Particle acceleration and magnetic field in the hotspot of 3C445

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Motivations

Constrain the main particle acceleration process responsible for optical synchrotron emission in the hotspot region on kpc scale

Understanding the role of the magnetic field and describing its topology with adequate resolution

Outline

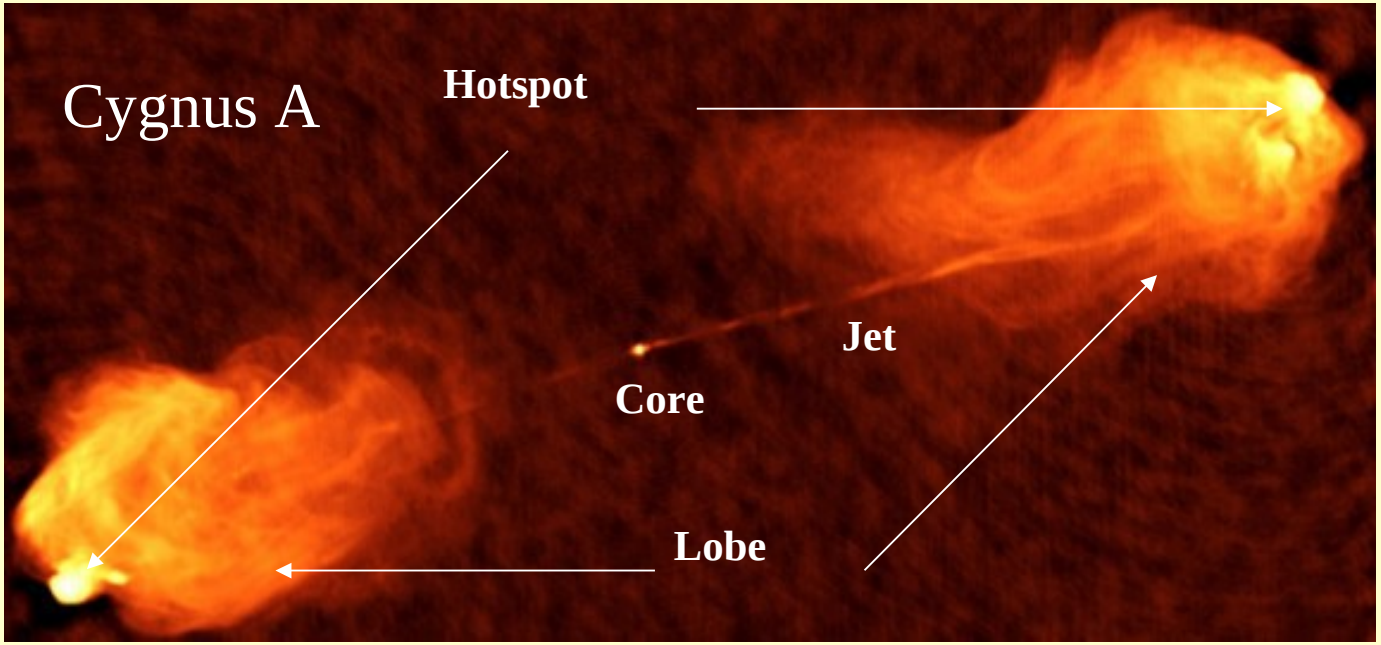
Hot spots in radio galaxies

Optical synchrotron emission on kpc scale

The peculiar case of 3C445 South and the role of ALMA observations

Powerful radio sources

Synchrotron radiation from relativistic particles in a magnetic field



Relativistic particles are reaccelerated in the hotspots and deposited in the lobes where they age

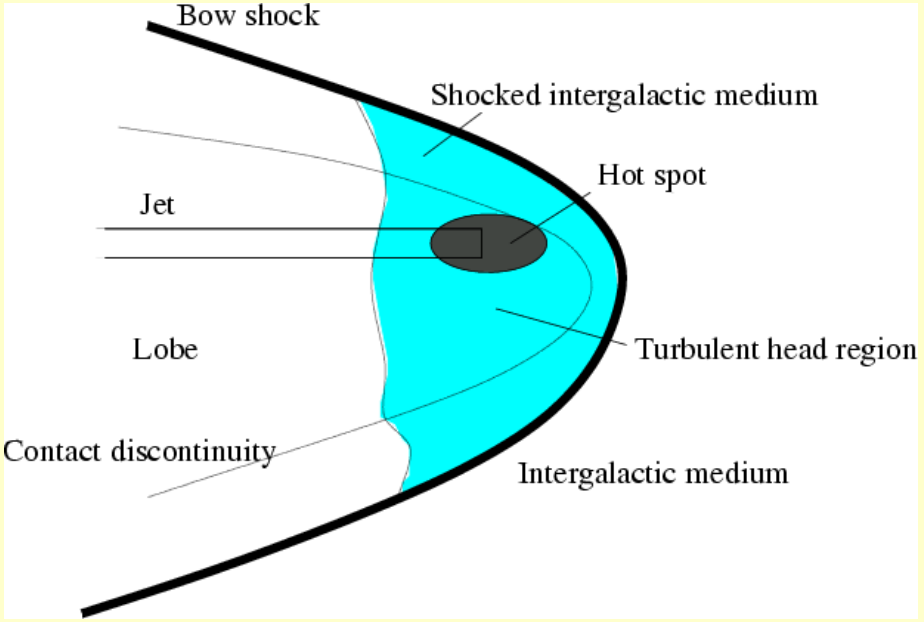
Hot spots

Hot spots are bright and compact regions located up to hundred kpc or Mpc distance from the core.

• Loss-free particle transport may work for HS not far away from the core:

$$\nu_0 \propto B/D^2_{max}$$

• In-situ particle acceleration from shocks and turbulence due to jet-ICM interaction.



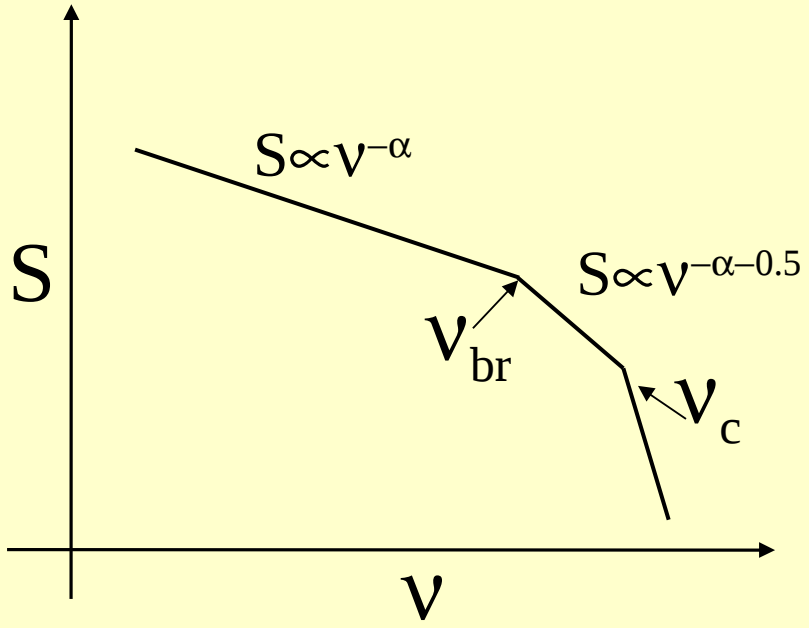
Synchrotron spectrum

- Power-law up to ν_{br};

  $\alpha \sim 0.5 - 0.7$

- ν_{br} ⟶ oldest electrons;

- ν_{cutoff} ⟶ acceleration/losses;



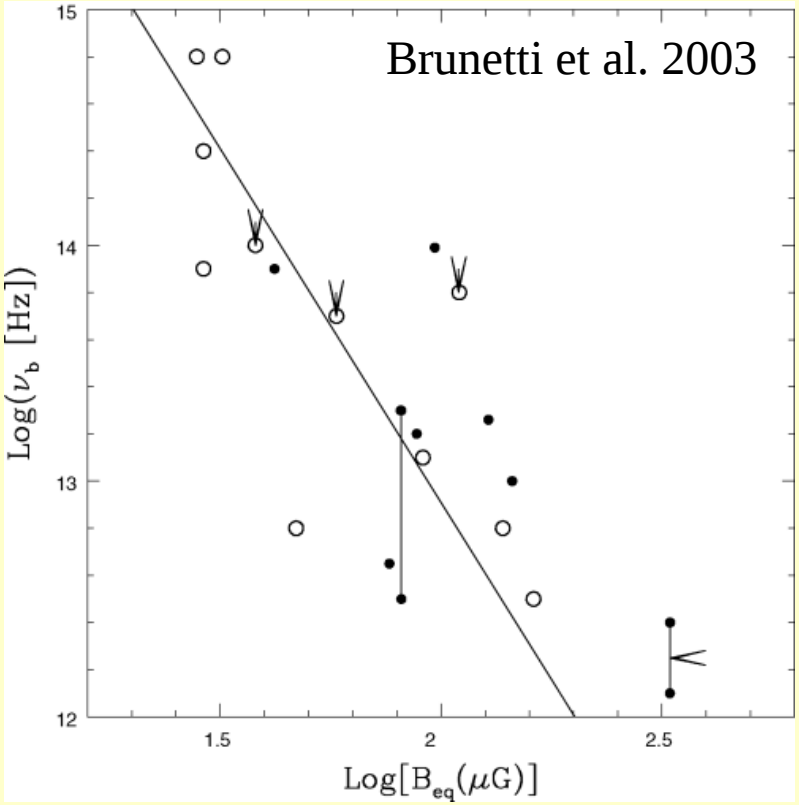
Not many HS observed in NIR/optical

The role of the magnetic field

The magnetic field strongly influences the spectral shape:

- $L \propto B^2 \gamma^2$
- $\nu_{br} \propto B^{-3} t_{syn}^{-2}$
- $\nu_{br} \propto B^{-3} \gamma^2$

The lower B, the longer the electron radiative age, the higher ν_{br} (ν_c)



Sample selection

From the 2-Jy sample, we selected the hot spots with:

- L ~ 10^{41} – 10^{42} erg/s;
- B ~ 40 – 130 μG.

The final sample consists of 10 objects:

3C 105S, 3C 195 N, S; 3C 227 E,W; 3C 327 E, W;
3C 403 W, 3C 445 N, S;

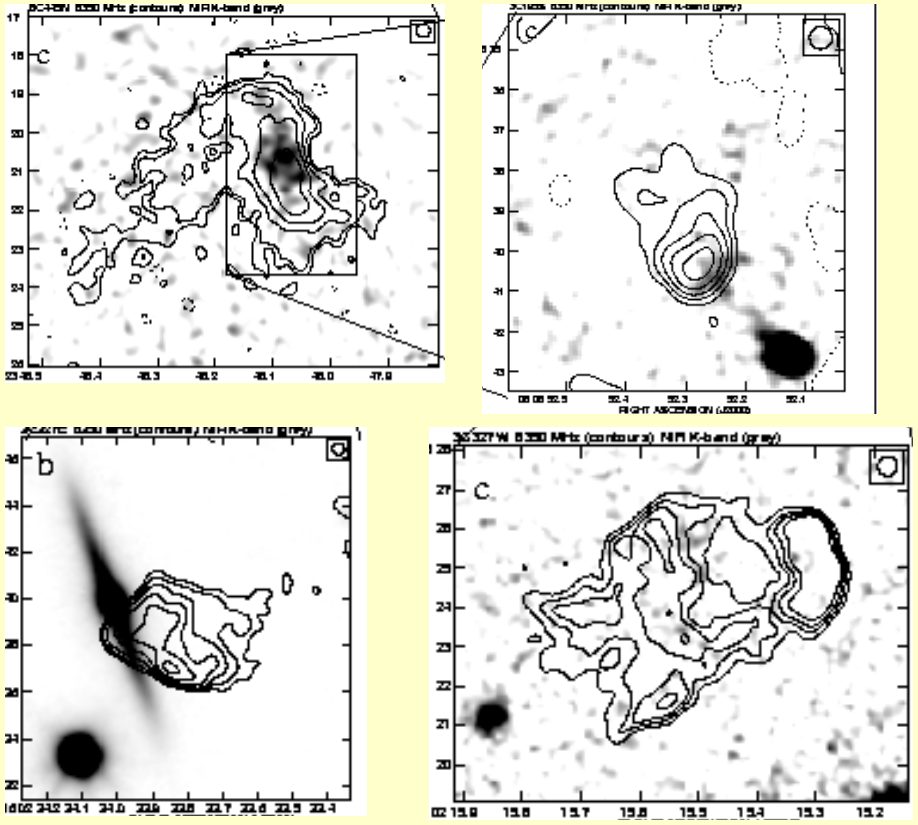
Target of:

- VLA observations at 1.4, 5, and 8.4 GHz;
- VLT observations in K, H, J, R and B bands;

VLT observations

Unexpected high detection rate (45% - 67%):

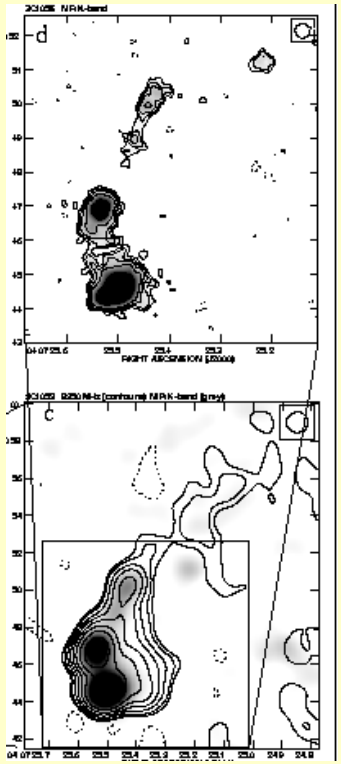
- 4 HS have a clear optical emission (3C 105 S, 3C 227 W, 3C 445 N, 3C 445 S);
- 3 HS with no optical emission (3C 195 N; 3C 327 W; 3C 403 W)
- 2 HS with no secure optical identification (3C 195 S; 3C 227 E)
- 1 HS is hidden by a foreground galaxy (3C 327 E)



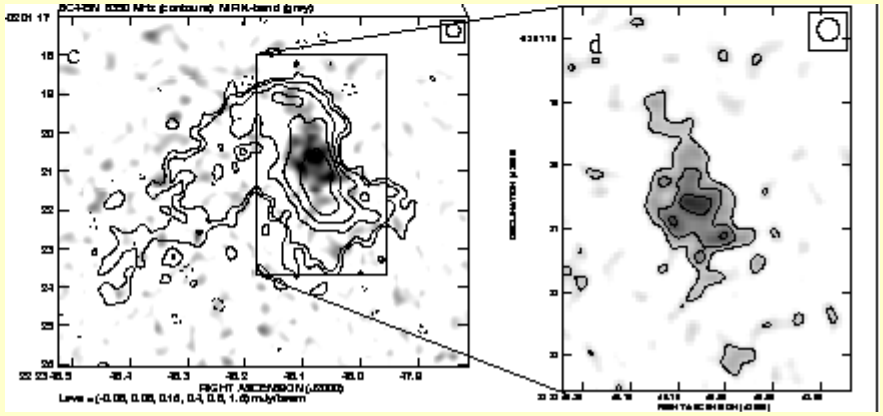
Mack et al. 2008

Extended optical emission

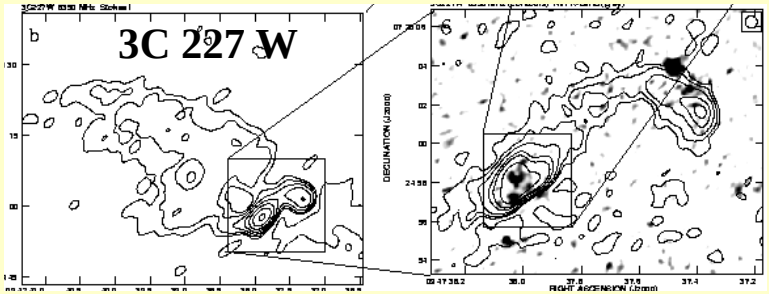
3C 105 S



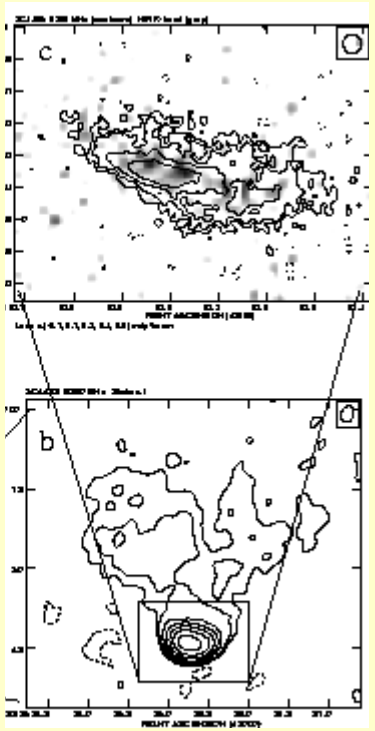
3C 445 N



3C 227 W



3C 445 S



Mack et al. 2008

Indication of efficient additional acceleration mechanism taking place across the kpc-scale HS region

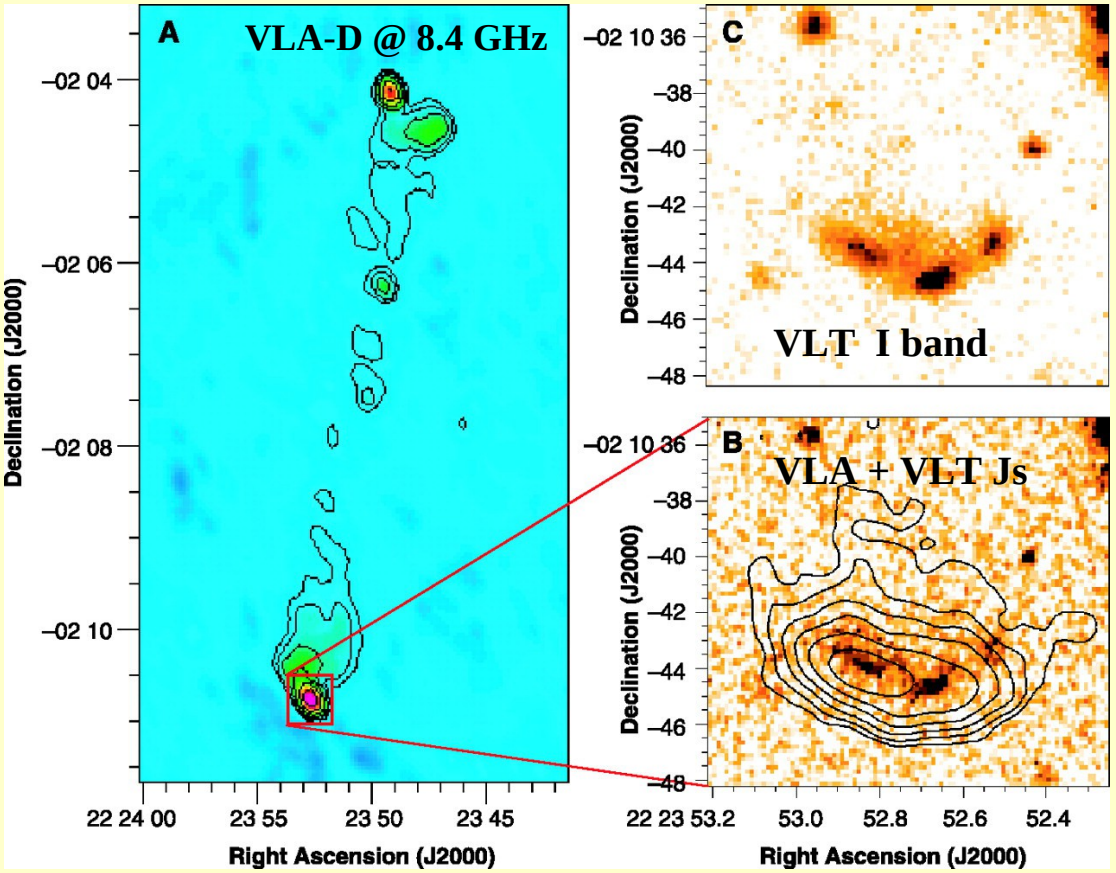
The peculiar case of 3C 445 South

Host galaxy:

- BLRG at z=0.05623;
- LS ~ 600 kpc;

The hotspot:

- LS ~ 10 kpc;
- Arc-shaped structure;
- Resolved into 3 components;
- Diffuse optical emission on kpc-scale;



Prieto et al. 2002

High resolution multi-band observations

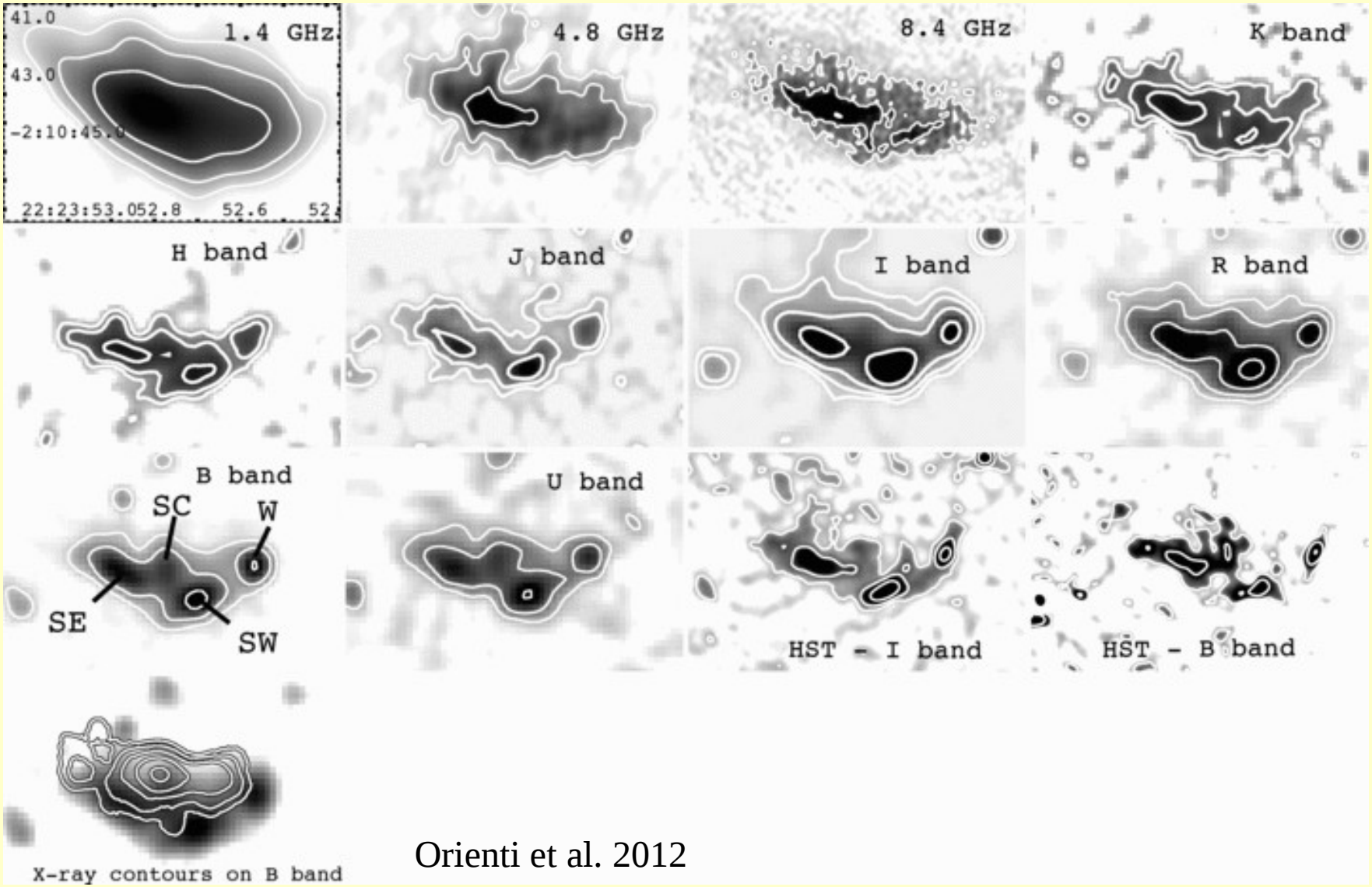
Radio: VLA-A at 1.4, 4.8, and 8.4 GHz

NIR: VLT-ISAAC in K, H, Js bands

Optical: VLT-FORS in I, R, B, U bands
HST in I, U bands

X-rays: *Chandra* 0.5-7 keV
Swift 0.3-10 keV

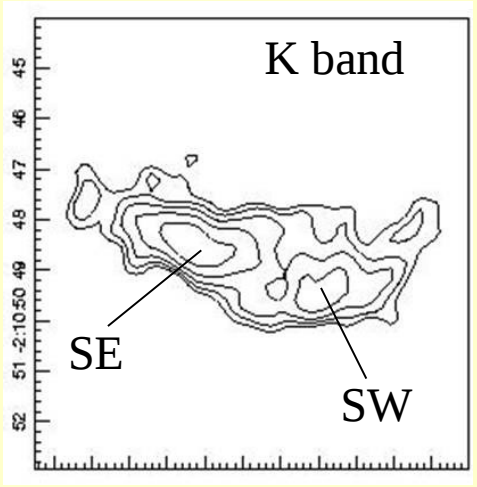
High resolution multi-band observations

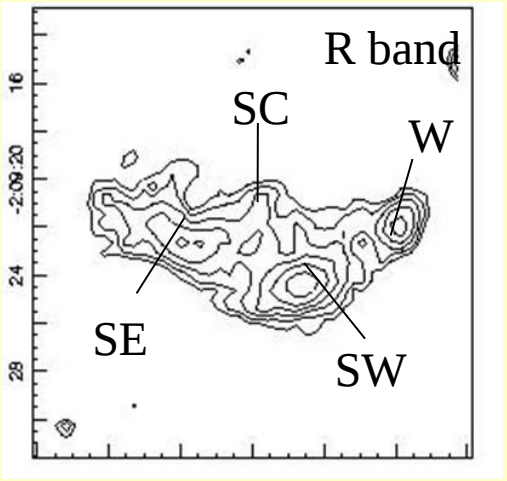


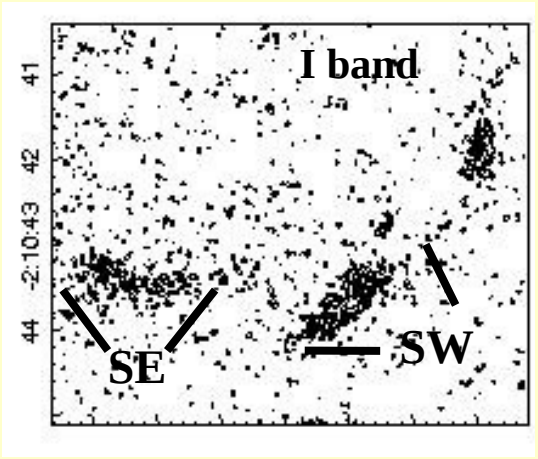
Orienti et al. 2012

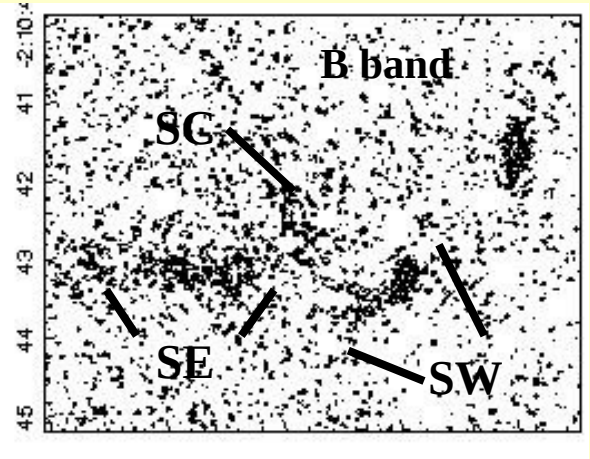
NIR/optical images

- Similar in structure and size to the radio emission;
- 2 main components visible in all bands;
- W component is likely a background galaxy;
- SC component visible in R, B, U bands, **not** at lower energies;







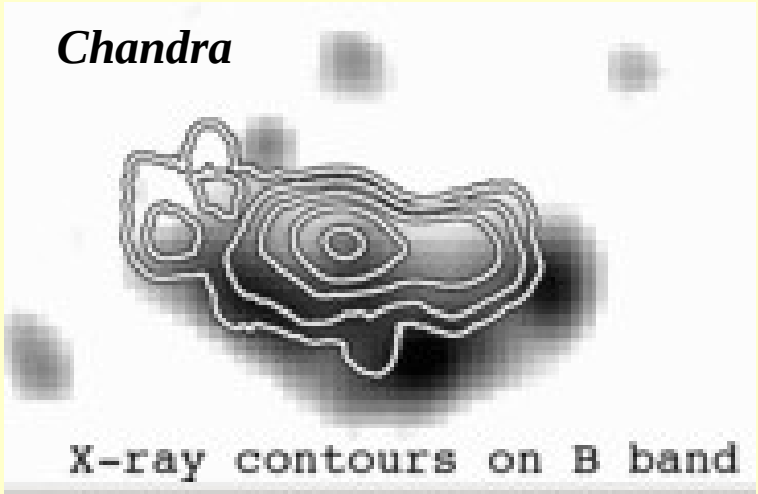


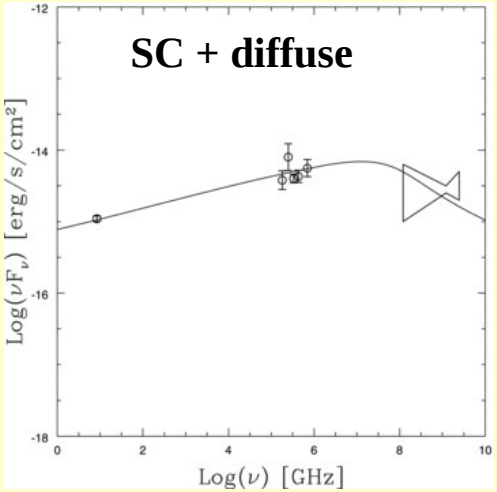
Orienti et al. 2012

X-ray emission

- X-ray emission from a region of ~6 kpc in size
- Displacement between X-ray and radio-to-optical emission
- SC component is ~1 arcsec downstream the X-ray peak

Orienti et al. 2012





SC+diffuse emission may account for a significant part of the X-ray emission interpreted as synchrotron radiation

Ongoing efficient particle acceleration

Open question

What is the main particle acceleration mechanism?

Scenario 1: Efficient spatially distributed Fermi-II acceleration processes driven by turbulence

Scenario 2: Multiple/complex shock structure produced in the hotspot region with SC and X-ray peak marking the place of the most recent episode of acceleration

Observational expectations

- **Scenario 1:** turbulent structure of the magnetic field

  Low fractional polarization ($\lesssim$1-3%)

  Random orientation of the EVPA

- **Scenario 2:** Several shocks locally compressing and aligning the magnetic field

  High fractional polarization (> 5-10%)

  EVPA trace the structure/topology of the magnetic field

The role of ALMA

High resolution band-3 observation in full polarization

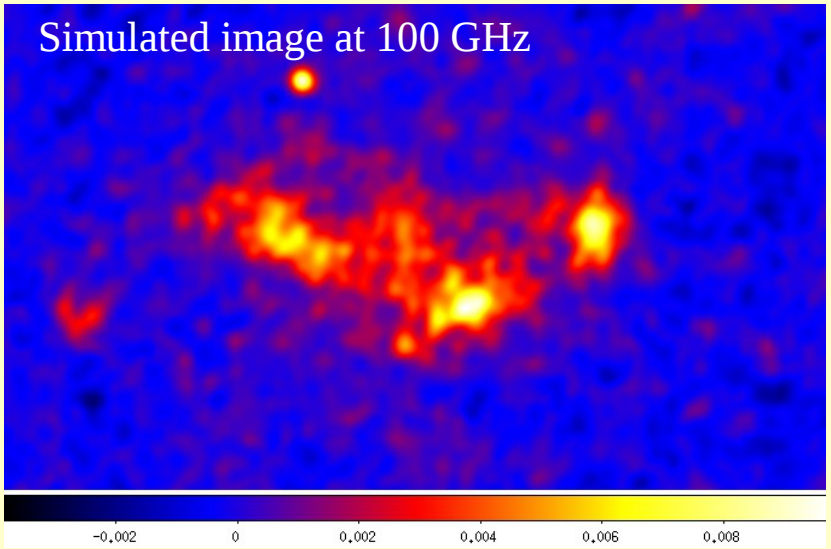
On-source time: ~2hr

Total time: ~3.7hr, OK for PA

rms = 0.01 mJy

S/R ~100

beam = 0.5 arcsec



Rank: B, 10-20%

Why ALMA?

Negligible contamination from the lobe

No significant RM affecting the determination of the intrinsic EVPA

Conclusions

Waiting for the observations.....

BACKUP SLIDES

Spectral energy distribution