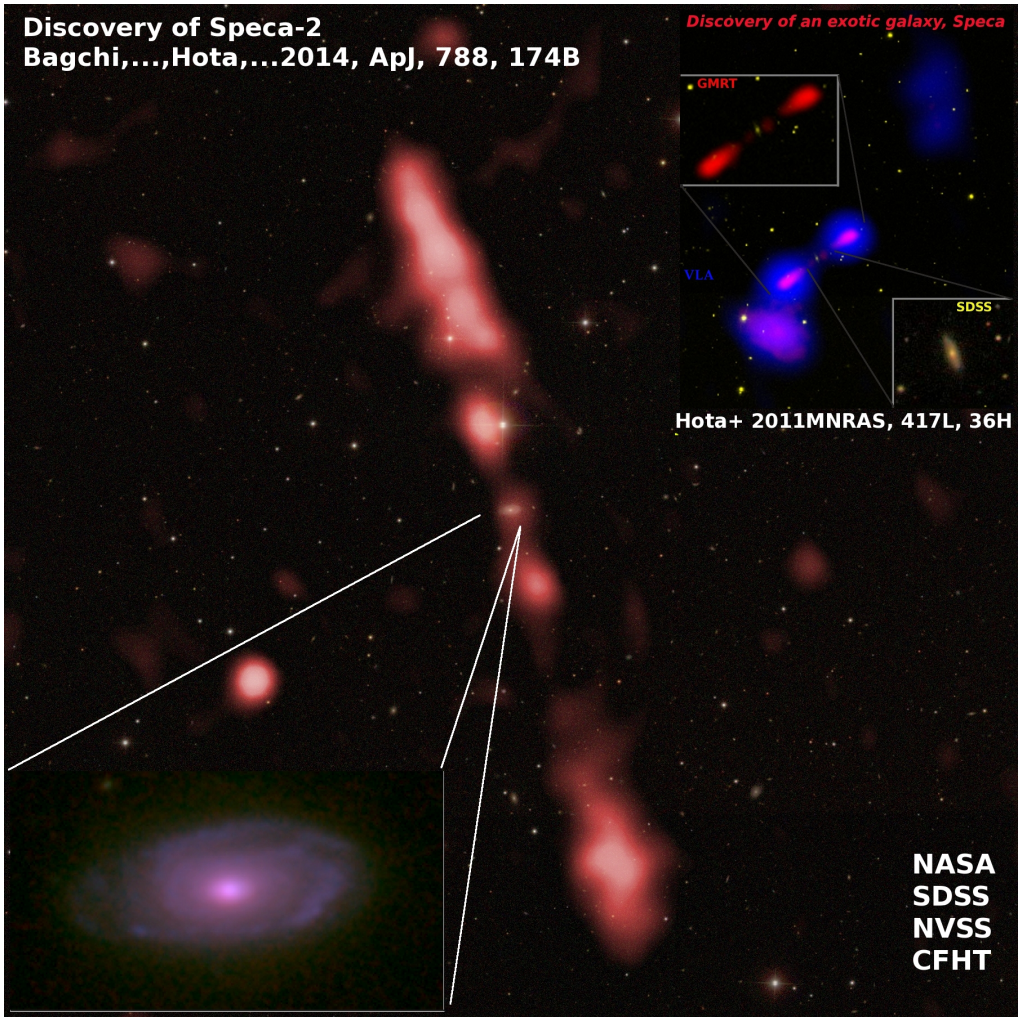


An Unusual Radio Galaxy in Abell 428:
A Large, Powerful FR I Source in a Disk-dominated Host

Ledlow, Michael J.;
Owen, Frazer N.;
Keel, William C.

1998ApJ...495..227L

Speca: Hota+ 2011
J2345: Bagchi+ 2014
J0836: Singh+ 2015



Discovery of a spiral-host episodic radio galaxy
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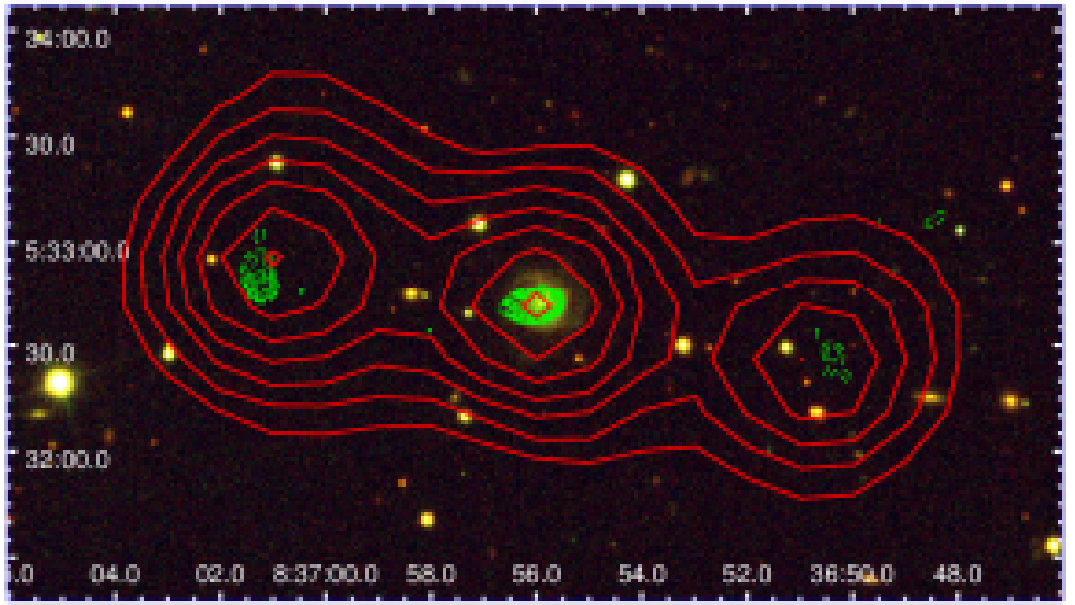

J0836+0532 Singh et al 2015

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Mon. Not. R. Astron. Soc. **417,** L36–L40 (2011) doi:10.1111/j.1745-3933.2011.01115.x

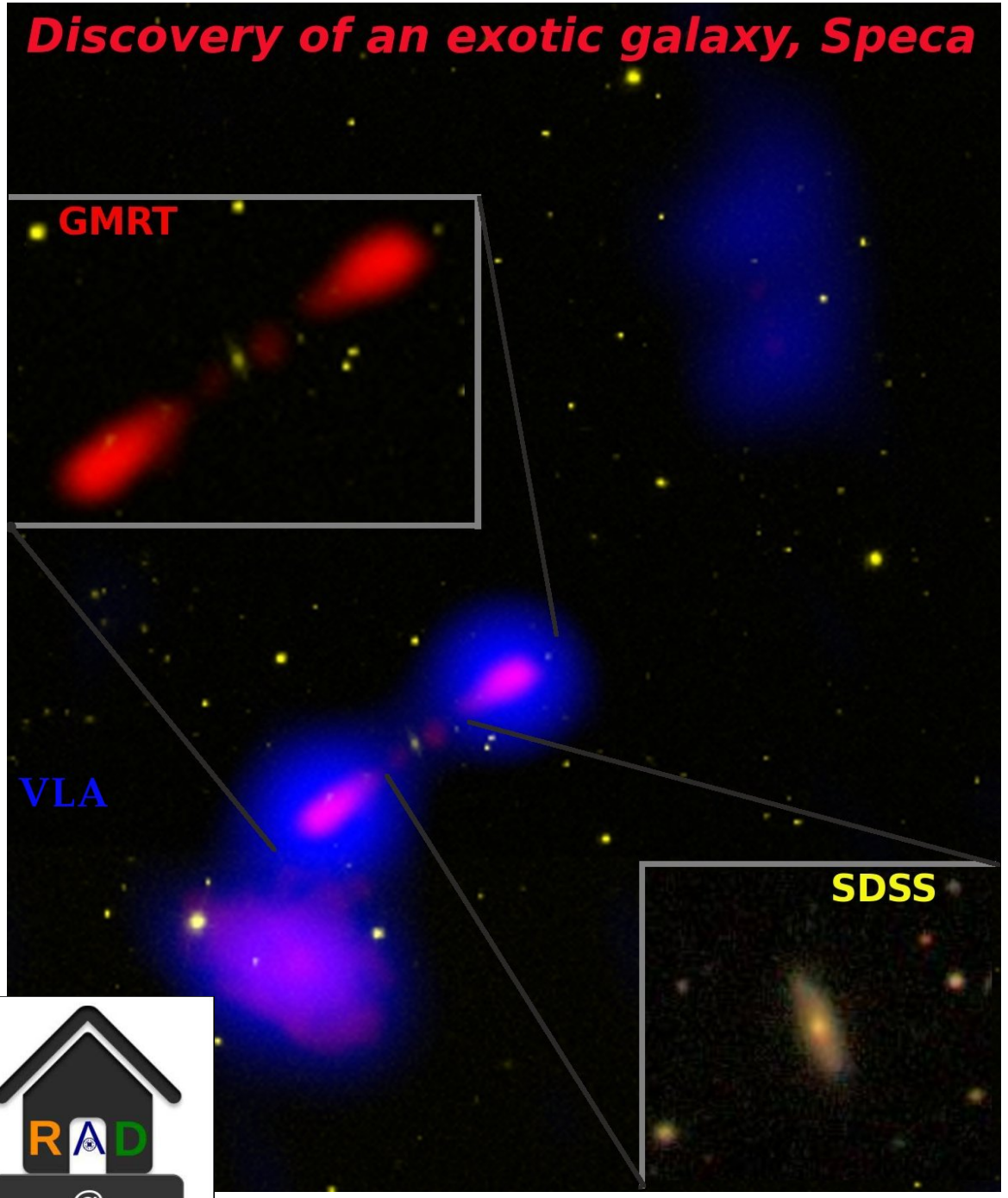
Discovery of a spiral-host episodic radio galaxy

Ananda Hota,[1]★ S. K. Sirothia,[2] Youichi Ohyama,[1] C. Konar,[1] Suk Kim,[3] Soo-Chang Rey,[3] D. J. Saikia,[2] J. H. Croston[4] and Satoki Matsushita[1,5]

[1]*Academia Sinica Institute of Astronomy and Astrophysics, PO Box 23-141, Taipei 106, Taiwan*
[2]*National Centre for Radio Astrophysics, TIFR, Post Bag 3, Ganeshkhind, Pune 411007, India*
[3]*Department of Astronomy and Space Science, Chungnam National University, Daejeon 305-764, South Korea*
[4]*School of Physics and Astronomy, University of Southampton, Southampton SO17 1BJ*
[5]*Joint ALMA Office, Alonso de Córdova 3107, Vitacura, Santiago, Chile*

Accepted 2011 July 8. Received 2011 July 8; in original form 2011 February 28

Discovery of a Spiral-host Episodic radio galaxy



Speca
Hota, Sirothia, Ohyama et al.
2011, MNRAS Letters

NRAO (VLA), NSF, NCRA-TIFR
Royal Astronomical Society
Press Release
Indian Express

Became very popular
~ 3 lakhs peak google hits

RAD@

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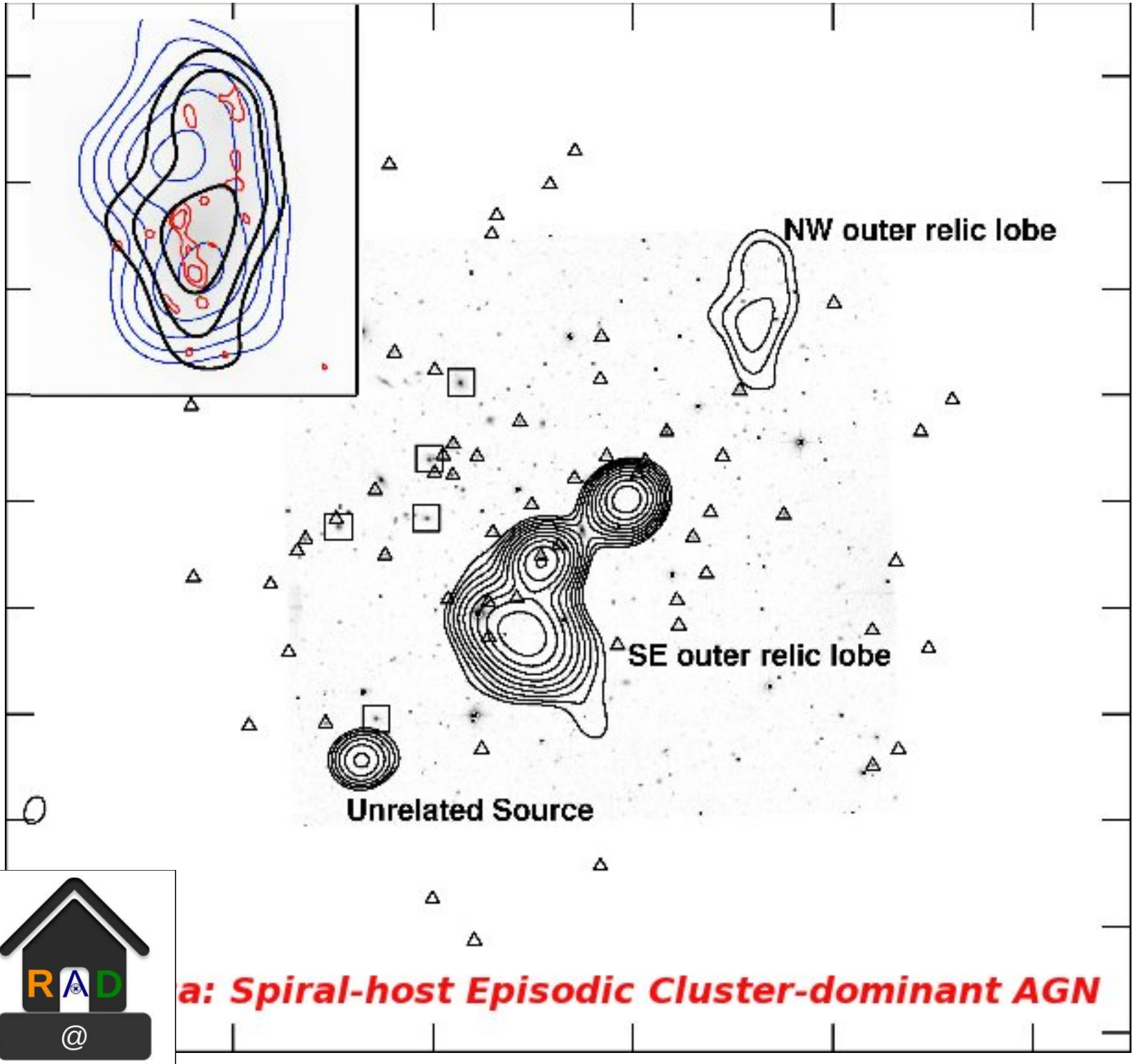


Spectral index

-0.32

-0.92

-0.98

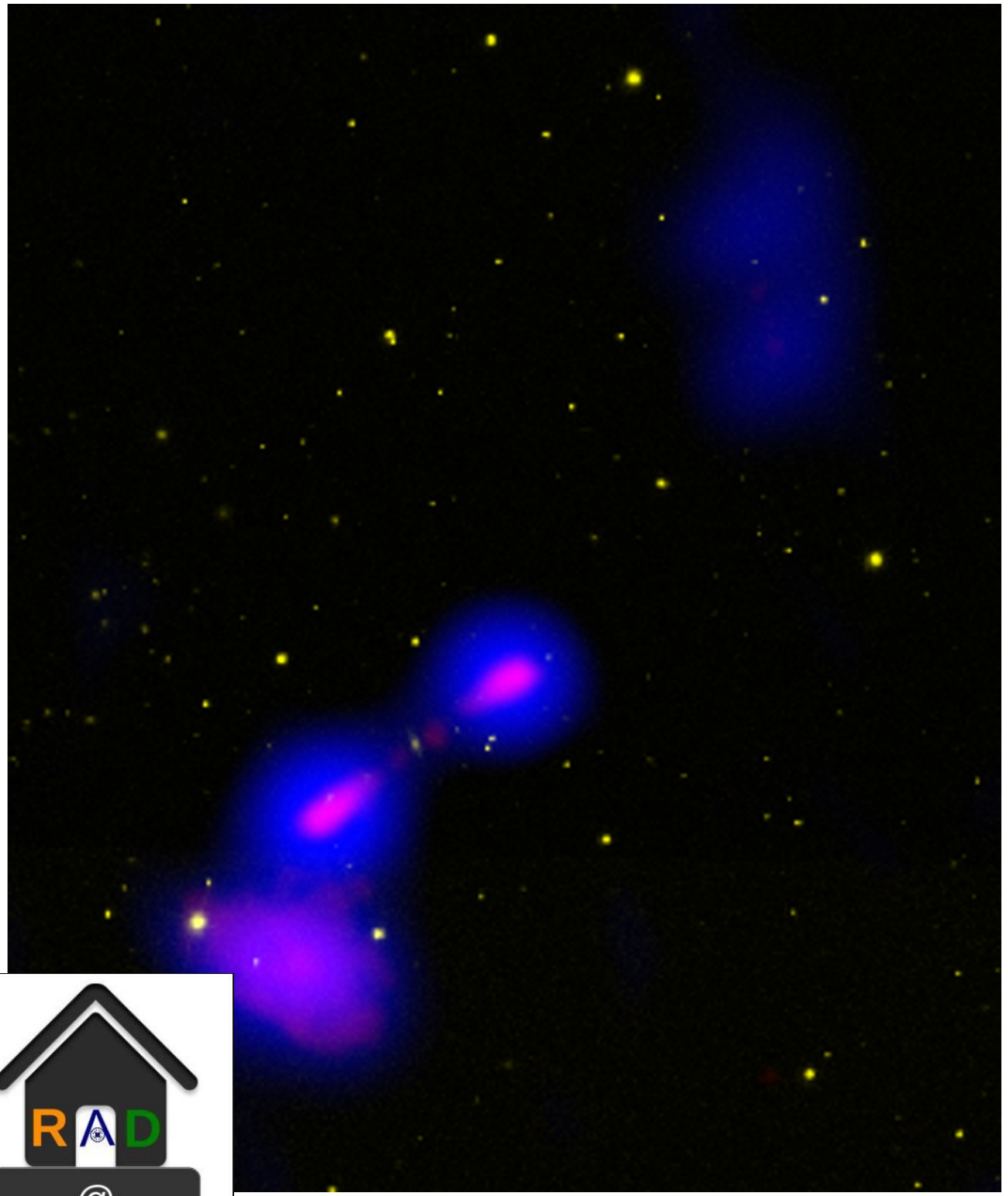
-0.75

19 % polarised

1.3 Mpc separatn

a: Spiral-host Episodic Cluster-dominant AGN

Speca....traces Accretion ?



Is the diffuse plasma in
Morphology
Spectral index
Polarisation

Suggest cosmic accretion ??

Multi-Mpc giant radio galaxies
Several 100 Myr relic plasma
May trace continuing accretion
On to the galaxy clusters

Can we also see the cosmic web ??

RAD@

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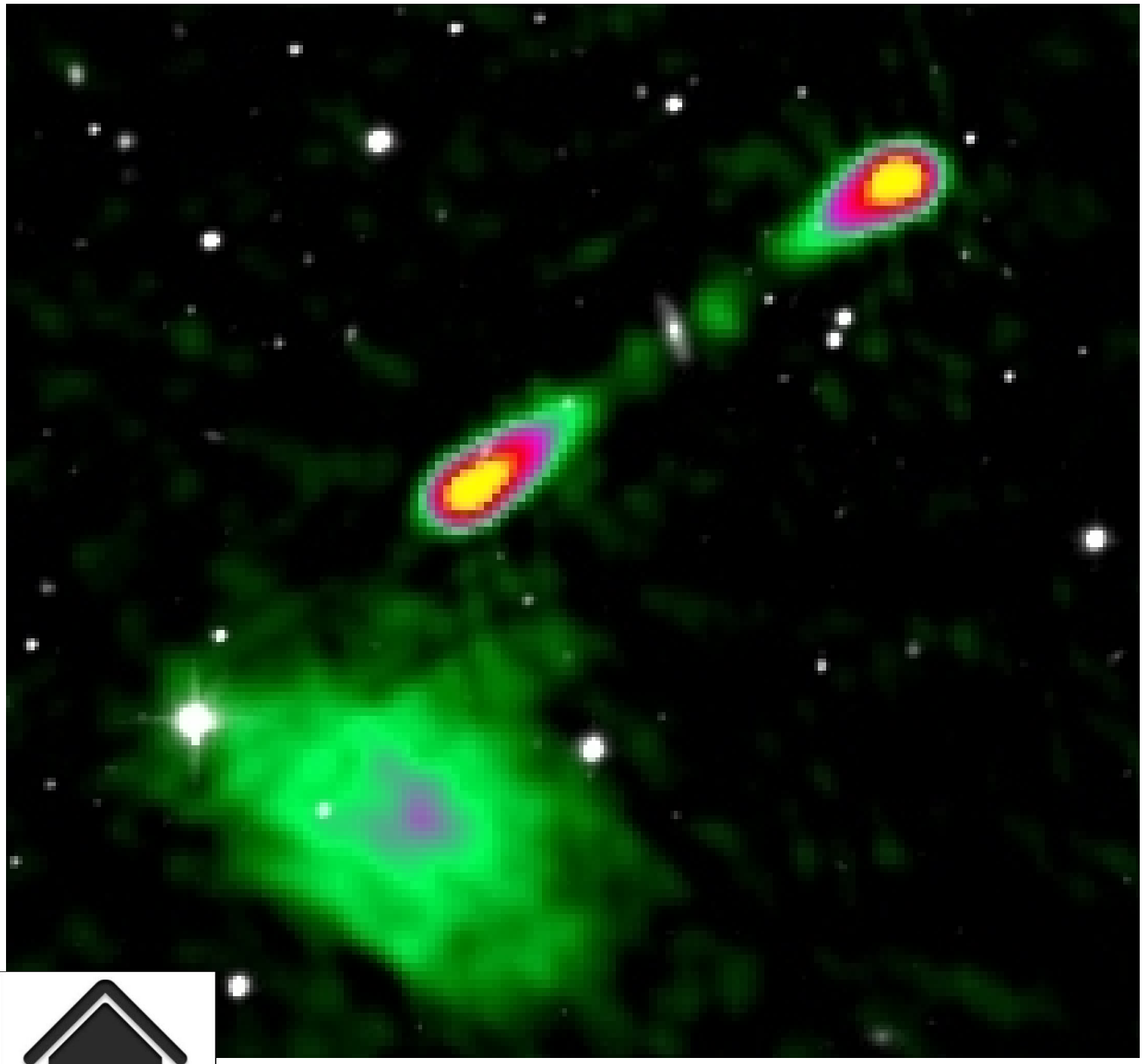


Speca

Z~0.14
BCG

spiral/disk galaxy
3 episodes of AGN jet

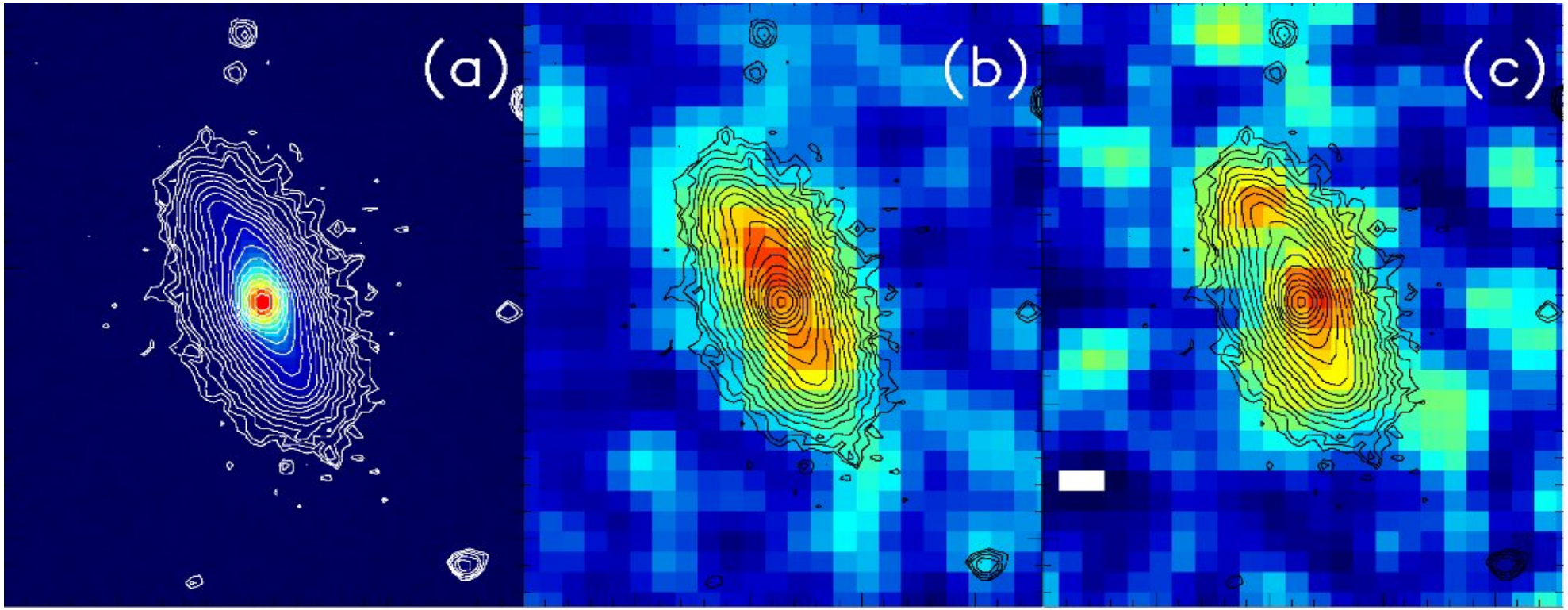
Incomplete quenching ?
Merger/ ICM-accretion ?

cluster merger ~ NO
Filament accretion ? ..!!

(Odd balls of Today
or
Messengers from Early Universe ?)

***Speca**: Spiral-host Episodic radio galaxy tracing Cluster Accret*
GMRT 90cm image on Lulin optical (Hota, Sirothia, Ohyama et

Speca: BCG, star forming disk !



Speca: Lulin 1 m Tel. R-band contours, on R-band, NUV, FUV from GALEX

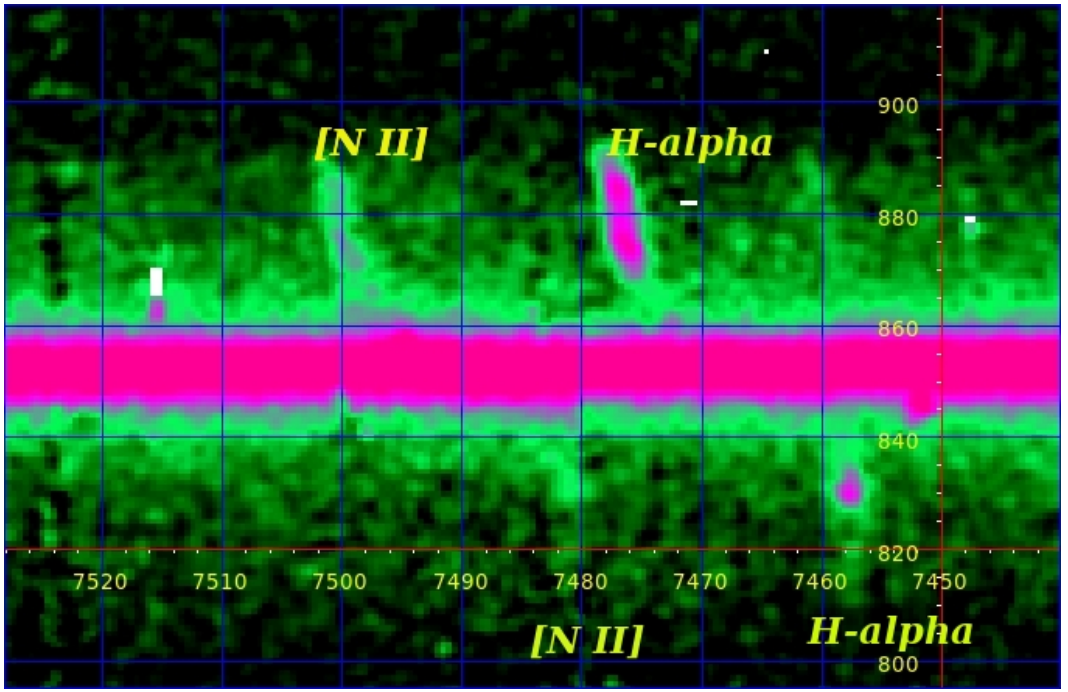
UV colour suggest young stellar population < 500 Myr old.

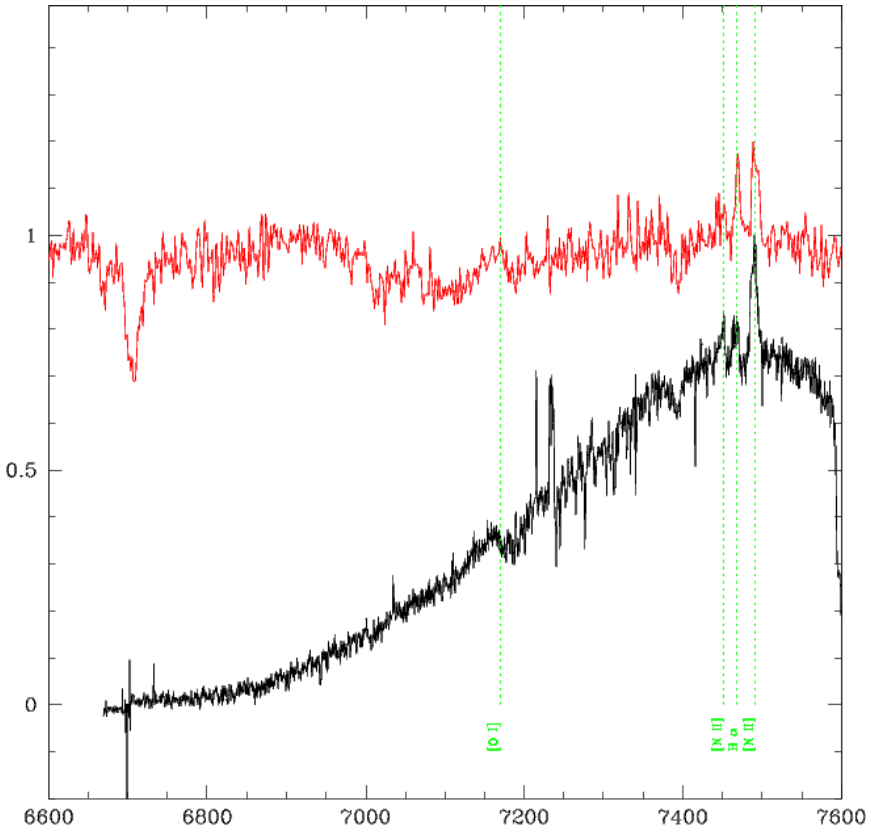
a BCG with spiral nature and young stars is pretty unusual.

Such objects are likely common in high-z

Jet @ ICTS

Speca: Subaru spectroscopy





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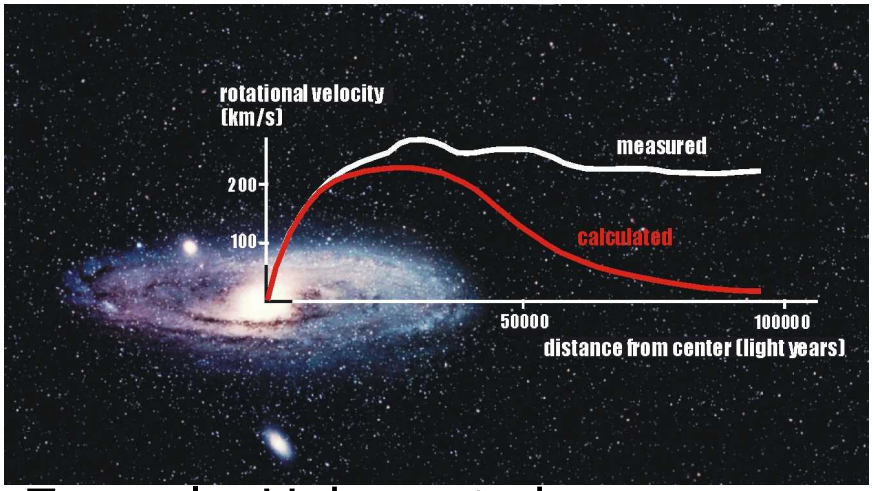
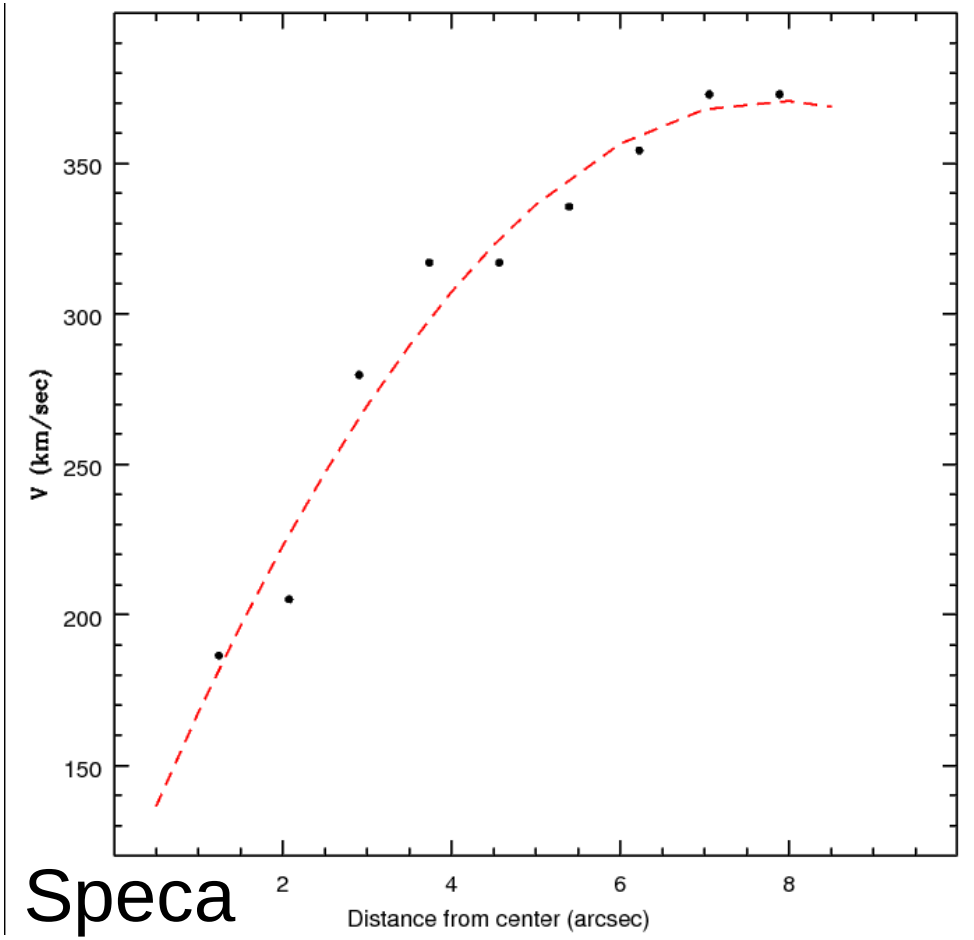
Speca: A massive Fast rotating Star forming Disk



Example: Universetoday.com



Speca

Long-slit Subaru Spectroscopy

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@
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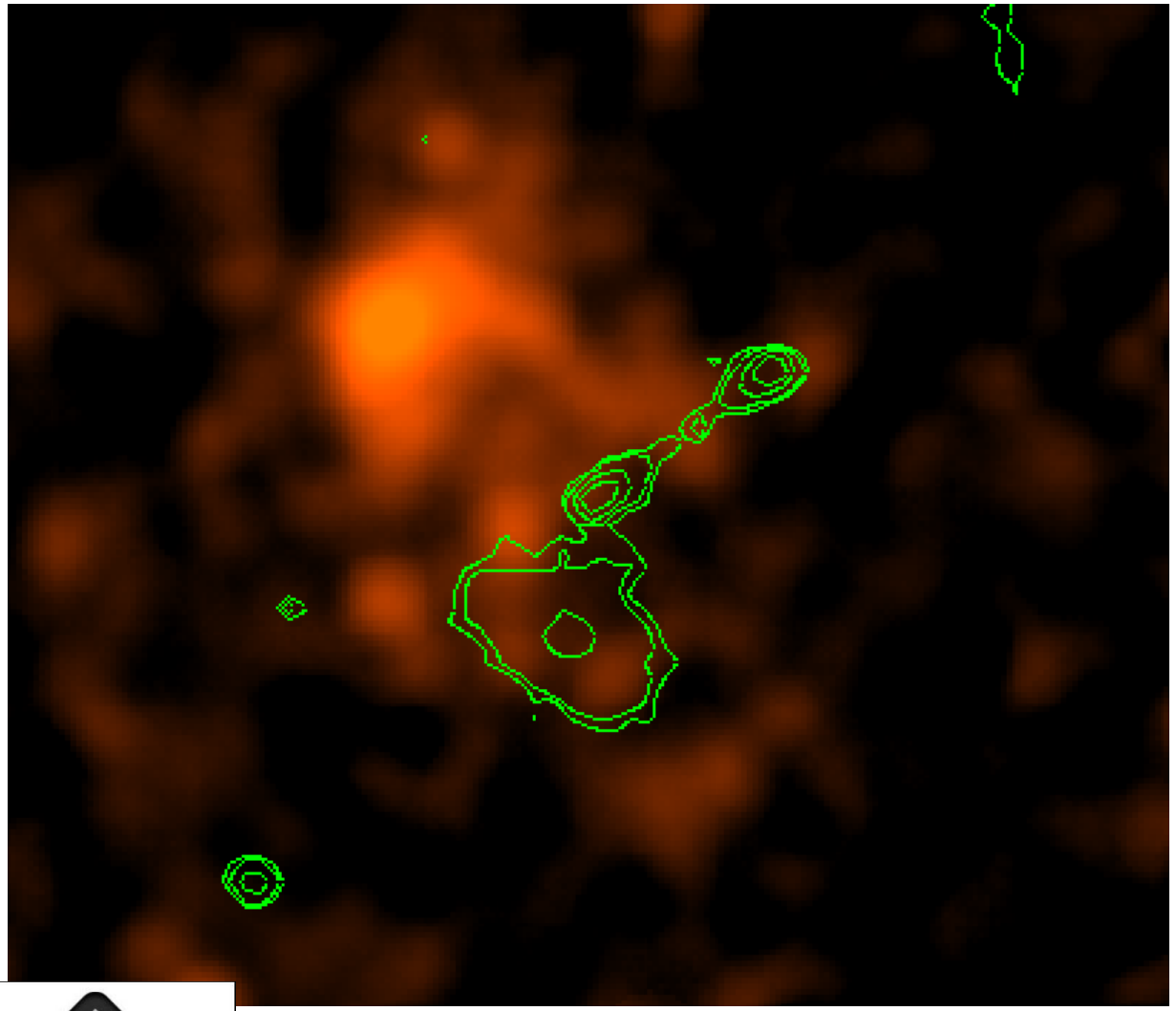
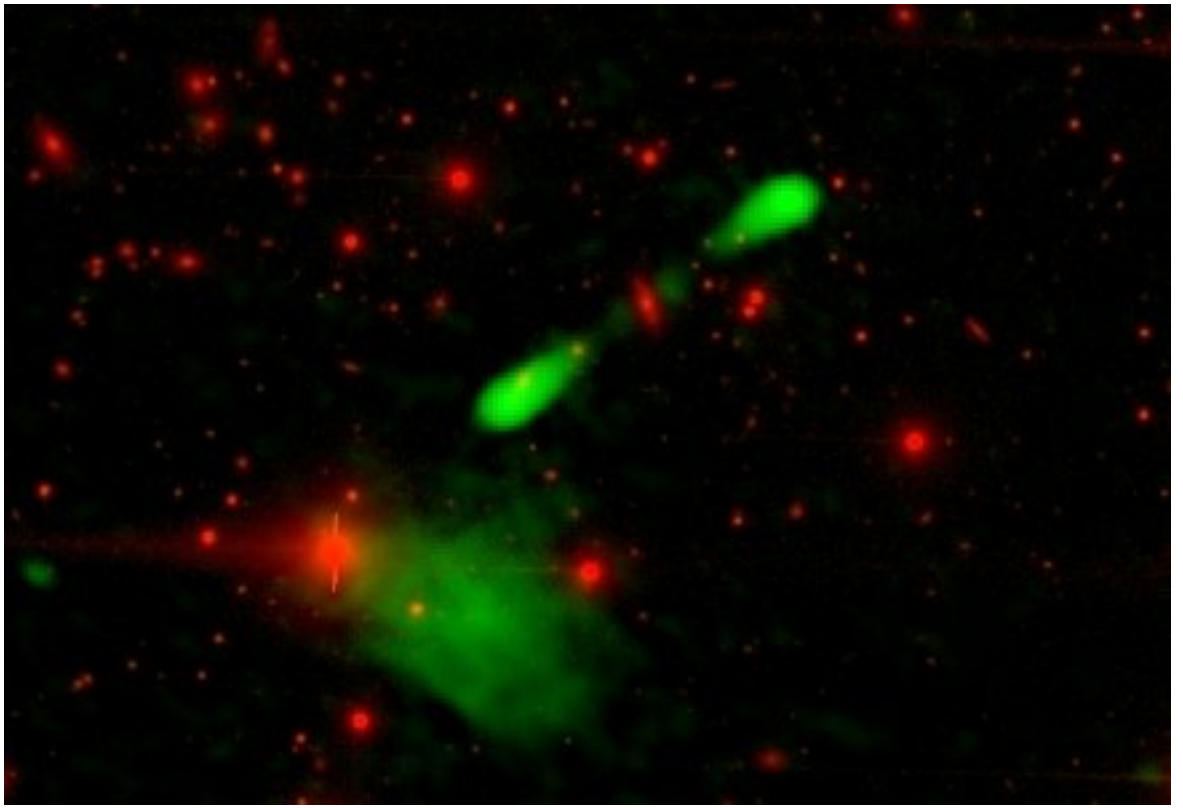
Speca: XMM + GMRT 325



Ananda Hota Judith Croston
Martin Cardcastle
Chiranjib Konar

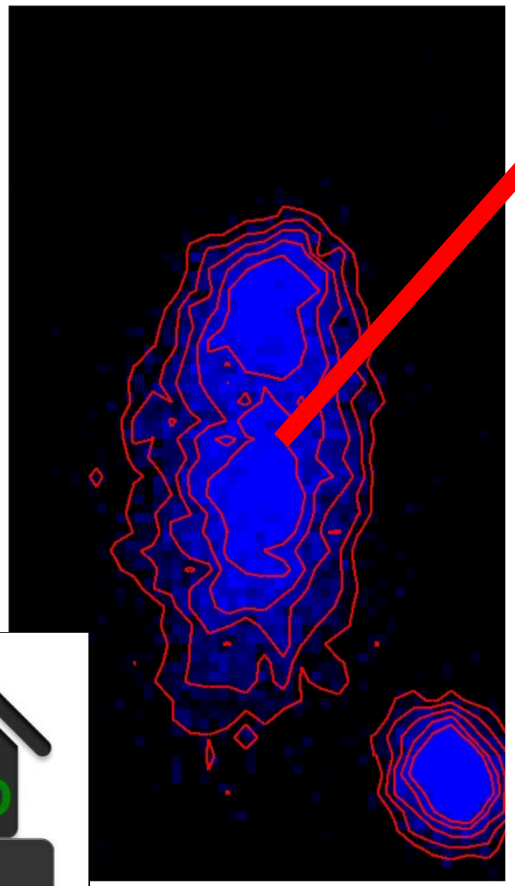
Detecting Infalling galaxies...

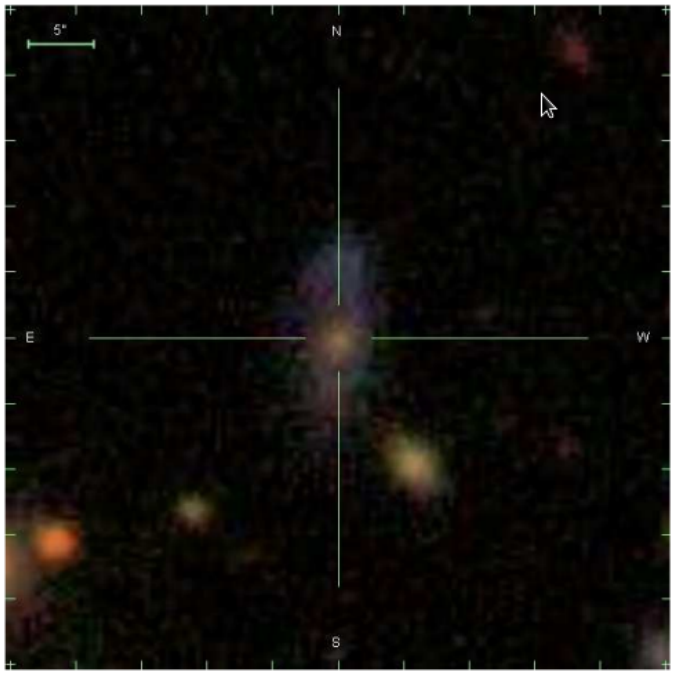
(HCT Obsn).



GMRT-325 MHz
HCT R-band

HCT-B band





SDSS

Ananda Hota
C. S. Stalin (IIA, India)

RAD@

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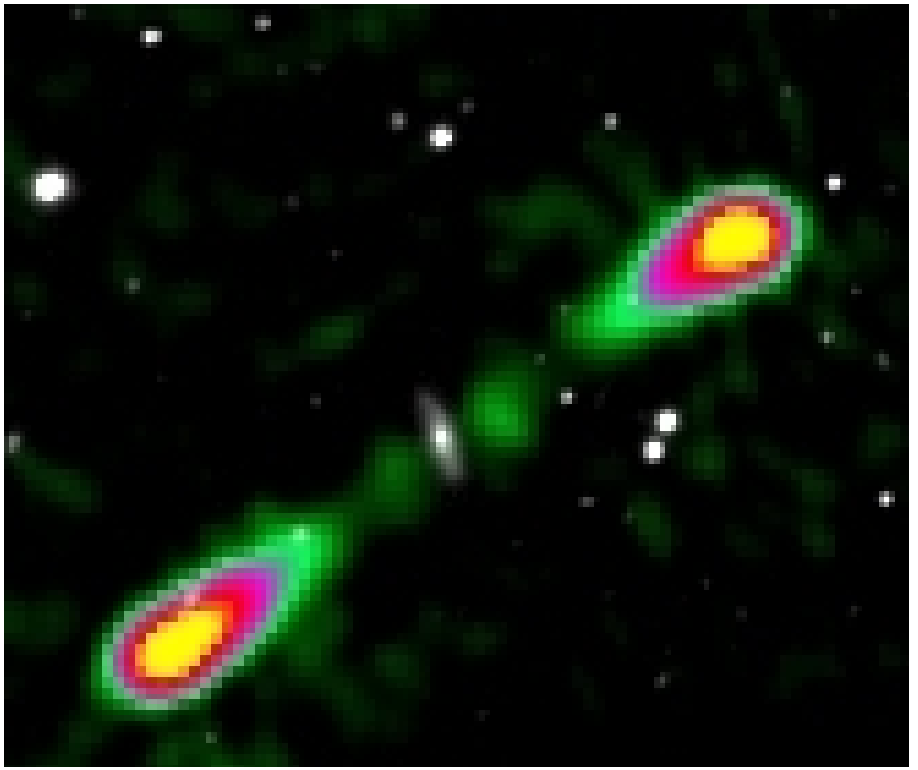
Speca: Is it a missing link ???

Earliest big spiral with supermassive black holes ???

Linking
Early irregulars
First Spirals
High-z Quasars
First ellipticals
Radio galaxies (ellipticals)



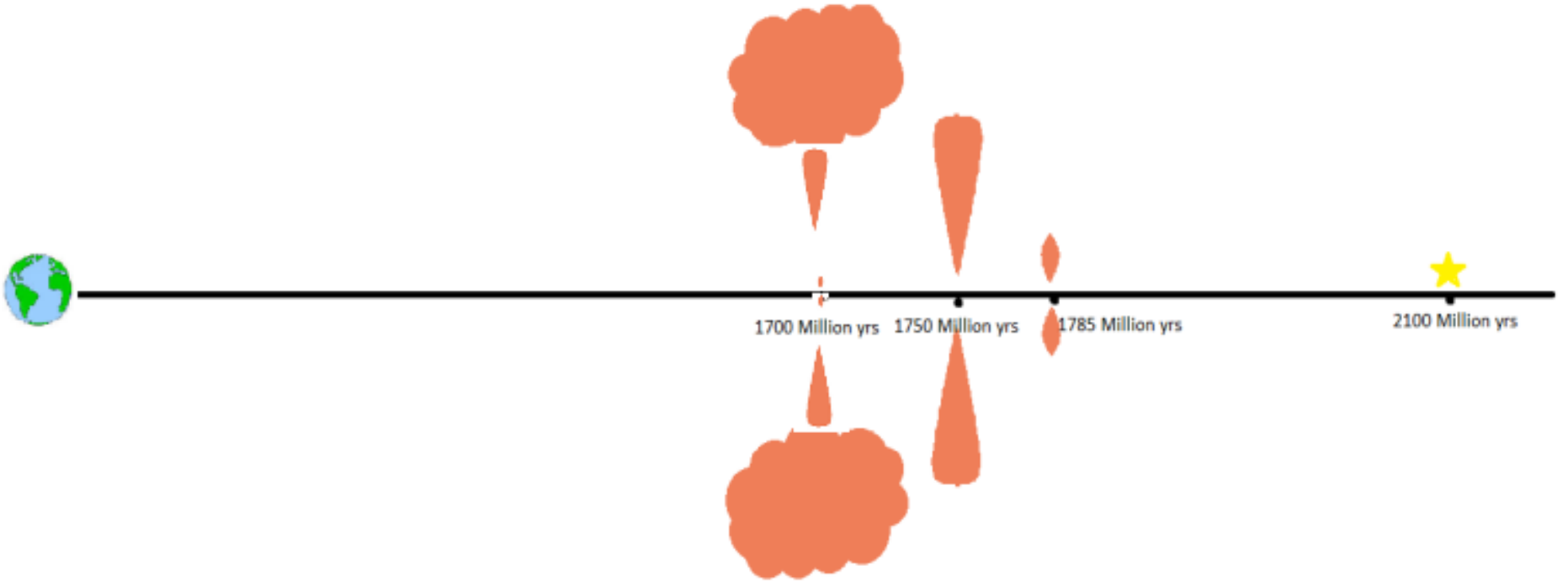


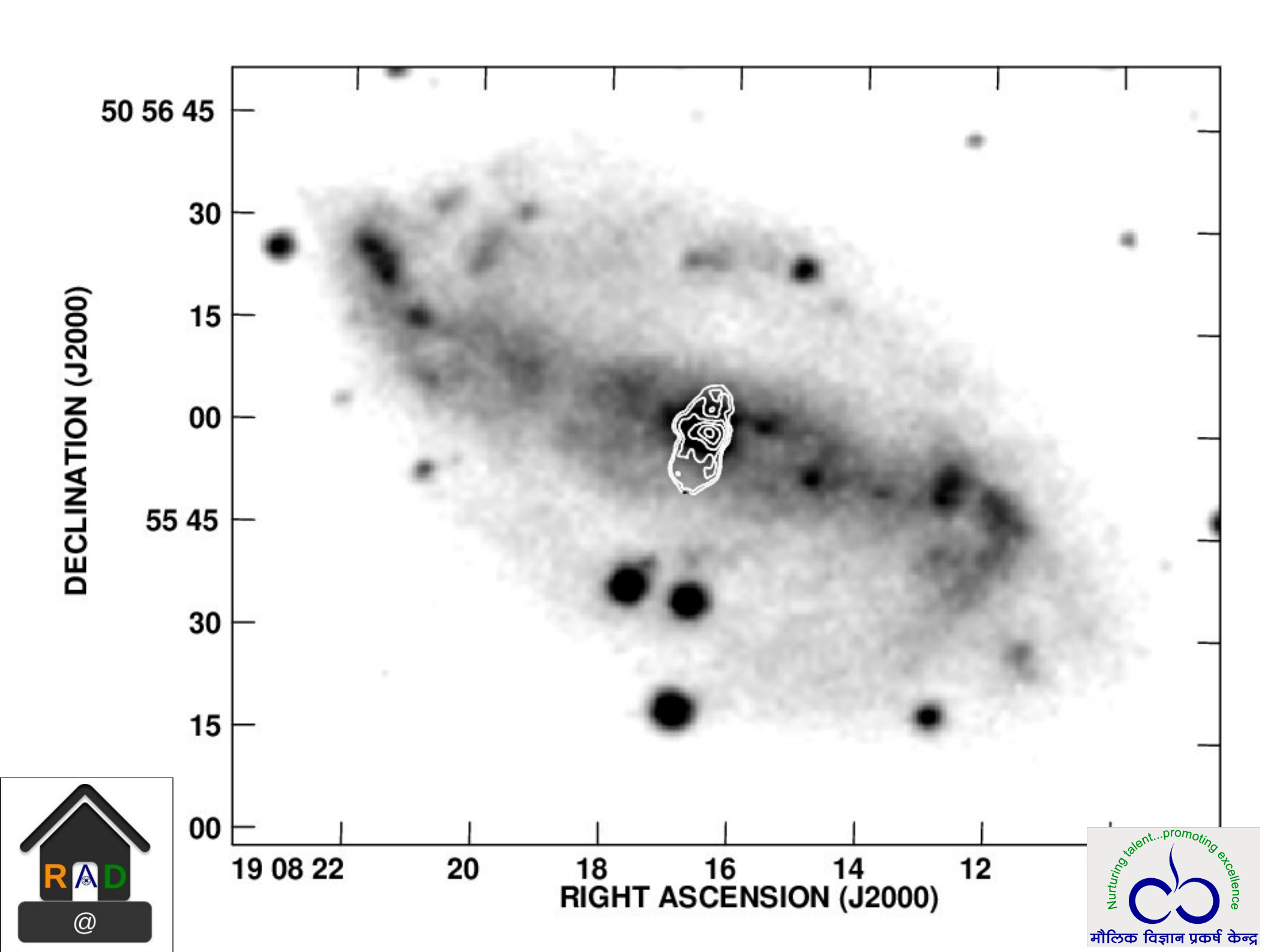
Fig. 4.1.1 (a) ***Schematic Timeline of evolution of a black hole-galaxy system***

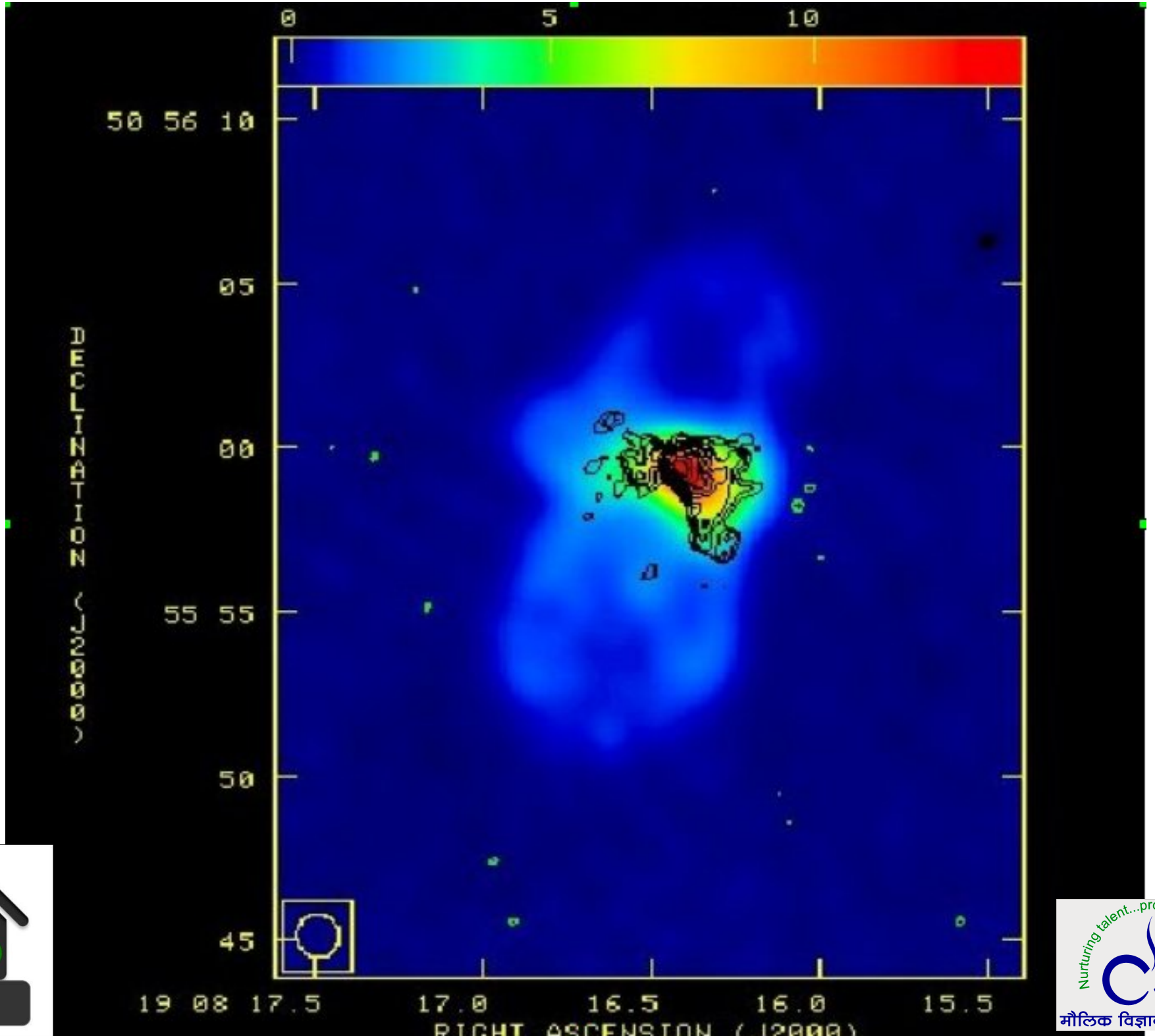
Anjali A. (MSc thesis)

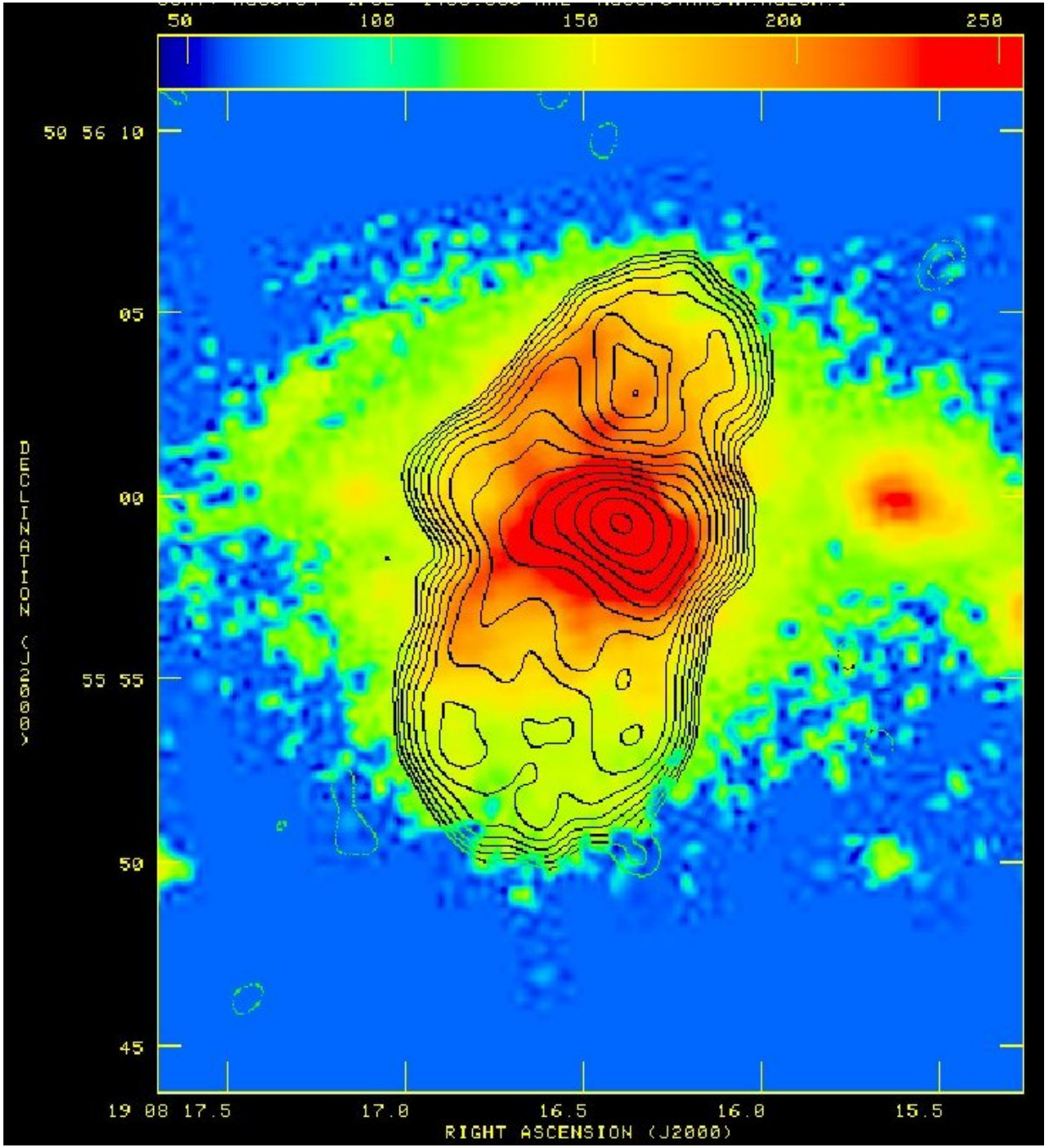
Radio bubbles in the composite AGN-starburst galaxy NGC6764
Hota & Saikia 2006

Chandra Evidence for AGN Feedback in the
Spiral Galaxy NGC 6764
Croston, Hardcastle, Kharb, Kraft, Hota 2008

PARSEC-SCALE IMAGING OF THE RADIO-BUBBLE
SEYFERT GALAXY NGC 6764
Kharb, Hota, Croston, Hardcastle, O'Dea, Kraft, Axon, Robinson 2010


50 56 45
30
15
00
55 45
30
15
00
DECLINATION (J2000)
19 08 22
20
18
16
14
12
RIGHT ASCENSION (J2000)


0
5
10
50 56 10
05
00
55 55
50
45
DECLINATION (J2000)
19 08 17.5
17.0
16.5
16.0
15.5
RIGHT ASCENSION (J2000)



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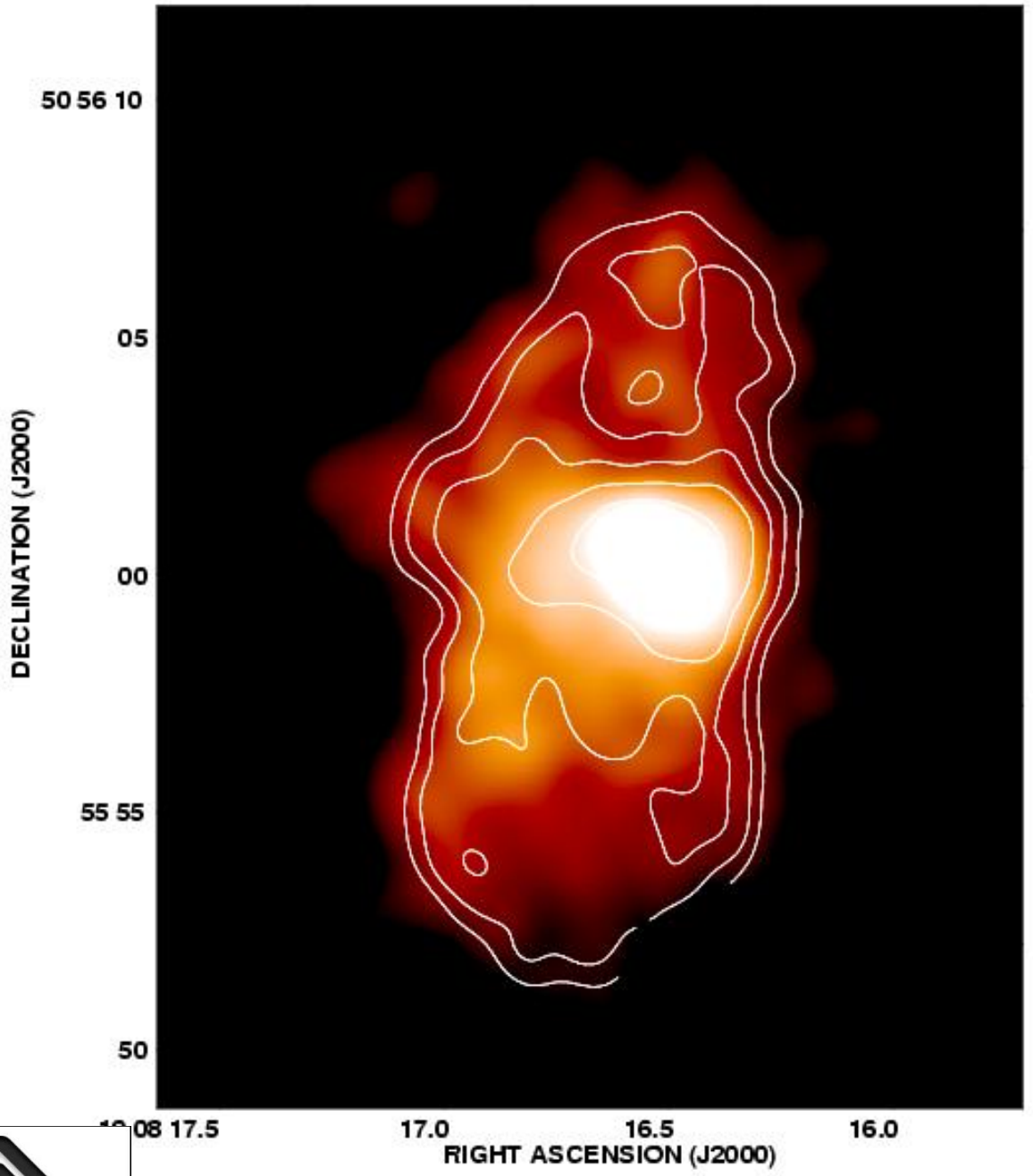
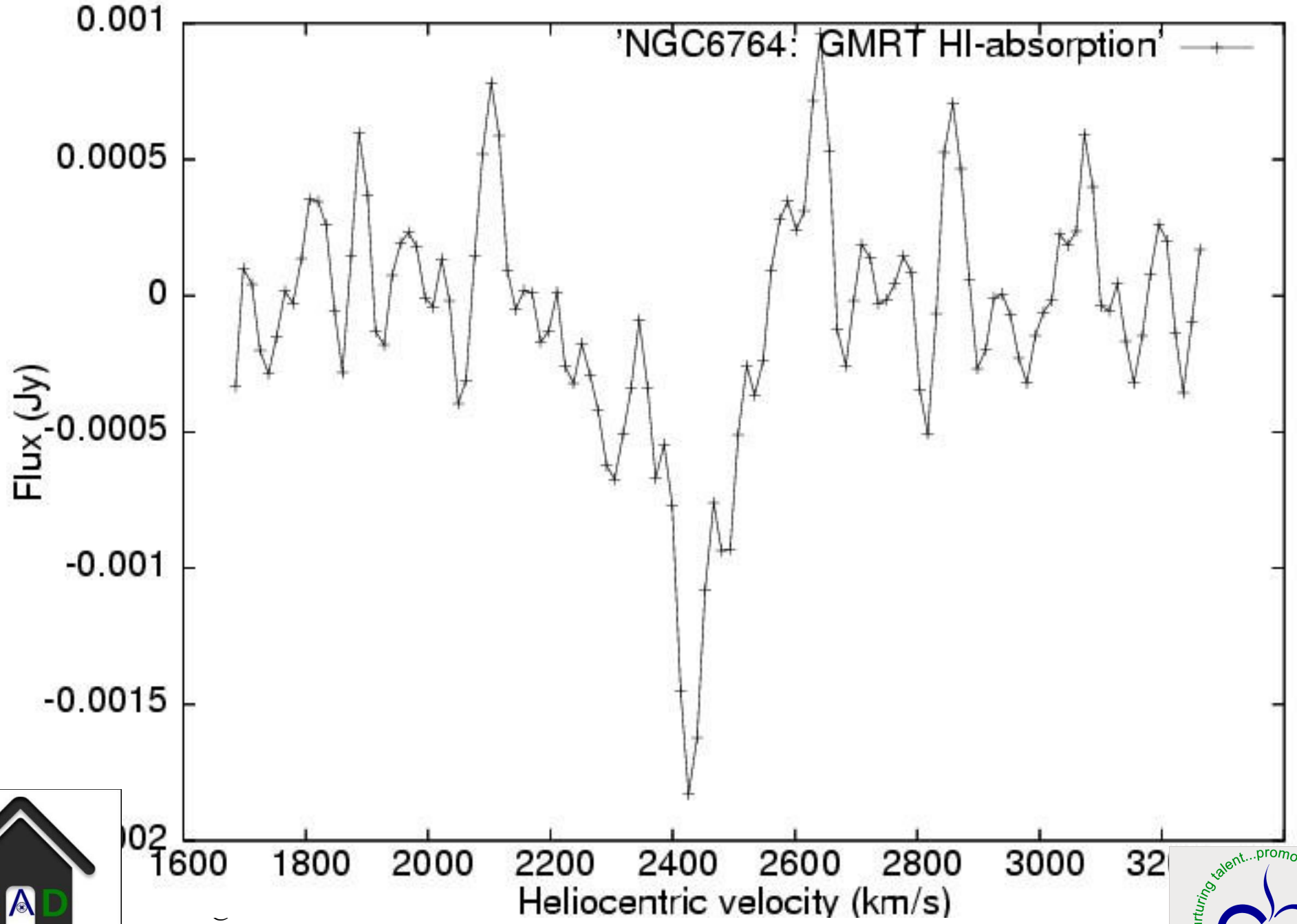
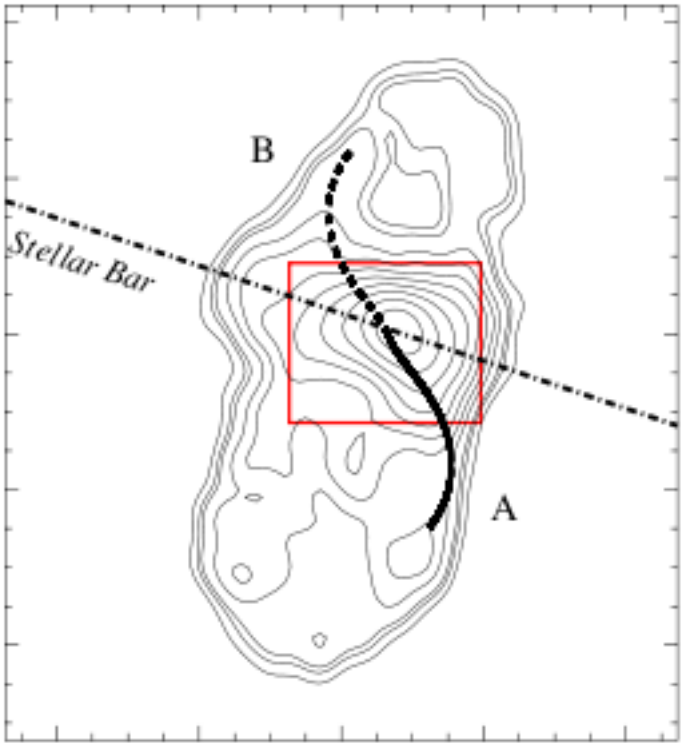


Chandra Evidence for AGN Feedback in the Spiral Galaxy NGC 6764

Croston, Hardcastle, Kharb, Kraft, Hota 2008


'NGC6764: GMRT HI-absorption'
0.001
0.0005
0
-0.0005
-0.001
-0.0015
Flux (Jy)
1600
1800
2000
2200
2400
2600
2800
3000
Heliocentric velocity (km/s)

The dynamical time scale of the radio bubble
Matches the time since decline of star formation
!!
Can we see the same on large-scale



3-5 MYA Star Formation

12-21 Myr time for bubble expansion

.

.

15-50 MYA Star Formation

Mon. Not. R. Astron. Soc. **356**, 998–1008 (2005)

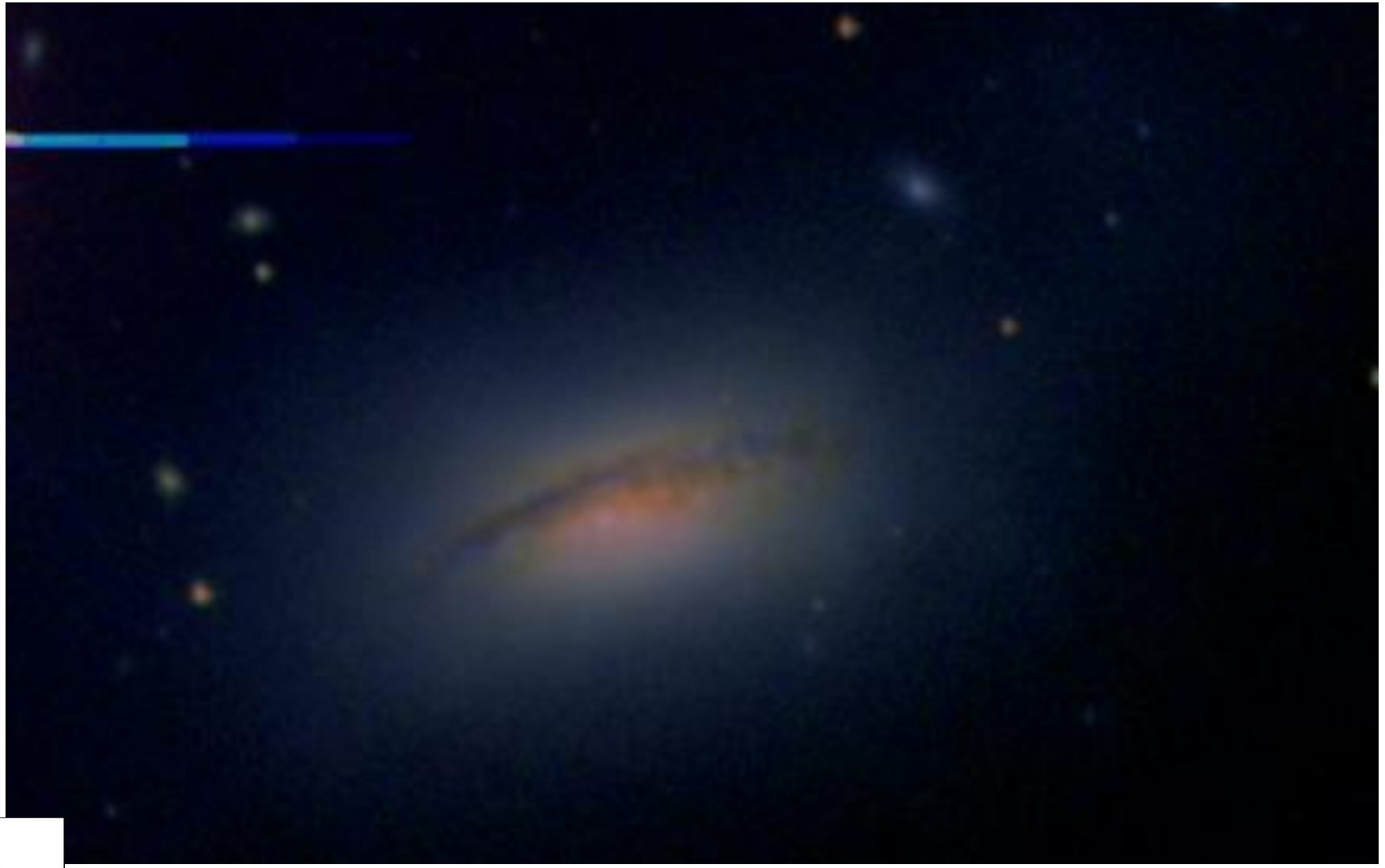
A radio study of the superwind galaxy NGC 1482

Ananda Hota[1,2★] and D. J. Saikia[2★]

[1] *Joint Astronomy Programme, Indian Institute of Science, Bangalore 560012, India*

[2] *National Centre for Radio Astrophysics, TIFR, Pune University Campus, Post Bag 3, Pune 411 007, India*

A merger-remnant early-type galaxy with
Starburst-driven Superwind
Tidal-tails binary nuclei
One AGN(?) other star burst
A rare opportunity for Feedback-studies



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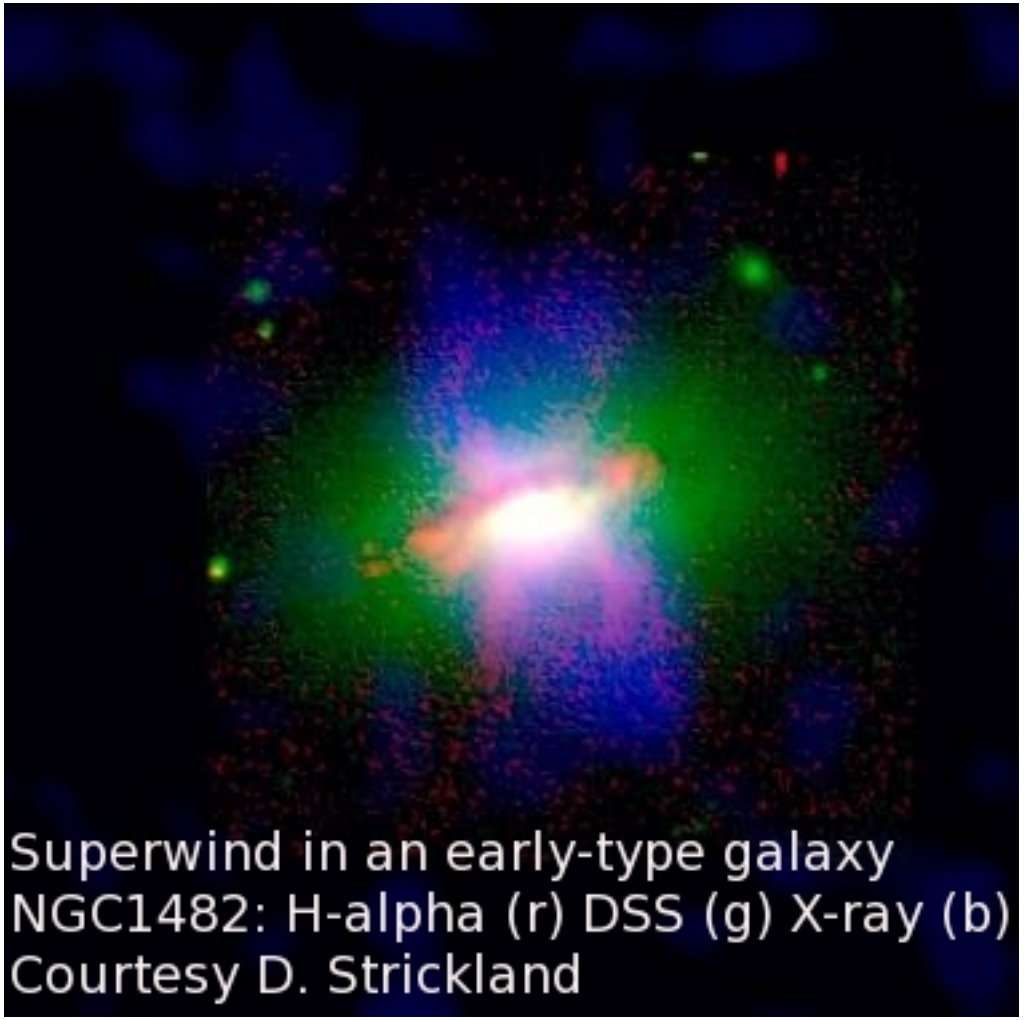
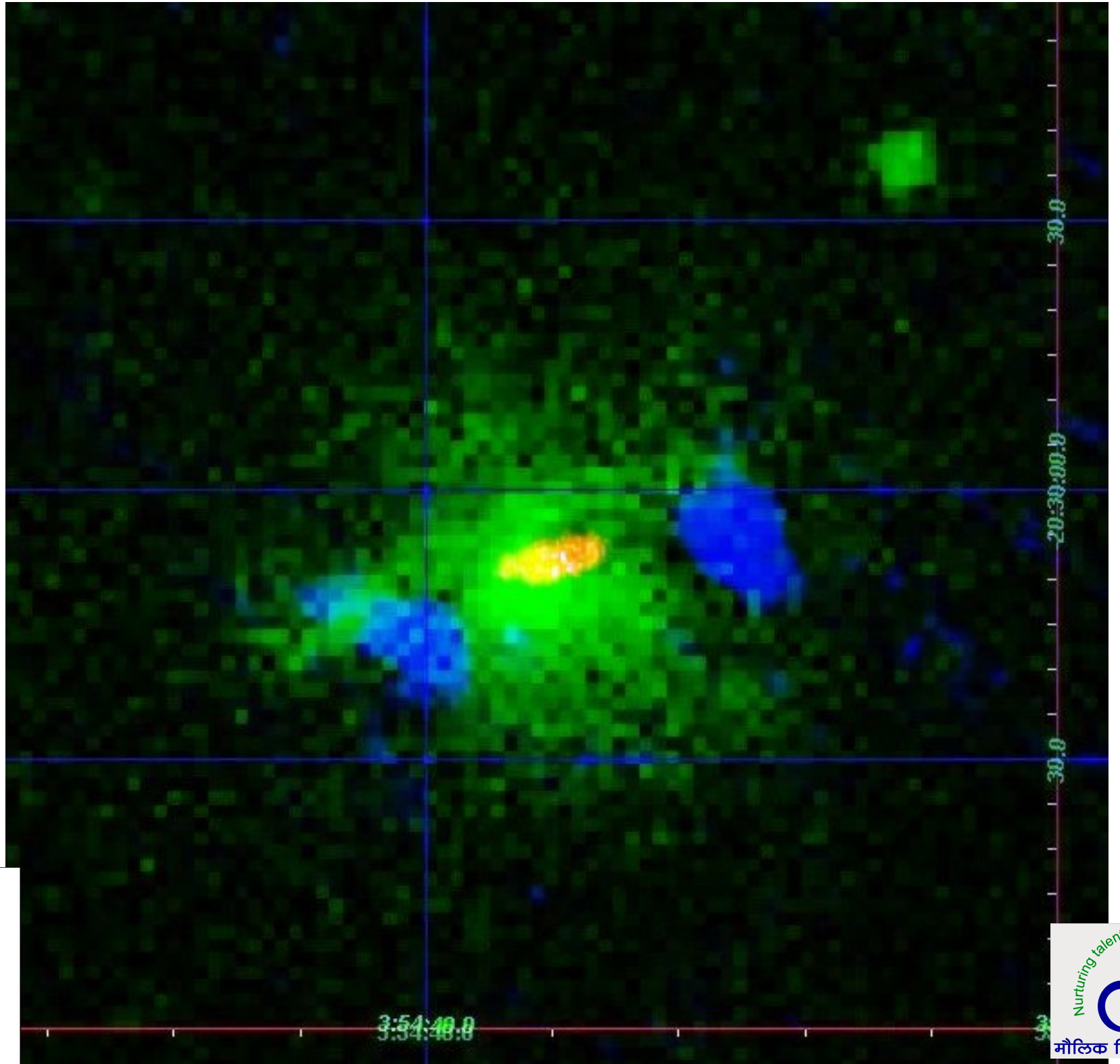
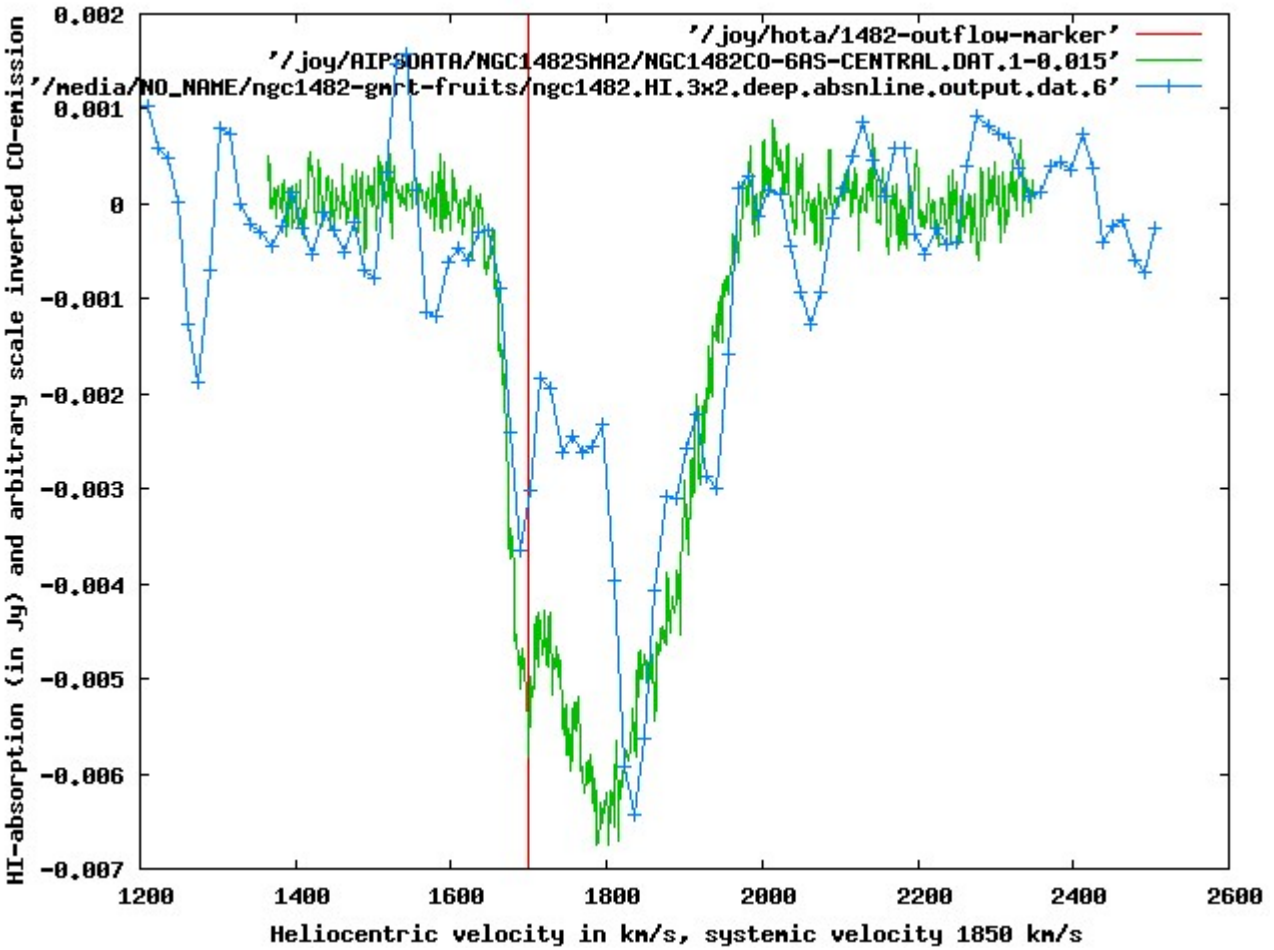

Superwind in an early-type galaxy
NGC1482: H-alpha (r) DSS (g) X-ray (b)
Courtesy D. Strickland

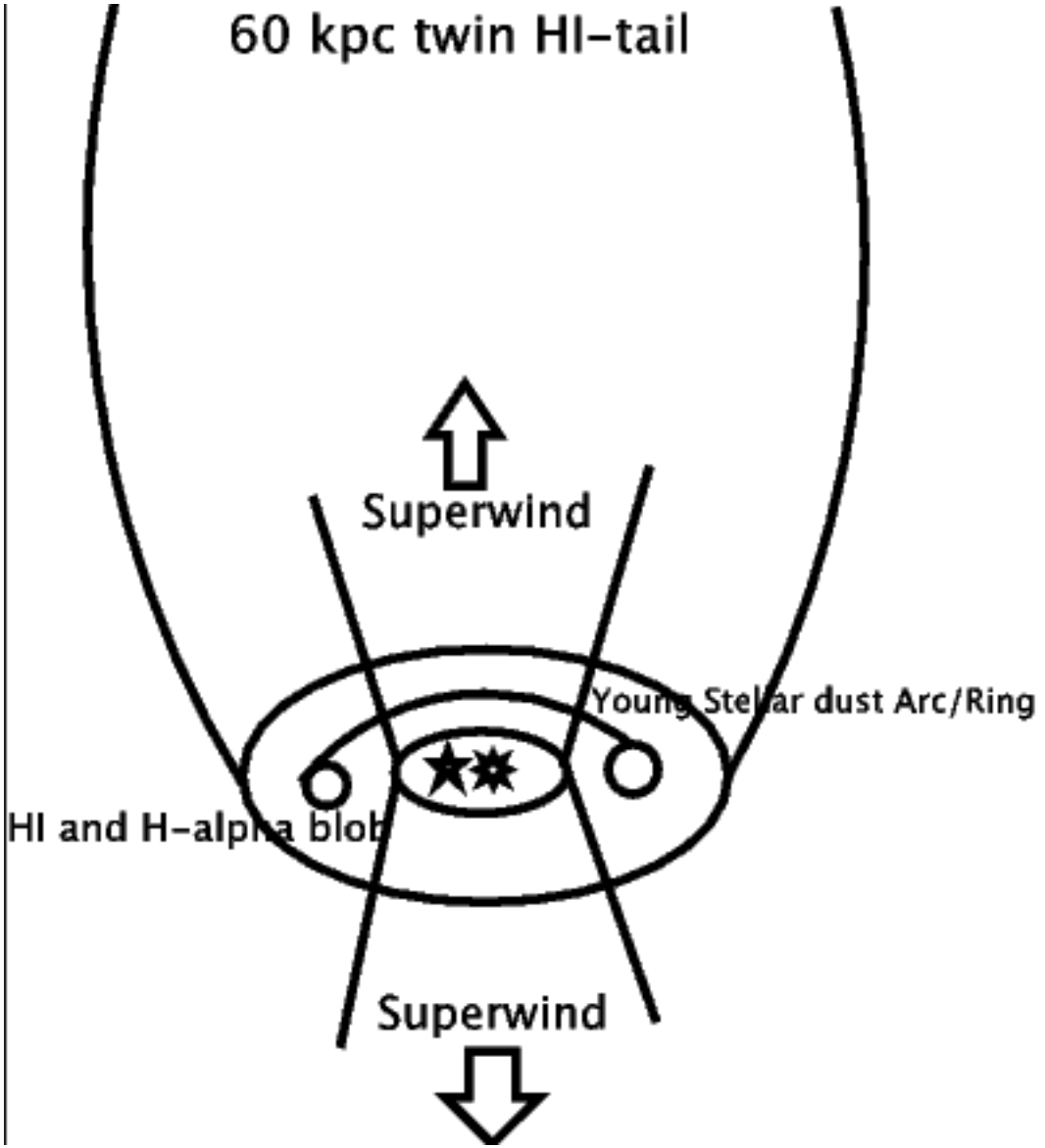
Jet @ ICTS

Jet @ ICTS

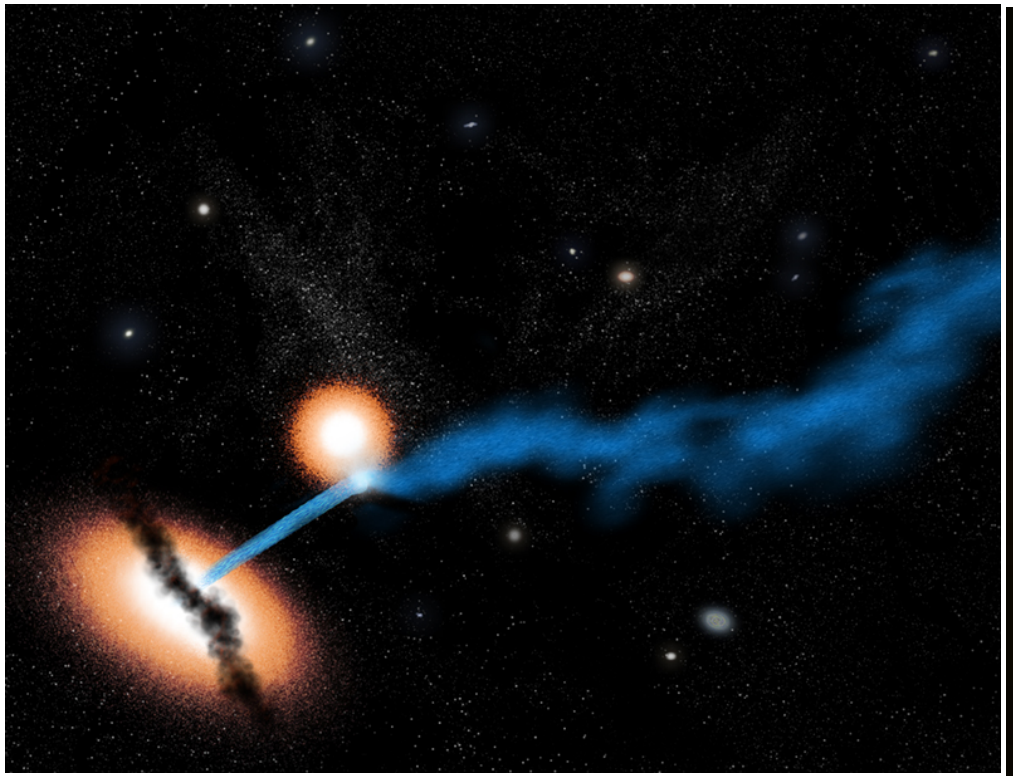


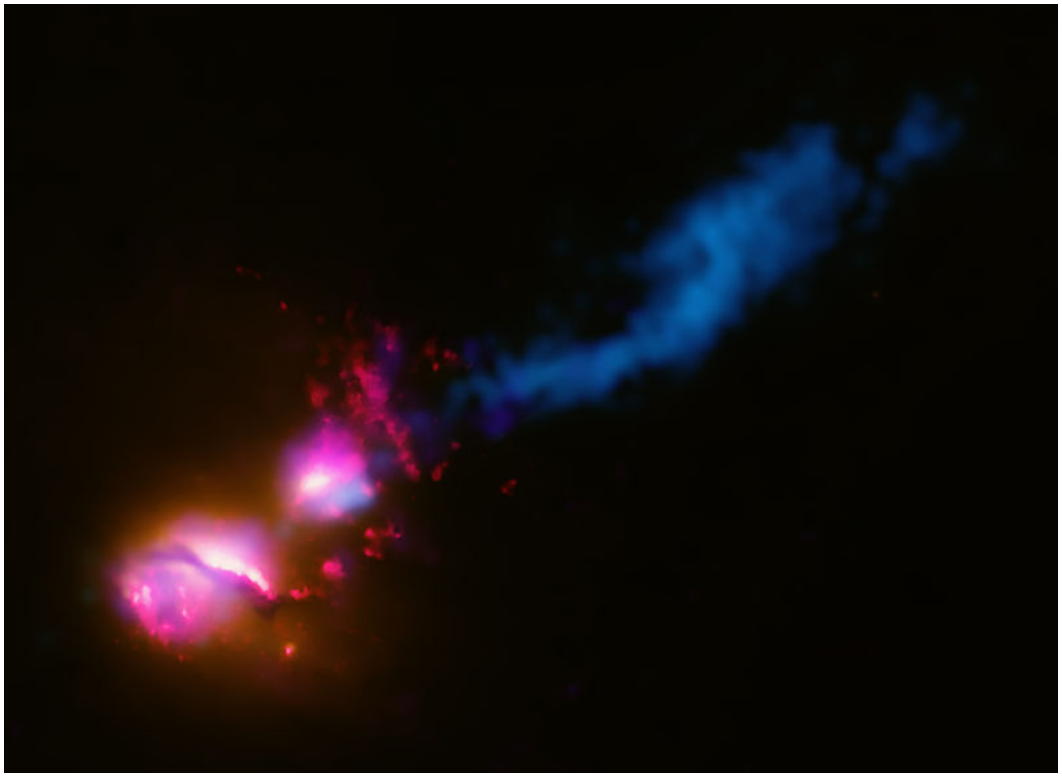


GMRT HI: Hota & Saikia 2005
SMA CO: Hota, Espada, Matsushita, Kotaro....


60 kpc twin HI-tail
Superwind
Young Stellar dust Arc/Ring
HI and H-alpha blob
Superwind

3C321: The Death Star galaxy





Review in Advance first posted online on June 18, 2015. (Changes may still occur before final publication online and in print.)

Ideas for Citizen Science in Astronomy

Philip J. Marshall,[1] Chris J. Lintott,[2] and Leigh N. Fletcher[3]

[1]Kavli Institute for Particle Astrophysics and Cosmology, Stanford, California 94309; email: dr.phil.marshall@gmail.com

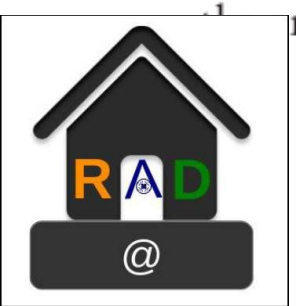
[2]Department of Physics, Denys Wilkinson Building, University of Oxford, Oxford, OX1 3RH, United Kingdom; email: cjl@astro.ox.ac.uk

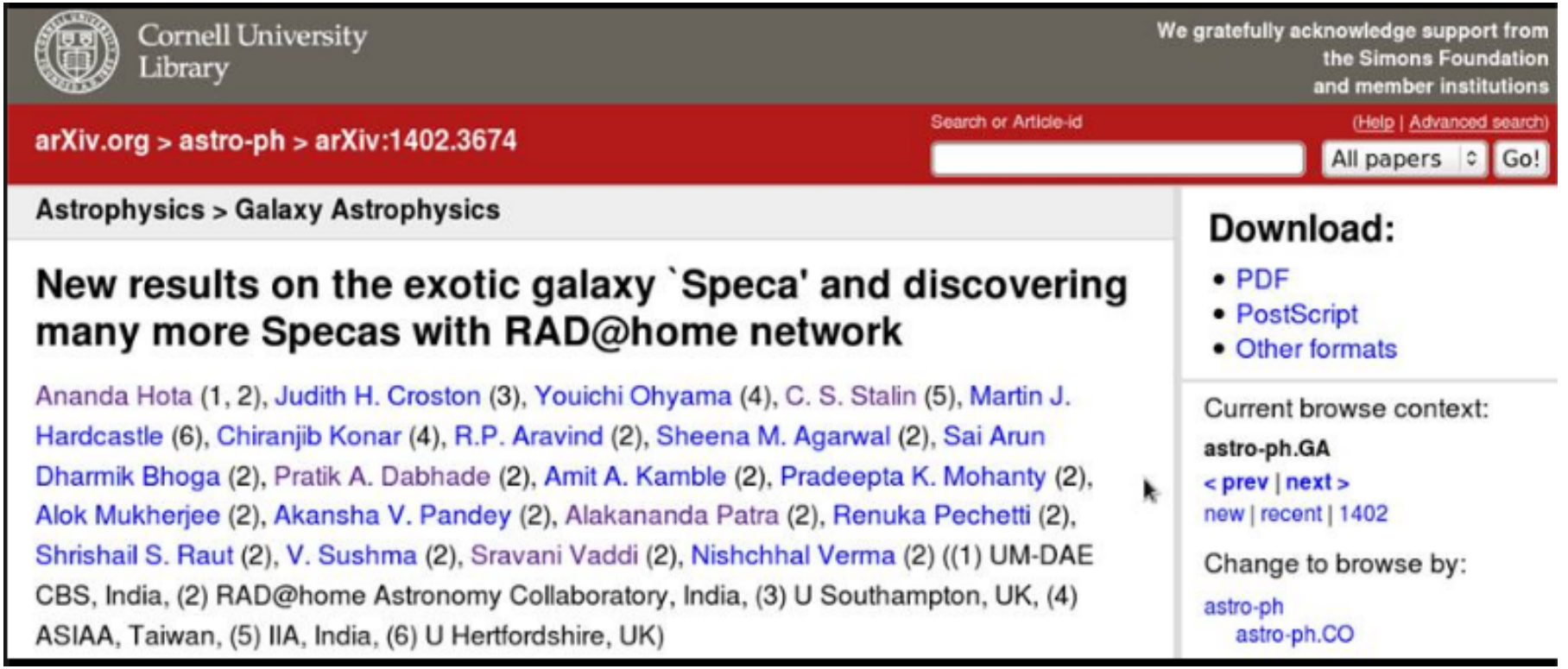
[3]Atmospheric, Oceanic and Planetary Physics, Clarendon Laboratory, University of Oxford, Oxford OX1 3PU, United Kingdom; email: fletcher@atm.ox.ac.uk

3.1.6. Using existing tools: Near-Earth Asteroid precovery and RAD@home. Online visual classification does not necessarily require a custom-built interface. Solano et al. (2014) describe an online classification project carried out by the Spanish Virtual Observatory (SVO) to refine the orbits of NEAs using archival images from the SDSS. Over 3,000 volunteers inspected pairs of images looking for and marking moving objects, leading to the improvement of 6% of known NEAs. Although designed and funded as an outreach project, the SVO made use of the *Aladin* (**http://aladin.u-strasbg.fr**) VO science user interface tool in use by professional astronomers and enabled the submission of results via the Minor Planet Circular system.

Citizen scientists utilizing publically available video data from observatories, such as SOHO and STEREO, and their choice of graphics software have been able to discover numerous sungrazing comets (Section 2). Indeed, the majority of 2,000+ SOHO sungrazer discoveries have been due to dedicated amateurs over 15+ years of operation, (e.g., Battams 2012), reporting their observations to professional observers via the Sungrazer Project (**http://sungrazer.nrl.navy.mil/**).

Similar in spirit to these projects is the RAD@home project (Hota et al. 2014), "a zero-funded, zero-infrastructure, human-resource network" using free web services and public astronomical data archives to organize and enable citizen astronomy research. The community of volunteers was formed around a Facebook group (**https://www.facebook.com/groups/RADathome**), and its initial investigations have focused on morphological identification of massive spiral galaxies hosting radio-loud AGN (Hota et al. 2011) in the Giant Metrewave Radio Telescope (GMRT) TIFR GMRT Sky Survey (TGSS) survey imaging. Some of the RAD@home volunteers have coauthored follow-up proposals, mentored by the project's principal investigator. We return to the enabling of volunteers to "graduate" to more advanced activities in Sections 4 and 5 below.

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arXiv.org > astro-ph > arXiv:1402.3674
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All papers
Go!
Astrophysics > Galaxy Astrophysics
New results on the exotic galaxy `Speca' and discovering many more Specas with RAD@home network
Ananda Hota (1, 2), Judith H. Croston (3), Youichi Ohyama (4), C. S. Stalin (5), Martin J. Hardcastle (6), Chiranjib Konar (4), R.P. Aravind (2), Sheena M. Agarwal (2), Sai Arun Dharmik Bhoga (2), Pratik A. Dabhade (2), Amit A. Kamble (2), Pradeepta K. Mohanty (2), Alok Mukherjee (2), Akansha V. Pandey (2), Alakananda Patra (2), Renuka Pechetti (2), Shrishail S. Raut (2), V. Sushma (2), Sravani Vaddi (2), Nishchhal Verma (2) ((1) UM-DAE CBS, India, (2) RAD@home Astronomy Collaboratory, India, (3) U Southampton, UK, (4) ASIAA, Taiwan, (5) IIA, India, (6) U Hertfordshire, UK)
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GOOD-RAC: GMRT Observation of Objects Discovered by RAD@home Astronomy Collaboratory I, II III cycles

NATIONAL CENTRE FOR RADIO ASTROPHYSICS

Tata Institute of Fundamental Research, Pune

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    - CYCLE 25 (OCT 13 - MAR 14)
    - CYCLE 24 (APR 13 - SEP 13)
    - CYCLE 23 (OCT

CYCLE 26 (APR 14 - SEP 14)

Proposal No	Title Of Proposal	Authors	Affiliation	Time Allotted
26_001	Low frequency study of a few Wolf Rayet (WR) Galaxies	Shweta Srivastava Nimisha Kantharia	DDU NCRA	18
26_002	A Search for Giant Pulses from Millisecond and Young Pulsars	Yogesh Maan BHAL CHANDRA JOSHI	IISc NCRA	21
26_003	GMRT Observation of Objects Discovered by RAD@home Astronomy Collaboratory, India (GOOD-RAC)	Ananda Hota Chiranjib Konar C.S. Stalin Aravind Ravi Pazhayath SHEENA MUKESH AGARWAL SaiArun Dharmik Bhoga Pratik Anand Dabhade Saurabh Pravin Deshpande Amit Ashok Kamble PRADEEPTA KISHORE MOHANTY Alok Mukherjee Akansha Virendra Pandey	CEBS ASIAA IIA RAD@home RAD@home RAD@home RAD@home RAD@home RAD@home RAD@home RAD@home RAD@home RAD@home RAD@home	6

SKA-India recognised it as a successful model of training students in large number and taking them up to GMRT Observation

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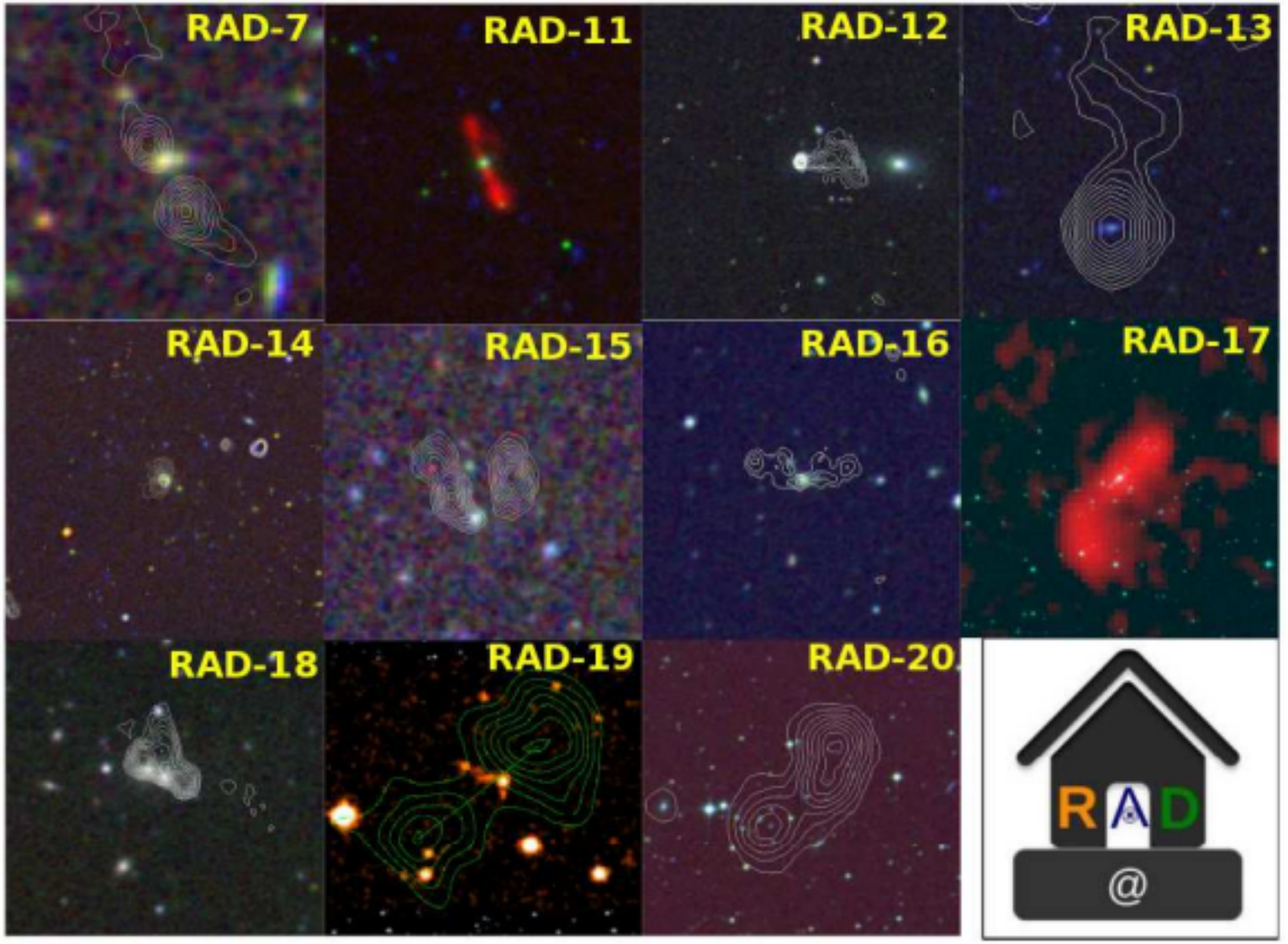

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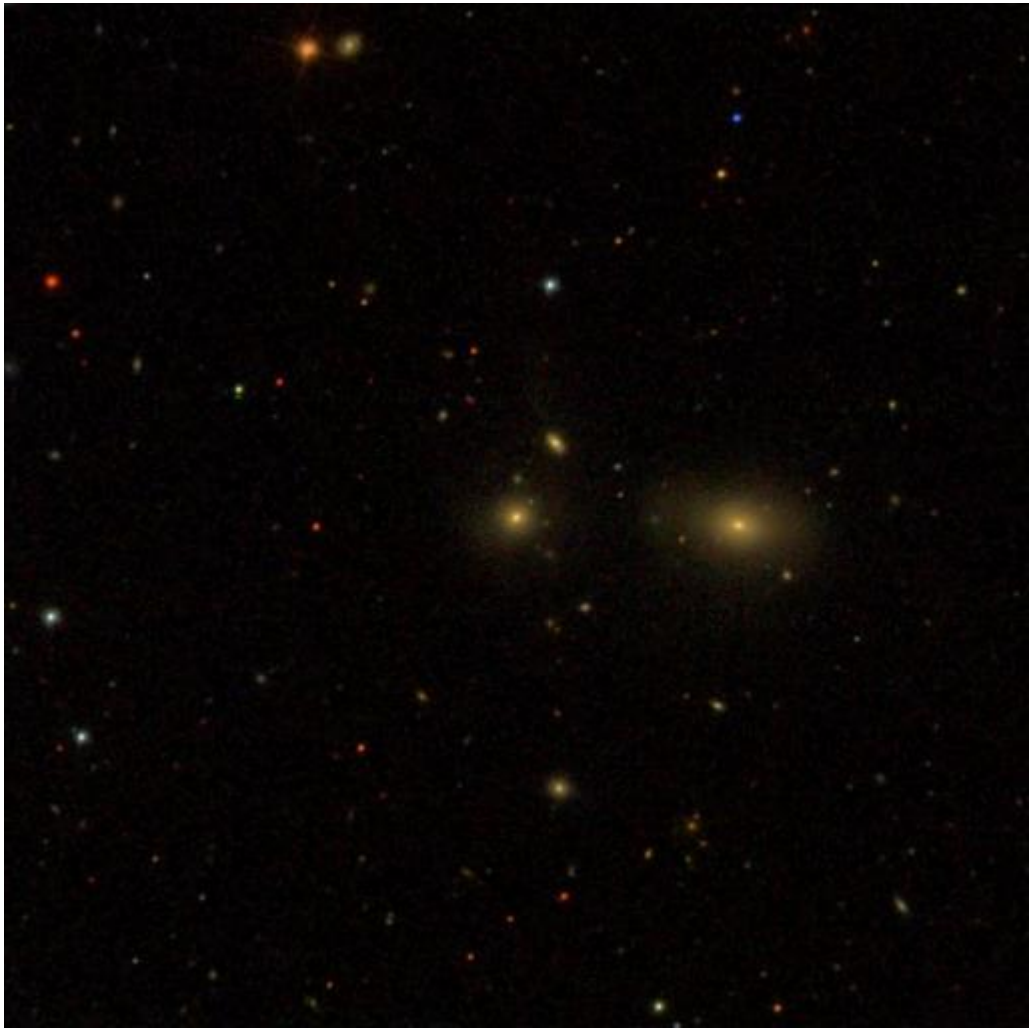

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Survey: *sdss* Program: *legacy* Target: *GALAXY_RED GALAXY*
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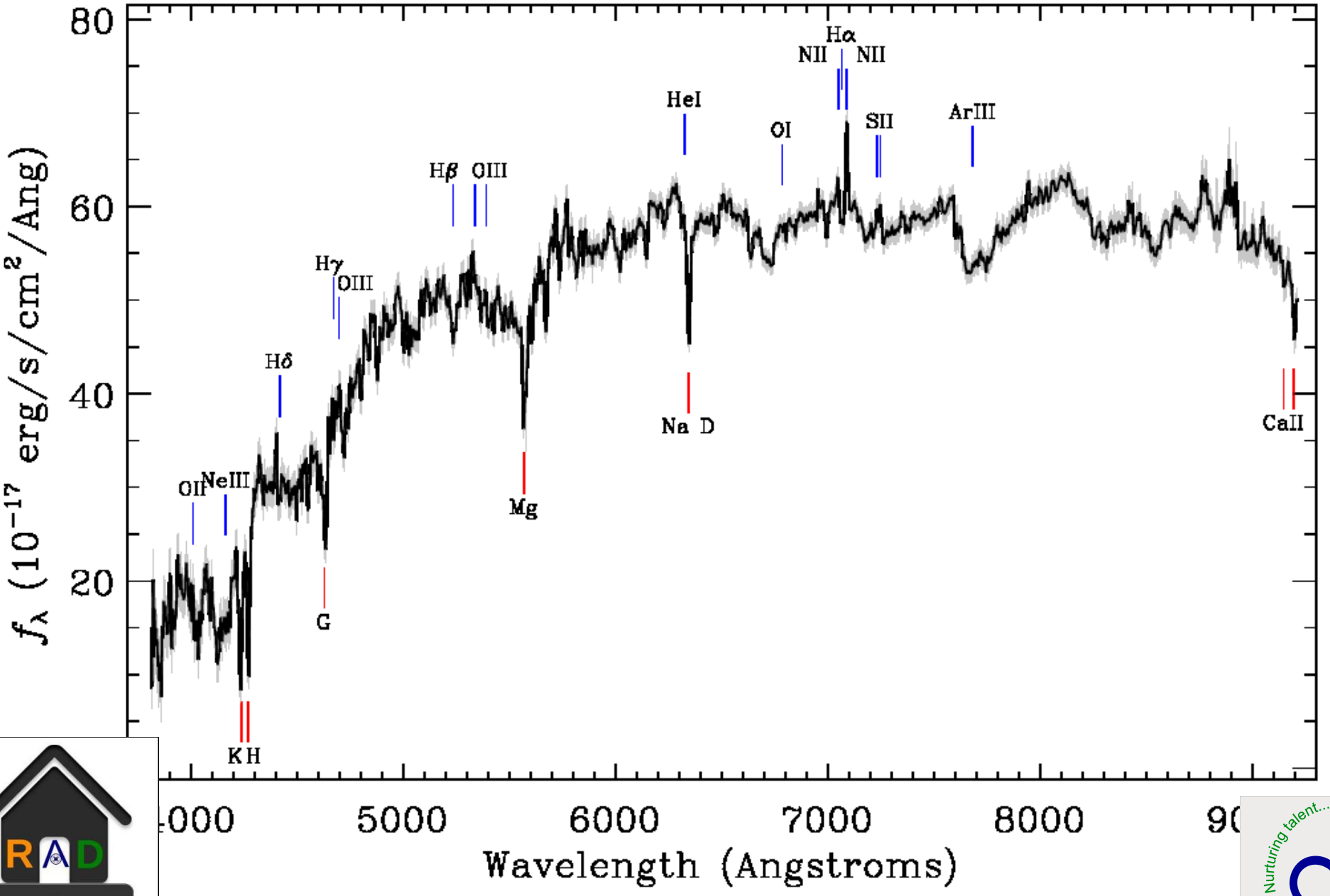
No warnings.



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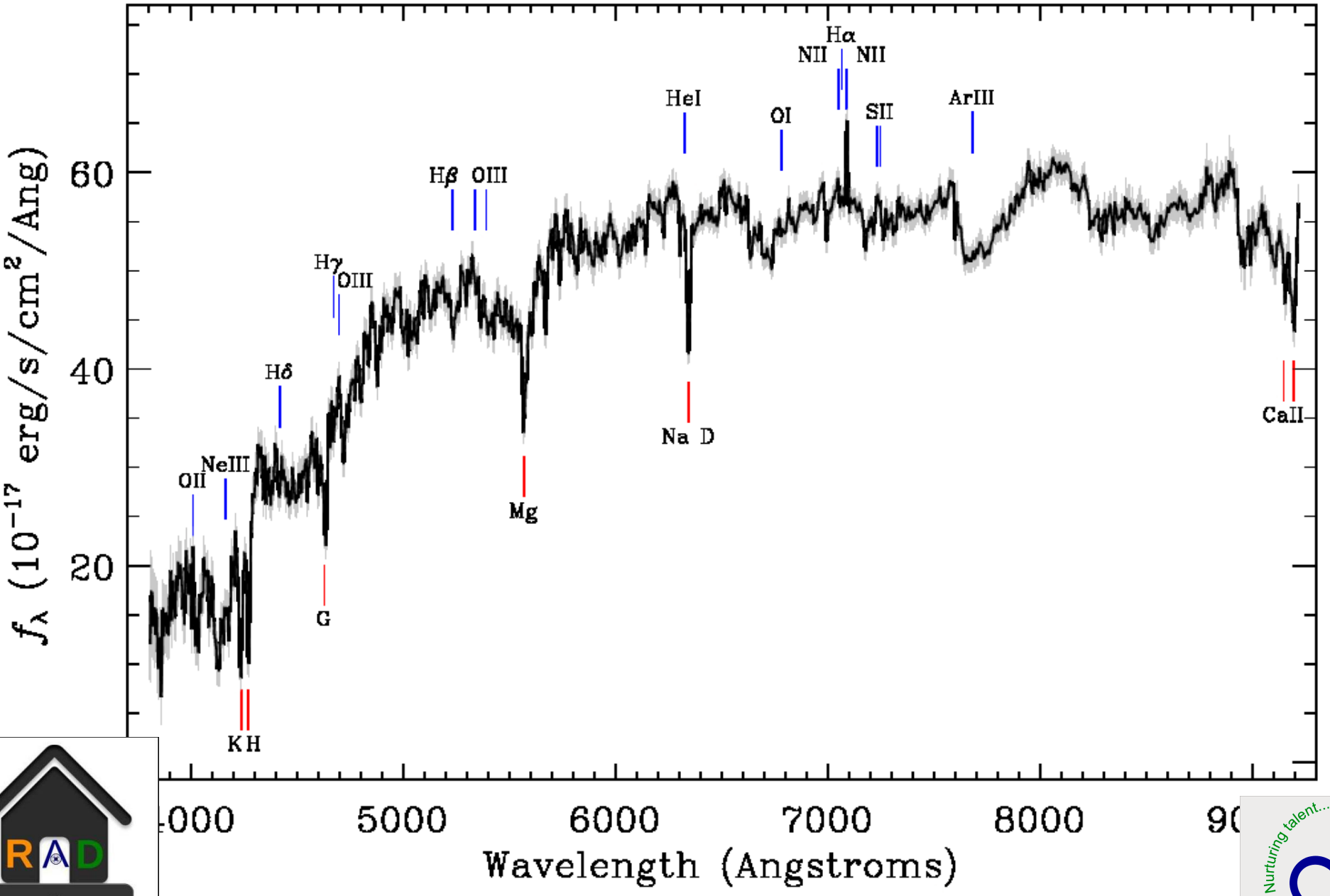
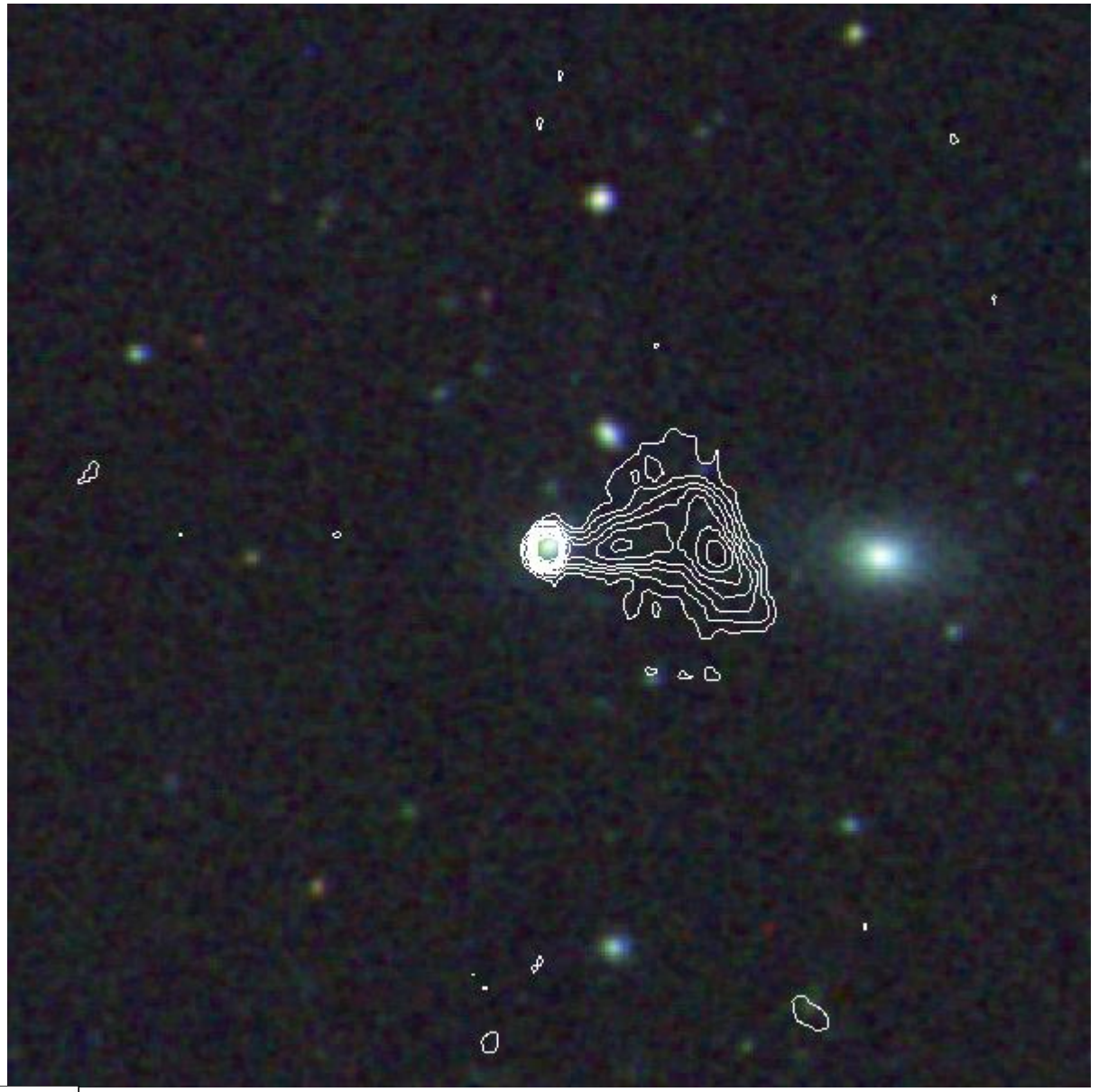
No warnings.





RAD-12
Hota et al 2013
With
Sravani Vaddi (RAD@home)

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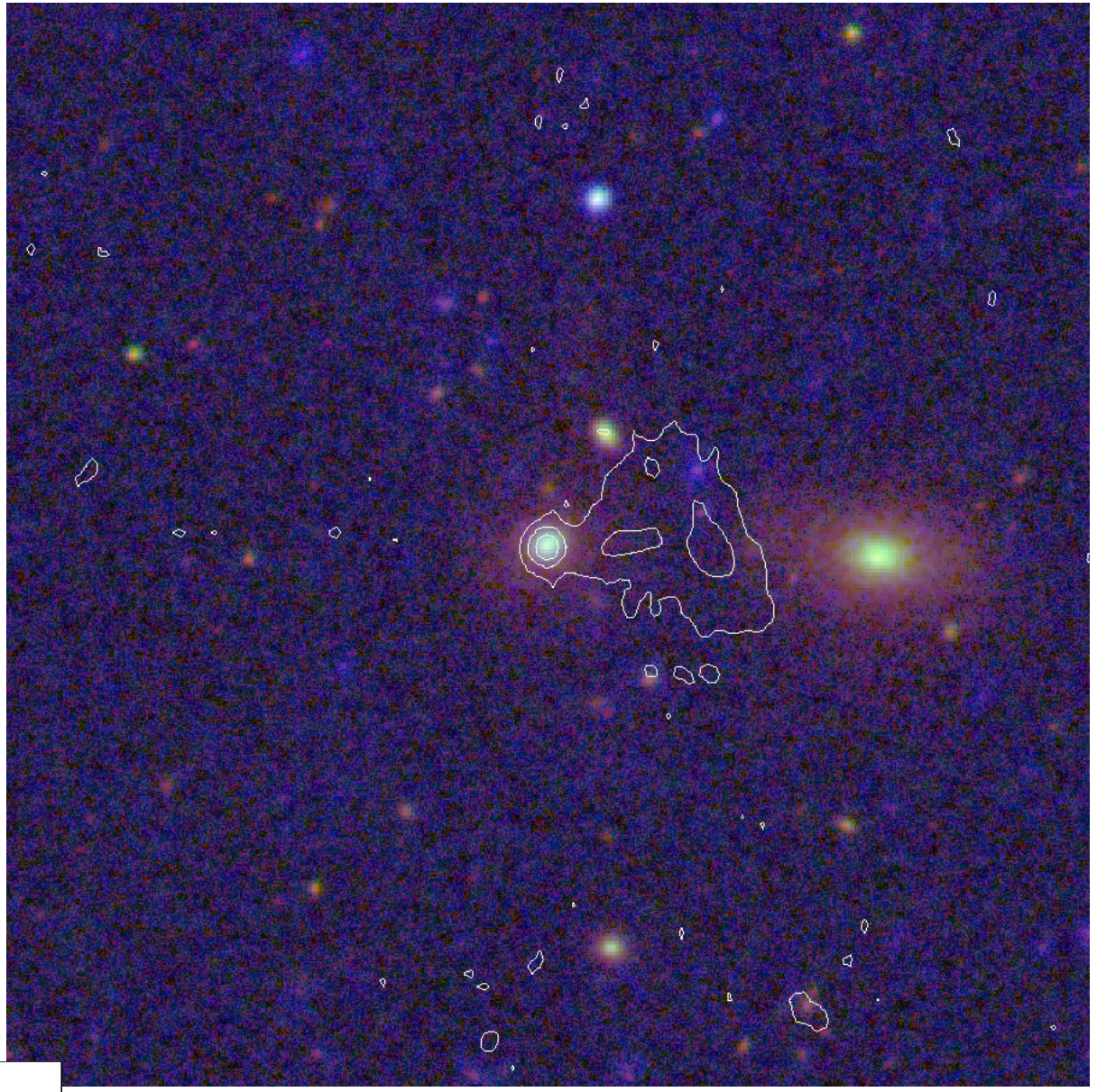

Positive Feedback
(short time)

Negative Feedback
(Long term)

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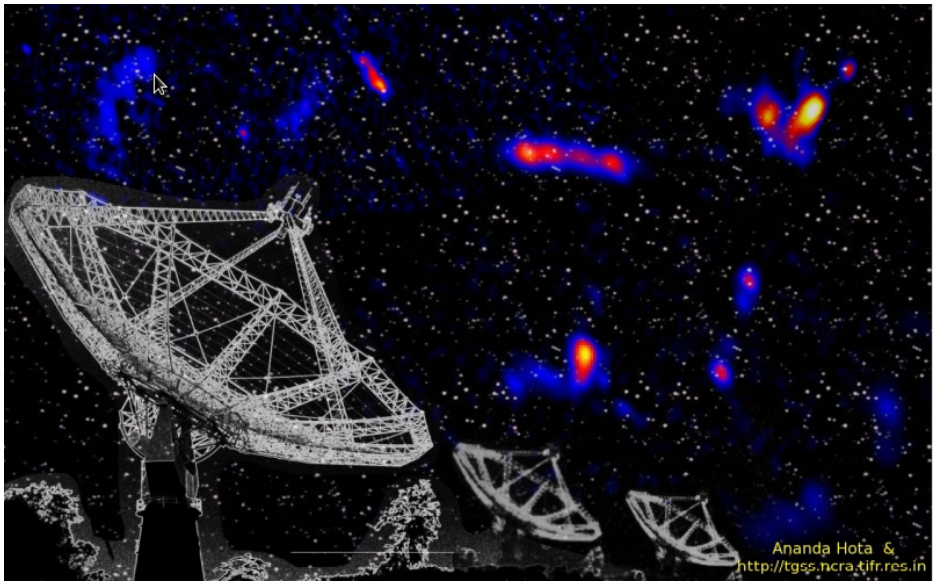
2.5 yr old the only Indian Citizen-science project, RAD@home



Ref: TGSS press-release News

Please
Help
RAD@home

Thank You

GOOD-RAC: GMRT Observation of Objects
Discovered by RAD@home Astronomy Collaboratory
Zero-funded Zero-infrastructure Human Resource Network
Through Facebook & Google, trying to discover
Observe with the GMRT and publish with you...
Addressing BIG-DATA & socio-economic geo-political inequality

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E-astronomers
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NP, VP, DST, NCRA
ASI, SKA-India etc etc

Contact: RADatHOMEindia@gmail.com
RDCC members:
Pratik Dabhade, Alakananda Patra, Pdadeepta Mohanty,
Megha Rajoria, Sagar Sethi, Charitarth Vyas

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Hota et al. 2014 arXiv1402.3674H

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