Detection of short-term flux density variability and intraday variability in polarized emission at millimeter-wavelength from S5 0716+714

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Polarized Emission from Astrophyscial Jets
Ierapetra, Greece
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Korea Astronomy and Space Science Institute

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S5 0716+714

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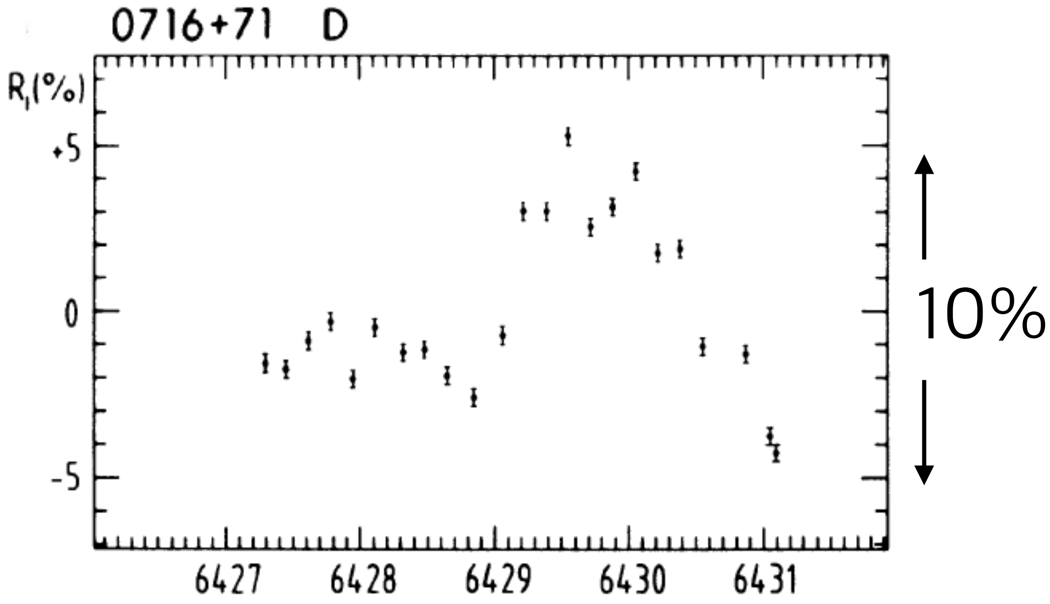
- **Detection of Intraday variability in polarized emission at mm-wavelengths**

S5 0716+714

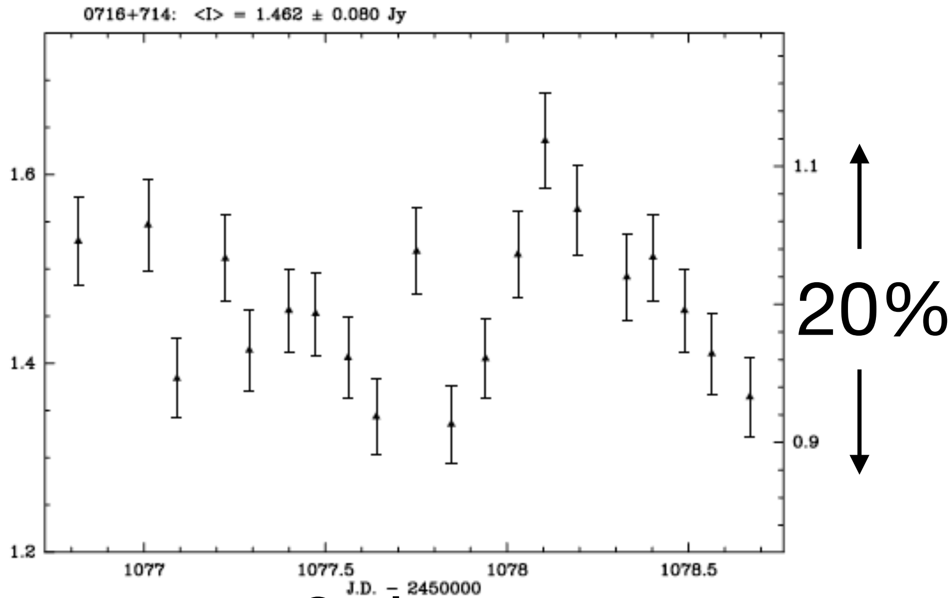
Heeschen et al. 1987



5 days

2.7 GHz

Kraus et al. (2003)



2 days

32 GHz

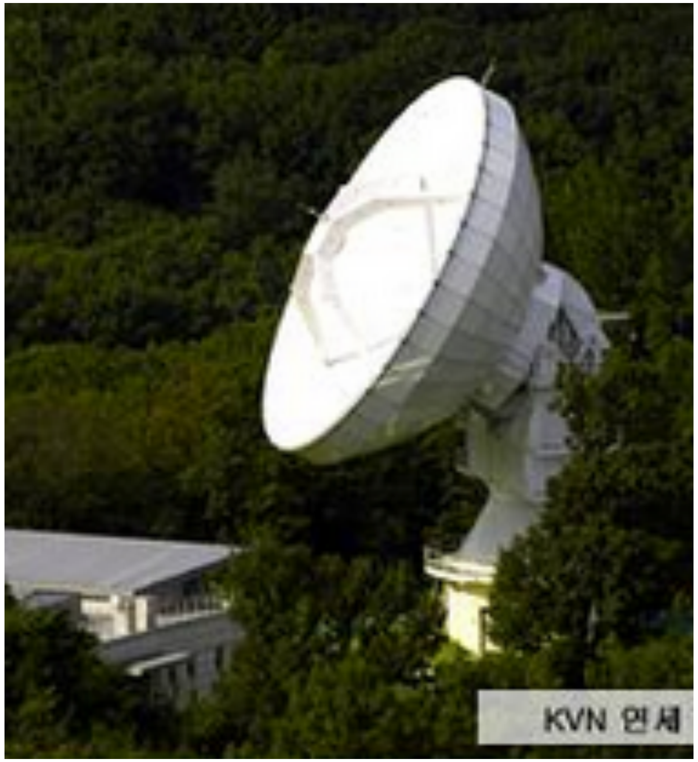
Explanations of Intraday variability

- Intrinsic - Relativitic beaming
  - Shock-in-jet model
- Extrinsic - Scintillation in ISM

Observations

- Telescope : Korean VLBI Network (KVN) radio telescope (21-m diameter single-dish)
- Frequency : 21.7 GHz, 42.4 GHz
- Bandwidth : 512 MHz
- Cadence: ~30-60 mins. (over 12-24 hours)
- Integration time : 40 sec at 22 GHz, 20 sec at 43 GHz
- 1 sigma RMS : 0.08-0.16 Jy at 22 GHz
  0.2-0.42 Jy at 43 GHz
- Calibrator :0836+710, 3C286

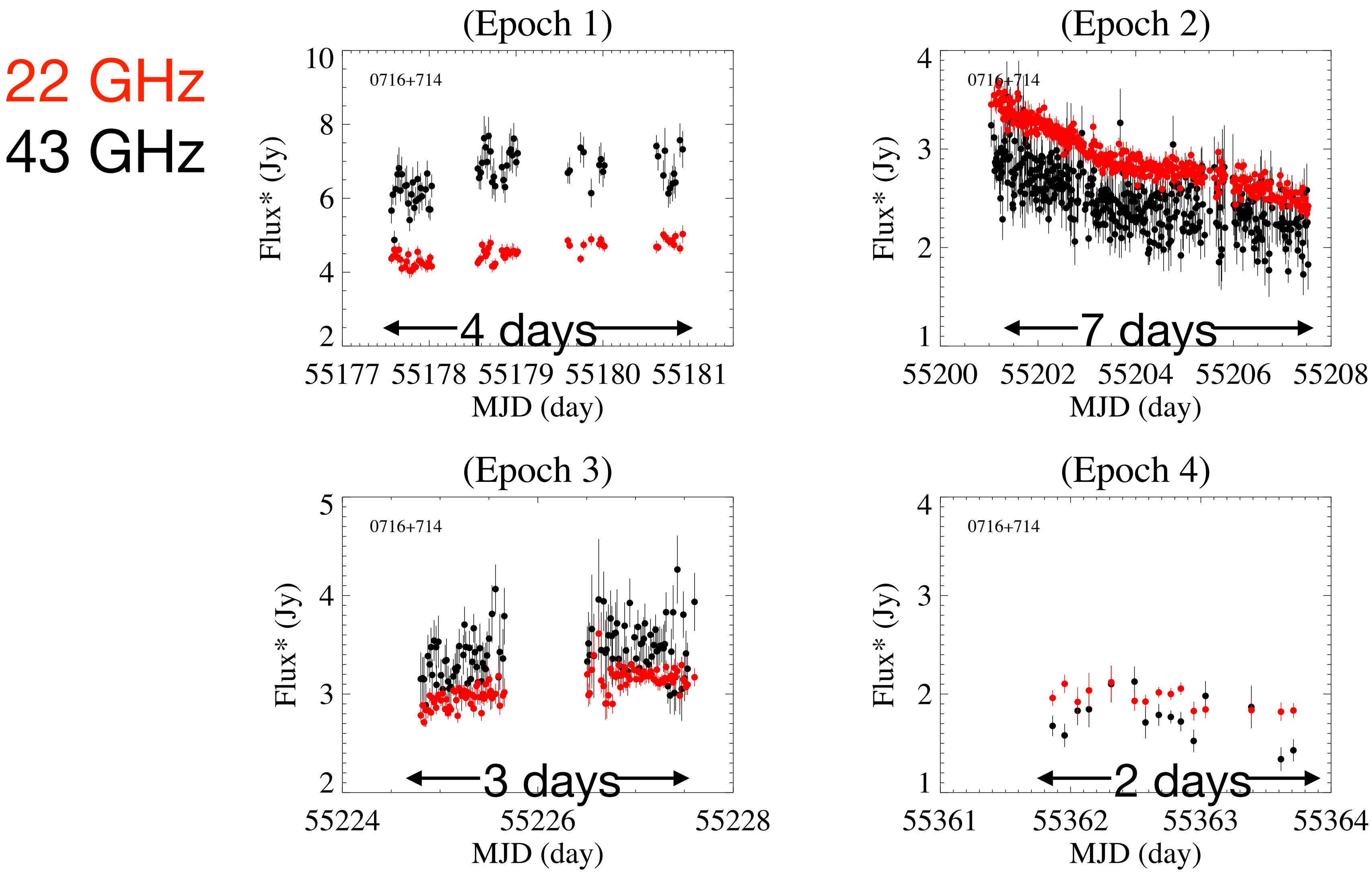
22/43/86/129 GHz



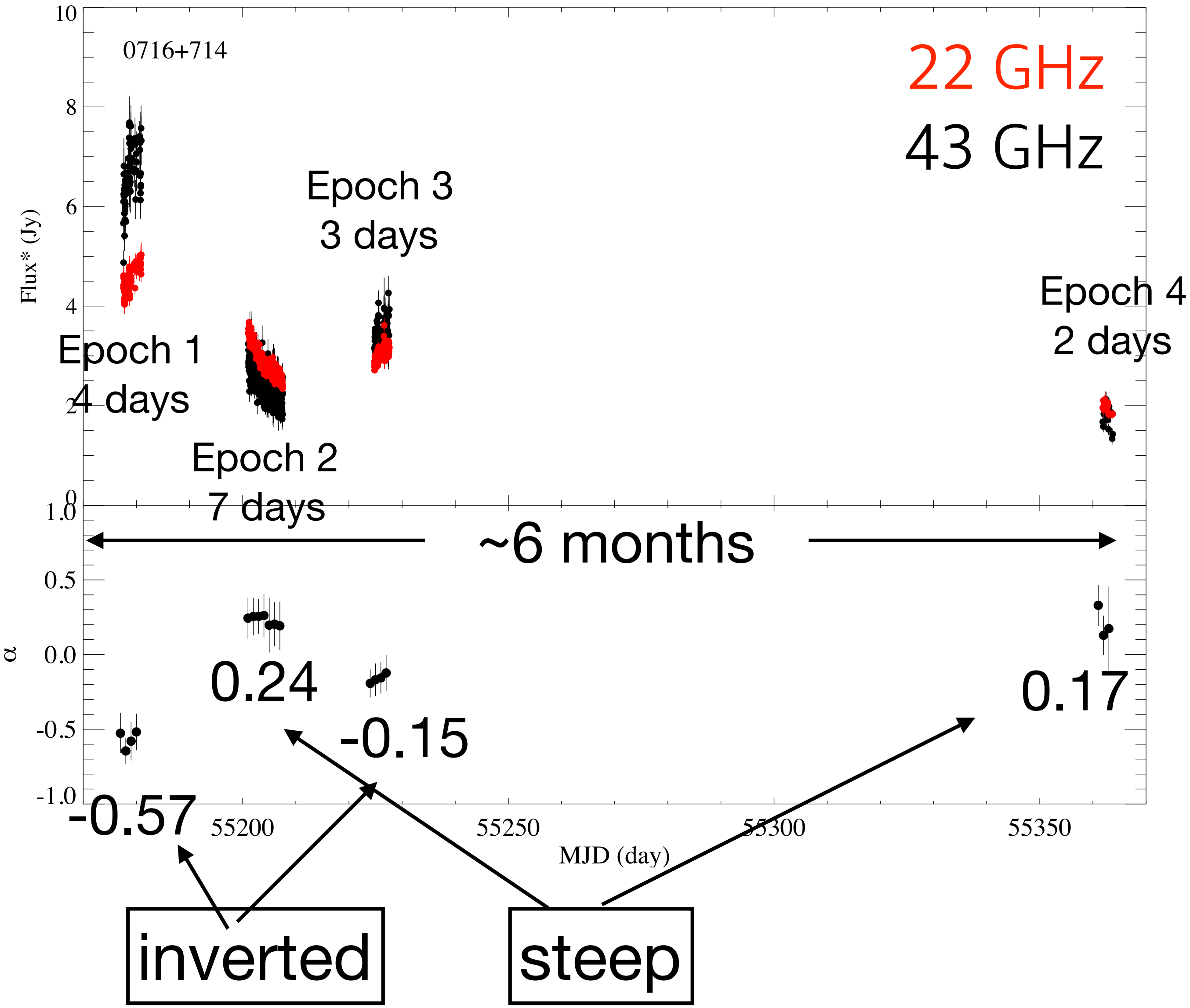
Epoch	Date
1	12 Dec. 2009–15 Dec. 2009
2	5 Jan. 2010–11 Jan. 2010
3	28 Jan. 2010–31 Jan. 2010
4	14 Jun. 2010–16 Jun. 2010

Light curves of S5 0716+714

- **No IDV** in the flux density at 22 and 43 GHz
- monotonic increase and decrease in flux density



Modulation index and Spectral index



Modulation index

m [%] =100*σ_S / <S>

<S>; mean flux density,

σ_S; standard deviation

ν	22 GHz	43 GHz
m [%]	20	36

Spectral index

$S_\nu \propto \nu^{-\alpha}$

S : flux density
ν: frequency
alpha : index

Large variability amplitude at higher frequency and spectral variability ➜ shock-in-jet model

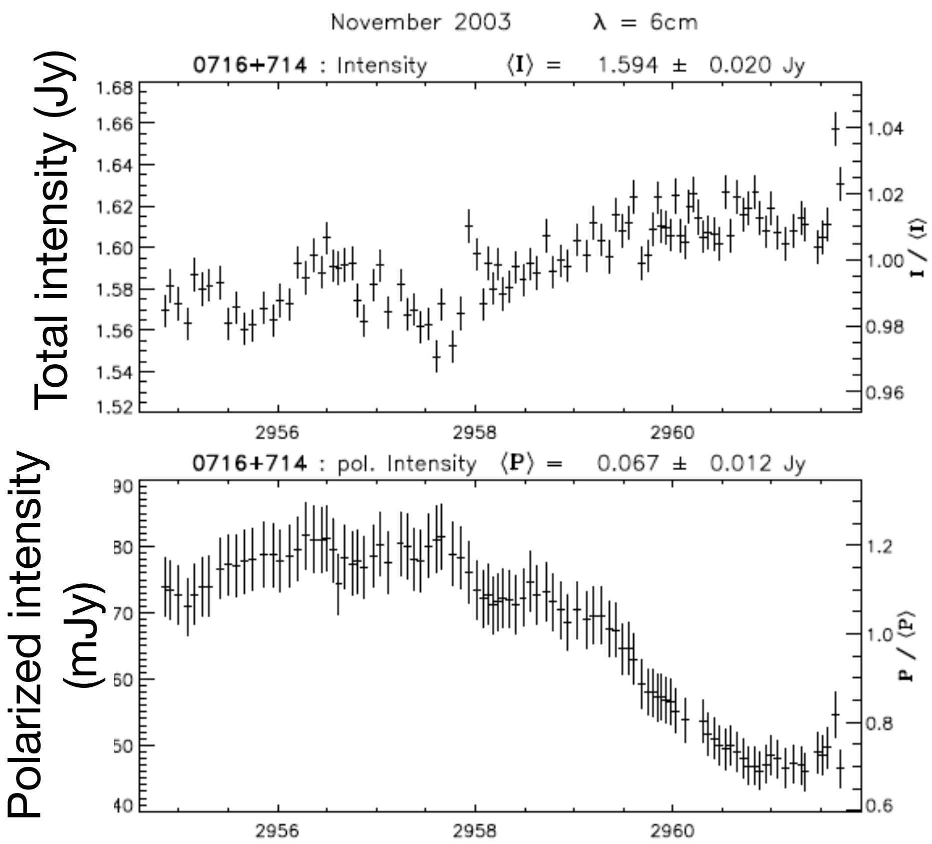
Detection of millimeter-wavelength intraday variability in polarized emission from S5 0716+714

Jee Won Lee, Sang-Sung Lee, Sincheol Kang,
Do-Young Byun, and Sungsoo S. Kim

Polarization of IDV

◉As well as in the flux density, the intraday variability in polarized emission has also been detected at centimeter.

◉Amplitude of the variations in polarized flux density is greater than that in total flux density.

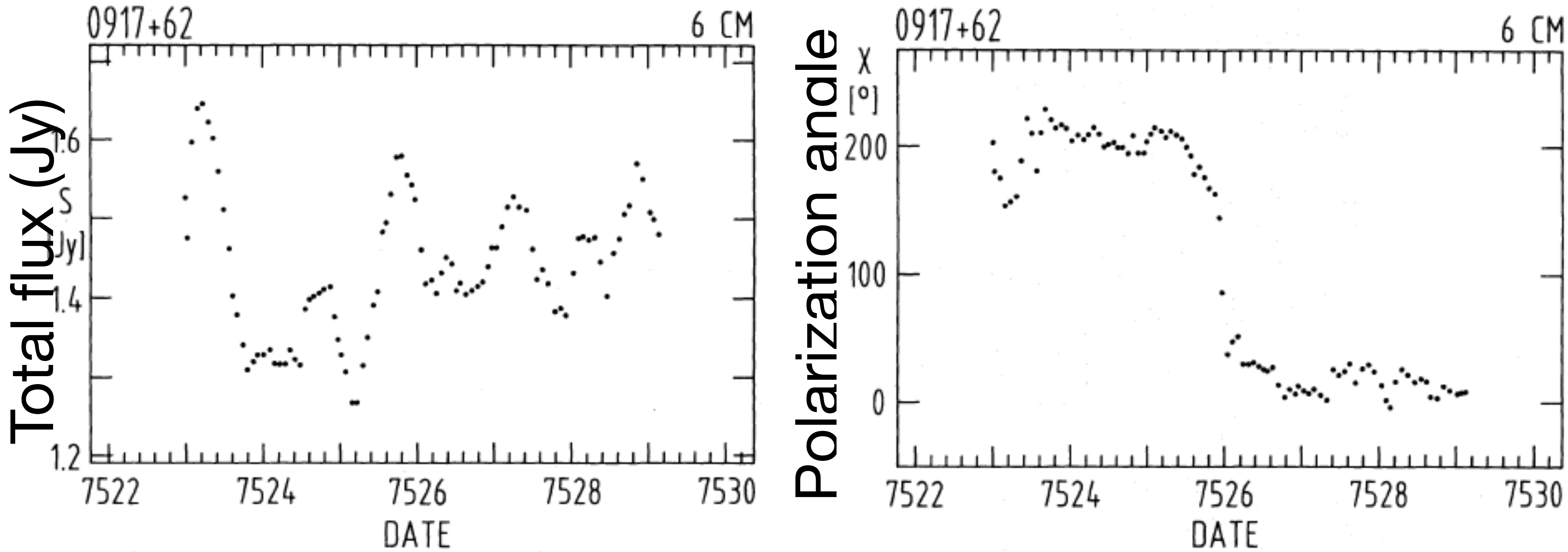


Anti-correlation
between total flux and polarized flux
➜ multi-component sub-structure of emitting region

Fuhrmann et al. 2008

Polarization of IDV

0917+62 at 6 cm (Quirrenbach et al. 1989)



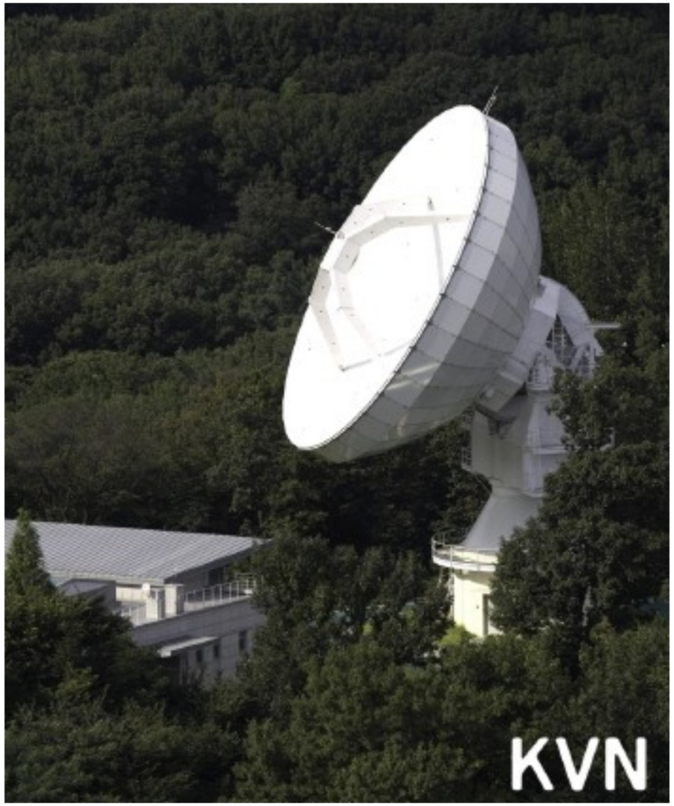
180° Swing of polarzation angle

➜ **Shock propagation in a magnetized jet**

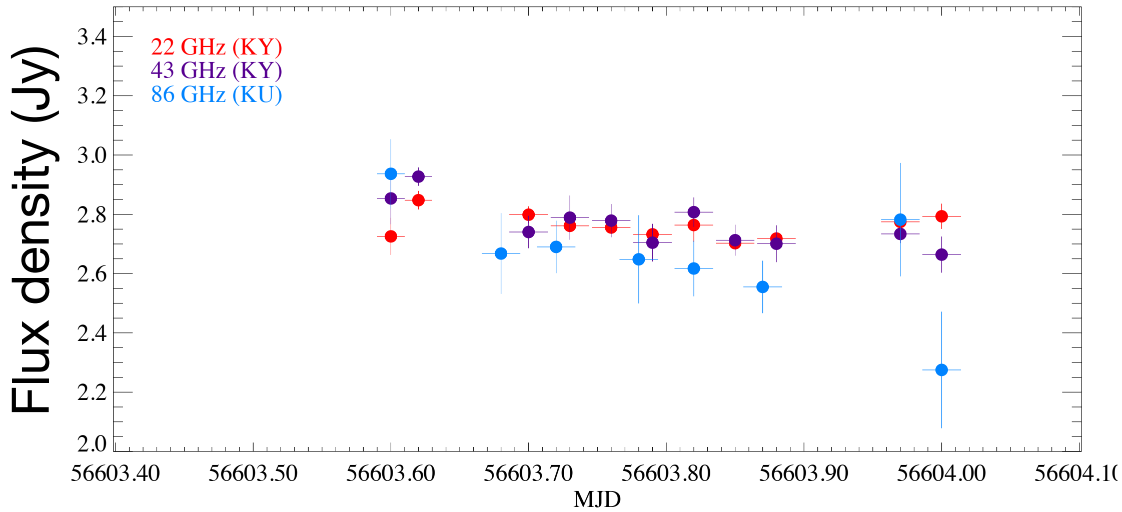
Pol IDV at cm ➜ YES
Pol IDV at mm ➜ NO or Rare (?)

Observations

- Polarization observation
- Frequency : 22.4, 43.1, 86.2 GHz
- Date : November 7, 2013
  (MJD 56603-56604)
  ~15 hours
- Obs mode : on-off switching
- Cadence : 40 minutes
- Calibrator : Jupiter (intstrumental polarization)
  Crab nebula (polarization angle)
  3C286 (standard polarization calibrator)



Flux density of 0716+714



No significant intraday variations in flux density

modulation index

m [%] =100*σ_s / <S>

<S>; mean flux density,

σ_s; standard deviation

reduced chi square-test

$$\chi_r^2 = \frac{1}{N-1}\sum_{i=1}^{N}\left(\frac{I_i - \langle I \rangle}{\Delta I_i}\right)^2,$$

N : number of data

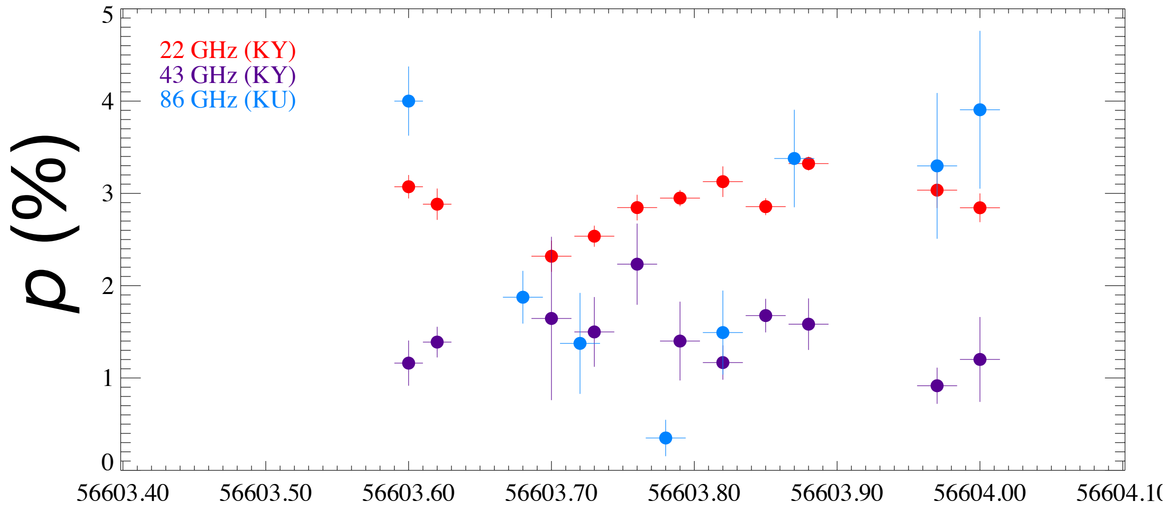
<I> : mean flux density

ΔI : error

(Kraus et al. 2003)

Freq. [GHz]	22 GHz	43 GHz	86 GHz
flux density [Jy] (mean flux density)	2.7-2.9 Jy (2.8 Jy)	2.7-2.9 Jy (2.8 Jy)	2.3-2.9 Jy (2.7 Jy)
Modulation index m [%]	1.5%	2.8%	7.2%
χ_r^2 test ($\chi^2_{99.9\%}$)	2.6 (3.0)	4.1 (3.0)	1.6 (3.5)

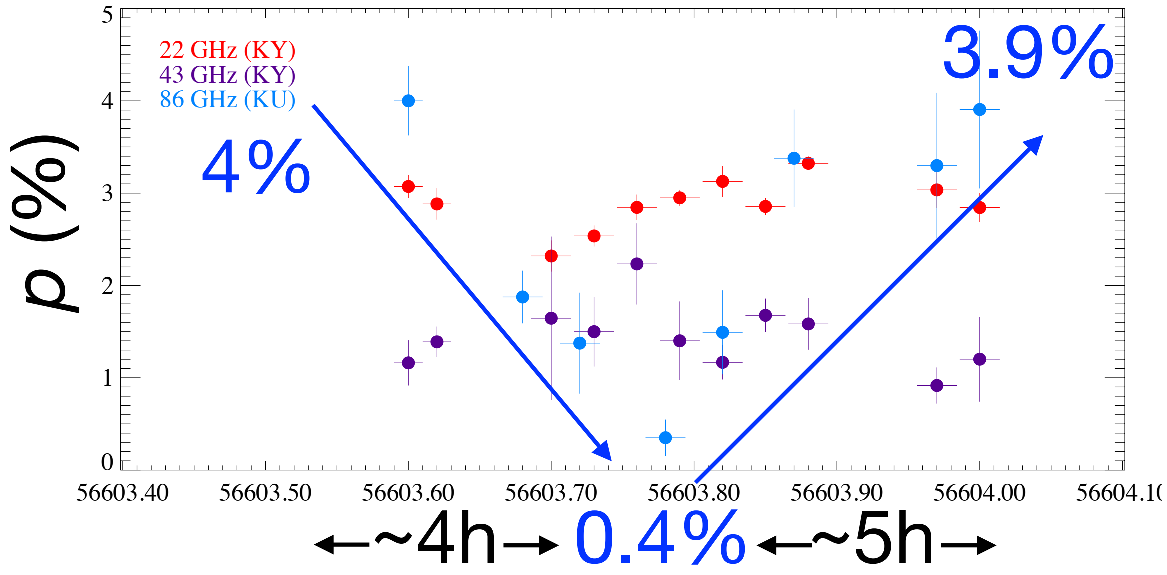
Degree of linear polarization *p*



- Variations of p at 22 GHz and 86 GHz
- Decreasing by a factor of 10 from 4.0% to 0.4% in about 4 hours

Freq. [GHz]	22 GHz	43 GHz	86 GHz
p [%]	2.3% - 3.3%	0.9% - 2.2%	0.4% - 4.0%
m_p [%]	9.7%	23.6%	54.3%
χ_r^2 test ($\chi^2_{99.9\%}$)	4.8 (3.0)	1.5 (3.0)	20.0 (3.5)

Degree of linear polarization *p*



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Freq. [GHz]	22 GHz	43 GHz	86 GHz
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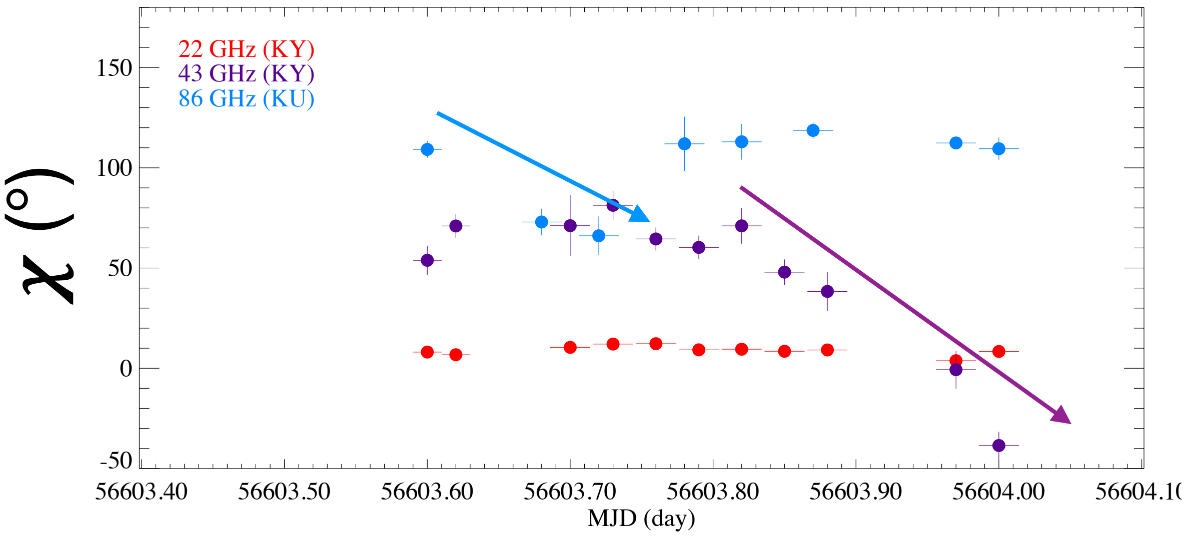
χ_r^2 test ($\chi^2_{99.9\%}$)	4.8 (3.0)	1.5 (3.0)	20.0 (3.5)

Linear polarization angle χ

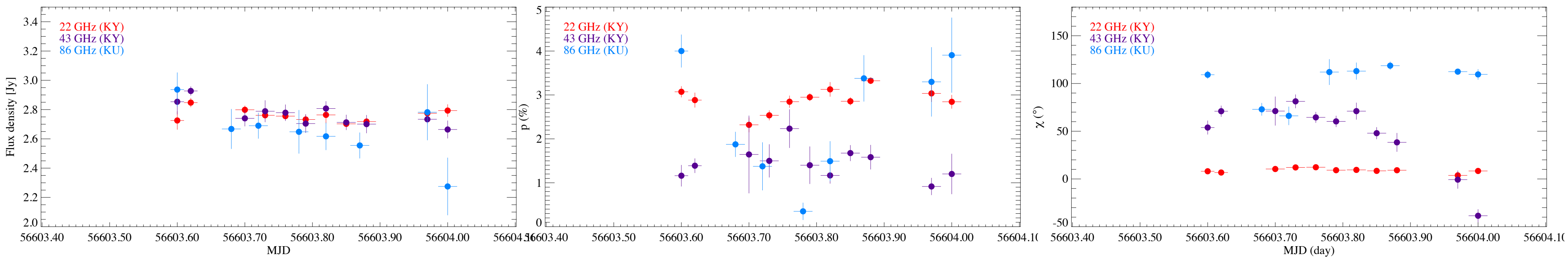


Freq. [GHz]	22 GHz	43 GHz	86 GHz
χ [°]	4° ~ 12°	-39° ~ 81°	66° ~ 119°
m_χ [%]	27%	77%	20%
χ_r^2 test ($\chi^2_{99.9\%}$)	1.4 (3.0)	24.4 (3.0)	9.7 (3.5)

Significant variation of χ at 43 and 86 GHz

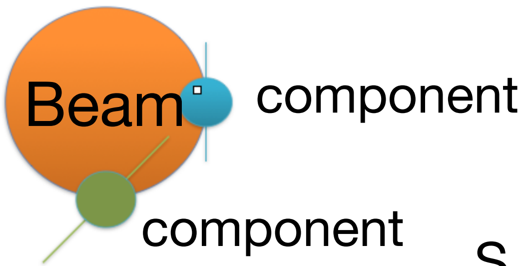
Multiple components model

Light curves | Degree of inear polarization | Polarization angle



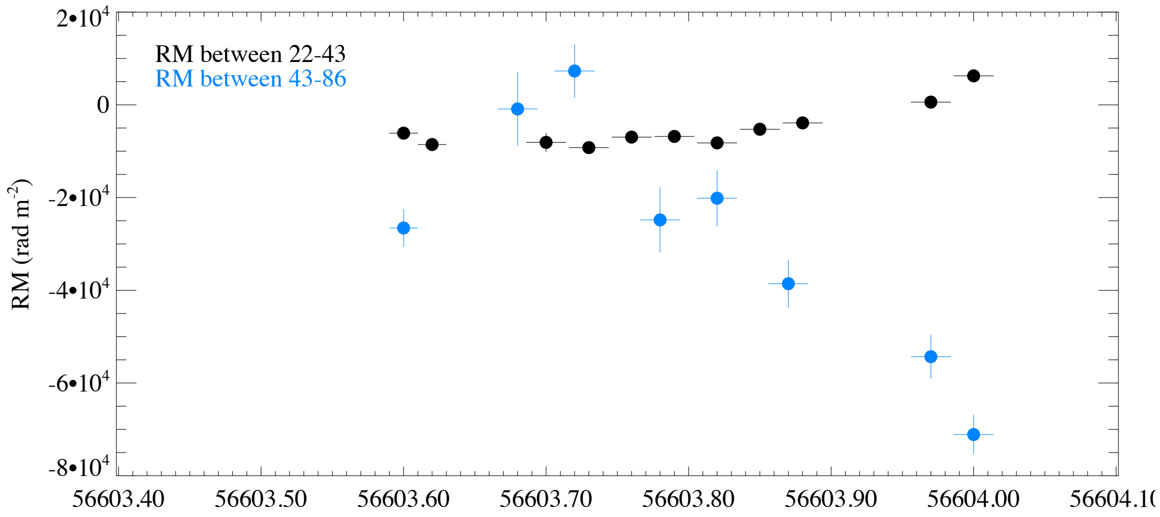
ν (GHz)	$\langle S_\nu \rangle$ (Jy)	m_s (%)	χ_r^2	$\langle p \rangle$ (%)	m_p (%)	χ_r^2	$\langle \chi \rangle$ (°)	m_χ (°)	χ_r^2
22.4	2.76	1.5	2.6	2.9	9.7	4.8	8.9	26.5	1.4
43.1	2.76	2.8	4.1	1.4	23.6	1.5	47.3	76.6	24.4
86.2	2.65	7.2	1.6	2.5	54.3	20.0	101.7	19.8	9.7

- Polarization IDV at mm with non-variable total flux density
  ➔ The combination of the variability of differently polarized multiple compact jet components within the beam size (Bach et al. 2006).



S.-S. Lee et al. in prep.

Faraday Rotation Measure (RM)



$$RM \propto \int B_{||} n_e dl$$

$B_{||}$: parallel magnetic field strength
n_e : electron density
l : path length

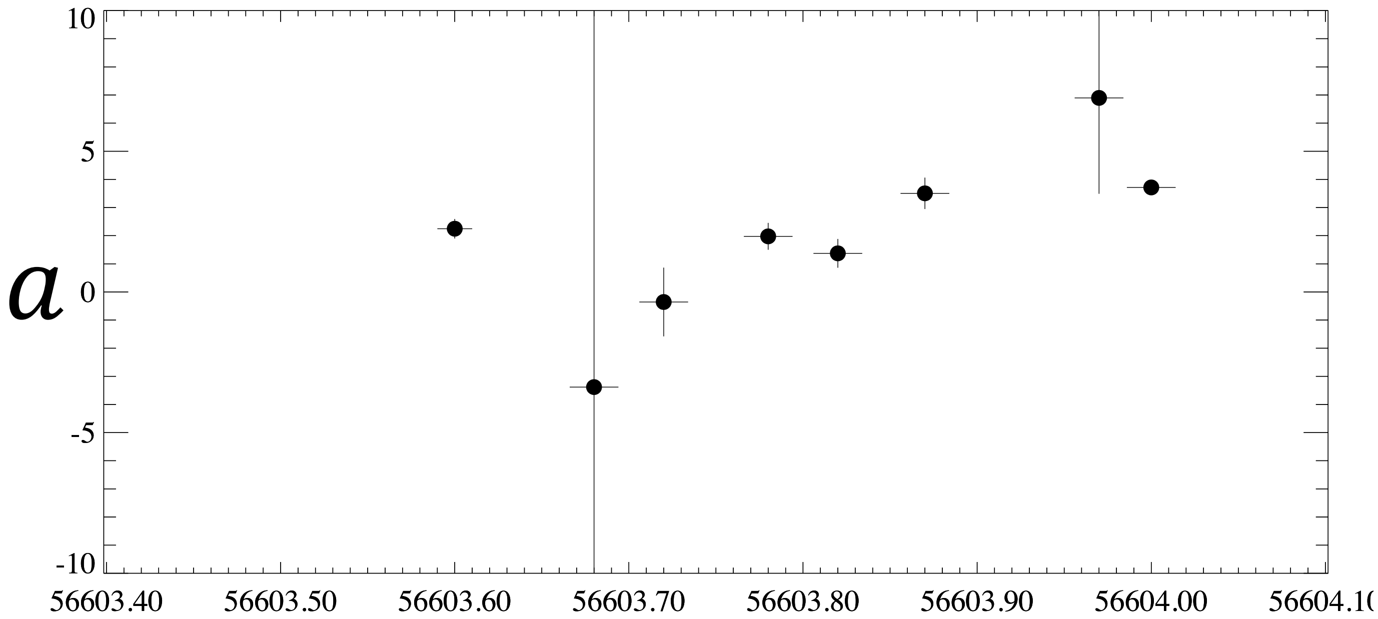
$\chi_{obs} = \chi_0 + RM\lambda^2$ (Jorstad et al. 2007)

$\chi 0$: intrinsic polarization angle
χobs: observed linear polarization angle
λ: observing wavelength

Freq. [GHz]	22-43 GHz	43-86 GHz
RM [rad m^{-2}]	-9200 ~ 6300	-71000 ~ 7300

- High RM values ➔ Traverse extragalactic Faraday screens
- Rapid variation and change of sign of RM ➔ Fast changing local external Faraday rotation of multiple compact emission regions that are spatially different in beam (Gabuzda et al. 2000)

Power Index of a



$$RM \propto \int B_{||} n_e dl$$

$dl \propto r$

$\nu \propto r^{-1}$

$B_{||} \propto r^{-1}$

$n_e \propto r^{-2}$

$$|RM(\nu)| \propto \nu^a, \quad a=2$$

ν : observing frequency

a : power index

r : distance from the central engine

(Jorstad et al. 2007)

By assuming that the Faraday rotation generates within jet or close to the jet, simple jet model yielded a frequency dependence of RM as RM $\propto \nu^a$, a=2

Estimated range of a : -3.4 ~ 6.9, mean of a : 2.0

➔ The Faraday screen dominantly affecting the polarized emission may be located near the jet of the source

Summary

- The multi-frequency polarization observations of S5 0716+714 polarization IDV at mm

  - No significant intraday variability in the flux density
  - The varations in the linear polarization degree and angle
    ➔ The combination of the variability of the multiple compact jet components differently polarized within the beam size

  - The Rapid variation of RM and the change of sign of RM
    ➔ Fast changing local external Faraday rotation of multiple compact emission regions that are spatially different

  - Mean power-index of 2
    ➔ The Faraday screen dominantly affecting the polarized emission may be located near the jet of the source

THANK YOU