KVN-ALMA Collaborations for Polarimetry Commissioning

ALMA polarization commissioning team

Paulo C. Cortes, Seiji Kameno, Edward Fomalont, Charles Hull, Hiroshi Nagai, Kouichiro Nakanishi, Crystal Brogan, Bill Cotton, Rosita Paladino, George Moellenbrock, Josep M. Girart

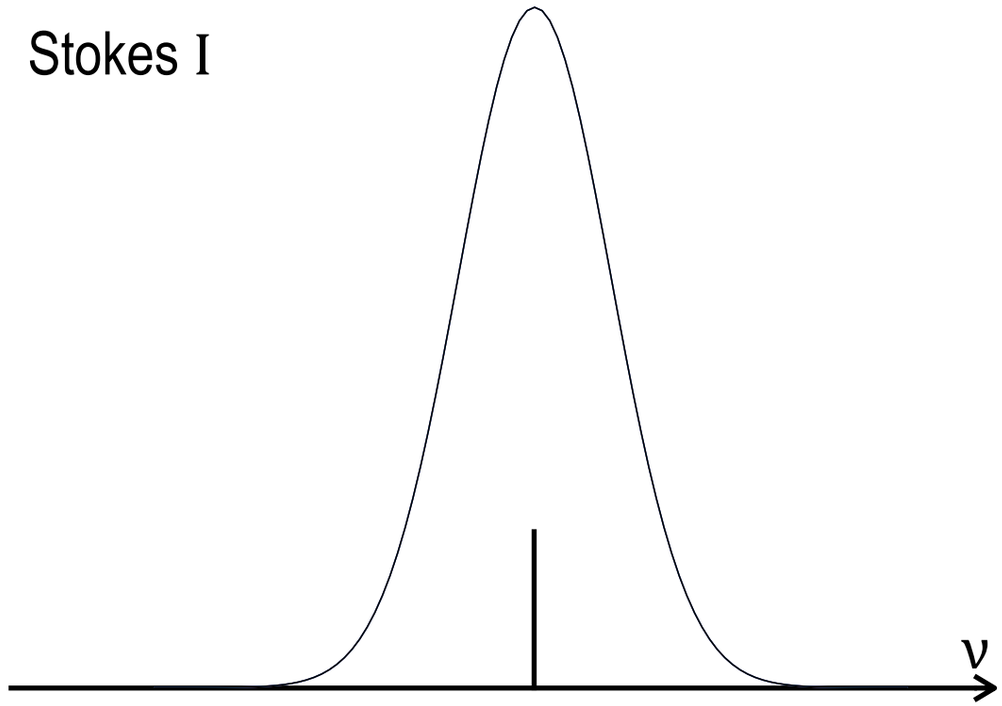
KVN team

JongSoo Kim, Youngju Yun, Do-Young Byun, Ji-Hyun Kang

Priorities of Cycle-6 / 7 polarization capabilities

1.Circular polarization

Zeeman effect
Linear-to-Circular conversions
Gyro synchrotron emission
Chirality



2. Wider field of views

<1/3 FWHM until Cycle 5

3. Shorter calibration

> 3-hour continuous observations required
to cover parallactic angle range

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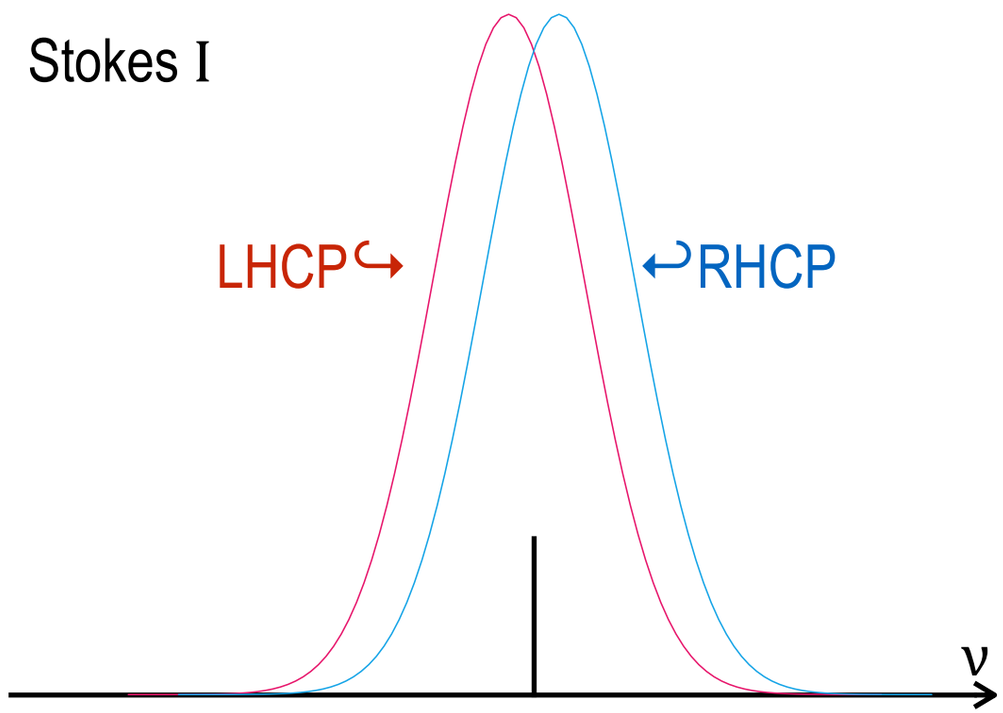

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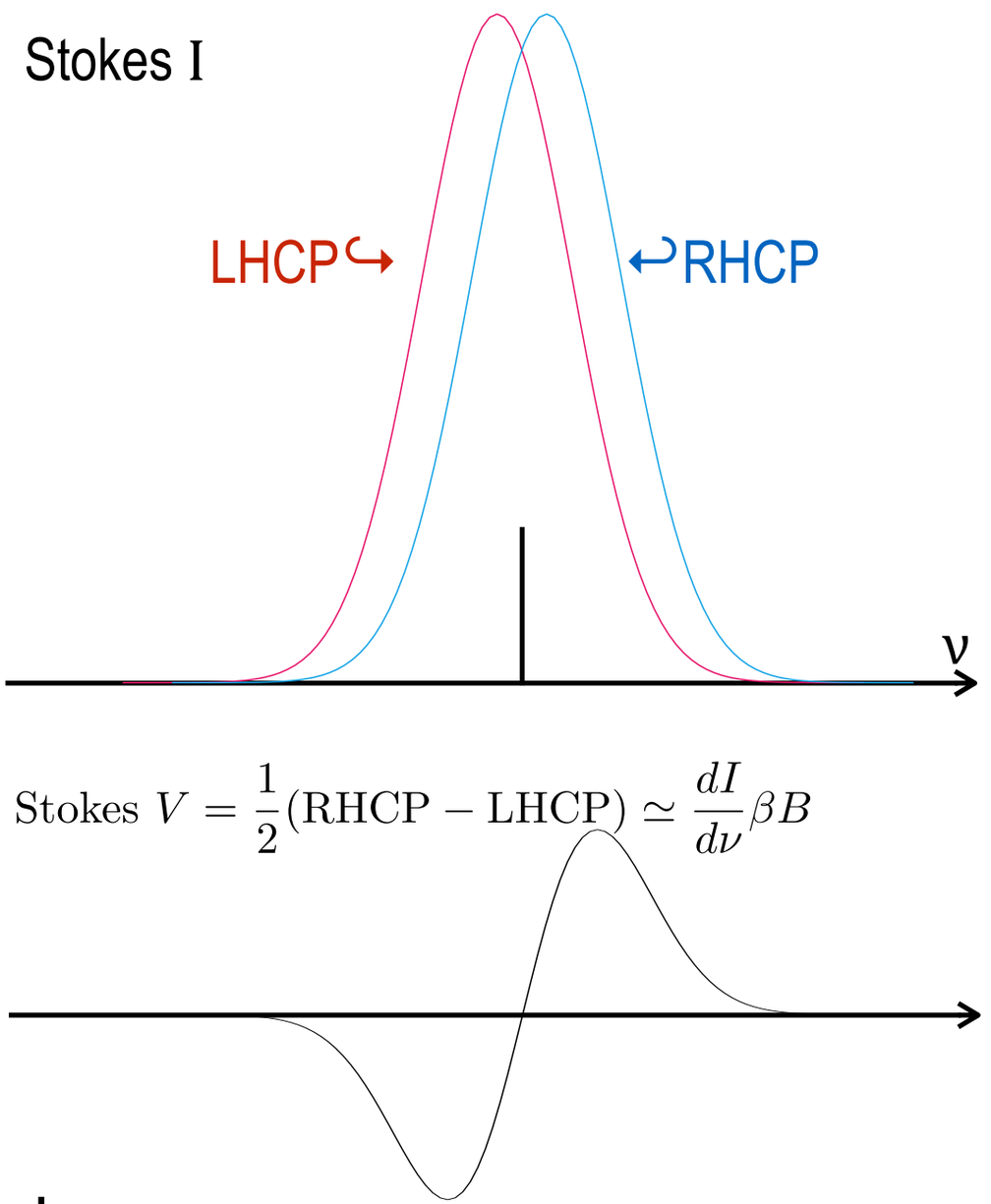

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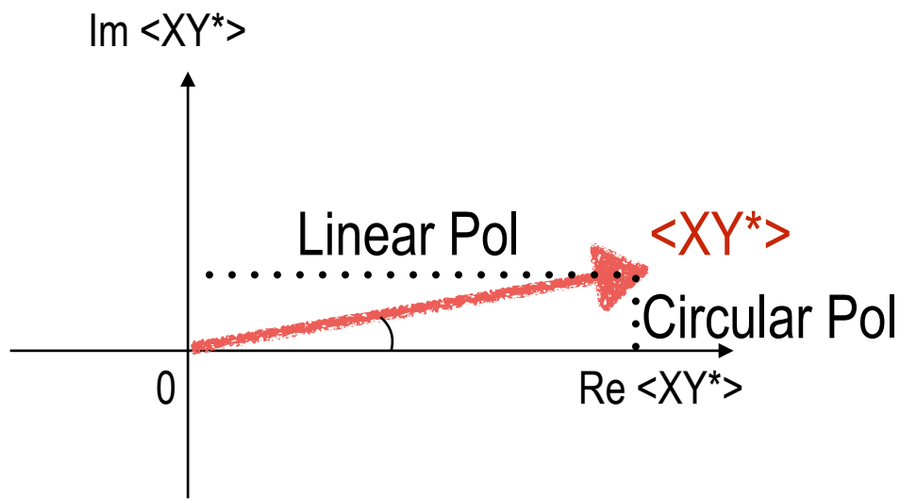
Challenges for Circular Polarimetry with ALMA

Stokes V measurements with a Linear Feed

$$\begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix} = \frac{1}{2} \begin{pmatrix} 1 & 0 & 0 & 1 \\ \cos 2\psi & -\sin 2\psi & -\sin 2\psi & -\cos 2\psi \\ \sin 2\psi & \cos 2\psi & \cos 2\psi & -\sin 2\psi \\ 0 & -i & i & 0 \end{pmatrix} \begin{pmatrix} \langle XX^* \rangle / (G_X G_X^*) \\ \langle XY^* \rangle / (G_X G_Y^*) \\ \langle YX^* \rangle / (G_Y G_X^*) \\ \langle YY^* \rangle / (G_Y G_Y^*) \end{pmatrix}$$

- Stokes V responses Im <XY*>
- XY-phase error causes fake Stokes V

XY-phase calibration is crucial for Stokes V



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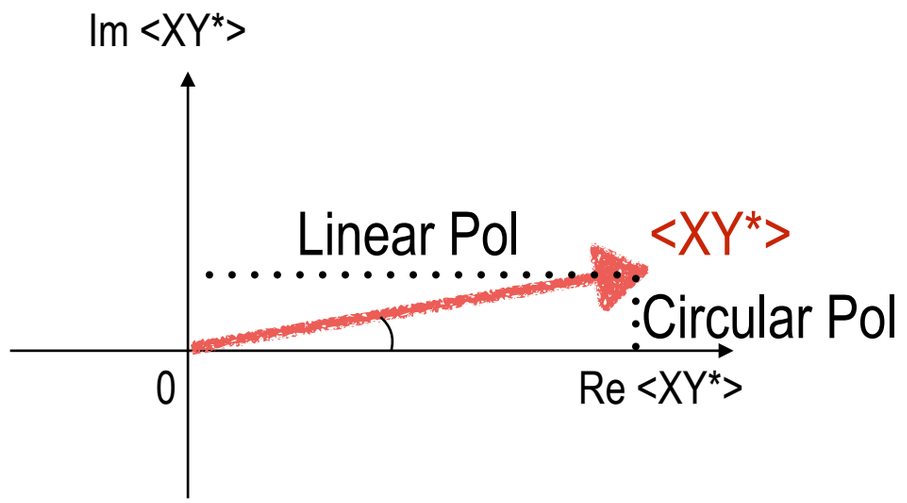


XY-phase calibration is crucial for Stokes V

No XY-phase calibration device, installed

- No wire grid to generate linearly-polarized signals
- Artificial signal (comb-tone) emitter will be available later than 2019

Linearly polarized radio sources (blazars) are only references for XY phase

Q, U, and XY-phase determination

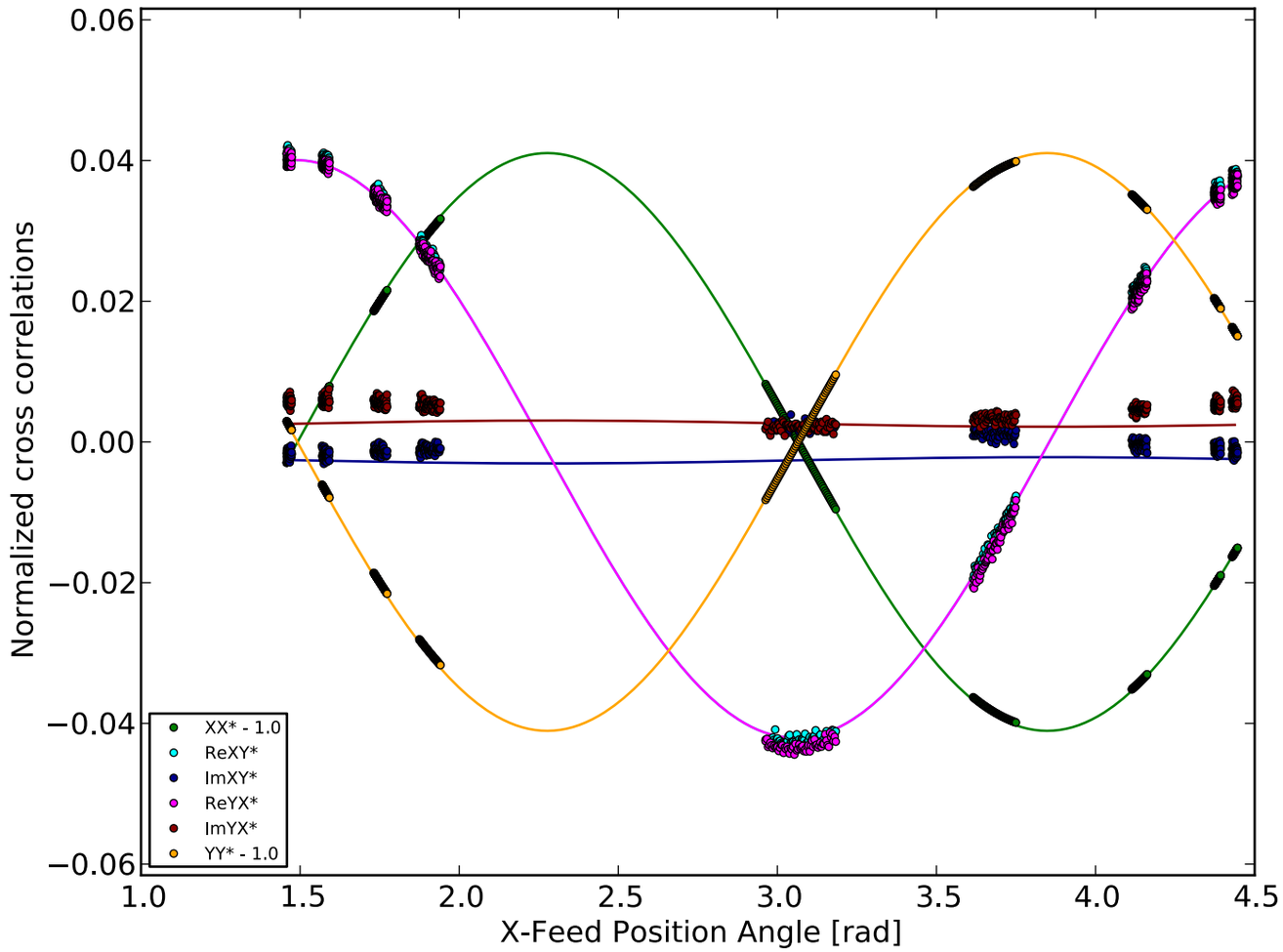
- solve for Q and U of pol calibrator and ϕ using <XX*>, <YY*>, and <XY*>

initial guess for Q and U

$$\frac{\frac{\langle XX^* \rangle}{\boldsymbol{G}_x \boldsymbol{G}_x^*} - \frac{\langle YY^* \rangle}{\boldsymbol{G}_y \boldsymbol{G}_y^*}}{\frac{\langle XX^* \rangle}{\boldsymbol{G}_x \boldsymbol{G}_x^*} + \frac{\langle YY^* \rangle}{\boldsymbol{G}_y \boldsymbol{G}_y^*}} = 2\left(\frac{Q}{I}\cos 2\psi + \frac{U}{I}\sin 2\psi\right)$$

fine determination

$$\frac{\langle XY^* \rangle}{\boldsymbol{G}_x \boldsymbol{G}_y^*} + \frac{\langle YX^* \rangle}{\boldsymbol{G}_y \boldsymbol{G}_x^*} = 2\left(\frac{U}{I}\cos 2\psi - \frac{Q}{I}\sin 2\psi\right)$$

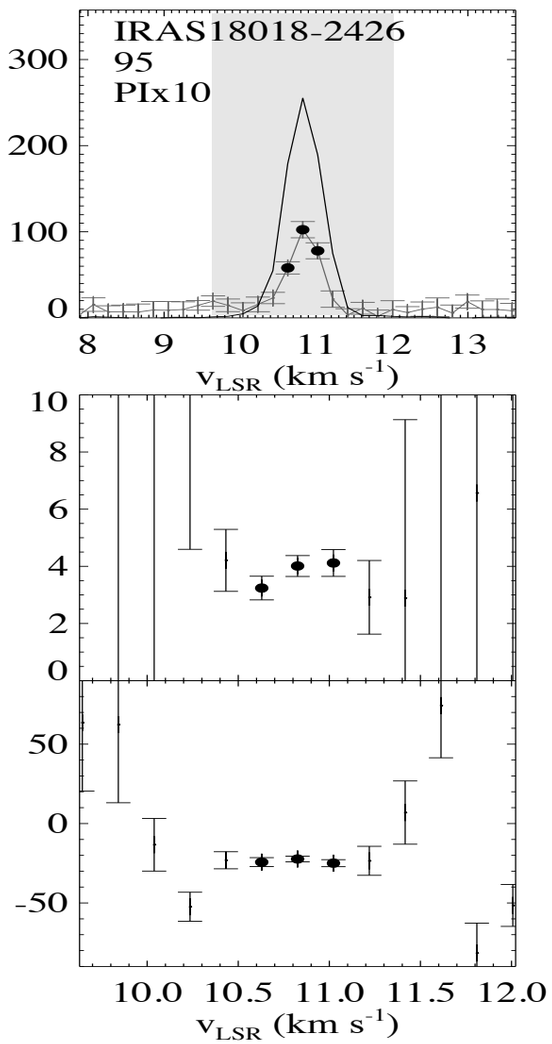


$\longrightarrow$ removing degeneracy between (Q, U, ϕ) and (-Q, -U, $\phi+\pi$)

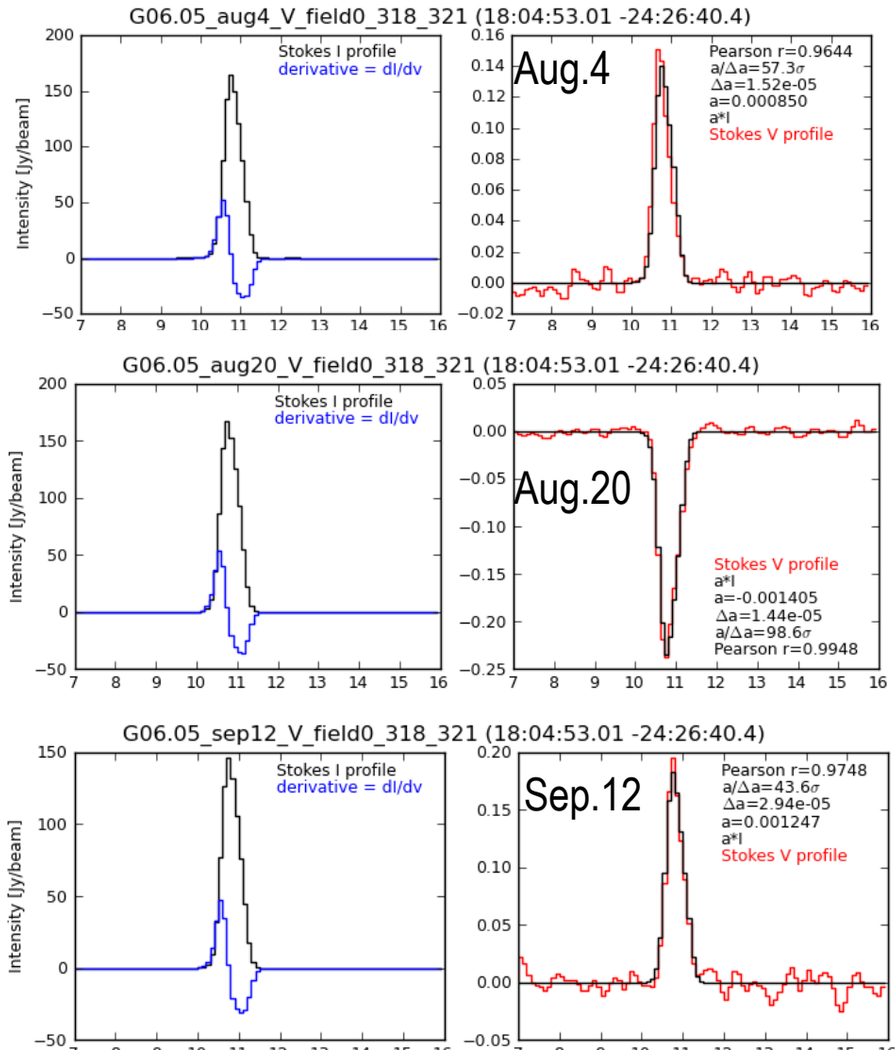
1st Trial … failed to verify circular polarimetry

- CN (J=1-0) Zeeman effect in M 17 : resolved out
- Class I CH_3OH maser (95 GHz) toward G06.05 (IRAS18018-2426)

KVN survey: Kang+16 ApJS, 227, 17



ALMA CSV : Brogan, Hunter, Moellenbrock (2015)



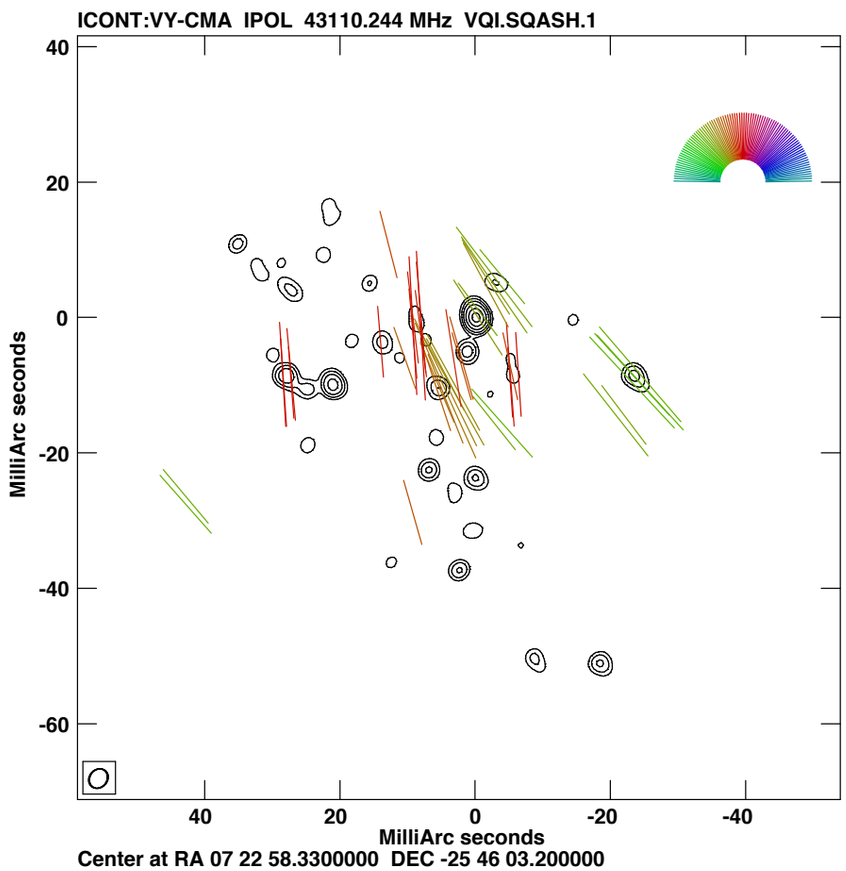
not proportional to dI/dv

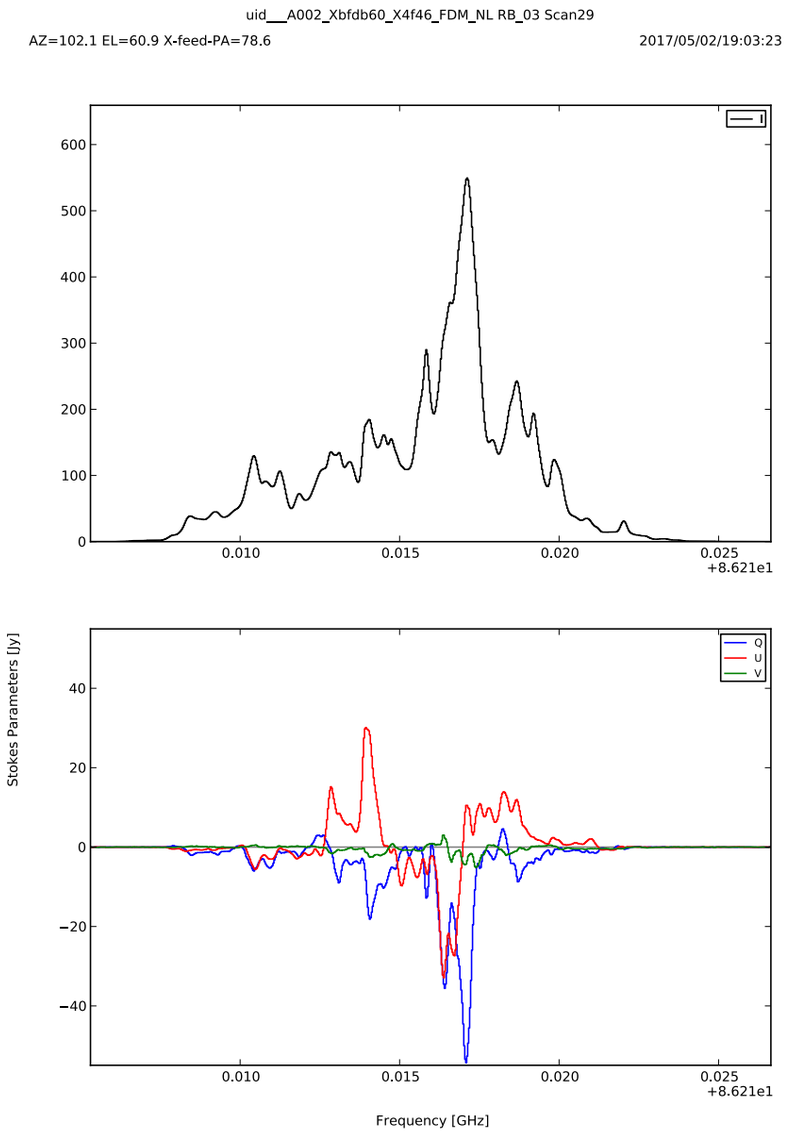
← Stokes-V flip

2nd Trial

- SiO (v=1, J=2-1 86 GHz) maser toward VY CMa and VX Sgr
- Intra-day observations with KVN and ALMA for comparison

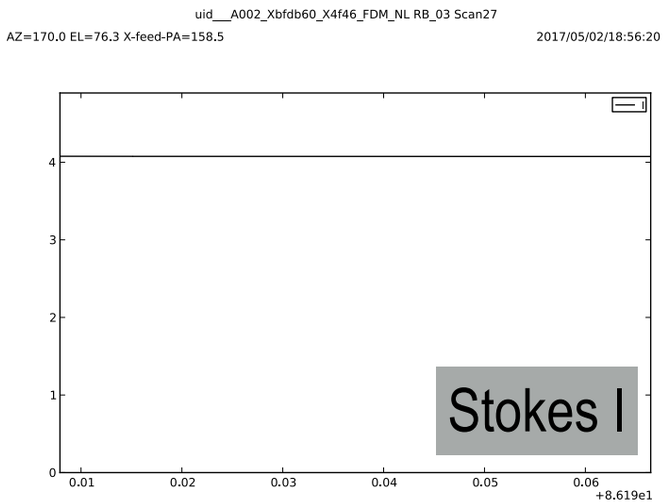
SiO v=1 J=1-0 map: VY CMa

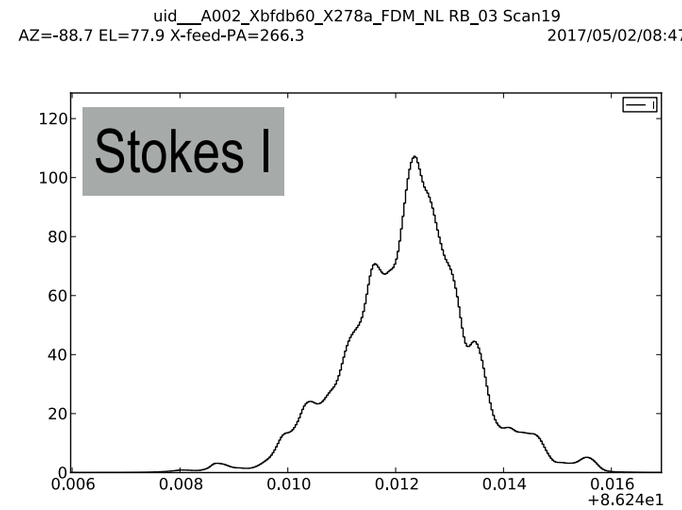


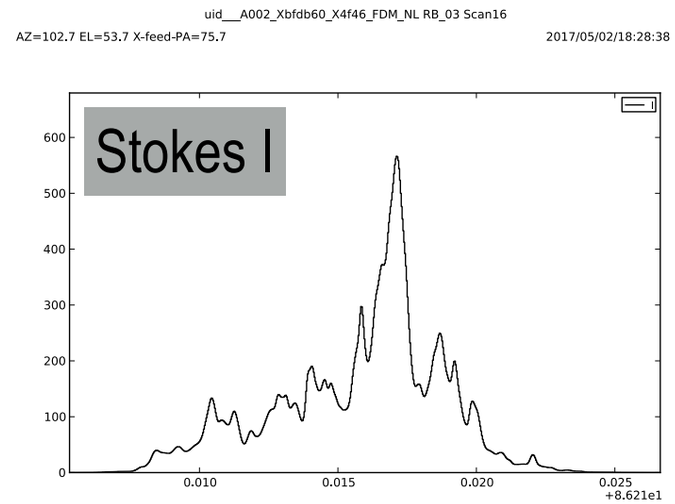


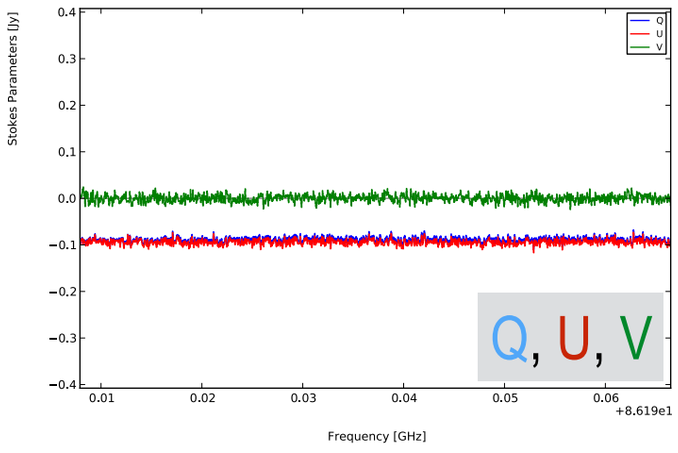
Stokes Spectra with ALMA

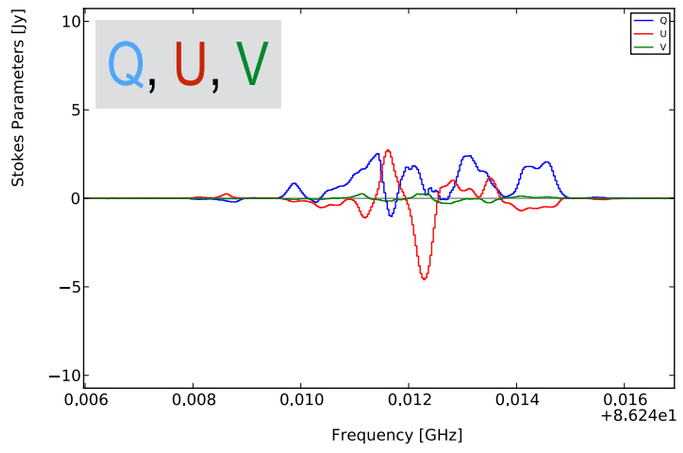
- Calibrator : Stokes V = 0 (assumed)
- max. 2% circular polarization in SiO masers

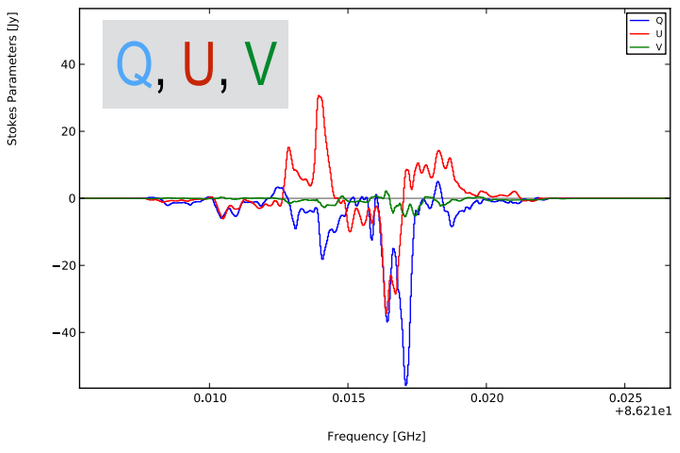












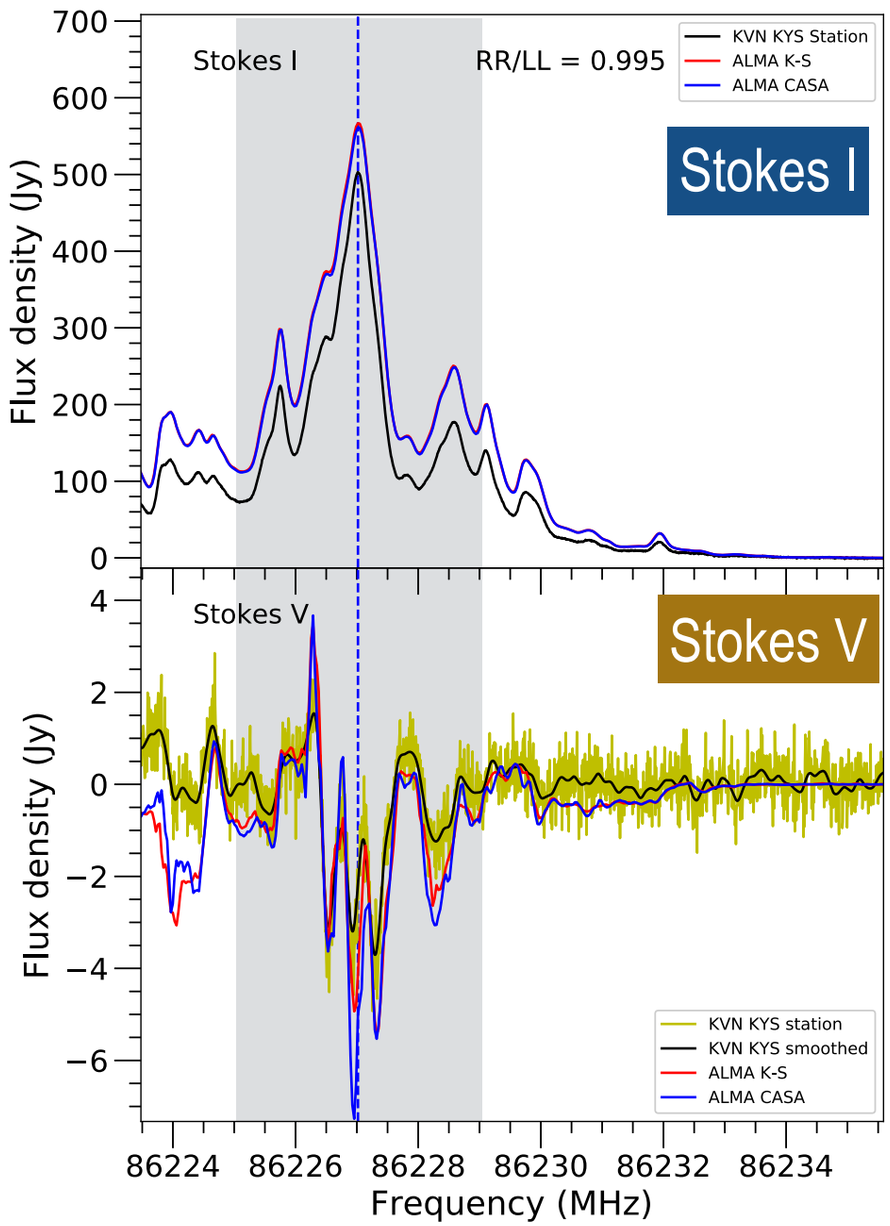
J0522-3627

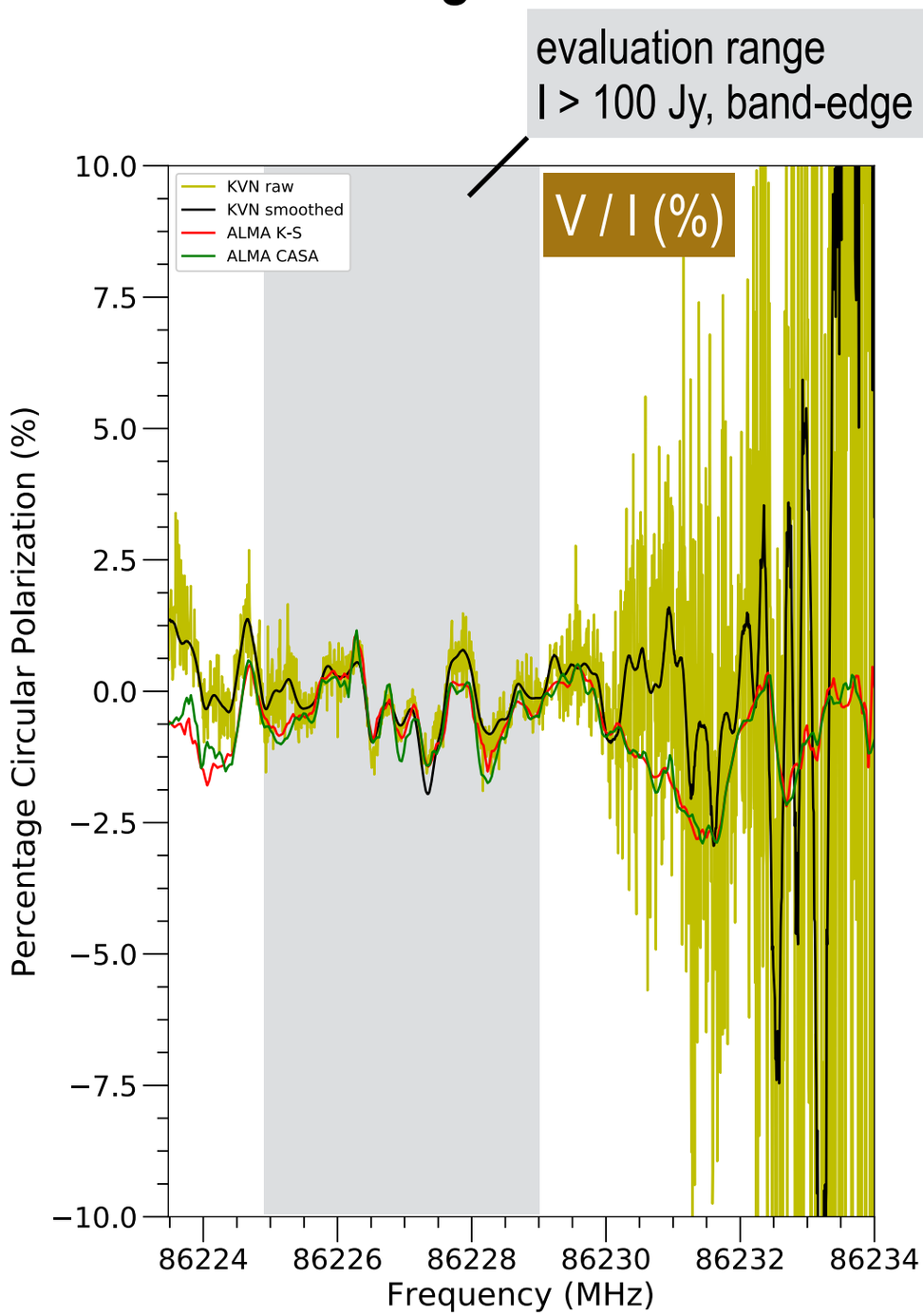
VX Sgr

VY CMa

Comparison with KVN

- In the evaluation range, mean deviation = 0.3% among KVN and ALMA





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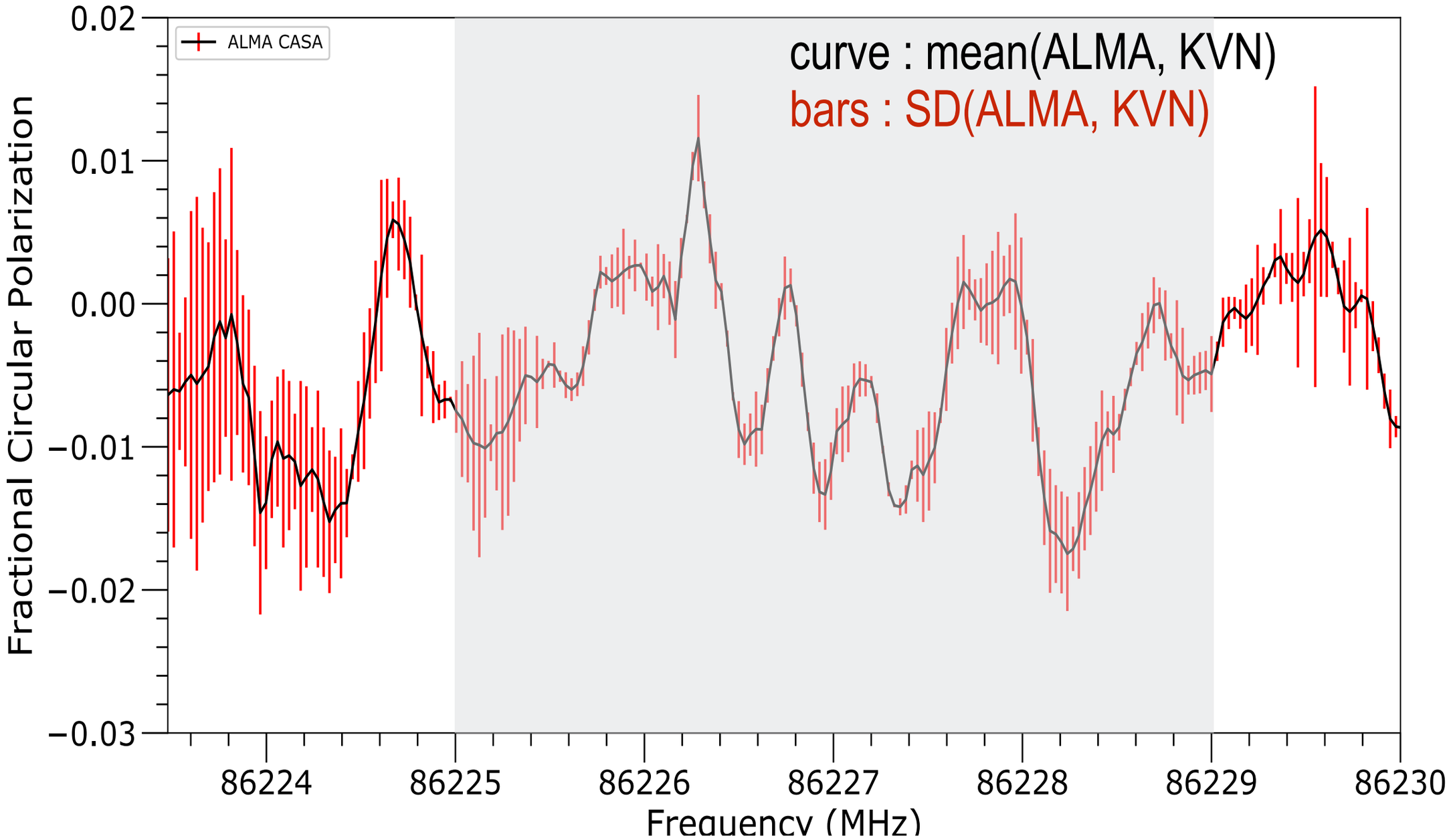


Summary of the 2nd Trial

- KVN image of VY CMa : maser distribution in 80 mas
  - Unresolved with ALMA (C40-3, 1".2 resolution)
  - Spatially resolved with KVN … Use single-dish (autocorrelation) to compare

- Agreements of Stokes V
  - mean difference of (V / I) = 0.32 % between 86.225 and 86.229 GHz)
  - max difference = 1.7% (at band-edge of KVN spectrum)

<u>Even though</u>

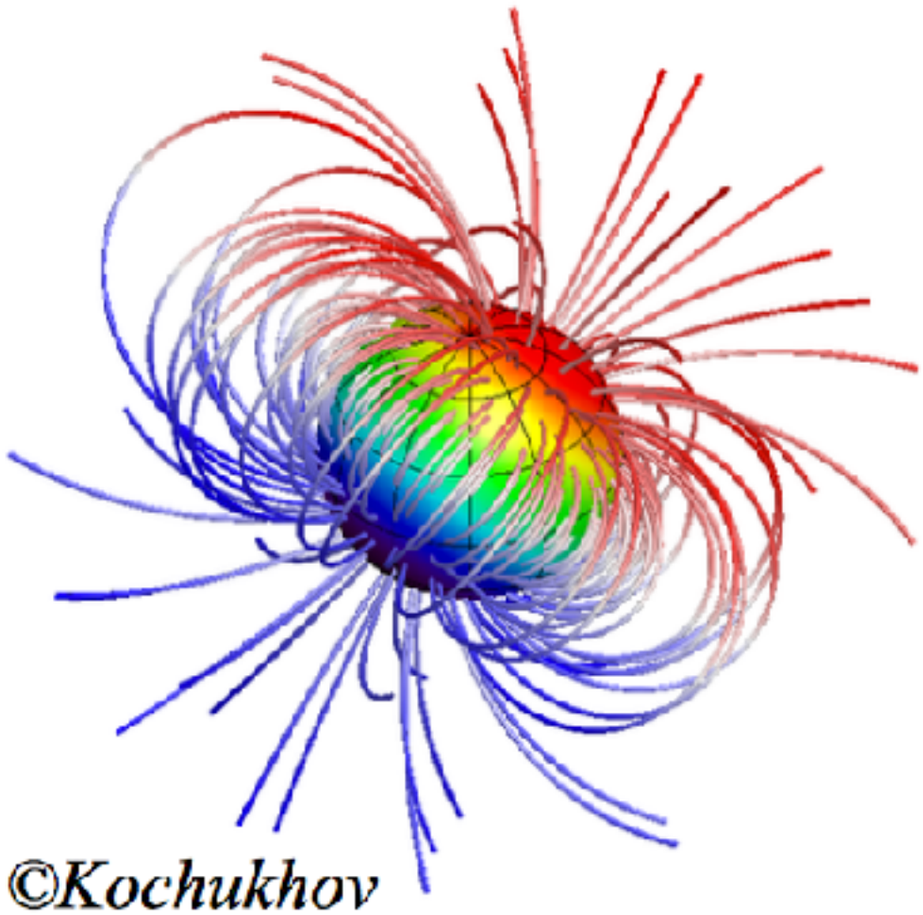
- Different receiving systems (XY in ALMA, RL in KVN)
- Different reduction schemes (CASA for ALMA, AIPS for KVN)

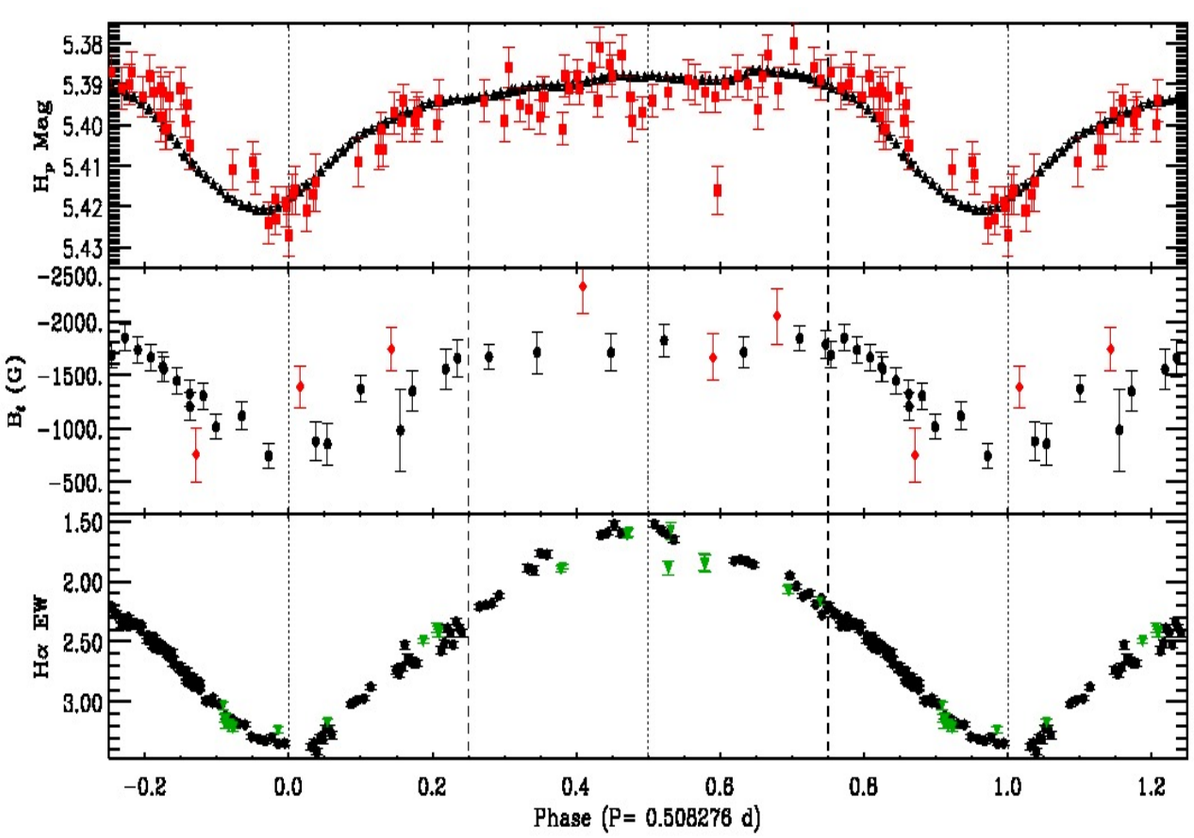
Continuum Circular Polarization

HR 5907 (V1040 Sco) : a rapidly rotating magnetic early B-type star

Grunhut+11 MNRAS, 419, 1610

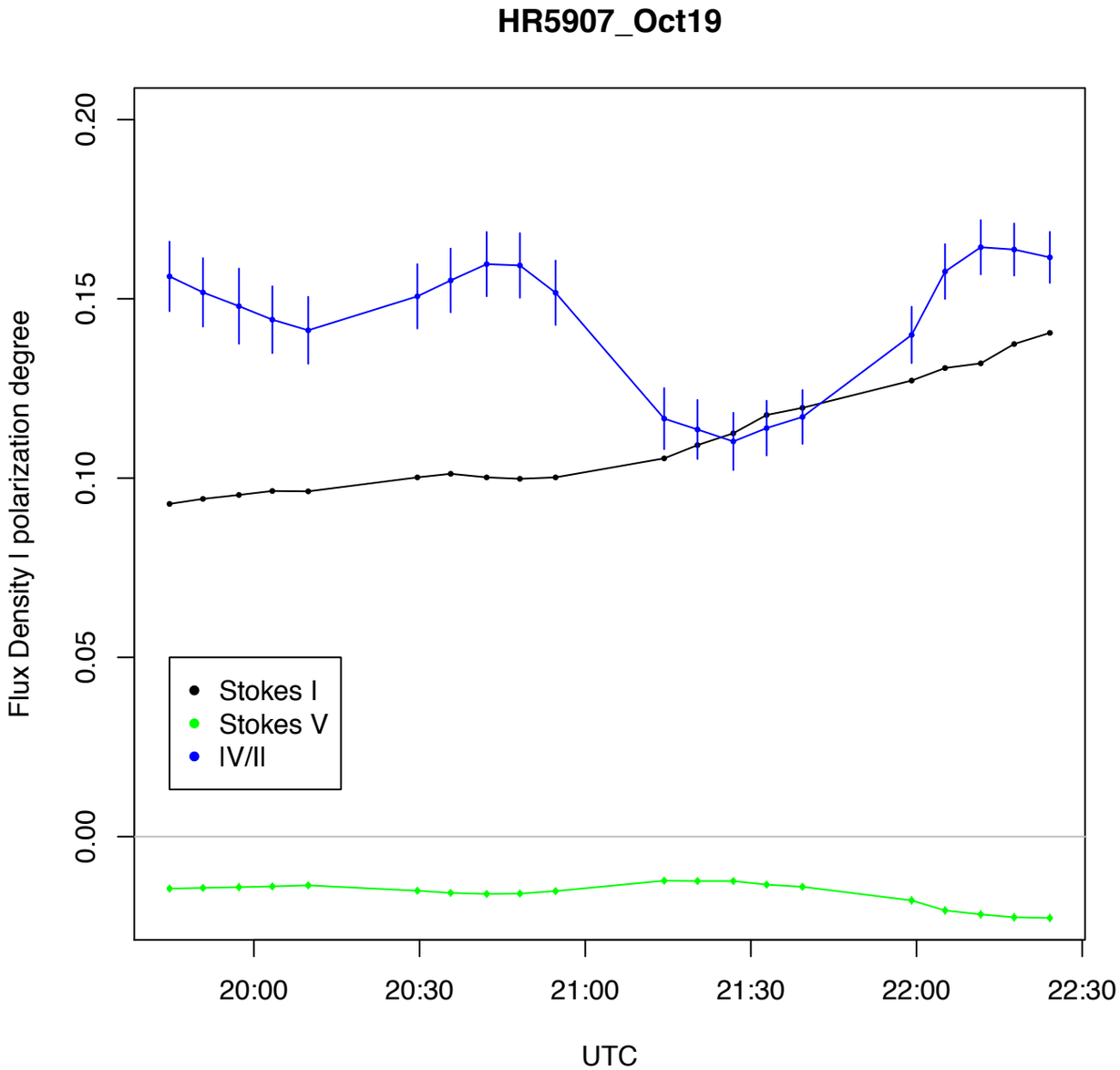
- B(los) ~ 15.7 kG
- Periodicity : 12 hours
- Circularly polarized gyro synchrotron radiation : Stokes I~0.1 Jy, V/I ~ 10%

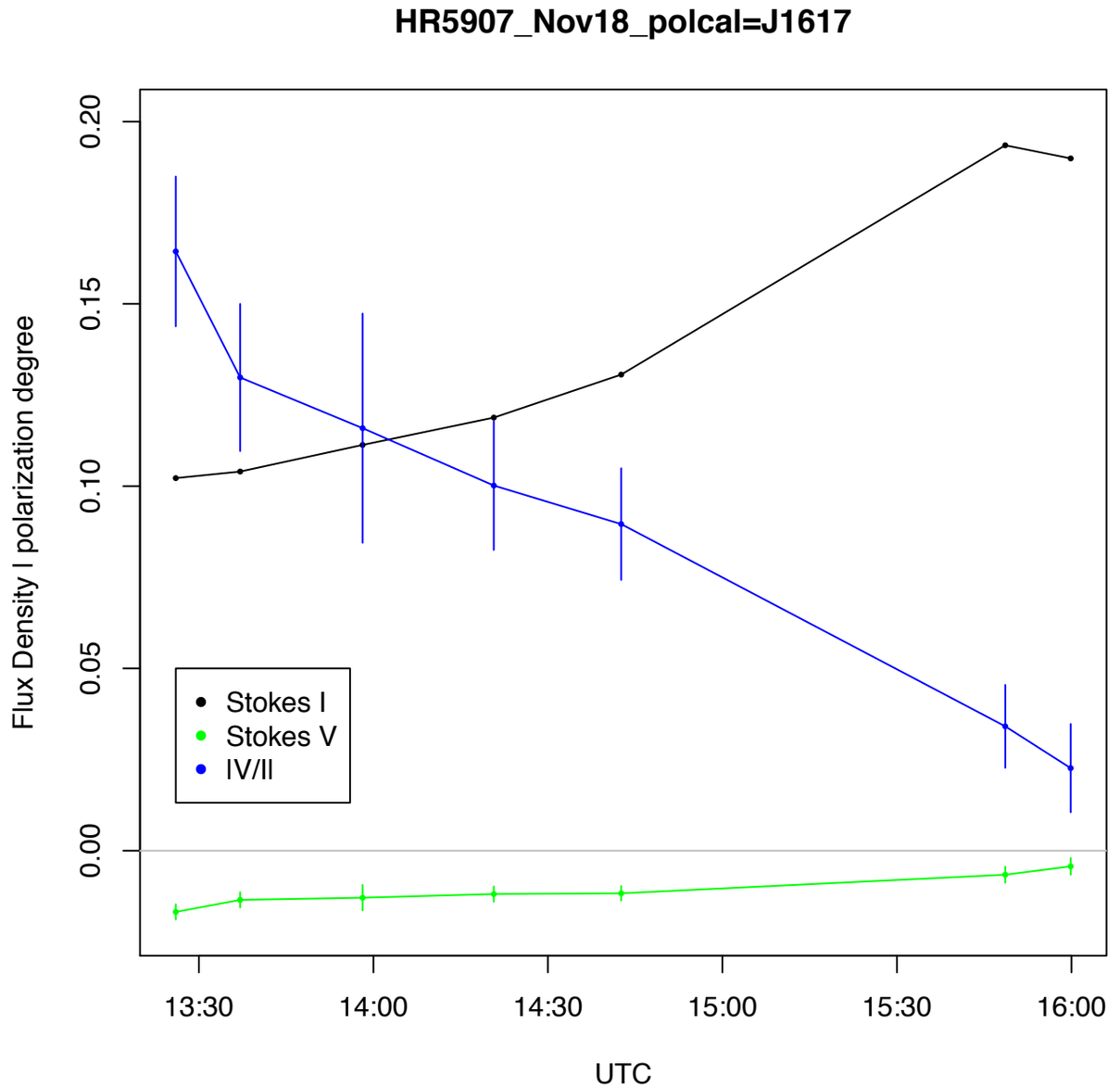




ALMA Band-3 observations toward HR 5907

- Detection of Stokes V (V/I ~ 4 - 16%, variable)
- Time variability in 2 hours
- Consistent Stokes V value with VLA 44 GHz measurements (private comm.)
- No significant Q and U





Summary

We recommend Cycle-6 capability of circular polarimetry

- Both spectral and continuum observation modes
- Limited accuracy (0.6% of Stokes I) … insufficient for the Zeeman effect
- On-axis (limited FoV)

Go/No Go decision on Nov.29 (tonight)

Requirements for circular polarimetry

- QA0 process to verify XY phase stability

Future works

- Improvement of accuracy to allow Zeeman effect
- Wider FoV
- Short calibration scheme

Thanks for KVN collaborations!

- Providing the CH_3OH maser source list
- Simultaneous SiO maser observations
- Imaging SiO masers
- Comparison of Stokes I and V spectra