Searching for dual AGN in galaxy mergers and their effect on galaxy evolution

Rubinur Khatun

Postdoctoral Fellow
NCRA-TIFR

Collaborators

- Preeti Kharb (NCRA)
- Mousumi Das (IIA)
- Honey M (Koyilandy Govt College)
- Rahna P.T. (IIA)
- Sravani Vaddi (NCRA)
- Jayant Murthy (IIA)

How do AGN pairs form in the centers of galaxies?

i) During mergers, the SMBHs sink to the centre of the merger remnant

ii) They result in gravitationally bound SMBH dual/binary systems.

Iii) Simulations show that mergers cause gas accretion onto the SMBHs which can ignite AGN activity in the BH pair. So they form **dual/binary AGN.**

iv) Finally they coalesce emitting huge amount of gravitational wave energy.

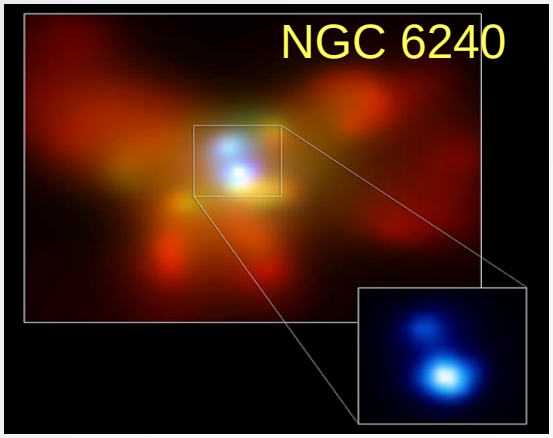
Lotz et al. (2011)
hipacc.ucsc.edu

(Begelman et al. 1980, Thorne & Braginskii 1976)

Dual/Binary AGN can help us understand the end stage of mergers and its effect on the nuclear regions of galaxies. Hence their detection is very important. But the number of confirmed binary/dual AGN is yet very less.

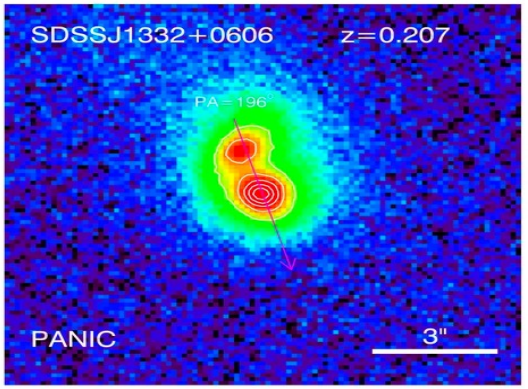
Dual/binary AGN : Direct detections

1. Two cores in X-ray map



Komossa et al. (2002)

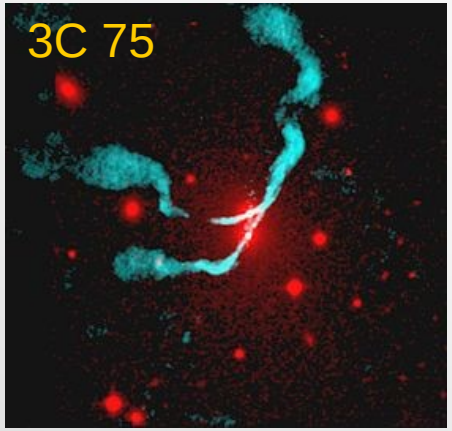
2. Two cores in Optical/UV imaging



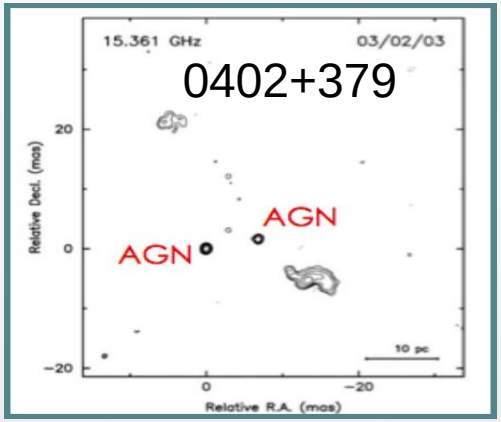
Liu et al. (2013)

AGN:I. Robson

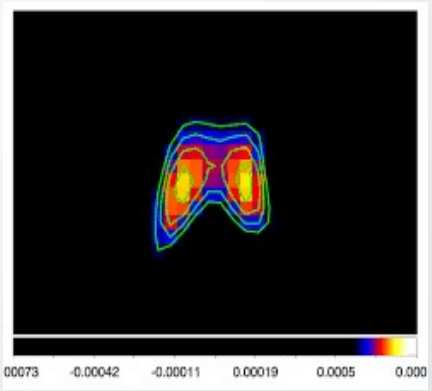
3. Two cores in radio image



F.N. Owen et al. (1985)



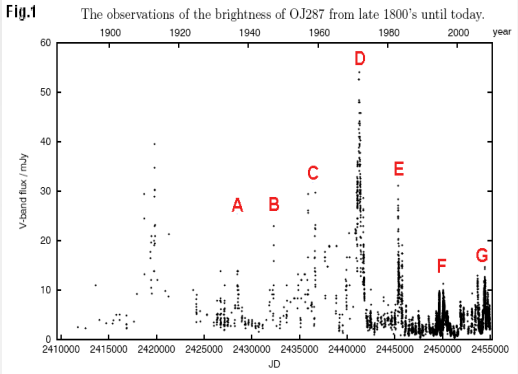
Rodriguez et al. (2006)

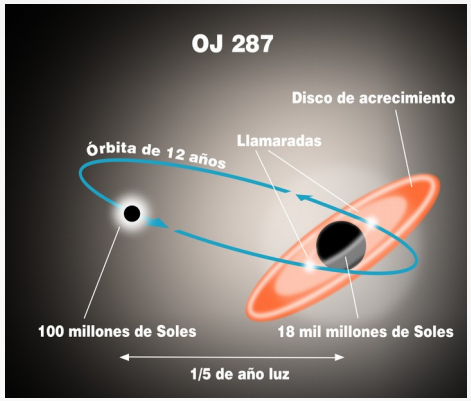


Kharb et al. (2017)

Indirect Signatures: Binary/dual AGN

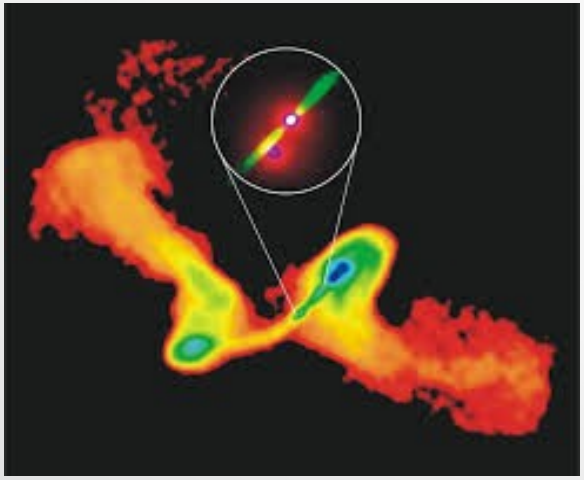
1. Periodicity in flux variability:





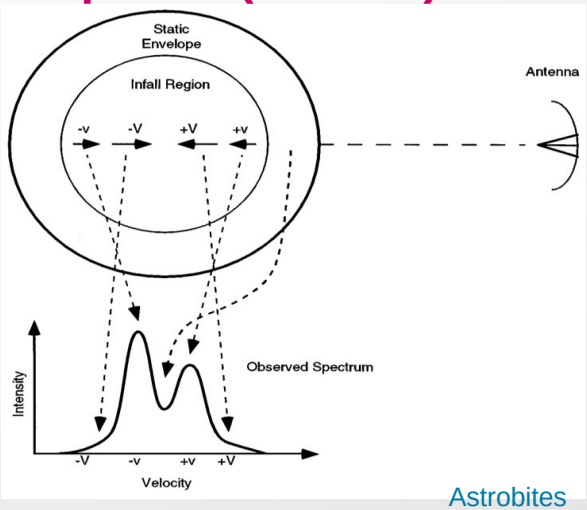
(Sillanpaa et al. 1988; M Valtonen 2011)

2. X- or S-shaped radio galaxies:



(Merritt & Ekers 2002)

3. Double-peaked emission lines ([OIII]) in optical spectra (DPAGN)



Astrobites

(Zhou et al. 2004, Greene & Ho 2005, Kharb et al. 2015, Comerford et al. 2012)

EVLA Radio observations of DPAGN

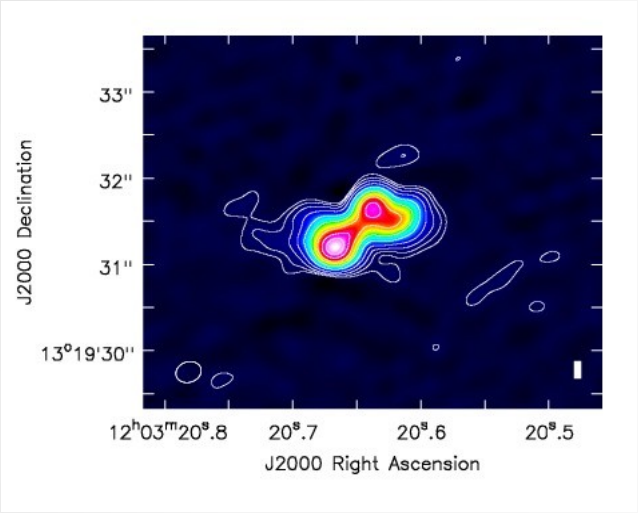
The Karl G. Jansky Very Large Array (VLA) is a cm- wavelength radio astronomy observatory located in central New Mexico.

Sample and Observation: We observed 20 double-peaked emission line AGN (DPAGN) with EVLA in different cycles;

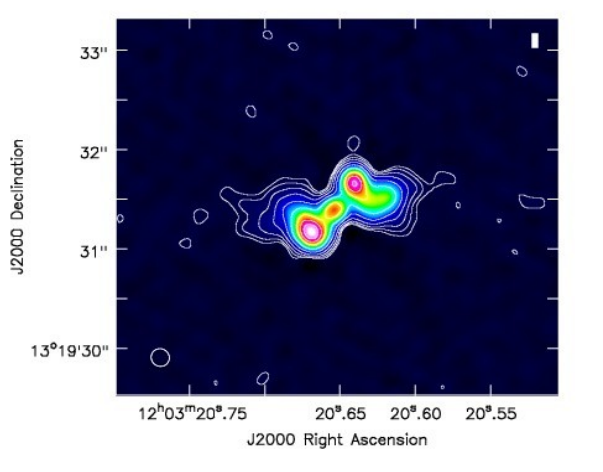
Proposal ID: 15A-068, 16B-002, 16A-144 at 6, 8.5, 11.5 and 15 GHz

2MASXJ12032061+1319316: S-shaped radio jets

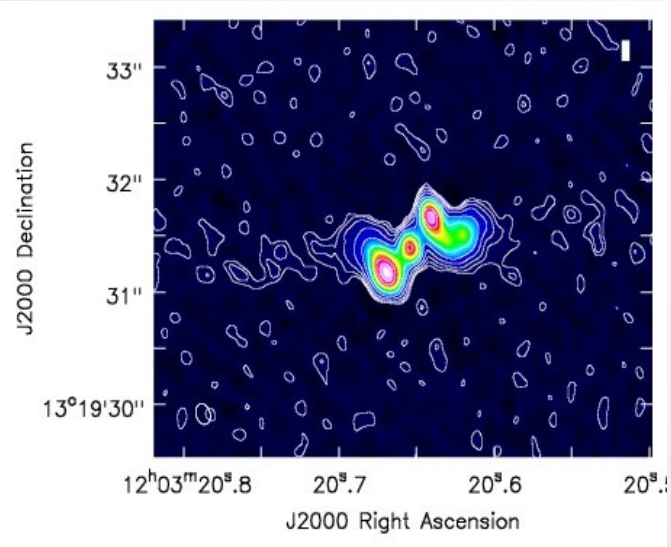
6 GHz image



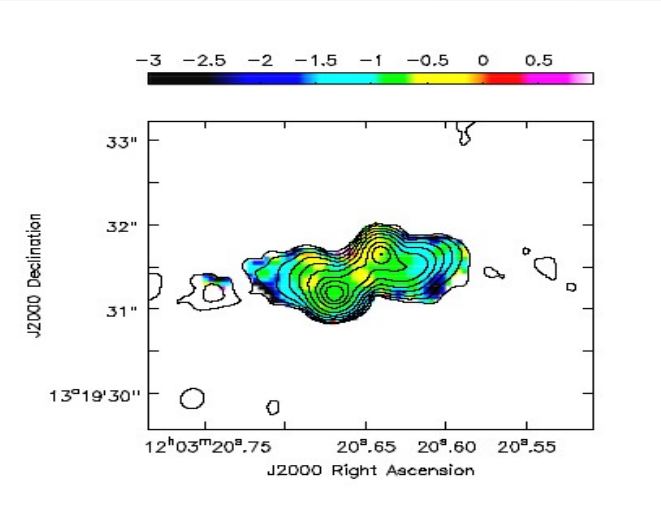
8.5 GHz image



11.5 GHz image



Spectral index map

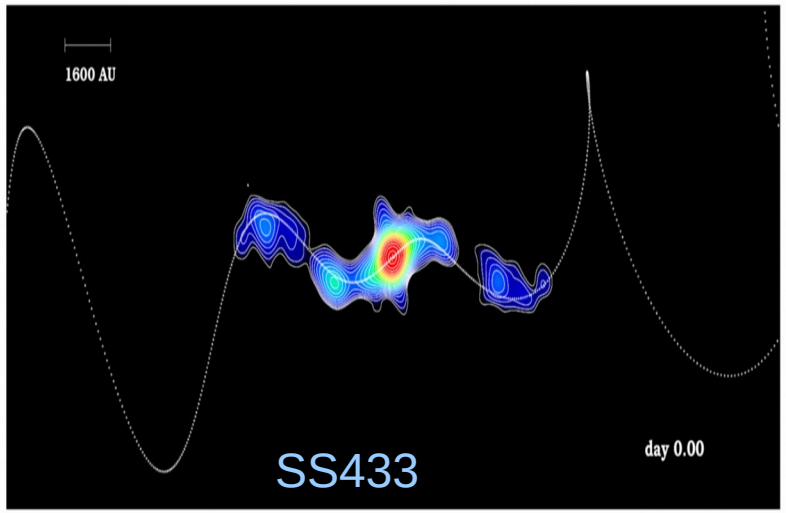


Total size of ~3kpc

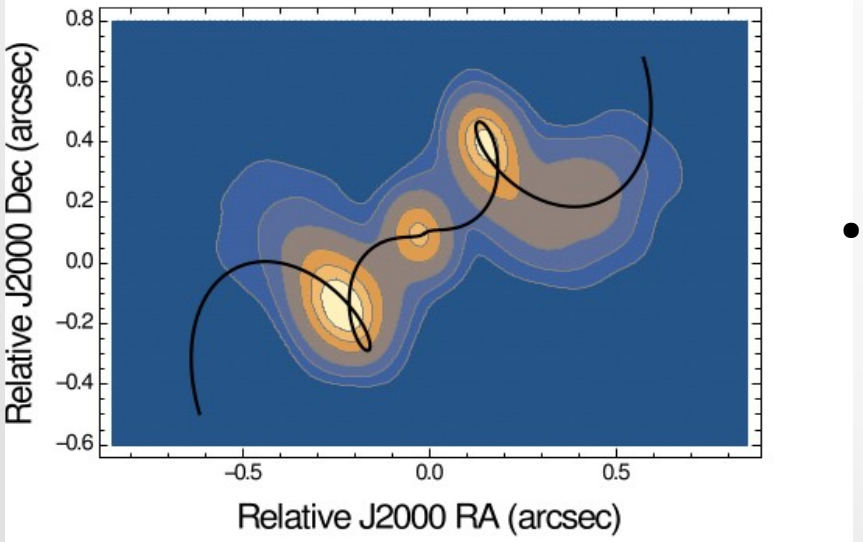
Core has flat spectral index (α)

Jets have steeper α.

Modeling the S-shaped structure: jet precession



CREDIT: A. Mioduszewski et al., NRAO/AUI/NSF

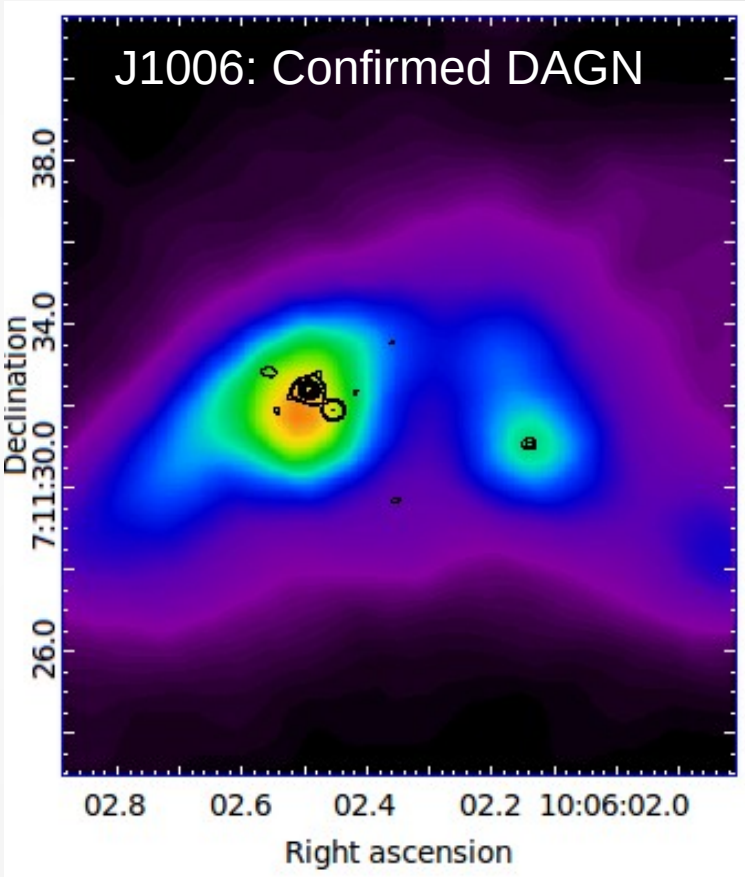


- S-shaped radio jet with total size 3kpc.
- The fitted Hjellming & Johnston (1981) jet precession model (black curve) provides a Period ~10^5 yrs.
- Estimates of lifetimes from the equipartition theory (Burbidge 1959) matches precession timescale.
- The calculated separation of binary SMBH (if present) to be ~0.02 pc using Begelman et al. (1980).

Rubinur et al. (2017)

Results: A confirmed DAGN, S-shape source and more

- Spectral index map and optical spectra, confirmed dual AGN in one dual core galaxy with separation ~5”.
- While other two can be dual AGN or AGN+SF nuclei pairs.
- We found that not good indicators of dual/binary AGN. Instead, closely interacting galaxies or merger remnants are better candidates for detecting dual AGN.



Rubinur et al. (2018, 2019)

Galaxy Merger and its effects: Star- formation and AGN feedback

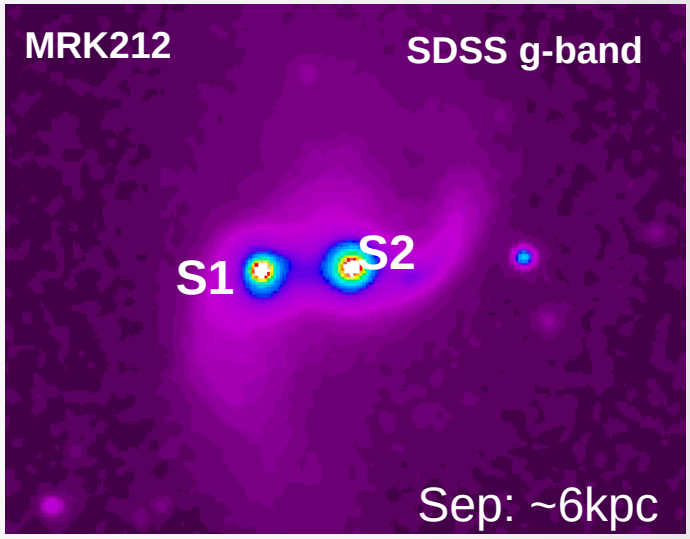
- The models predict an increase of the star formation rate during mergers (e.g. Duc et al. 2000).
- **AGN feedback:** After reaching a certain critical mass of SMBH, AGN gives out energy to the surrounding medium via winds, jets and radiation. These can enrich the circum-galactic medium (CGM), triggering star formation by shocking gas as well as suppressing star-formation by blowing out the gas.

Sample: We complied observed a sample of 10 dual nuclei galaxies with UVIT on board Astrosat.

www.camaracoin.org

Sample Galaxy: MRK 212

- MRK 212 : Merger galaxy with two nuclei in SDSS optical and FIRST radio image.
- Redshift: 0.023
- Two nuclei are at the separation of ~6kpc.
- Core 2 has SDSS spectra.



www.sdss.org

Mezcua et al. (2014)

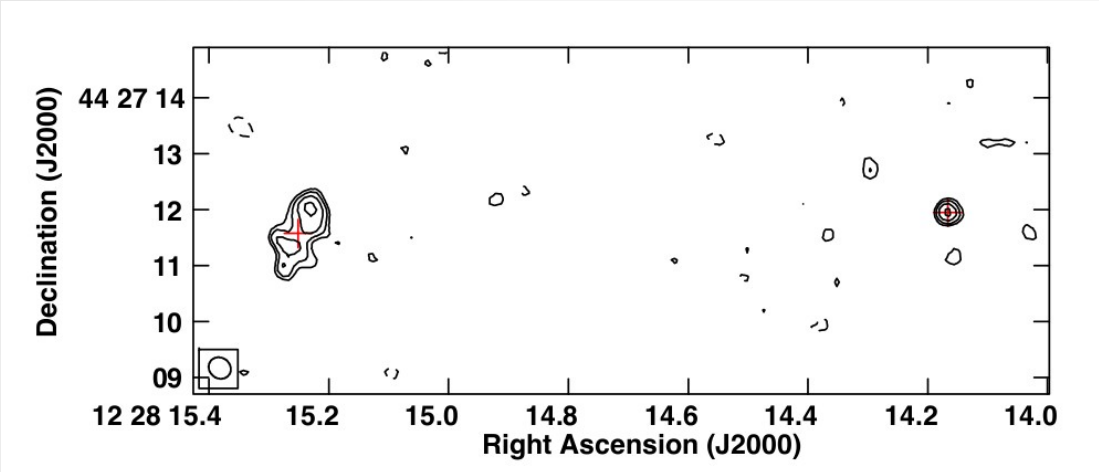
Motivation:

1. Two nuclei are AGN or star-forming nuclei?

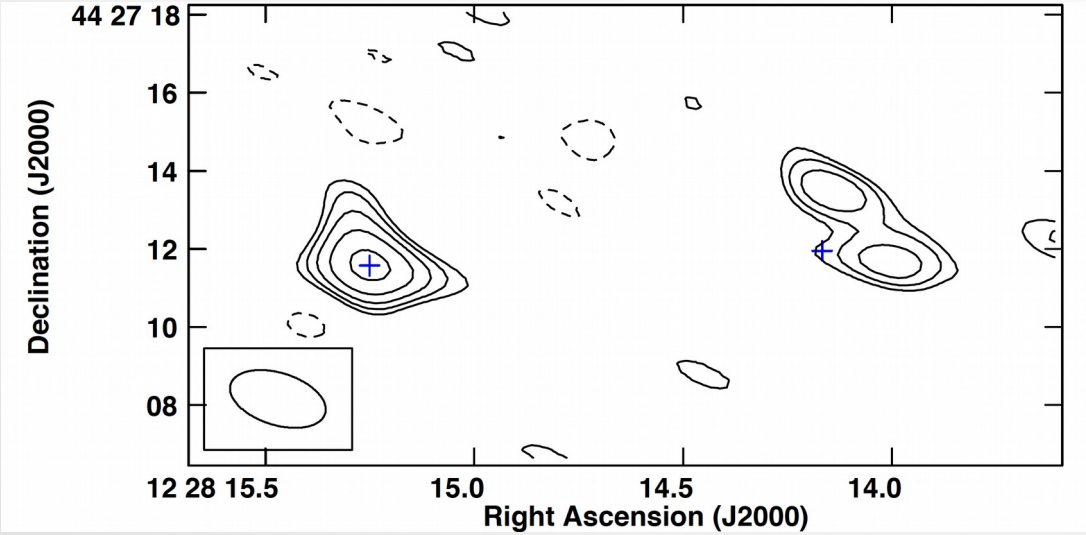
2. AGN outflows or star-formation winds?

Data: UVIT deep observations, radio continuum data from EVLA, uGMRT; optical spectra from HCT.

EVLA Radio observations: 15 GHz and 8.4 GHz image

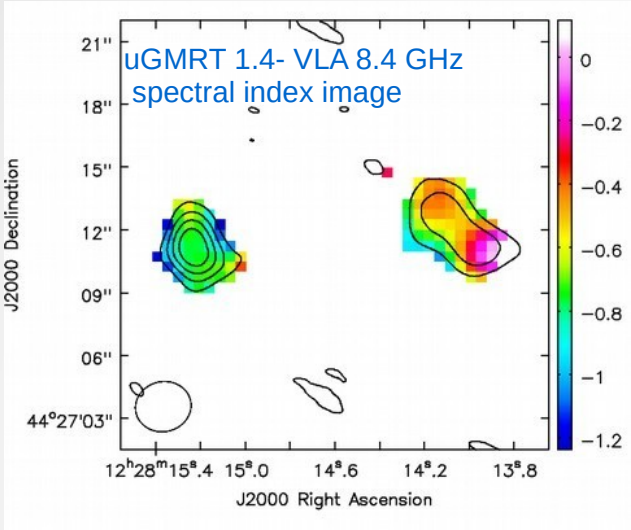


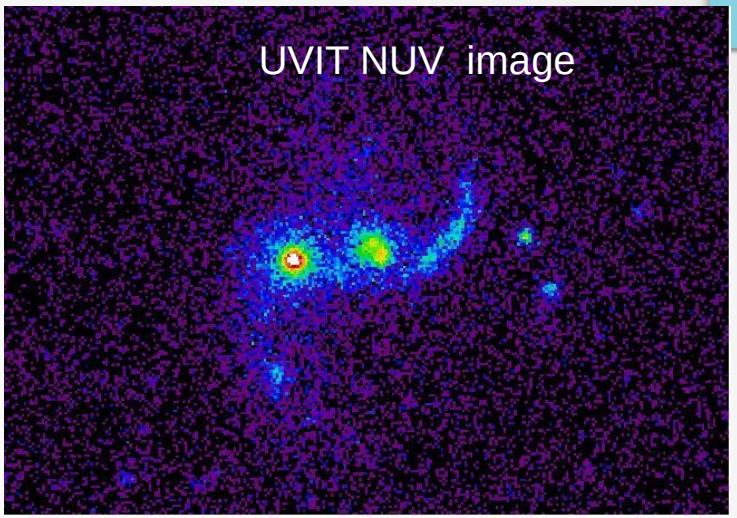
15 GHz contour image. Red crosses are the optical position obtained from Pan-STARSS1 r-band image.



8.46 GHz contour image with optical position from Pan-STARSS1 in blue crosses. There is a shift of 1arcsec.

Results: UVIT sample galaxy, MRK 212



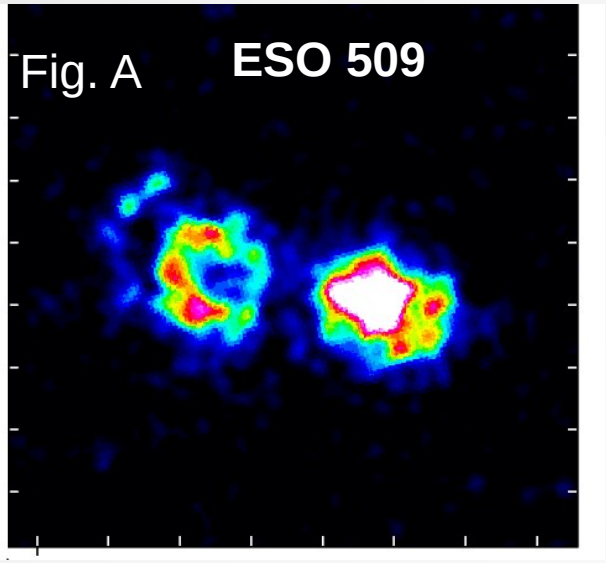


- The UV SF knots around the right nuclei coincide with the extended radio structure
- The radio spectral indices are consistent with SF.
- Radio morphology, spectral index, optical spectra supported low-luminosity dual AGN. Hernández-Ibarra et al. (2016)
- AGN positive feedback?

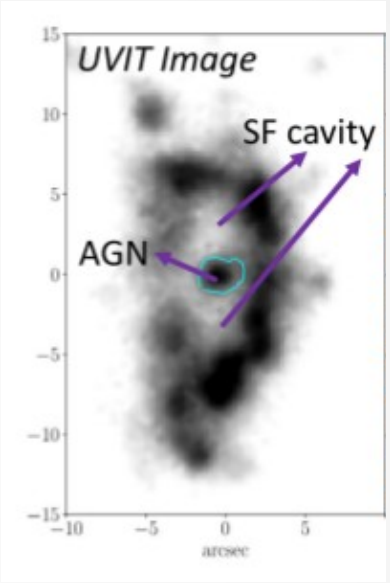
(**Rubinur et al. 2021**)

Ongoing project: Star-formation in galaxy mergers

Results:



Jellyfish galaxy JO201.



George et al. (2019)

- (Fig. A) A UV deficiency in the left nuclei supports results of x-ray study (Kosec et al. 2017): a low accretion state?
- Star-forming (SF) knots are resolved in many sample galaxies.

Rubinur et al. (2021), Rubinur et al. 2022a (to be submitted soon)

Conclusion and Summary

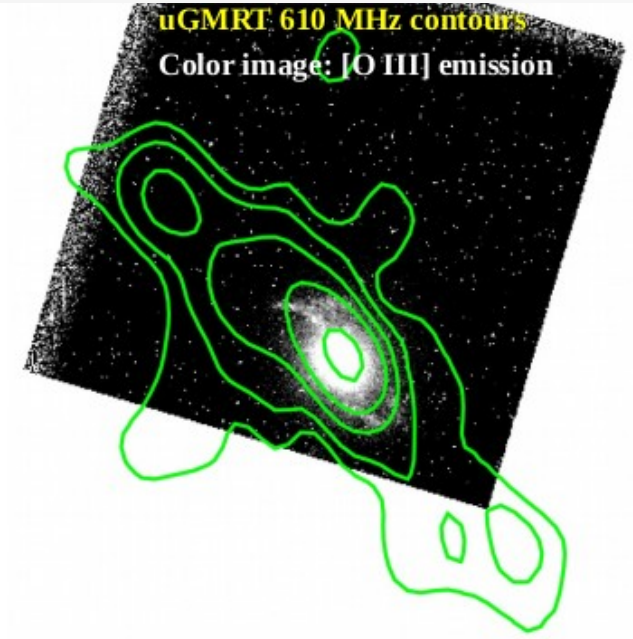
- We have detected three dual core, two S-shaped* core-jet, one extended source and 13 compact single cores and one is not detected.
- The present data support low-luminosity dual AGN in MRK 212.
- Recent UVIT 15 ksec image has resolved the star-forming regions.
- UVIT observations of three dual nuclei galaxies show signatures of AGN feedback.

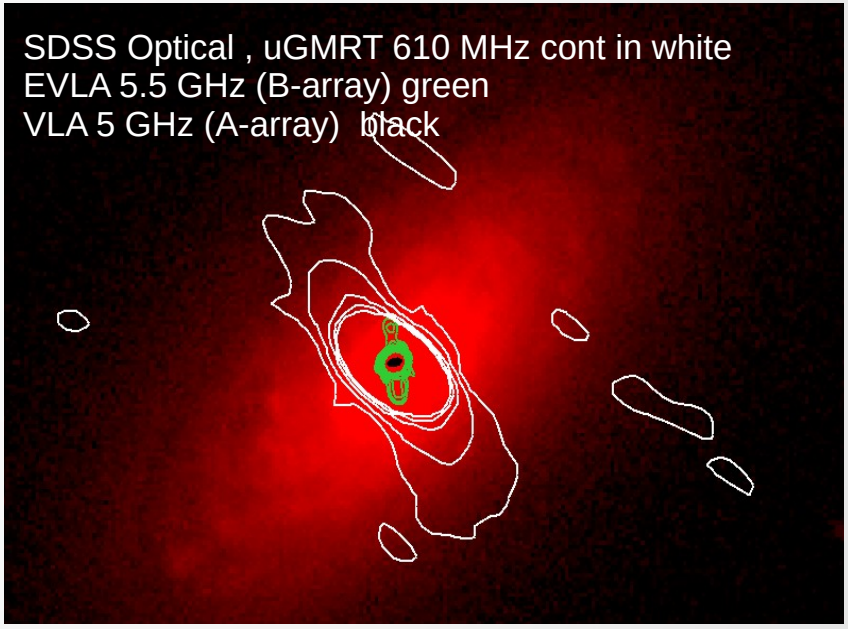
Ongoing projects: Understanding kilo-parsec radio structure (KSR) in low-luminosity AGN using GMRT

Motivations: origin of KSR, evolution of AGN jet, AGN feedback by radio outflows

Sample:
28 Seyferts

Observation:
GMRT 325 and 610 MHz and Archival data.





Results: 64% of KSR has AGN origin, signatures of Jet-ISM interaction, episodic AGN activity.

Rubinur et al. (2022b); in preparation