NGC 1167 (B2 0258+35):

A gas-rich, compact radio galaxy

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Outline

- Introduction to (compact) radio galaxies
- Data of NGC 1167
- Large-scale disk: Evidence for halo gas
- A 250 kpc relict structure
- Nuclear HI absorption
- Outlook

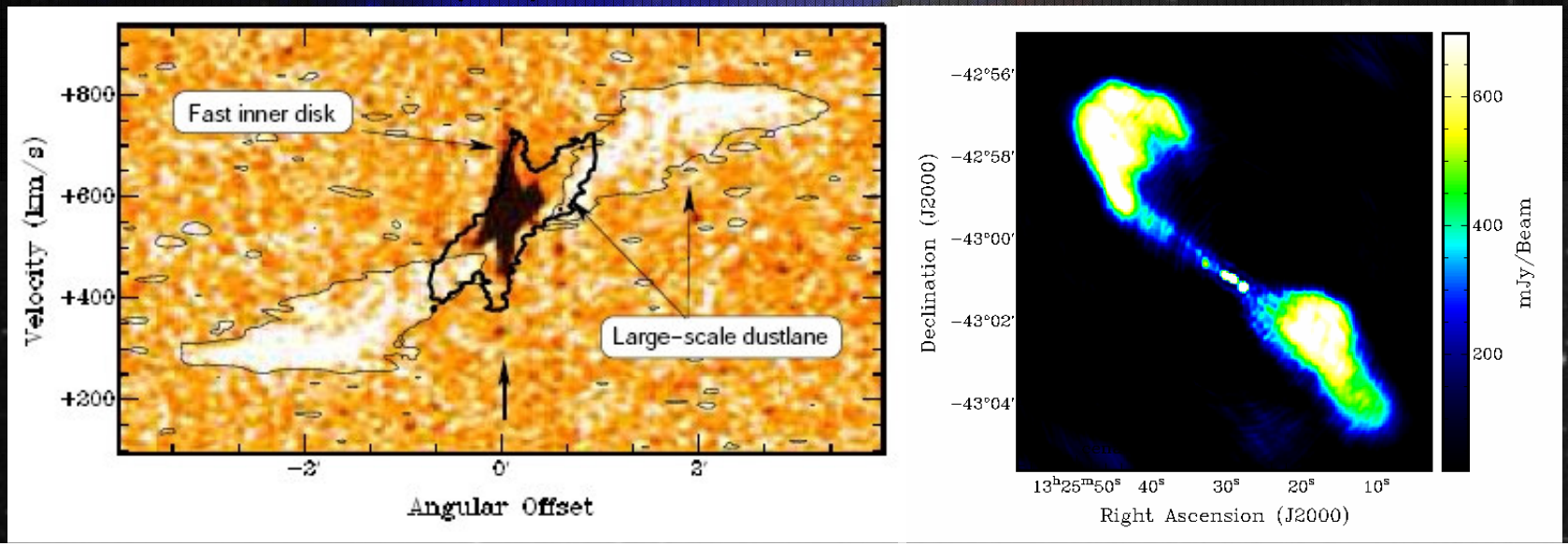
Low luminosity radio Galaxies:

- Close enough to be observed in the HI emission (and absorption) line
- HI can trace merger, interaction and accretion events
- Infalling HI can trigger nuclear activity

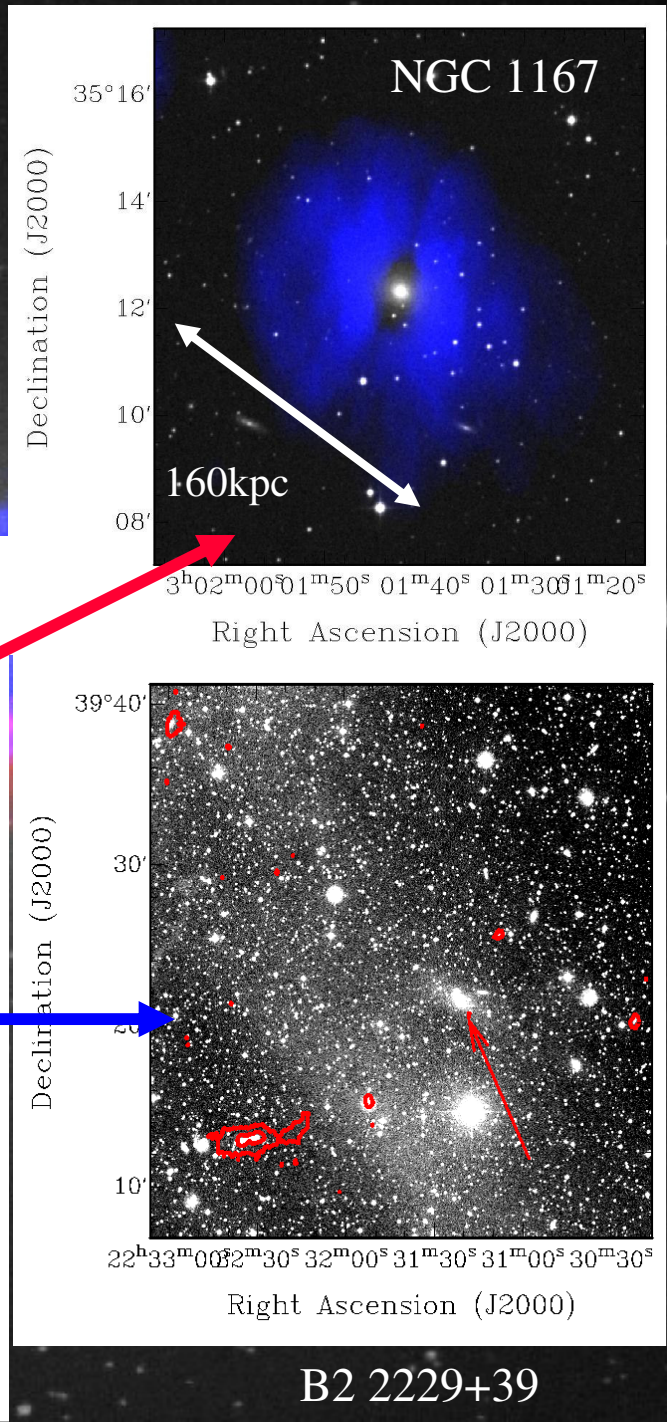
→ HI is the perfect tracer

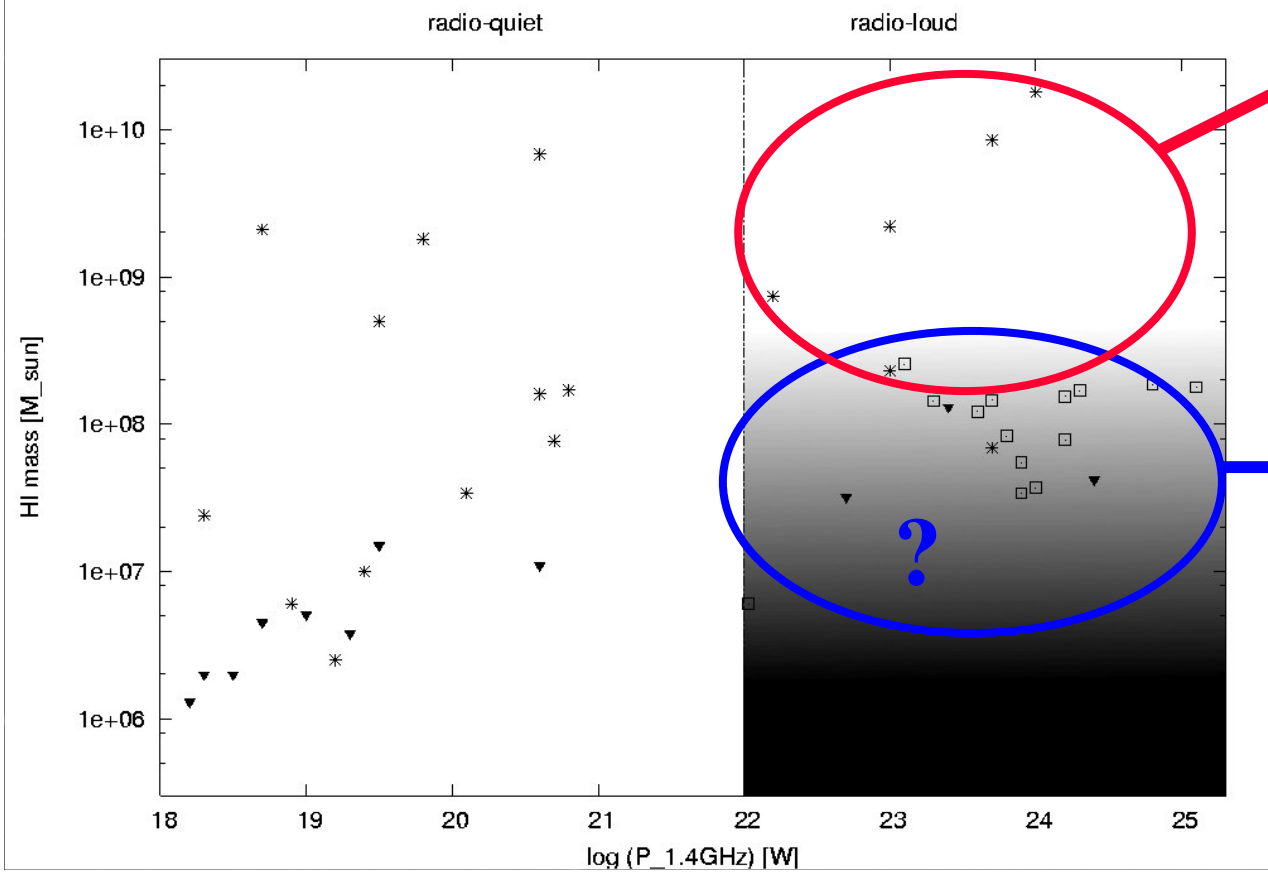
Centaurus A:

Morganti et al. 2008, A&A 485, L5
Struve et al. 2009 in prep.



FR-I vs. Compact:





Compact radio galaxies:

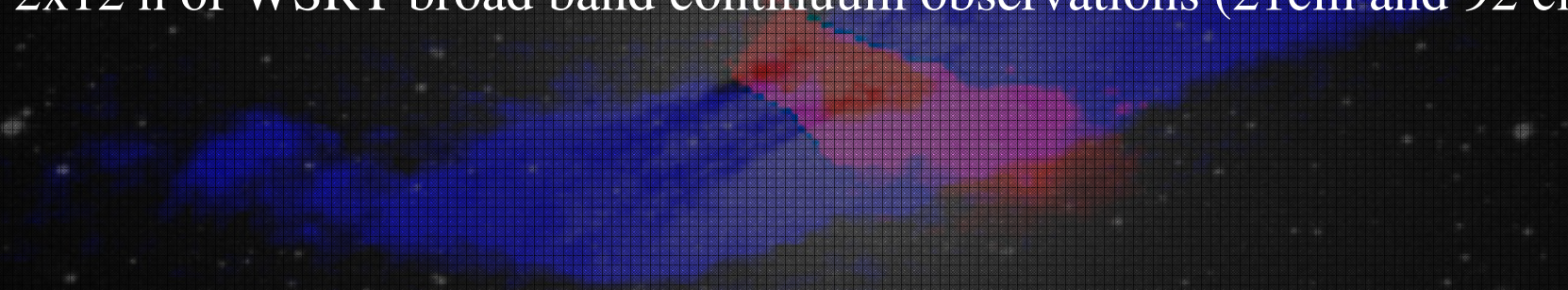
Central Questions:

- What triggers/causes the AGN activity?
- How do compact radio galaxies form and evolve?
- What is the accretion mode (interaction, merging, cold accretion)?

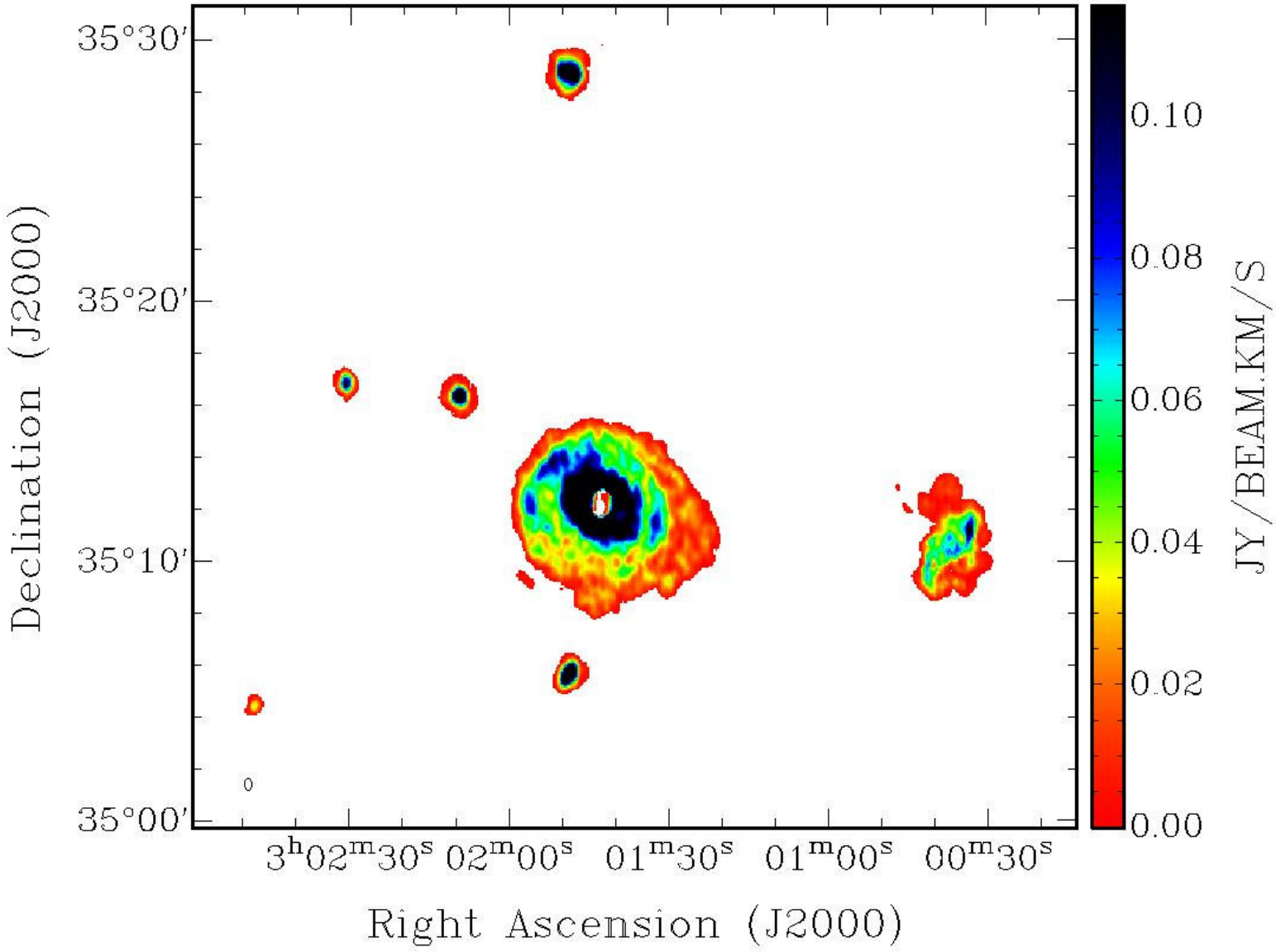
NGC 1167 (B2 0258+35):

New data:

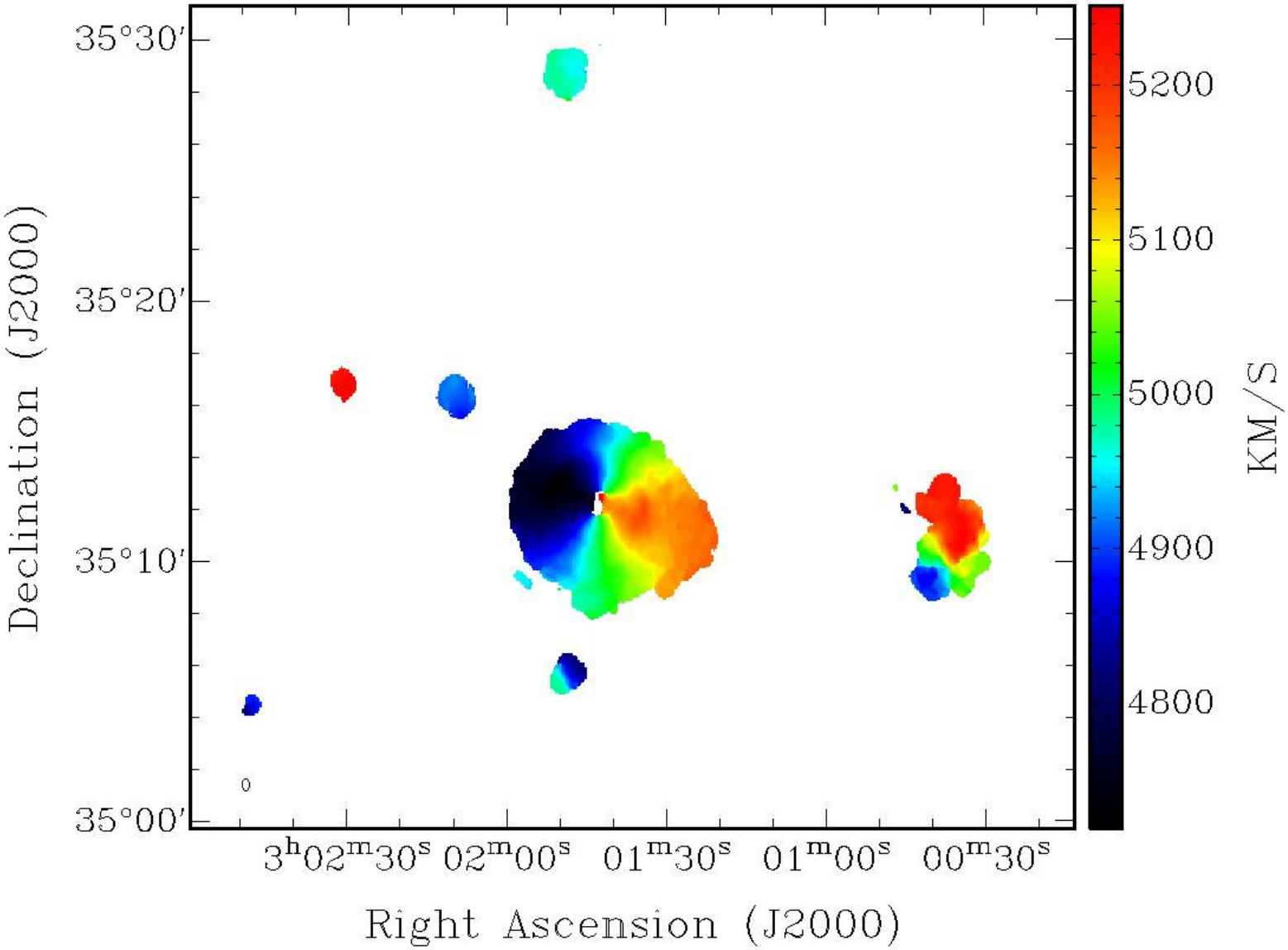
- ~110 h of WSRT HI observations (20“ resolution)
- 8 h of VLA-A HI absorption observations (1“ resolution)
- 2x12 h of WSRT broad band continuum observations (21cm and 92 cm)



- deepest HI observations of an early-type/radio galaxy
- (probably) deepest HI observations of such a massive galaxy (M_{dyn}>2.2e12M_{sun})

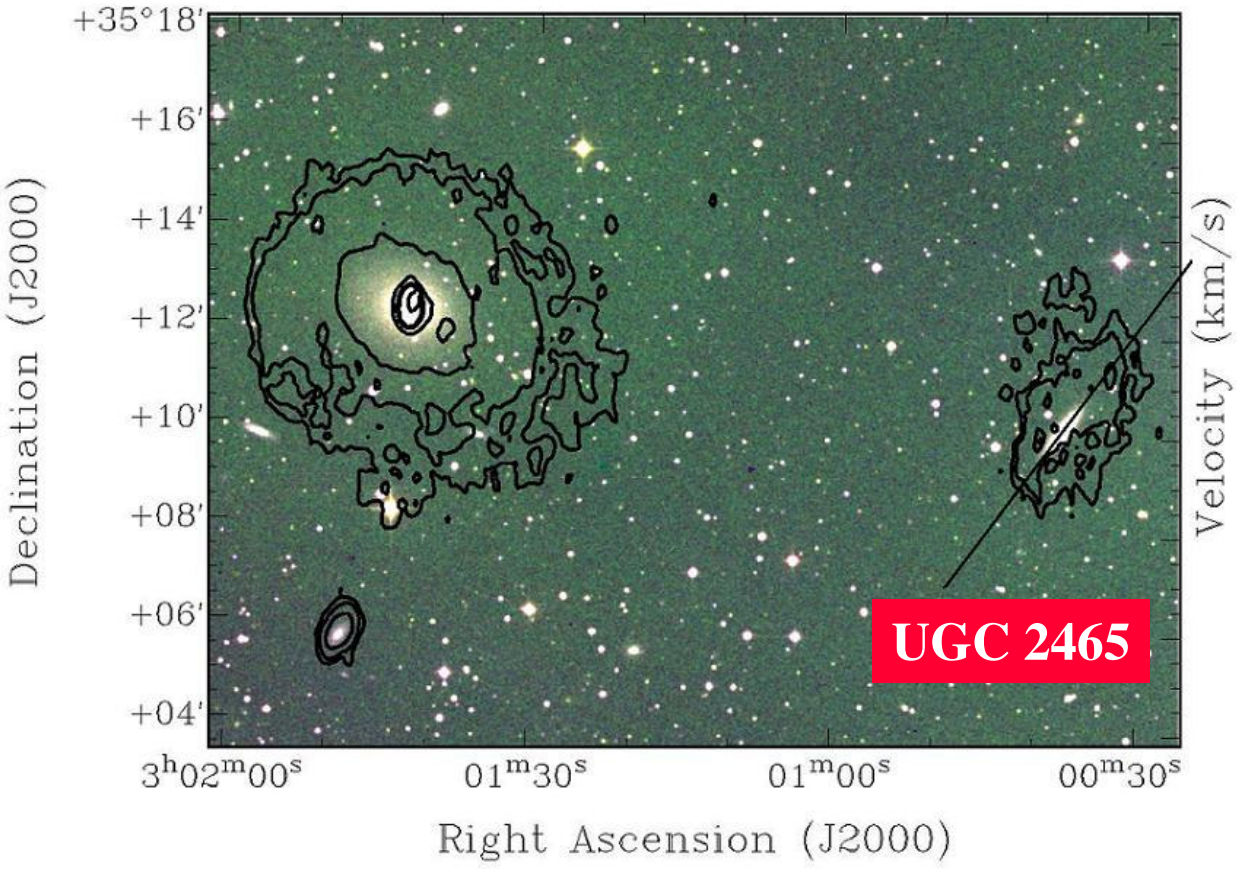


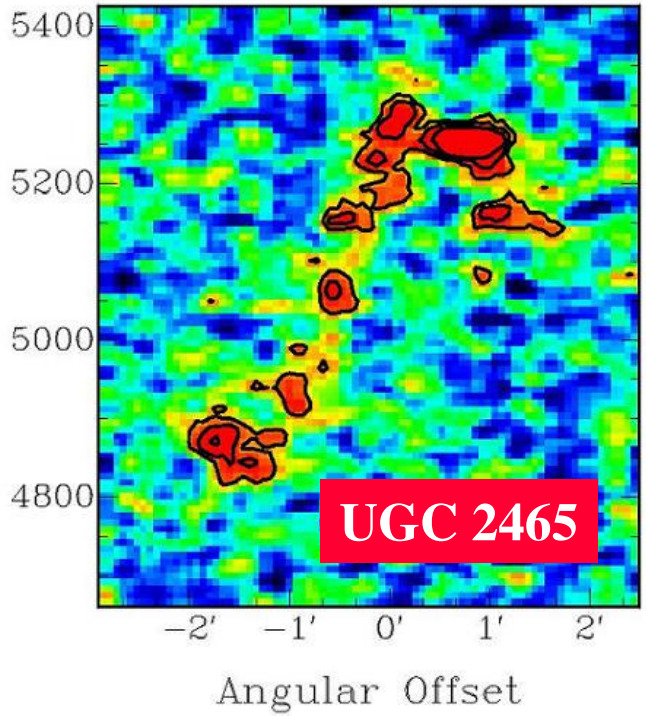
Total Intensity map



Velocity Field

NGC 1167 (B2 0258+35):

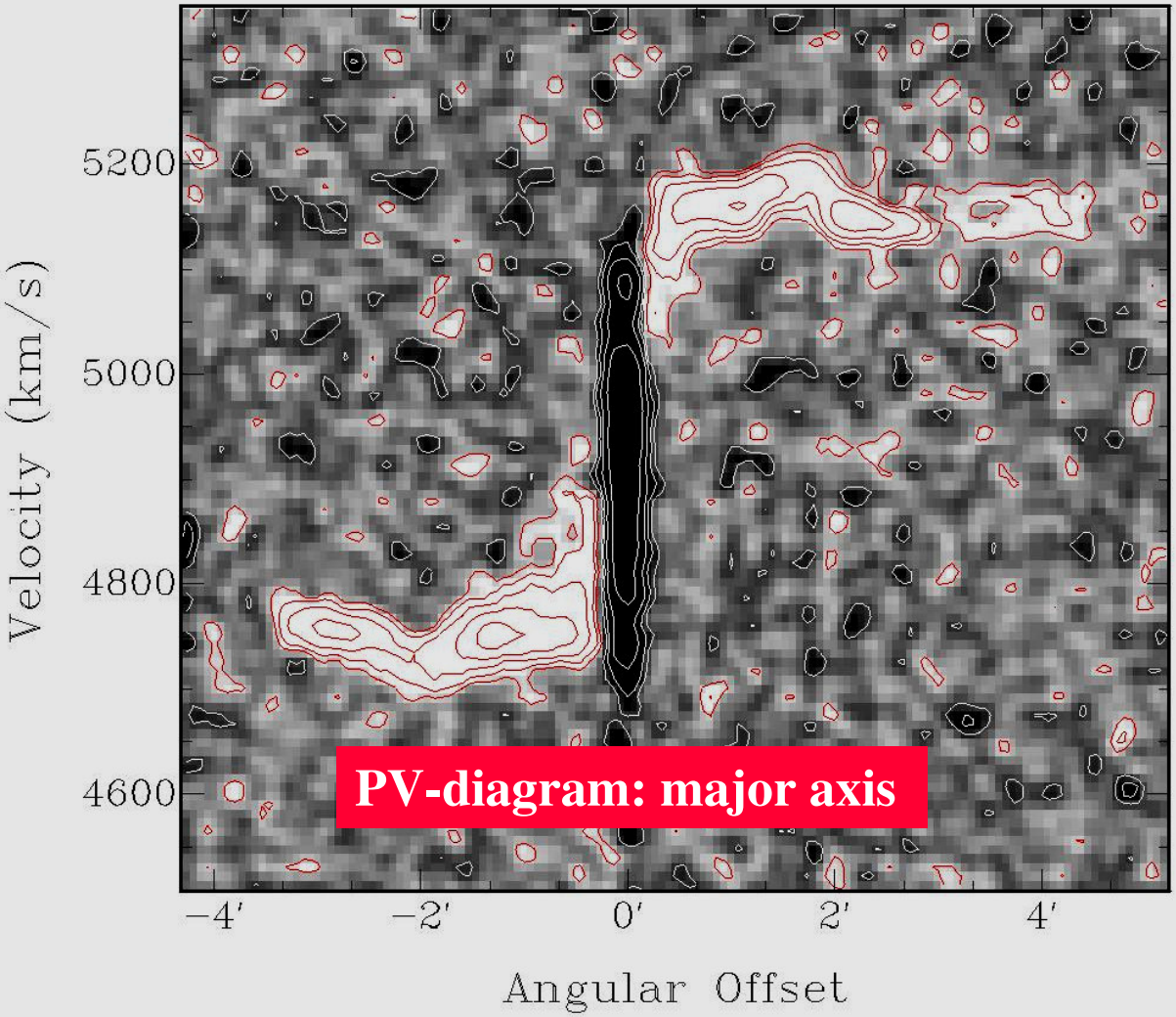




- Unsettled gas at r>75kpc in the west of NGC 1167
- UGC 2465 shows irregular HI kinematics
- But: Timescales are large: ~ 1 Gyr !!!

Current AGN activity not caused by a merger

NGC 1167 (B2 0258+35):



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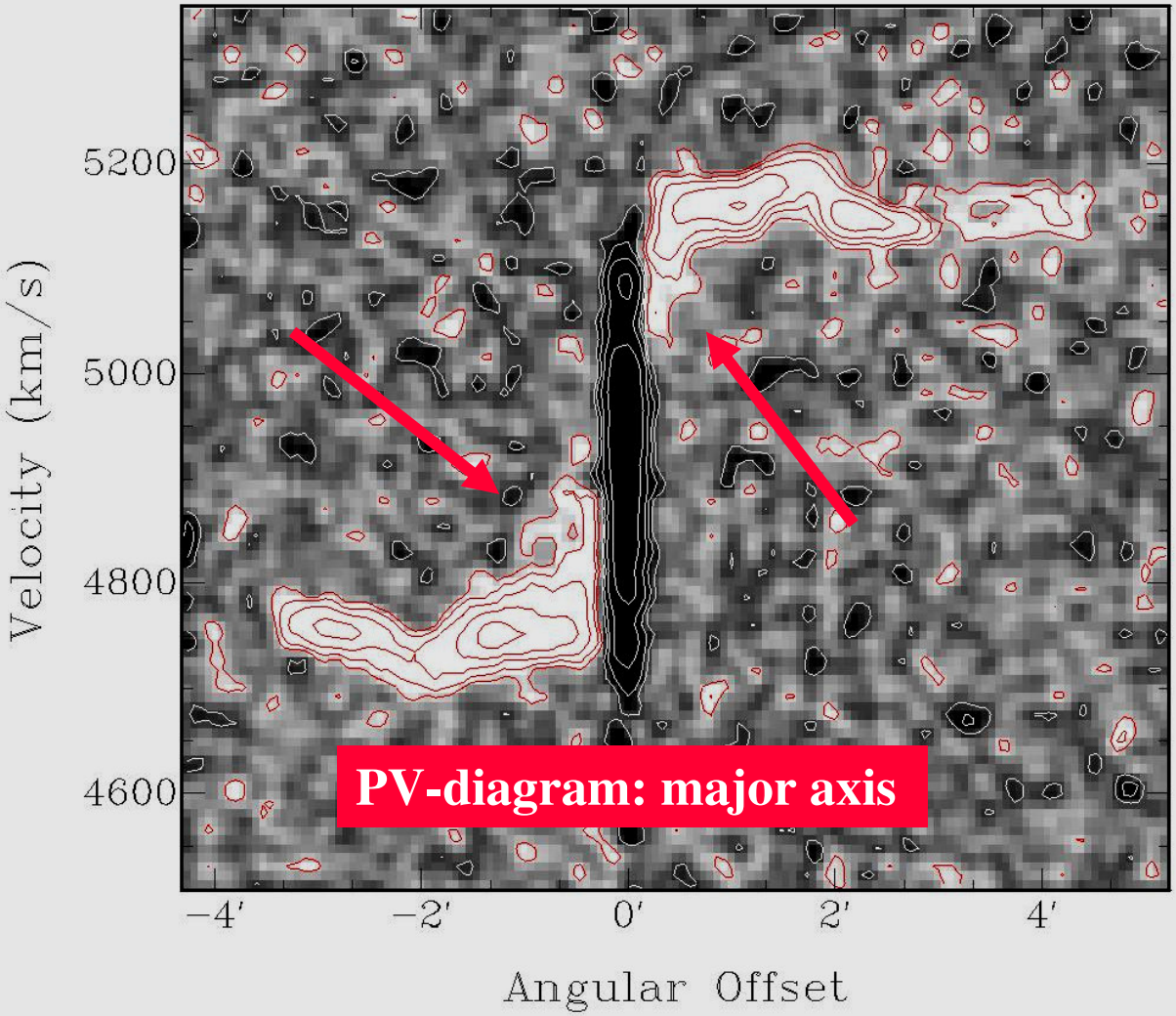

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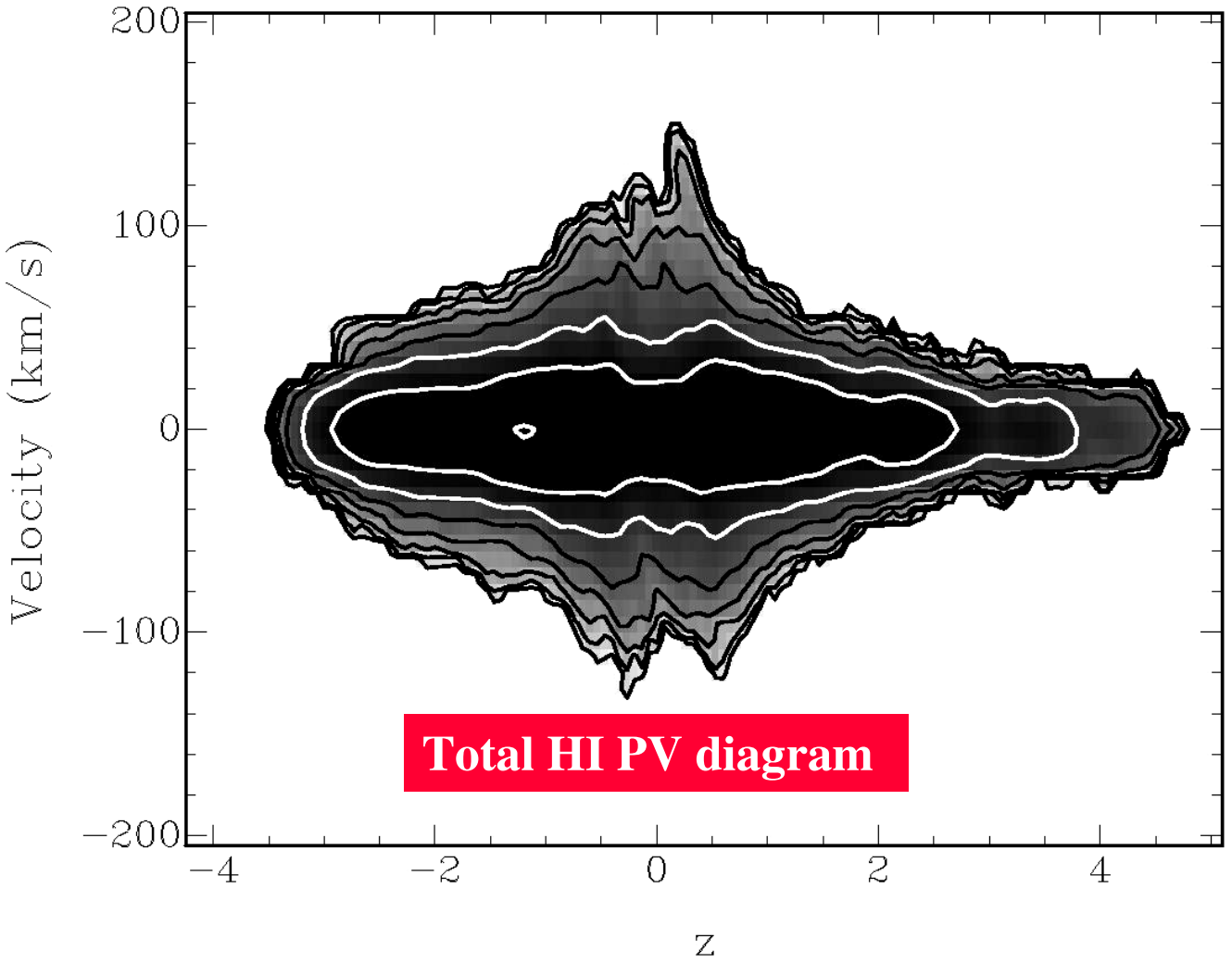


NGC 1167 (B2 0258+35):

Results I:

- HI detected in the halo
- BUT: Effect of beamsmearing needs to be further tested
- No current star formation (S0 galaxy!)

  - gas accreted from the IGM ("cold accretion")

  - gas blown into the halo a long time ago ("stellar mass loss/recycled gas")
- Halo gas provides the fuel for the AGN activity?

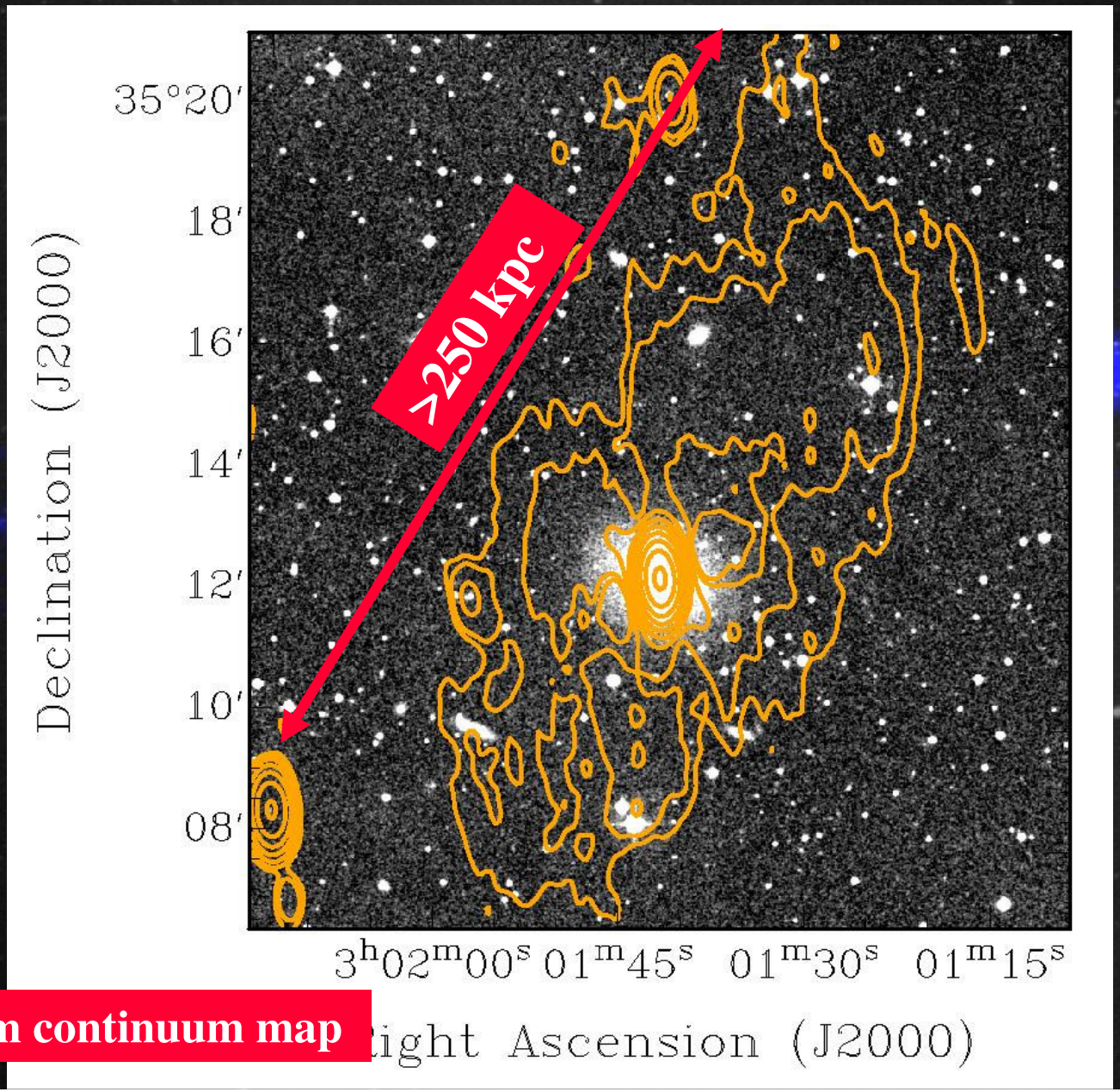
Why do we also care about halo gas?

- SFR and gas content of galaxies constant over cosmic times
- Star forming galaxies run out of fuel very quickly

→ Need constant gas supply

On-going analysis !!!

NGC 1167 (B2 0258+35):



WSRT 21cm continuum map

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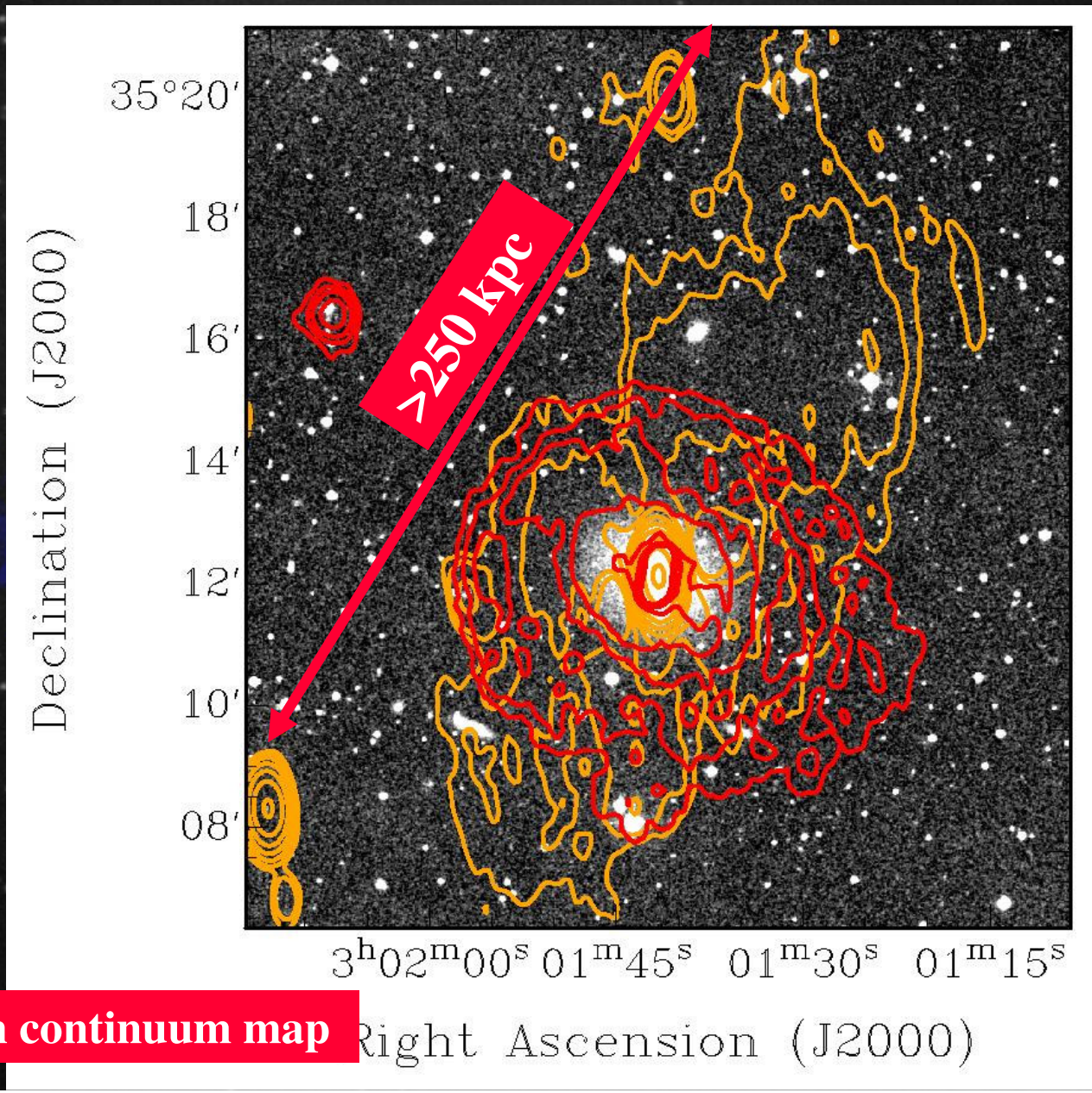

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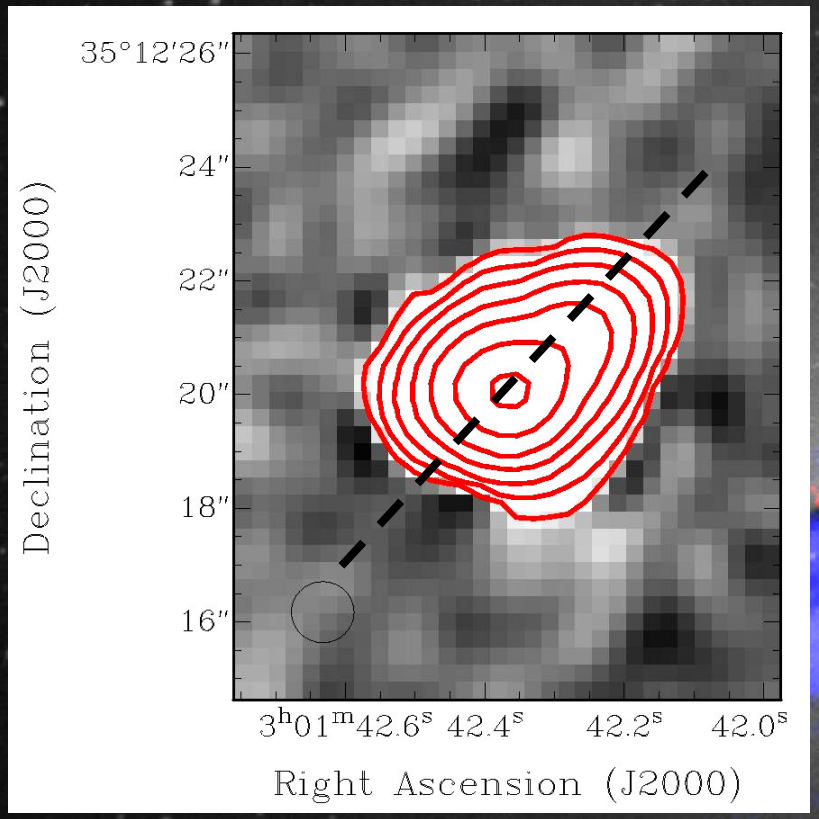

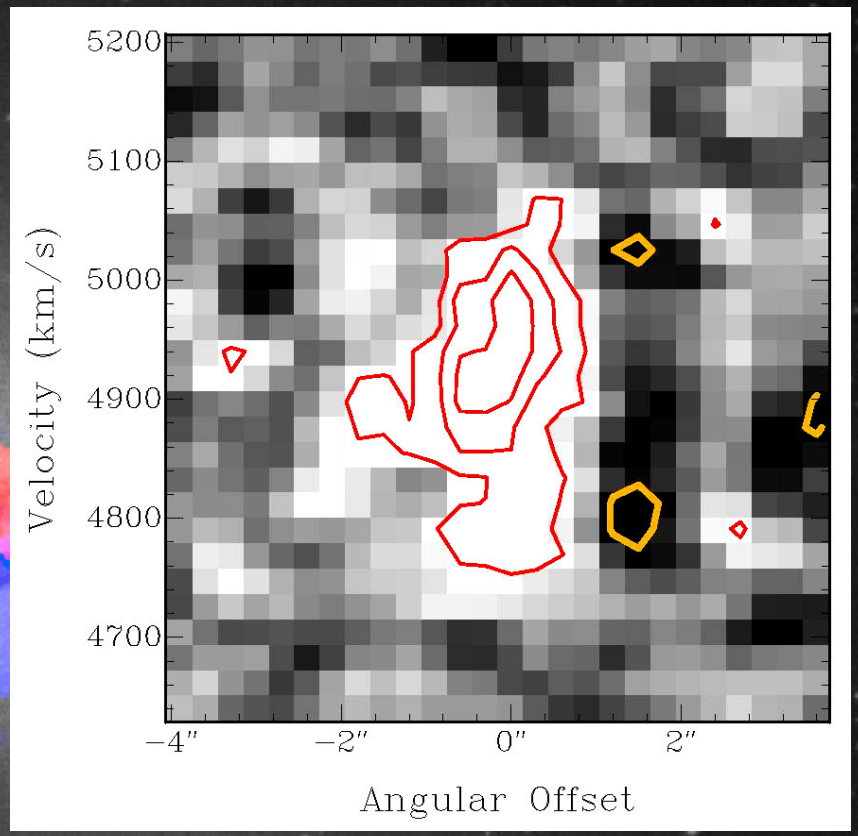

- Absorption is slightly extended along the radio-jet axis. Two components?
- Resolved component resembles large-scale disk?
- Unresolved circumnuclear disk, < 300 pc in diameter?

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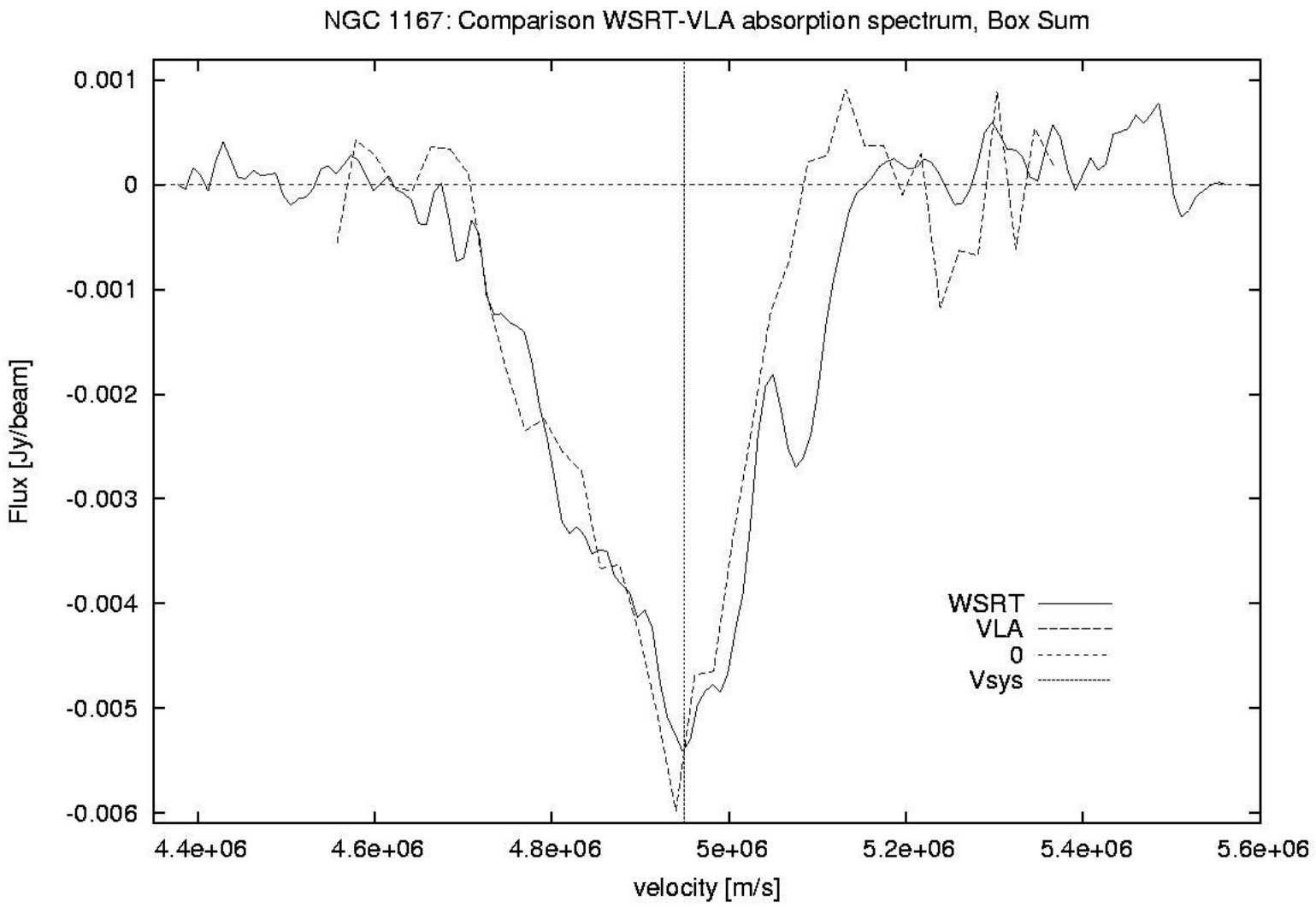

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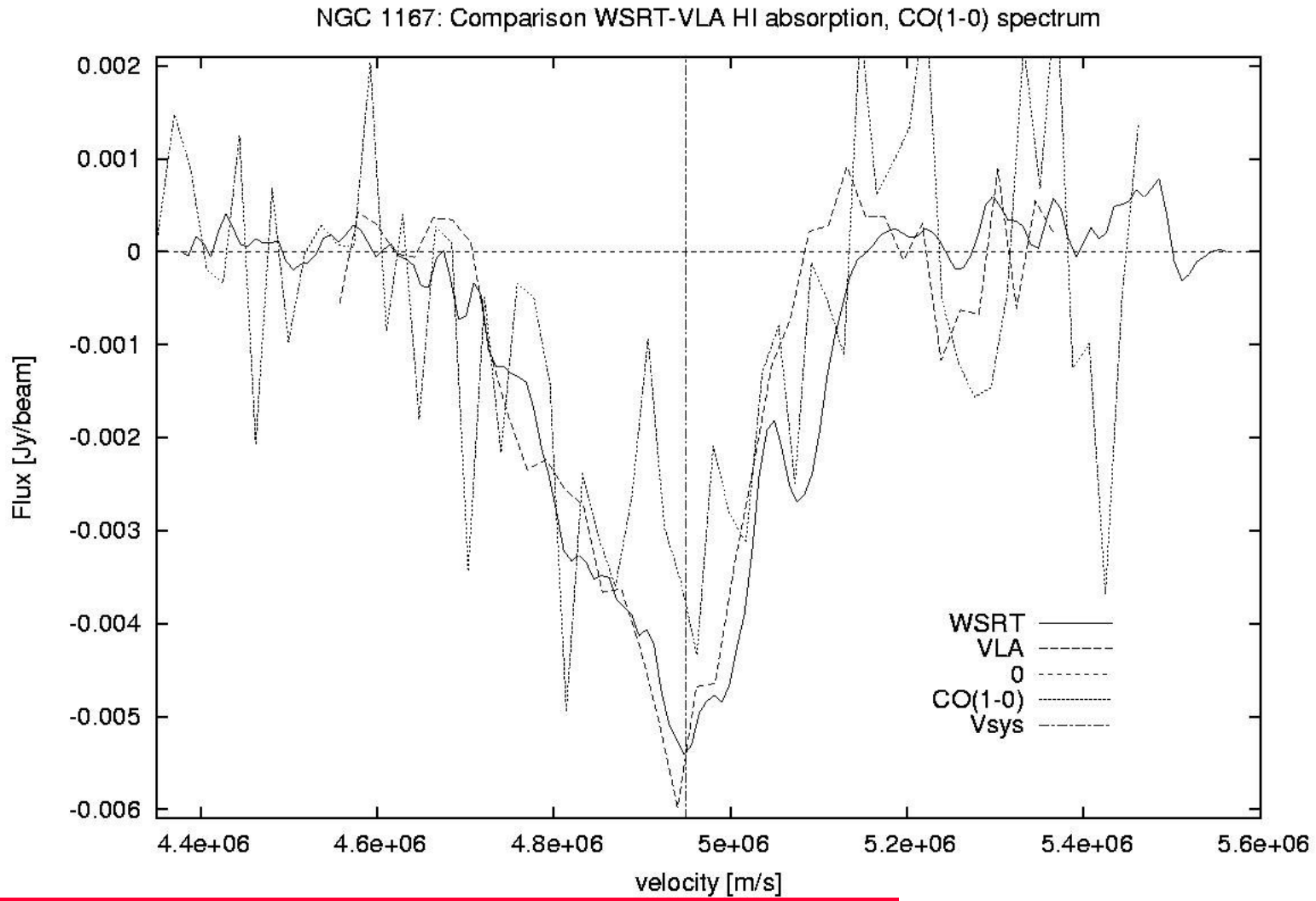


CO spectrum kindly provided by Isabella Prandoni

NGC 1167 (B2 0258+35):

Results II:

- Large-scale continuum structure indicates previous phase of AGN activity
- HI absorption column density is comparable to HI emission column density. → HI is part of the disk structure, no evidence for halo gas
- HI (VLA+WSRT) spectra asymmetric w.r.t. the systemic velocity
- Two absorption components?
- CO fits the HI spectrum → same structure?

What is the unresolved structure?

- Circumnuclear disk + outflow
- kinematically de-coupled core

Are there any indications of non-circular motions?

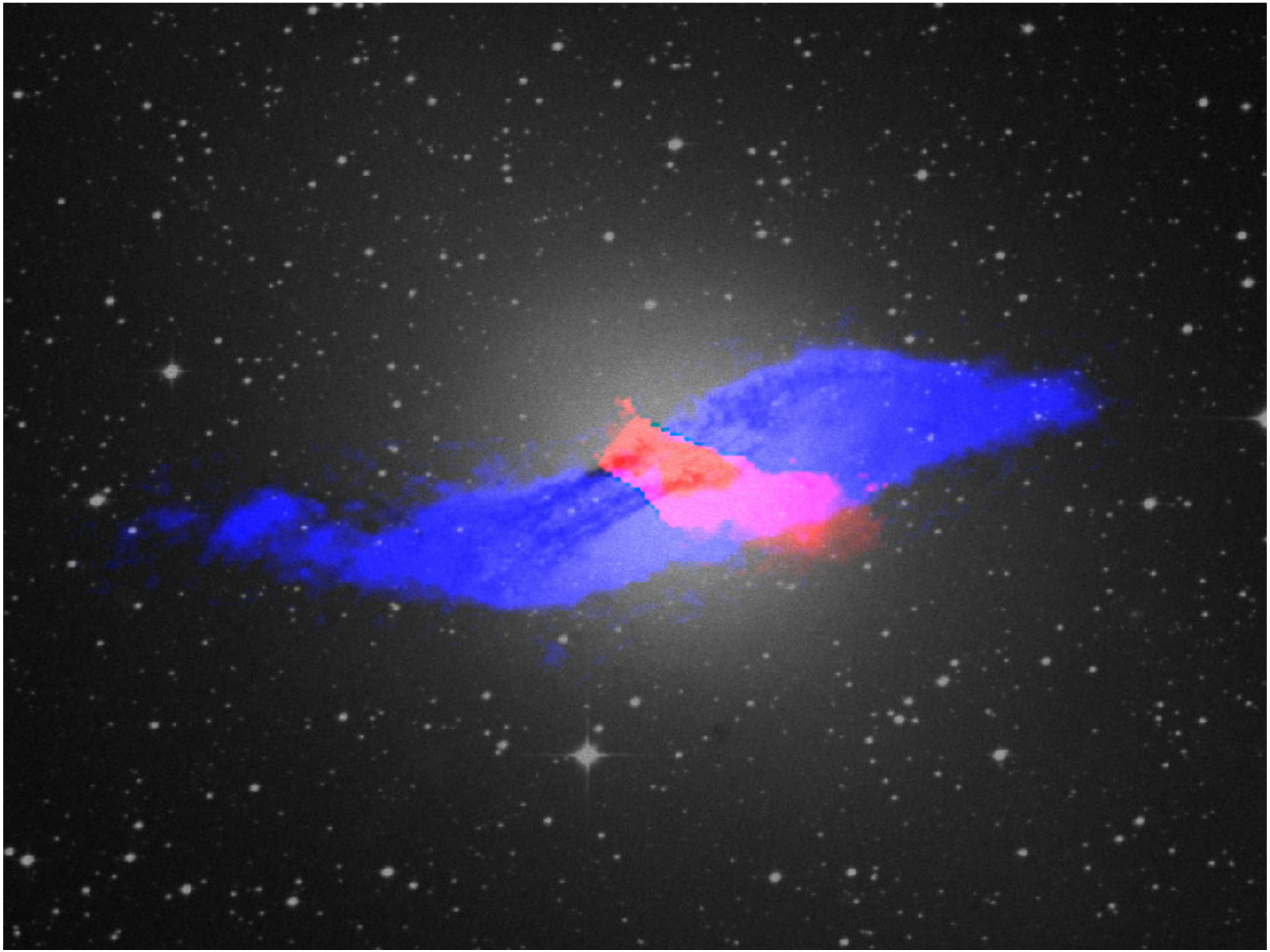
- infalling gas (no strong evidence for this at the moment)

What fuels the AGN?

On-going analysis !!!

Future Work

- Keep on analyzing the data
- Quantify how much of the deviating large-scale HI is due to beamsmearing effects
- Clarify the origin of the halo gas: cold accretion vs. recycled gas
- Interpret the circumnuclear region (HI and CO data): disk structure, infall/outflow, kinematically de-coupled core
- What triggers the AGN?
- Could cold gas accretion deliver the fuel for the AGN?
- Reduce and analyze the 92cm continuum observations and derive age estimate for the 250 kpc relict structure

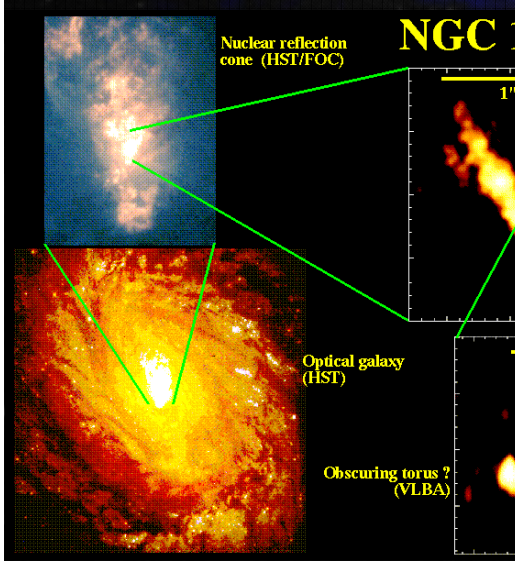


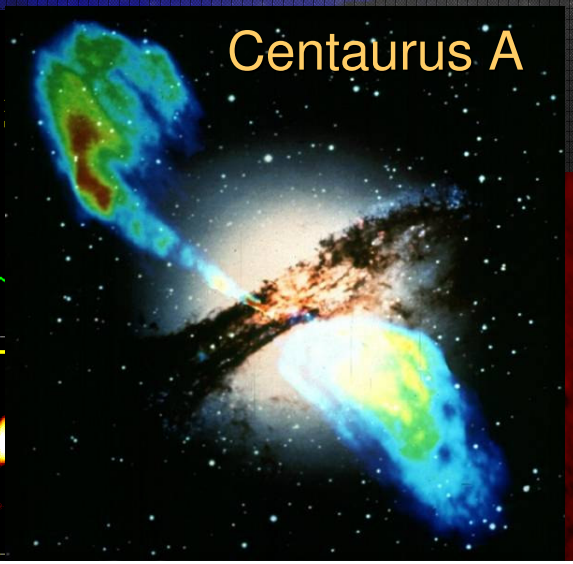
Different classes of Radio Galaxies:

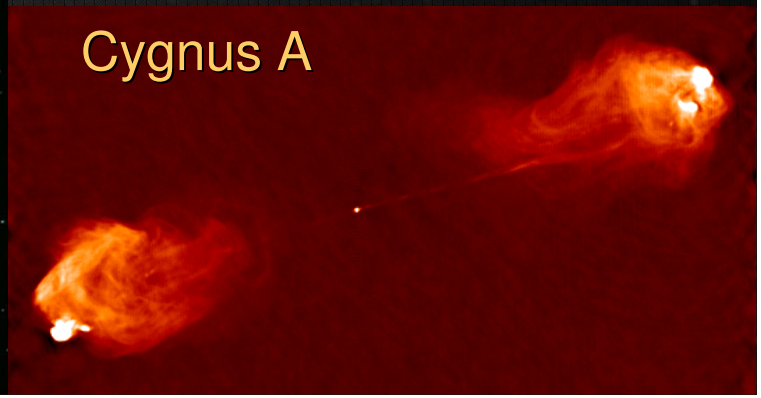
Starburst/AGN
- Seyfert

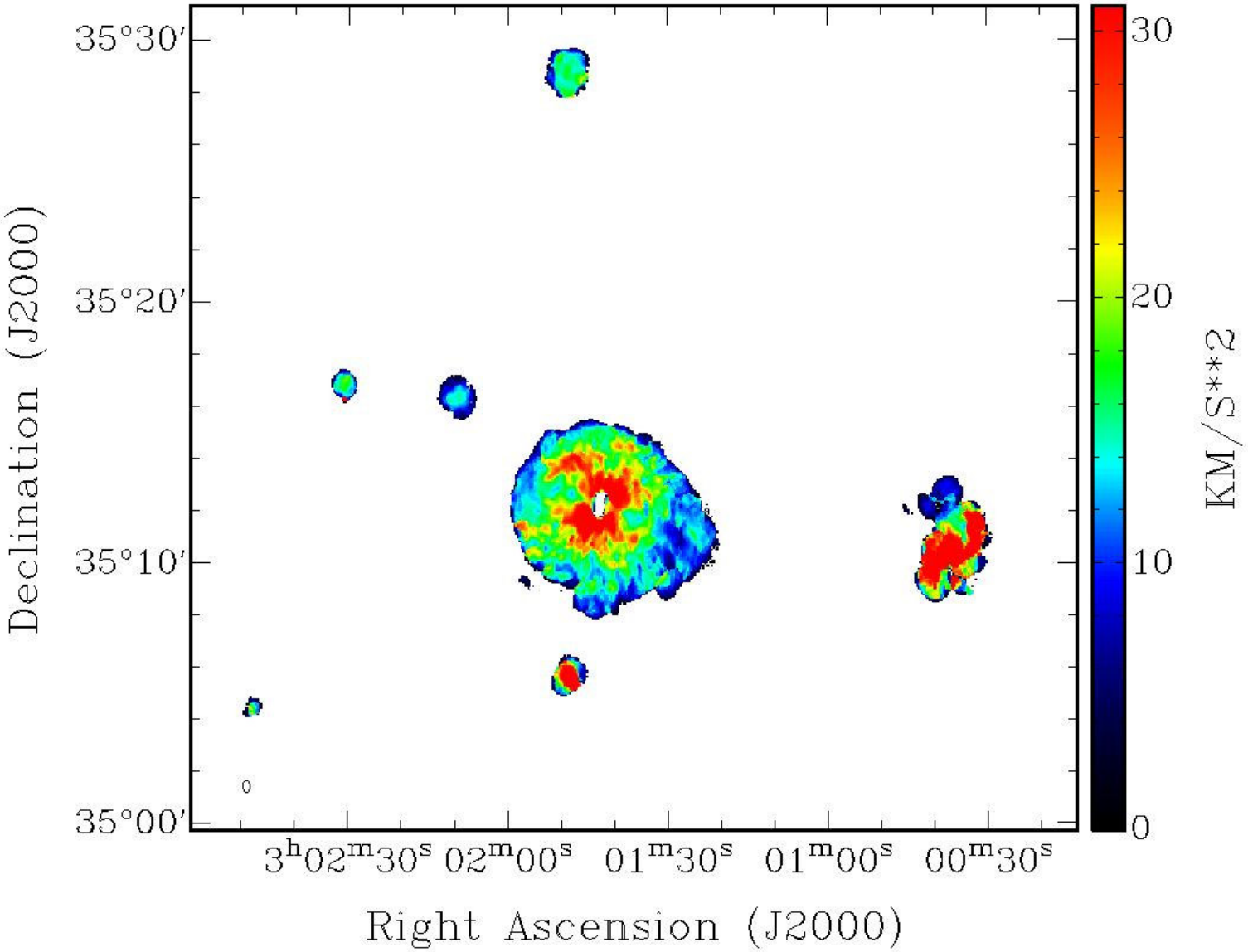
Low luminosity
- FR-I
- compact

High luminosity
- FR-II








35°30′
35°20′
35°10′
35°00′
Declination (J2000)
3h02m30s
02m00s
01m30s
01m00s
00m30s
Right Ascension (J2000)
30
20
10
0
KM/S**2

Why is the existence of a circumnuclear HI disk interesting?

- How does the gas gets close to the black-hole of an active galaxy?

- Mergers are important for powerful radio galaxies
- But accretion from ISM/IGM important as well

- Redshifted absorption often seen as evidence for infall
- Blueshifted absorption occurs as often as redshifted (outflow)

- Theoretical work predicts existence of circumnuclear disks
- Observations indicate presence of circumnuclear disks
  (Cygnus A, Cen A, NGC 1167)

NGC 1167

Why do we care about halo gas?

- SFR and gas content of galaxies constant over cosmic times
- Star forming galaxies run out of fuel very quickly
- Gas supply via:
  - merging
  - recycled gas / stellar mass loss
  - cold gas accretion

How to distinguish external from internal processes?

- Supernovae (as the result of continuuing star formation) can blow gas into the halo
  - galactic fountain model