A Follow-up RM Observation of Helical Magnetic Field in 3C 273 Jet

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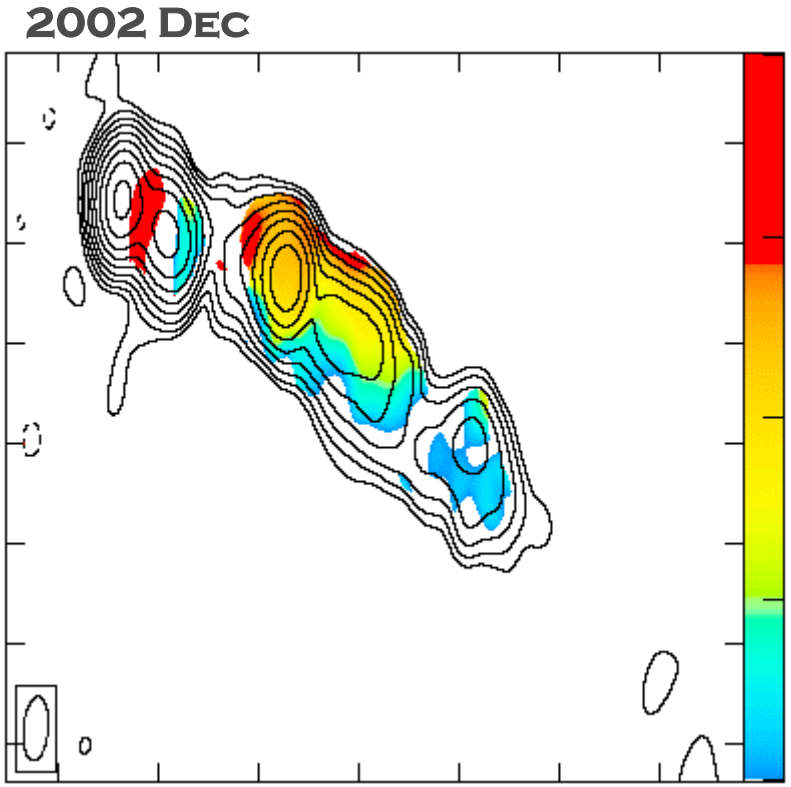
Summary

We had found RM Grad across the in 3C 273 . (Asada et al. 2002).

RM Gradient can be well explained by A Helical B Field.

We made a Follow-Up O



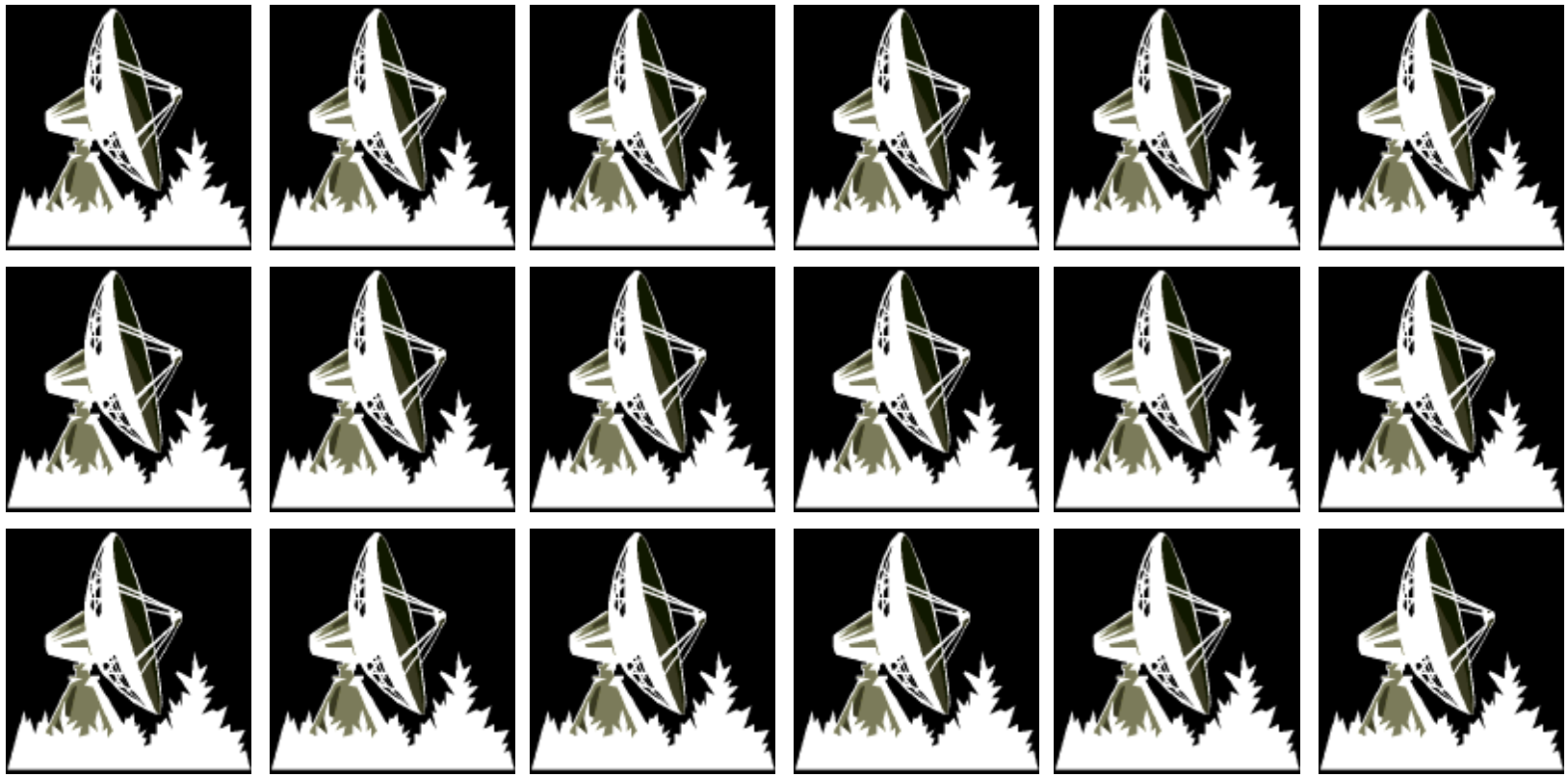
Contour: total intensity
Color: RM

We Confirmed The RM Gradient.
Also We detected time variation of RM.
It can be explained by proper motion of Magnetized Plasma associated with jet.

Outline

- Introduction
  - AGN Jets and MHD model
  - Previous our Results
- Observations and Results
- Discussion
- Conclusion

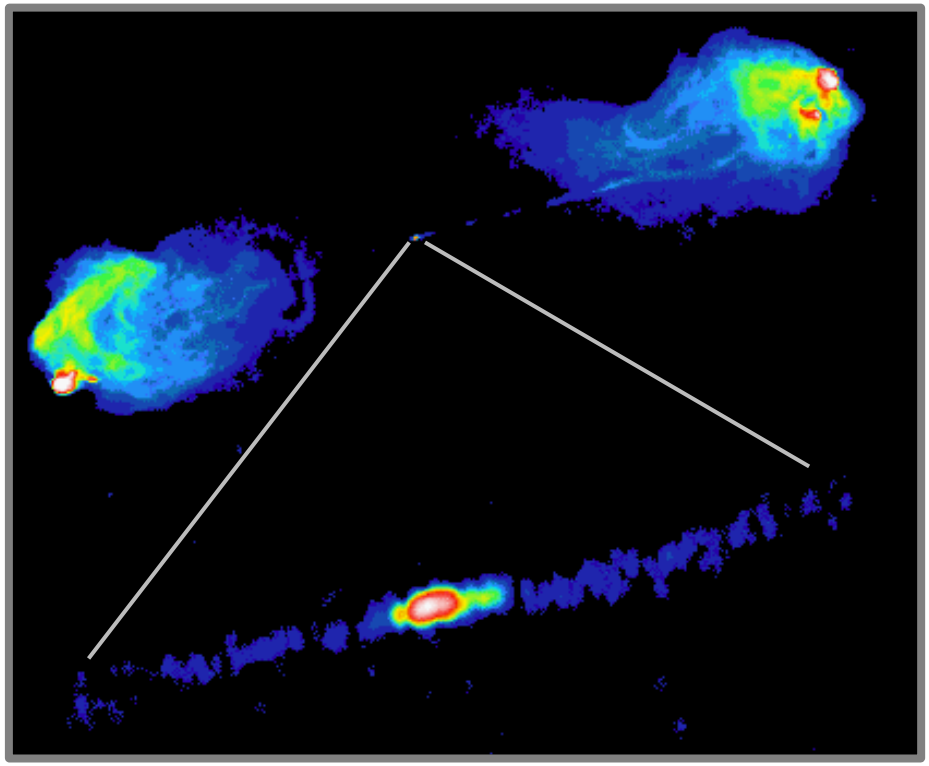
Introduction



AGN Jets

AGN jets

- Highly Accelerated
  (Sometimes up to c)
- Well Collimated
  (Sometimes up to Mpc)



Krichbaum et al. (1998) A&A 329, 873

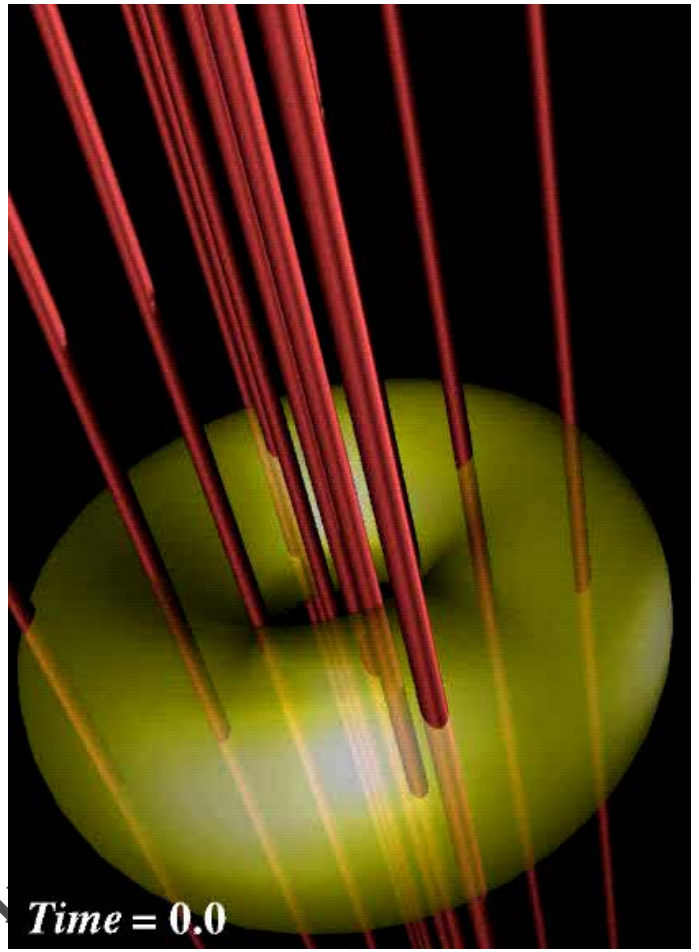
Scientific issue

- How jets are accelerated ?
- How jets are collimated ?

We have not known for 80 years !!

MHD Jet Model

- Acceleration
  - Magnetic
  - Centrifugal Force
  - &
  - Pressure
- Collimation
  - Toroidal comp. of B Field



Acceleration & Collimation
Are Simultaneously Explained

Nakamura, M. et al. (2001)

Previous Results 1. Asada et al. 2002

In order to reveal 3D structure of B field

We analyzed VLBA Polarimetry Data

- PA $\perp B_{\perp}$

  $B_{\perp}$: Projected B Field

  PA: Polarization Position Angle

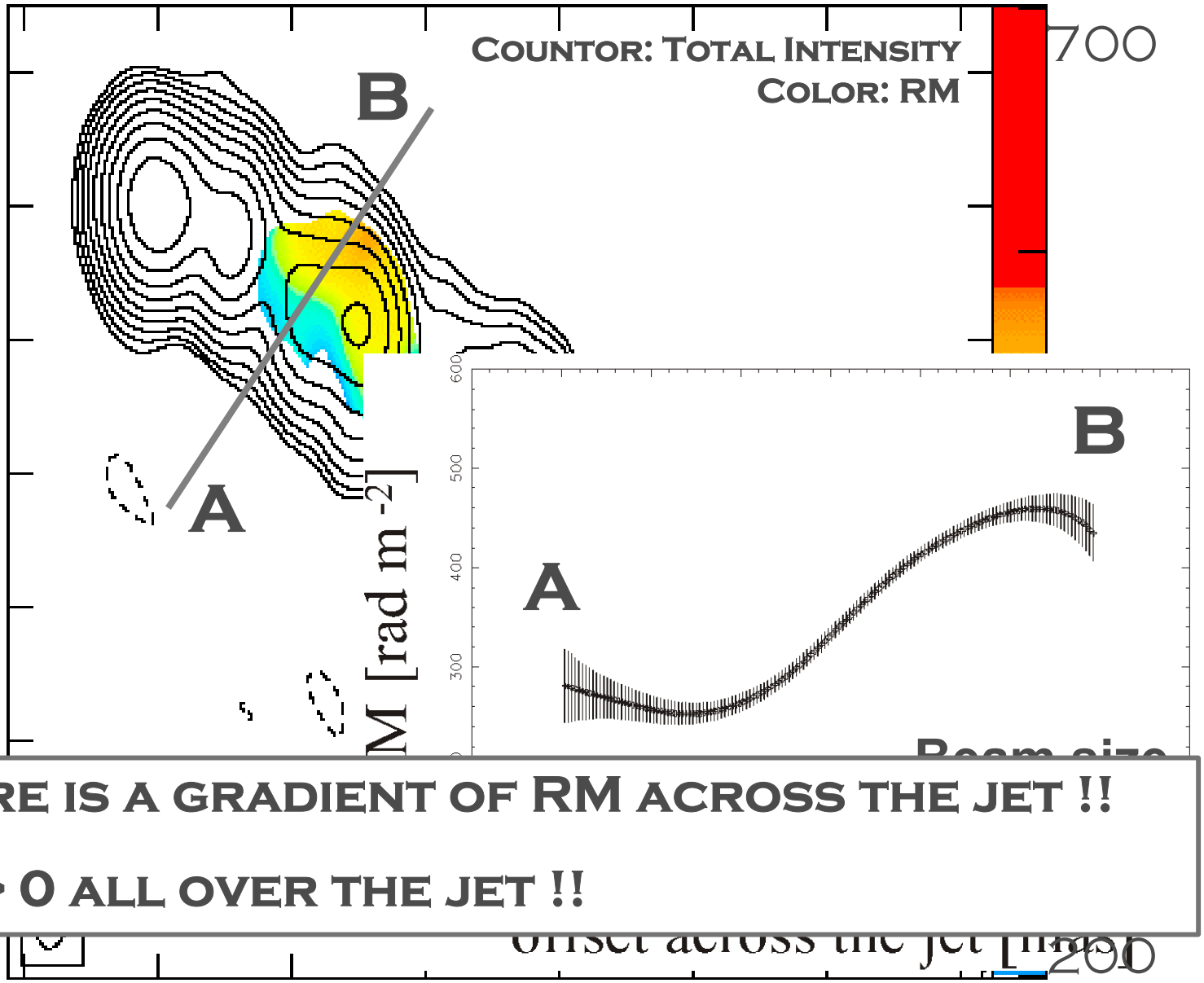
- $RM = 8.1 \times 10^{5} \int_{LOS} n_e B_{\parallel} dl$

  $B_{\parallel}$: Line of sight component of B Field

  RM: Faraday Rotation Measure

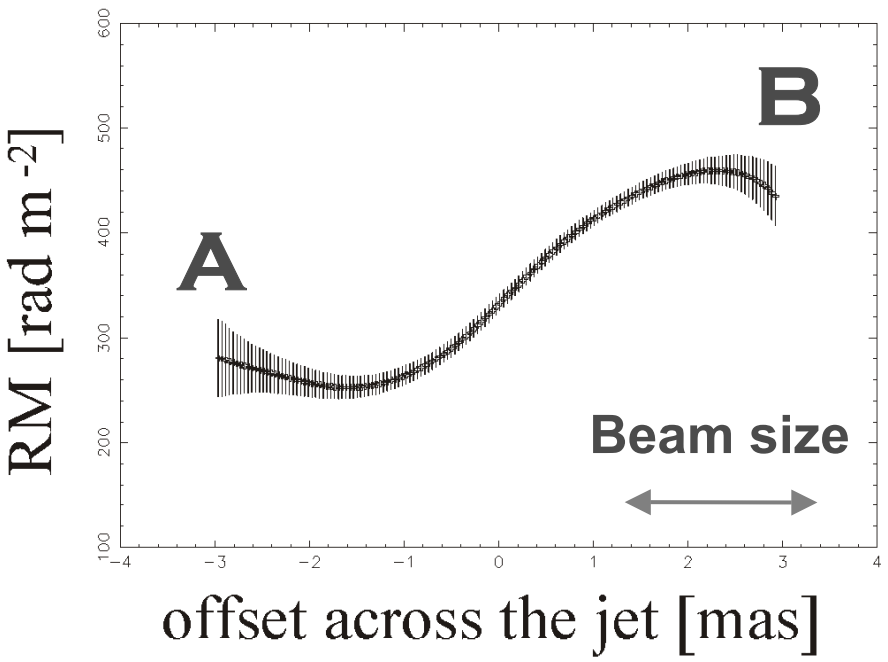
  n_e : Density of Electron

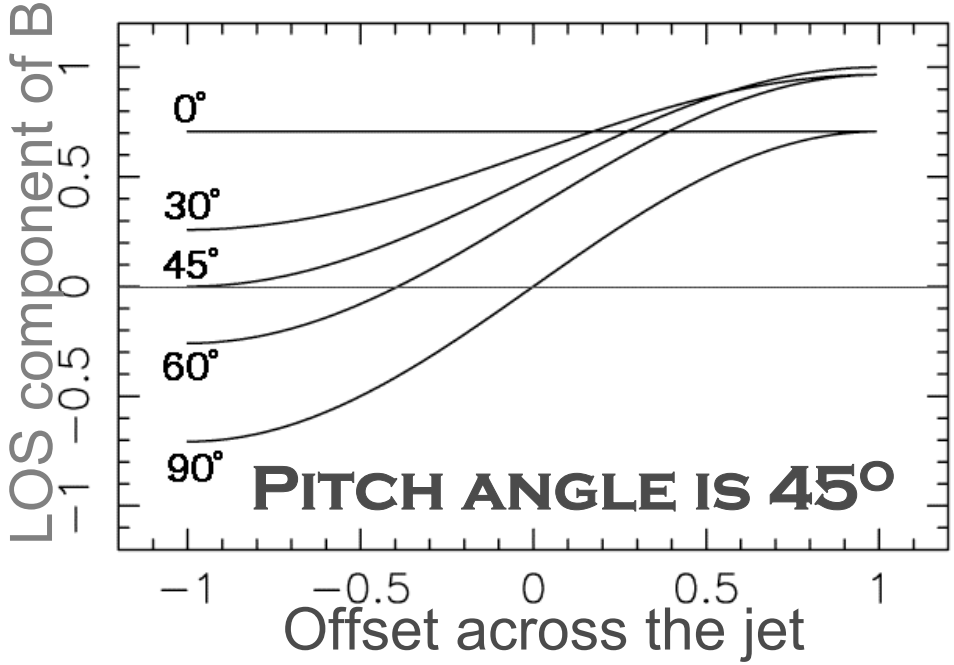
Previous Results 2. Asada et al. 2002



- There is a gradient of RM across the jet !!
- RM > 0 all over the jet !!

Previous Results 3. Asada et al. 2002





$$RM = 8.1 \times 10^{5} \int_{LOS} n_e B_{\parallel} dl$$

Apparent Velocity of jets

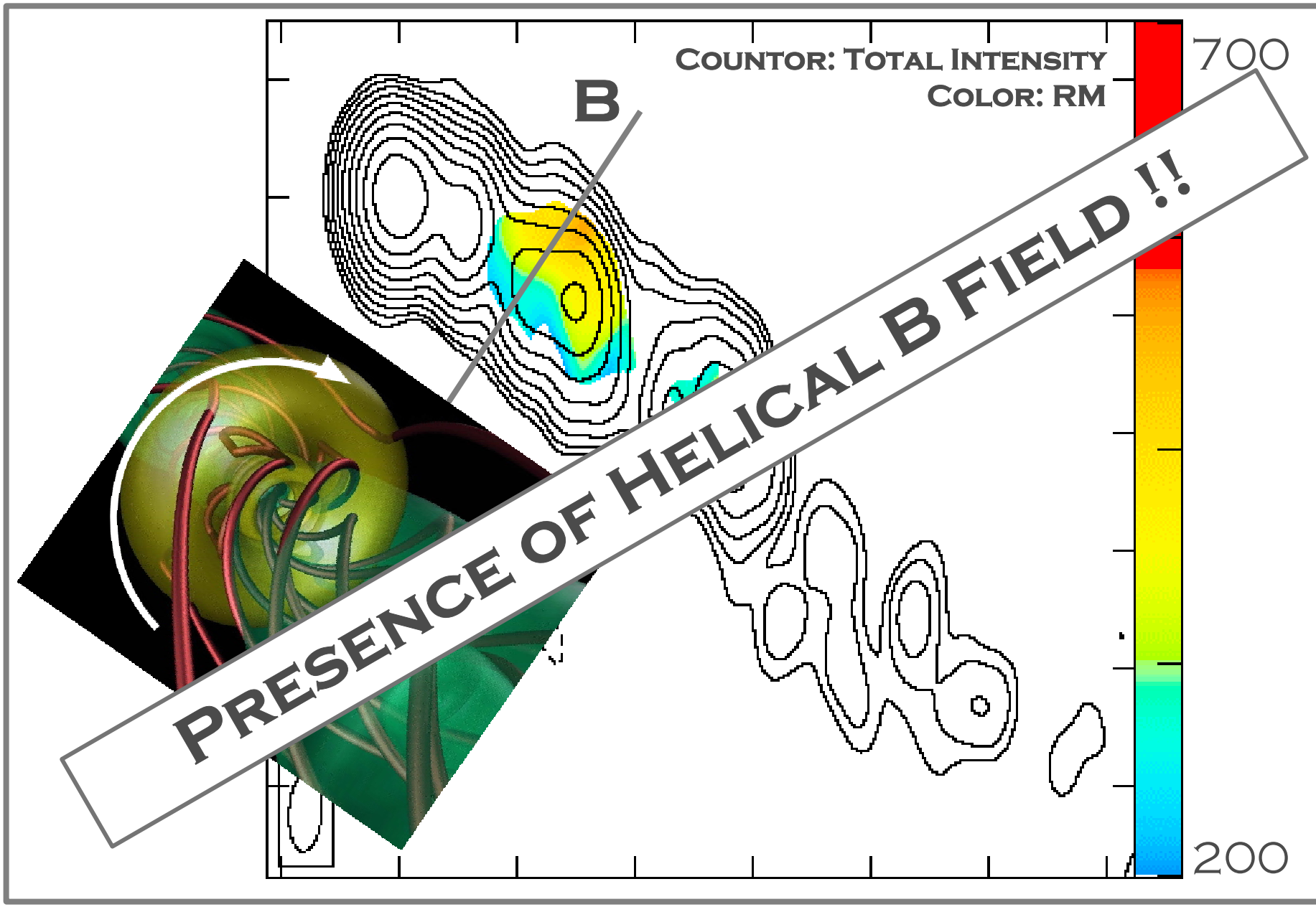
$\theta_{MAX} = 2\arctan \beta_{APP}^{-1}$

$\beta_{APP} = 4.4 \sim 7.0$ c

Upper limit of Viewing Angle

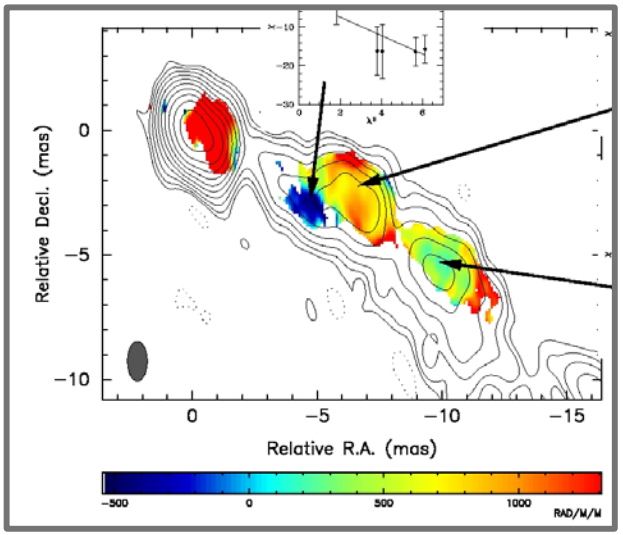
$\theta_{MAX} = 16^{o}.3 \pm 0^{o}.5$

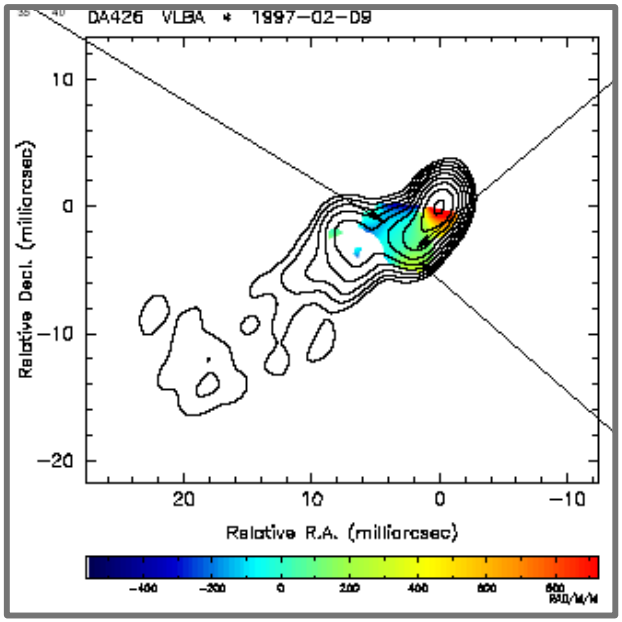
Previous Results 4. Asada et al. 2002

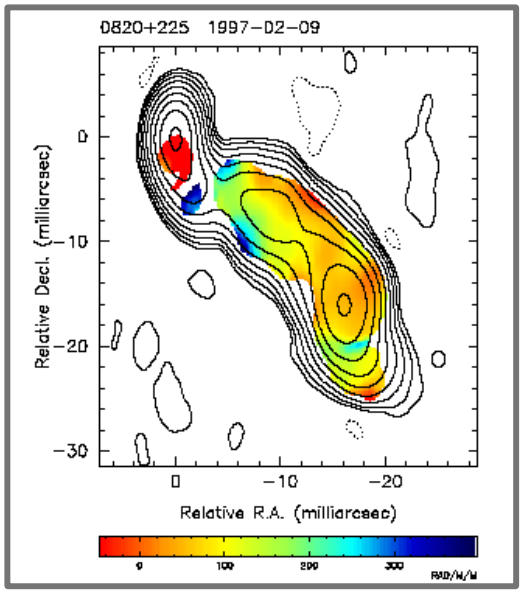


RM Grad. of Other Sources

Gradient of RM across the Jets for Other sources !!

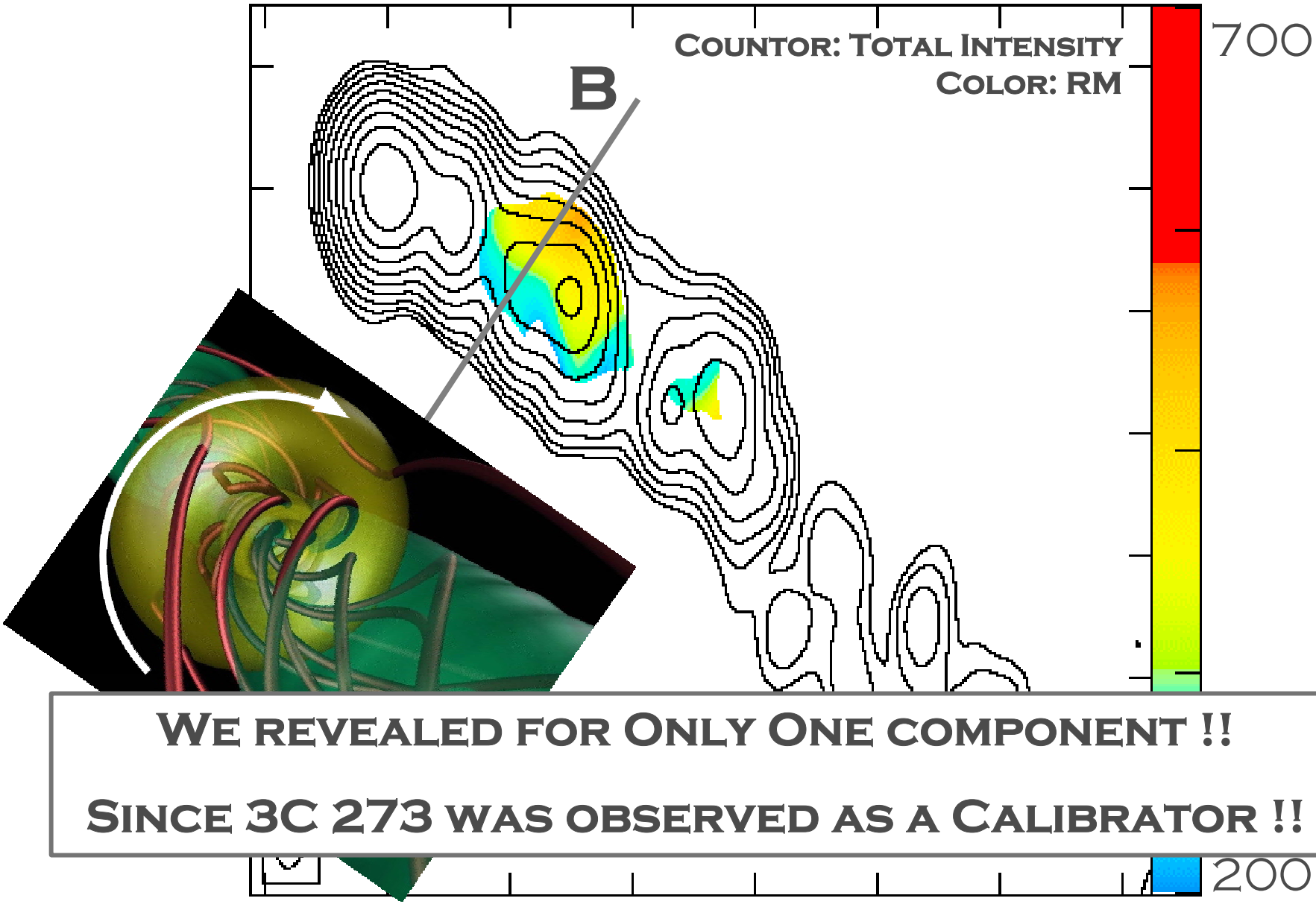






Gabuzda, D.C., Murray, E., Cronin, P. 2004, MNRAS, 351, 89L
Zavala, R.T., & Taylor, G.B. 2004 in Proc of the VLBA 10th Anniversary conference

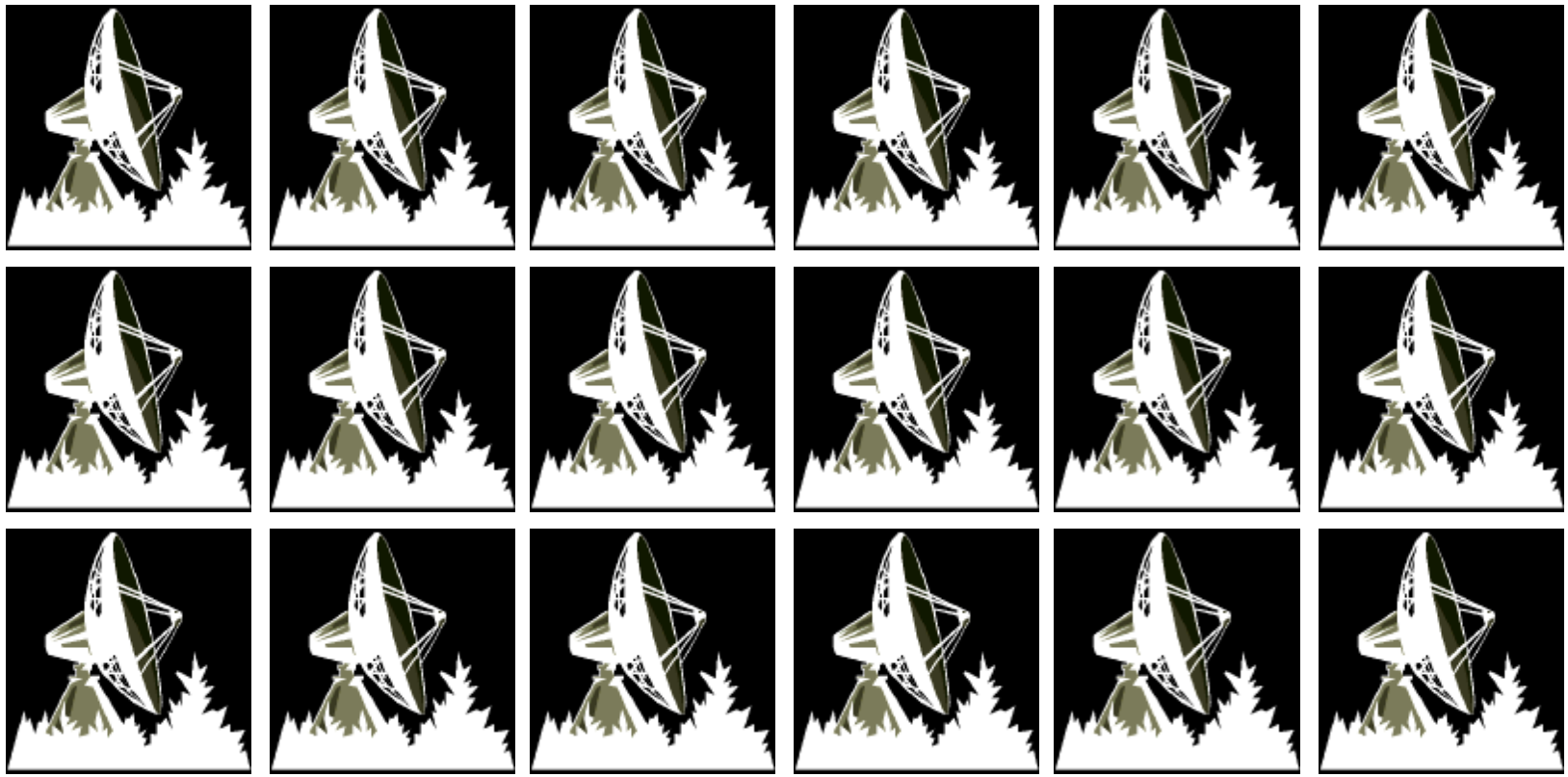
Aim of our study



We revealed for Only One component !!

Since 3C 273 was observed as a Calibrator !!

Observations and Results



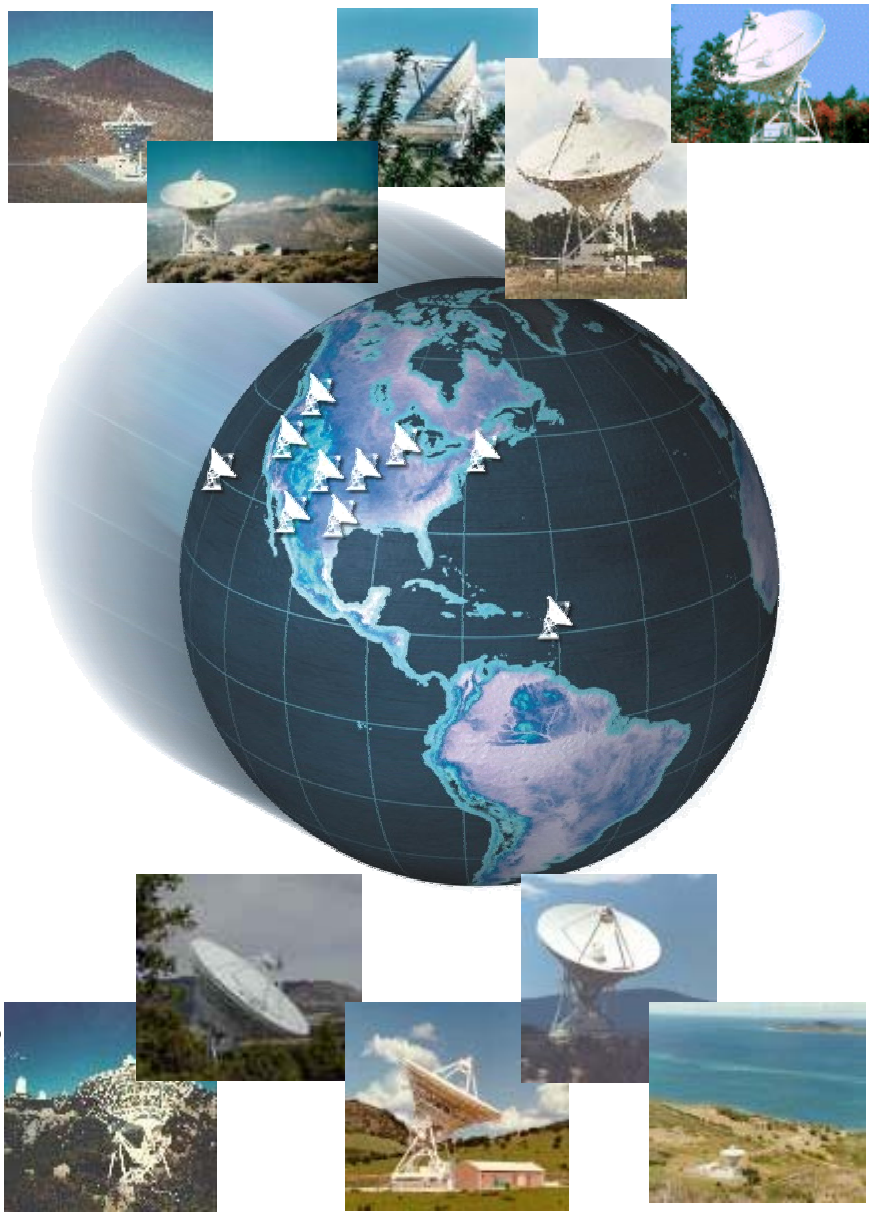
Observations

- **Frequencies:**
  4. 618 - 5.093 GHz
  8.118 - 8.593 GHz

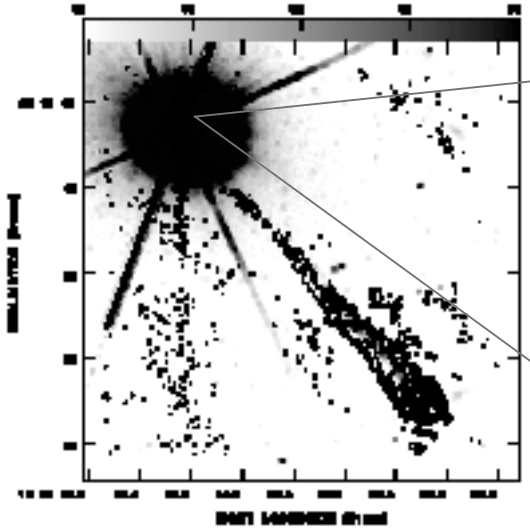
- **Date:**
  Dec, 15, 2002

- **Stations:**
  VLBA 10 Stations

- **Integration Time:**
  66 Min for Each Freq.



3C 273



- **RedShift:**
  z = 0.158

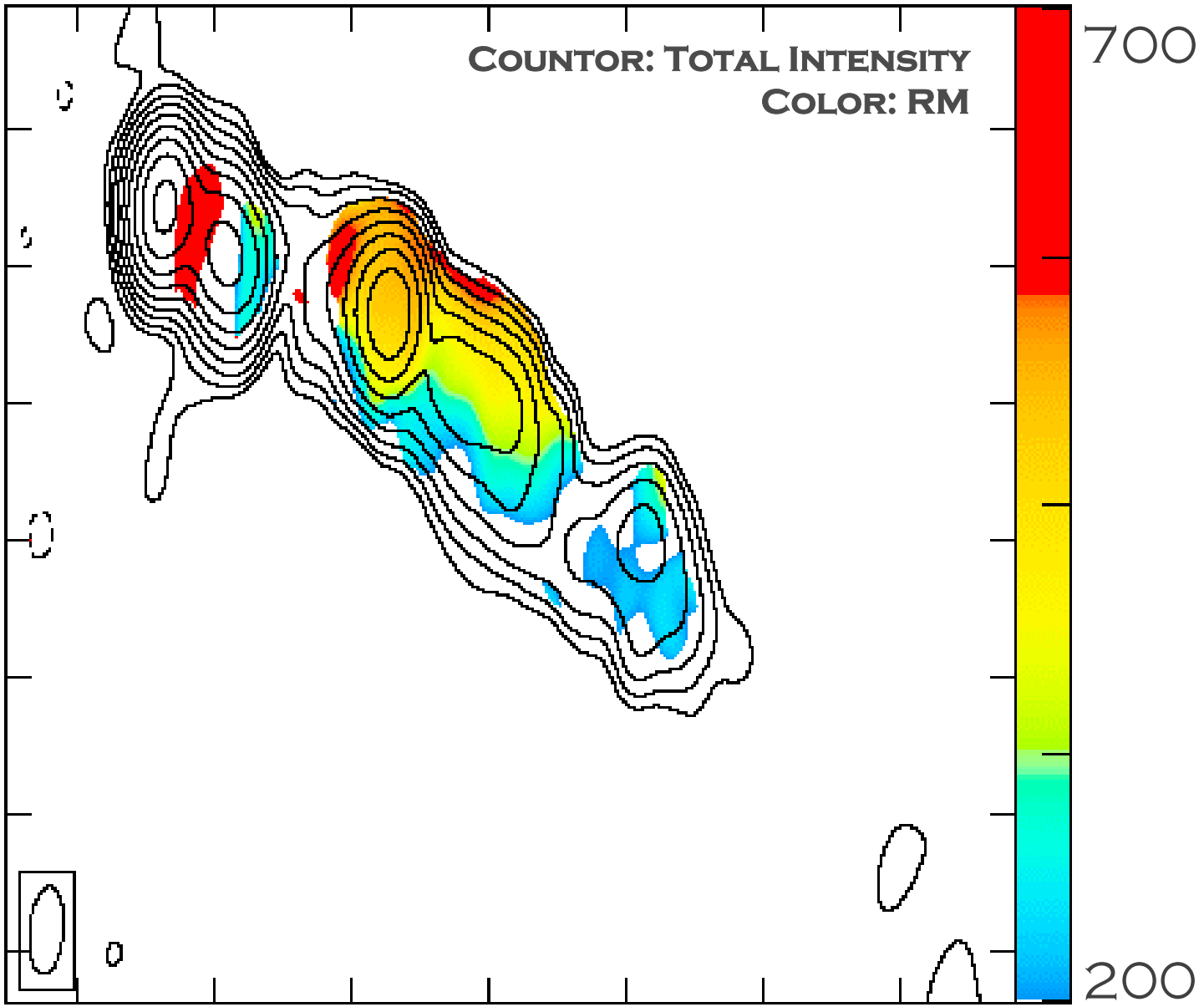
  1 mas = 1.86 pc

  (H_0 = 100 km s^{-1} Mpc^{-1}, Q_0 = 0.5)

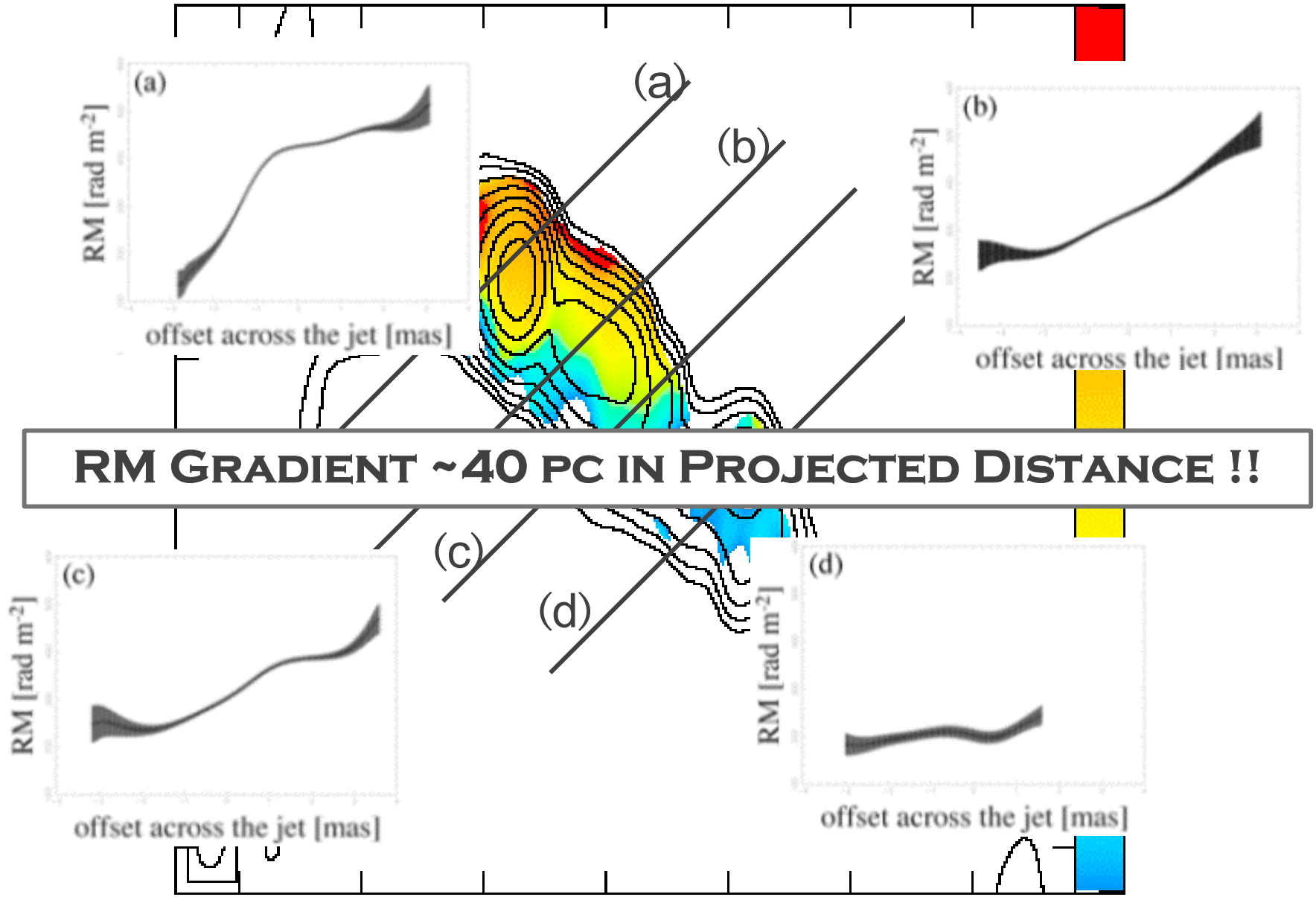
- **SuperLuminal motions:**

  4.7 - 7.0 c (Abraham et al. 1996)

Results

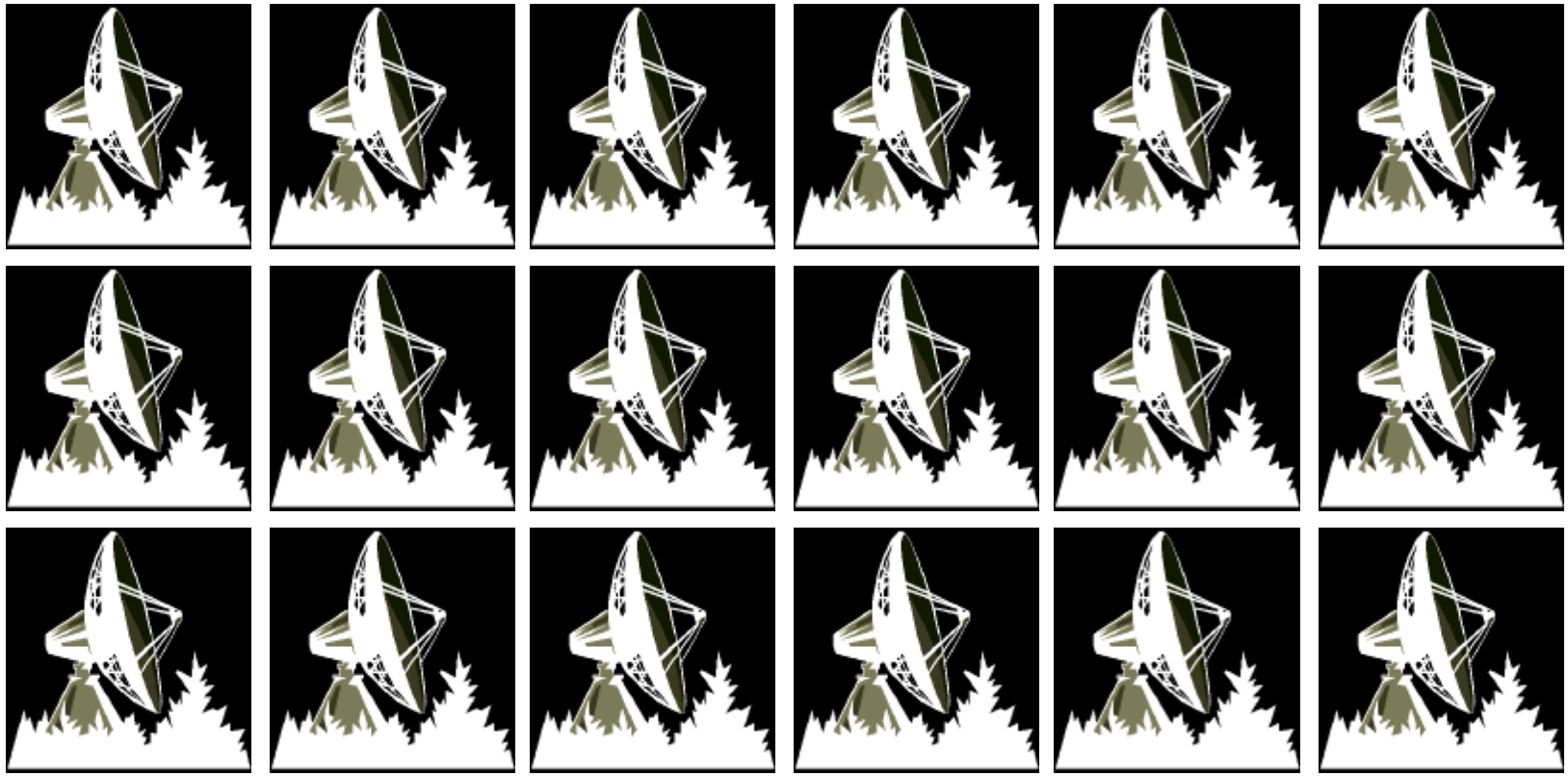


Results



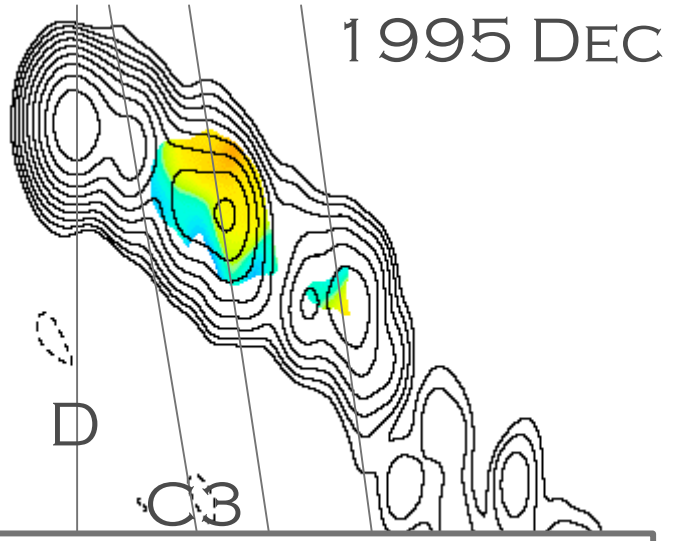
RM Gradient ~40 pc in Projected Distance !!

Discussions



Super Luminal Motions

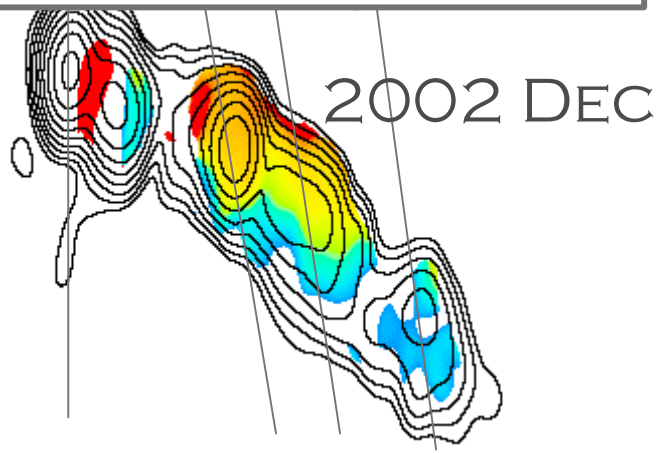
	β_{app}	PA
C1	5.90 +/- 0.03	223°.1
C2	5.26 +/- 0.01	239°.6
C3	7.24 +/- 0.01	239°.3



RM Gradient > 115 pc in Actual Distance !!

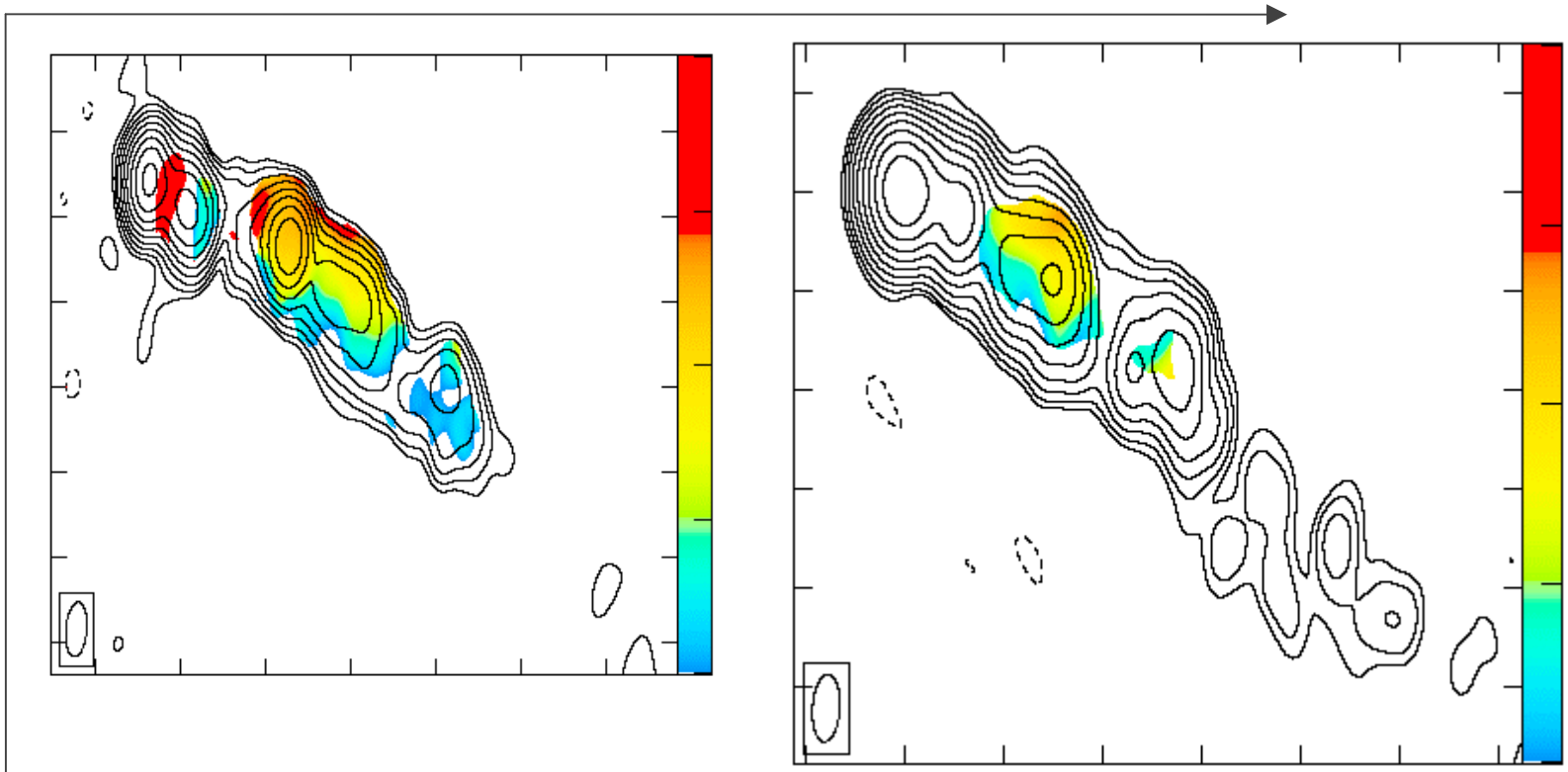
Upper limit of Viewing Angles

	θ_{MAX}
C1	19.2° +/- 0.1
C2	21.5° +/- 0.1
C3	15.7° +/- 0.1



$\theta_{MAX} = 2 \arctan \beta_{app}^{-1}$

Discussions

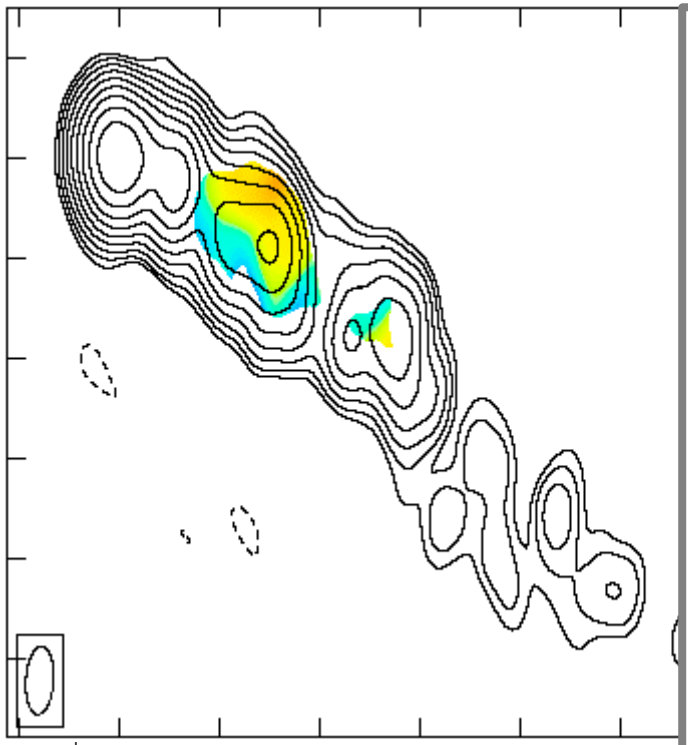


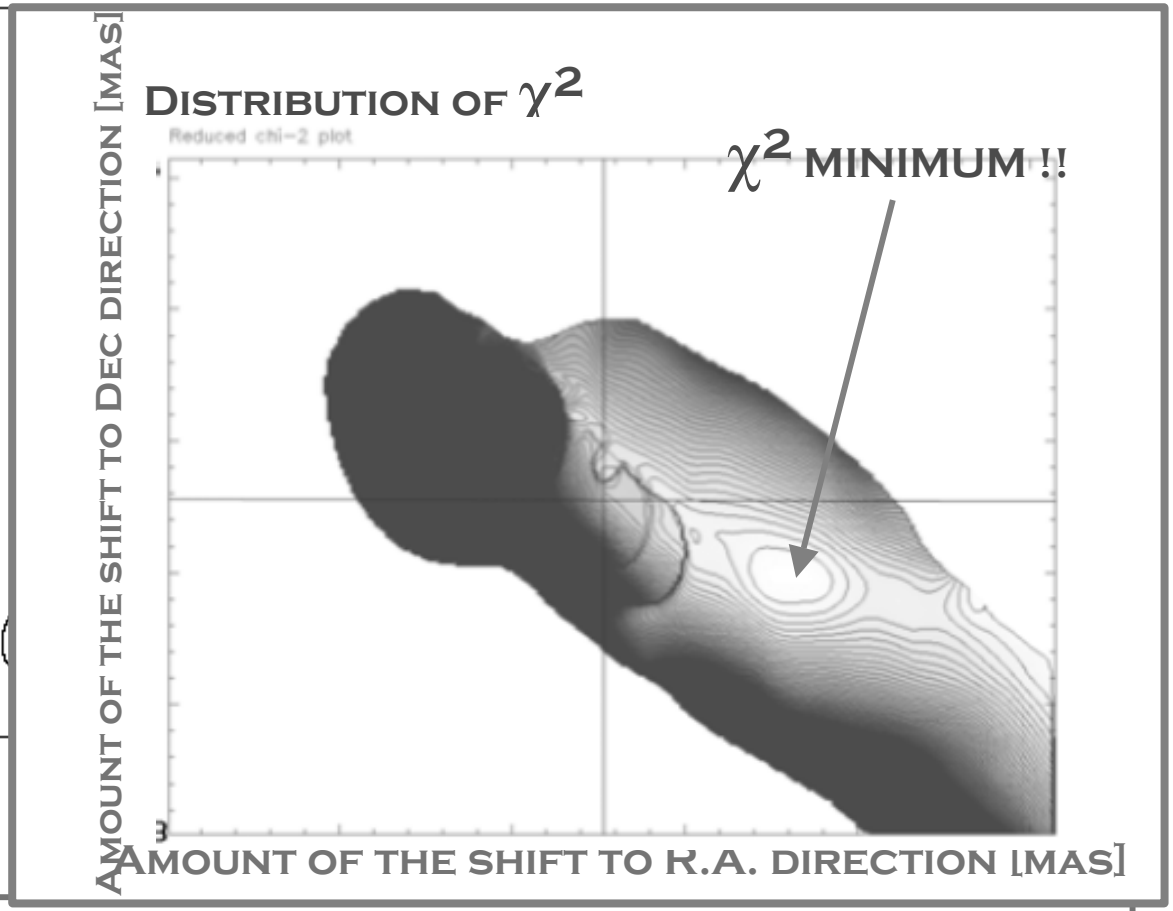
$\chi^2(\delta_x, \delta_y)$ Minimum at $(\delta_x, \delta_x) = (5.5, -2.5)$ [mas]

5.25 c in position angle of 245°.6

(c.f. β_{app} of C2 5.26 c in position angle of 239°.6)

Discussions



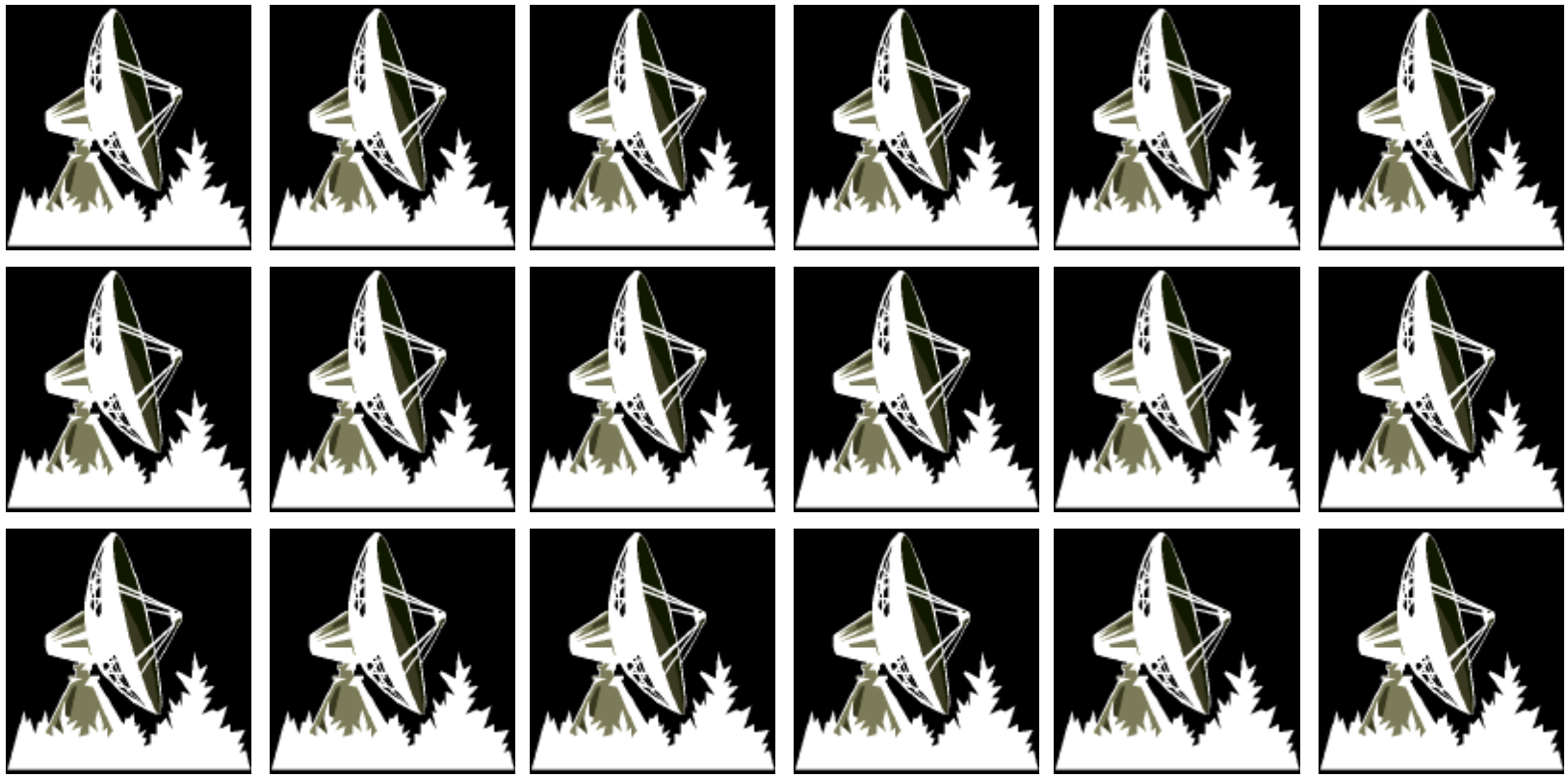


RM Gradient Should be associated

with the Jet,

And Then, with the Helical Magnetic Field !!

Conclusion



Conclusions

- a Follow-up RM Observation revealed the RM Gradient In Larger part of the Jet.
- It confirmed our previous Result of the existence of the Helical Magnetic Field.
- Time Variation of RM is well explained by a proper motion of plasma which associates with the jet.