Probing HI outflows on parsec scales in radio galaxies with VLBI

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HI outlfows

Massive outflows of HI detected in powerful radio galaxies

What is driving them – radio jet or radiative winds?
=> Requires mas-resolution observations (VLBI)

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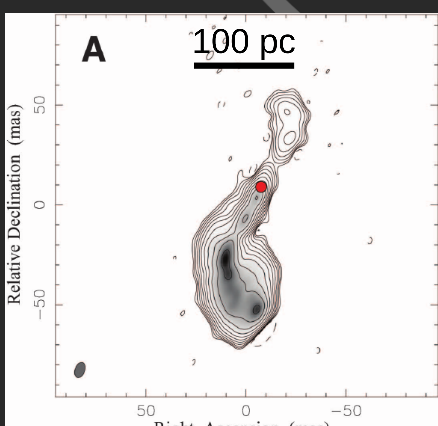

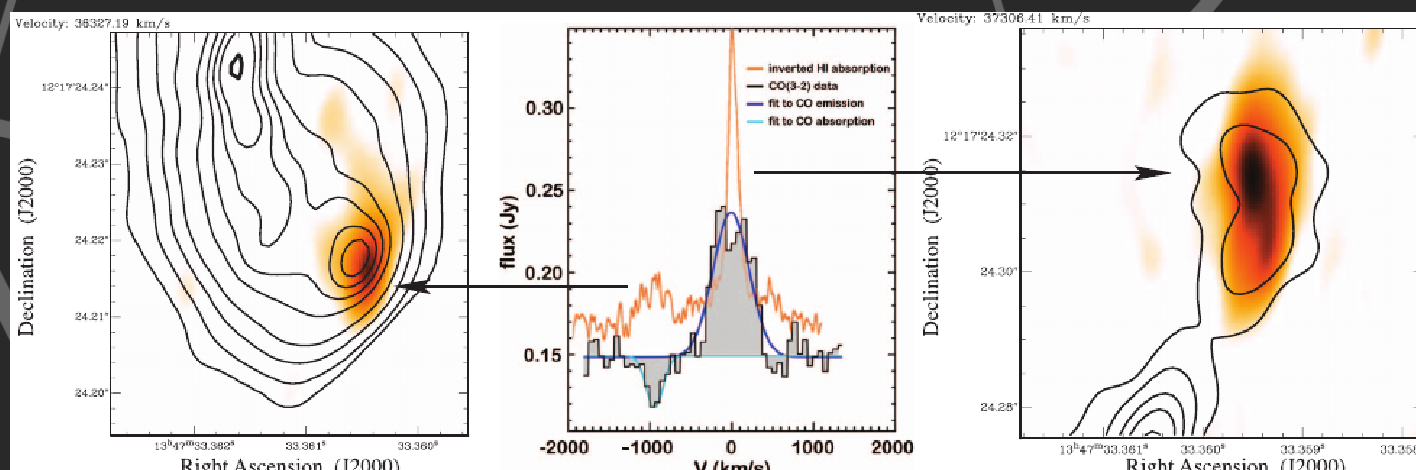

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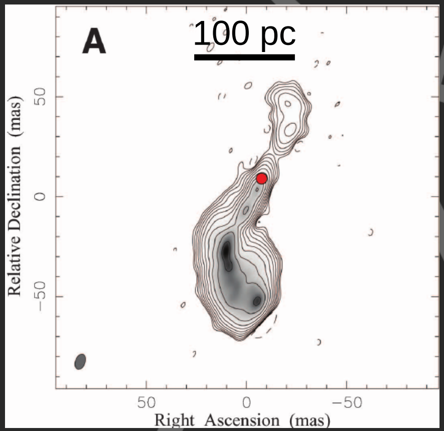
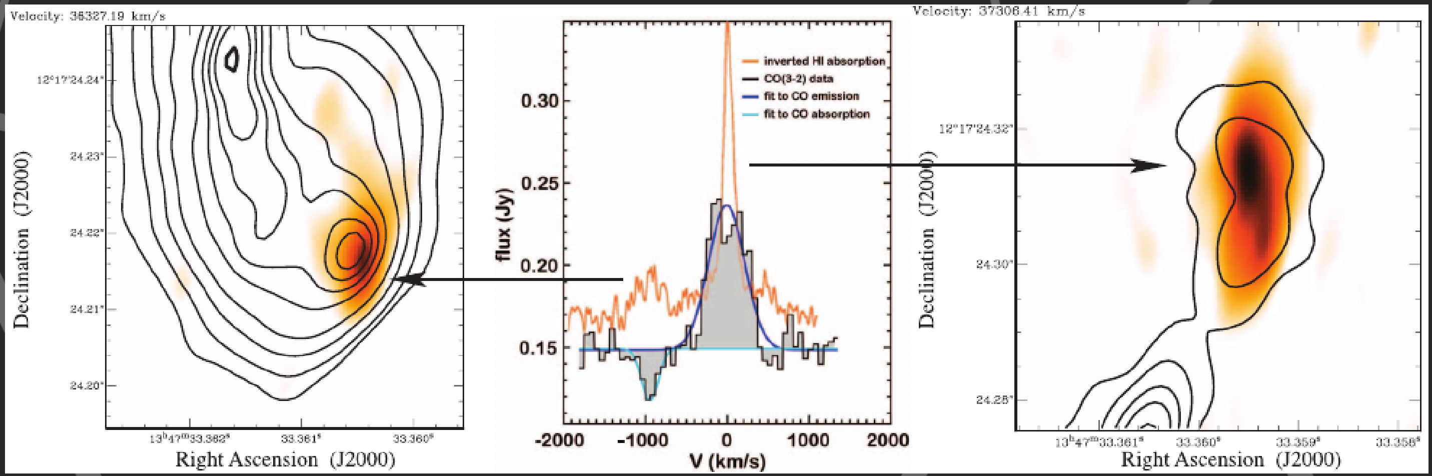




=> Observer multiple radio AGN to study potential differences

The sample

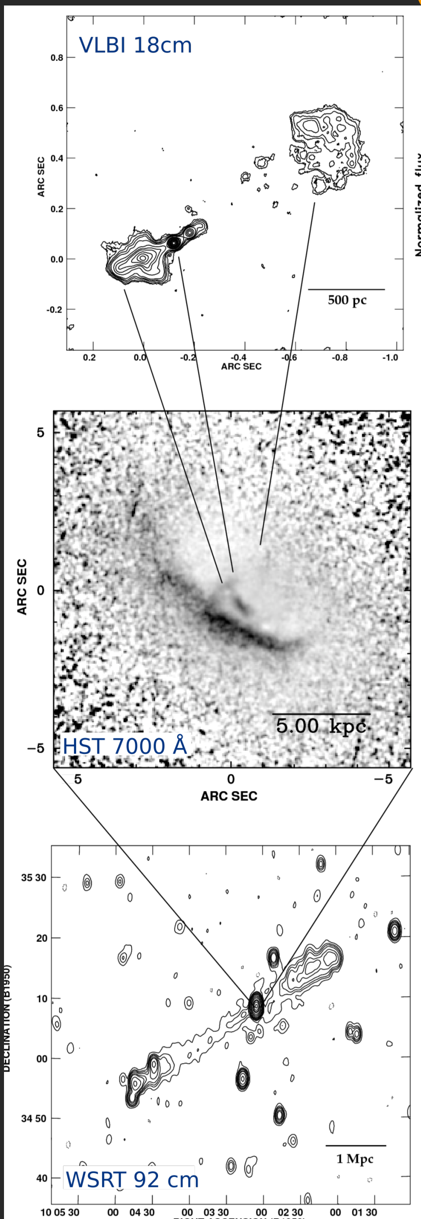
4C +12.50 3C 236 3C 293 4C +52.37

The sample

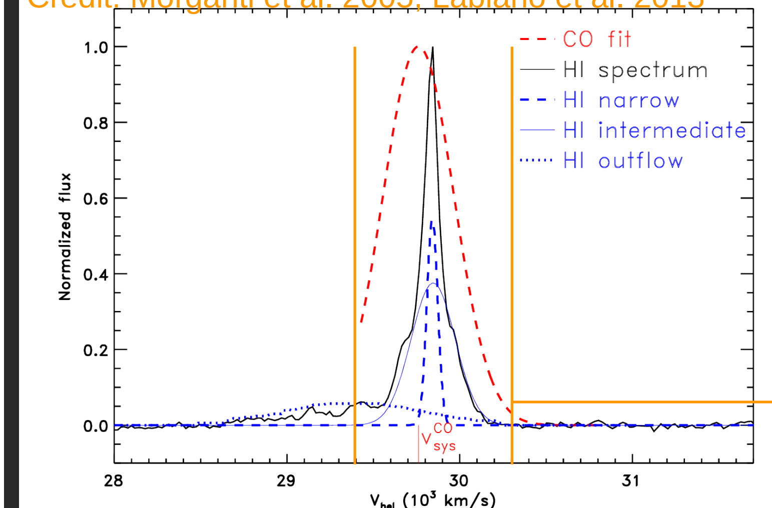
4C +12.50 | **3C 236** | 3C 293 | 4C +52.37

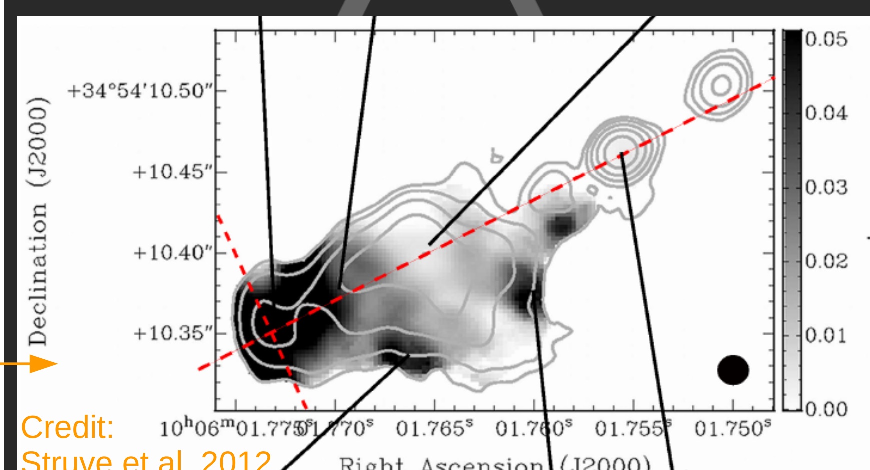
Giant re-started radio galaxy at z=0.1
(Barthel et al. 1985, Schilizzi et al. 2001)

$S_{1.4,VLA}$ = 2.6. Jy
Log $P_{1.4}$ = 25.8 W Hz^{-1}



Credit: Schilizzi et al. 2001

Credit: Morganti et al. 2005, Labiano et al. 2013




Credit: Struve et al. 2012

The sample

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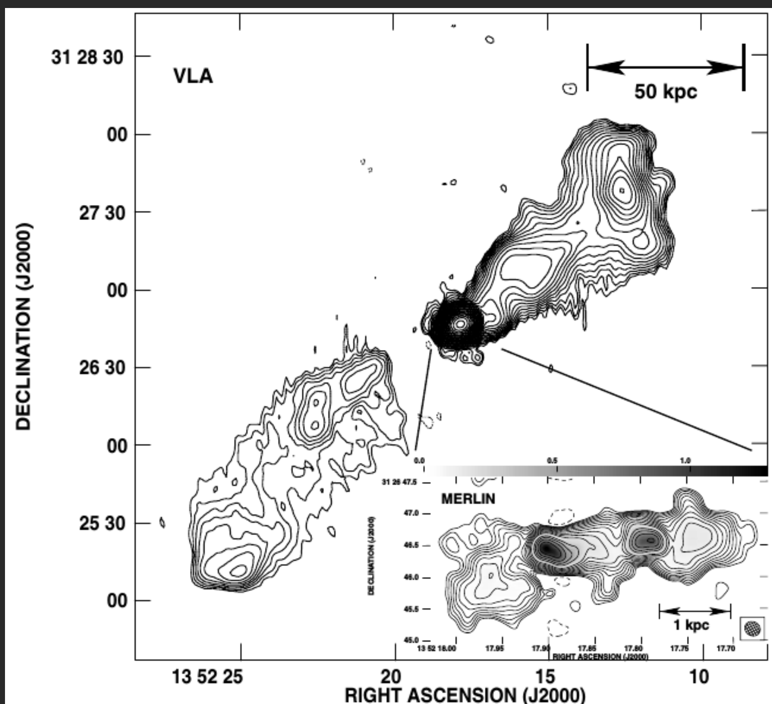


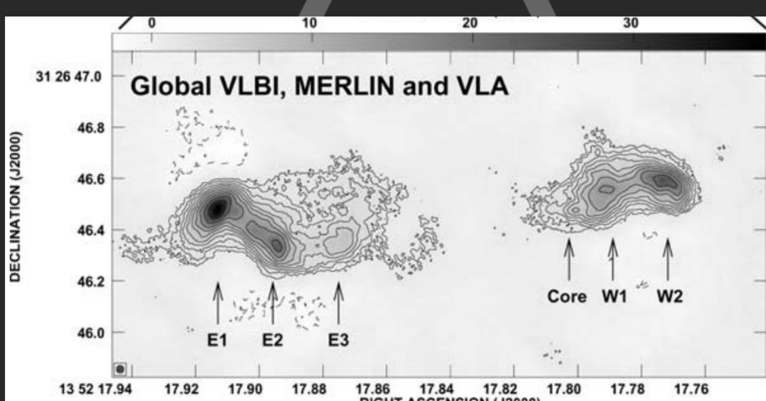
Re-started radio galaxy at z=0.045

(Sandage 1966, Beswick et al. 2014)

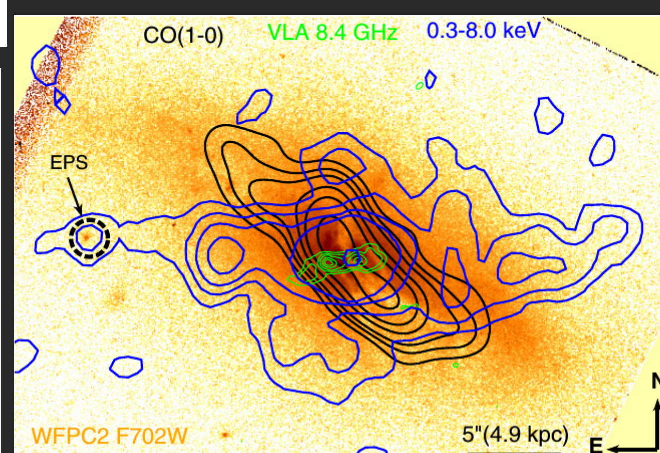
$S_{1.4,WSRT}$ = 3.53 Jy

Log $P_{1.4}$ = 25.3 W Hz^{-1}

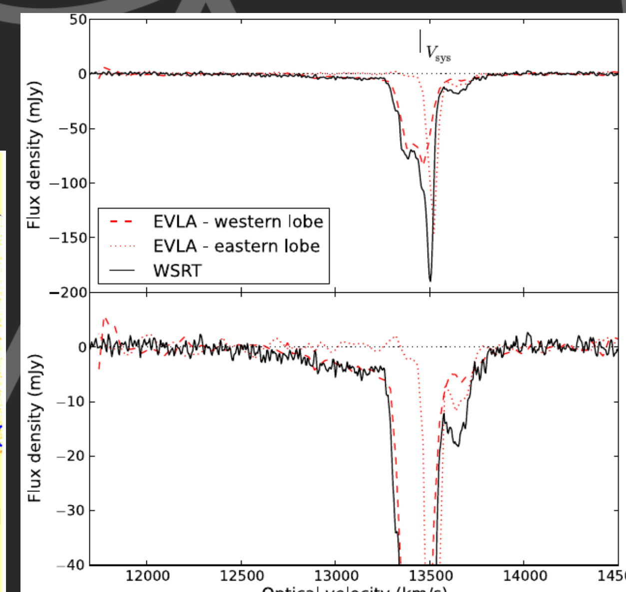
(Maccagni et al. 2017)



Credit: Beswick et al. 2004



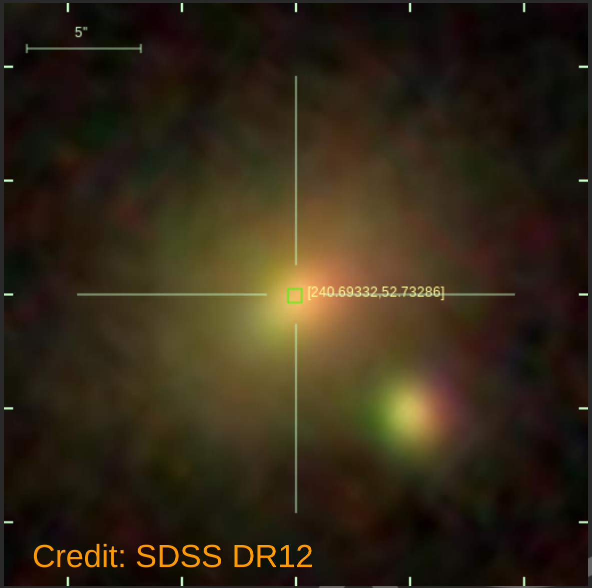
Credit: Lanz et al. 2015



Credit: Mahony et al. 2016

The sample

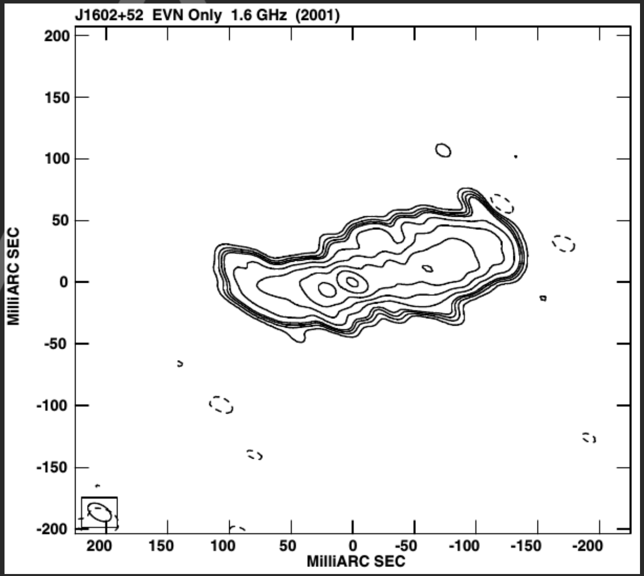
4C +12.50 | 3C 236 | 3C 293 | 4C +52.37



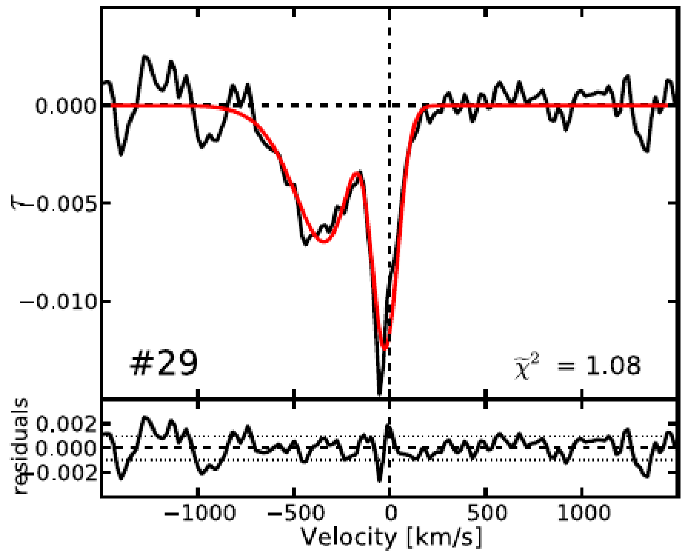
Credit: SDSS DR12

Compact symmetric object at z=0.106
(e.g., de Vries et al. 2009)

$S_{1.4,WSRT}$ = 0.577 Jy
Log $P_{1.4}$ = 25.2 W Hz^{-1}
(Maccagni et al. 2017)

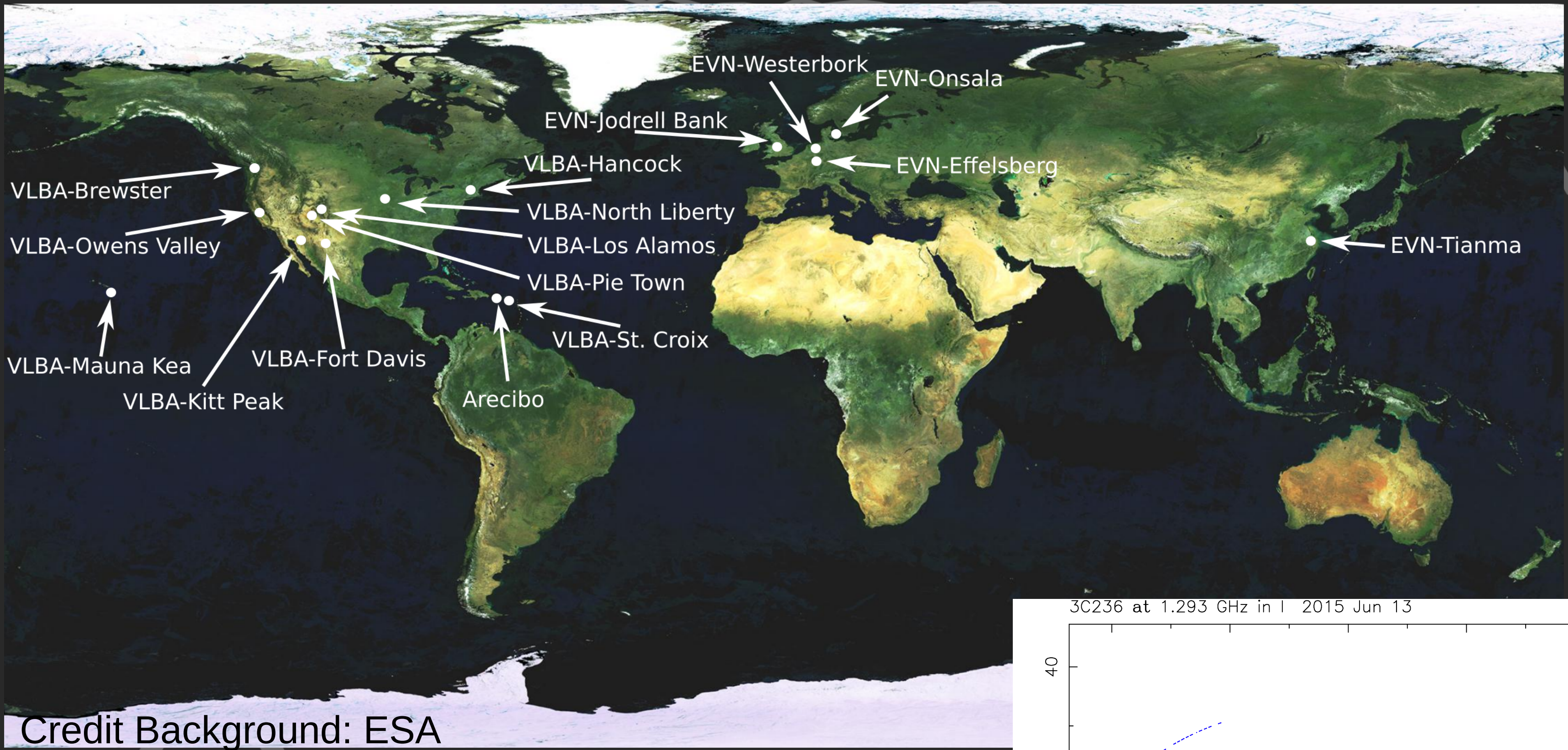


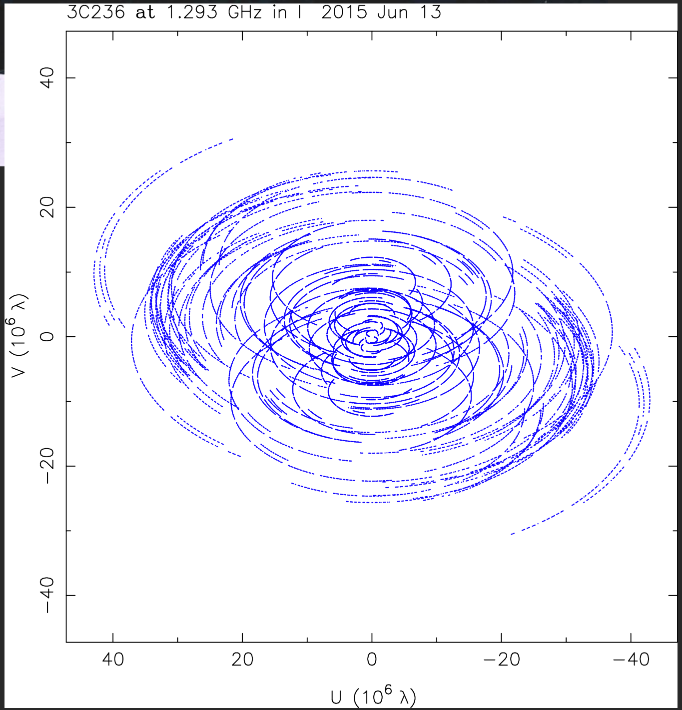
Credit: de Vries et al. 2009



Credit: Gereb et al. 2015

Global VLBI HI Observation





EVN + VLBA + Arecibo (~12h)

Phase-referencing
Angular resolution: <20 mas
BW 16 MHz (512 channels)

Global VLBI HI Observation

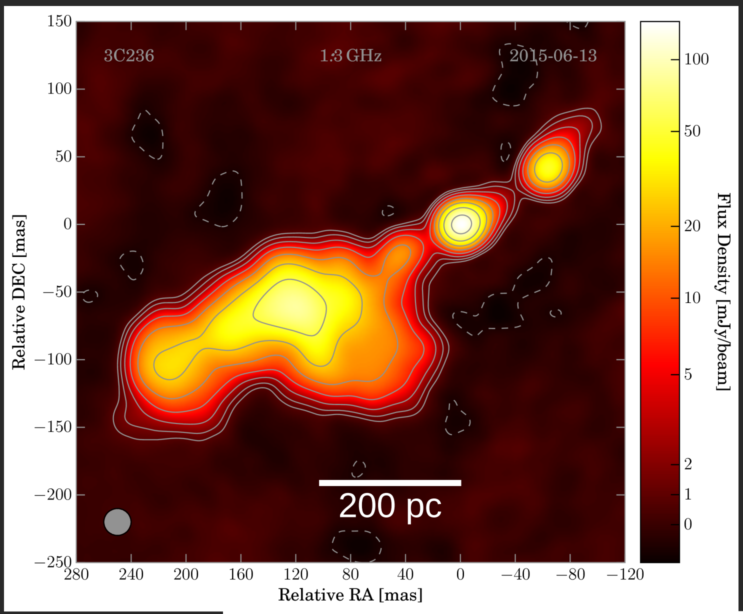
Some considerations

- Calibration: (manual) Flagging
- Imaging & self-calibration: manual vs. automatic
- Zero-spacing problem

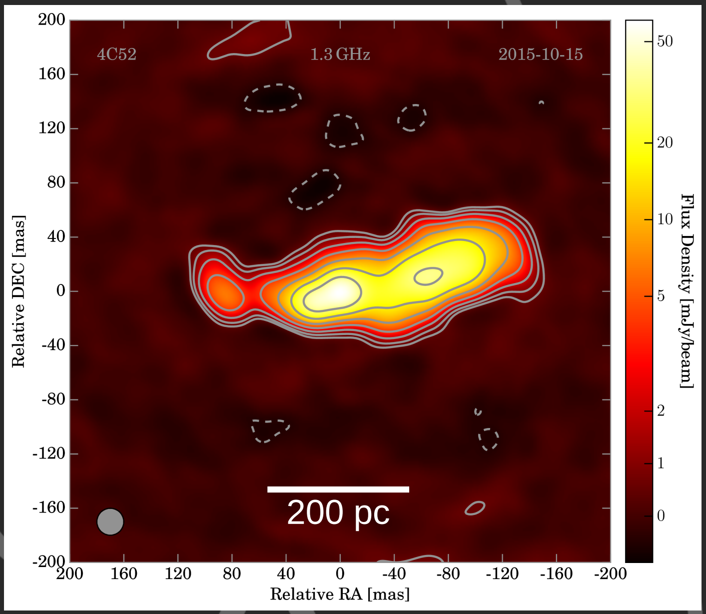
Software: mainly AIPS & Difmap (future: CASA?)

Continuum Images

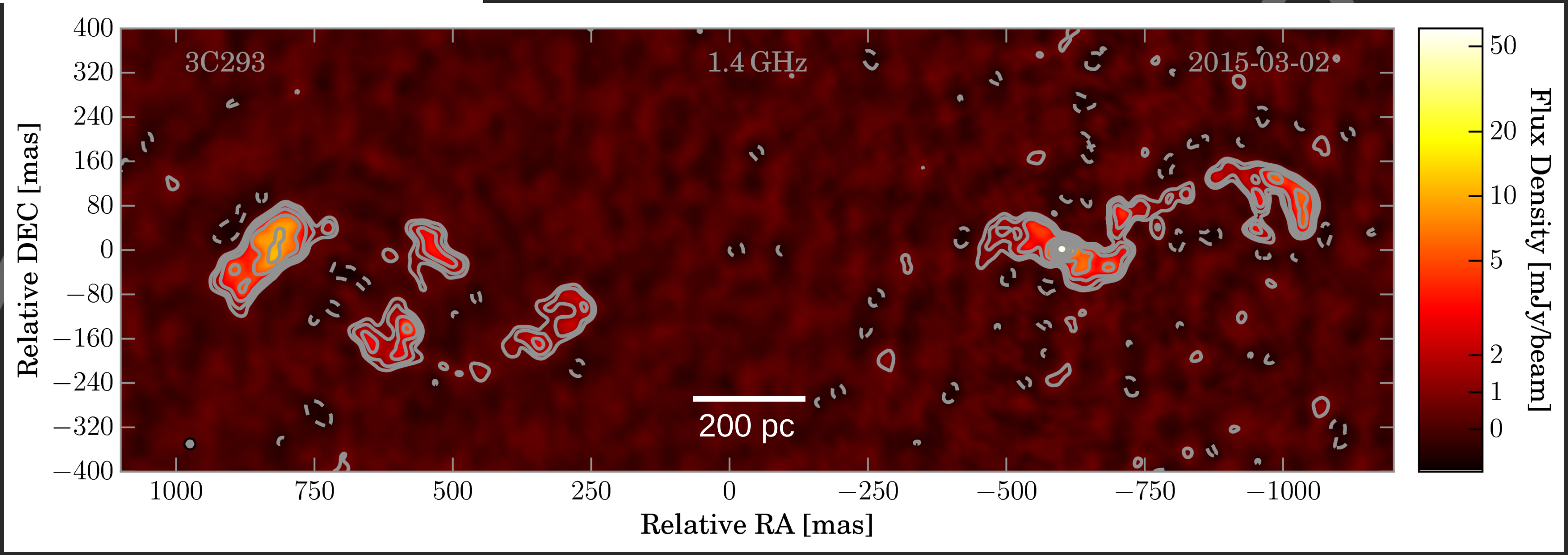
3C 236



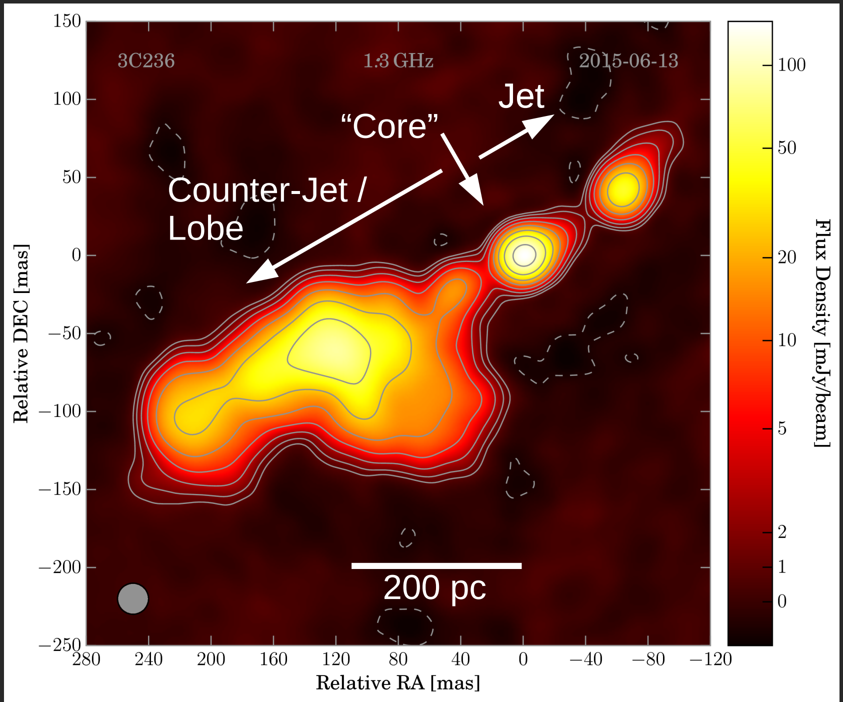
4C +52.37
(preliminary)

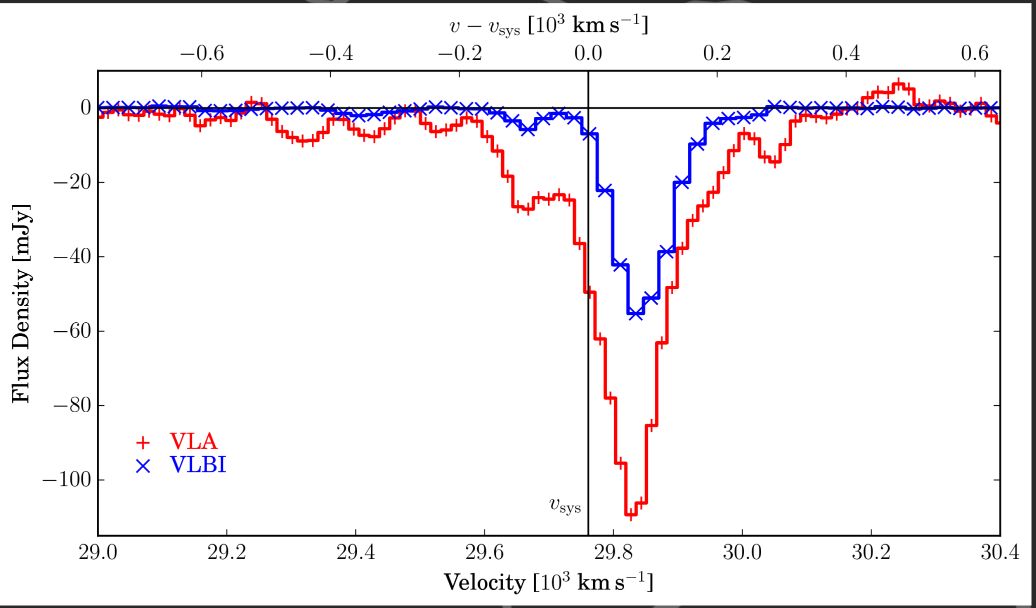


3C 293
(preliminary)



3C 236 - Spectrum

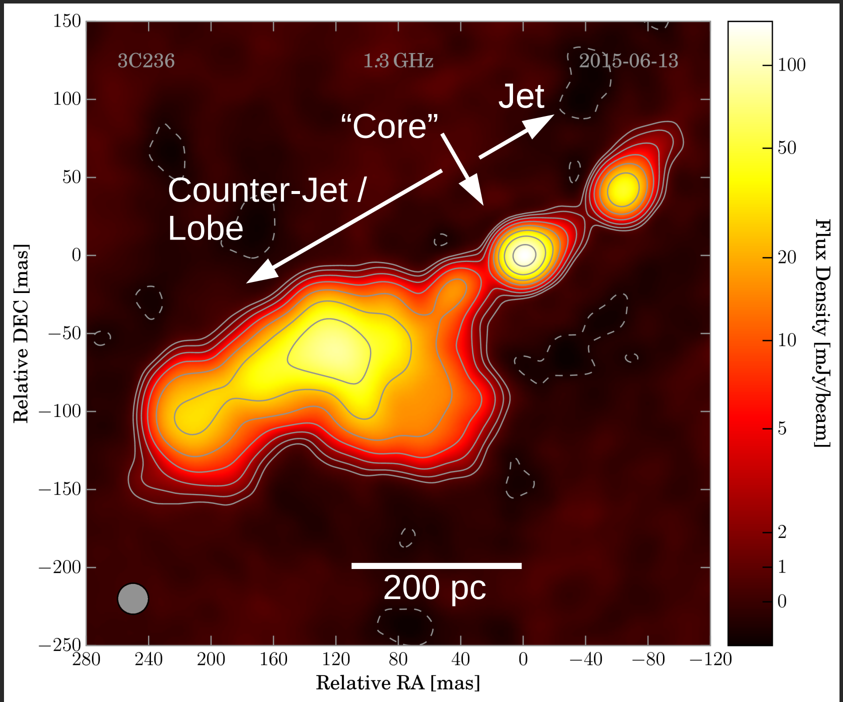


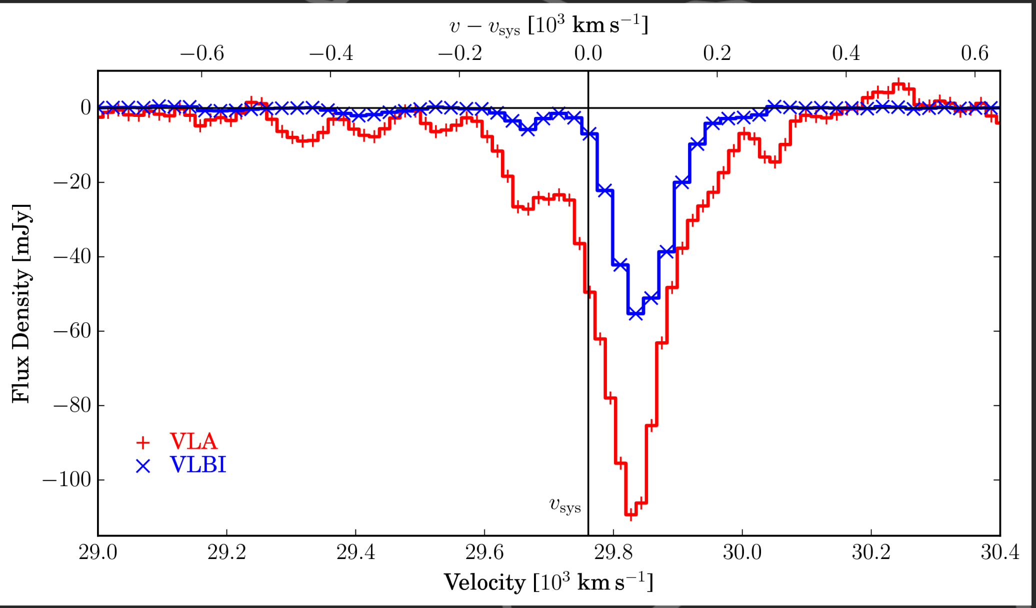


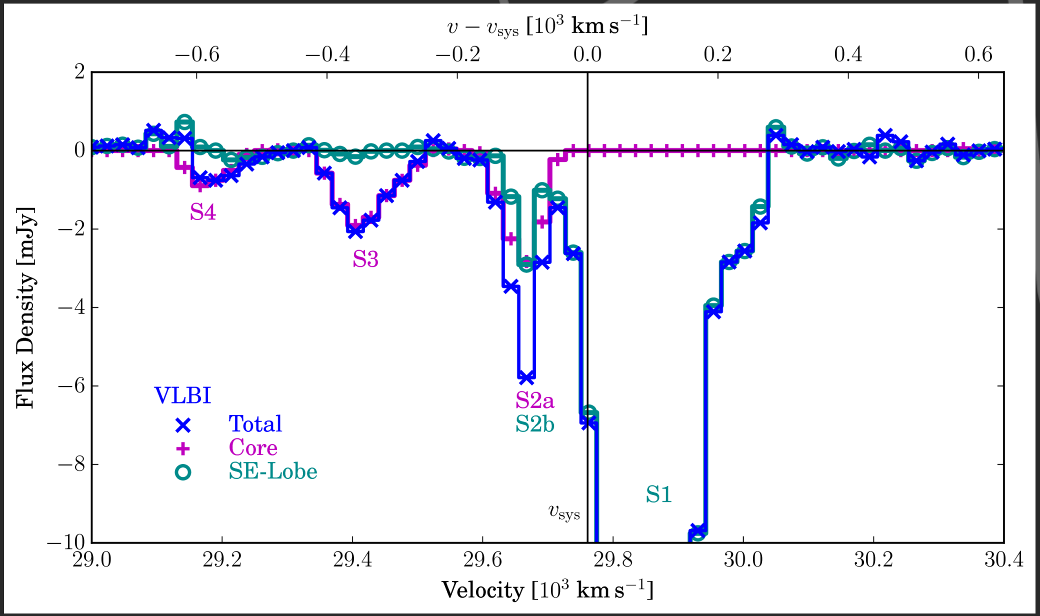
VLA spectrum consistent with WSRT data

VLBI partially recovers broad wing

3C 236 - Spectrum



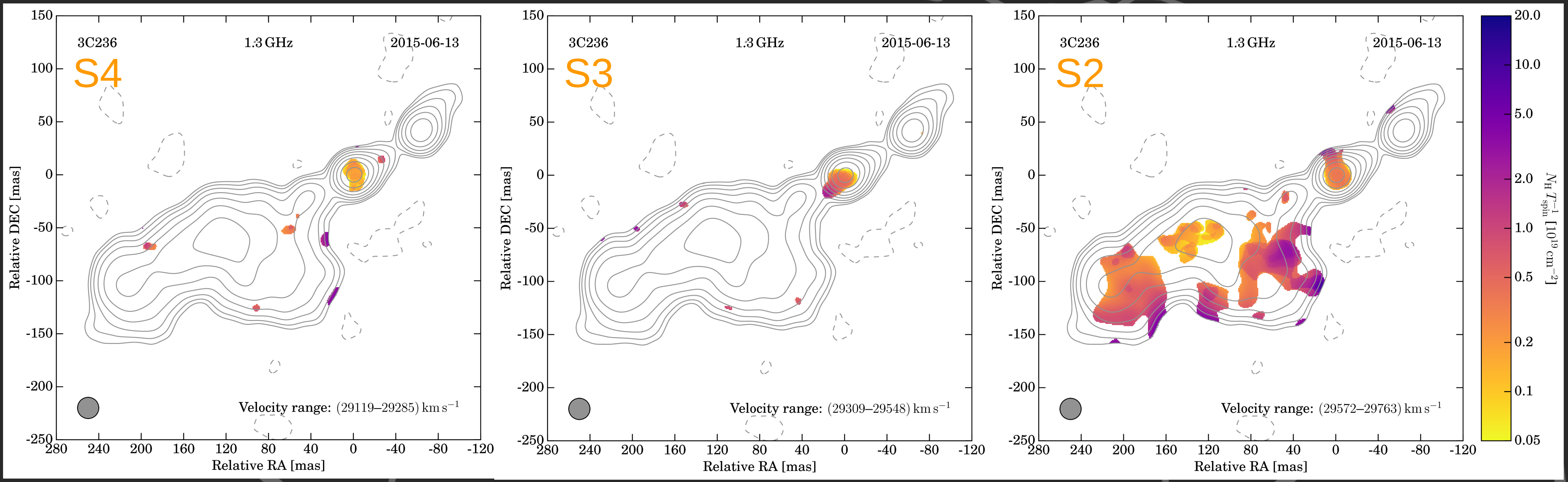


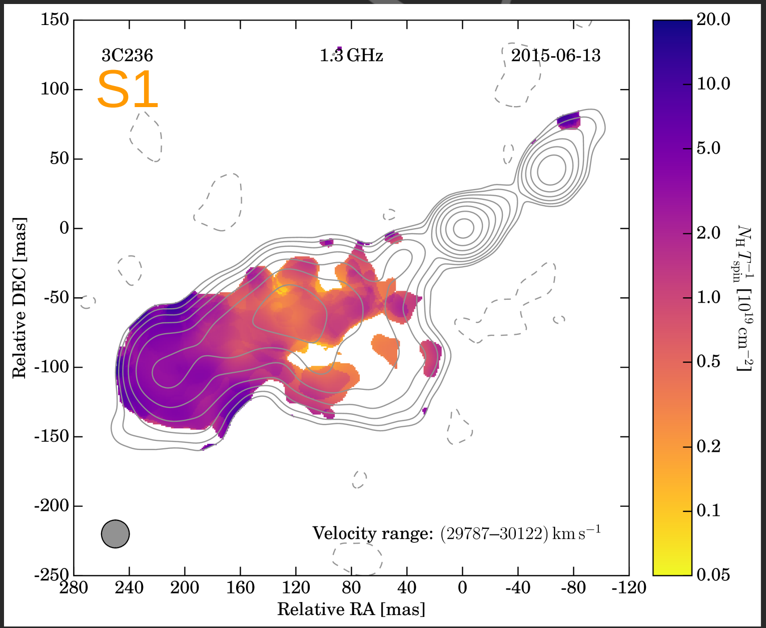


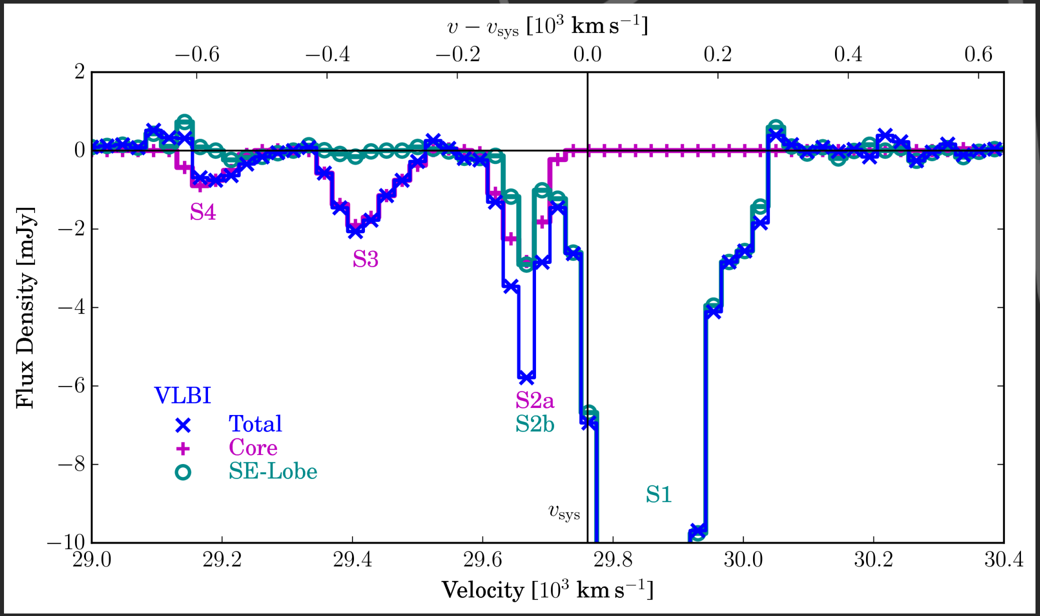
Most blue-shifted features co-spatial with the “core”-region

BUT: part of the wing also co-spatial with the lobe

3C 236 - Gas distribution







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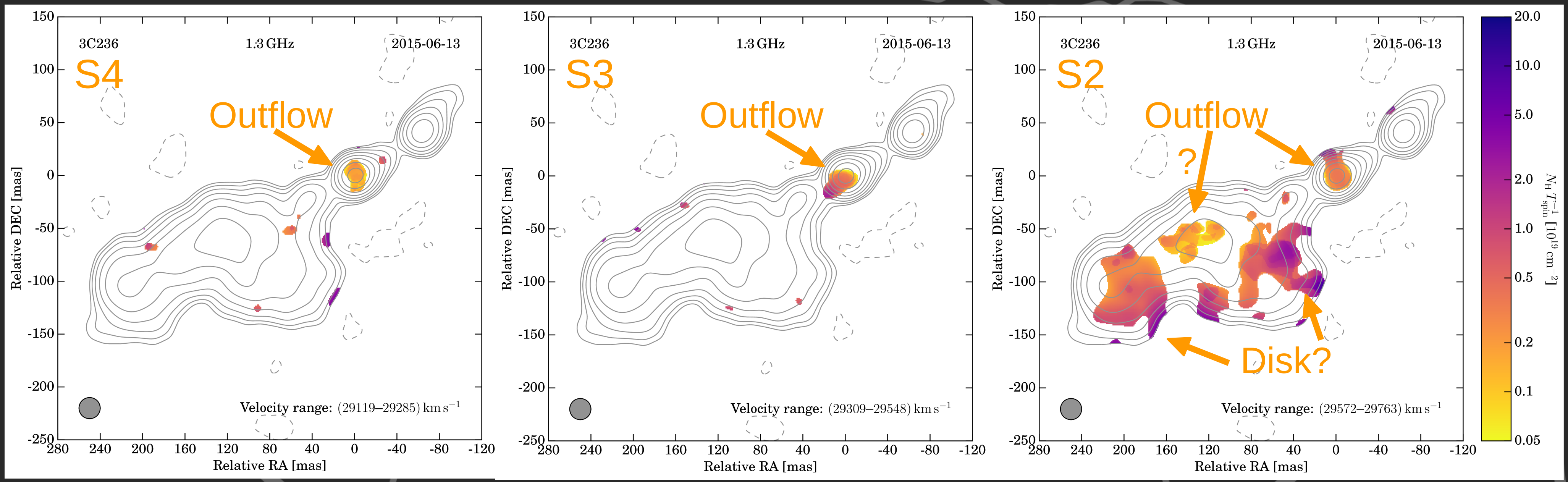

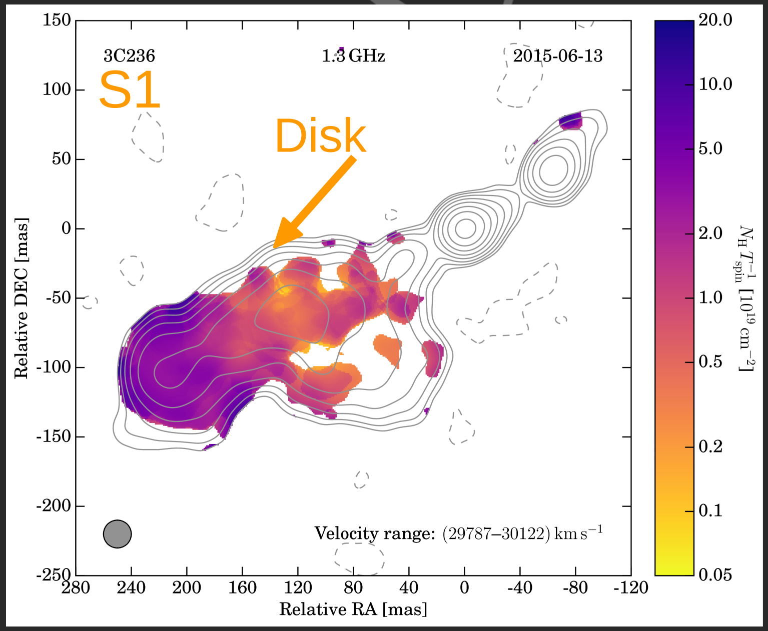

Clumpy HI gas distribution

Outflowing gas could be jet and wind driven

Mass HI: 3-15 x 10^3 M_{sun}
Rate (if jet-driven): 0.5-1.4 M_{sun} yr^{-1}

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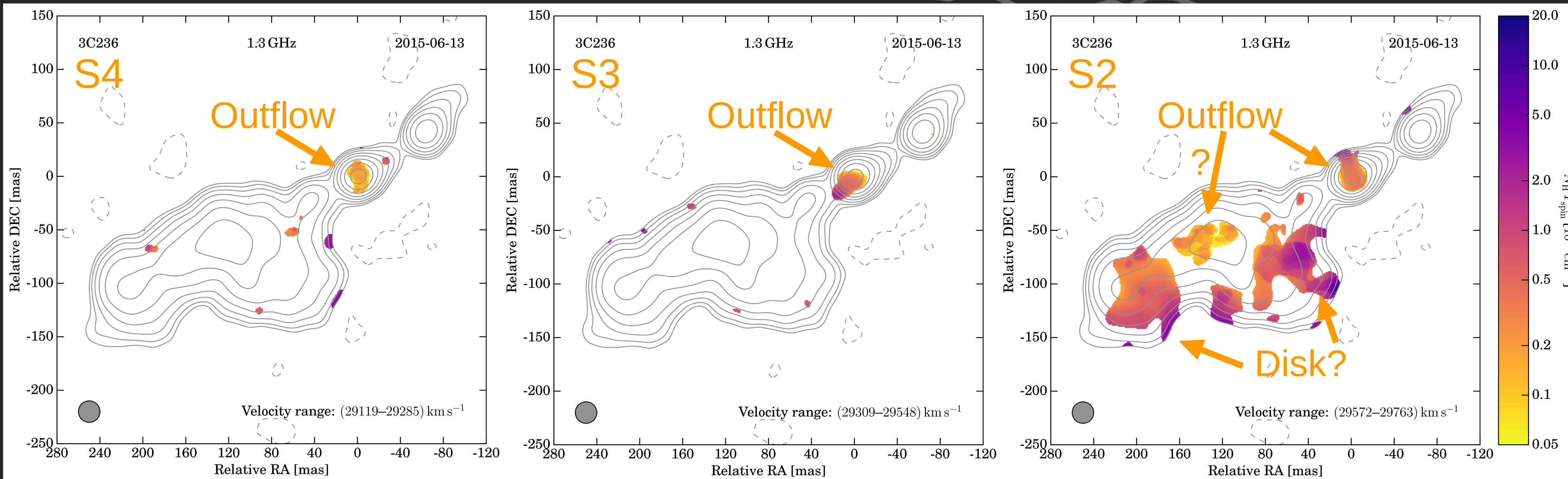

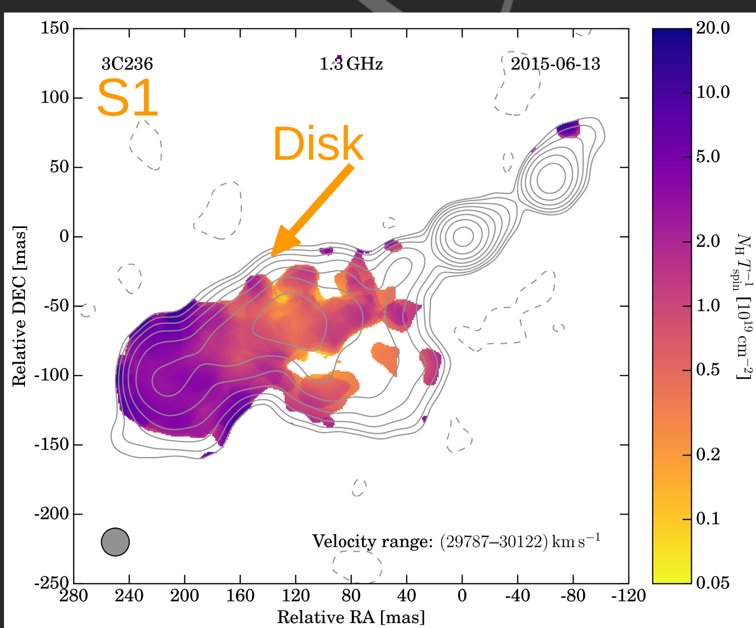

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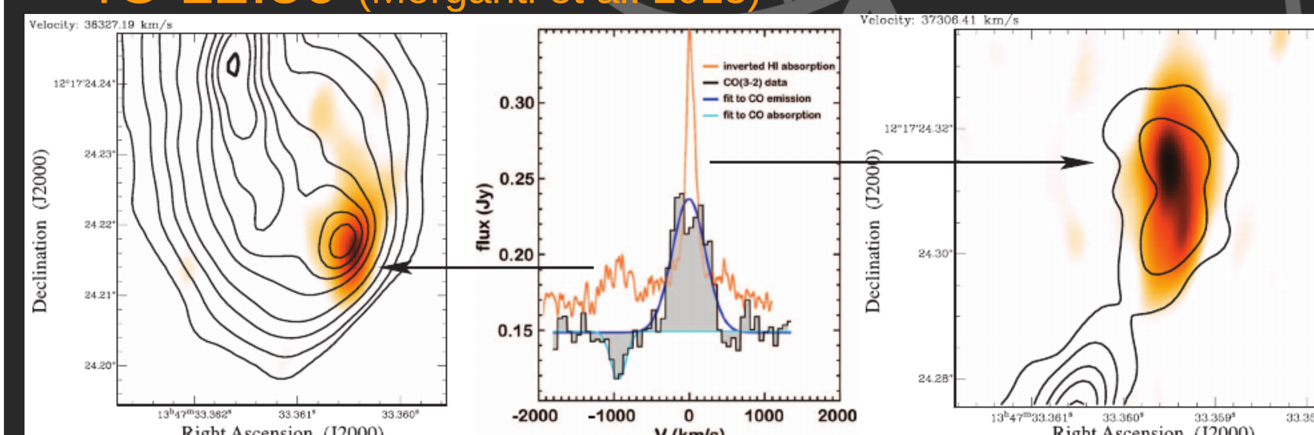

Both sources may represent different stages of evolution

Summary

VLBI is necessary to constrain the location of HI outflows

Observation of initial sample (3C236, 3C293, 4C+52.37)

3C236:

- VLBI data reveal clumpy outflow with a strong diffuse component in the lobe and core region
- Very different to 4C12.50 => Sign of evolution?

Outlook

Expanding the sample

Modelling the HI spectrum

General:

- Southern hemisphere - follow-ups to ASKAP (& SKA)
- Improvements to sensitivity & frequency coverage?
- Pipeline?