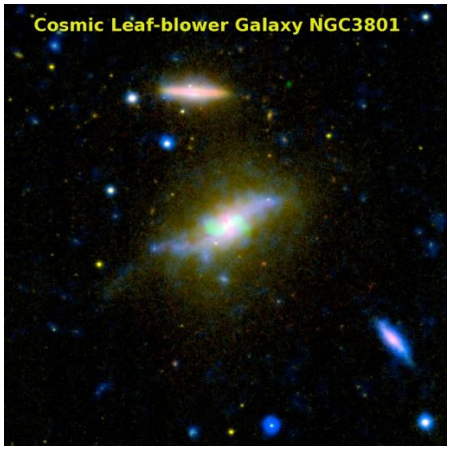
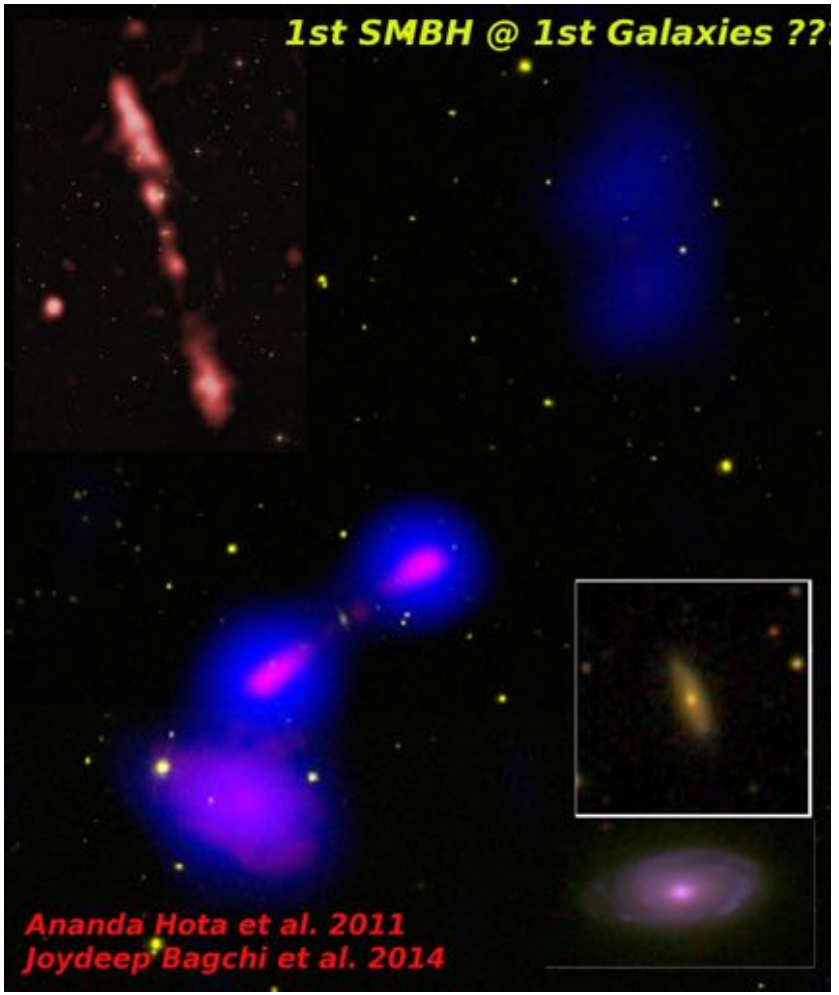
Tracking galaxy evolution through merger and feedback using GMRT and citizen-science collaboratory RAD@home.

Ananda HOTA
UM-DAE CEBS, Mumbai, India
RAD@home, India





#RADatHomeIndia
#ABCDresearch
#SKAscicon16

Ref: Hota et al. 2016
https://arxiv.org/abs/1610.09798

My collaborators ,

C. Konar (Amity Univ., RAD@home),
Joydeep Bagchi (IUCAA, India),
C.S. Stalin (IIA, India),
Youichi Ohyama (ASIAA, Taiwan),
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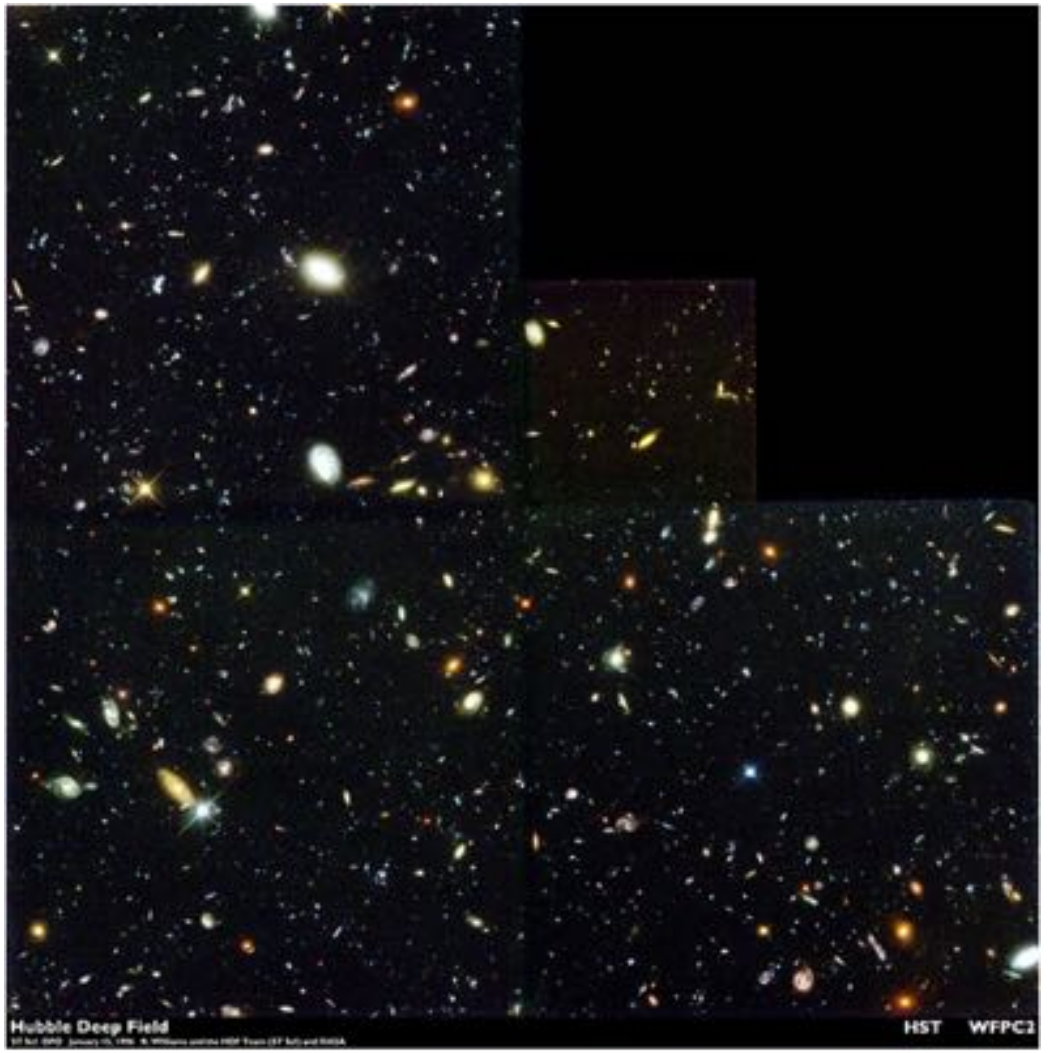
Univ of Cambridge, UK),
S.K. Sirothia (NCRA-TIFR, India, SKA, S. Africa),
Martin Hardcastle (Univ. of Hertfordshire, UK),
J.F. Gallimore (Bucknell Univ, USA),
Soo-Chang Rey (Chungnam Nat.Univ. Korea),
Preeti Kharb (NCRA-TIFR, India),
Veeresh Singh (PRL, India),
Sravani Vaddi (NCRA-TIFR & RAD@home, India)
Pratik Dabhade (RAD@home),
Pradeepta Mohanty (RAD@home, India),
Sagar Sethi (RAD@home),
Megha Rajoria (RAD@home),
Lavanya Nemani (RAD@home).
Shilpa Dubal (RAD@home)

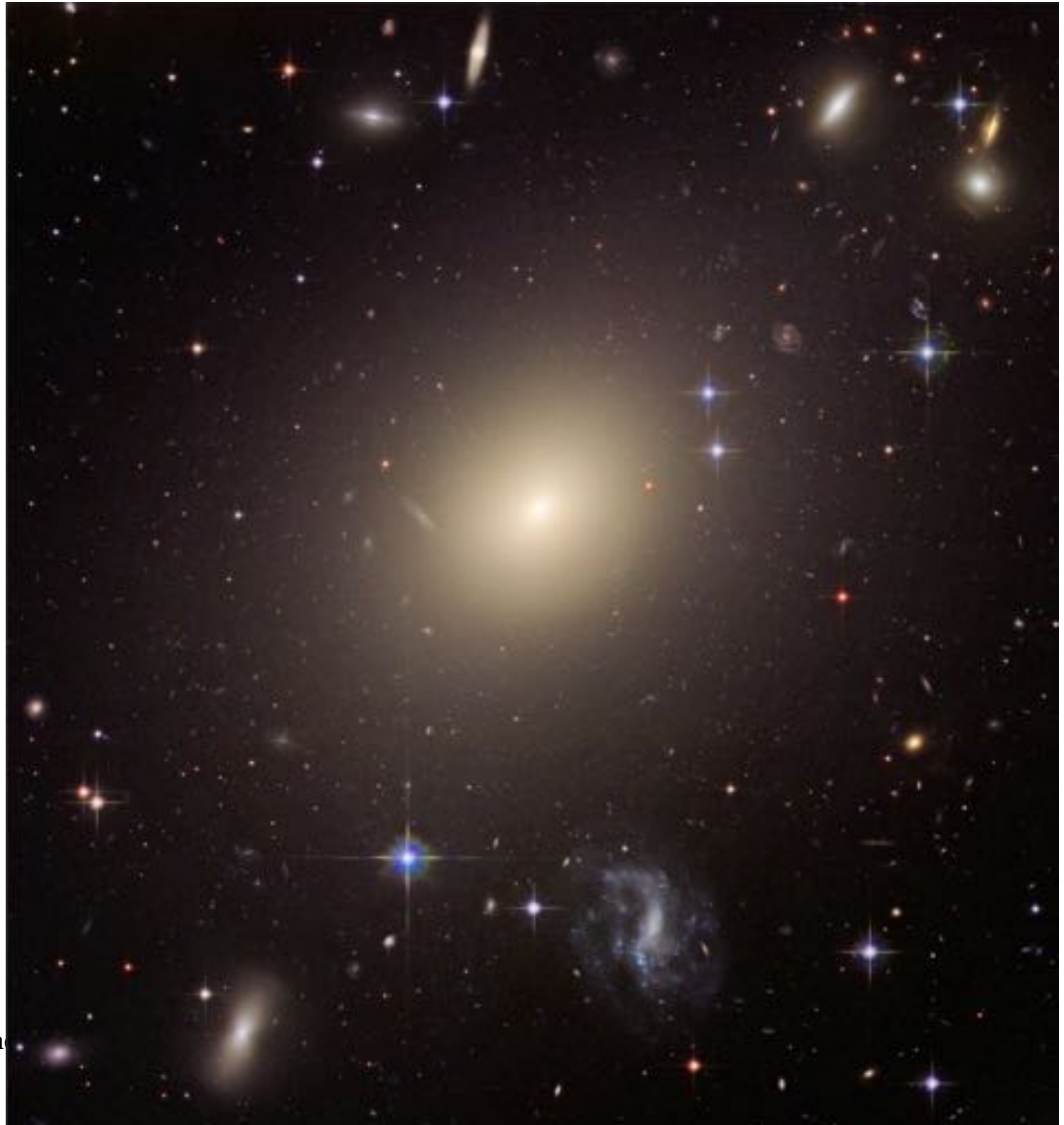


Varieties of galaxies => different evolutionary stages.

RAD@home w/ SKA & GMRT

M101: Spiral galaxy HST picture

Shu, Lin, Chi have theory of why Spiral form



RAD@hom

Ref: wikipedia

Ref: wikipedia

Barred-spirals: gas from the spiral arm goes to the centre via the bar

Ref: wikipedia

NGC4676 interacting galaxies; pulled towards each other by gravity

Same gravity of Newton, due which apple falls down

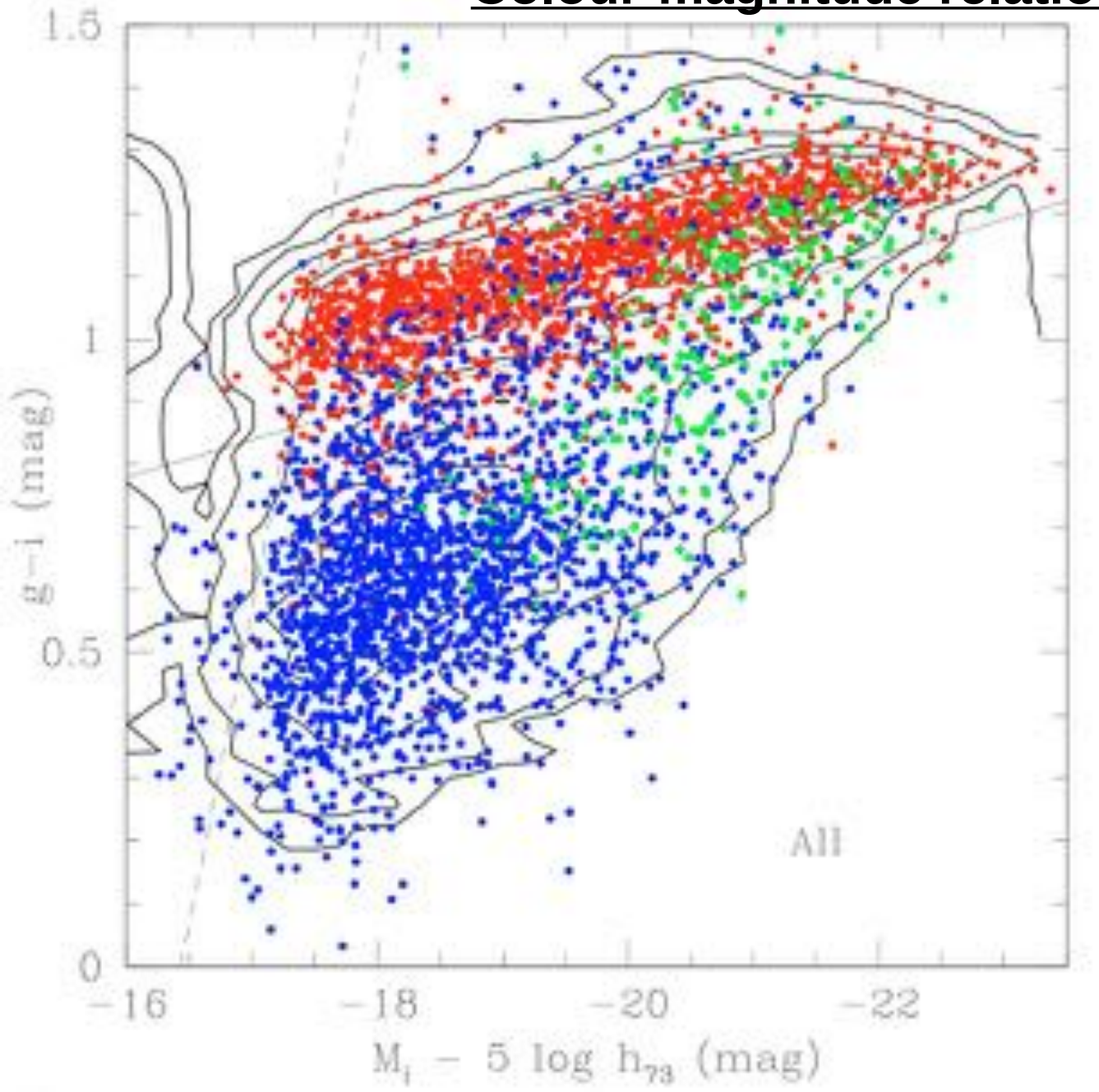
Colliding
Galaxies
Lot of gas
Lot of new stars

Lot of supernova
Explosions

spiral+spiral
=
elliptical

Ref: wikipedia

Colour-magnitude relation



Star forming
Blue colour
Late-type galaxies

Old-stellar
Red-colour
Early-type galaxies

Red-sequence

Blue-cloud

4000 galaxies in the great wall, colour-density-morphology relation (Gavazzi et al. 2010), Dressler et al. 1997

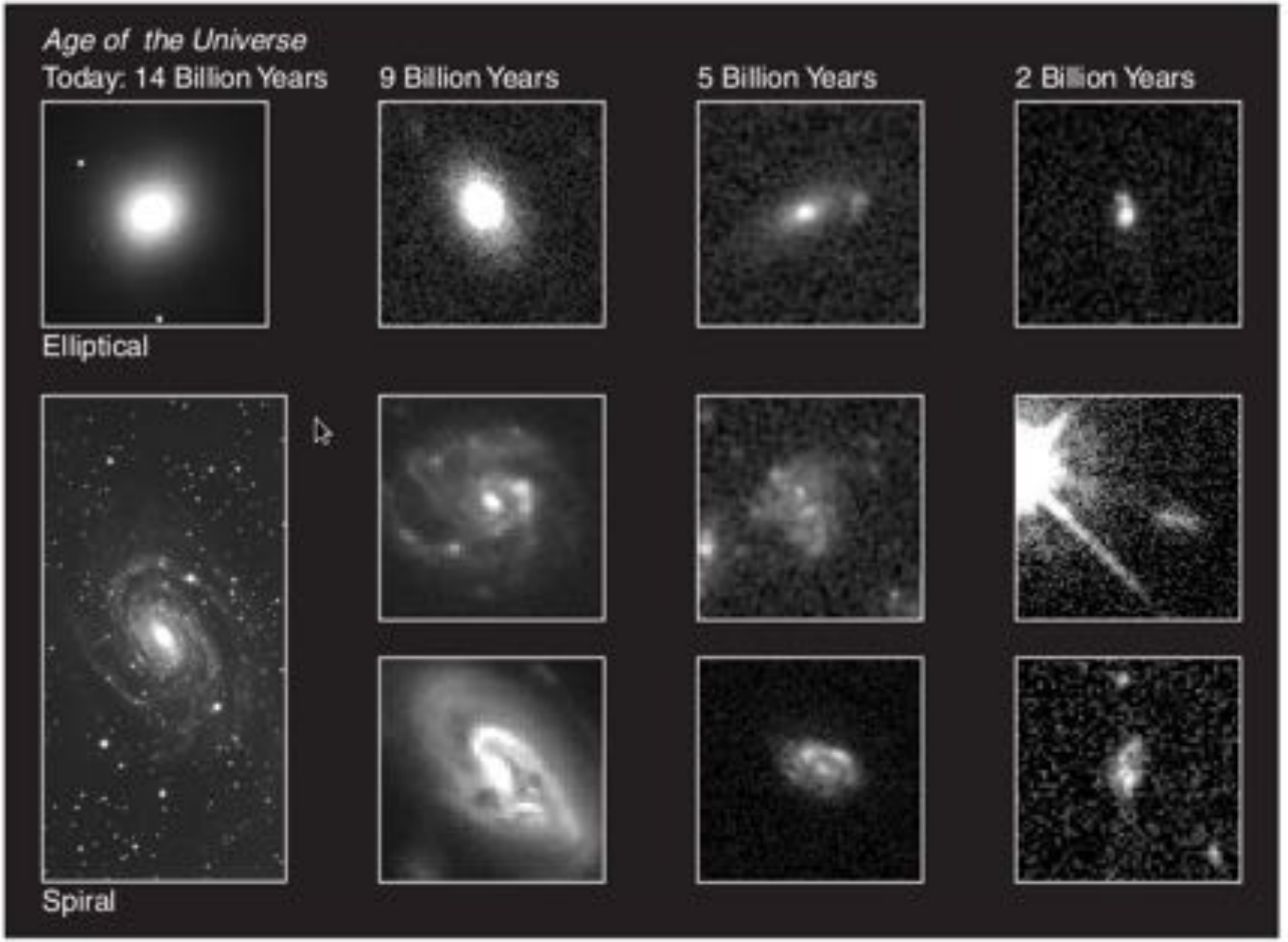
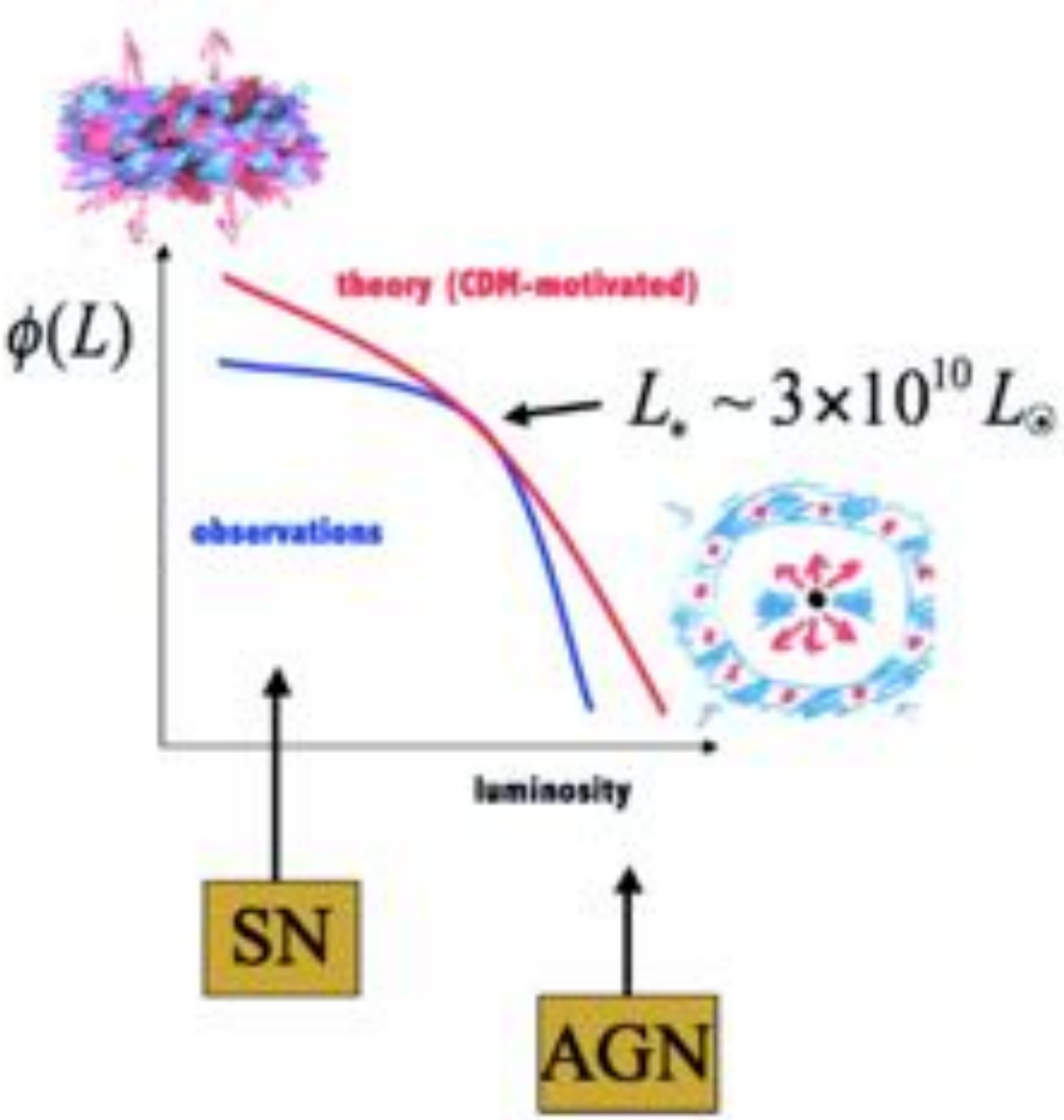


Figure 5. Comparison between galaxies observed at various cosmic epochs (expressed as time after the Big Bang). The traditional morphological types can be recognized already at ~ 5 billion years. At earlier epochs the morphology seems to differ from that of later epochs, although galaxies do exhibit various degrees of compactness and irregularity in their morphologies, ranging from galaxies with light profiles similar to that of ellipticals and bulges to those with disk-like morphology, in resemblance to the Hubble types. (Photo credit: STScI OPO, M Dickinson, M Giavalisco and NASA.)

Need of Feedback (Superwind and AGN-jet/wind)



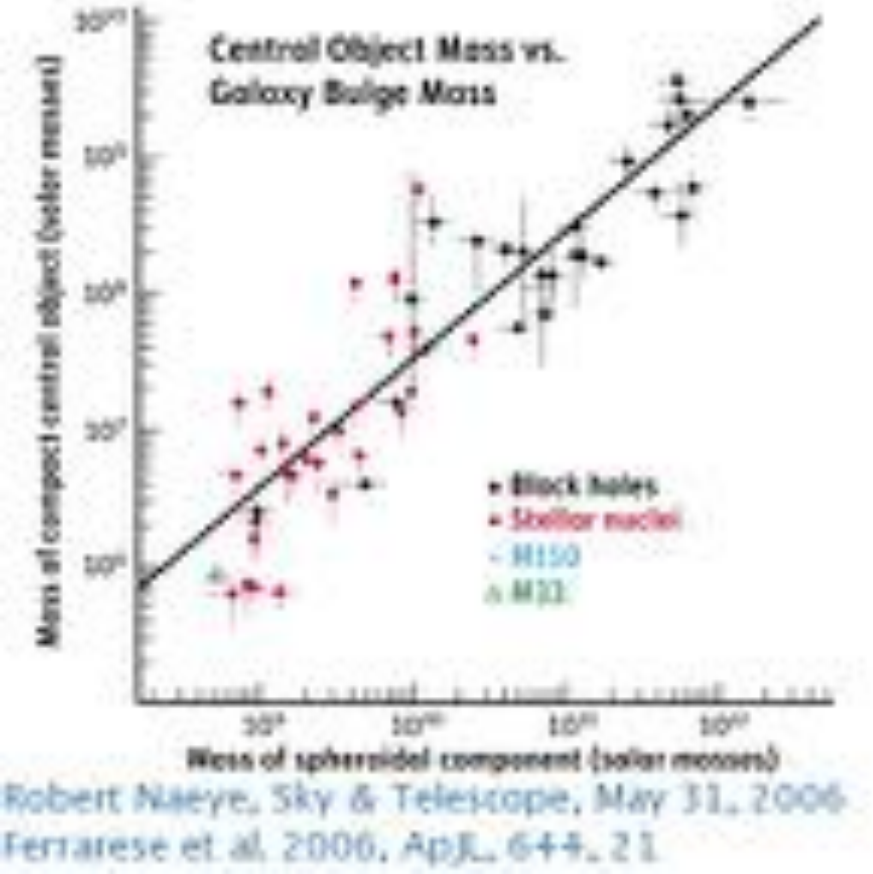
Missing low-mass Galaxies

Not many high-mass Star forming galaxies

Why dont they Accrete and continue Forming more stars??

Silk 2011

Black hole - galaxy co-relations



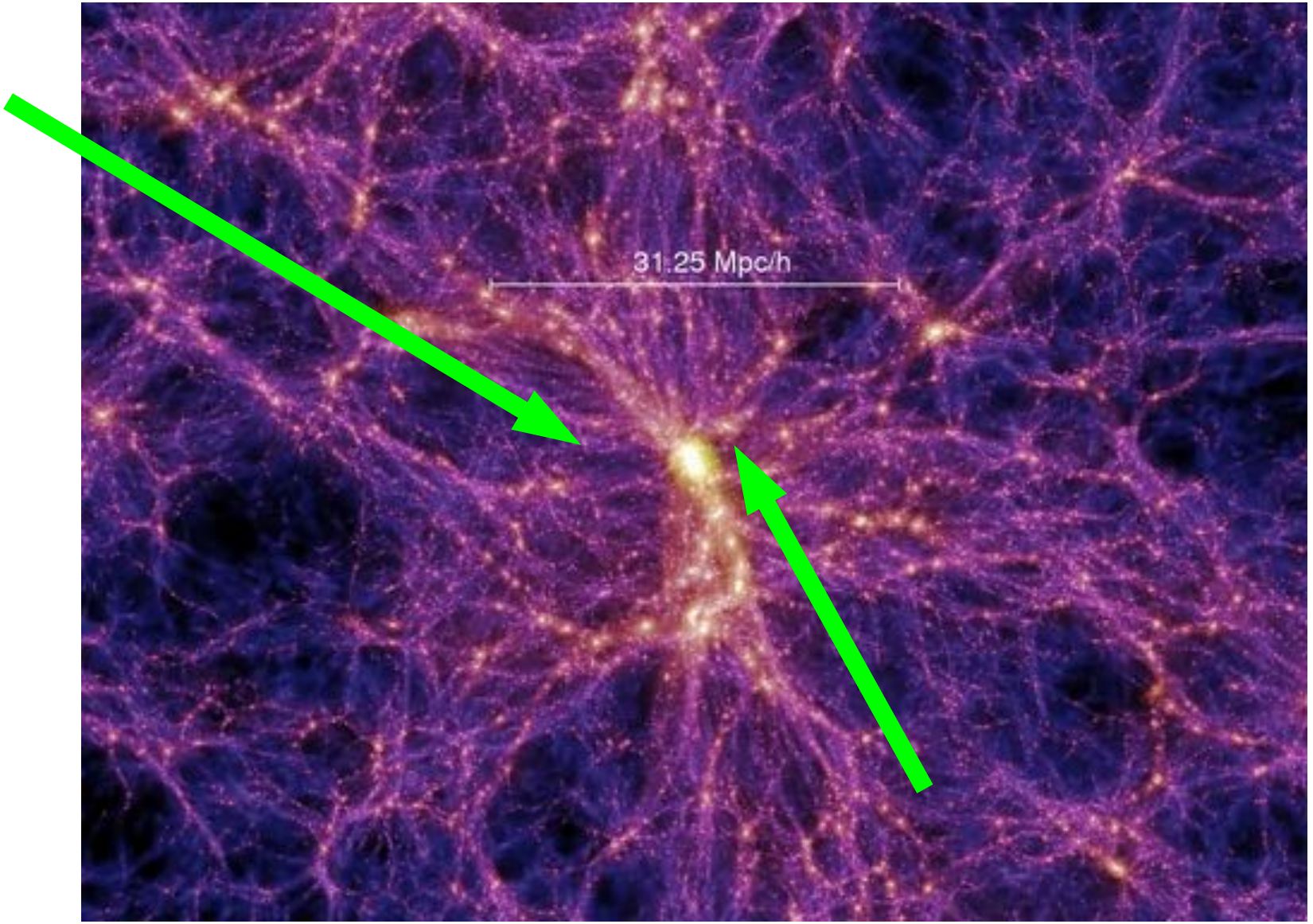
Galaxy-black hole co-evolution

Merger-infall-feedback

explain theory-simulation

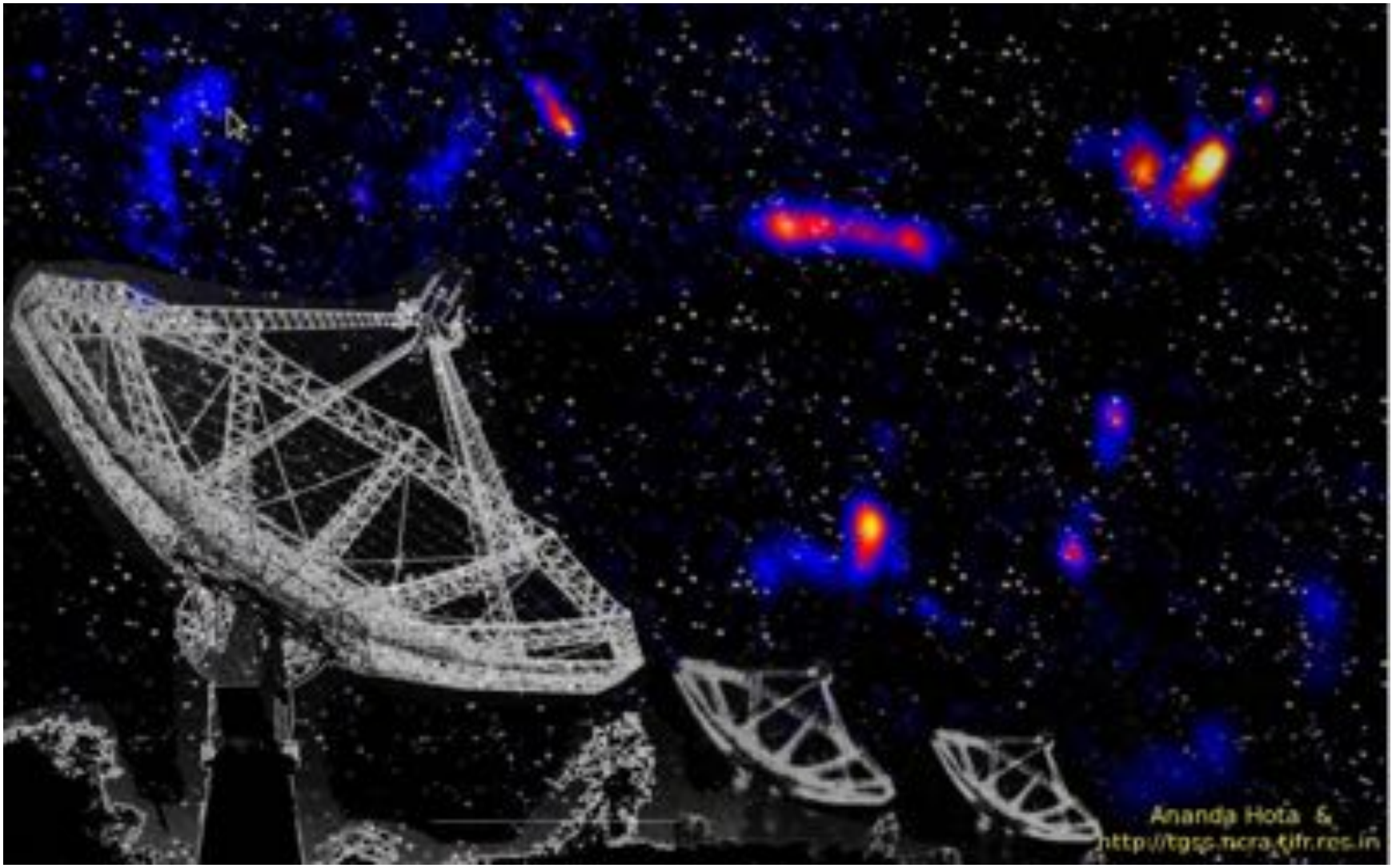
how it actually works...

no observational understanding yet !!

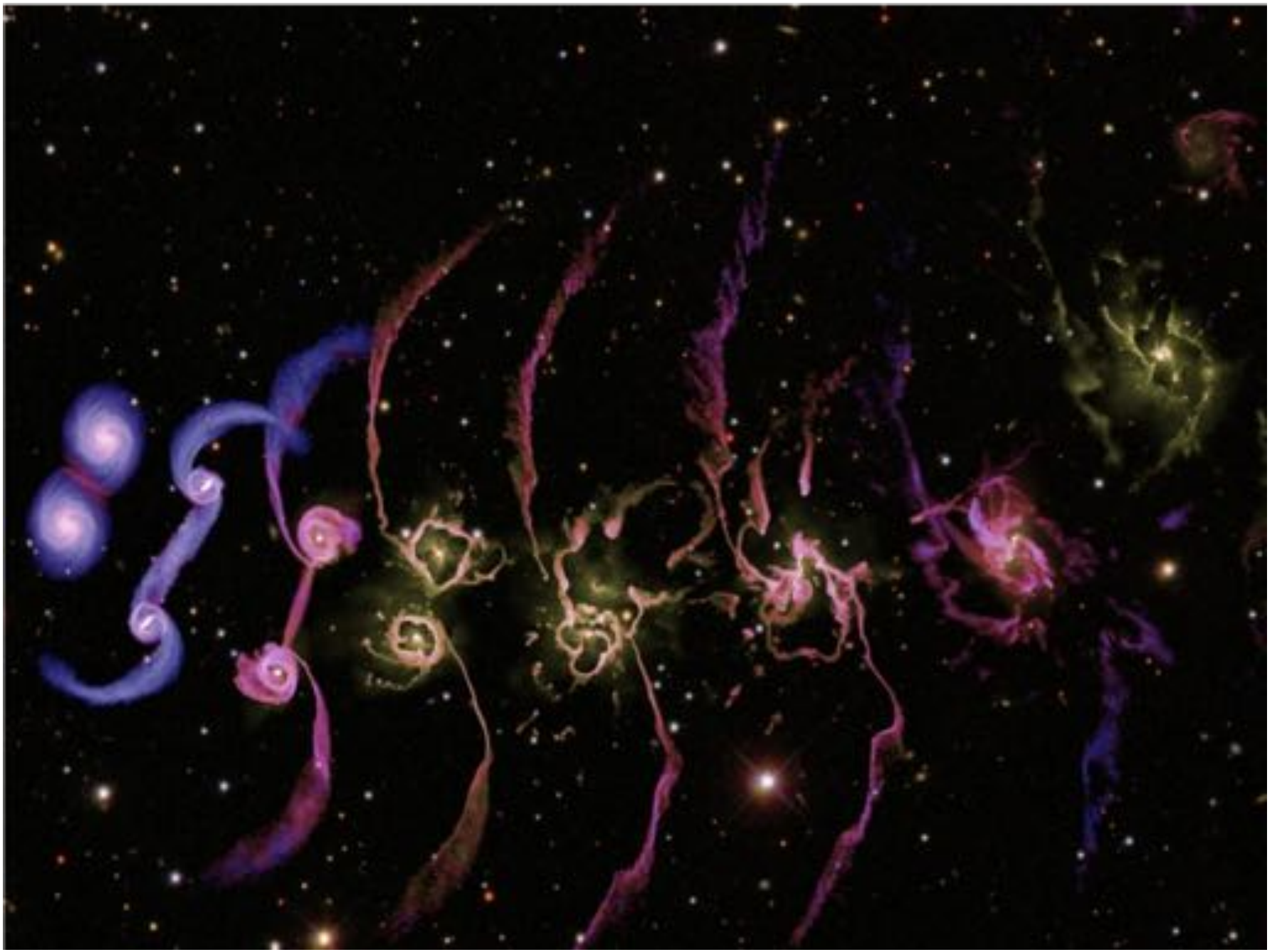


The yet to be imaged 'Cosmic Web' Millennium Simulation (Springel et al. 2005)

Aim is to understand the physical processes behind galaxy evolution
(In migration from filaments to cluster core).

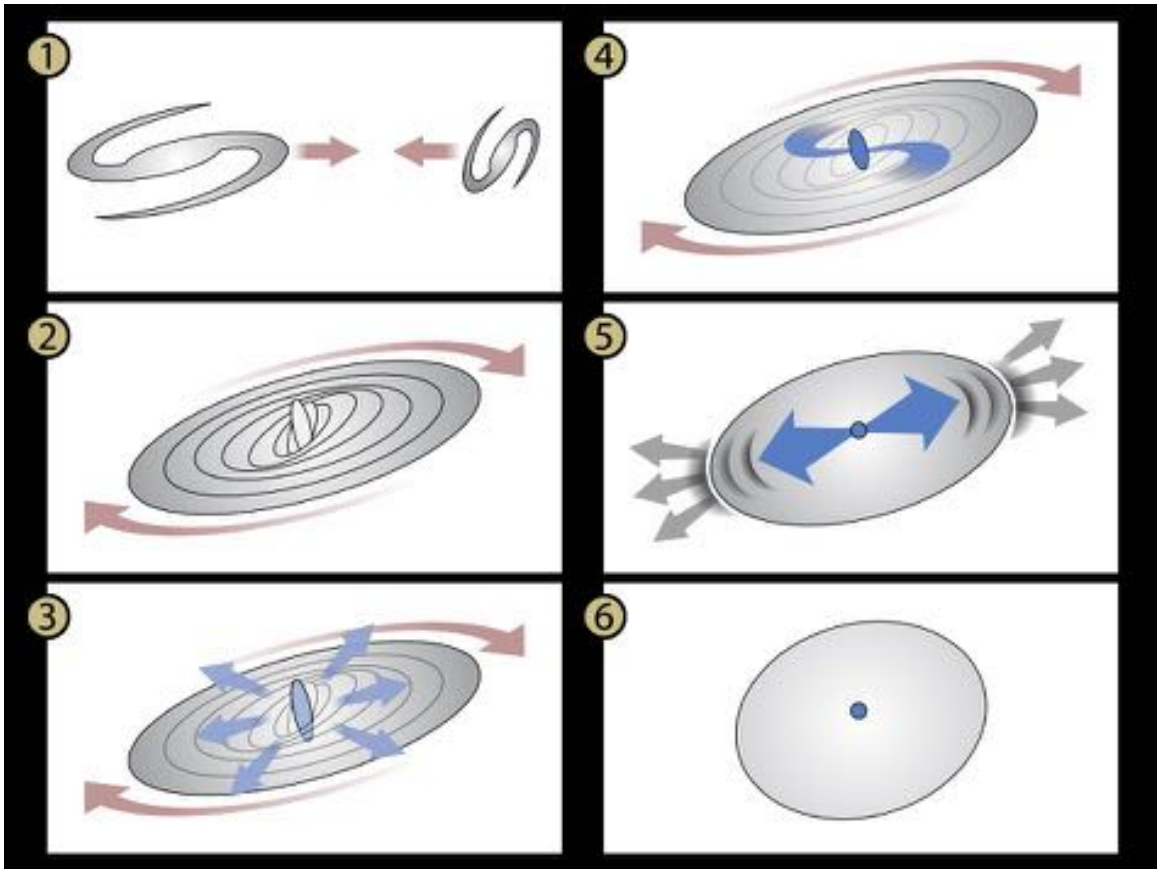


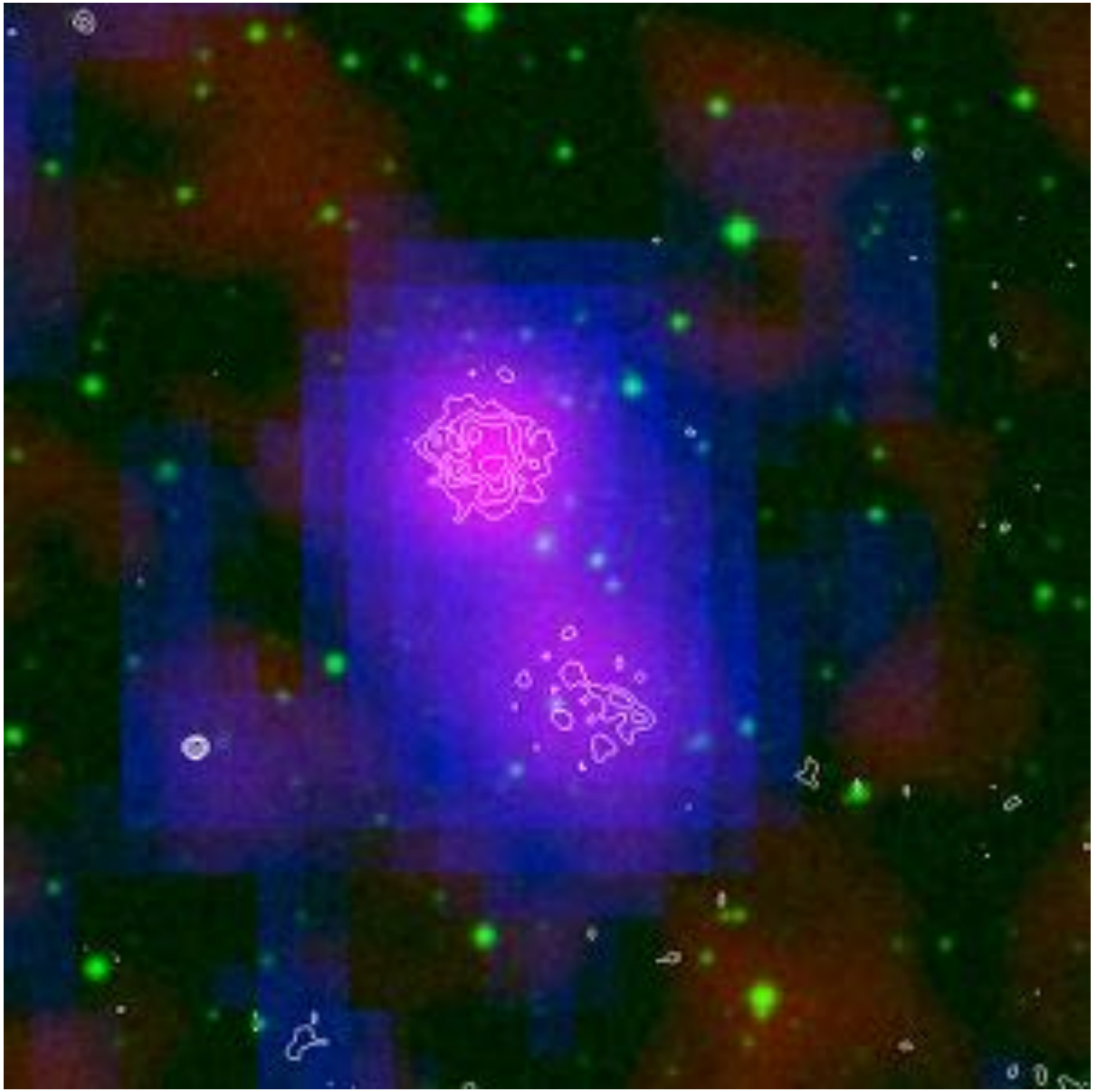
RAD@home w/ SKA & GMRT



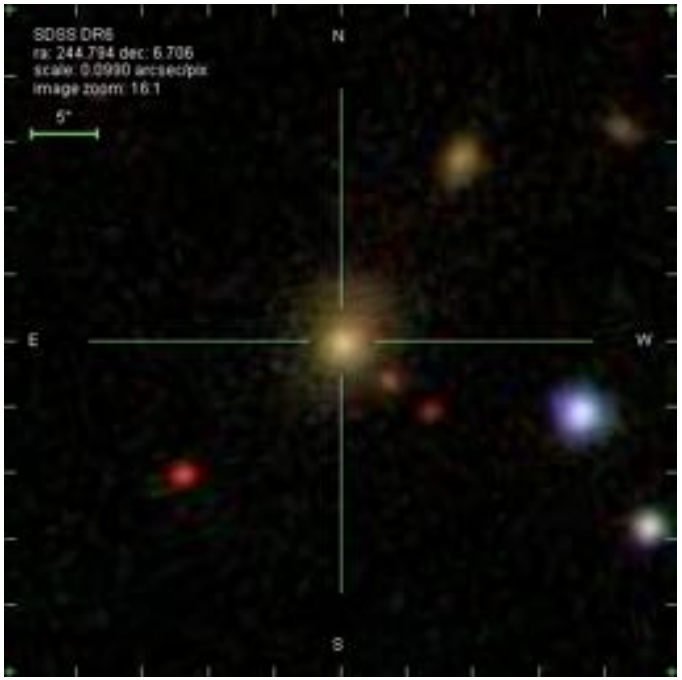
Feedback during major galaxy merger (Springel et al. 2005)

Galaxy Merger and jet/wind Feedbacks

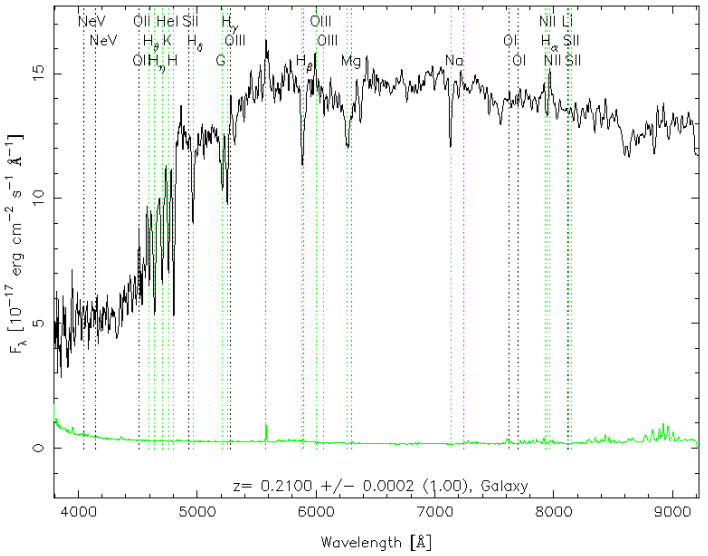


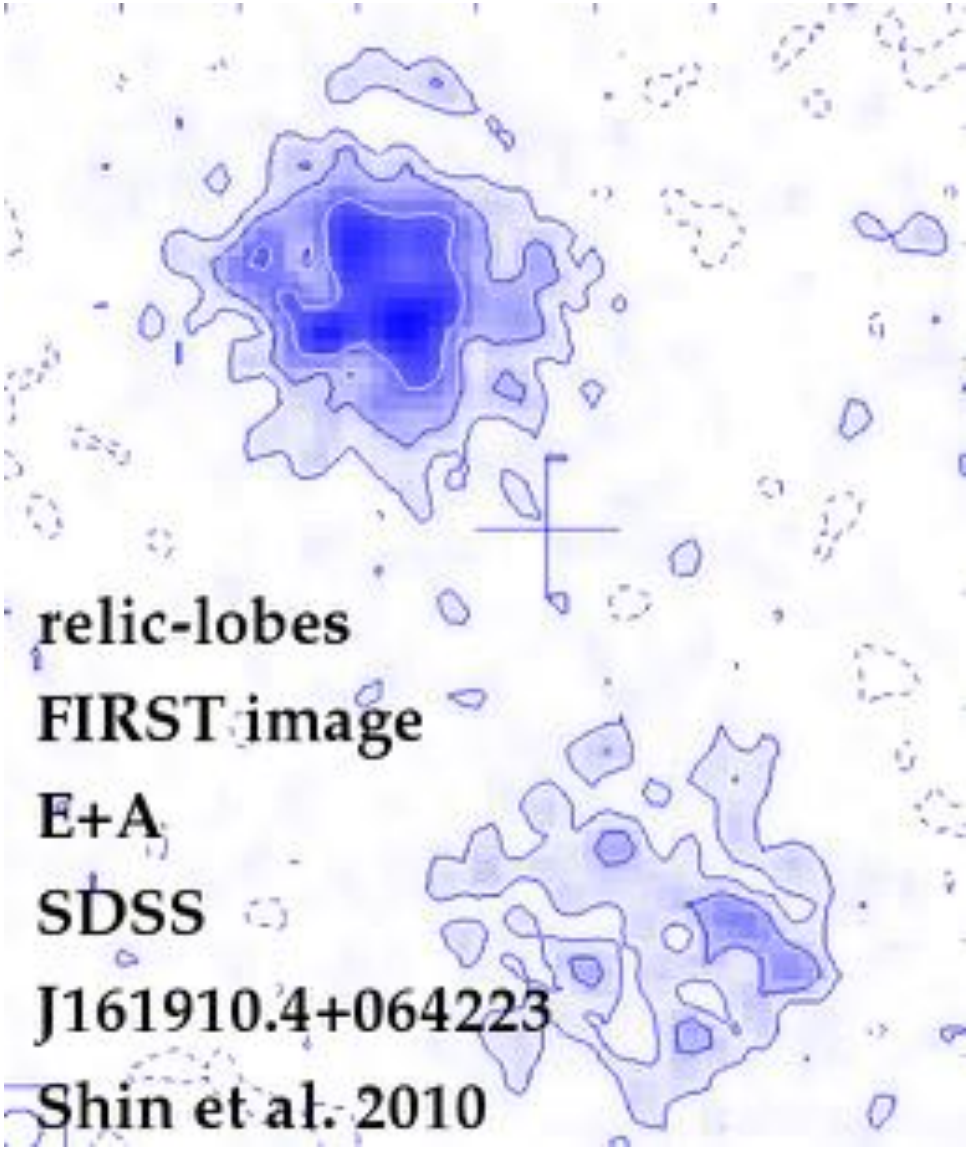


RAD@home w/ SKA & GMRT



RA=244.79369, DEC= 6.70647, MJD=53501, Plate=1732, Fiber=130





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

Nurturing talent...promoting excellence
मौलिक विज्ञान प्रकर्ष केन्द्र

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

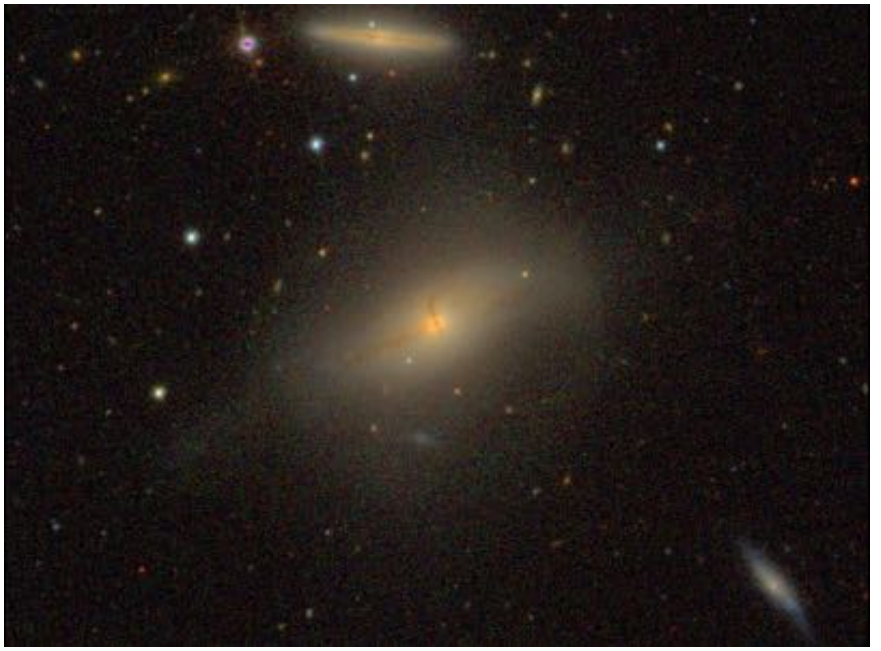
Small town school teachers making discoveries
Will inspire the next generation.

Mis-match in age-dating
Opt relic (Hanny') few 10 k yrs

Radio Relic lobes ___ a few 100 M yrs

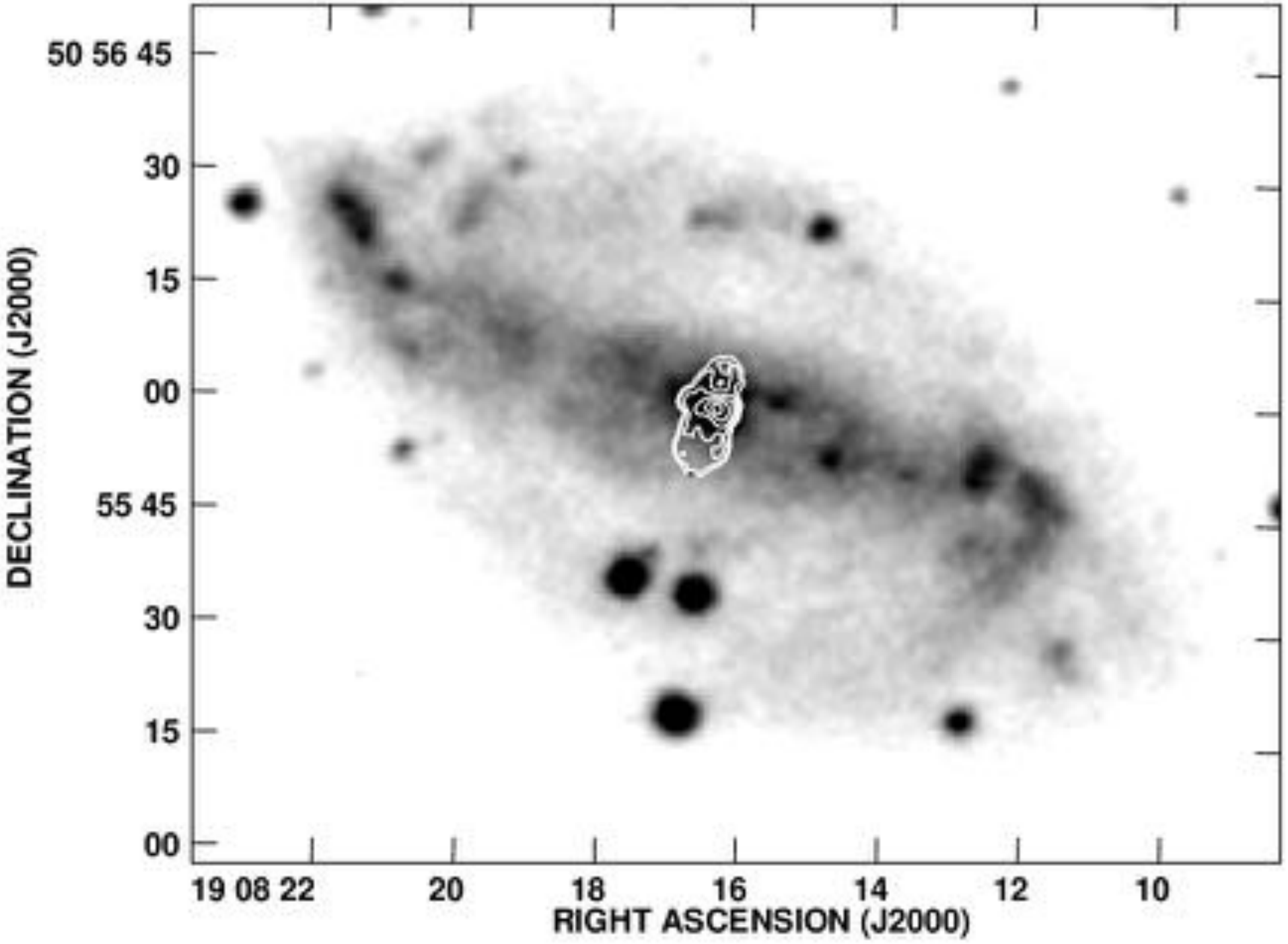
Post-merger post Star burst or
Residual star formation 0.5-1 Gyr

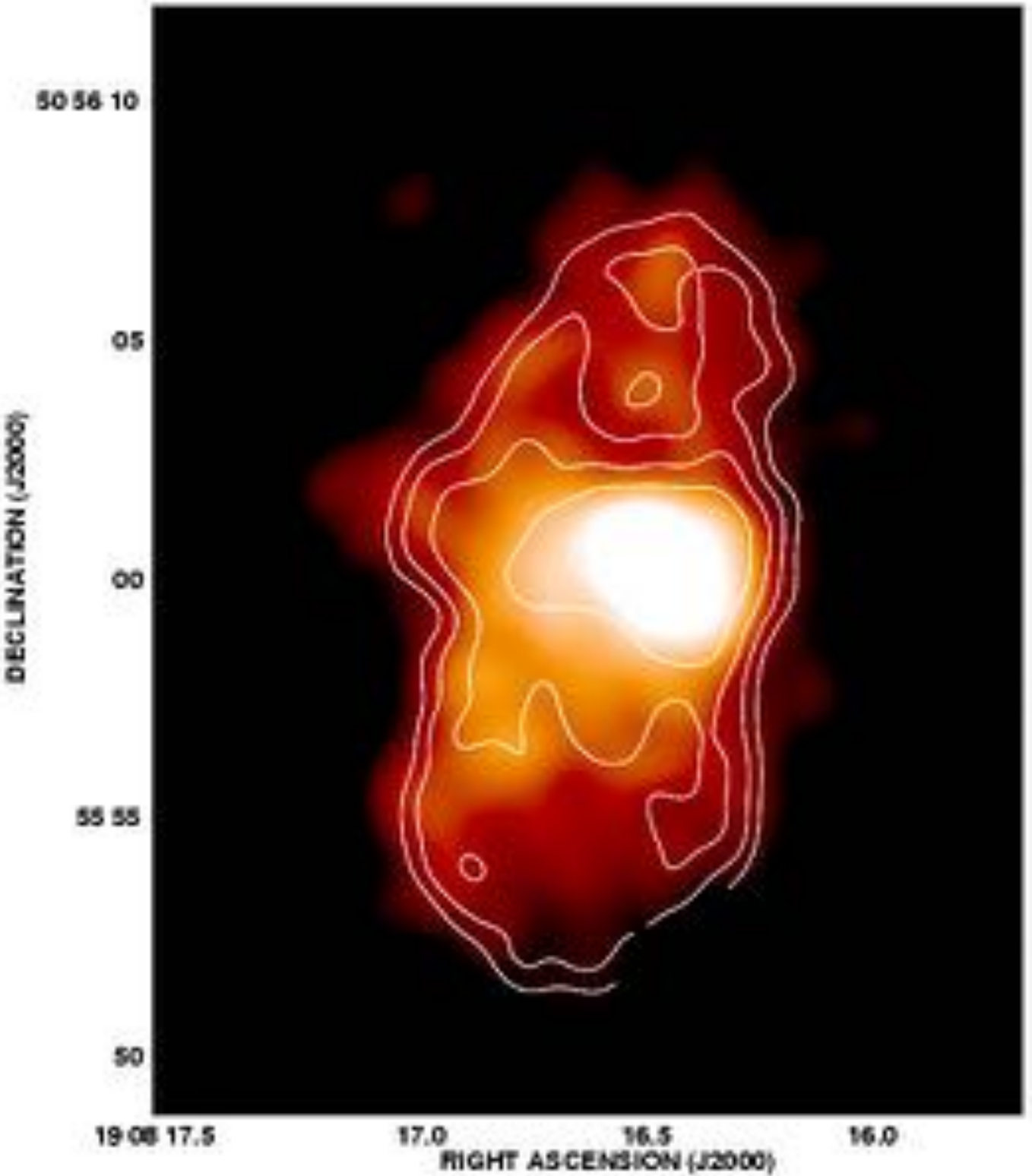
Smoking gun Evidence of AGN-feedback
Wait.....Timescle has to match
Need to push the limit a few Myr to 100s to billion yrs.
Only radio seems to be capable of....



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

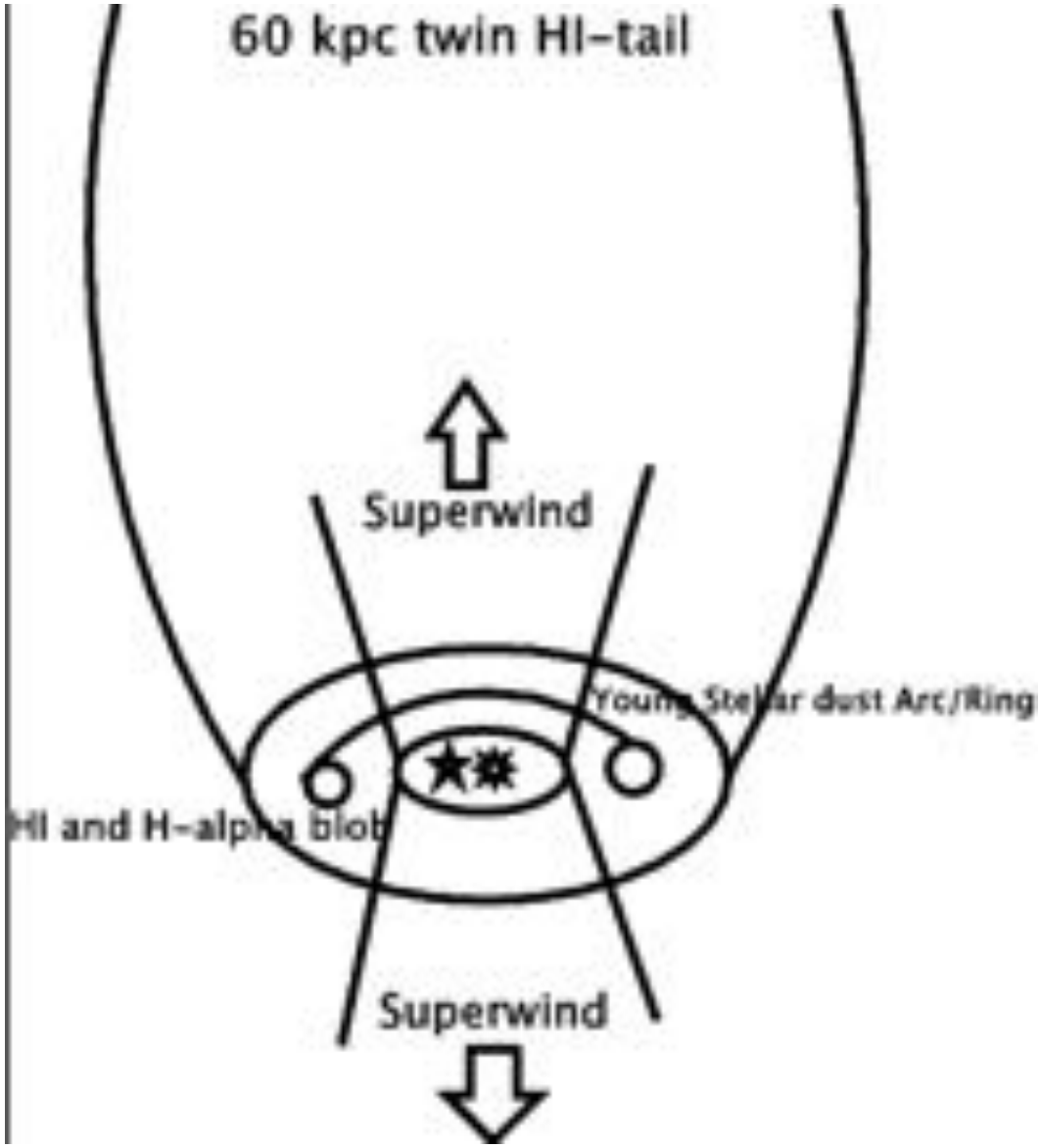
Aim is to discover
Faint and Fuzzy
UV-Opt radio emission
Beside a galaxy
Or
Anywhere
Relics of
AGN Feedback

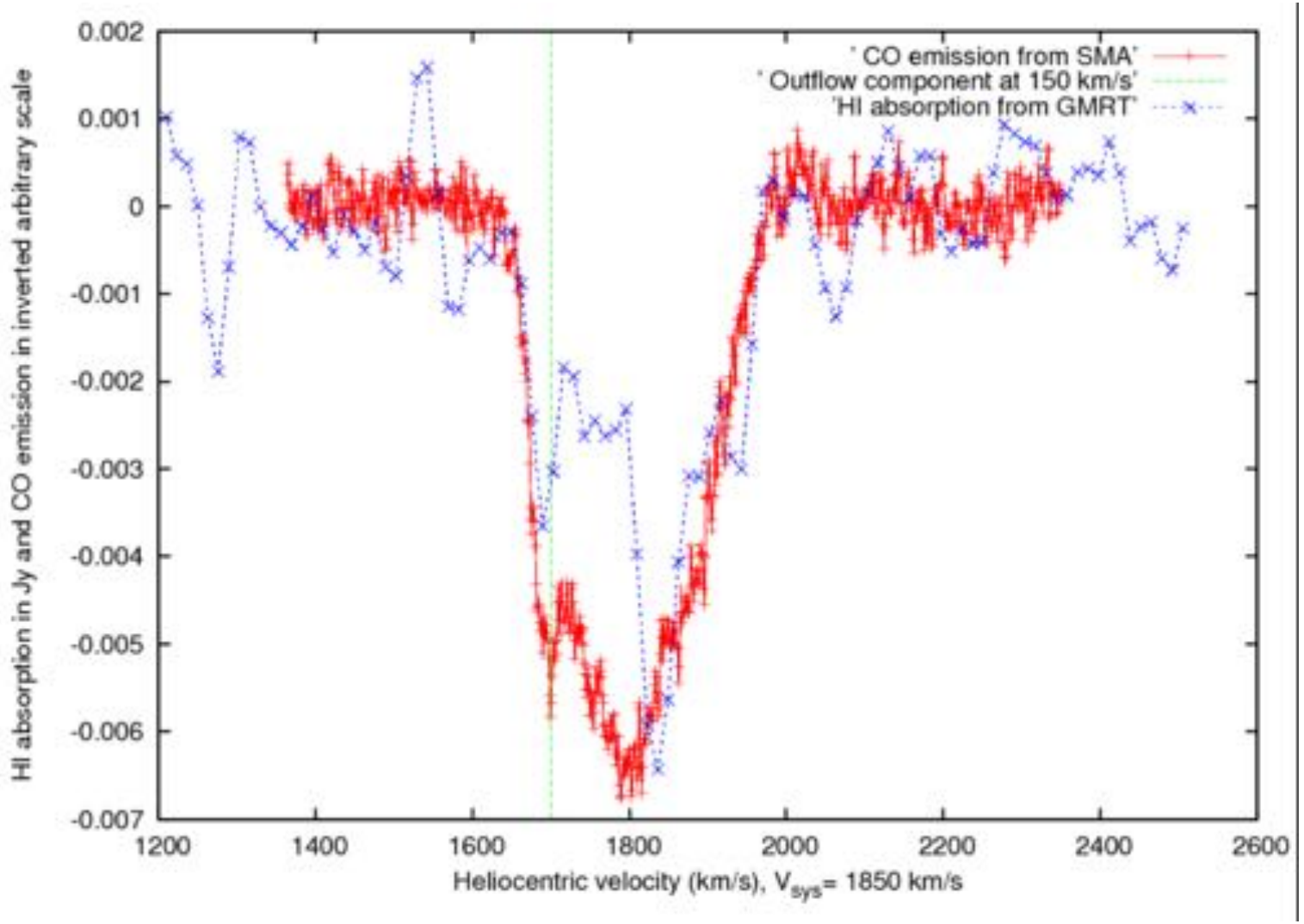

50 56 45
30
15
00
55 45
30
15
00
DECLINATION (J2000)
19 08 22
20
18
16
14
12
10
RIGHT ASCENSION (J2000)


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

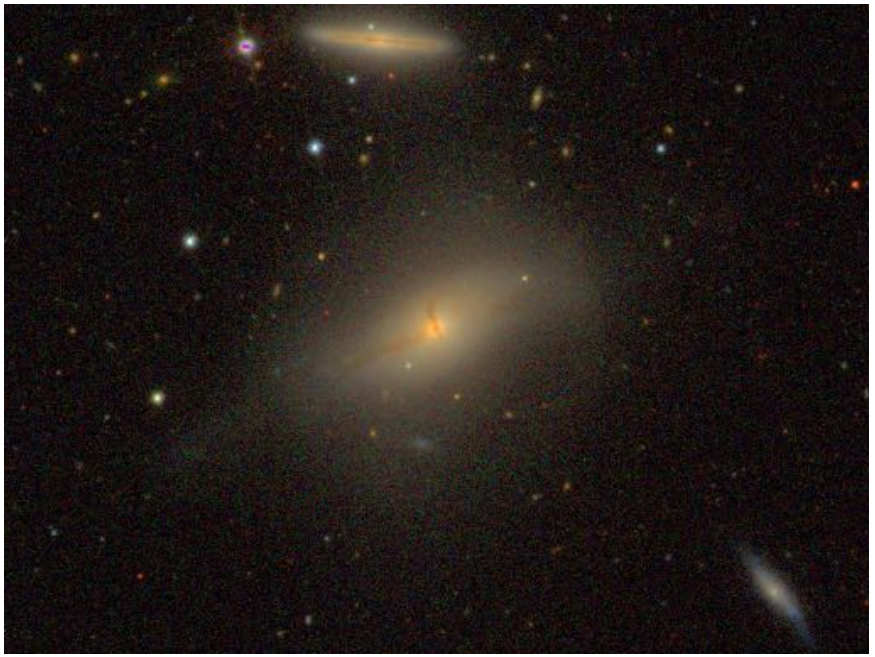
RAD@home w/ Sl

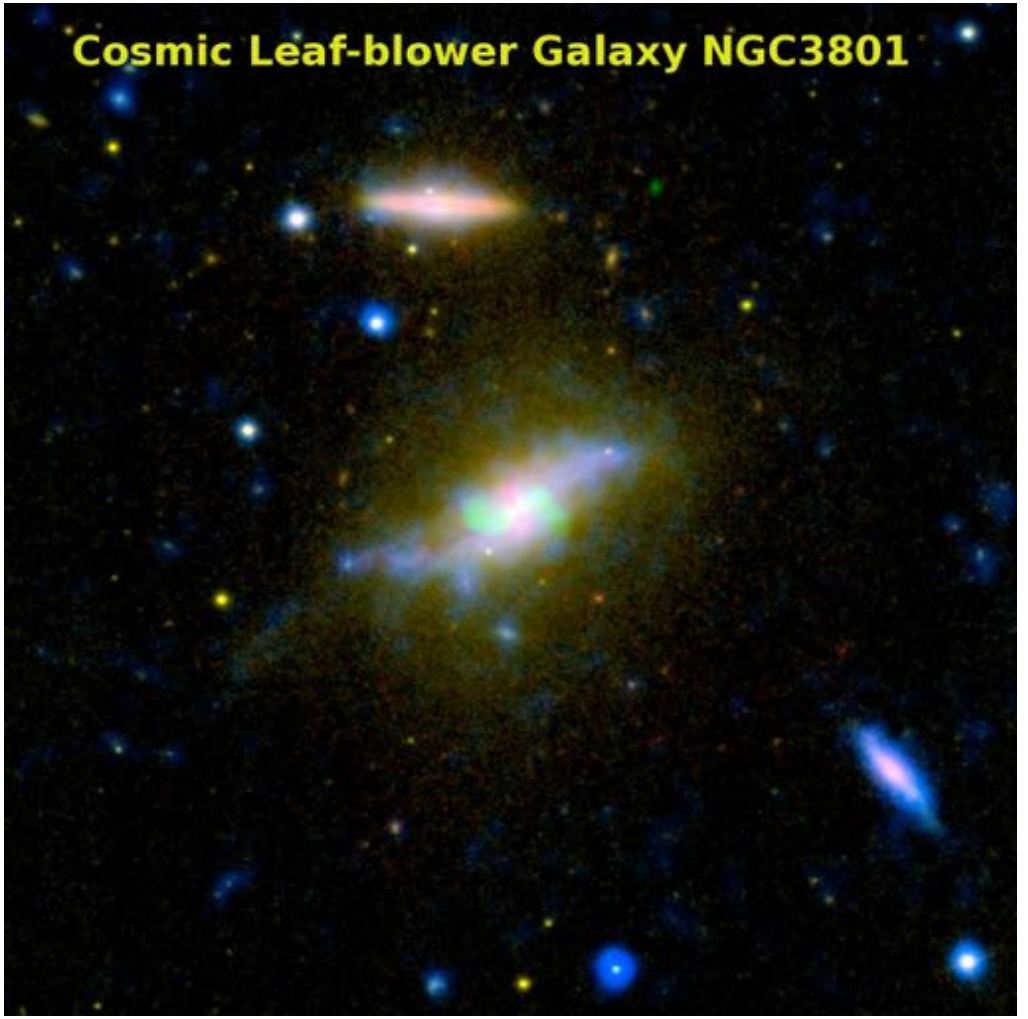

Superwind in an early-type galaxy
NGC1482: H-alpha (r) DSS (g) X-ray (b)
Courtesy D. Strickland


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

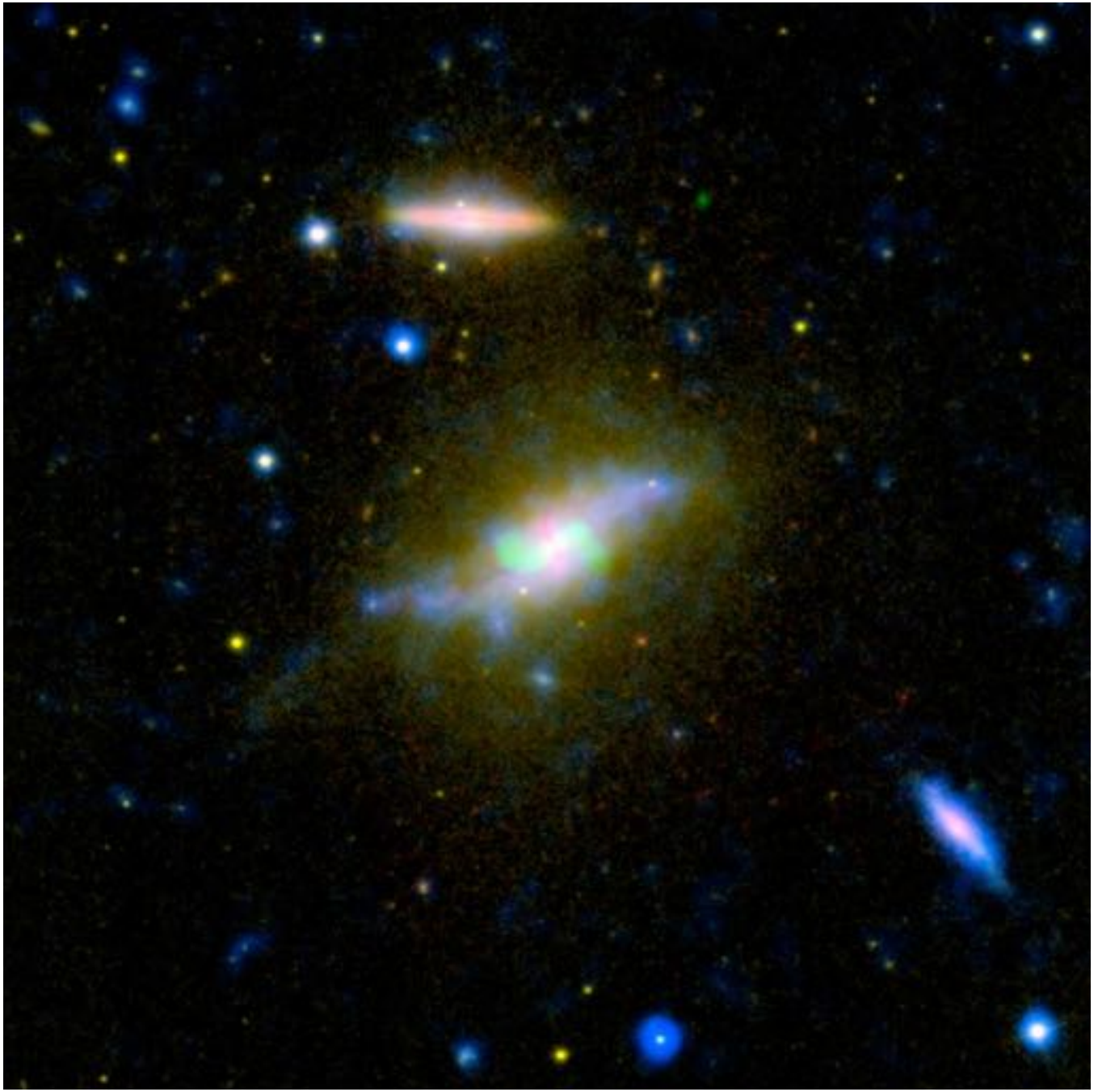


RAD@home w/ SKA & GMRT




Cosmic Leaf-blower Galaxy NGC3801

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

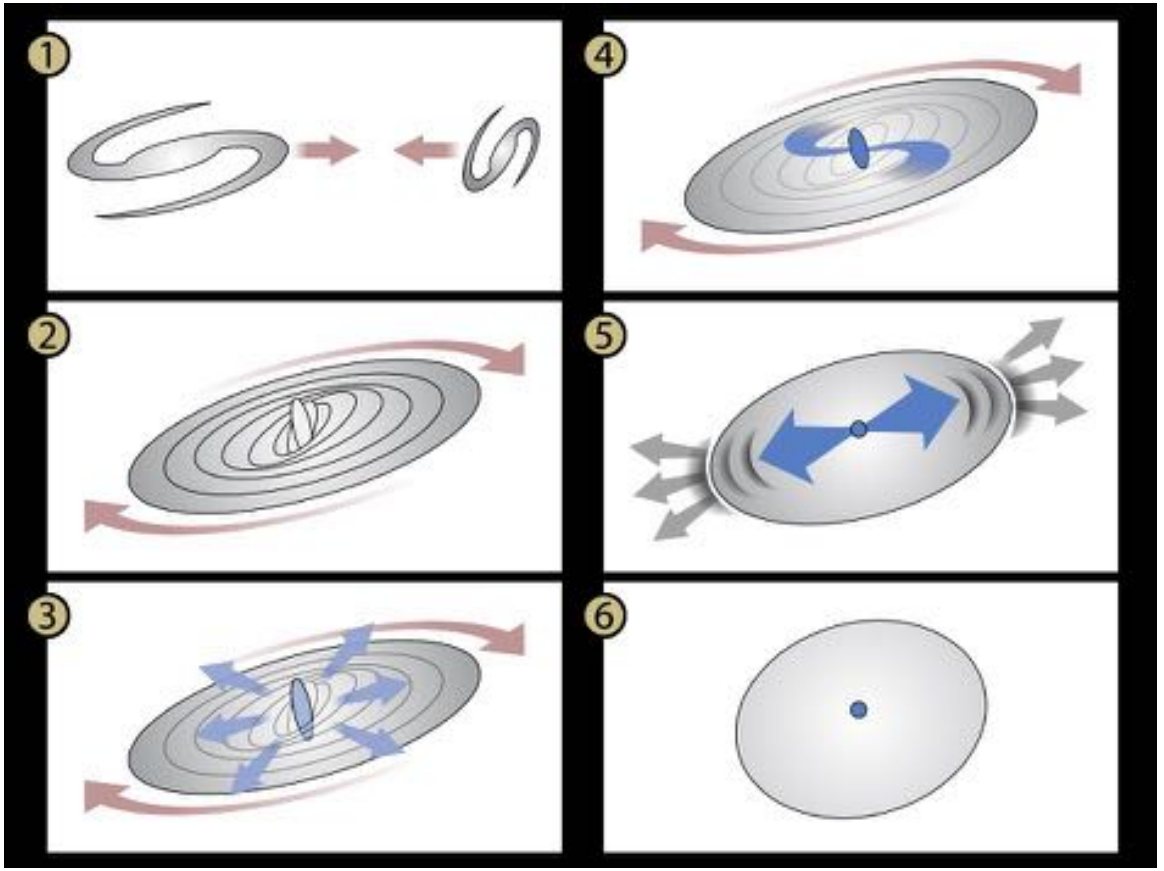
GALEX NUV young stars

VLA 20m radio bent jets

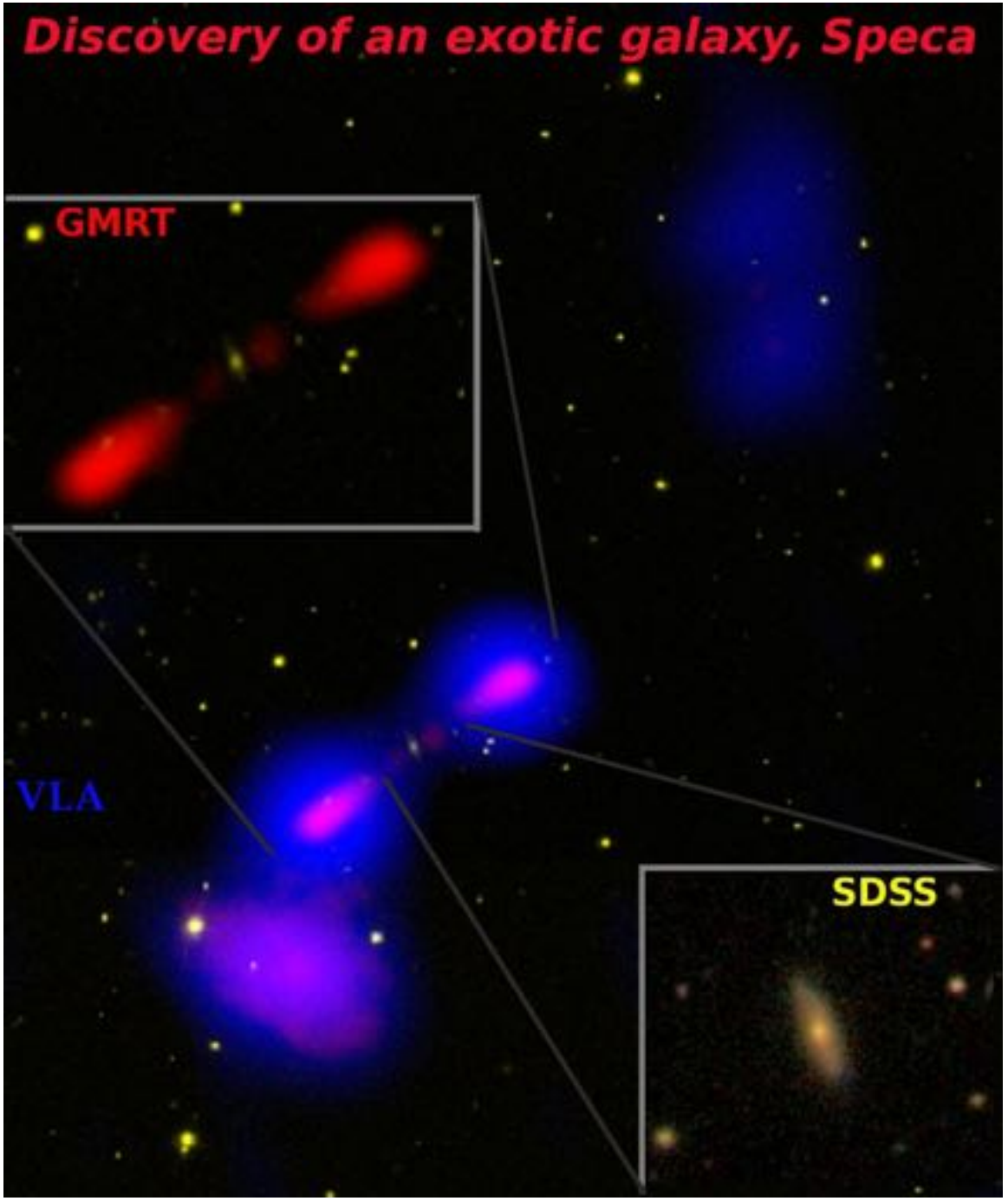
NASA-JPL-CalTech news release,
TIME magazine site
Times of India

Cosmic Leaf Blower

Hota et al. 2012
MNRAS, Letters

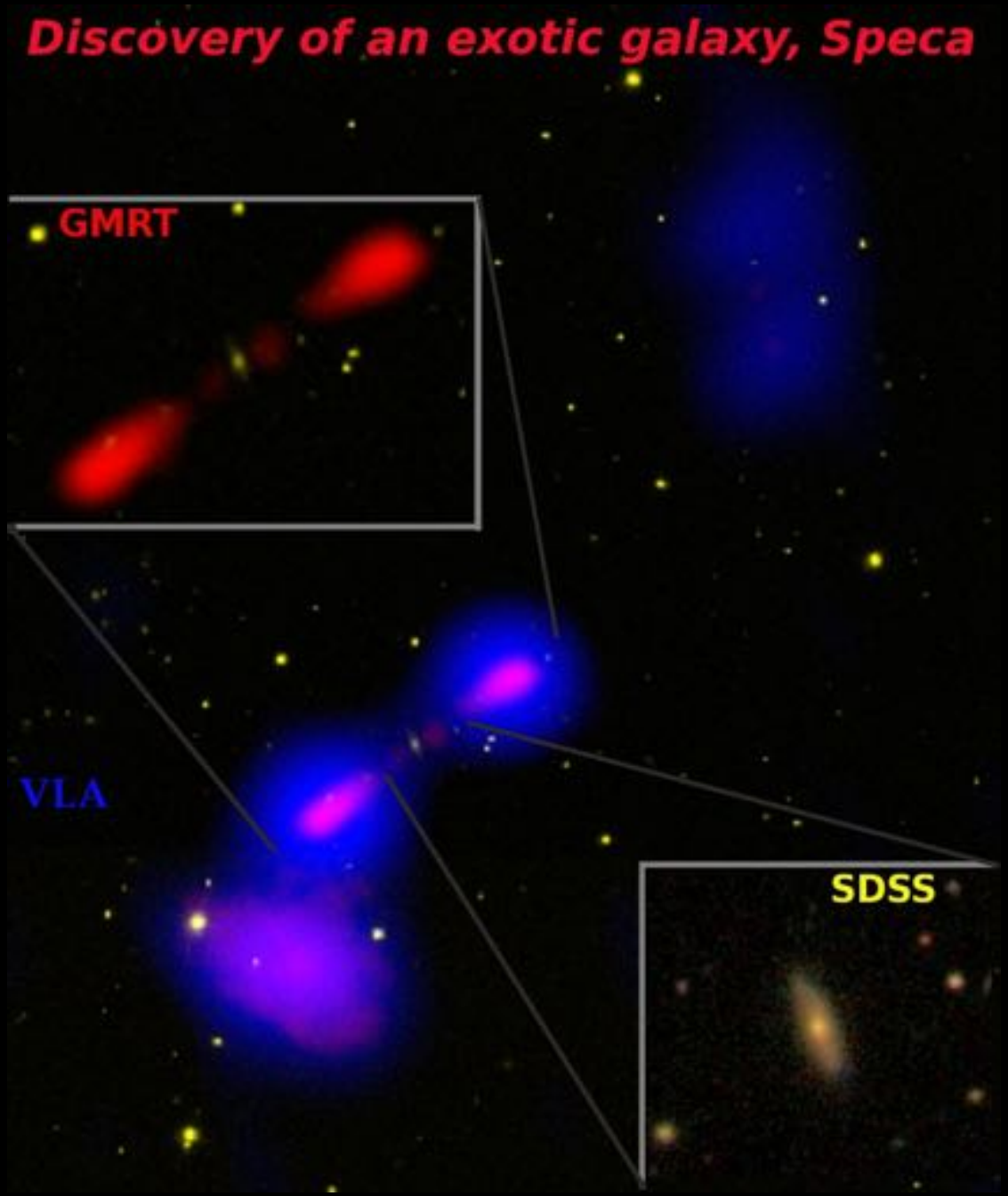

1
2
3
4
5
6

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

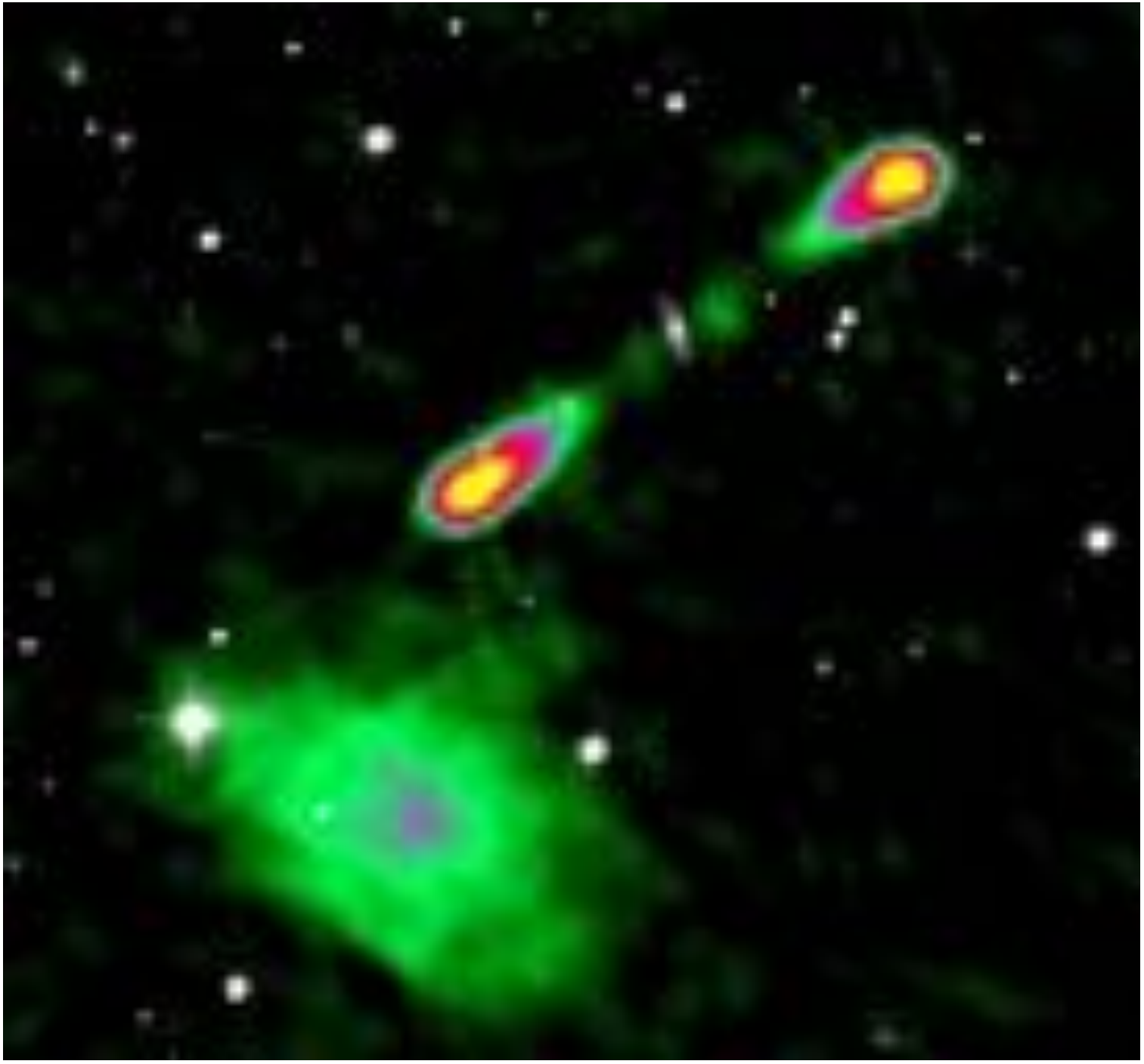


2nd Spiral-host radio galaxy
2nd three episode radio galaxy

Possible first case of

Flat spectrum relic radio lobe
Tracing accretion shock

Hota et al. 2010
NRAO, NCRA, RAS press release



Speca

Z~0.14
BCG

spiral/disk galaxy
3 episodes of AGN jet

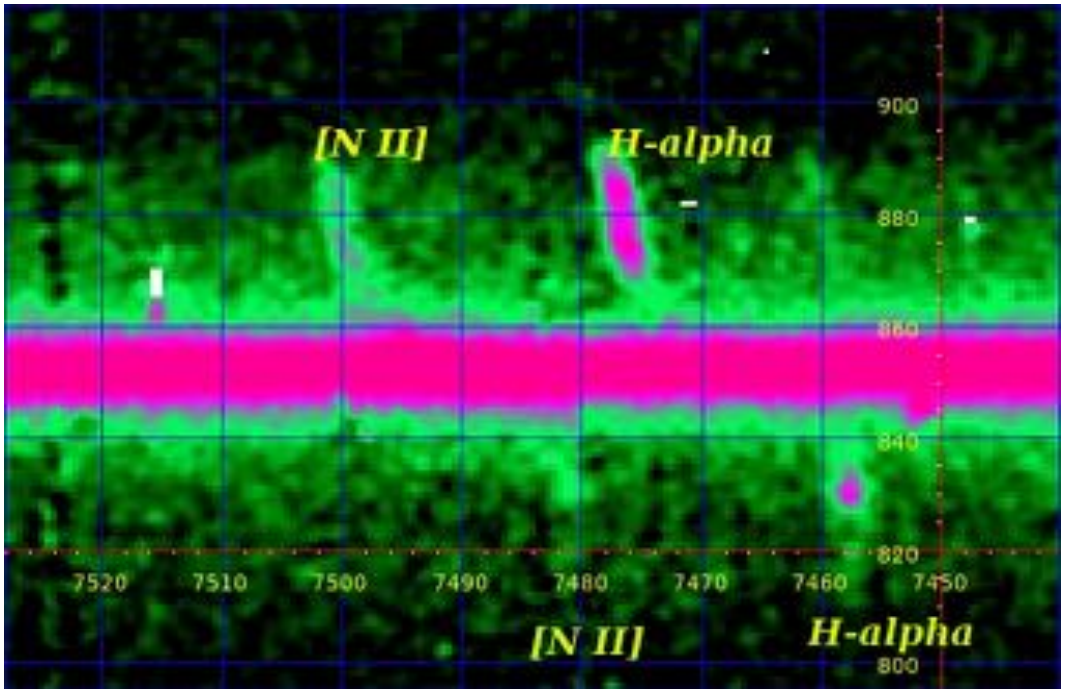
Incomplete quenching ?
Merger/ ICM-accretion ?

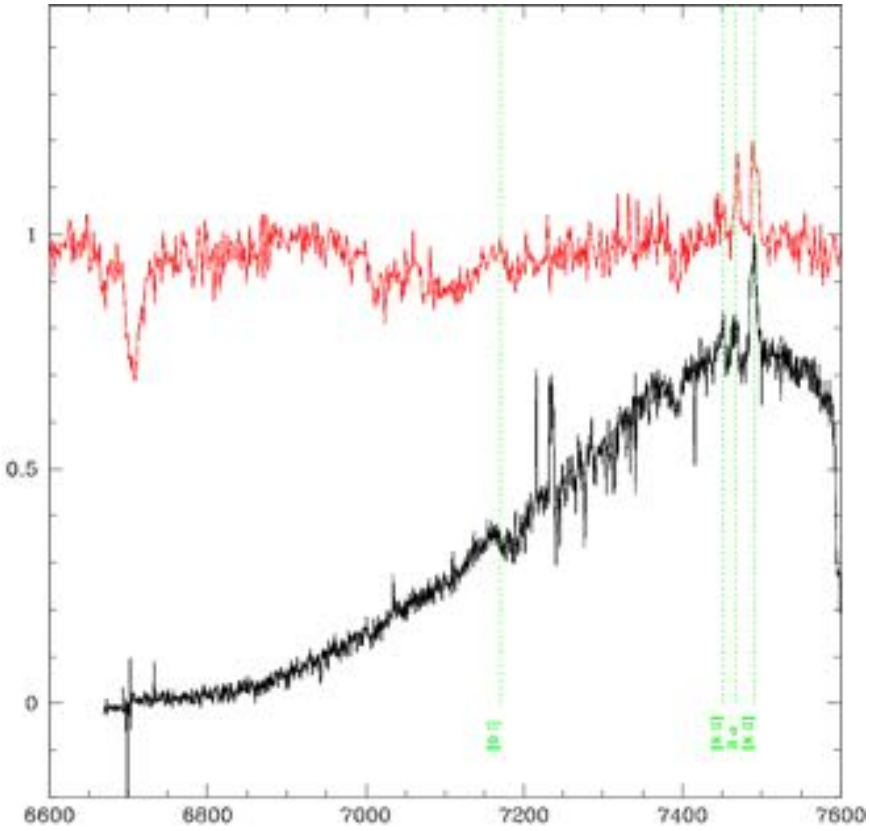
cluster merger ~ NO
Filament accretion ? ..!!

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

***Speca*: Spiral-host Episodic radio galaxy tracing Cluster Accretion**
GMRT 90cm image on Lulin optical (Hota, Sirothia, Ohyama et al. 2011)

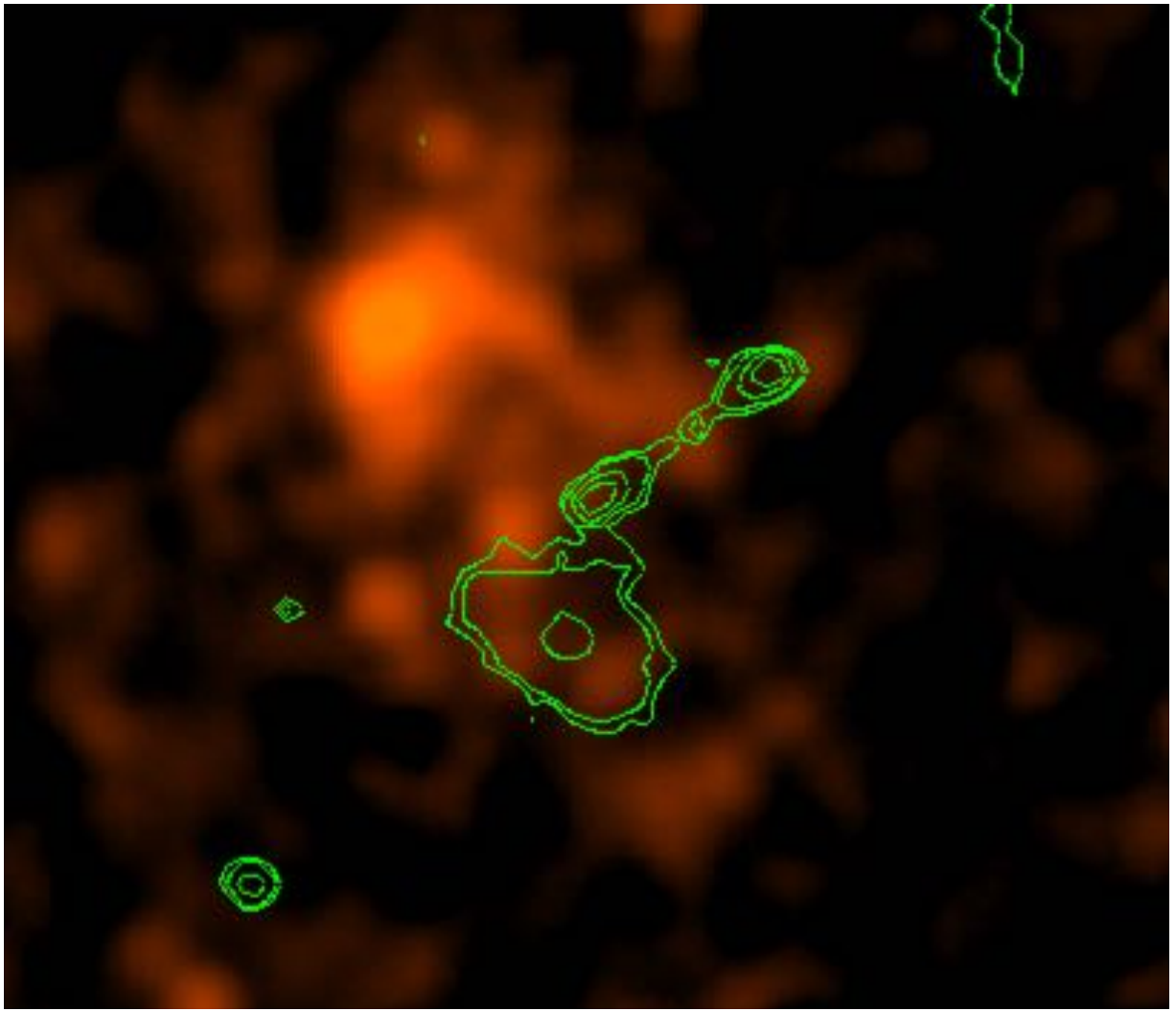
Speca: Subaru spectroscopy





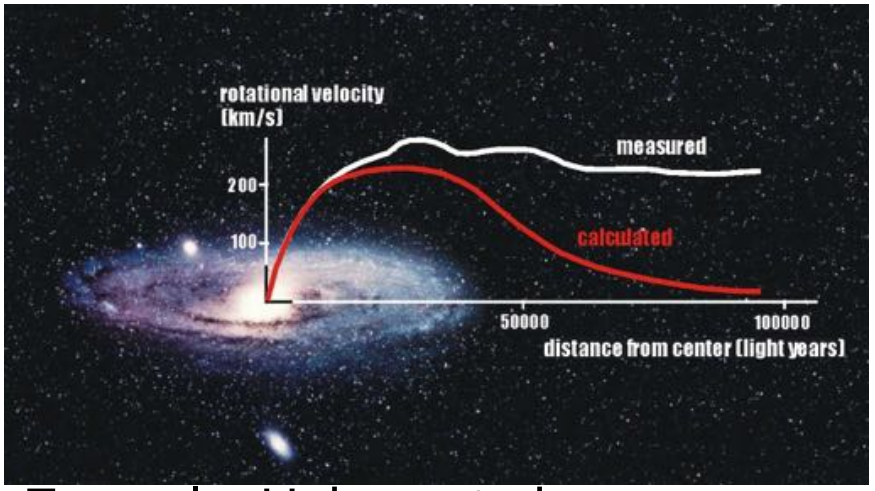
Ananda Hota (CBS/RAD@home, India)
Youichi Ohyama (ASIAA, Taiwan)
C.S. Stalin (IIA, India)

Speca: XMM + GMRT 325

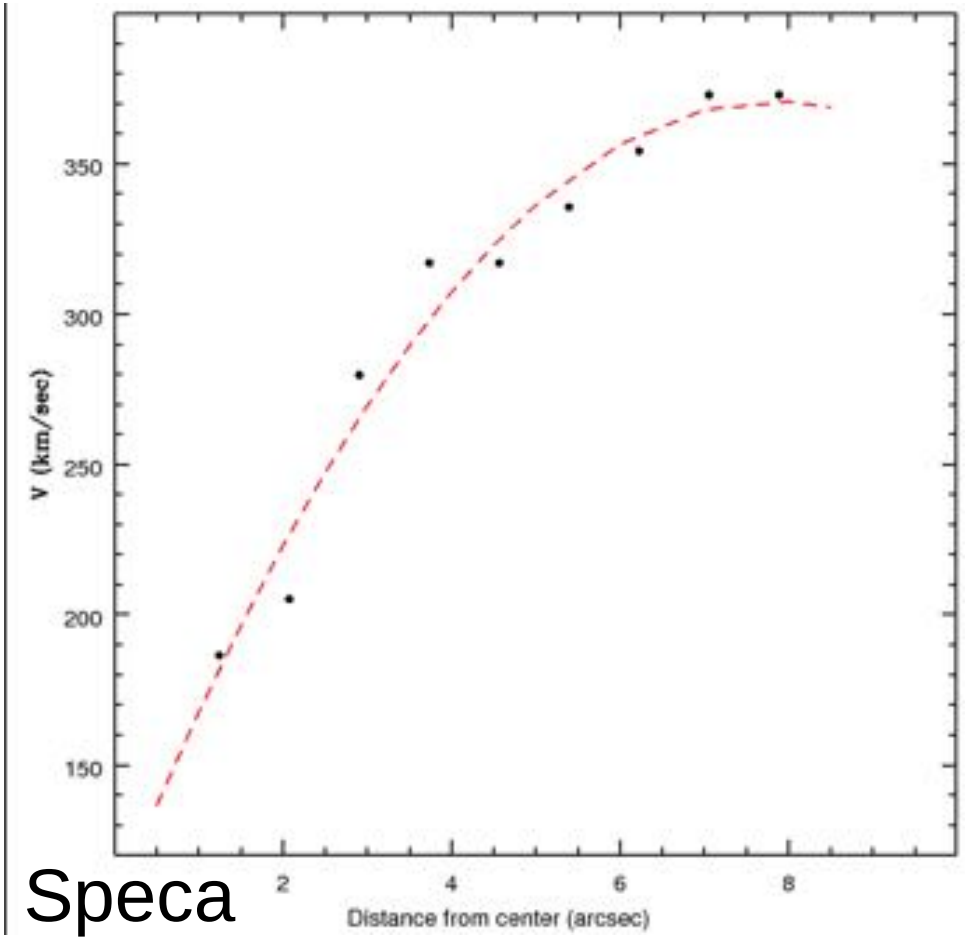


Ananda Hota (CBS/RAD@home)
Judith Croston (U. Southampton)
Martin Cardcastle (U. Hertfordshire)
Chiranjib Konar (ASIAA, Taiwan)

Speca: A massive Fast rotating Star forming Disk



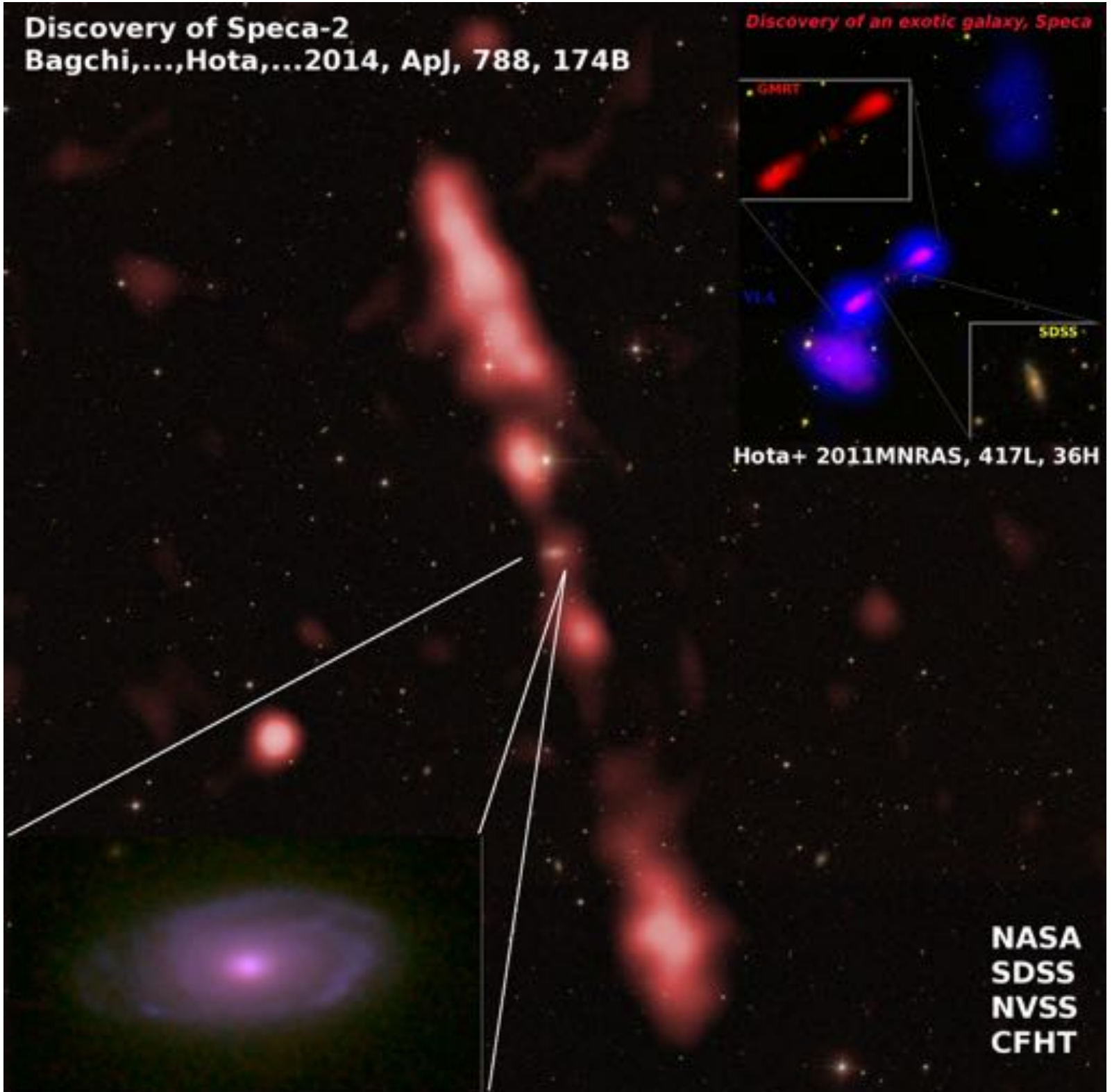
Example: Universetoday.com



Speca

Long-slit Subaru Spectroscopy

Ananda Hota (CBS/RAD@home, India)
Youichi Ohyama (ASIAA, Taiwan)
C.S. Stalin (IIA, India)

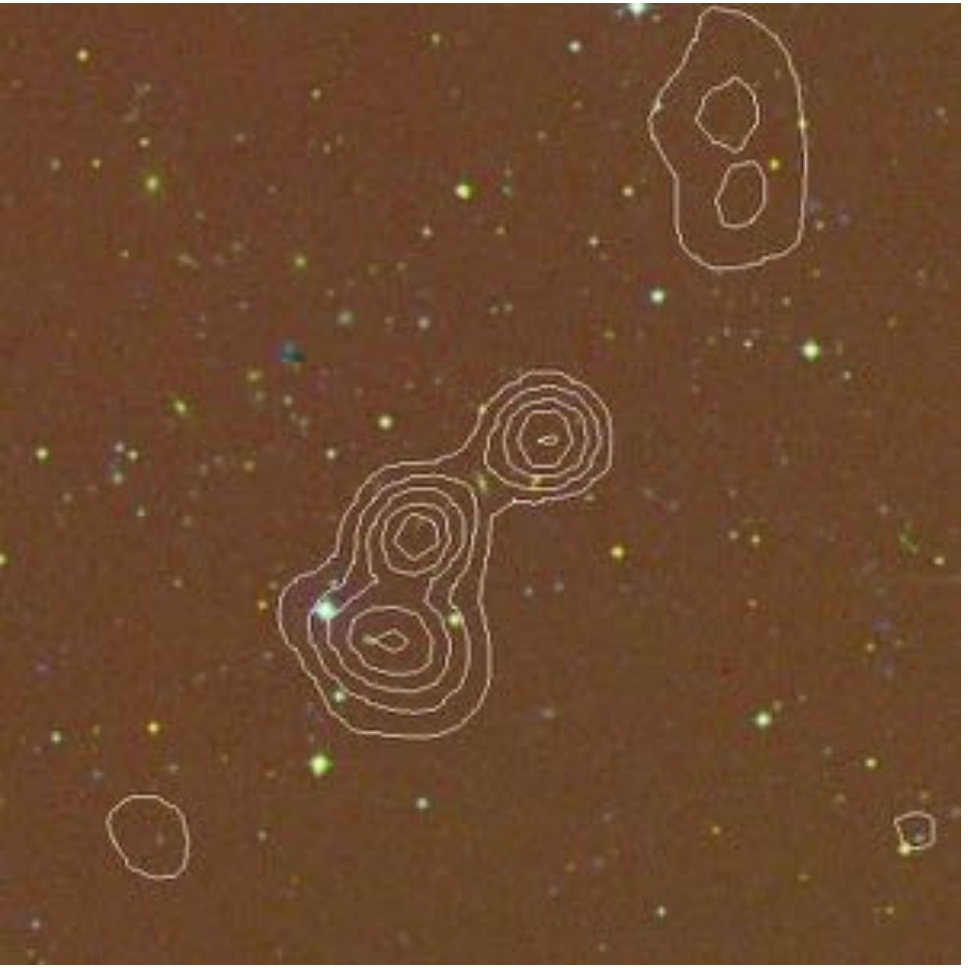


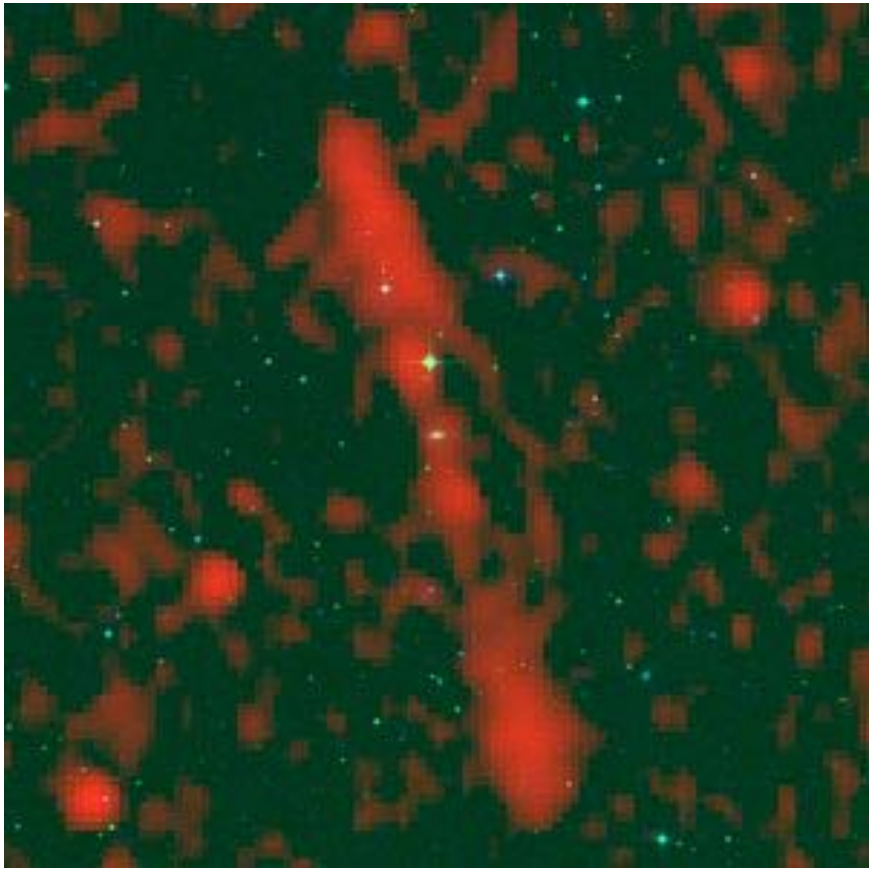
Most massive
Spirals
Giant Jets
No merger

1st Galaxies
1st SMBH ??

BCGs
Signs r lost

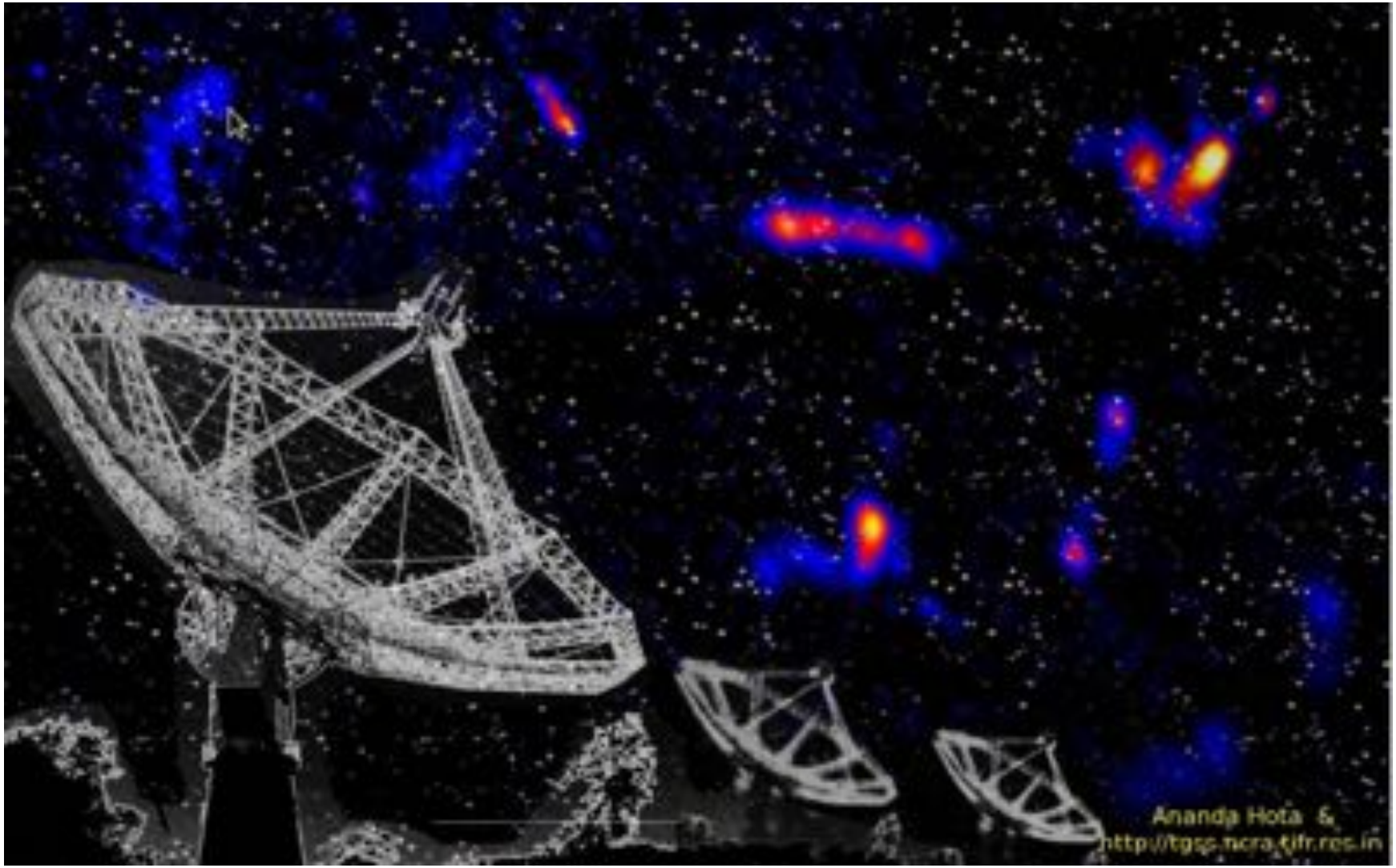
Speca was spotted in DSS, NVSS, FIRST





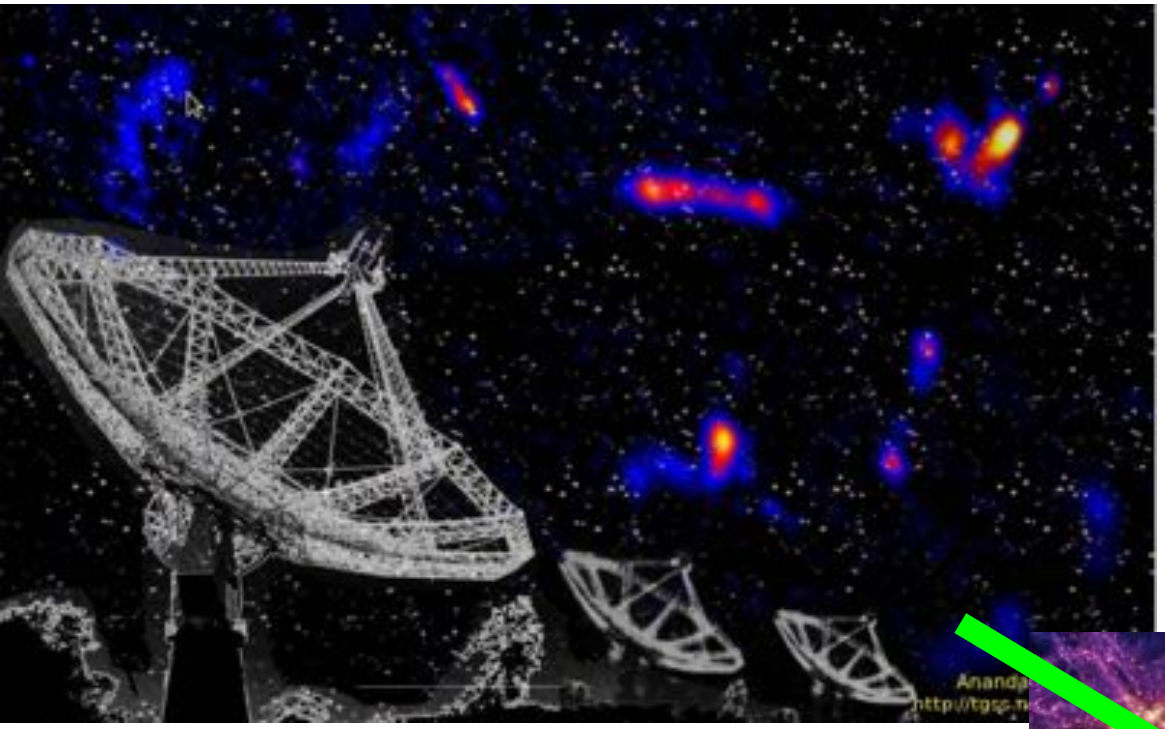
Also in old data.

Anybody can find a Speca in decare-old archival data
You dont need Largest telescopes with new sensitive data.

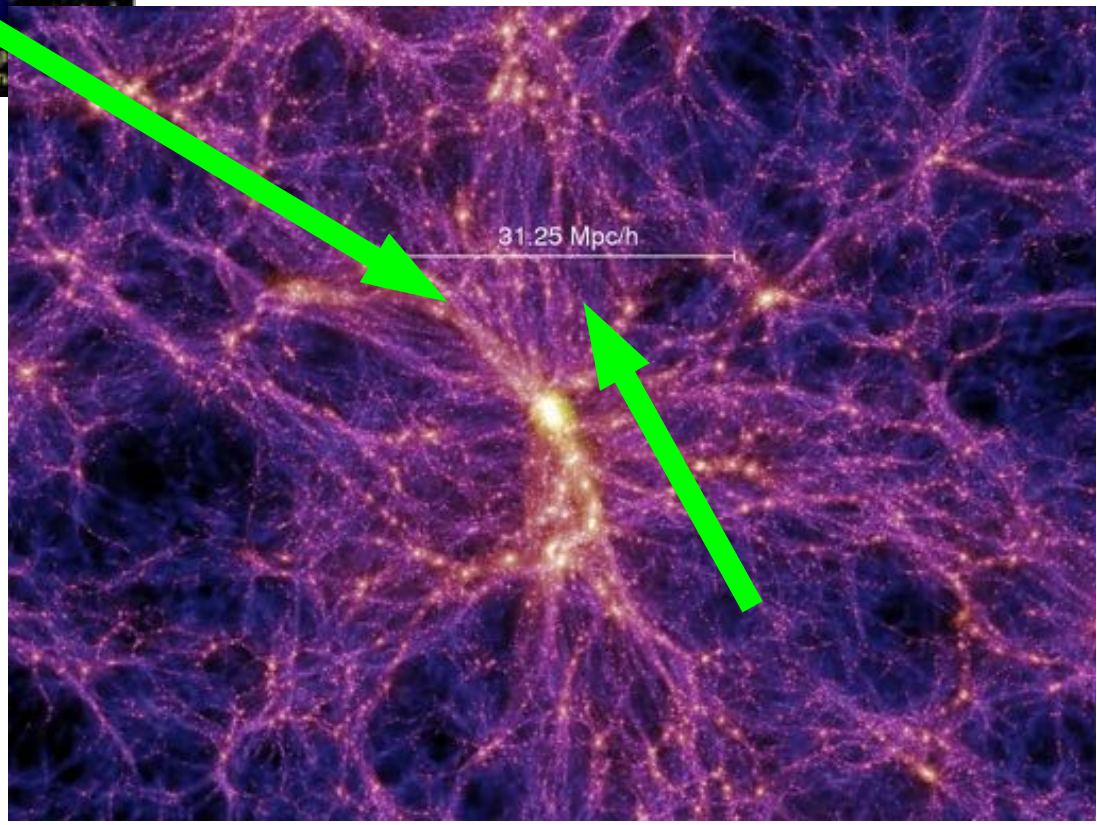


Ref: TGSS press-release News

I found many new meter wavelength sources
I want **many** to find many more such from TGSS



For Patterm recognition &
Extracting science-meaning from data
We need many many semi-experts.



Computers can never replace

Eye+Brain workers

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

Small town school teachers making discoveries
Will inspire the next generation.

Citizen-science solves the
BIG DATA problem of scientists

I also want to solve
Problems of the People as well

Who am I ? 2/2

RAD@home w/ SKA & GMRT

Step-1

Get Yourself "RGB-qualified".

Make multi-wavelength image of galaxies.
(.....UV-Optical-IR-Radio....)

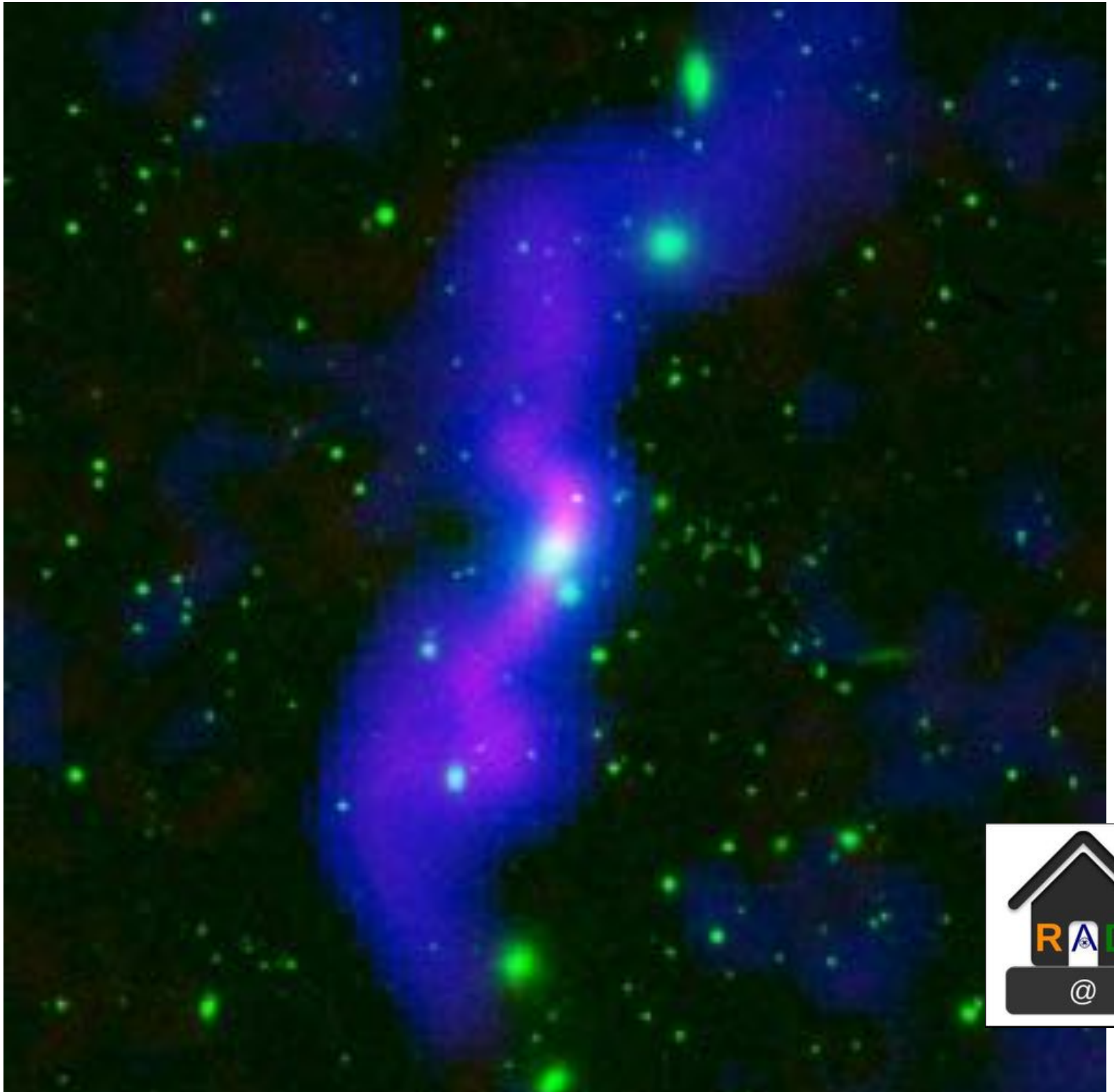
At **NASA's Skyview** web-tool
http://skyview.gsfc.nasa.gov/cgi-bin/skvadvanced.pl

Read about Galaxies in wikipedia.
(Next will be to make RGB-C image)

radathomeindia@gmail.com

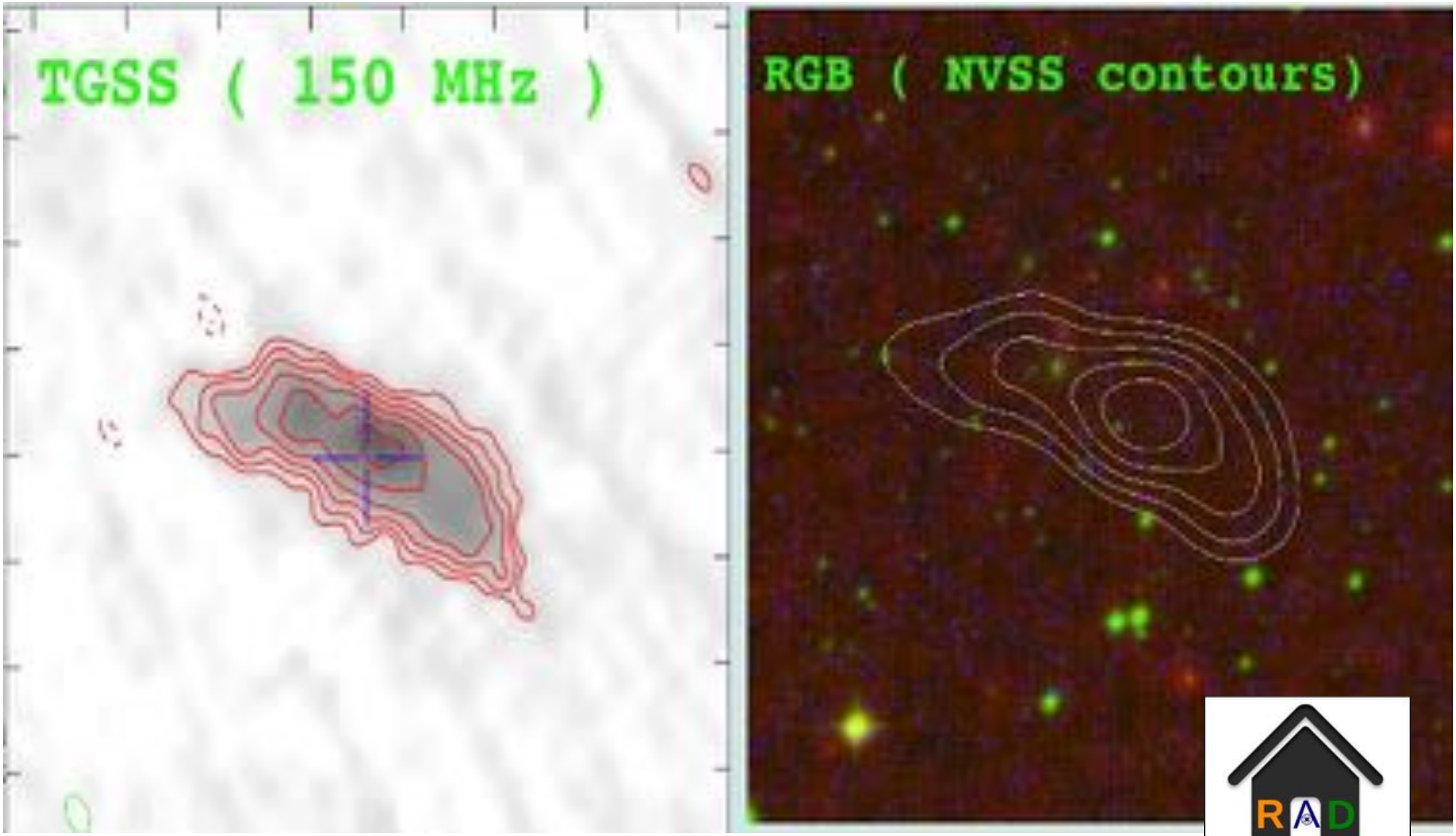

NGC6872: The largest known spiral galaxy
RAD
@
NASA
SkyView
The Internet's Virtual Telescope
Blue: GALEX near UV
Green: DSS2 red (optical)
Red: WISE 22 micron

RAD@home



RAD@home


R A D
@



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R A D
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NATIONAL CENTRE FOR RADIO ASTROPHYSICS
Tata Institute of Fundamental Research, Pune

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  - Feedback Form
  - News
  - Observing Help
  - Current Status
  - Approved Proposals
    - CYCLE 26 (APR 14 - SEP 14)
    - CYCLE 25 (OCT 13 - MAR 14)
    - CYCLE 24 (APR 13 - SEP 13)

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	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

RAD@home w/ SKA & GMRT

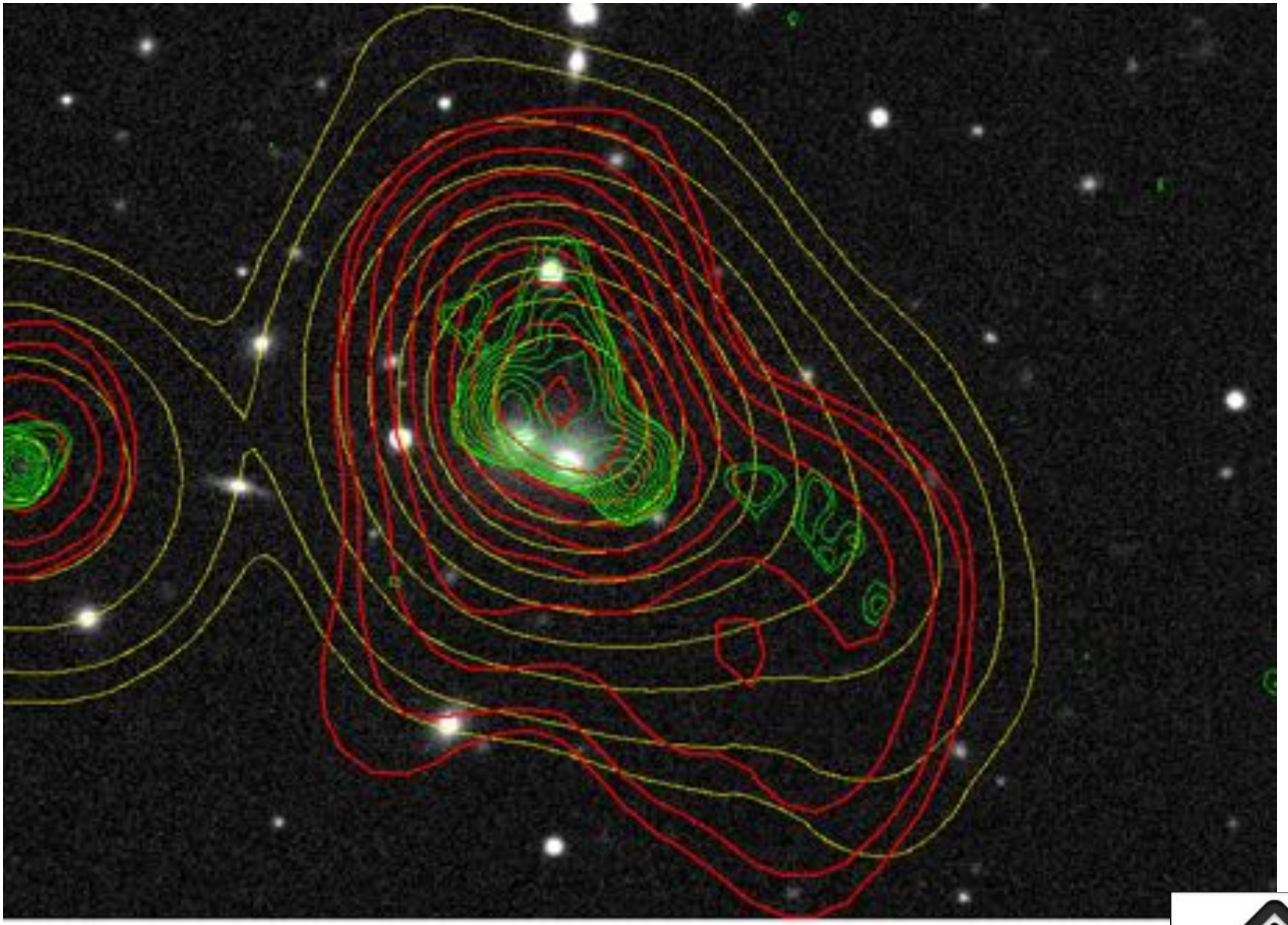
Helping
RAD@home

Thank you

SDSS image

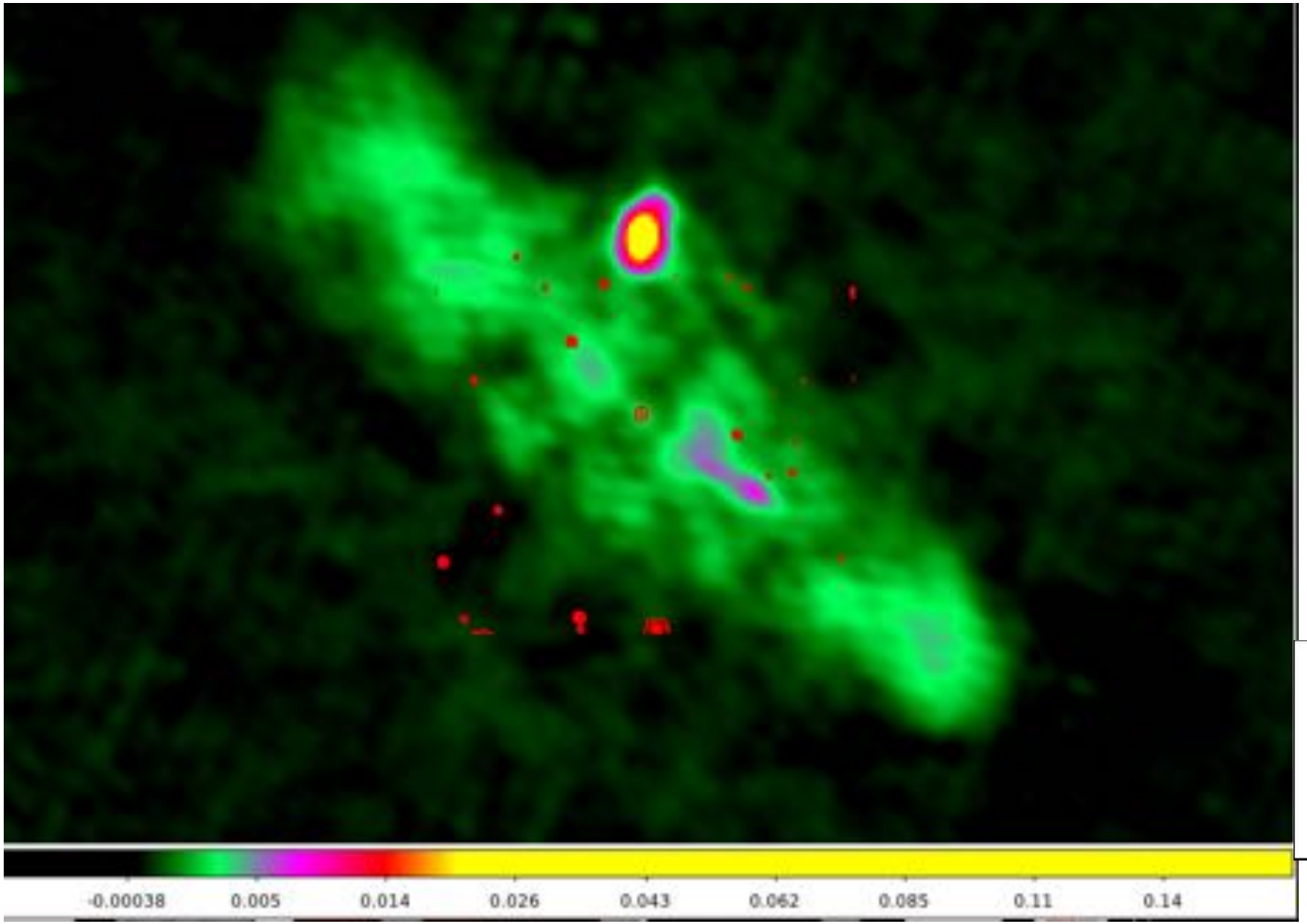
Dry merger

notice the fan
=>
clock-wise
rotation

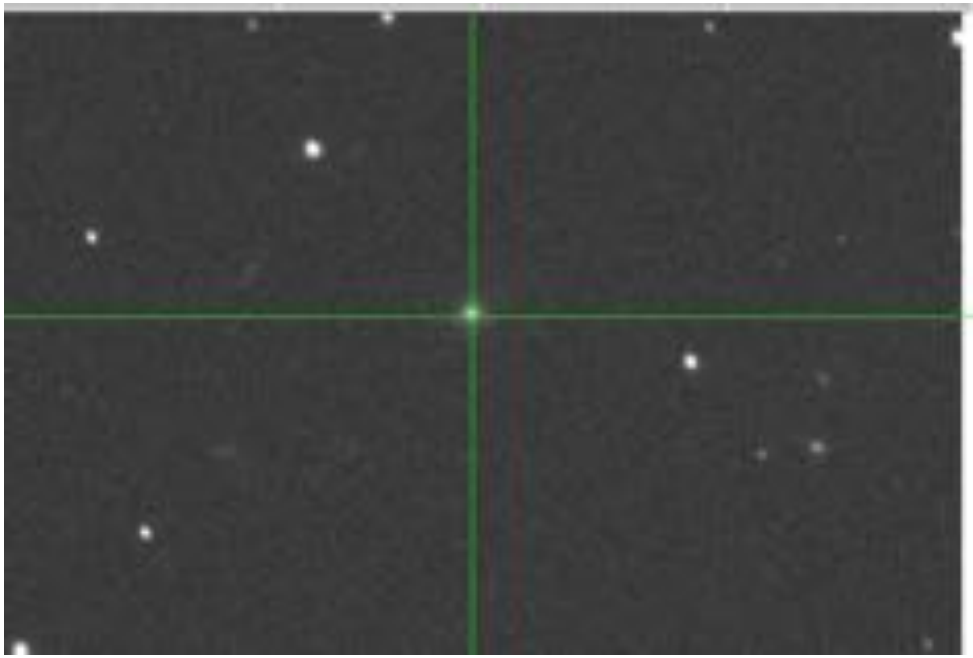


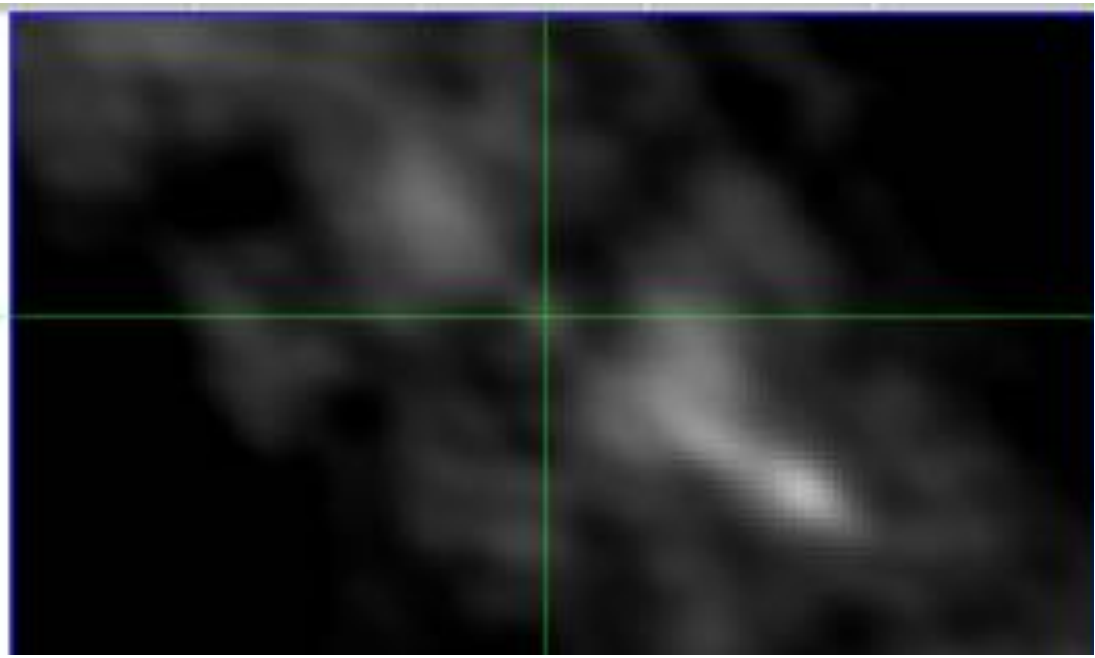
Two Episodes of jets-lobes, Past episode one lobe interacted with the merging companion

RAD@home w/ SKA & GMRT



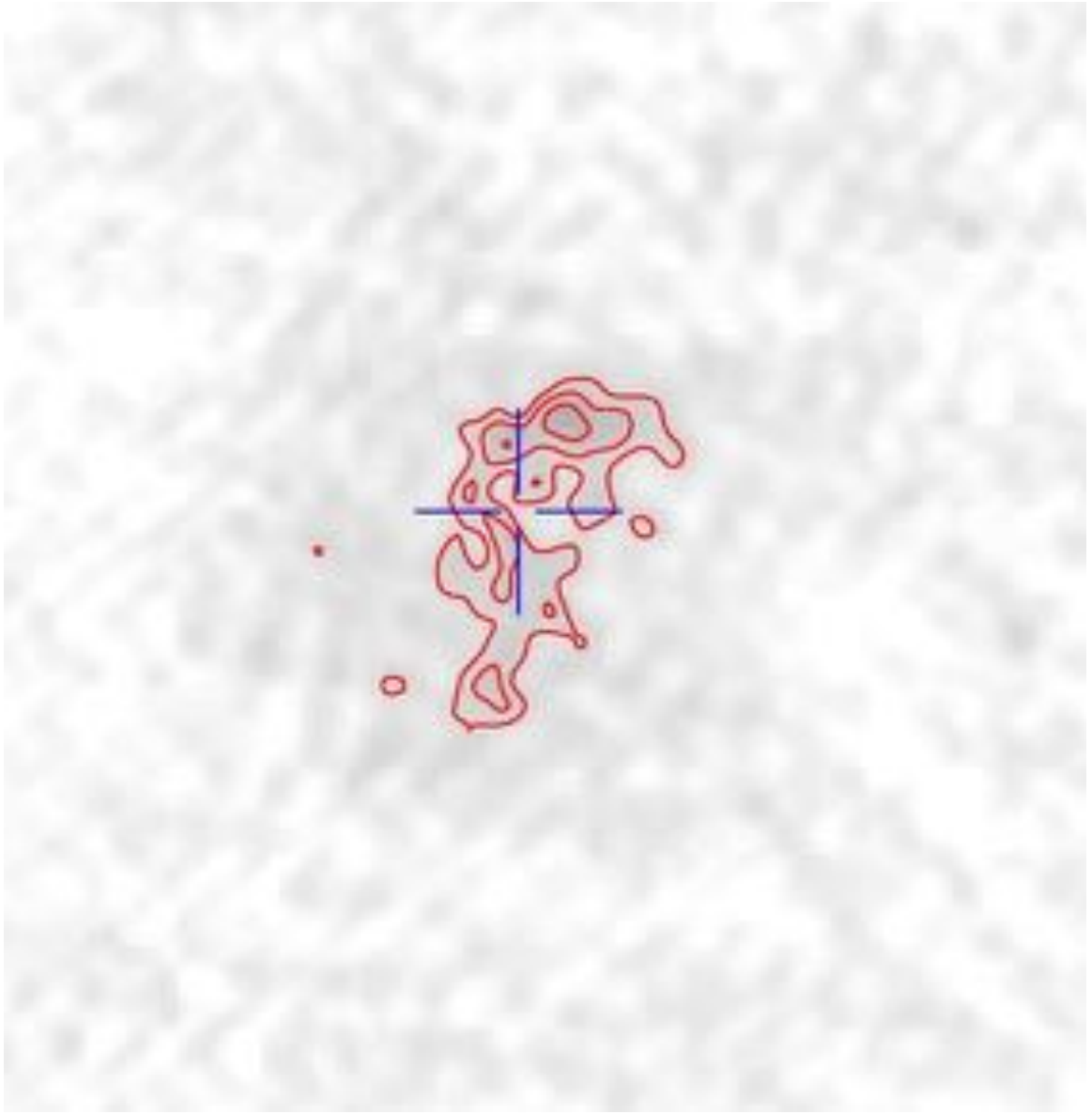
325 MHz follow up observation with the GMRT
Under GOOD-RAC project
Its a DDRG, its a giant 800 kpc relic radio lobes
(Pratik used SPAM help by Intema ……





SDSS

GMRT 325



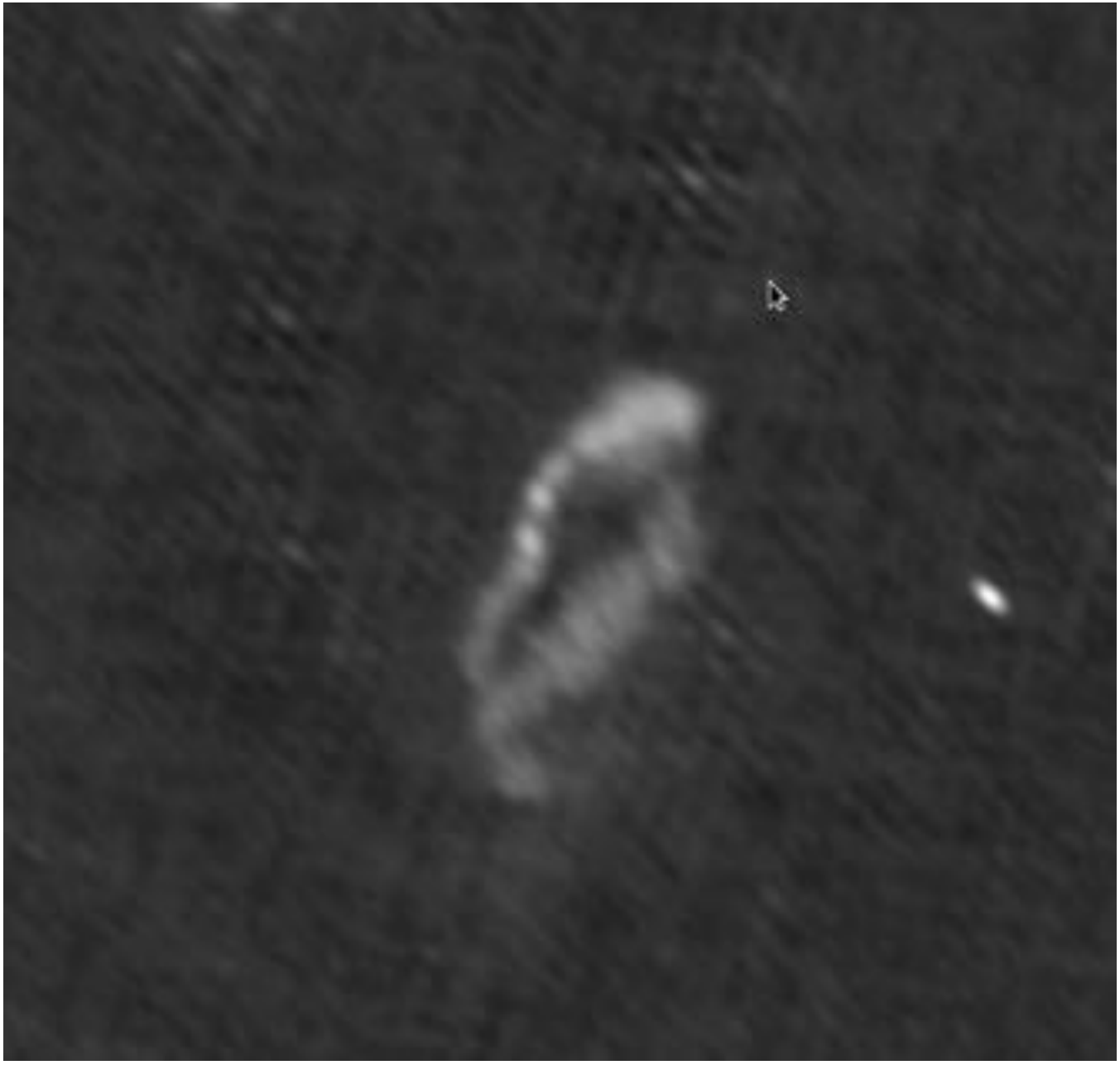
TGSS DR5
GMRT
150 MHz

shock ?

WAT

DSS RGB
NVSS contour

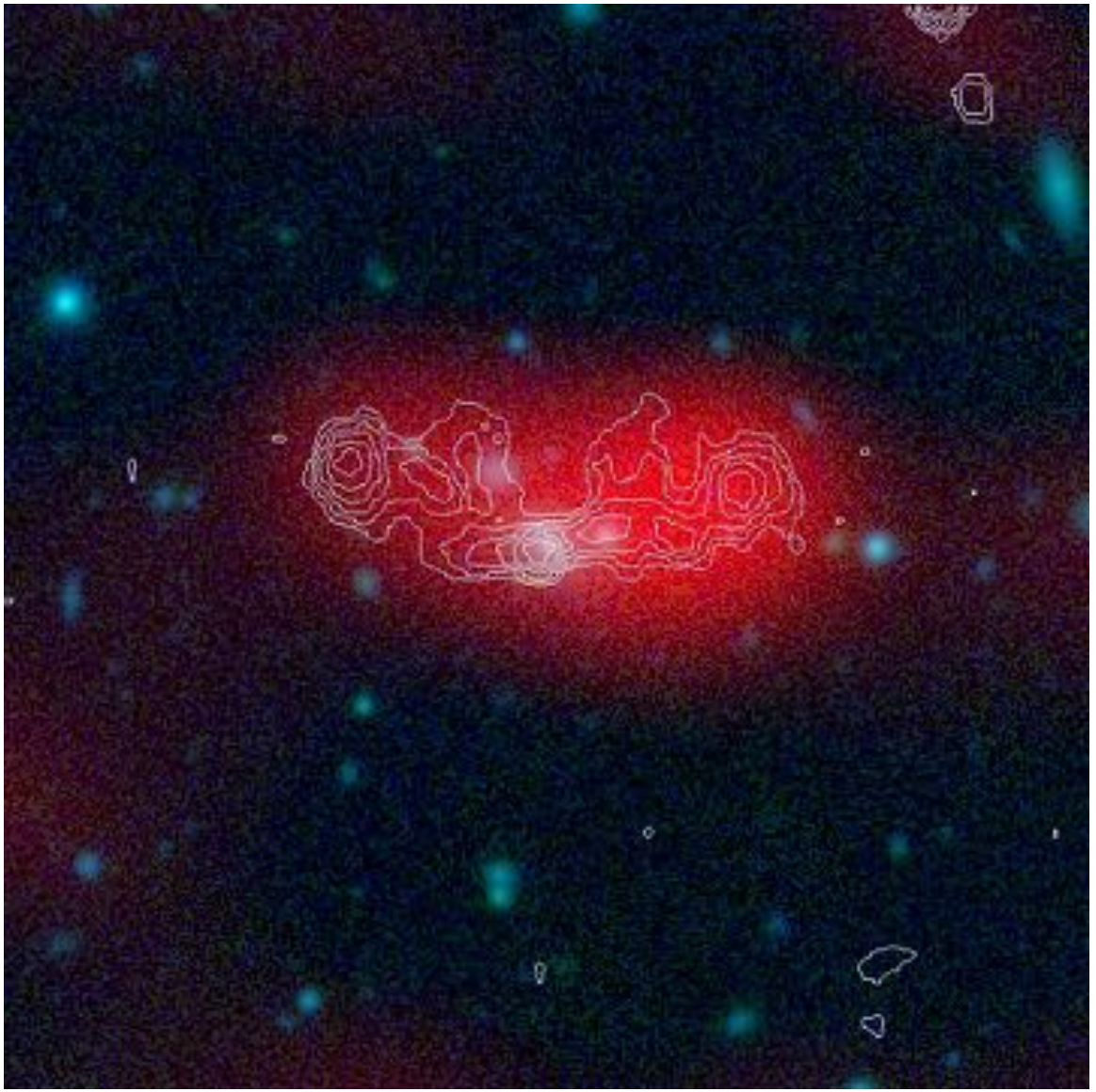
WAT ?



WAT with

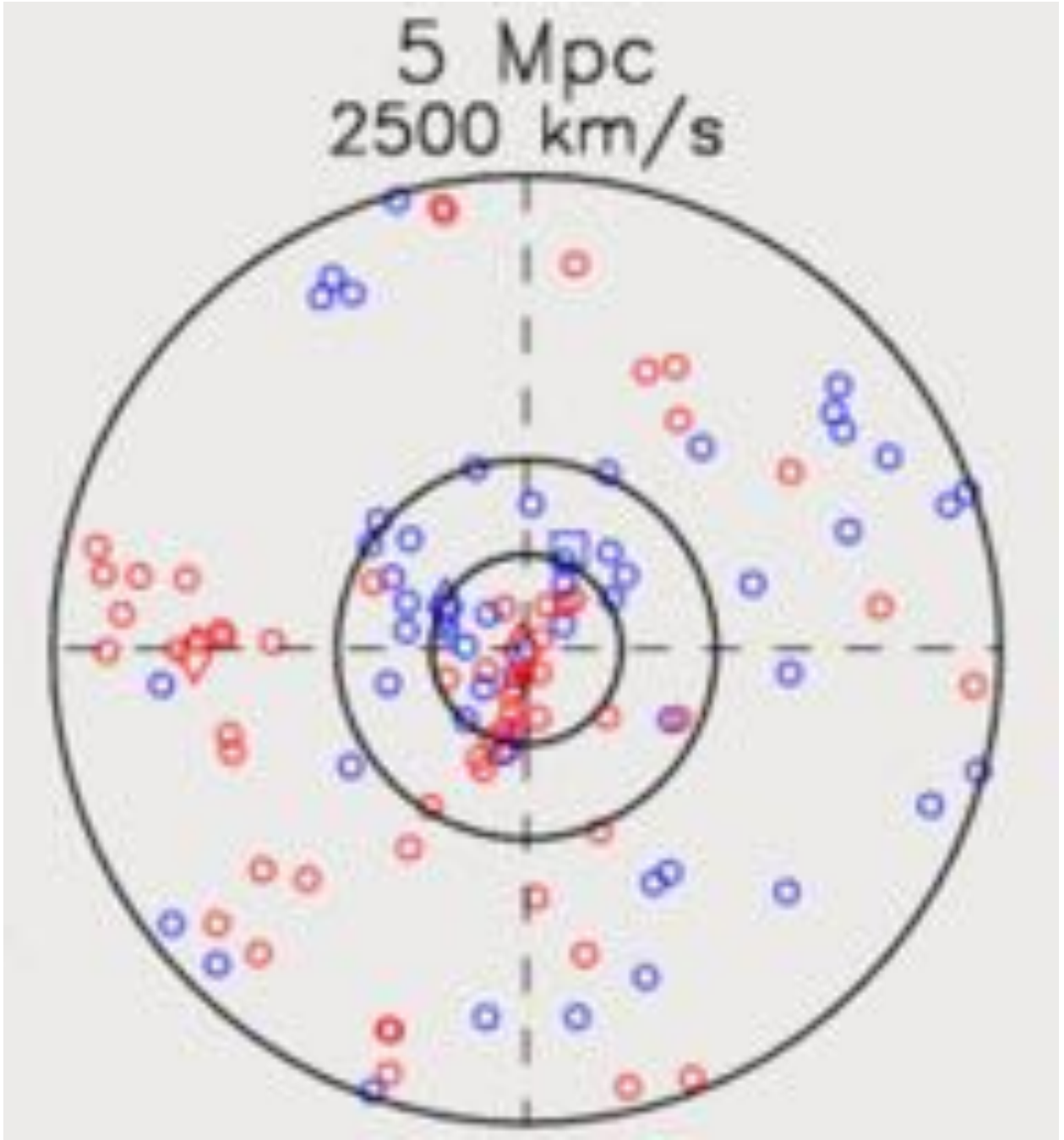
Episodic

Cluster Accretion



WAT ?

But....

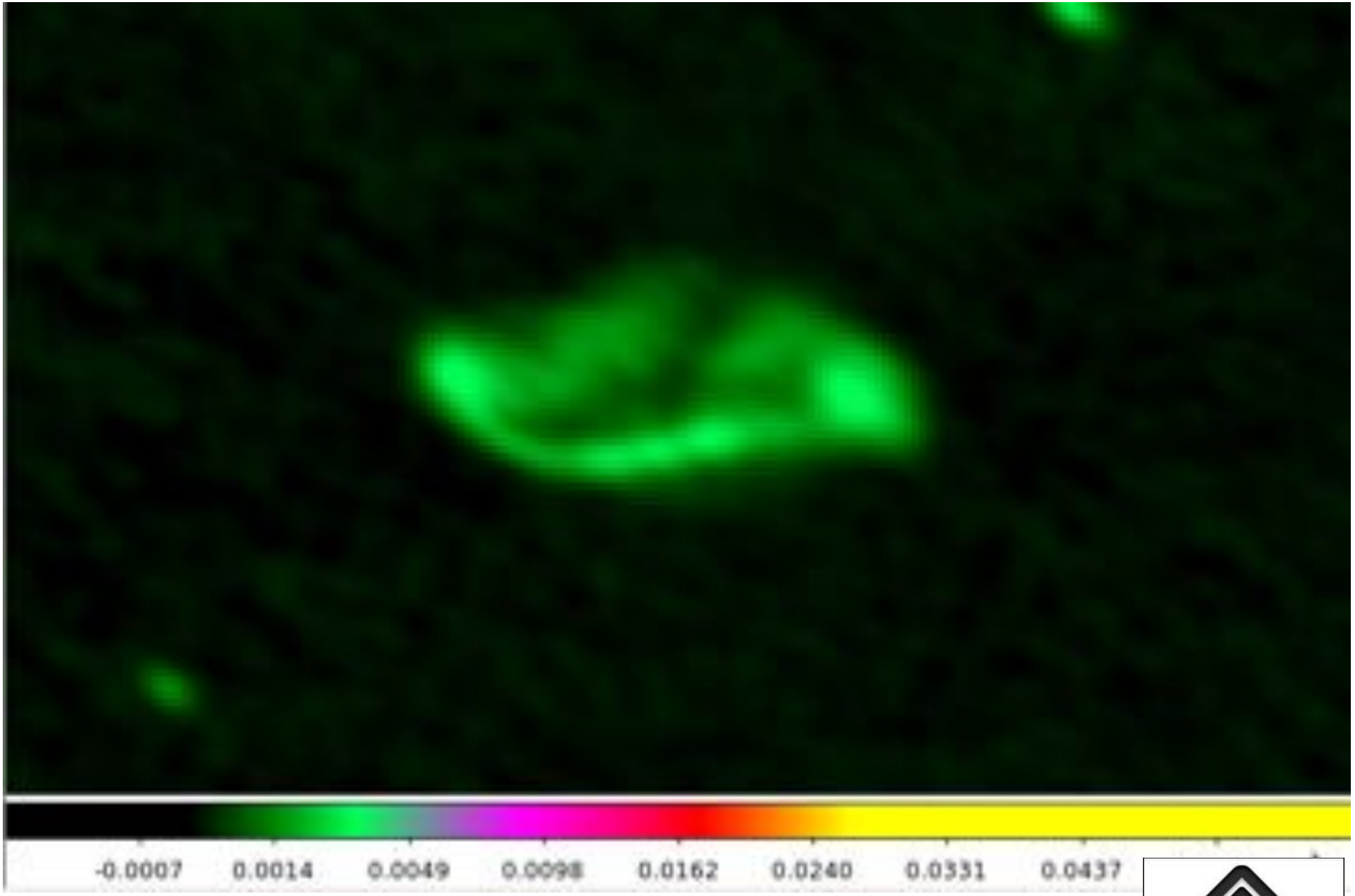


Mpc-scale

galaxy Filament

WAT in the middle

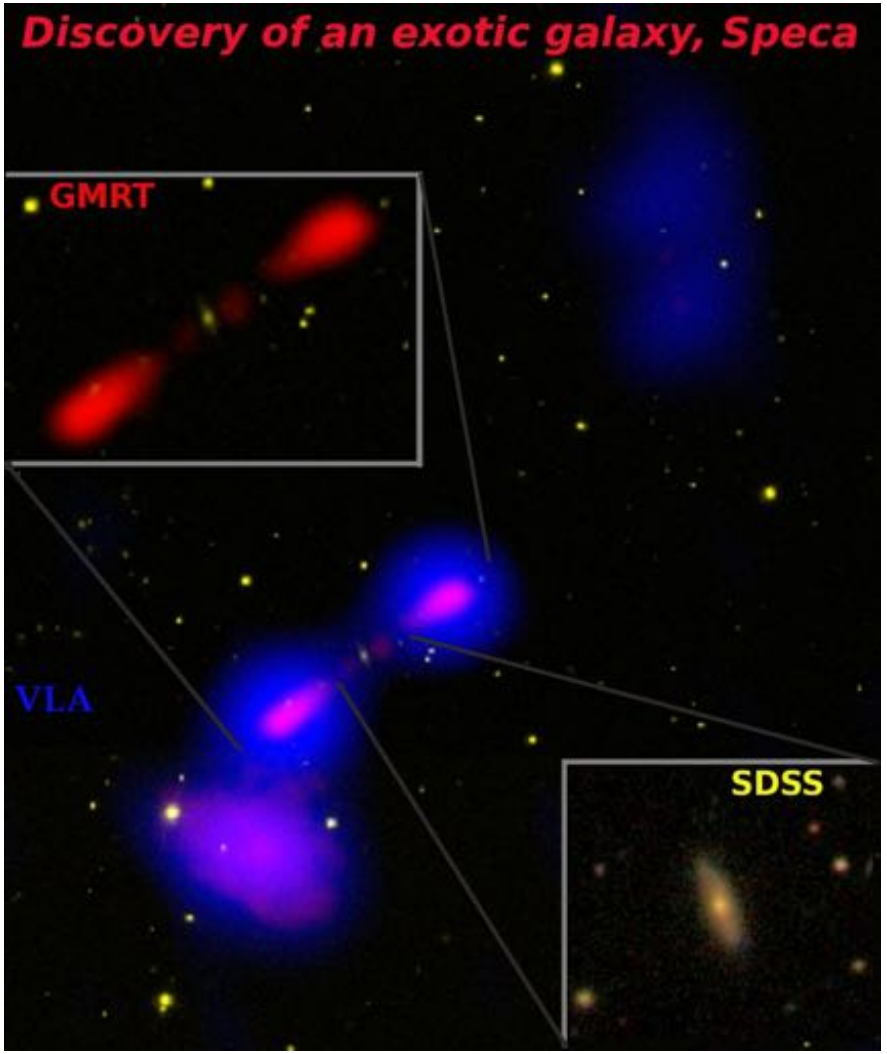
RAD@home w/ SKA & GMRT



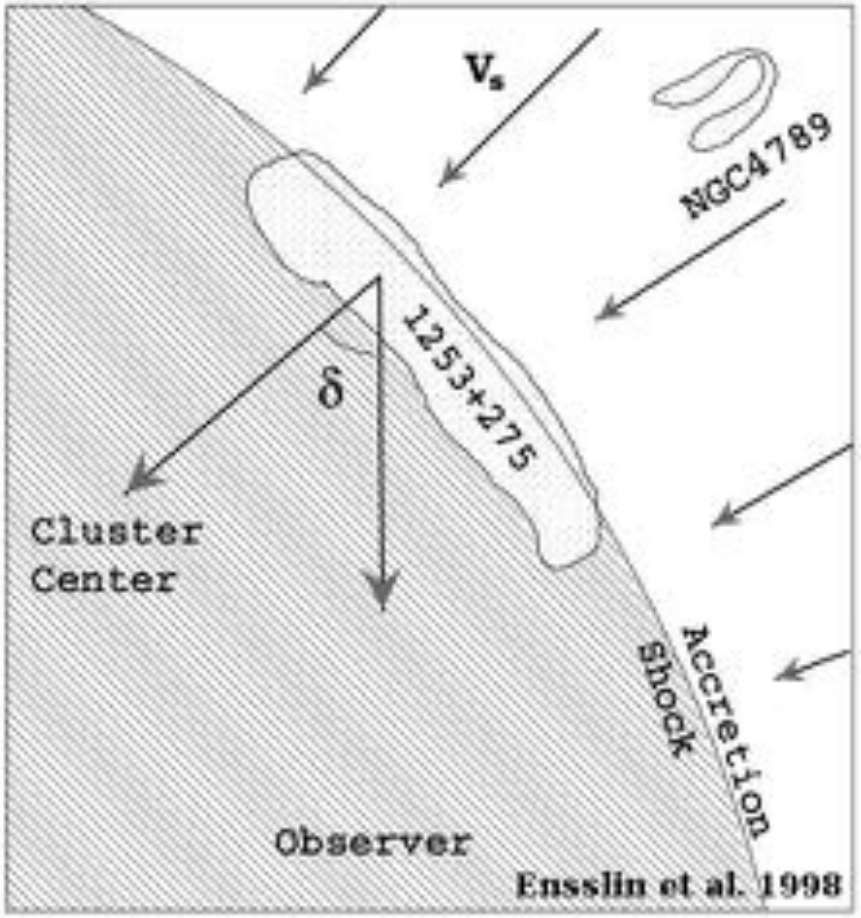
GMRT 610 MHz 2nd WAT@filament

Diffuse plasma trailing, cluster accretion

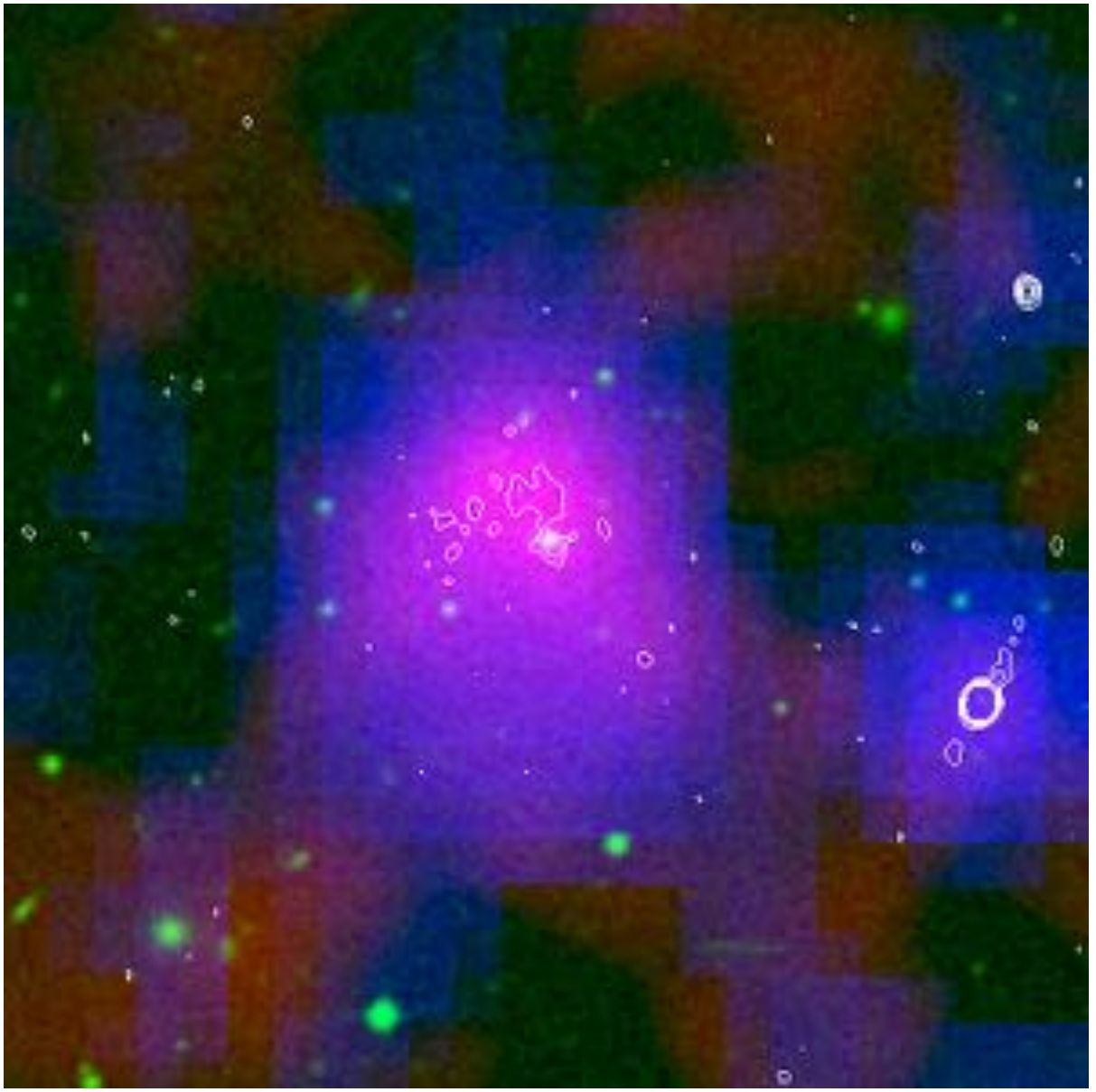
Spiral-host Episodic radio galaxy tracing Cluster Accretion



Tracing Cluster Accretion



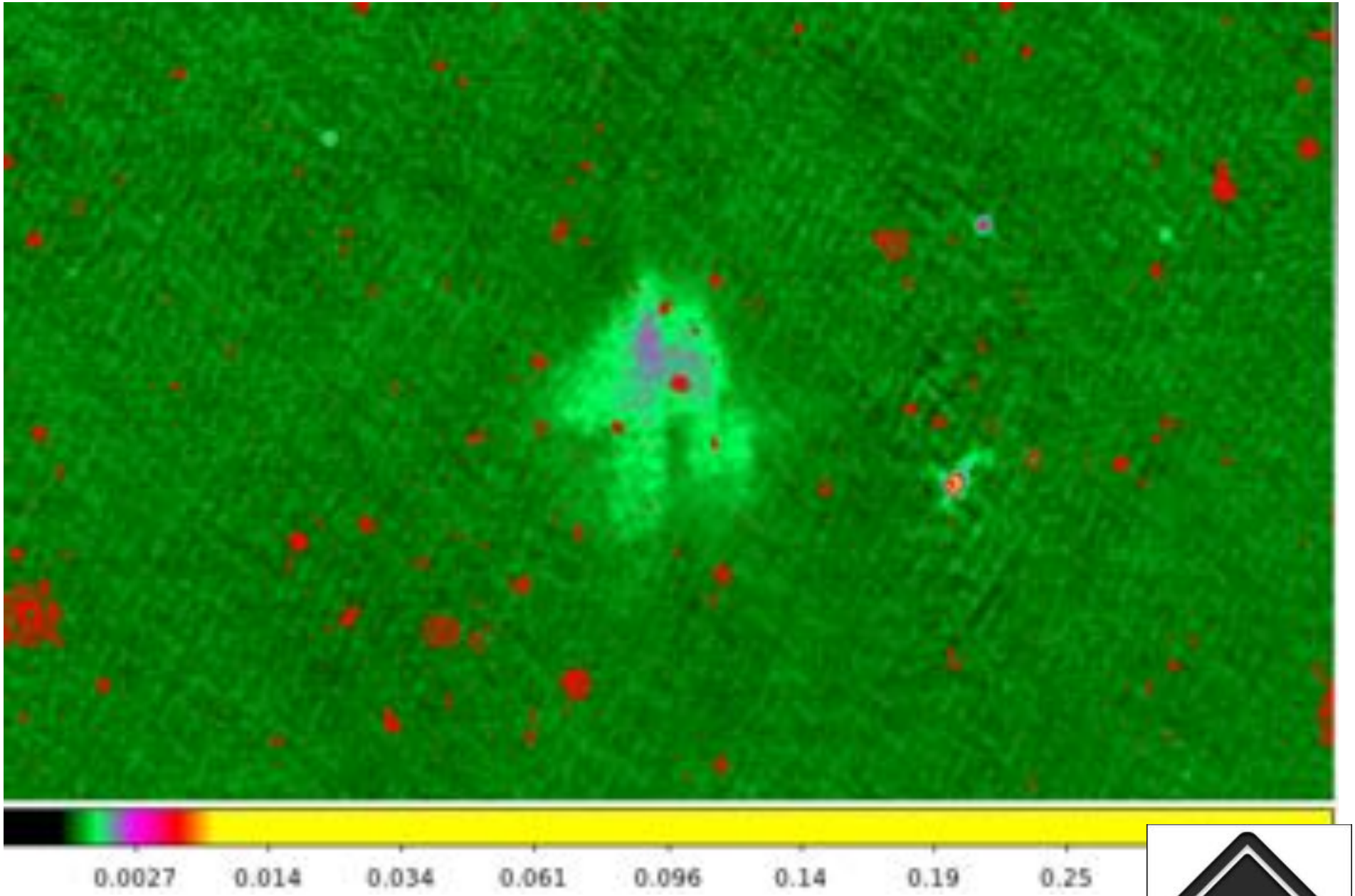
RAD@home w/ SKA & GMRT



RGB-C
TGSS ADR1
NVSS
DSS
FIRST-contour

A relic radio lobe

Radio phoenix
Revived by cluster
Accretion ?



GMRT 610 MHz or phoenix

Facebook.com/RADatHomeIndia

SKA BigData problem can be a prospect with social-implications....

Please help RAD@home

Thank You...

We will present multi-wavelength observational results leading to understanding of the evolutionary history of some interesting galaxies in the process of transition. Telescopes like GMRT, VLA, SMA, Subaru, Chandra, XMM-Newton have been used in our study of target galaxies like NGC1482 (merger-remnant early-type with Superwind), NGC6764 (barred-spiral with radio bubble), NGC3801 (merger-remnant with shock-shells around sub-galactic radio lobes), Speca (Spiral-host episodic radio galaxy tracing cluster accretion) etc. Stellar population synthesis models and synchrotron spectral ageing have been used along with archival data in the UV, optical and IR to track back the history of various processes in these transitional galaxies caught-in-the-act. They serve as ideal labouratories for understanding the physical progress that drive evolution from spiral to elliptical through merger, star formation and AGN activities and feedback processes like starburst-driven superwind and AGN-jet driven outflows.

Though AGN or quasar activity is extremely energetic, it is extremely short-lived. This justify focusing on transitional galaxies to find relic-evidences of the immediate past AGN-feedback which decide the future course of evolution of a galaxy. Relic radio lobes can be best detected in low frequency observations with the GMRT, LOFAR and in future SKA. Only in the year 2007, the very first relic-evidences of a past quasar activity (“Hanny's Voorwerp”) was discovered by Galaxy Zoo citizen-scientists, in the optical bands. RAD@home (www.facebook.com/RADatHomeIndia/), the only Indian citizen-science research project in astronomy, analysing TGSS data and observing from the GMRT, was launched in April 2013. Unique, zero-infrastructure zero-funded design and findings from RAD@home will be presented in the meeting.

These new findings include, radio bubbles in spiral galaxies, episodic radio galaxies, dead/relic lobe radio galaxies, diffuse relic/halo radio emissions in groups/clusters, possible shock fronts of cluster merger, radio-jet and companion galaxy interaction, radio galaxies bent by relative motion of the intra-filament medium in Mpc-scale galaxy filaments etc.Citizen-science has not only opened up a new way.

or astronomy research but also given us possibly the only promising way to extract maximum science out of the BIG DATA in the SKA-era .As our tag line Any BSc/BE Can Do research (#ABCDresearch) using GMRT sitting anywhere in India, RAD@home allow participation from all citizens with undergraduate science and engineering education in analysing data from GMRT (in particular TGSS survey data). Through one-week short-term trainings hosted in various research institutes and on-line e-class e-research discussion sessions a growing community of citizen-scientists or collaboratory of e-astronomers (current total 65) has been created. With such modifications, citizen-science can not only contribute to the knowledge creation in never-seen-before speed and approach but also give an equal opportunity of career growth in astronomy to people
even in the under-developed regions where we always put our optical and radio telescopes.