

1st Indian Citizen Science Research Platform in Astronomy (April 2013)

Nationwide inter-University Collaboratory of scientists & trained Citizen-scientists for research on black hole galaxy co-evolution using GMRT radio telescope, largest such, pride of India.

#RADatHomeIndia GMRT

RAD@home Citizen scientists discover a monster blackhole spewing fire at another galaxy.

RAD12 tricolour image GMRT (red), CFHT(green) & MeerKAT (blue)
MNRAS Letters (Ananda Hota, Pratik Dabhade, Sravani Vaddi et al. 2022)

12TH SOUTHEAST ASIA ASTRONOMY NETWORK MEETING
1 - 3 February 2023 | Siem Reap, Cambodia

International expansion of RAD@home citizen science collaboratory for black hole galaxy co-evolution

Dr. Ananda Hota

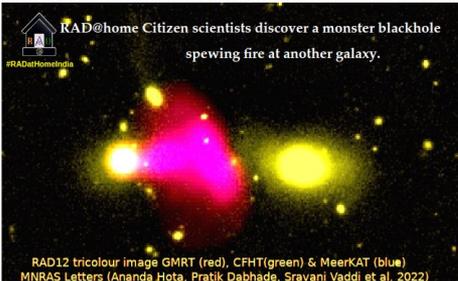
UGC faculty, UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, & Director & Principal Investigator, RAD@home Astronomy Collaboratory, India



12th SEAAN meeting (1-2 Feb 2023) <https://indico.narit.or.th/event/175/>

#RADatHomeIndia <https://radathomeindia.org/> radathomeindia@gmail.com





Monthly Notices

ROYAL ASTRONOMICAL SOCIETY

MNRAS **517**, L96–L101 (2022)

<https://doi.org/10.1093/mnras/ltac116>

RAD@home citizen science discovery of an active galactic nucleus spewing a large unipolar radio bubble on to its merging companion galaxy

Ananda Hota,^{1,2*} Pratik Dabhade,^{2,3*} Sravani Vaddi,^{2,4*} Chiranjib Konar,^{2,5} Sabyasachi Pal,^{2,6} Mamta Galati,^{2,7} C. S. Stalin,^{2,8} Ck Avinash,² Avinash Kumar,² Megha Rajoria² and Arundhati Purohit²

¹AcadLeah, UM DAE Centre for Excellence in Basic Sciences, University of Mumbai, Santacruz East, Mumbai-400098, India

²RAD@home Astronomy Collaboratory, Kharghar, Navi Mumbai-410210, India

³Observatoire de Paris, LERMA, Collège de France, PSL University, Sorbonne University, Paris F-75014, France

⁴Arecoho Observatory, NAIC, HC3 Box 53905, Arecoho, PR 00602, USA

⁵Faculty Institute of Applied Sciences, Amity University Uttar Pradesh, Sector-125, Noida-201305, India

⁶Maharaja City College, Kurum, Bhadrachalam, Andhra Pradesh, West Bengal-751120, India

⁷School of Mathematics, Thapar Institute of Engineering and Technology, Patiala, 147004, Punjab, India

⁸Indian Institute of Astrophysics, Koramangala II Block, Bangalore 560014, India

12TH SOUTHEAST ASIA ASTRONOMY NETWORK MEETING
1 - 3 February 2023 | Siem Reap, Cambodia

Archaeoastronomy in the Modern Era

Registration: indico.narit.or.th/e/seaan2023

Important dates
Registration opens: 21 DEC 2022
Registration closes: 10 JAN 2023
Notification of acceptance: 13 JAN 2023

Venue: Sofitel Angkor Phokeethra Golf & Spa Resort

Topics: Archaeoastronomy, Solar and stellar physics, Extragalaxy, Cosmology, Astronomy education & outreach

Keynote speakers: B. Soonthornthum – NARIT, Kaz Sekiguchi – NAOJ, Hakim Malasan - ITB, Paul Ho - EAO

Local Organising Committee: Chan Oeurn Chey - RUPP, Sriv Tharith - RUPP, Saran Poshychinda - NARIT, Wiphu Rujopakarn - NARIT, Wichan Insiri - NARIT, Supaluck Chanthawan - NARIT, Tanakorn Traiwattanaporn - NARIT

Scientific Organising Committee: B. Soonthornthum – NARIT, Hakim Malasan – ITB, Abel Yang – NUS, Yee Yee Qo – KSUNI, Rosario Ramos – PAGASA, Chan Oeurn Chey - RUPP, P. Irawati – NARIT, Pham Tuan Anh - VNSC, Hasan Abu Kassim - UM

Contact: foreignaffairs@narit.or.th



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#RADatHomeIndia GMRT

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International recognitions to #RADatHomeIndia



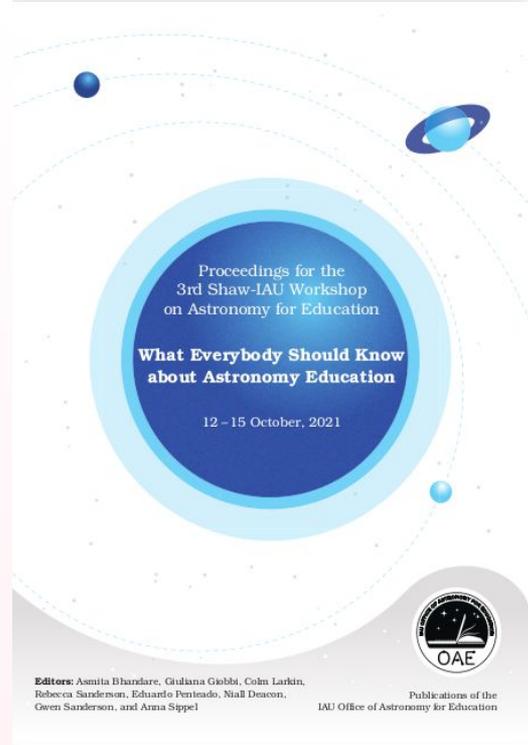
RAD@home is 1 of 7 citizen science research programme in the world in radio astronomy f

www.go.nature.com/2ZJraif

<https://www.iau.org/public/callforonlineresources/>

<https://www.skatelescope.org/outreachandeducation/outreach-resources/citizen-science/>

#RADatHomeIndia <https://radathomeindia.org/> radathomeindia@gmail.com



#RADatHomeIndia a Collaboratory Model of Citizen Science Research

(Big-data is a big-resource for development if citizen science follows a Collaboratory approach)

Speaker: Ananda Hota, UGC-faculty, UM-DAE Centre for Excellence in Basic Sciences, RAD@home Astronomy Collaboratory, India

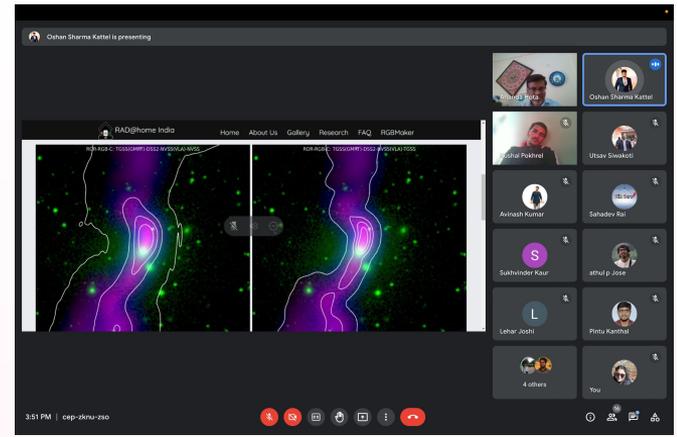


RAD@home (#RADatHomeIndia) is a nationwide, Inter-University Collaboratory of professional astronomers, trained citizen scientists and technical/administrative facilitators. It is the only Indian citizen science research platform in astronomy. Nearly 30 institutes and similar number of professionals have contributed to its growth since 2013. In a "flying pyramid" model, scientists and facilitators are its wings, and large number trained citizen-scientists (e-/i-astronomers) at multiple levels of expertise make the multi-layer pyramid. It has 150 e-astronomers, 1000 i-astronomers, 2500 active learners, 4700 total members. This way citizens achieve GMRT telescope time, co-authorship in papers on galaxy evolution and MS/PhD selections abroad or all round growth.

Talk link: <https://youtu.be/VMZzP4BPCsU>



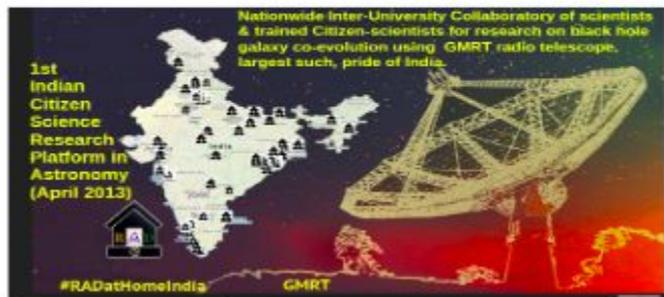
THE
SHAW
PRIZE
邵逸夫獎



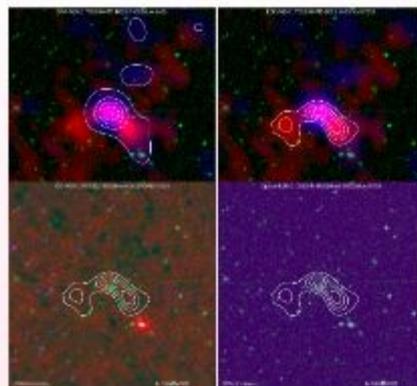
RAD@home participated in the IAU symposium 375: Multi-messenger Chakra of Blazer jets (w/ IAU & UGC grants)

#RADatHomeIndia <https://radathomeindia.org/> radathomeindia@gmail.com

RAD@home Inter-University Collaboratory for citizen science in galaxy evolution with multi-wavelength RGB images



By
Megha Rajoria
Head of collaborative Programs
RAD@home India
6 December 2022



RAD@home RGB-maker tool for citizen science research

In multiwavelength study of AGNs with
radio jets

Avinash Kumar
RAD@home India

6 December 2022, RAD@IAUSymposium375, Kathmandu



Certificate of outreach organization

The organisers of IAU symposium 375 are grateful to RAD@home Astronomy Collaboratory (India) and glad to certify that RAD@home members:

1. Contributed three oral presentations to the scientific program of the symposium.
2. Trained nearly a dozen student-participants for citizen science research before the start of the symposium in online weekend e-classes.
3. Conducted one of the three successful in-person outreach events, organized as part to the symposium's activities, with over 100 participants.
4. Attracted more than 200 online registrations who will continue to receive educational/outreach content through emails.

Date: 09/12/22

Professor Vasiliki Pavlidou
Institute of Astrophysics & Physics Department, University of Crete.
Chair of the Scientific Organizing Committee.



Registration for the Outreach event
RAD@home Astronomy workshop at
IAU Symposium 375, Nepal
#RADatIAUsymposium375Nepal



IAU Symposia: The multimessenger chakra of blazar jets



Register at <https://tinyurl.com/RADatIAUsymposium375Nepal>

The organisers of IAU symposium 375 are grateful to RAD@home Astronomy Collaboratory (India) and glad to certify that RAD@home members:

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OCTOBER-DECEMBER 2022

VOL 6 (2)

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Science Diplomacy

India's Global Digest of Multidisciplinary Science



Citizen Science

RAD@home India Citizen Science Diplomacy at the International Astronomical Union Symposium 375, Nepal

Megha Rajoria*, **Ananda Hota***[†]

[†]RAD@home Astronomy Collaboratory, India

[†]UGC-faculty, UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, India

*Corresponding author: megharajoria3@gmail.com

"When you look at the stars and the galaxy, you feel that you are not just from any particular piece of land, but from the solar system" Kalpana Chawla

The striking words of Kalpana Chawla give us a reason to believe that all of us are just a dot in the Universe. And we are separated by human-made borders, although astronomically, we belong to one of the solar systems. RAD@home Astronomy Collaboratory, which is India's first citizen science research project in astronomy, has gone beyond the Indian border and was part of the International Astronomical Union's (IAU) Symposium 375, "The multi-messenger chakra of blazar jets", held in Kathmandu, Nepal between 5-9 December 2022. Leading members of the Collaboratory presented their recent discovery of a black hole galaxy system RAD12(1-3) and also conducted an Astronomy workshop for Nepali citizens. The collaboratory has been active in India for almost a decade now. It enables the science-educated masses from across the country in discovering Radio Galaxies by training them with the support of various Indian institutes.



Figure 1. RAD@home Astronomy Workshop, an outreach event as part of IAU symposium 375, Kathmandu, Nepal

RAD@home Inter-University Collaboratory

Zero Funded - Zero Infrastructure - Nationwide Human Resource Network

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#RADatHomeIndia GMRT



RAD@home Discovery Camp

07 May 2018 to 13 May 2018



#RADatIAU375 #RADatHomeIndia www.radathomeindia.org

#RADatHomeIndia <https://radathomeindia.org/> radathomeindia@gmail.com

Dream & Reality



Science Education @University
and Doing Research@home



fb.com/groups/RADathome/

Primary Science Goals of RAD@home Collaboratory

Discovery of an exotic galaxy, Spica

Cosmic Leaf Blower Galaxy NGC3801
SDSS (y) GALEX (b) Spitzer (r) VLA (g)

Discovery of a spiral-host episodic radio-galaxy
Ananda Hota et al. 2011 MNRAS, 2016 JApA, P.R.
NGC3801 caught in the act: A post-merger starforming early-type galaxy with AGN-jet feedback
Ananda Hota et al. 2012 MNRAS, 2016 JApA, P.R.

Science with the SKA

RAD@home Citizen scientists discover a monster black hole spewing fire at another galaxy.

RAD12 citizen science discovery of an active galactic nucleus spewing a large unipolar radio bubble on to its merging companion galaxy

Ananda Hota,^{1,2*} Pratik Dabhadre,^{1,2*} Sravani Vaddi,^{1,2*} Charanjit Kumar,^{1,2*} Subhaschandra Pal,^{1,2*} Manish Gohil,^{1,3} C.S. Stalin,^{1,4} Ch. Aravind,¹ Avinash Kumar,⁵ Misha Rajwani,⁶ and Anandkumar Panthri⁷

1) Tata Institute of Fundamental Research, Mumbai, India; 2) Centre for Astrophysics, Tata Institute of Fundamental Research, Mumbai, India; 3) Indian Institute of Space Science and Technology, Thiruvananthapuram, India; 4) Indian Institute of Space Science and Technology, Thiruvananthapuram, India; 5) Indian Institute of Space Science and Technology, Thiruvananthapuram, India; 6) Indian Institute of Space Science and Technology, Thiruvananthapuram, India; 7) Indian Institute of Space Science and Technology, Thiruvananthapuram, India.

Monthly Notices Letters

Artistic Graphics Animation
Mr Hemant Singhla & Dr Ananda Hota
RAD@home, India

RAD12 tricolour image GMRT (red), CFHT(green) & MeerKAT (blue)
MNRAS Letters (Ananda Hota, Pratik Dabhadre, Sravani Vaddi et al. 2022)

natureINDIA THE TIMES OF INDIA The Indian EXPRESS Down To Earth Science Reporter EurekAlert! AlphaGalileo etc.

RAD12 black hole citizen science discovery <https://radathomeindia.org/press-release>

RAD@home Astronomy Collaboratory India #RADatHomeIndia



GOOD-RAC (GMRT follow-up)

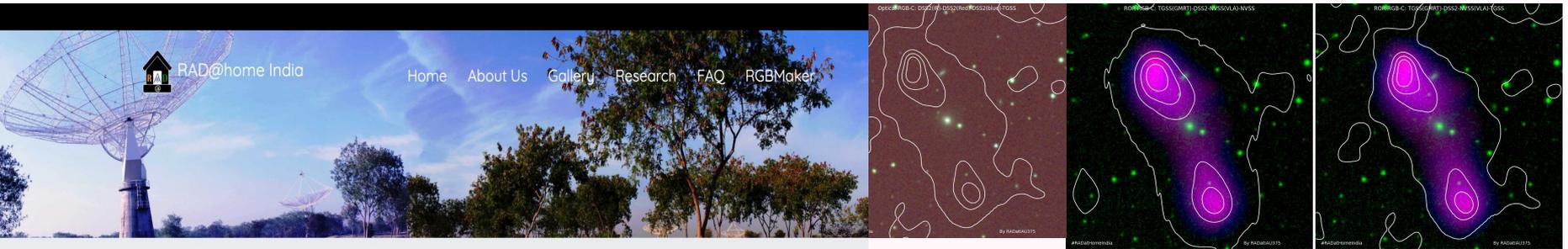
Discovery @ home



#RADatIAU375 #RADatHomeIndia www.radathomeindia.org

#RADatHomeIndia <https://radathomeindia.org/> radathomeindia@gmail.com

What do we teach? RGB Image Analysis!



#RADatHomeIndia RGB Maker

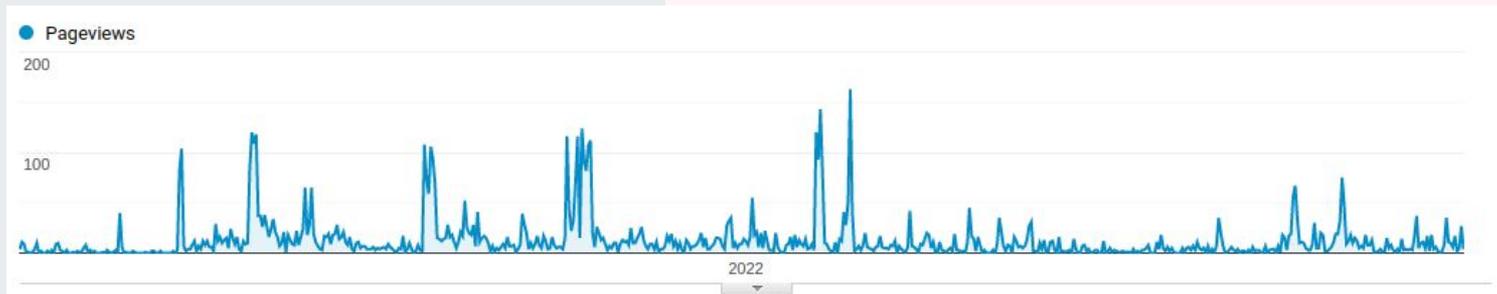
Name

Position

Size (in degrees)

Images (?)

Archives (?)



Interactive Learning in Social Media - Weekly e-class



RAD@home Astronomy Collaboratory, India

View 3 previous comments All comments

Ninisha Manaswini
Target 3C 315: ROR image with radio contour
This is an x-shaped radio source (butterfly structure) where two galaxies are merging. This can be clearly seen from the central two nuclei. Nvss contour is covered a wider region because of its lower resolution



Like Reply 16w

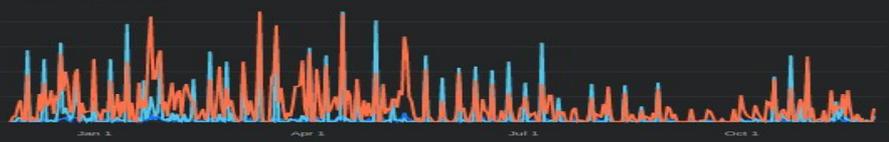
View 2 previous replies

Ananda Hota Author Admin
host is merging pair of ellipticals ?
Like Reply 16w
6 Replies

Yash Mahalim
Target Name: NGC 809, IOU image with none contour. It is an intermediate form between spiral and elliptical because we can see formation of ring liked structure surrounded around. Ringed structure consists of younger new born stars showing as UV emiss... See more



All 307 Posts 2,035 Comments 4,309 Reactions
Nov 27, 2021 - Nov 26, 2022



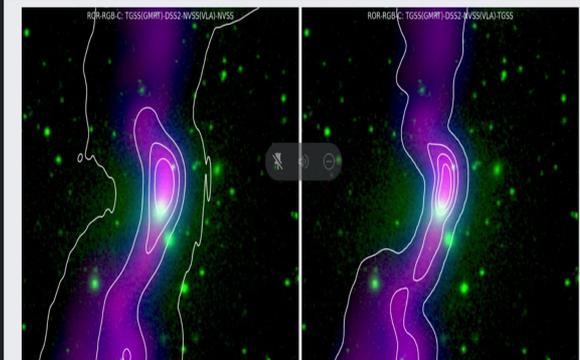
1,514 active members
Nov 26, 2021 - Nov 27, 2022



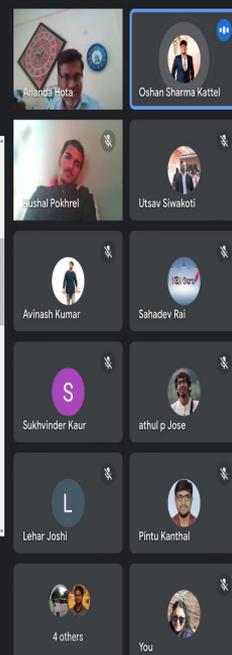
Active Members Per Day (Nov 26 - Nov 27)

Oshan Sharma Kattel is presenting

RAD@home India Home About Us Gallery Research FAQ RGBMaker



3:51 PM | cep-zknu-zso



4 others You

#RADatIAU375 #RADatHomeIndia www.radathomeindia.org

#RADatHomeIndia <https://radathomeindia.org/> radathomeindia@gmail.com

All ⓘ

289 Posts

1,800 Comments

4,079 Reactions

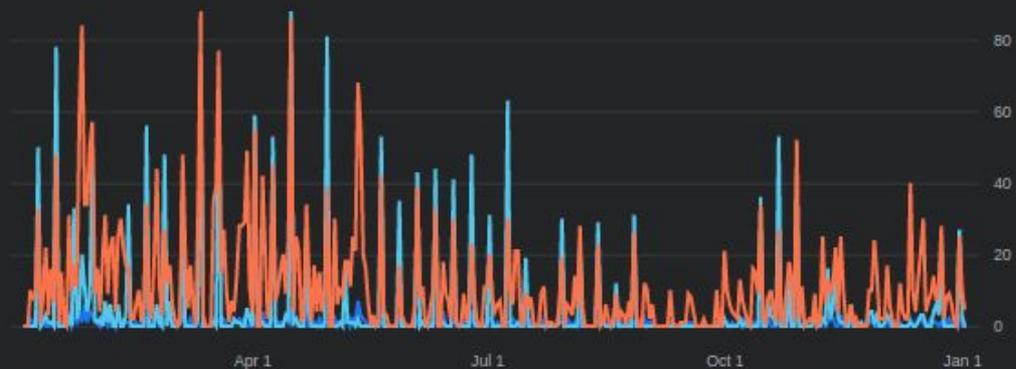
Jan 3, 2022 - Jan 2, 2023

Posts

Comments

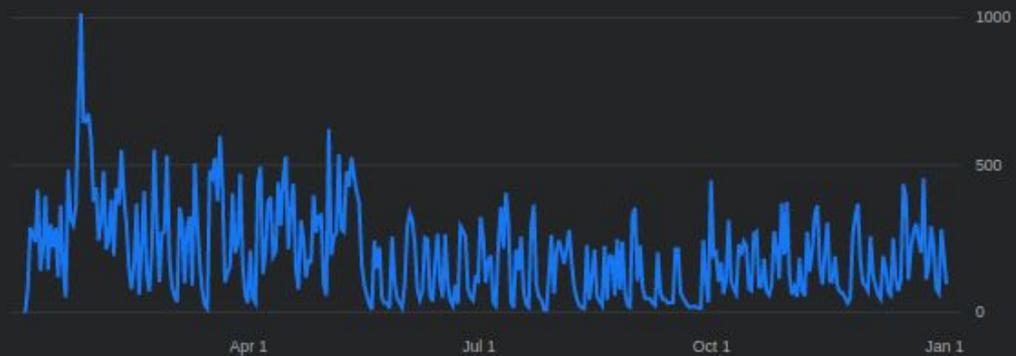
Reactions

All



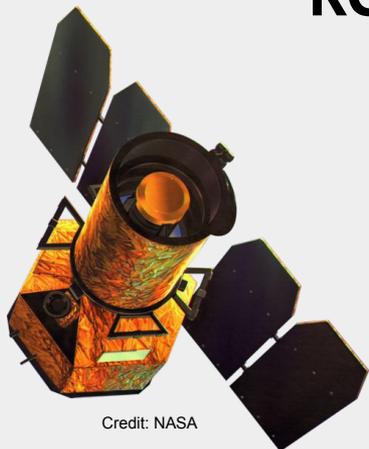
1,598 active members ⓘ

Jan 4, 2022 - Jan 3, 2023



Active Members Per Day (Jan 4 - Jan 3)

RGB Maker : Multiwavelength analysis



Credit: NASA

GALEX - NUV, FUV



Credit: NRAO/AUI/NSF

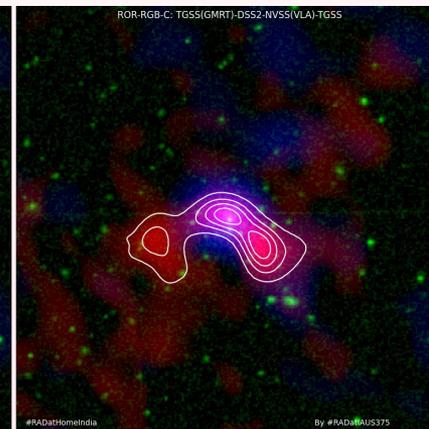
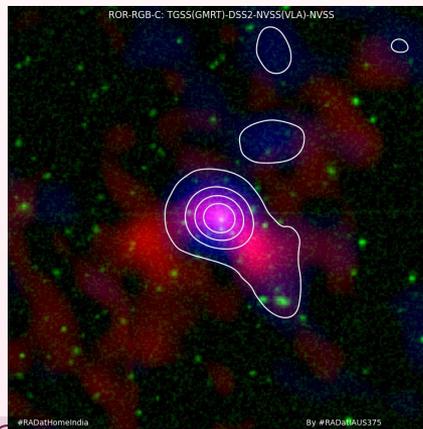
Very Large Array - FIRST, NVSS



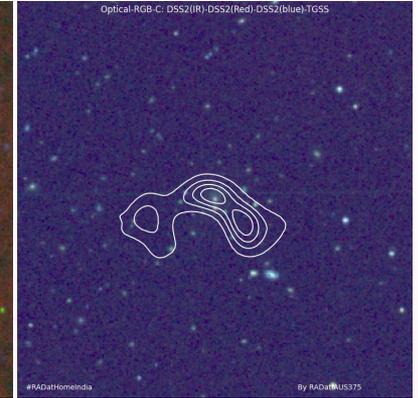
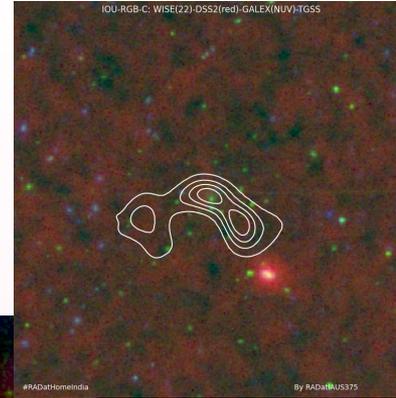
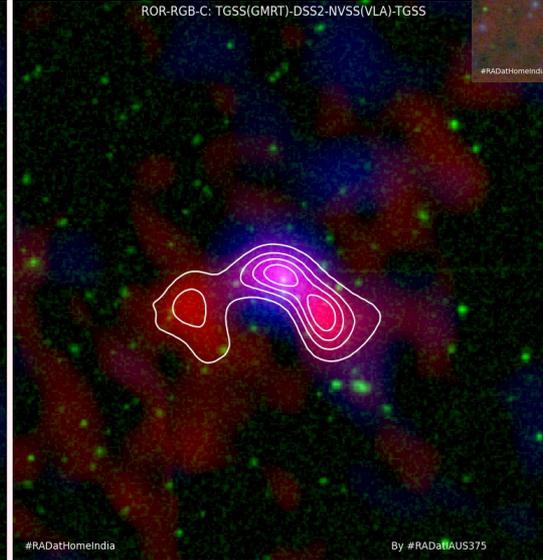
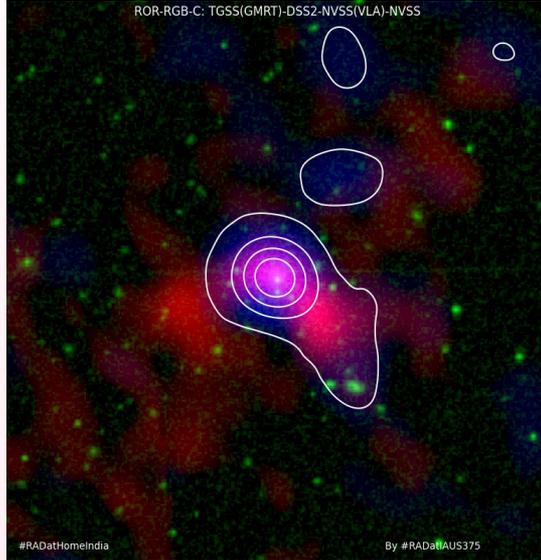
Credit: Avi

GMRT - TGSS
30 dishes, 25 Km Baseline

Each RGB image is a combination of these imaging survey data in Red, Green, and Blue color channels, with their respective intensities at each pixel, resulting in a false-colored image.



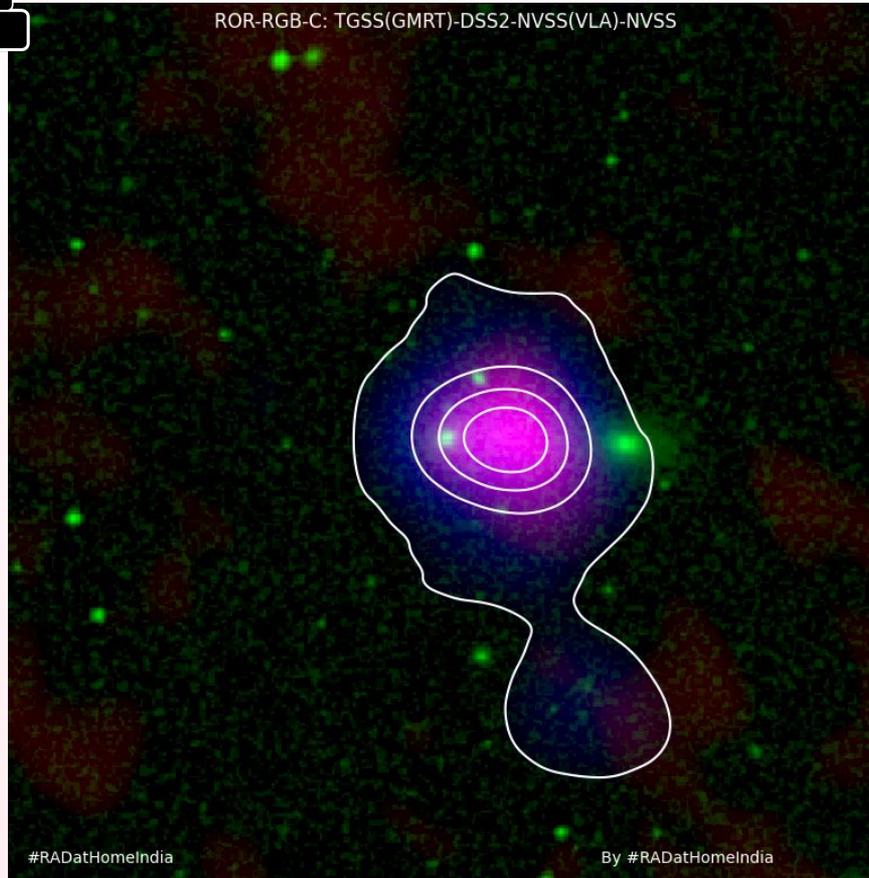
How to Discover ?





Gut-feeling for RAD-12 from RGB images in 2013 !!

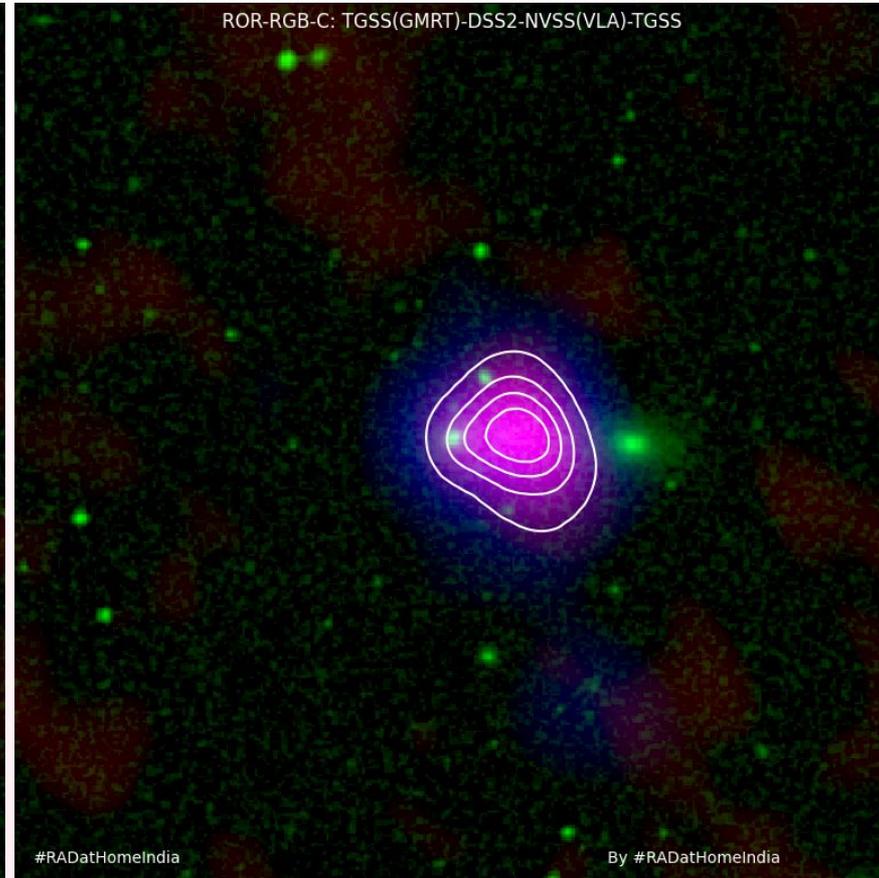
ROR-RGB-C: TGSS(GMRT)-DSS2-NVSS(VLA)-NVSS



#RADatHomeIndia

By #RADatHomeIndia

ROR-RGB-C: TGSS(GMRT)-DSS2-NVSS(VLA)-TGSS



#RADatHomeIndia

By #RADatHomeIndia

RAD@home Publications with Citizen scientists as co-author(s)



Cornell University Library
arXiv.org > astro-ph > arXiv:1402.3674

Astrophysics > Astrophysics of Galaxies

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)
(Submitted on 15 Feb 2014)

We present the first report on an innovative new project named "RAD@home", a citizen-science research collaboratory built on free web-services like Facebook, Google, Skype, NASA Skyview, NED, TGSS etc.. This is the first of its kind in India, a zero-funded, zero-infrastructure, human-resource network to educate and directly involve in research, hundreds of science-

Volume 37, Number 4, December 2016

Journal of Astrophysics & Astronomy

Special Issue: Science with the Square Kilometer Array: An Indian Perspective

Review
CrossMark

J. Astrophys. Astr. (2016) 37:41
DOI 10.1007/s12036-016-9415-8

Tracking Galaxy Evolution Through Low-Frequency Radio Continuum Observations using SKA and Citizen-Science Research using Multi-Wavelength Data

Ananda Hota^{1,2,*}, C. Konar^{2,3}, C. S. Stalin⁴, Sravani Vaddi⁵, Pradeepta K. Mohanty², Pratik Dabhade², Sai Arun Dharmik Bhoga², Megha Rajoria² & Sagar Sethi²

¹eAstroLab, UM-DAE Centre for Excellence in Basic Sciences, Vidyanageri, Mumbai 400 098, India.
²RAD@home Astronomy Collaboratory, Mumbai, India.
³Amity Institute of Applied Sciences, Amity University Uttar Pradesh, Sector-125, Noida, India.
⁴Indian Institute of Astrophysics, Koranganala, Bangalore 560 034, India.
⁵National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, Ganeshkhind, Post Bag No. 3, Pune 411 007, India.
*e-mail: hotaananda@gmail.com



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS 517, L86–L91 (2022)
<https://doi.org/10.1093/mnras/517/1>

RAD@home citizen science discovery of an active galactic nucleus spewing a large unipolar radio bubble on to its merging companion galaxy

Ananda Hota,^{1,2*} Pratik Dabhade^{2,3*}, Sravani Vaddi^{2,4*}, Chiranjib Konar,^{2,5} Sabyasachi Pal^{2,6}, Mamta Gulati,^{2,7} C S. Stalin,^{2,8} Ck Avinash,² Avinash Kumar², Megha Rajoria² and Arundhati Purohit²

¹eAstroLab, UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, Santacruz-East, Mumbai-400098, India
²RAD@home Astronomy Collaboratory, Kharghar, Navi Mumbai-410210, India
³Observatoire de Paris, LERMA, Collège de France, PSL University, Sorbonne University, Paris F-75014, France
⁴Arecibo Observatory, NAIC, HC3 Box 53995, Arecibo, PR 00612, USA
⁵Amity Institute of Applied Sciences, Amity University Uttar Pradesh, Sector-125, Noida-201303, India
⁶Midnapore City College, Kutturia, Bhadratala, Puschim Medinipur, West Bengal-721129, India
⁷School of Mathematics, Thapar Institute of Engineering and Technology, Patiala, 147004, Punjab, India
⁸Indian Institute of Astrophysics, Koranganala II Block, Bangalore 560 034, India

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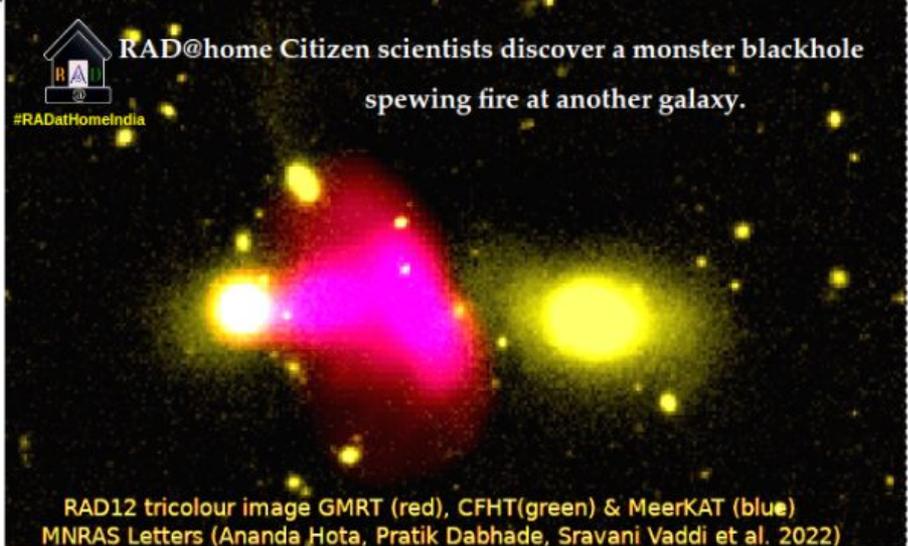
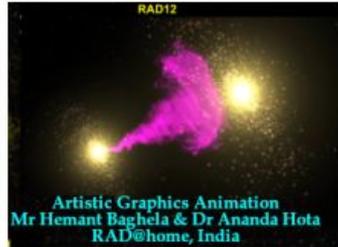
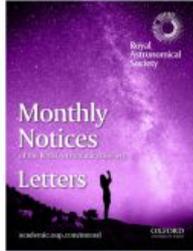
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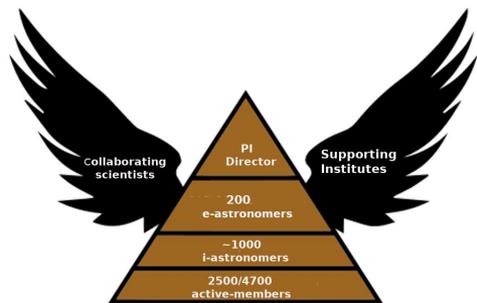
¹MumbaiLab, UM-DRL Centre for Excellence in Basic Sciences, University of Mumbai, Santacruz-East, Mumbai-400086, India
²RAD@home Astronomy Collaborators, Kharghar, New Mumbai-410209, India
³Observatoire de Paris, LERMA, Collège de France, PSL University, Sorbonne Université, Paris F-75014, France
⁴Aravali Observatory, NAAC, HC3 Box 33905, Anandis, PR 90612, USA
⁵Amey Institute of Applied Sciences, Amey University Uttar Pradesh, Sector-125, Noida-201303, India
⁶Milapuri City College, Kankar, Bhubaneswar, Bhubaneswar, Odisha, Bhubaneswar-751029, India
⁷School of Mathematics, Thapar Institute of Engineering and Technology, Patiala, 147004, Punjab, India
⁸Indian Institute of Astrophysics, Kuvempu Road II Block, Bangalore 560 014, India



RAD12 black hole citizen science discovery <https://radathomeindia.org/press-release>



#RADatHomeIndia



Nationwide Inter-University Collaboratory of scientists & trained Citizen-scientists for research on black hole galaxy co-evolution using GMRT radio telescope, largest such, pride of India.

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#RADatHomeIndia

RAD@home Citizen scientists discover a monster blackhole spewing fire at another galaxy.

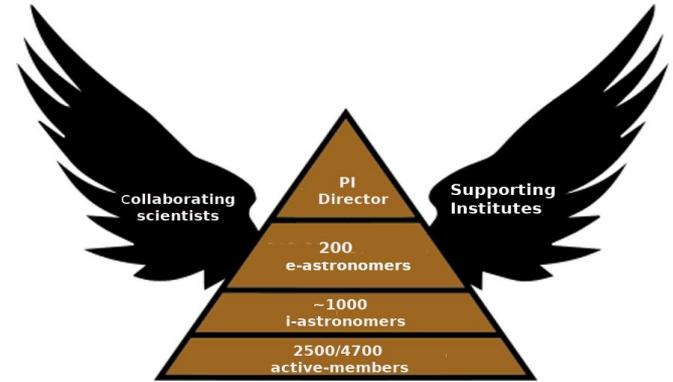
RAD12

Artistic Graphics Animation
Mr Hemant Baghela & Dr Ananda Hota
RAD@home, India

RAD12 image : GMRT (r), CFHT (γ) MeerKAT (b)
Ananda Hota, Pratik Dabhade, Sravani Vaddi et al.
Publication: MNRAS, Letters 2022
Press Release: RAS, NCRA, UM-DAE CEBS, RAD@home

<https://youtu.be/BwnfUq5mCEE>

International Expansion with RAD@IAU375



Registration for the Outreach event
RAD@home Astronomy workshop at
IAU Symposium 375, Nepal

#RADatIAUsymposium375Nepal



IAU Symposia: The multimessenger chakra of blazar jets



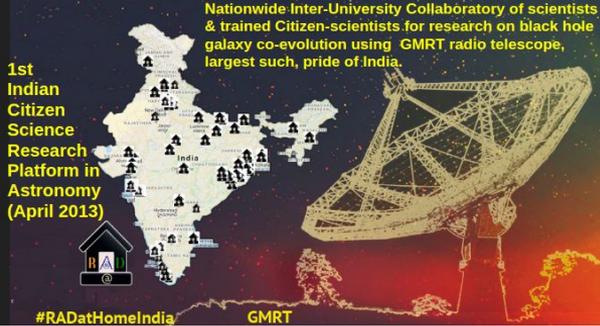
Register at <https://tinyurl.com/RADatIAUsymposium375Nepal>

Let's collaborate!
radathomeindia@gmail.com

Thank you IAU for the kick-start.

#RADatIAU375 #RADatHomeIndia www.radathomeindia.org

#RADatHomeIndia <https://radathomeindia.org/> radathomeindia@gmail.com



Monthly Notices
ROYAL ASTRONOMICAL SOCIETY
MNRAS 517, L86–L91 (2022) <https://doi.org/10.1093/mnras/lnac116>

RAD@home citizen science discovery of an active galactic nucleus spewing a large unipolar radio bubble on to its merging companion galaxy

Ananda Hota,^{1,2*} Pratik Dabhade^{1,2,3*}, Savrani Vaddi^{1,2,4*}, Chiranjib Konar,^{2,5} Sabyasachi Pal^{2,6}, Mamta Gulati,^{2,7} C. S. Stalin,^{2,8} Ck Avinash,² Avinash Kumar⁹, Megha Rajoria² and Arundhati Purohit²

¹Kaustubh, CMR DUE Centre for Excellence in Basic Science, University of Mumbai, Santacruz East, Mumbai-400006, India
²RAD@home Astronomy Collaboratory, Kharghar, Navi Mumbai-400210, India
³Observatoire de Paris, LERMA, Collège de France, PSL University, Sorbonne University, Paris F-75014, France
⁴Gamma Observers, NAIC, P.O. Box 5065, Anchorage, PR 99512, USA
⁵Anamity Institute of Applied Sciences, Anamity University Uttar Pradesh, Sector-125, Noida-201303, India
⁶Madanpore City College, Kanoria, Bhubaneswar, Physics Madanpore, West Bengal-721129, India
⁷School of Mathematics, Tatyasaheb Institute of Engineering and Technology, Peralia, 412004, Pune, India
⁸Indian Institute of Astrophysics, Kuvempu Road II Block, Bangalore-560 034, India

Thank you

Lets Collaborate....

12TH SOUTHEAST ASIA ASTRONOMY NETWORK MEETING
1 - 3 February 2023 | Siem Reap, Cambodia

Archaeoastronomy in the Modern Era

Registration: indico.narit.or.th/e/seaan2023

Important dates
Registration opens: 21 DEC 2022
Registration closes: 10 JAN 2023
Notification of acceptance: 13 JAN 2023

Venue: Sofitel Angkor Phokeethra Golf & Spa Resort

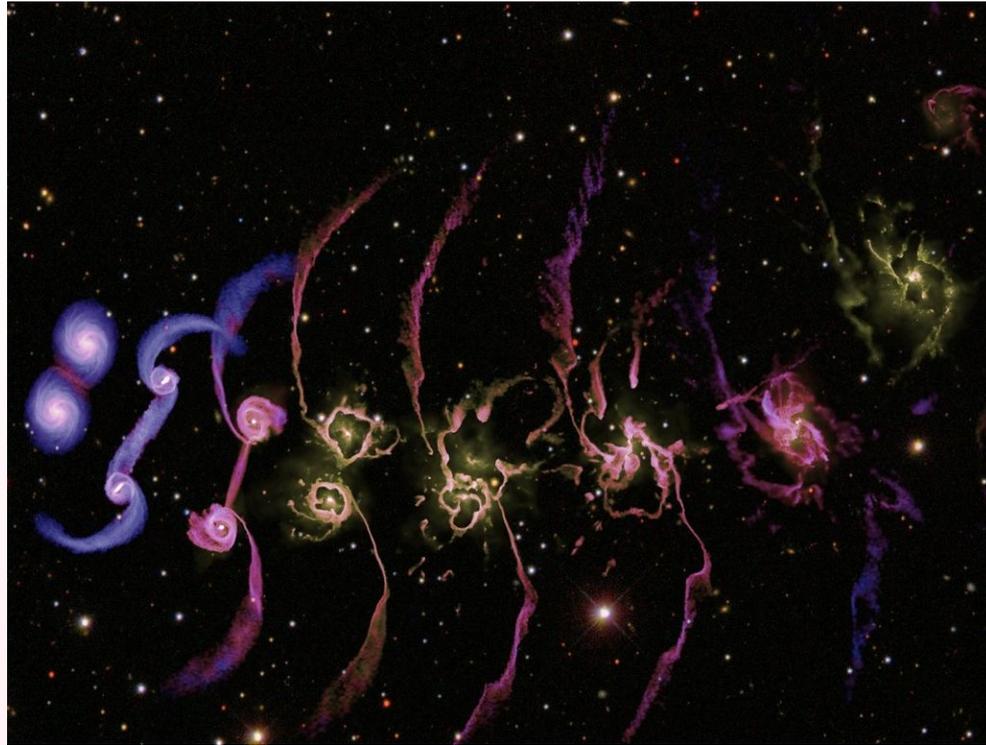
Topics: Archaeoastronomy, Solar and stellar physics, Extragalaxy, Cosmology, Astronomy education & outreach

Keynote speakers: B. Soonthornthum – NARIT, Kaz Sekiguchi – NAOJ, Hakim Malasan - ITB, Paul Ho - EAO

Local Organising Committee: Chan Oeurn Chey - RUPP, Sriv Tharith - RUPP, Saran Poshayachinda - NARIT, Wiphu Rujopakarn - NARIT, Wichan Insiri - NARIT, Supaluck Chanthawan - NARIT, Tanakorn Traiwattanaporn - NARIT

Scientific Organising Committee: B. Soonthornthum – NARIT, Hakim Malasan – ITB, Abel Yang – NUS, Yee Yee Oo – KSUNI, Rosario Ramos – PAGASA, Chan Ouern Chey - RUPP, P. Irawati – NARIT, Pham Tuan Anh - VNSC, Hasan Abu Kassim - UM

Contact: foreignaffairs@narit.or.th



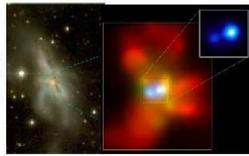
Feedback during major galaxy merger (Springel et al. 2005)

(c) Interaction/"Merger"



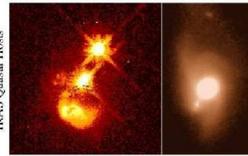
- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(d) Coalescence/(U)LIRG



- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

(e) "Blowout"



- BH grows rapidly; briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host
- high Eddington ratios
- merger signatures still visible

(f) Quasar



- dust removed: now a "traditional" QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(b) "Small Group"



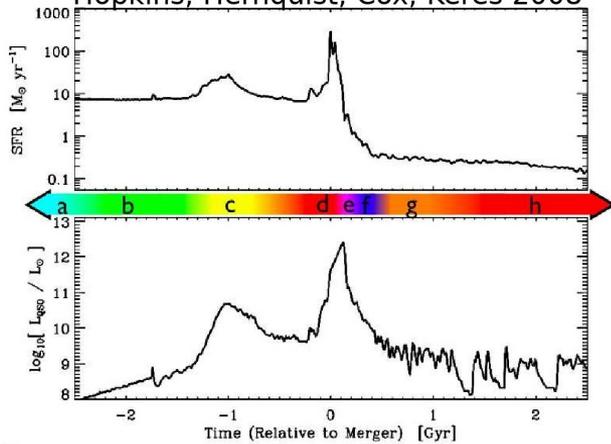
- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently

(a) Isolated Disk



- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Severfert" fuelline (AGN with $M_{\bullet} > 23$)

Hopkins, Hernquist, Cox, Kereš 2008



(g) Decay/K+A



- QSO luminosity fades rapidly
- tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- "hot halo" from feedback
- sets up quasi-static cooling

(h) "Dead" Elliptical



- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to "large group" scales: merger becomes inefficient

What about radio jets ?

Oh, they are powerful but In BCGs and massive ellipticals.

NO

Picture is changing....

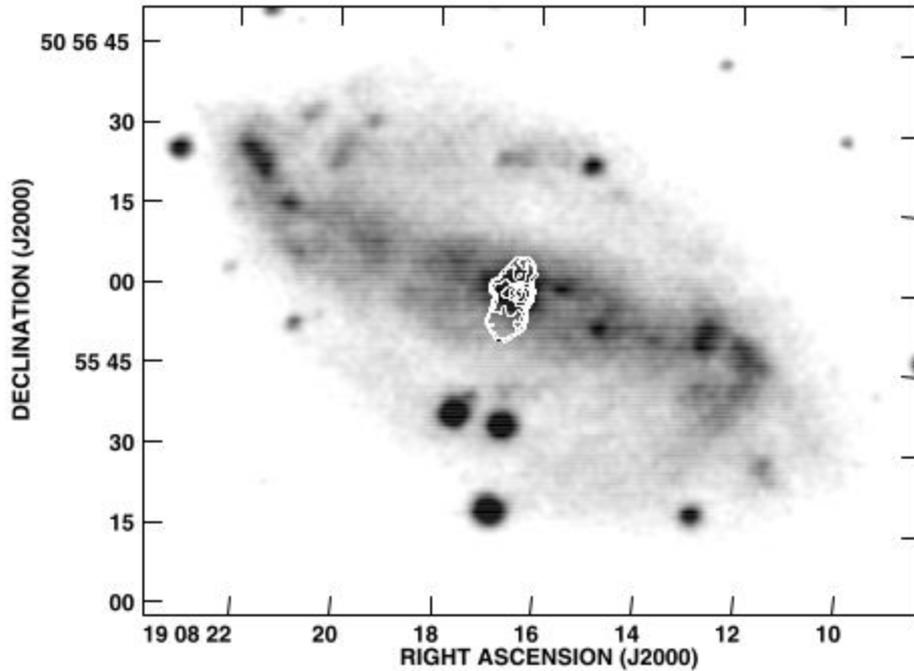
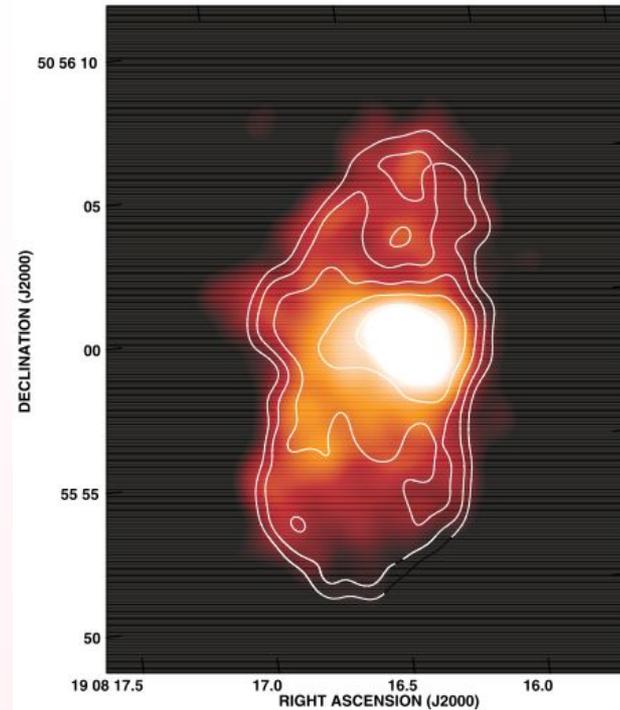


FIG. 1.— Shows 1.4 GHz radio contours of NGC 6764 overlaid on a DSS-2 optical image of the host galaxy. The radio map is made from VLA archival data as published in HS06. Contour levels are $(1.5 \times 10^{-4}) \times 1, 2, 4, \dots, 512 \text{ Jy beam}^{-1}$.

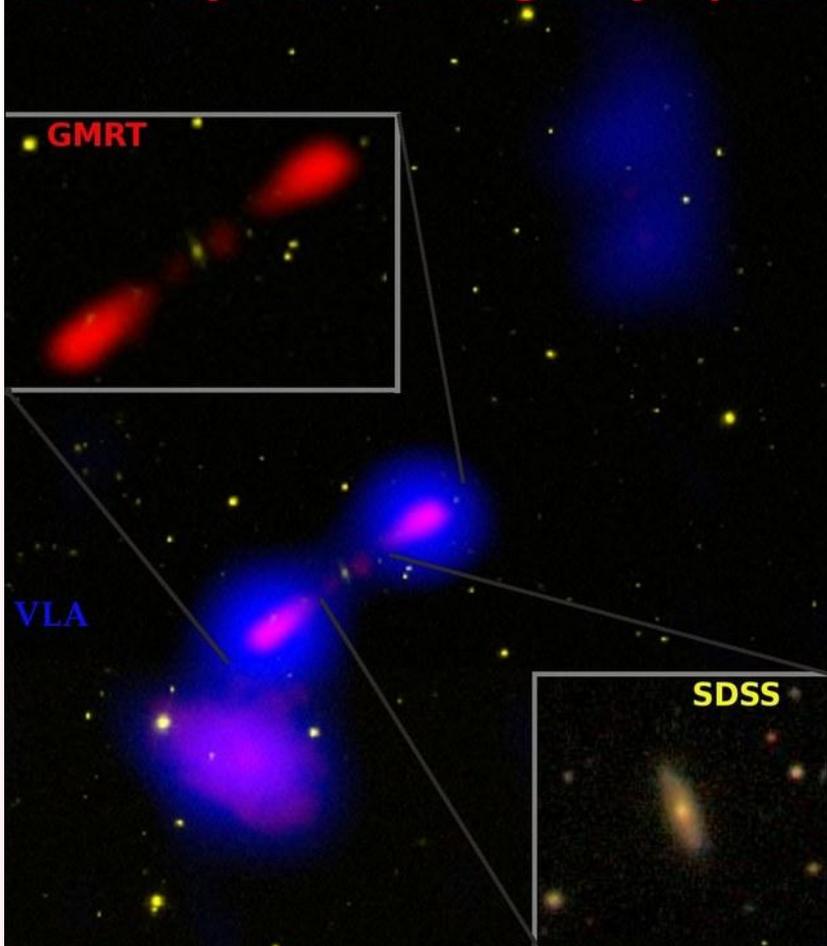
Hota & Saikia 2006, Croston et al. 2008



Chandra X-ray on VLA radio contours
Croston et al. 2008 & Hota & Saikia 2006

Prevalence of kpc-scale jet/bubble can be up to 50% in Seyfert galaxies If low frequency & diffuse sensitivity !
NGC6764 or Cen A, energy imparted can be comparable to binding energy of the ISM !

Discovery of an exotic galaxy, *Specu*



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. Croston⁴ and Satoki Matsushita^{1,5}

¹Academia Sinica Institute of Astronomy and Astrophysics, PO Box 23-141, Taipei 106, Taiwan

²National Centre for Radio Astrophysics, TIFR, Post Bag 3, Ganeshkhind, Pune 411007, India

³Department of Astronomy and Space Science, Chungnam National University, Daejeon 305-764, South Korea

⁴School of Physics and Astronomy, University of Southampton, Southampton SO17 1BJ

⁵Joint ALMA Office, Alonso de Córdova 3107, Vitacura, Santiago, Chile

1st suspected case 0313-192 by
Ledlow, Owen & Keel (1998)

1st Confirmed (due to episodic nature) giant radio galaxy
Hota et al. 2011 (after 12 years !!)

Subaru follow up, confirms a massive disk

XMM-Newton follow up confirms not a BCG

RAD@home launched *Specu*-2 hunting in 2013

~ 6 Speca-like galaxies for 10 years then

~18 more wit Galaxy Zoo and Zoo Gems (HST)

Gems of the Galaxy Zoos—A Wide-ranging Hubble Space Telescope Gap-filler Program*

William C. Keel¹ , Jean Tate^{14,2}, O. Ivy Wong^{3,4} , Julie K. Banfield⁵ , Chris J. Lintott⁶ ,
Karen L. Masters⁷ , Brooke D. Simmons⁸ , Claudia Scarlata⁹ , Carolin Cardamone¹⁰ ,
Rebecca Smethurst⁶  + [Show full author list](#)

Published 2022 March 7 • © 2022. The Author(s). Published by the American Astronomical Society.

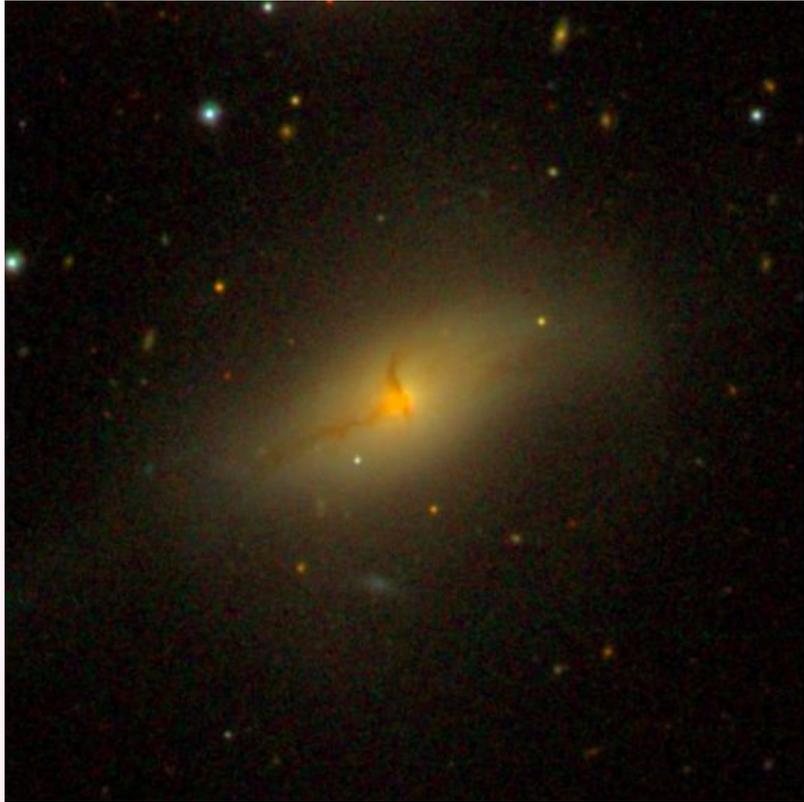
An Elusive Population of Massive Disk Galaxies Hosting Double-lobed Radio-loud AGNs

ZIHAO WU,¹ LUIS C. HO,^{2,1} AND MING-YANG ZHUANG^{1,2}

A population of galaxy-scale jets discovered using LOFAR

B. Webster¹★, J. H. Croston¹, B. Mingo¹, R. D. Baldi^{2,3,4,5}, B. Barkus¹, G. Gürkan⁶
M. J. Hardcastle⁷, R. Morganti^{8,9}, H. J. A. Röttgering¹⁰, J. Sabater¹¹, T. W. Shimwell^{8,10},
C. Tasse^{12,13} and G. J. White^{1,14}

Still looking for “smoking gun evidence” of AGN–jet feedback in any sample



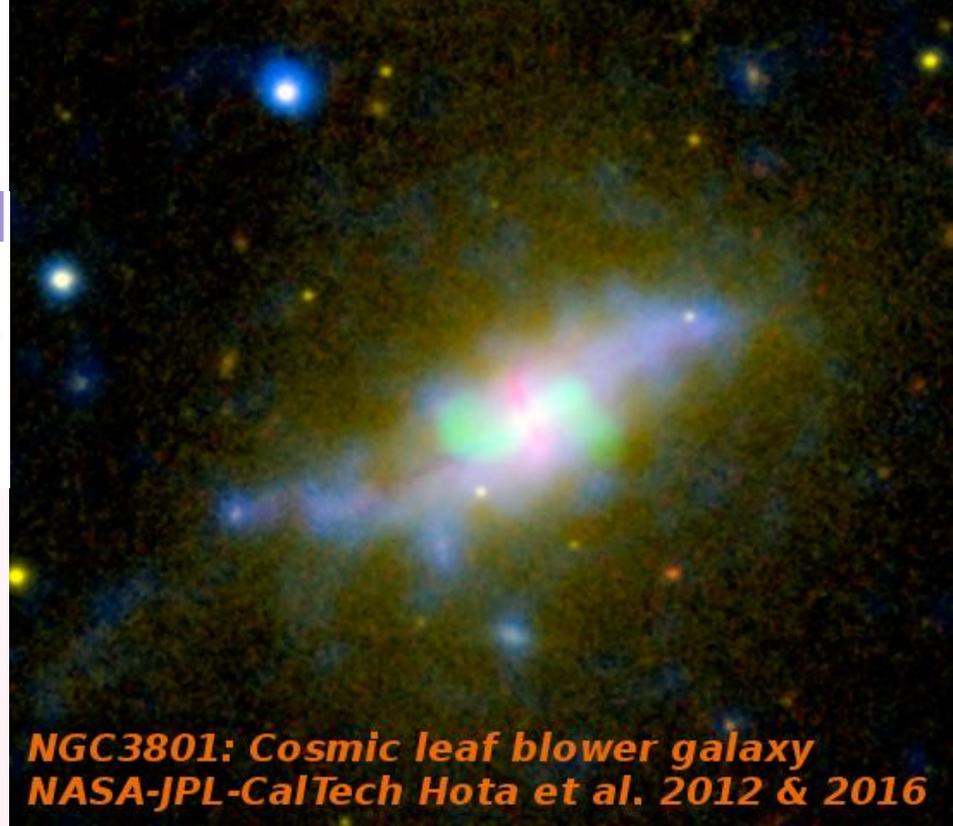
Can we find smoking gun evidence where the relic of the radio jet has an age comparable to Time since the decline of star formation ???



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

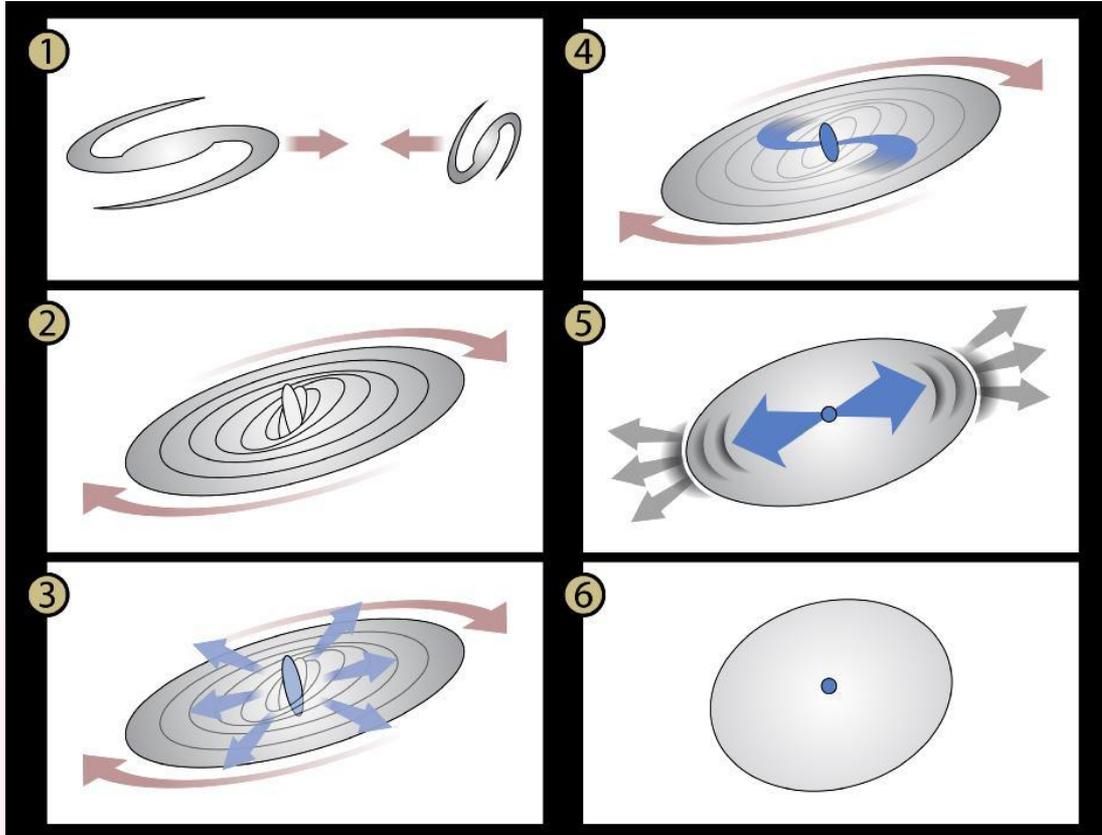
Ananda Hota,^{1*} Soo-Chang Rey,^{2*} Yongbeom Kang,^{2,3} Suk Kim,² Satoki Matsushita¹ and Jiwon Chung²

GALEX (blue)
VLA Green)
SDSS (yellow)
Spitzer (red)

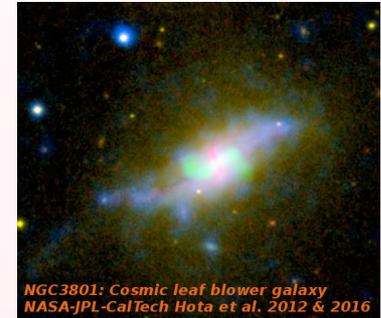


**NGC3801: Cosmic leaf blower galaxy
NASA-JPL-CalTech Hota et al. 2012 & 2016**

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



Star formation
declined 300 Myr back
Before the jet is fired
3 Myr back



Positive vs Negative
Feedback ??

RAD@home discovery RAD12: jet-galaxy interaction

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ROYAL ASTRONOMICAL SOCIETY

MNRAS 517, L86–L91 (2022)



<https://doi.org/10.1093/mnras/517/l86>

RAD@home citizen science discovery of an active galactic nucleus spewing a large unipolar radio bubble on to its merging companion galaxy

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¹*#eAstroLab, UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, Santacruz-East, Mumbai-400098, India*

²*RAD@home Astronomy Collaboratory, Kharghar, Navi Mumbai-410210, India*

³*Observatoire de Paris, LERMA, Collège de France, PSL University, Sorbonne University, Paris F-75014, France*

⁴*Arecibo Observatory, NAIC, HC3 Box 53995, Arecibo, PR 00612, USA*

⁵*Amity Institute of Applied Sciences, Amity University Uttar Pradesh, Sector-125, Noida-201303, India*

⁶*Midnapore City College, Kuturia, Bhadutala, Paschim Medinipur, West Bengal-721129, India*

⁷*School of Mathematics, Thapar Institute of Engineering and Technology, Patiala, 147004, Punjab, India*

⁸*Indian Institute of Astrophysics, Koramangala 11 Block, Bangalore 560 034, India*



Minkowski's Object (positive feedback)

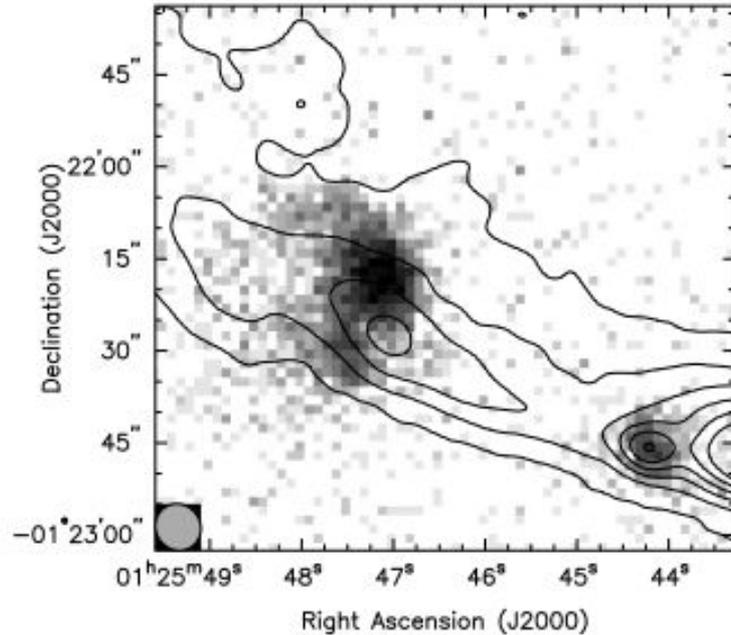


Possibly a short-term Positive

Long-term Negative

Need of detailed jet-galaxy interaction

Radiojet hitting HI cloud triggering young star formation



Radio contours + GALEXFUV

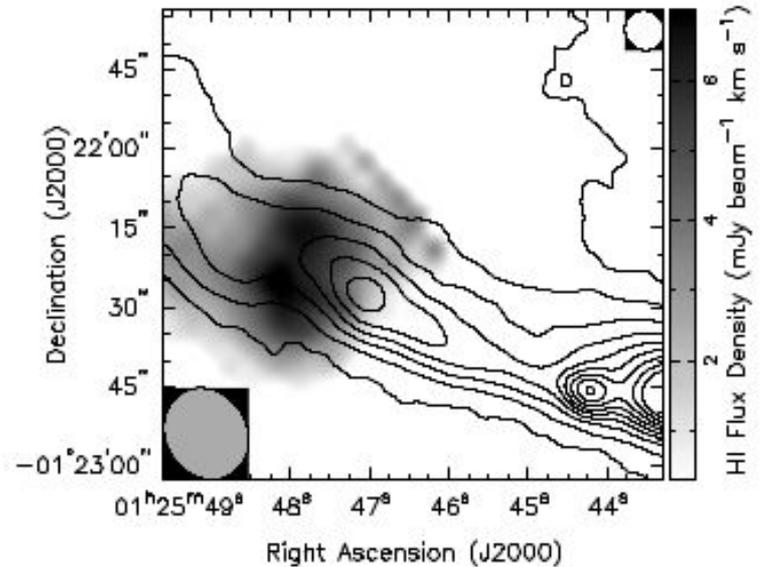
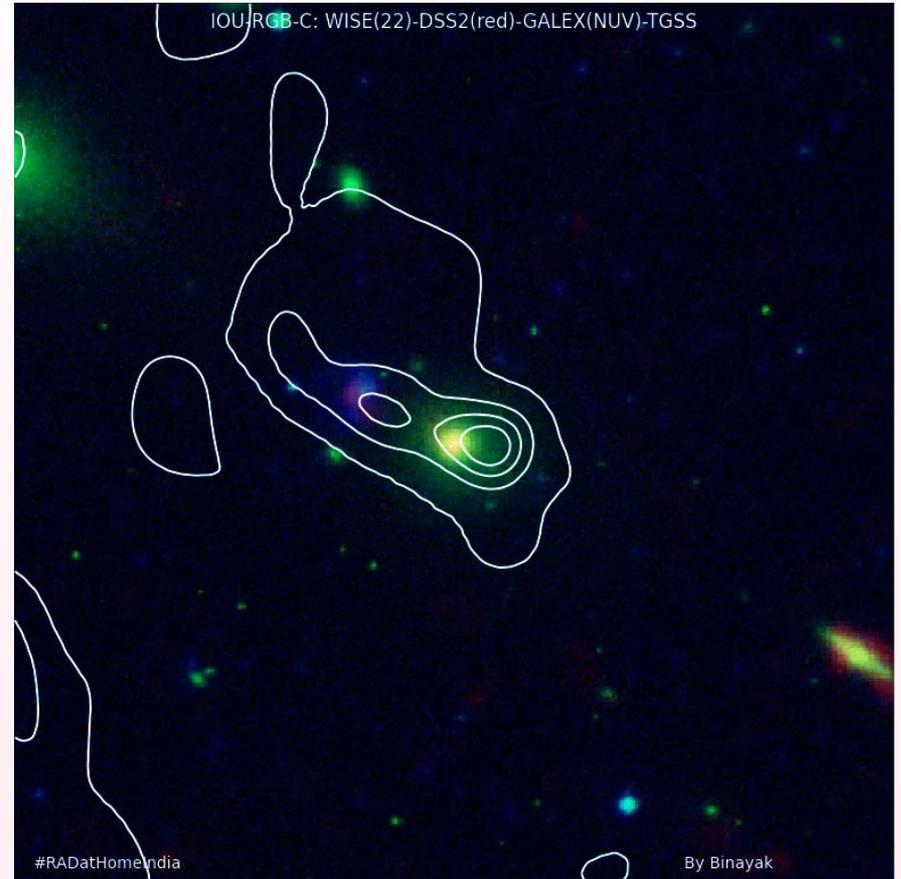
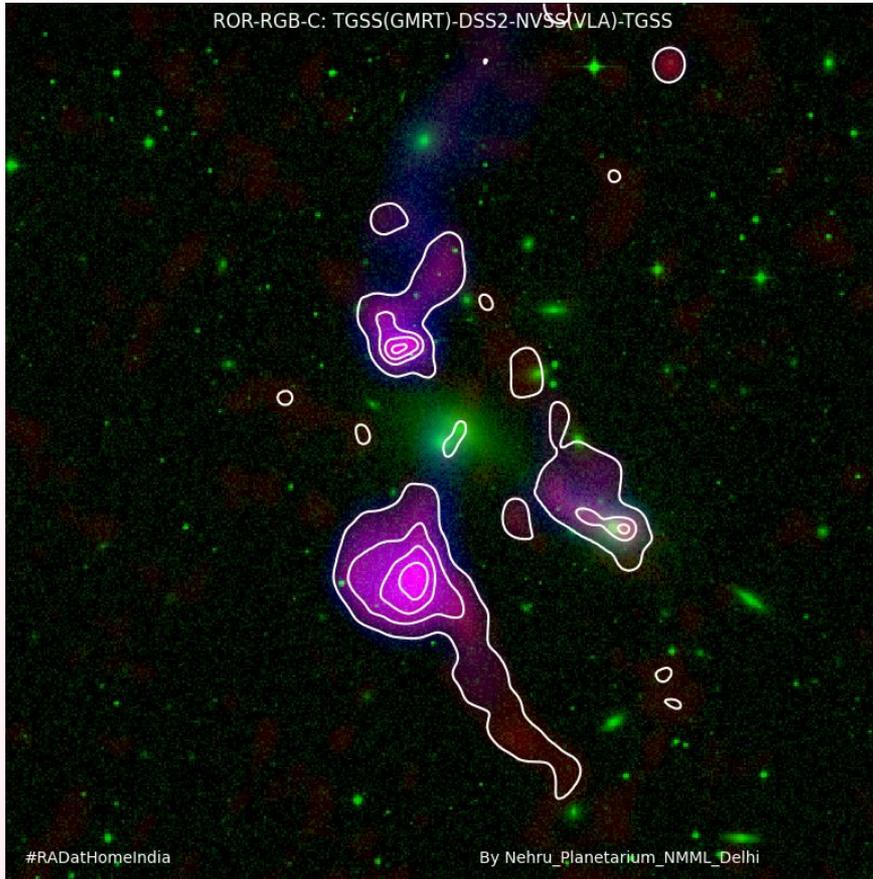


FIG. 9.—Map of the H I cloud adjoining MO, with radio continuum contours from the VLA overlaid. The H I cloud is shown with a linear scaling from 0.3–7 mJy beam⁻¹ km s⁻¹, corresponding to the gray-scale wedge at right. Continuum contours are from 1–17 mJy beam⁻¹ at 2 mJy beam⁻¹ intervals. The H I beam is shown as a gray ellipse (*lower left*), and the continuum beam is shown as a white ellipse (*upper right*).

Croft et al. ApJ, 2006

RAD-RGB style: Minkowski's Object (jet - galaxy interaction)



A few rare Jet minor-galaxy interactions

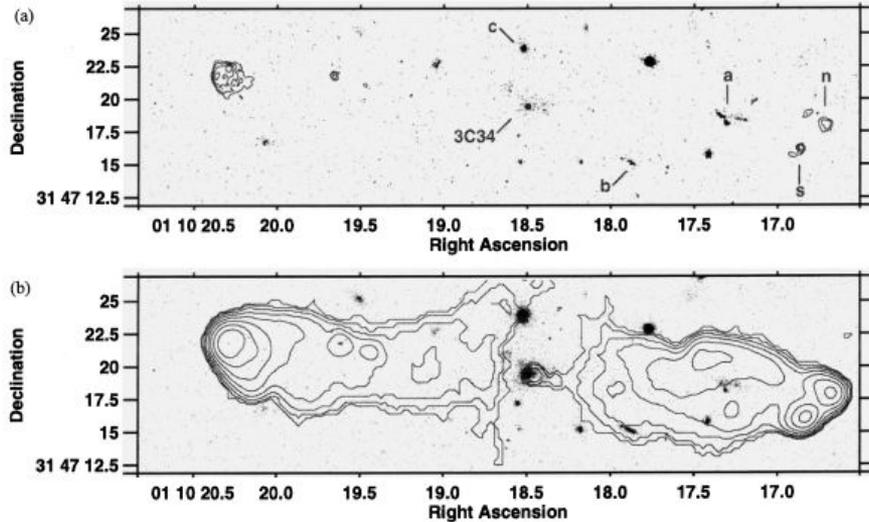


Figure 1. (a) (Top) An image of 3C 34 at 545 nm taken using the *Hubble Space Telescope*, with contours of the VLA A-array radio emission at 8.4 GHz overlaid. Contour levels are $120 \mu\text{Jy} \times (2, 4, 8, 16)$. (b) An *HST* image of 3C 34 at 865 nm, overlaid with contours of the radio emission at 4.8 GHz as seen using B- and C-arrays of the VLA (Johnson, Leahy & Gierington 1995). Contour levels are $\times (1, 2, 4, 8, 16, 32, 64, 128)$. All coordinates are measured in equinox J2000.

3C34 Best, Longair Rottgering 1997



A few rare Jet minor-galaxy interactions

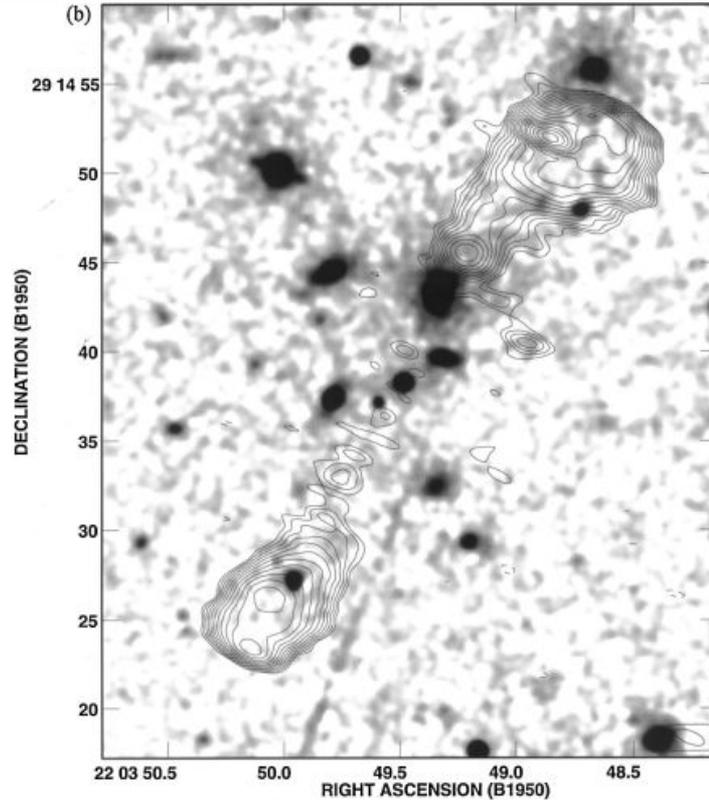


Figure 1 - continued

3C441 Lacy, Rawlings, Blundell & Ridgway 1998

A few rare Jet minor-galaxy interactions

JET/COMPANION-GALAXY INTERACTION IN 3C 321

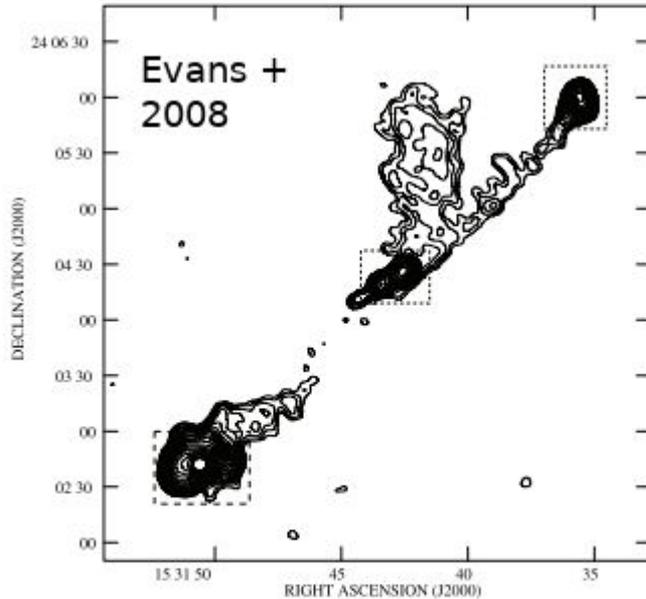


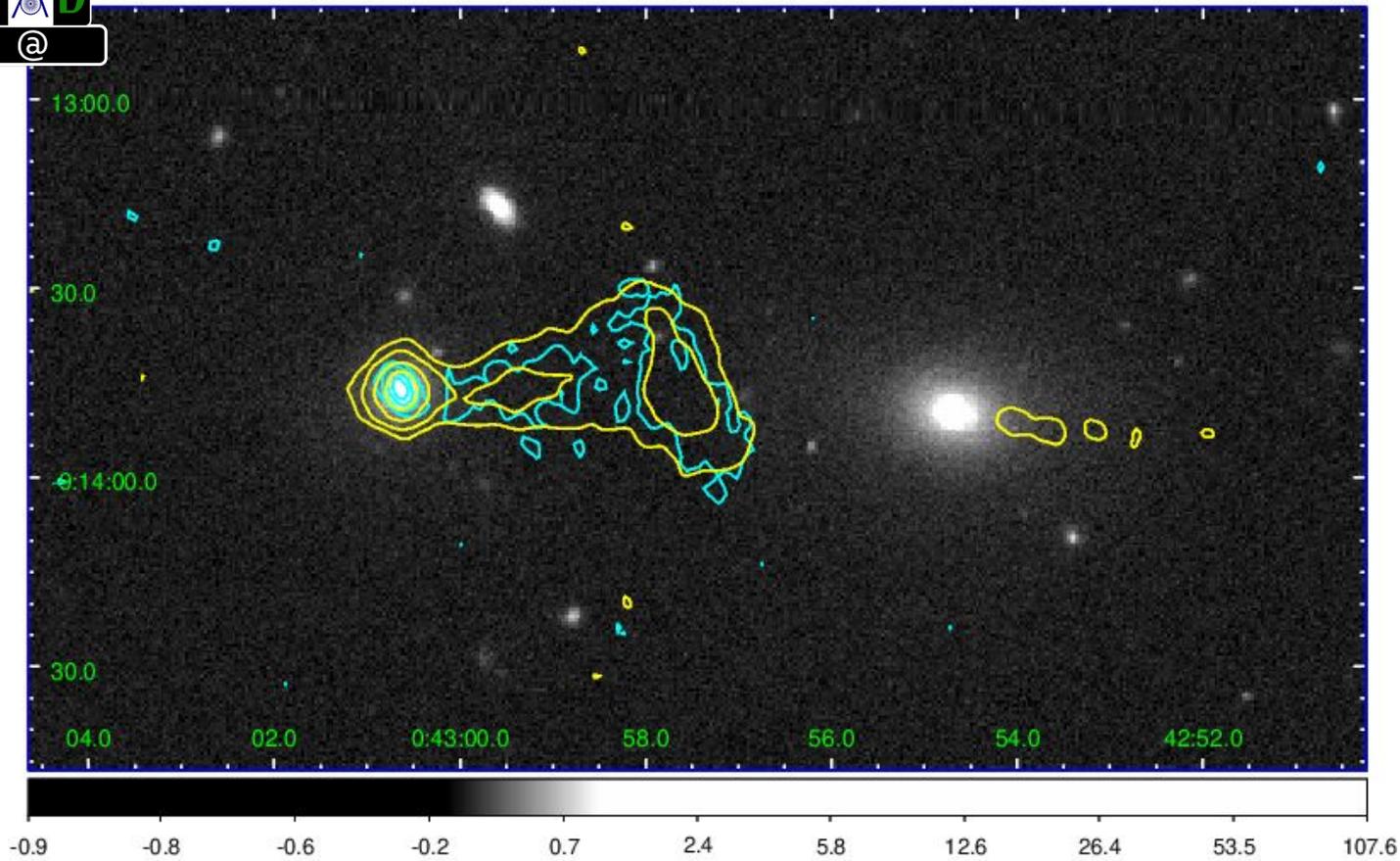
FIG. 1.—A 1.5 GHz VLA A + B + C array image at $6''$ resolution of the entire extent of 3C 321. Prominent radio emission is detected from the core, inner jet, and hot spots, together with a transverse extension to the radio lobe that lies to the north. The dashed boxes mark the approximate regions we used to image in detail the inner jet and hot spots in subsequent figures. Contours are at $0.8 \times (1, 2, 4, \dots)$ mJy beam $^{-1}$.



Animation: Chandra website



Gut-feeling for RAD-12 from RGB images in 2013 !!



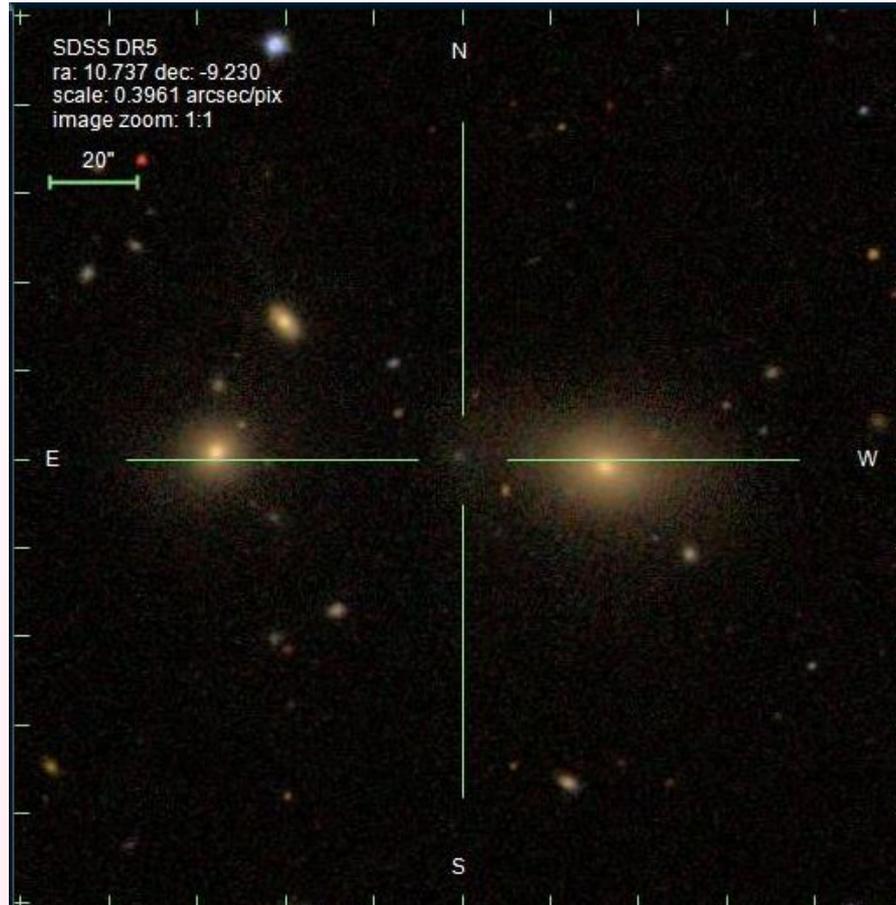
SDSS

FIRST (yellow)

VLASS (cyan)



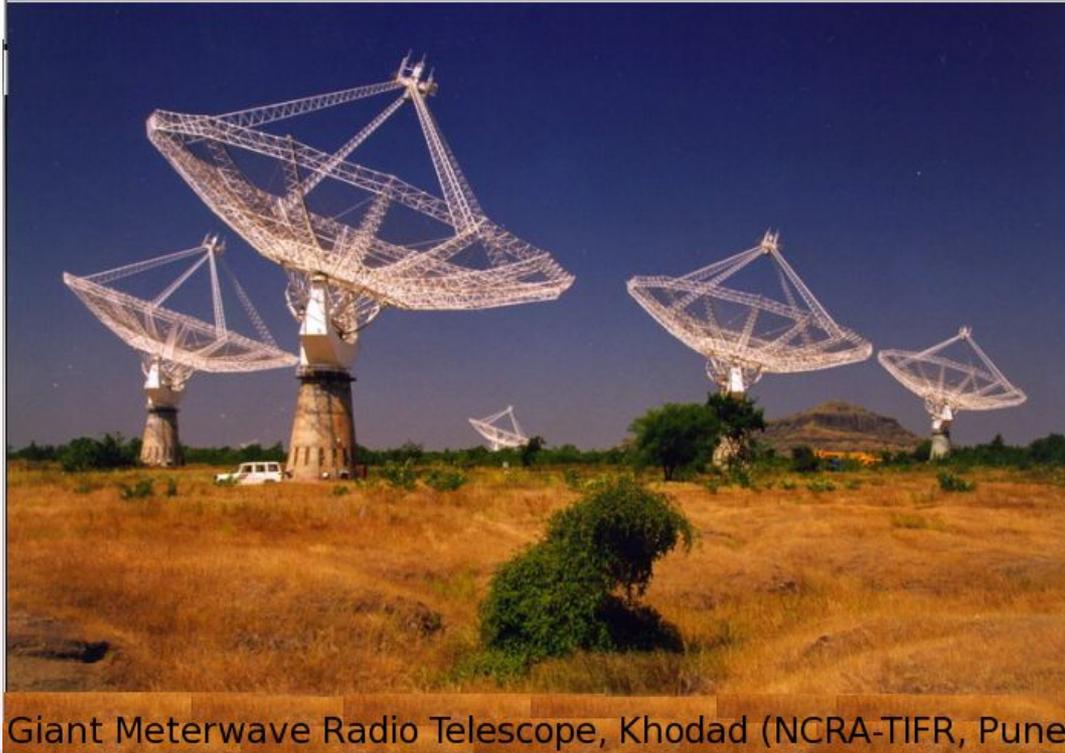
RAD12 or J004300.63-091346.3





GMRT was used for follow up observation of RAD-12 through the GTAC-approved proposal, GOOD-RAC

GMRT Observation of Objects Discovered by the RAD@home Astronomy Collaboratory



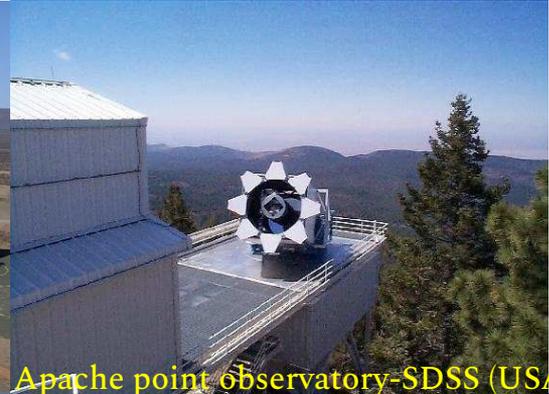
Giant Meterwave Radio Telescope, Khodad (NCRA-TIFR, Pune)



Along with GMRT following telescopes were also used



MeerKAT (South Africa)



Apache point observatory-SDSS (USA)



Very Large Array (USA)



Canada France Hawaii Telescope (USA)

42



RAD12: GMRT, MeerKAT, VLA

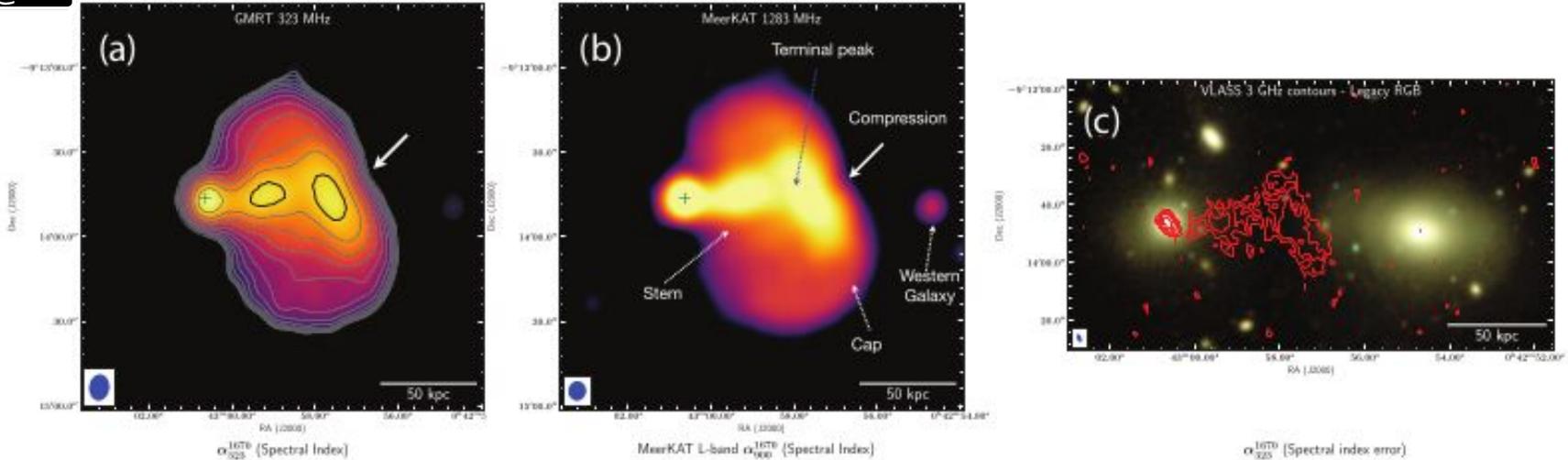


Figure 1. RAD12 images. (a) GMRT 323 MHz colour image with contour levels of 0.0007, 0.0008, 0.0009, 0.0011, 0.0014, 0.0018, 0.0025, 0.0036, 0.0053, 0.0080, 0.0124, 0.0193, and 0.0302 Jy beam⁻¹, with beam of 10.2 × 7.9 arcsec, -6.4°. (b) MeerKAT L-band image with beam of 7.7 × 7.1 arcsec, -8.2°. (c) Optical colour image from Legacy survey is superposed with 3 GHz contours (levels: 0.0004, 0.00066, 0.0013, 0.003, 0.008, 0.022, 0.057, and 0.153 Jy beam⁻¹) from Very Large Array Sky Survey (VLASS) (3.77 × 2.29 arcsec, 20.61°). (d) 11 × 11 arcsec, 0° spectral index map made using GMRT 323 MHz and MeerKAT L band. (e) In-band spectral index from 900 to 1670 MHz (MeerKAT L band) with beam same as the MeerKAT map. (f) Error in the spectral index map from GMRT and MeerKAT data. Cross mark in green colour in subfigures a and b marks the position of the optical nucleus of the host galaxy of RAD12. The centre of the western optical galaxy is also detected in both the radio bands.



RAD12: GMRT & MeerKAT, spectral index

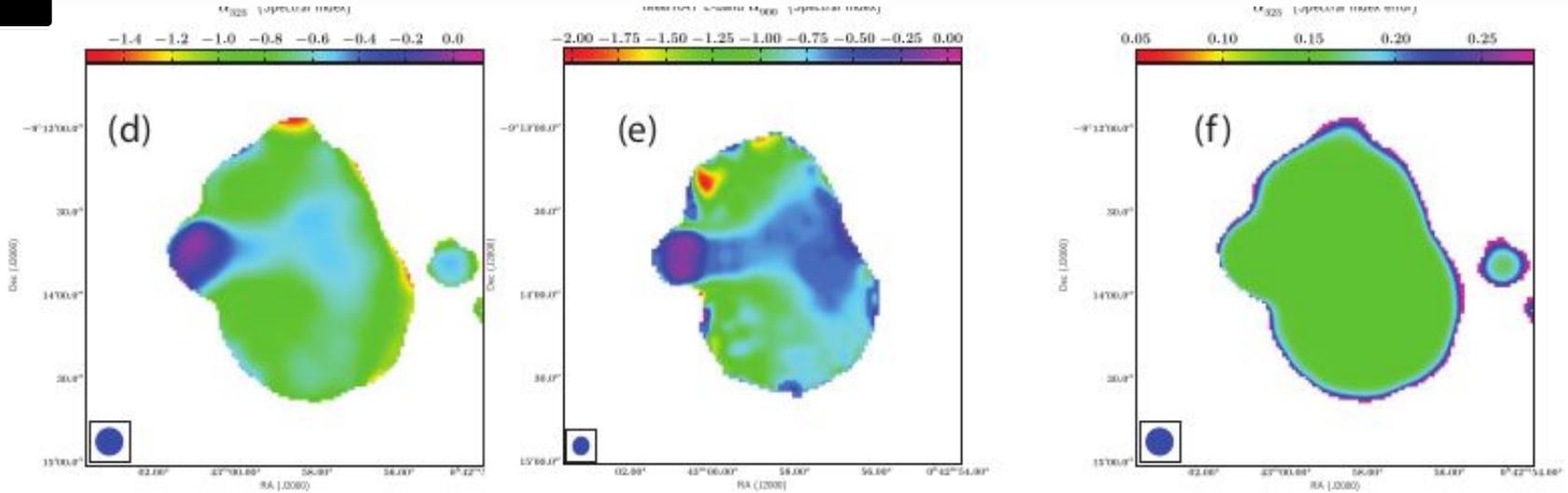


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RAD12: GMRT on CFHT

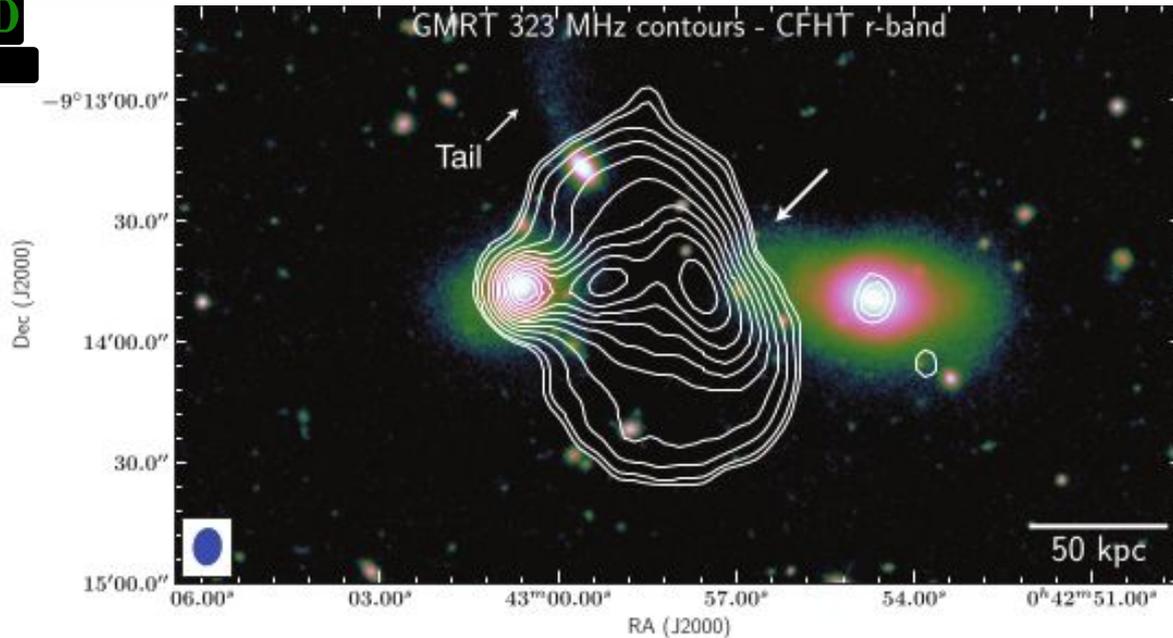


Figure 2. Optical *r*-band image from the *CFHT* of galaxies SDSS J004300.63–091346.3, host of RAD12 (left-hand panel) and companion galaxy SDSS J004254.69–091349.4 (right-hand panel) overlaid with *GMRT* 323 MHz contours.

One-sided jet ?

No positive feedback

1st case of major merger

Jet feedback bouncing back

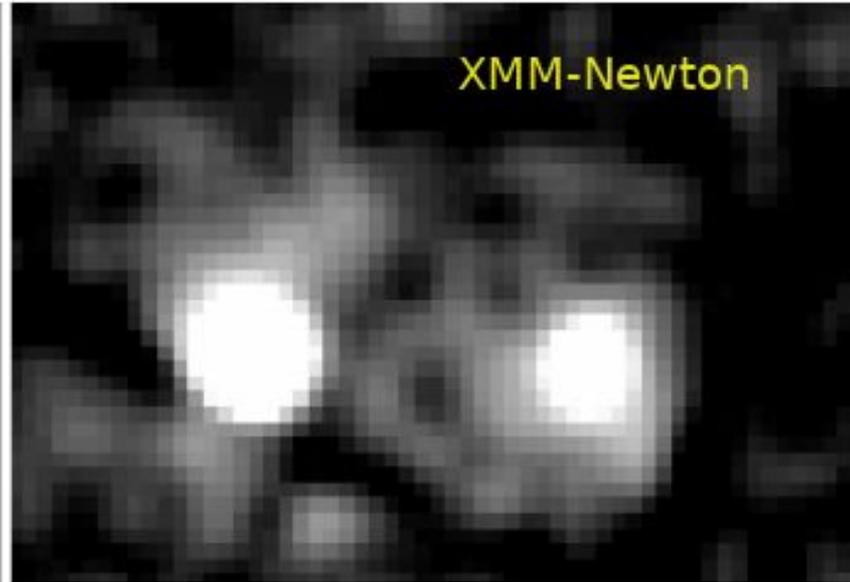
Mushroom bubble 137 kpc

Expanding out of merger plane ?

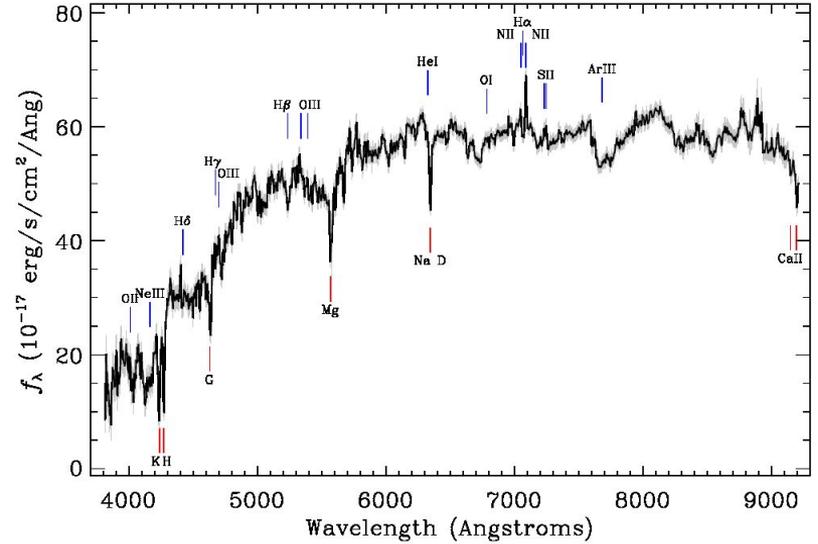
Any other gas driven out ?



Future investigations...



Survey: *sdss* Program: *legacy* Target: *GALAXY_RED GALAXY*
RA=10.75262, Dec=-9.22956, Plate=655, Fiber=581, MJD=52182
 $z=0.07628\pm 0.00001$ Class=GALAXY BROADLINE
No warnings.



Personal discussion with Lawrence Rudnick



The RAD12 tem



Ananda Hota



Pratik Dabhade



Sravani Vaddi



Chiranjib Konar



Sabyasachi Pal



Mamta Gulati



Team



C S Stalin



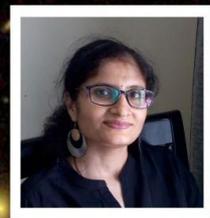
Avinash CK



Avinash Kumar



Megha Rajoria



Arundhati Purohit



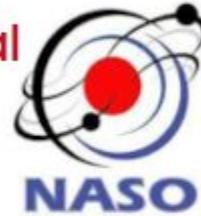


Thanks IAU for the 3rd Shaw-IAU talk & RAD@IAU375



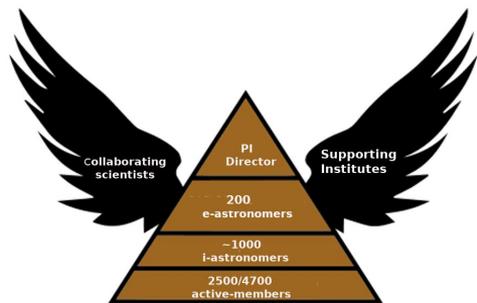
Registration for the Outreach event
RAD@home Astronomy workshop at
IAU Symposium 375, Nepal

#RADatIAUsymposium375Nepal



IAU Symposia: The multimessenger chakra of blazar jets





1st Indian Citizen Science Research Platform in Astronomy (April 2013)

Nationwide Inter-University Collaboratory of scientists & trained Citizen-scientists for research on black hole galaxy co-evolution using GMRT radio telescope, largest such, pride of India.

#RADatHomeIndia GMRT



Lets Collaborate ...

