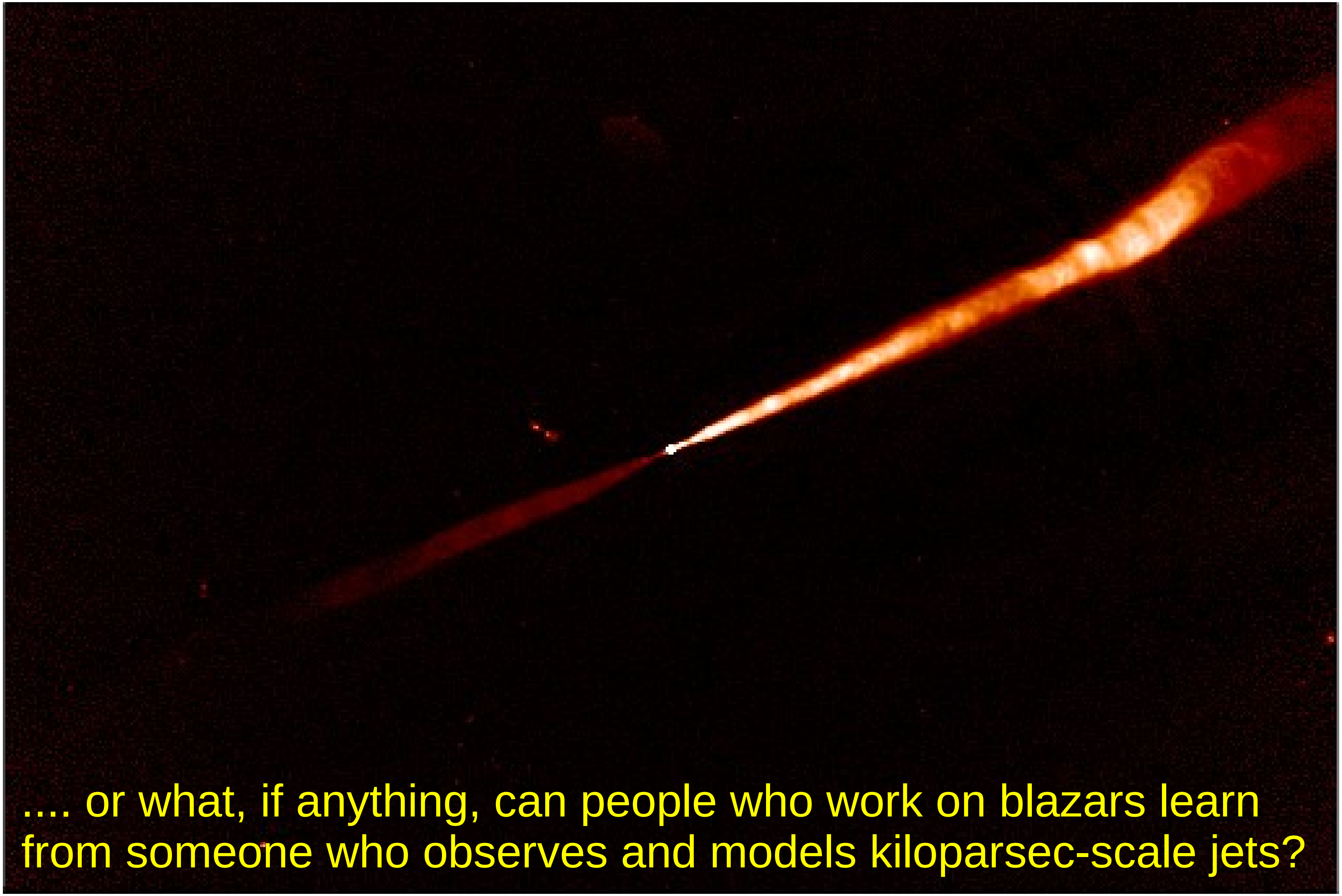
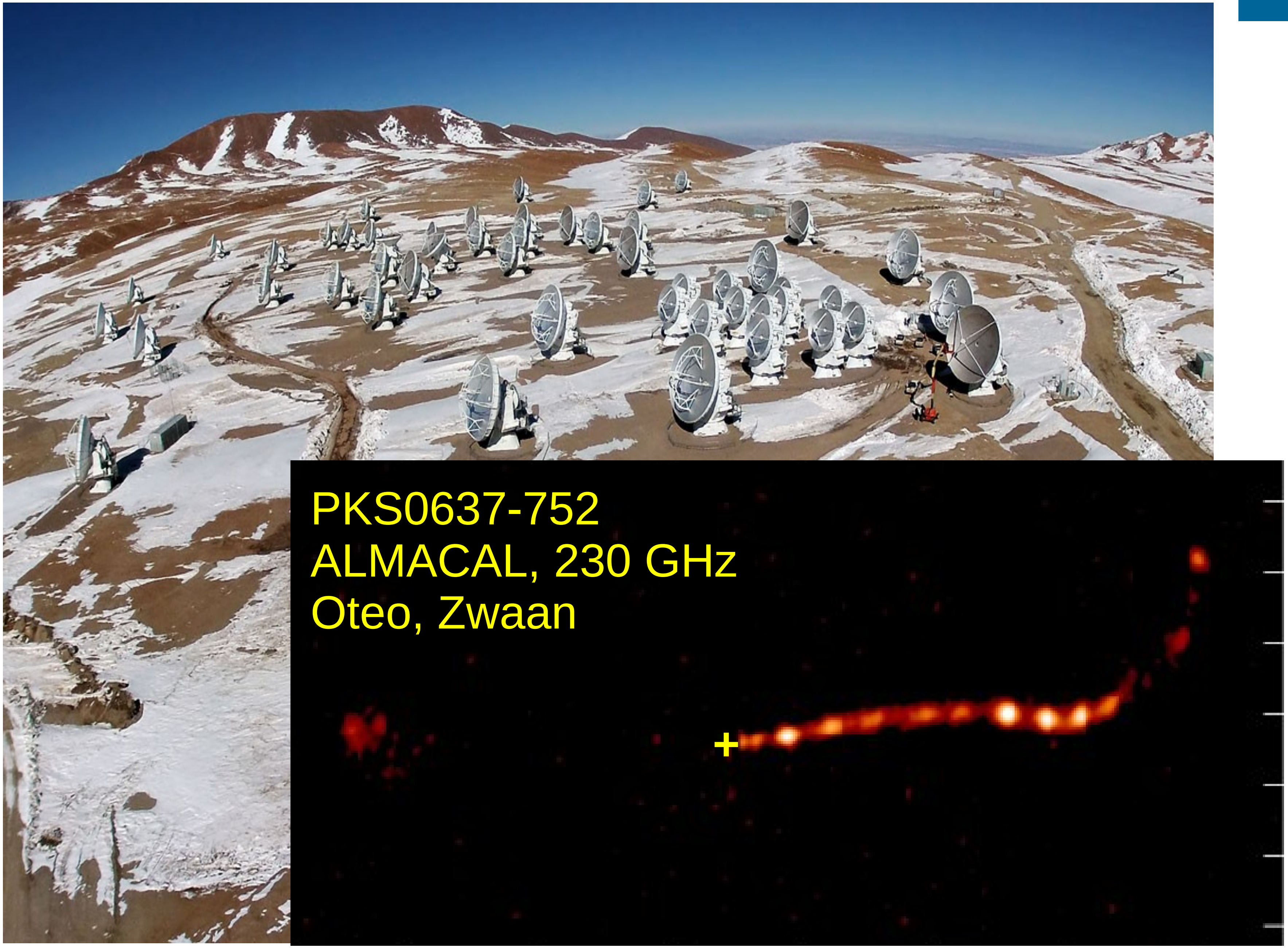
Magnetic Field and Polarization in AGN Jets

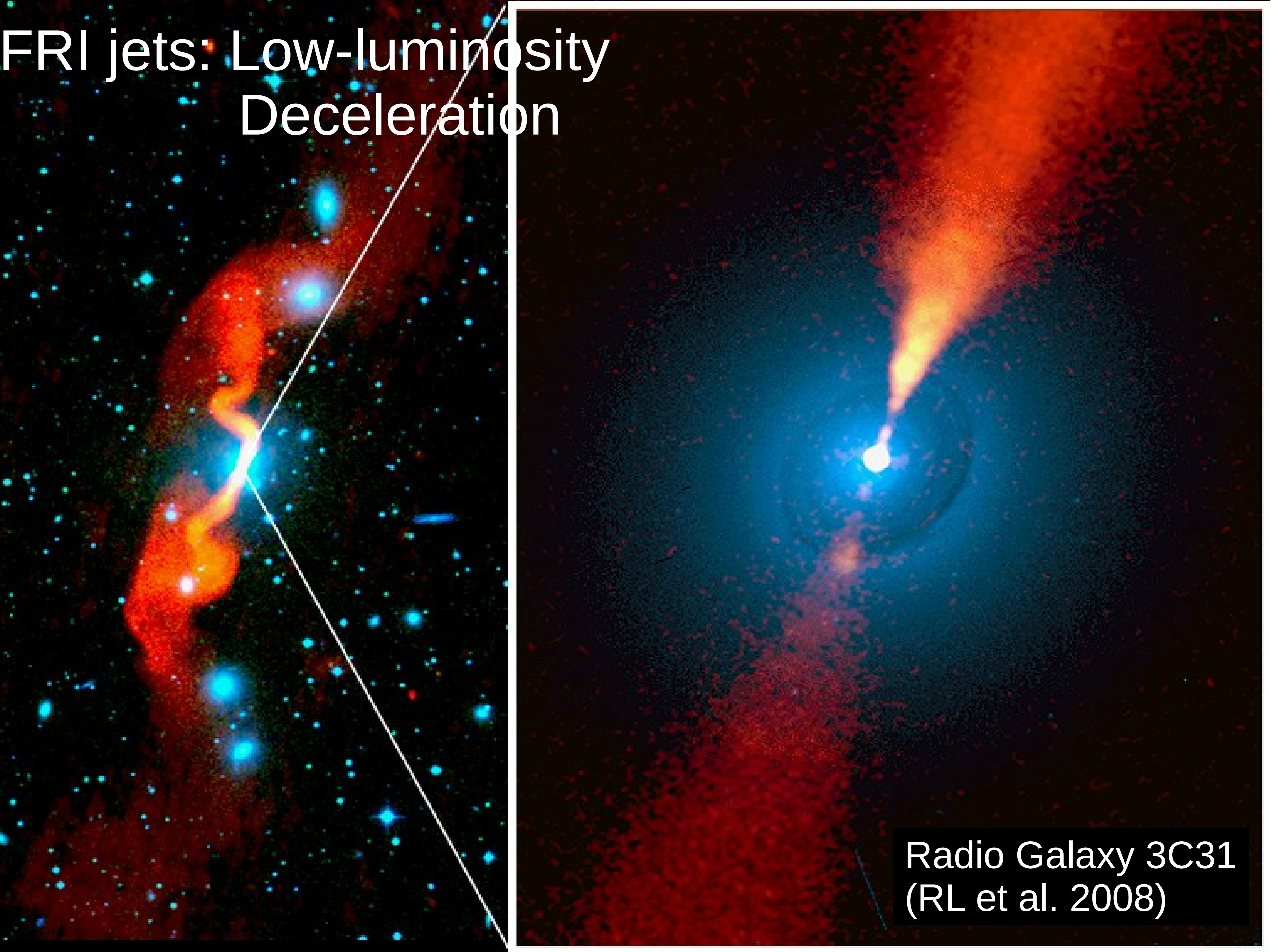


~~People who work on~~ Large-scale Jets?

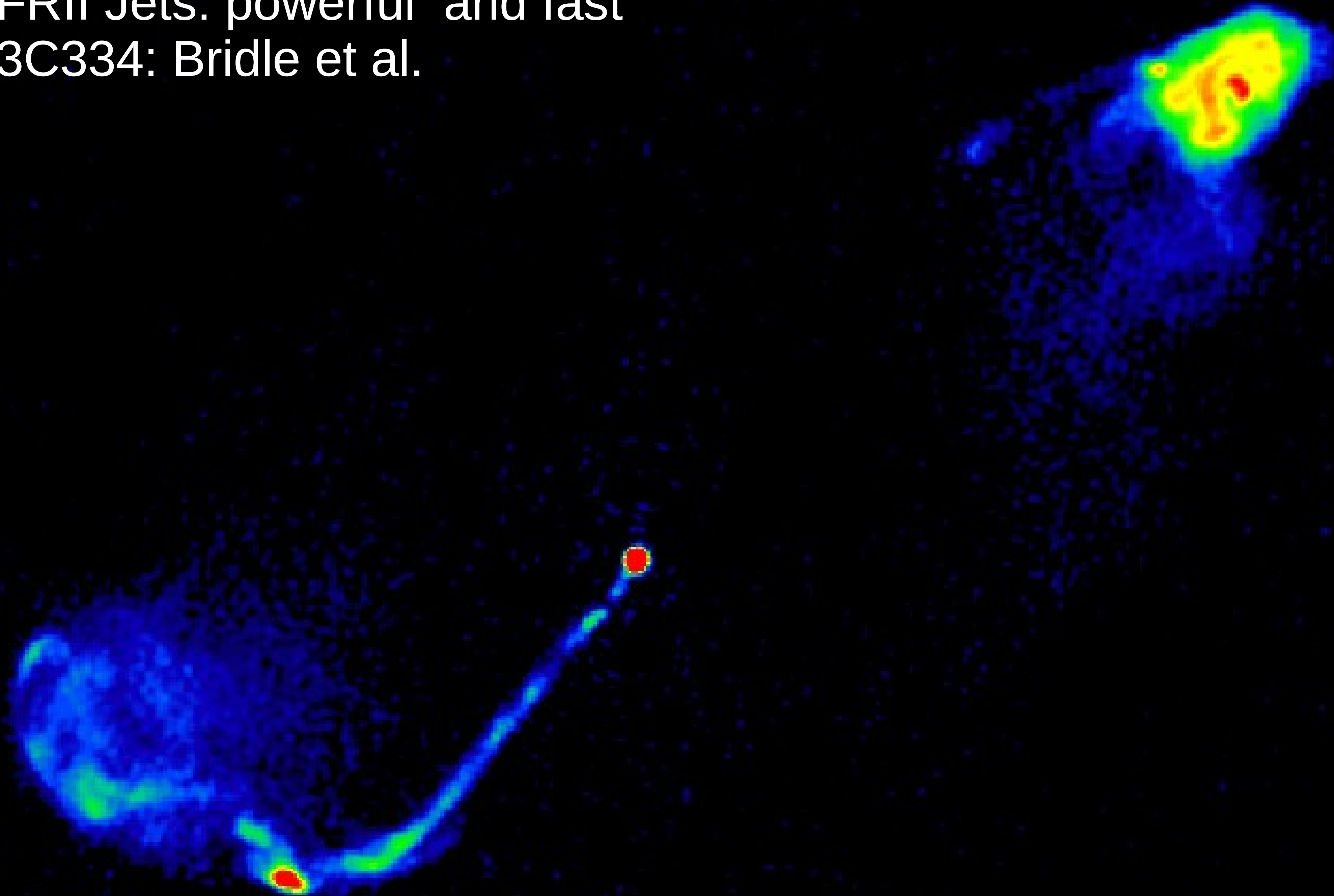
But first a word from my sponsors



FRI jets: Low-luminosity Deceleration



FRII Jets: powerful and fast
3C334: Bridle et al.



But how fast?

Bipolar relativistic jets

Flux density in observer's frame at frequency ν

$S(\theta,\nu) = D^{2+\alpha} \int \varepsilon'(\theta,\nu)\, dV/d^2$

Doppler factor

$D_j = [\Gamma(1- \beta\cos\theta)]^{-1}$ (approaching)

$D_{cj} = [\Gamma(1+ \beta\cos\theta)]^{-1}$ (receding)

$\sin \theta' = D \sin\theta$

Approaching jet is brighter The two jets are observed at different angles to the line of sight in the flow rest frame θ'

Polarization depends on θ' – different in the two jets

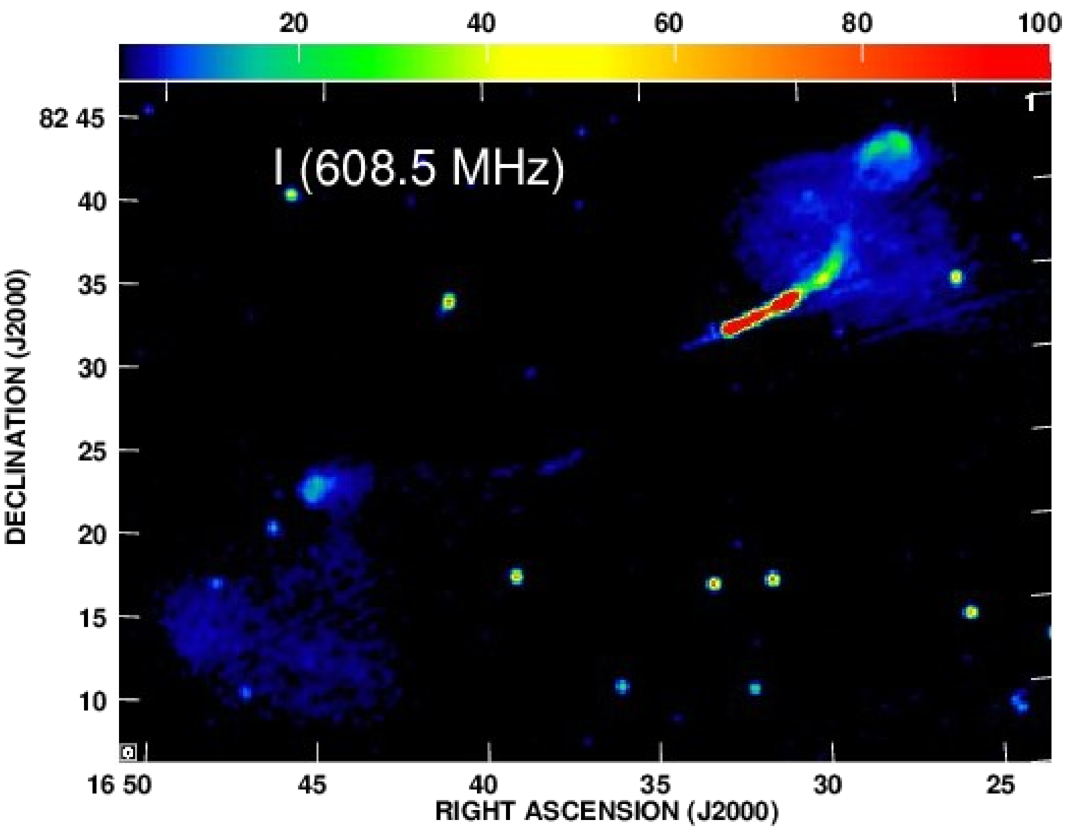
Jet Models

- What distributions of flow velocity, field geometry and rest-frame emissivity are consistent with observations?
- Observe:
  - Deep, high-resolution radio images; IQU, corrected for Faraday rotation
- Assume:
  - Symmetrical, axisymmetric, stationary, relativistic flow
  - Power-law energy distribution, optically-thin synchrotron
- Parametrised model of:
  - Geometry
  - Velocity field in 3D
  - Emissivity
  - Magnetic-field component ratios
- Calculate I, Q, U; optimise

Compare approaching and receding jets

Polarization is crucial!

NGC6251: a transition case

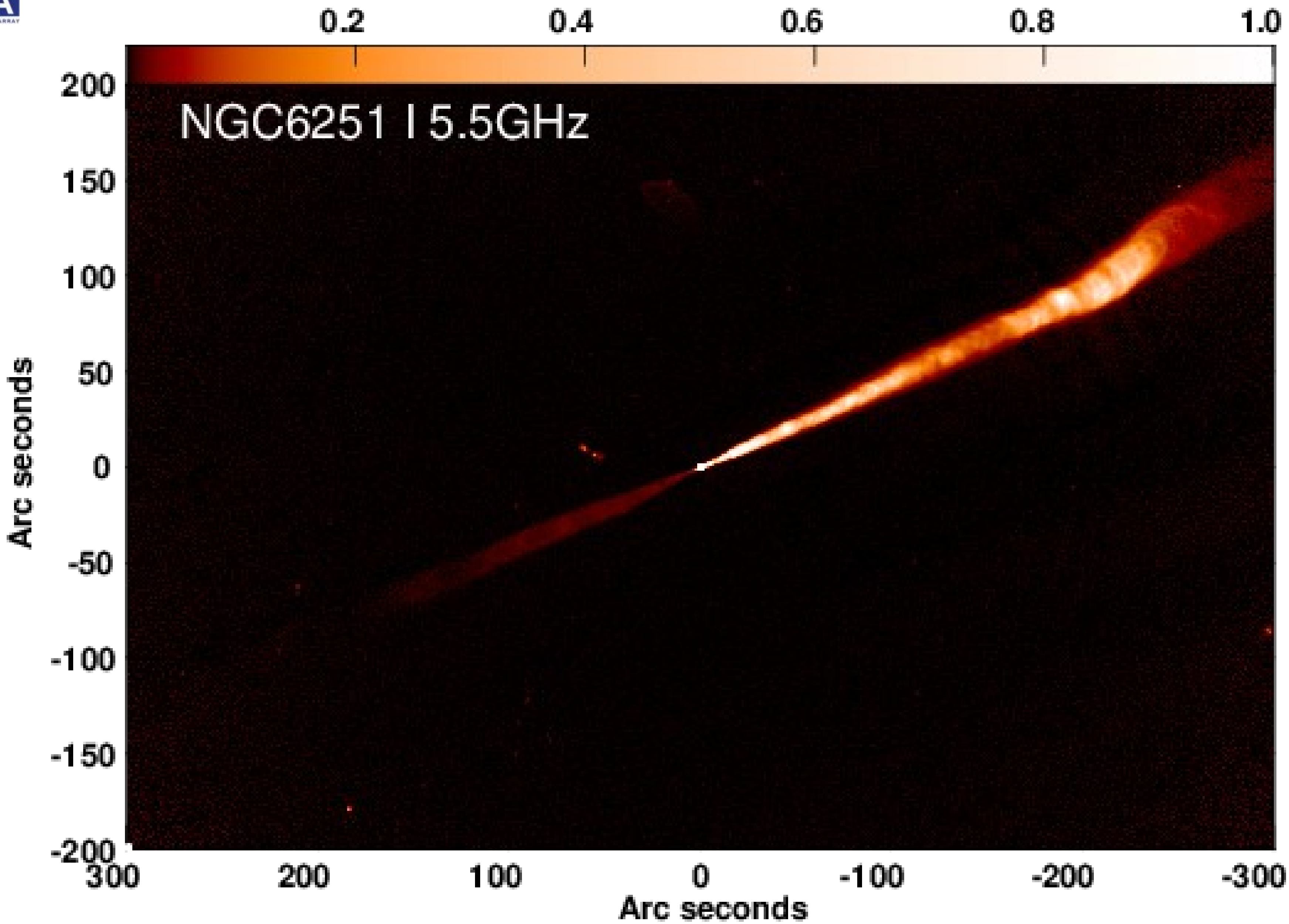


Giant radio galaxy NGC6251
(z=0.0247;1.8 Mpc projected)

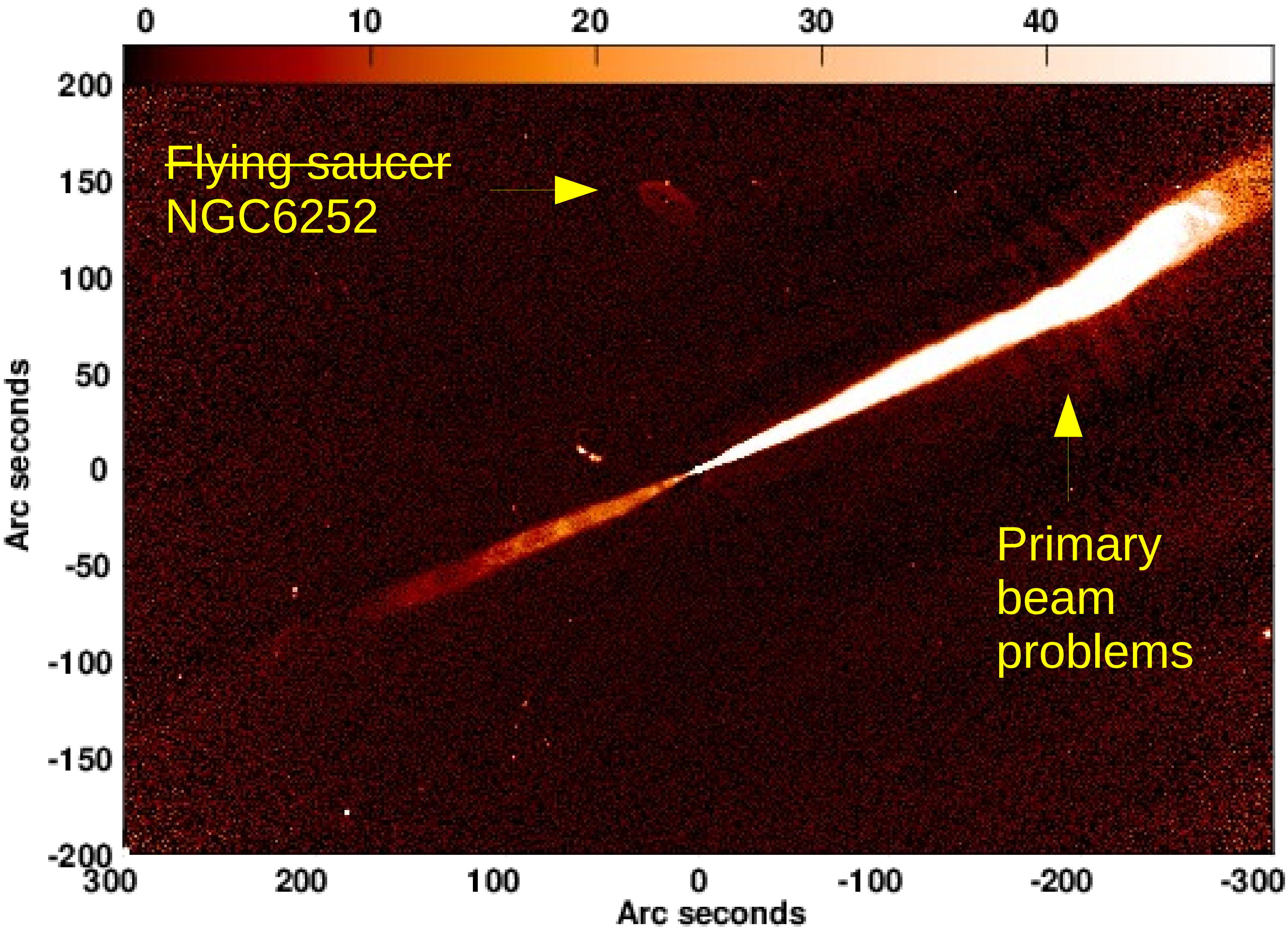
JVLA 4.5-6.5 GHz
BCD configurations (33 hr)
1.25 arcsec FWHM
1.1μJy/beam IQU
Peak/rms = 520000
I: CASA MFS Taylor term 0

Second-order D terms
Delay quantization
Core variable in spectral index as well as flux density
Faraday rotation across the band
Beam squint

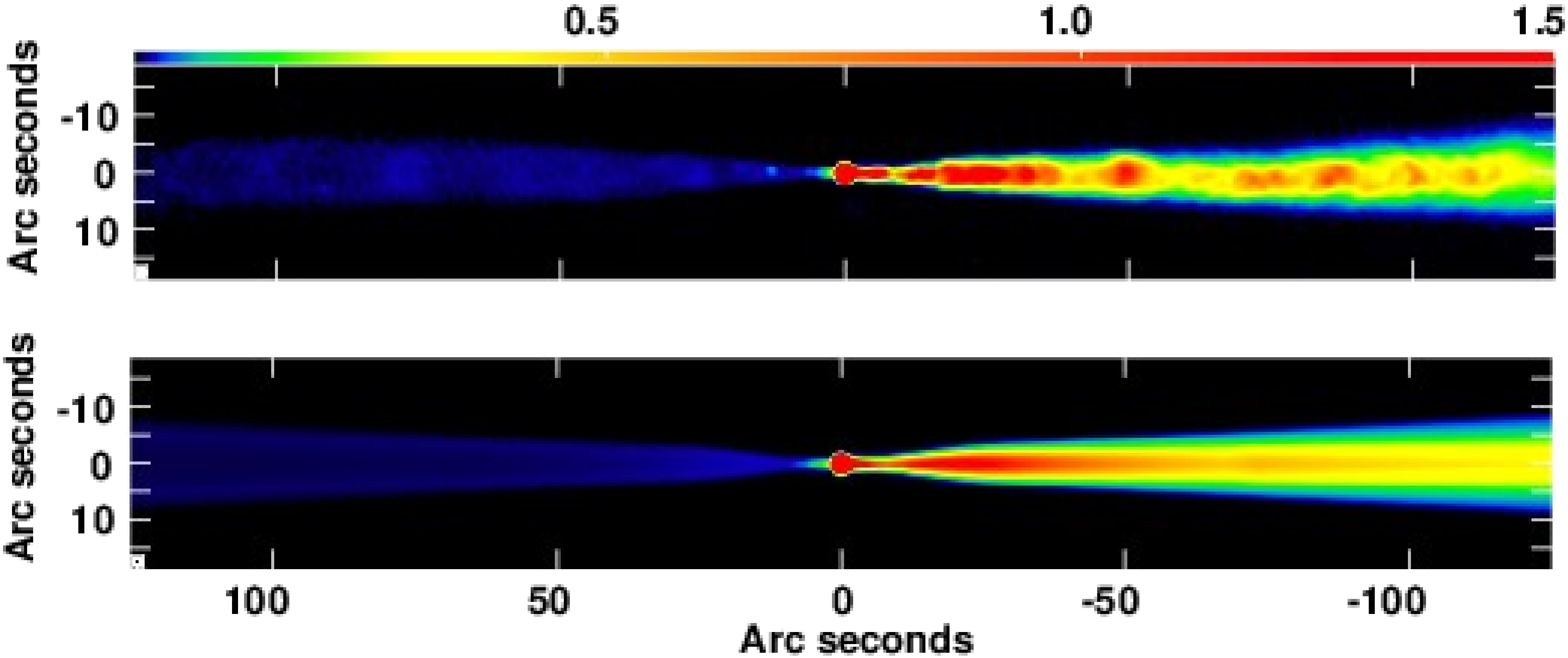
Total Intensity



Looking deeper

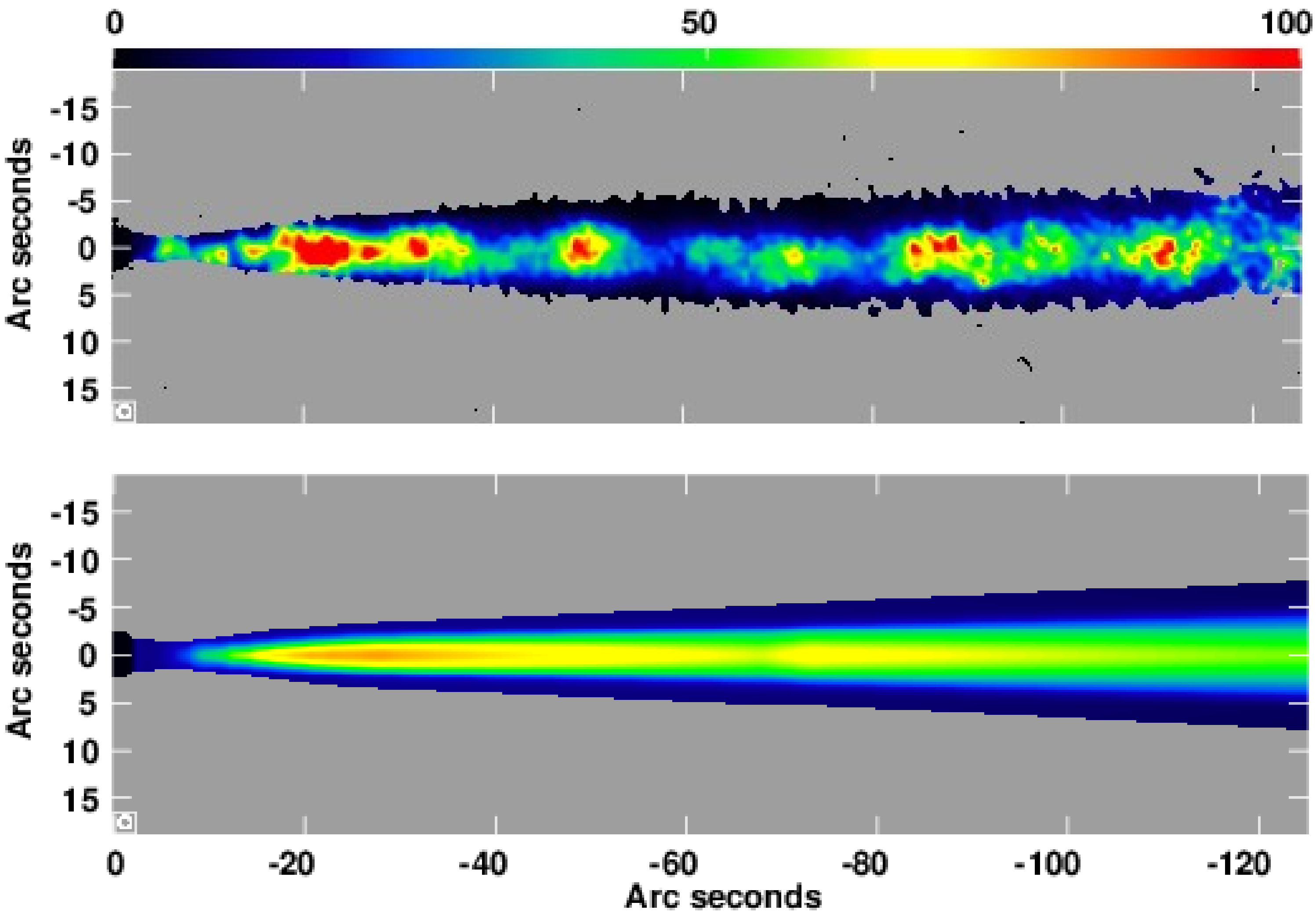


Model Fits: I



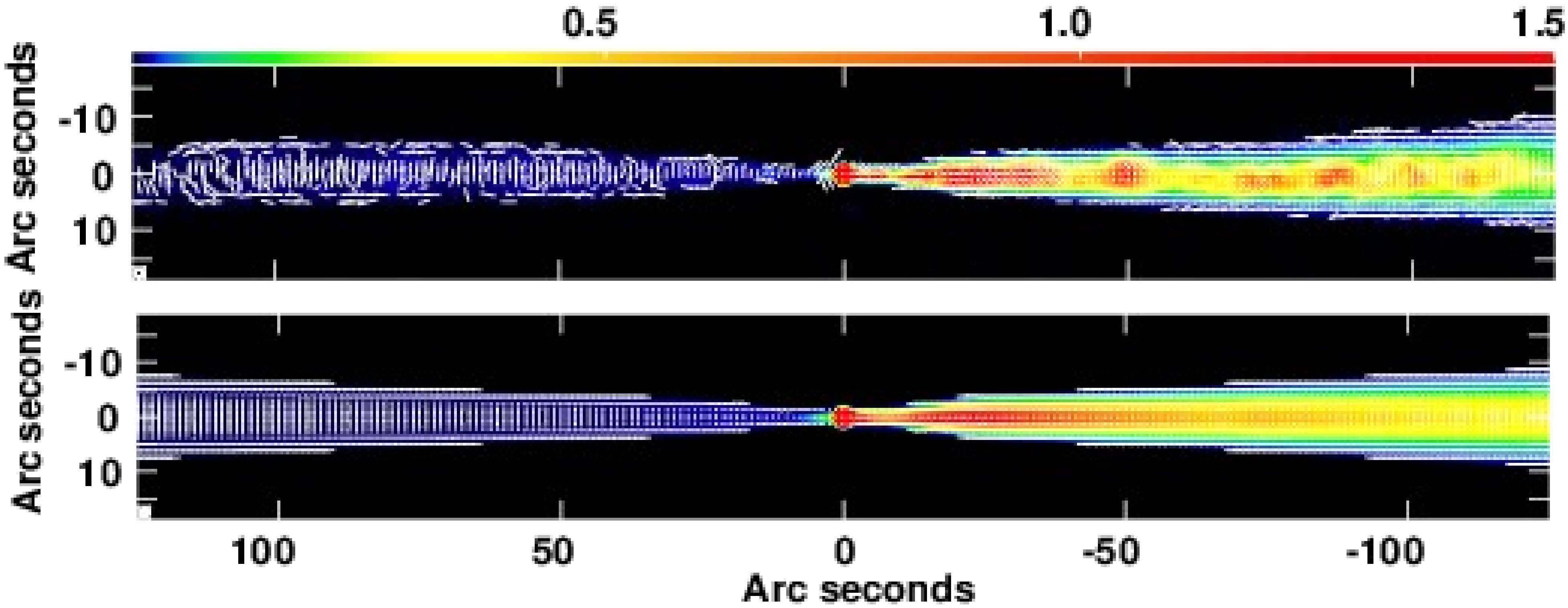
Total Intensity: $\theta = 30^{o}$

Model fits: sidedness ratio



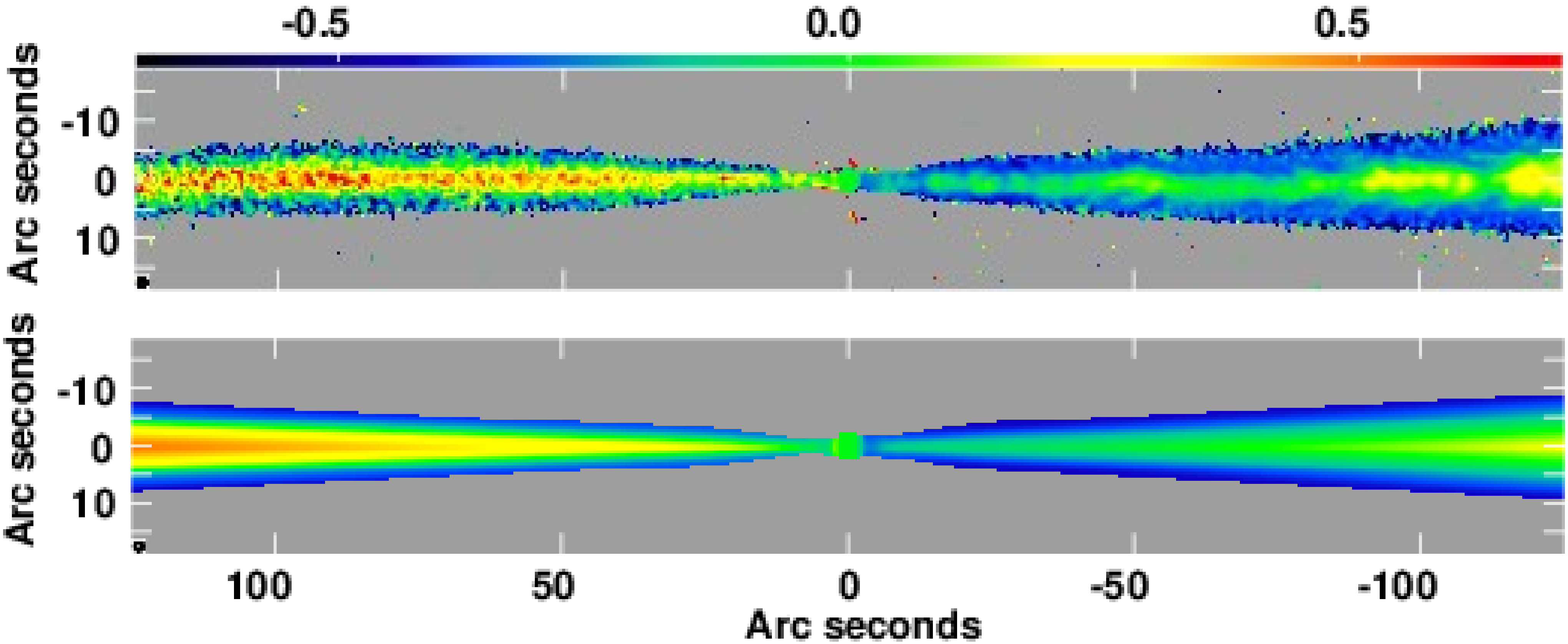
Sidedness ratio

Model fits: B vectors

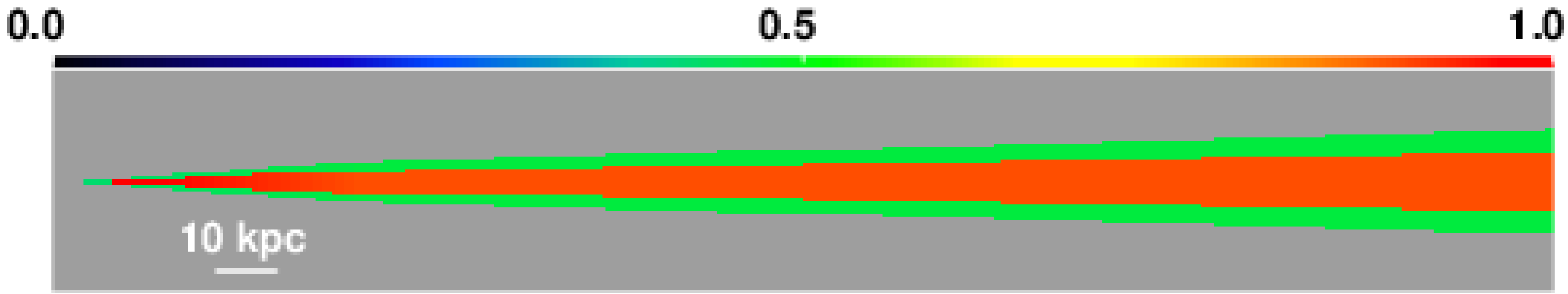


Model fits: Q/I

Parallel apparent field | Perpendicular apparent field



Velocity and Magnetic Field



Independent longitudinal velocity profiles for spine and layer
No transverse variation in either component

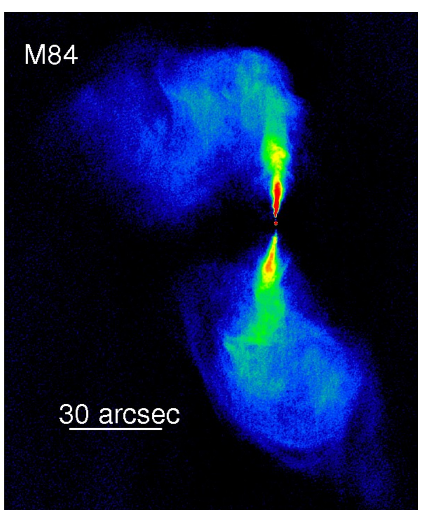
Spine $\beta \approx 0.99$ ($\Gamma \sim 7$) decelerating to $\beta \approx 0.89$ ($\Gamma \approx 2.2$)
Layer $\beta \approx 0.40$ ($\Gamma \approx 1.1$)

B field in both evolves from longitudinal to toroidally dominated.
Many local variations (knots and filaments)

How does NGC6251 compare with FRI jets?

Laing & Bridle (2014)

10 radio galaxies
0.015 < z < 0.05
Low-power, FRI

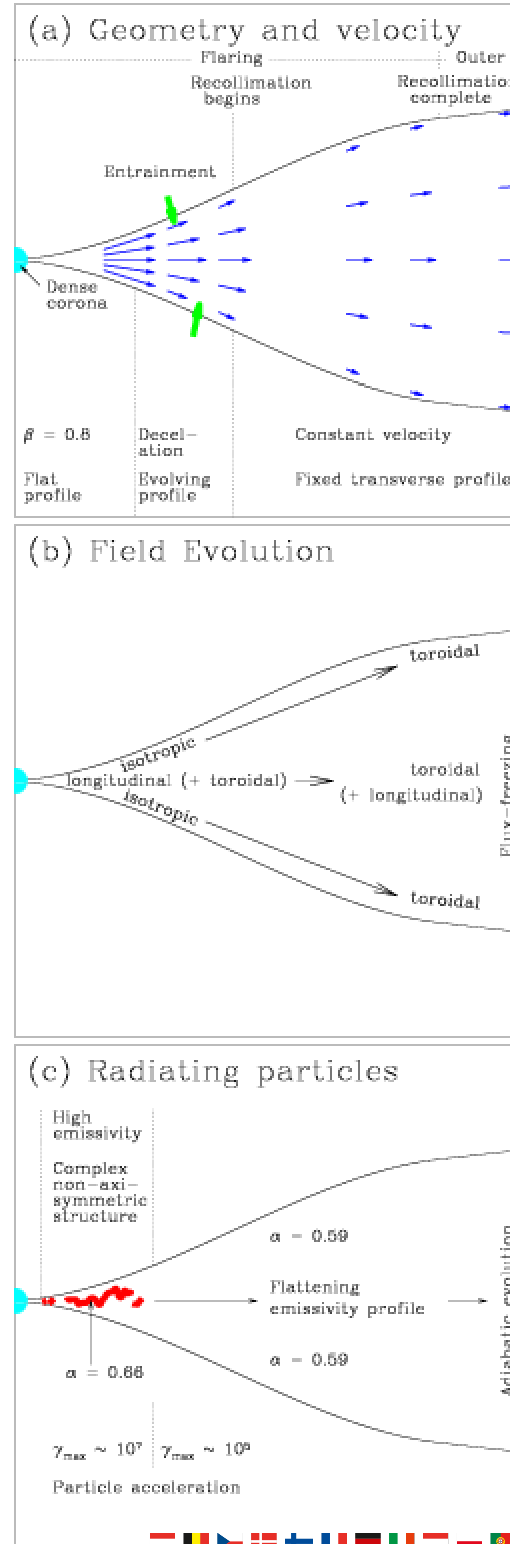


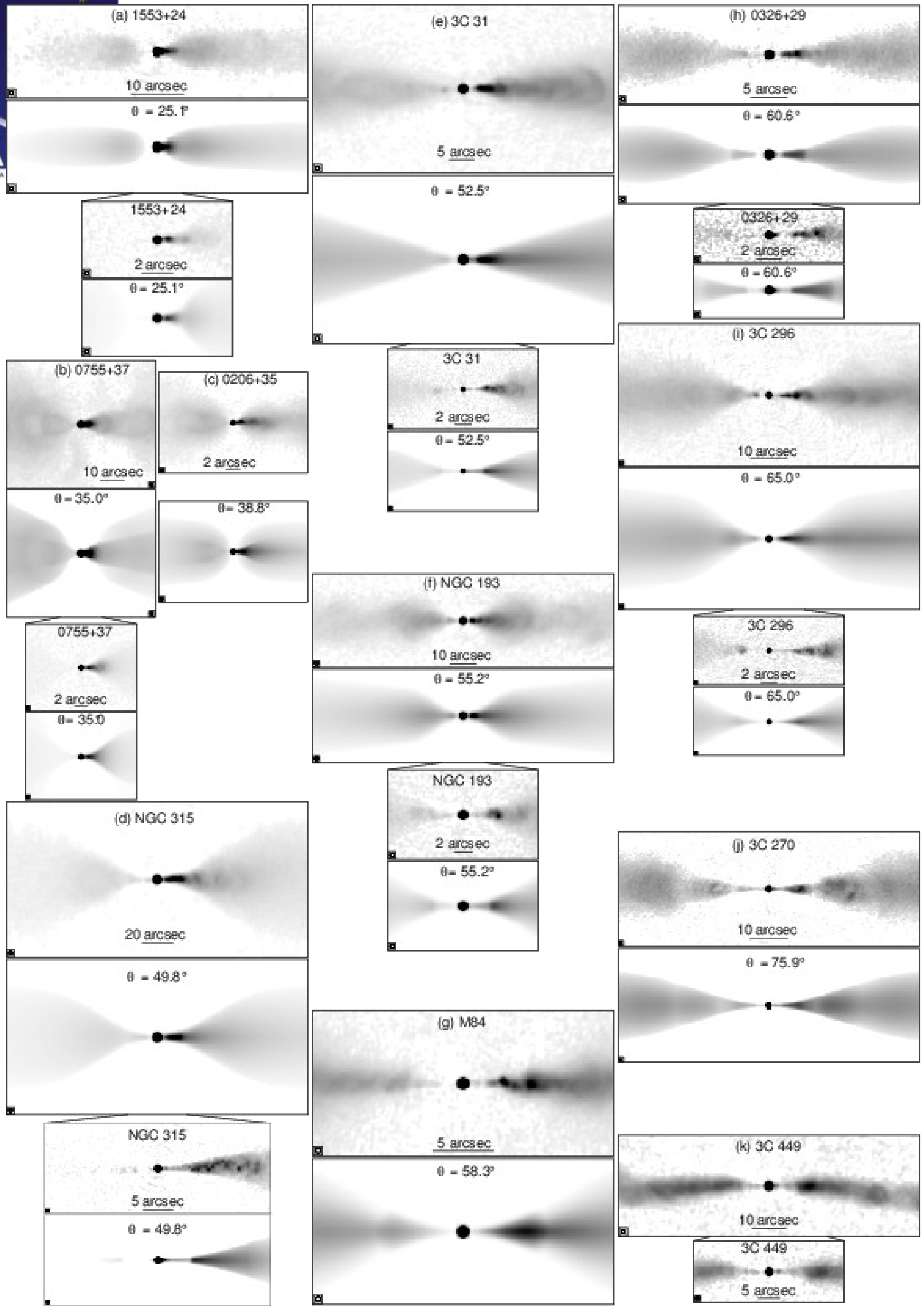
Differences:

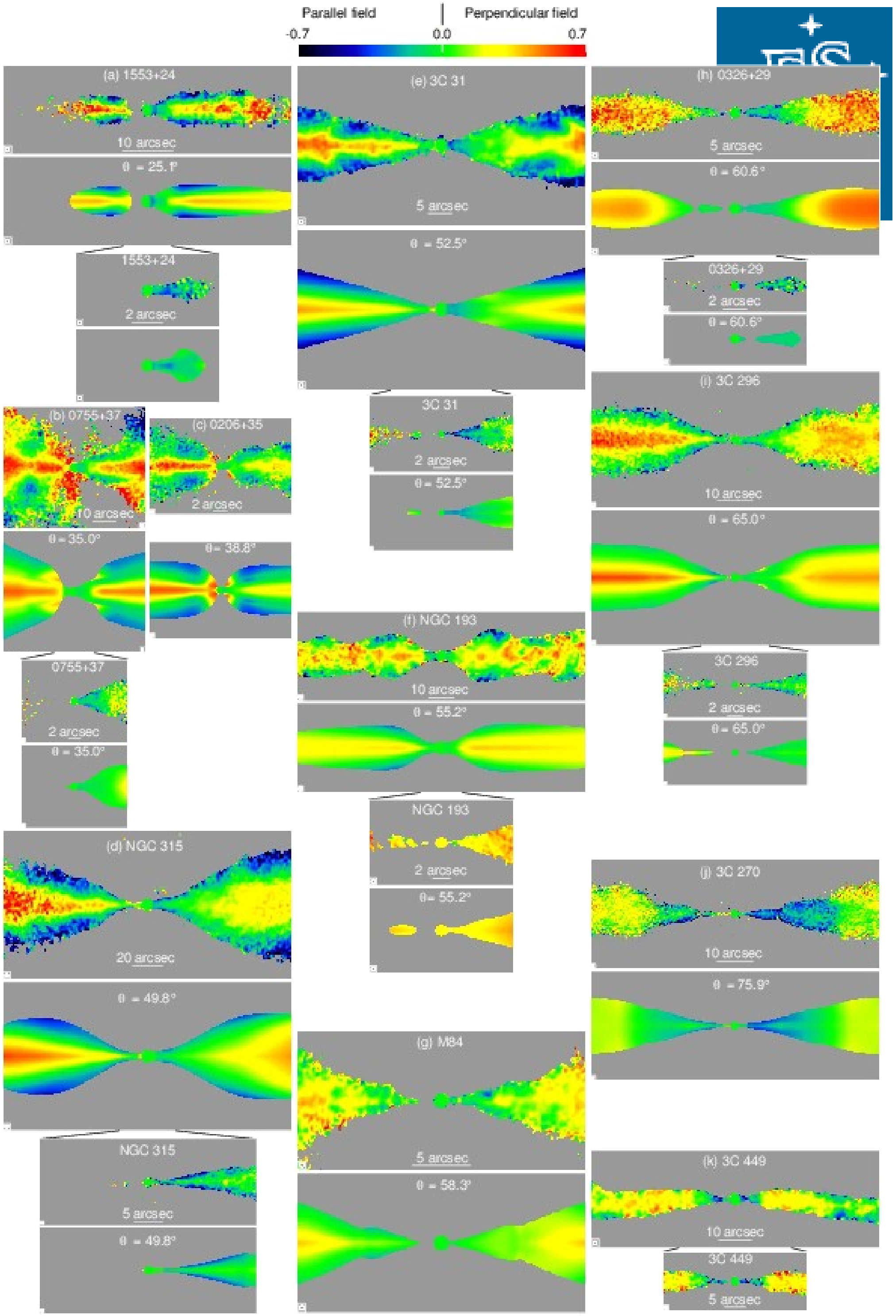
FRI jets:
- expand rapidly
- decelerate from $\Gamma \approx 2$ to $\Gamma \approx 1$

Similarities:

- Longitudinal → toroidal field
- Transverse velocity gradients




(a) 1553+24
10 arcsec
θ = 25.1°
1553+24
2 arcsec
θ = 25.1°
(b) 0755+37
10 arcsec
θ = 35.0°
(c) 0206+35
2 arcsec
θ = 38.8°
0755+37
2 arcsec
θ = 35.0
(d) NGC 315
20 arcsec
θ = 49.8°
NGC 315
5 arcsec
θ = 49.8°
(e) 3C 31
5 arcsec
θ = 52.5°
3C 31
2 arcsec
θ = 52.5°
(f) NGC 193
10 arcsec
θ = 55.2°
NGC 193
2 arcsec
θ = 55.2°
(g) M84
5 arcsec
θ = 58.3°
(h) 0326+29
5 arcsec
θ = 60.6°
0326+29
2 arcsec
θ = 60.6°
(i) 3C 296
10 arcsec
θ = 65.0°
3C 296
2 arcsec
θ = 65.0°
(j) 3C 270
10 arcsec
θ = 75.9°
(k) 3C 449
10 arcsec
3C 449
5 arcsec


Parallel field
Perpendicular field
-0.7
0.0
0.7
(a) 1553+24
10 arcsec
θ = 25.1°
1553+24
2 arcsec
(b) 0755+37
10 arcsec
θ = 35.0°
(c) 0206+35
2 arcsec
θ = 38.8°
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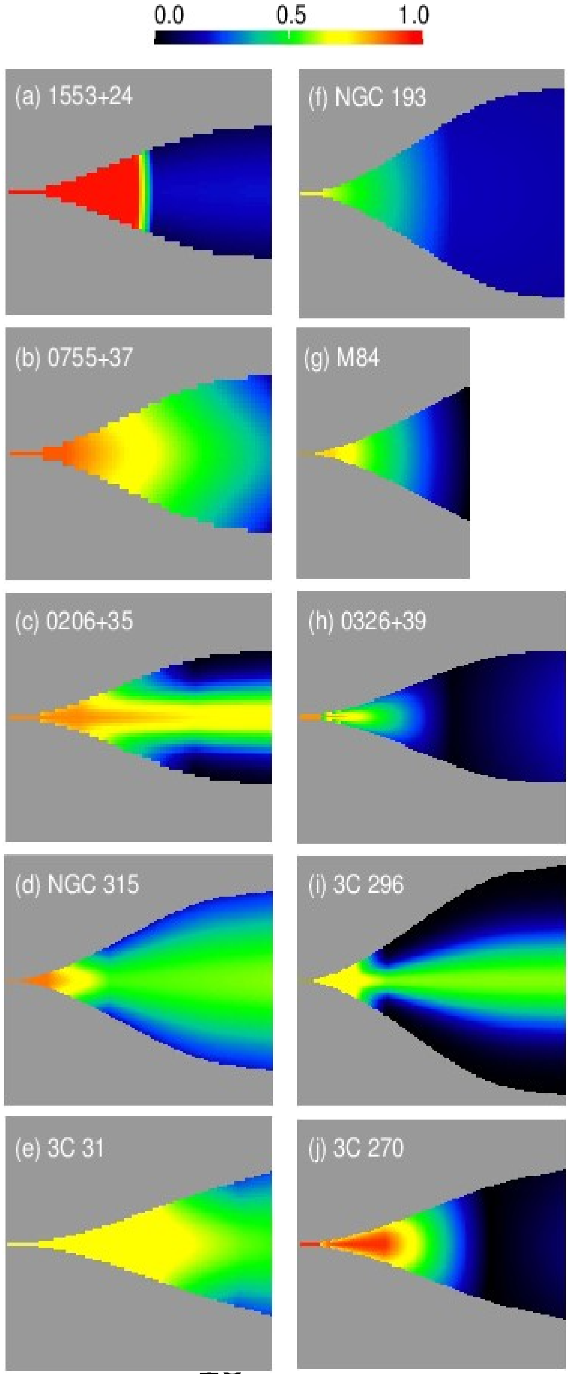
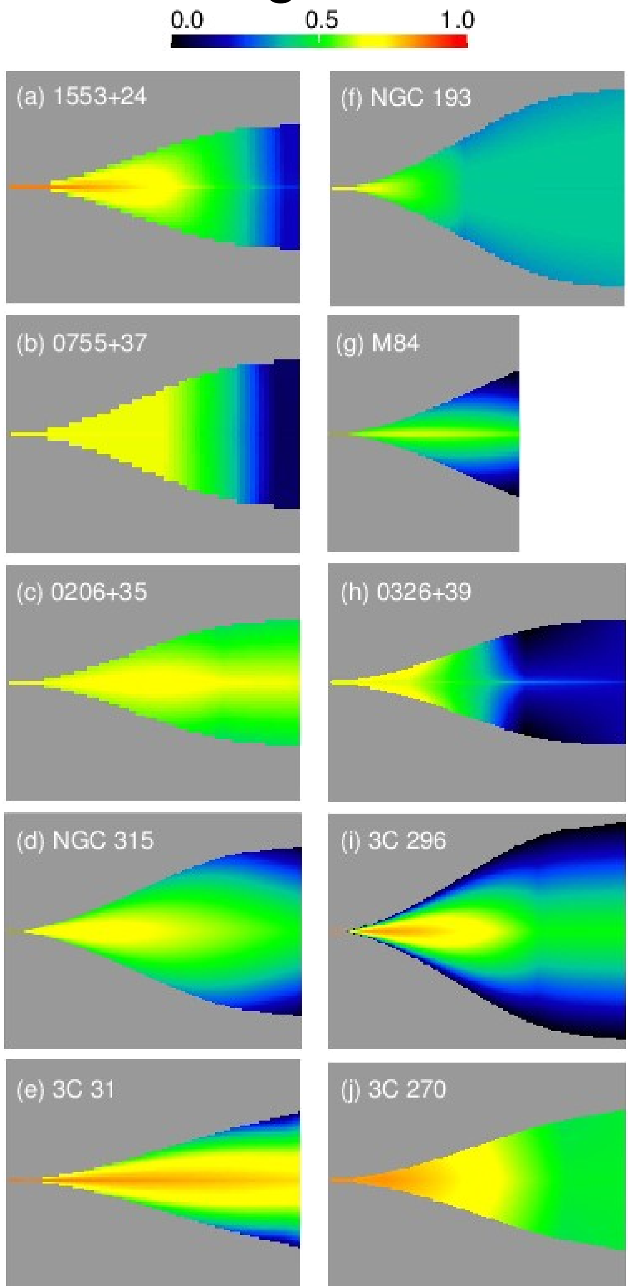
10 arcsec
θ = 75.9°
(k) 3C 449
10 arcsec
3C 449
5 arcsec

FRI jet velocities: deceleration

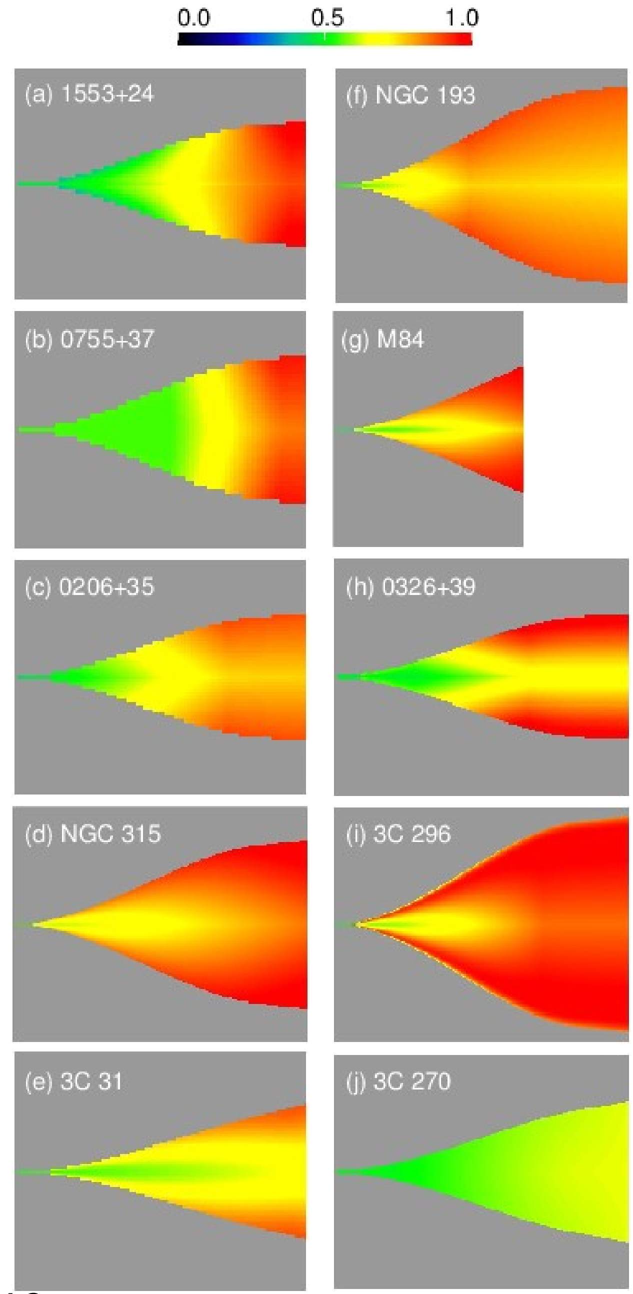


Fractional magnetic field components

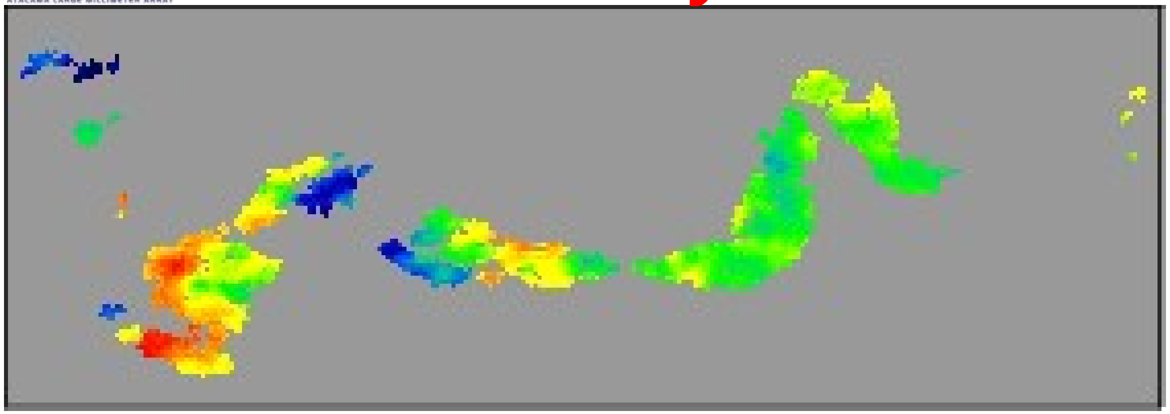
Longitudinal

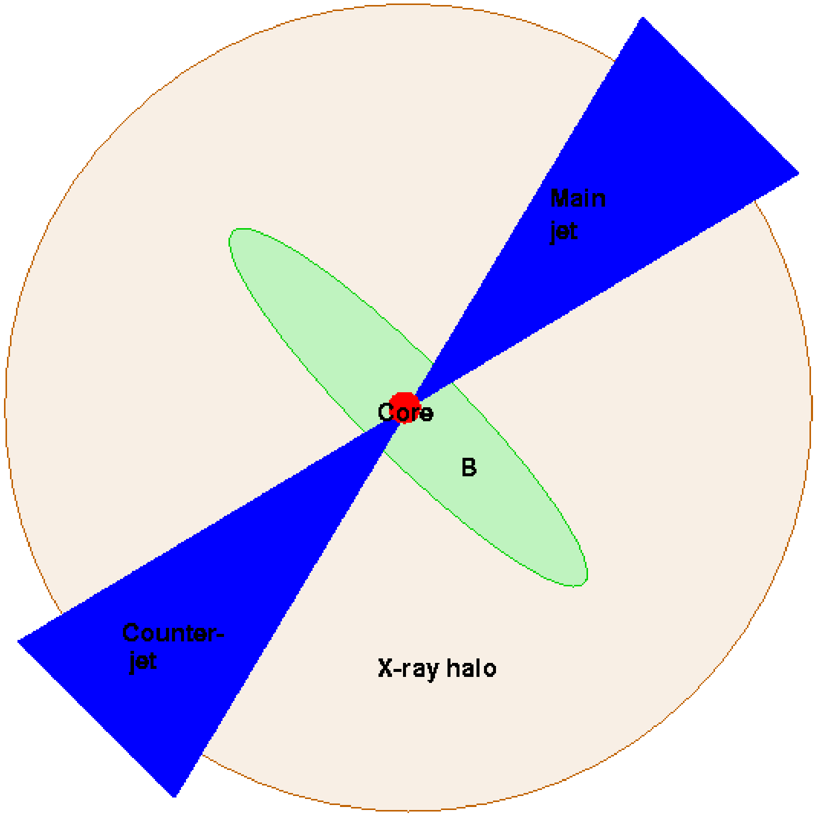


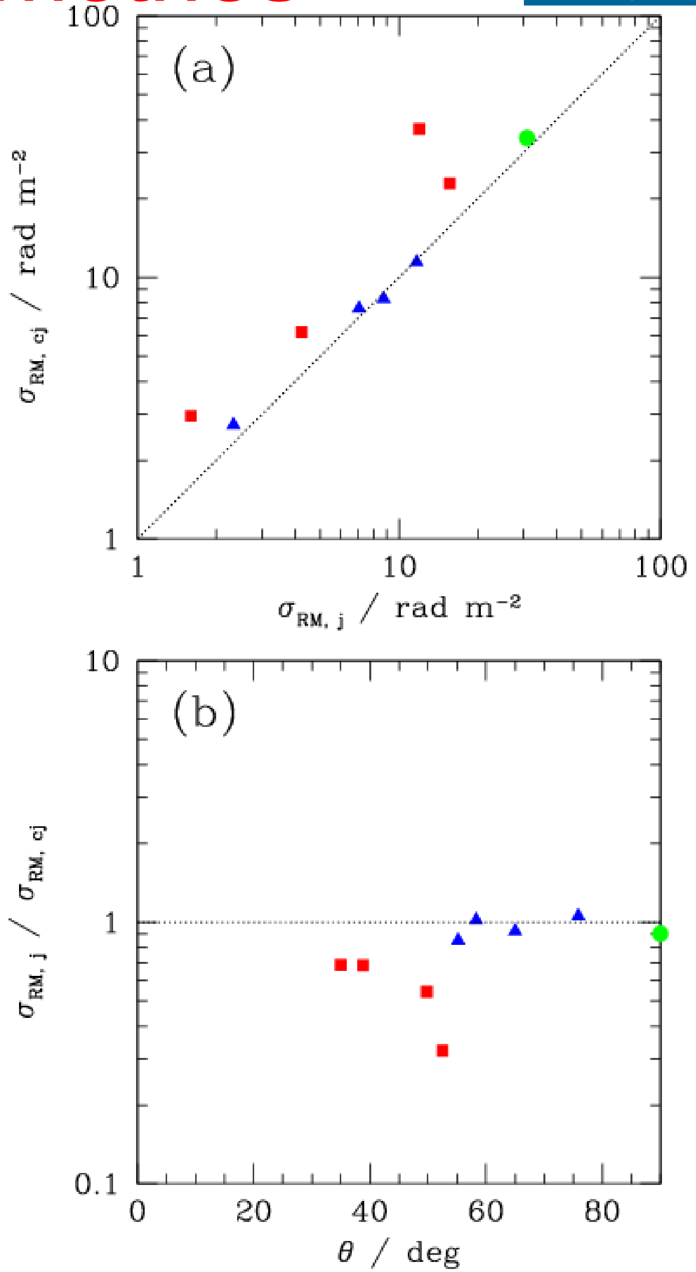
Toroidal



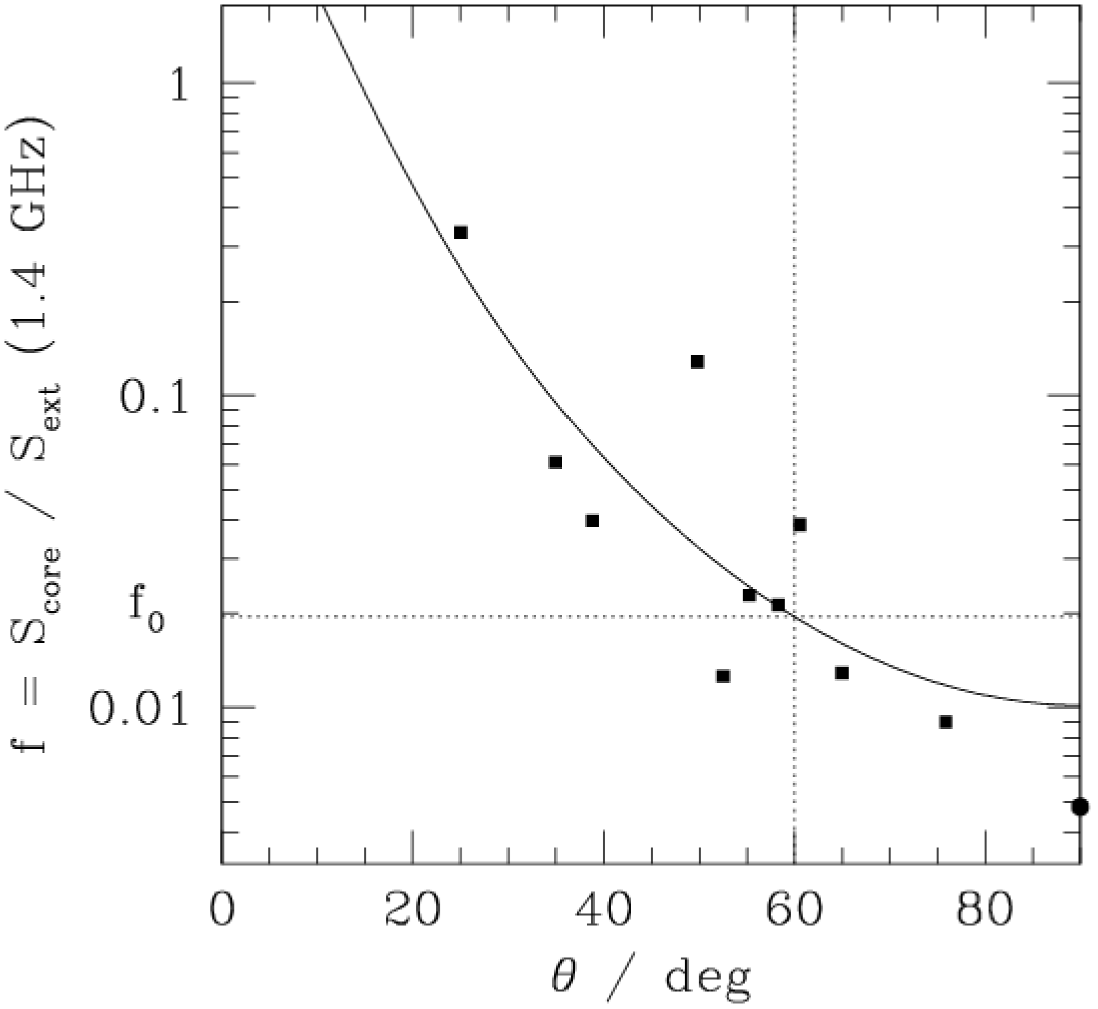
Consistency Test 1:
Faraday Rotation Asymmetries







Consistency test 2: core fraction



Core is the optically-thick base of the jet

Assume intrinsic ratio of core/extended emission is constant

Doppler beaming causes observed ratio f to be anticorrelated with θ

Conclusions

- Clear evidence for a fast spine and slow layer in one transition source, NGC6251 – but not extreme enough for iCCMB
  - Best fitted as two discrete components
  - Spine $\Gamma \sim 7$, decelerating to $\Gamma \approx 2.2$ by 25 kpc
  - Layer $\Gamma \approx 1.1$ everywhere
  - Narrow: $2.3^0 \rightarrow 1.5^o$ half-opening angle in jet frame
- In contrast, FRI twin jets decelerate rapidly (Laing & Bridle 2014)
  - $\Gamma \approx 2$ at the flaring point
  - Rapid expansion followed by deceleration and recollimation
  - Develop smooth transverse velocity gradients