

# **Magnetic fields in star-forming regions determined by maser polarization**

AfAS – 26 March 2026

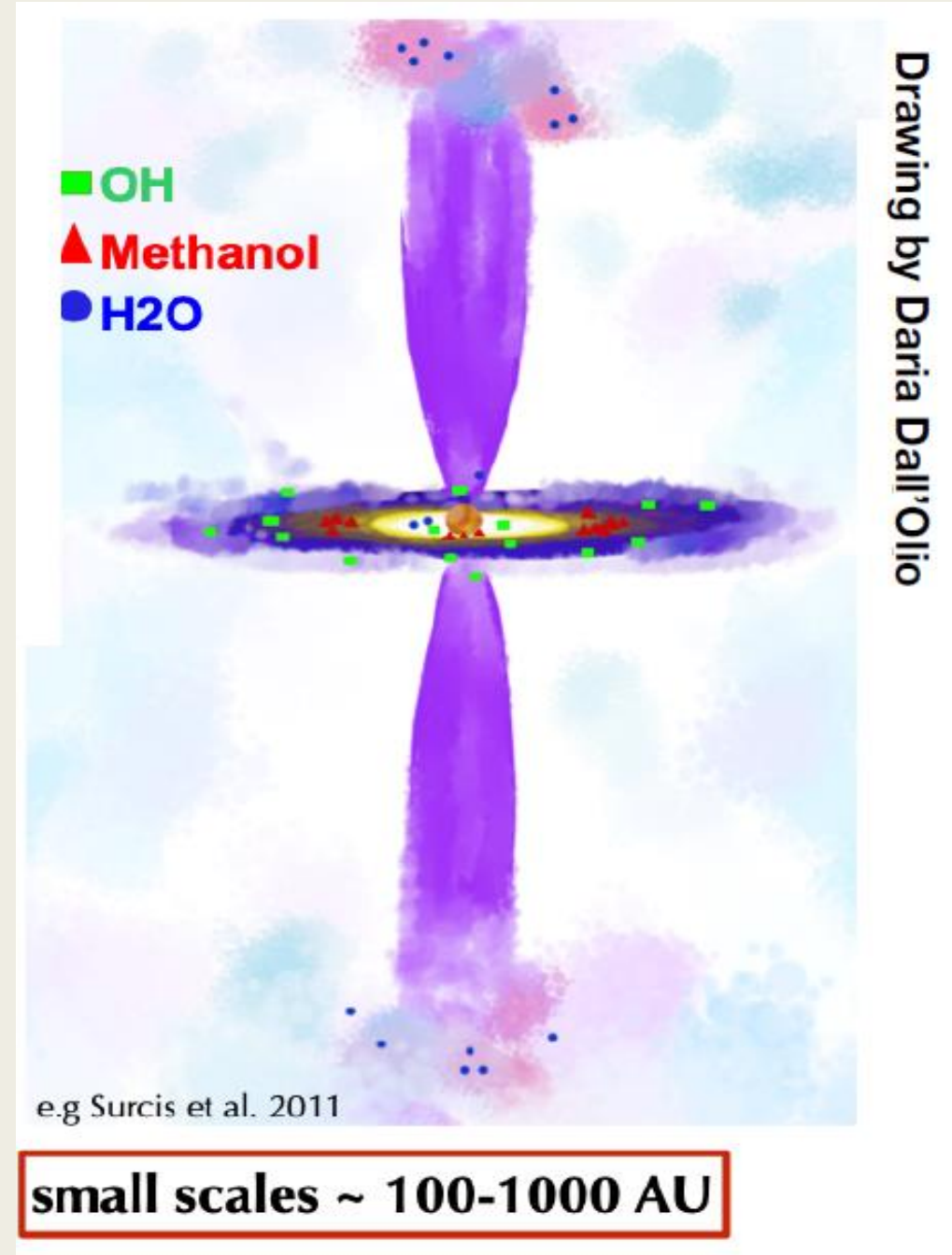
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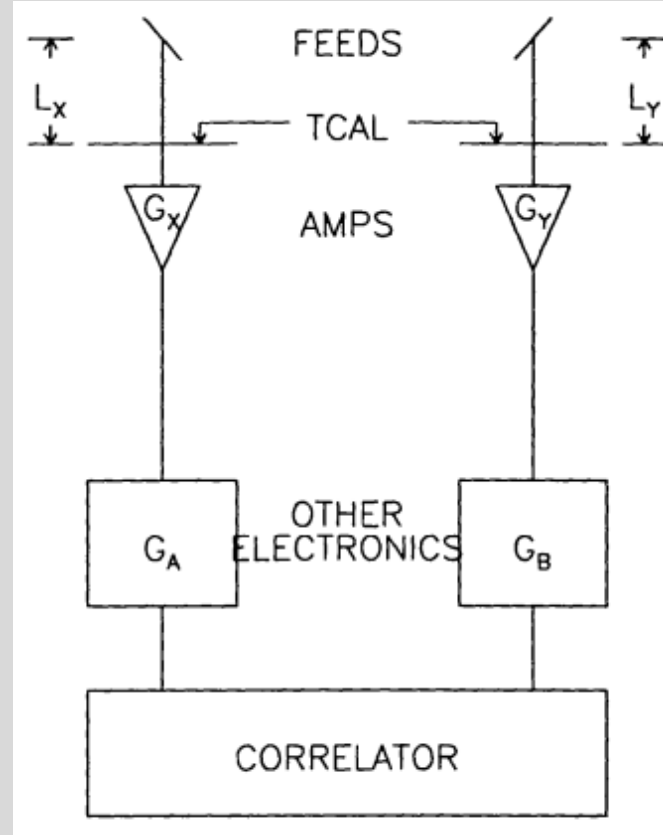


# Protostar environment

- Circumstellar accretion disk (rotating)
- Large-scale molecular bipolar outflow (from large sections of disk?)
- Rotating jets with helical magnetic field have been observed
- Red – CH<sub>3</sub>OH maser (in disk, 100s of AU from protostar)
- Green – OH maser (in disk, 100s of AU from protostar)
- Blue – H<sub>2</sub>O maser (along outflow)
- Magnetic fields in jets & disk notoriously difficult to measure
- Line-of-site magnetic fields estimated using masers
- Proposed & modelled magnetised & turbulent disk winds



# GBT maser observations – Mueller matrix correction for accurate polarization



Telescope, receiver and electronics introduce gain and phase differences in the X and Y channels and alter polarisation signal



**Stokes parameters**  
from observed spectra

$$I_{\text{obs}} = XX + YY$$

$$Q_{\text{obs}} = XX - YY$$

$$U_{\text{obs}} = 2 * XY$$

$$V_{\text{obs}} = 2 * YX .$$



**Mueller matrix correction**

$$\begin{bmatrix} I_{\text{src}} \\ Q_{\text{src}} \\ U_{\text{src}} \\ V_{\text{src}} \end{bmatrix} = (M_{\text{Mueller}} \cdot M_{\text{sky}})^{-1} \begin{bmatrix} I_{\text{obs}} \\ Q_{\text{obs}} \\ U_{\text{obs}} \\ V_{\text{obs}} \end{bmatrix}$$

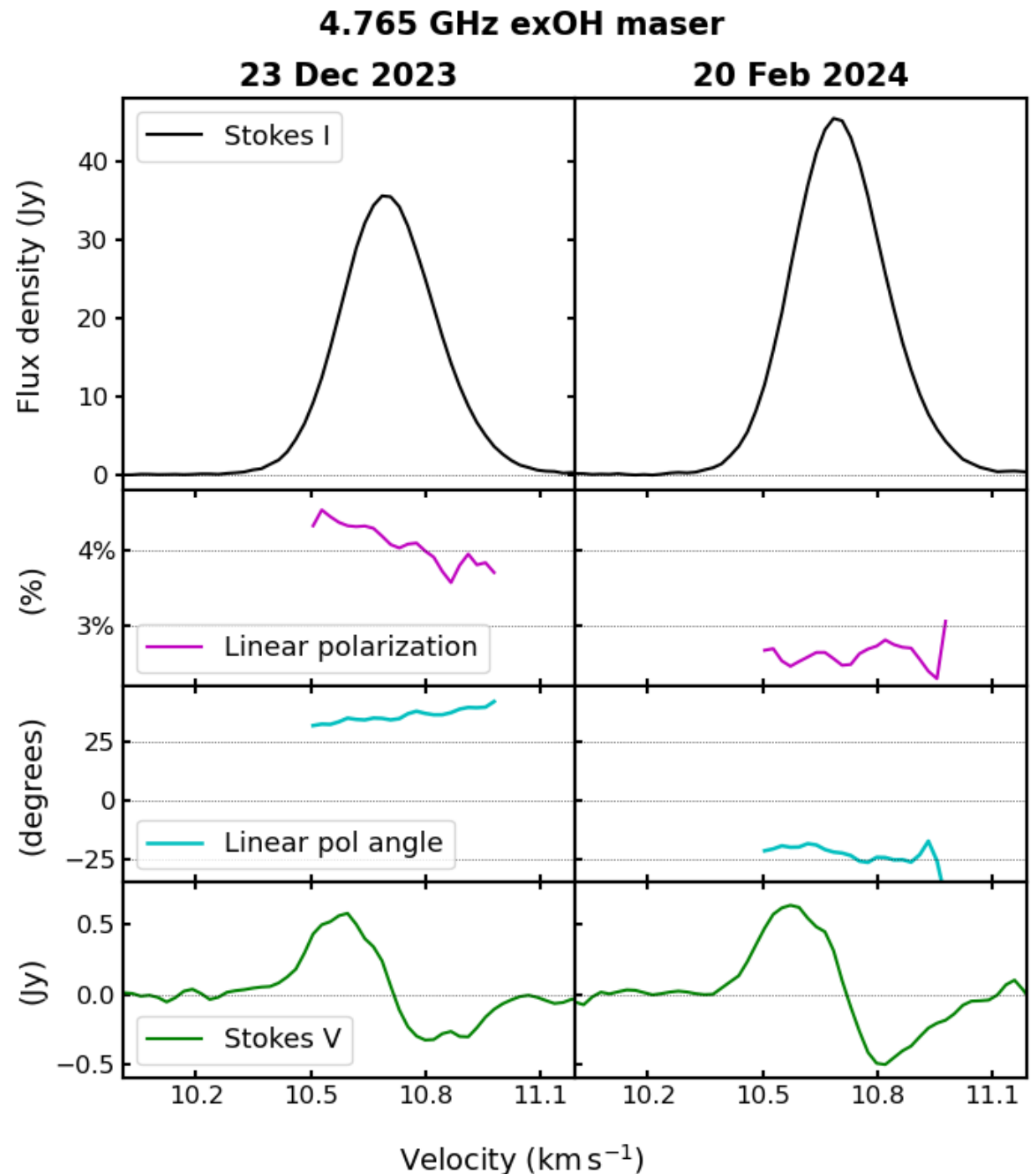


**Linear polarization**

**Circular polarization**

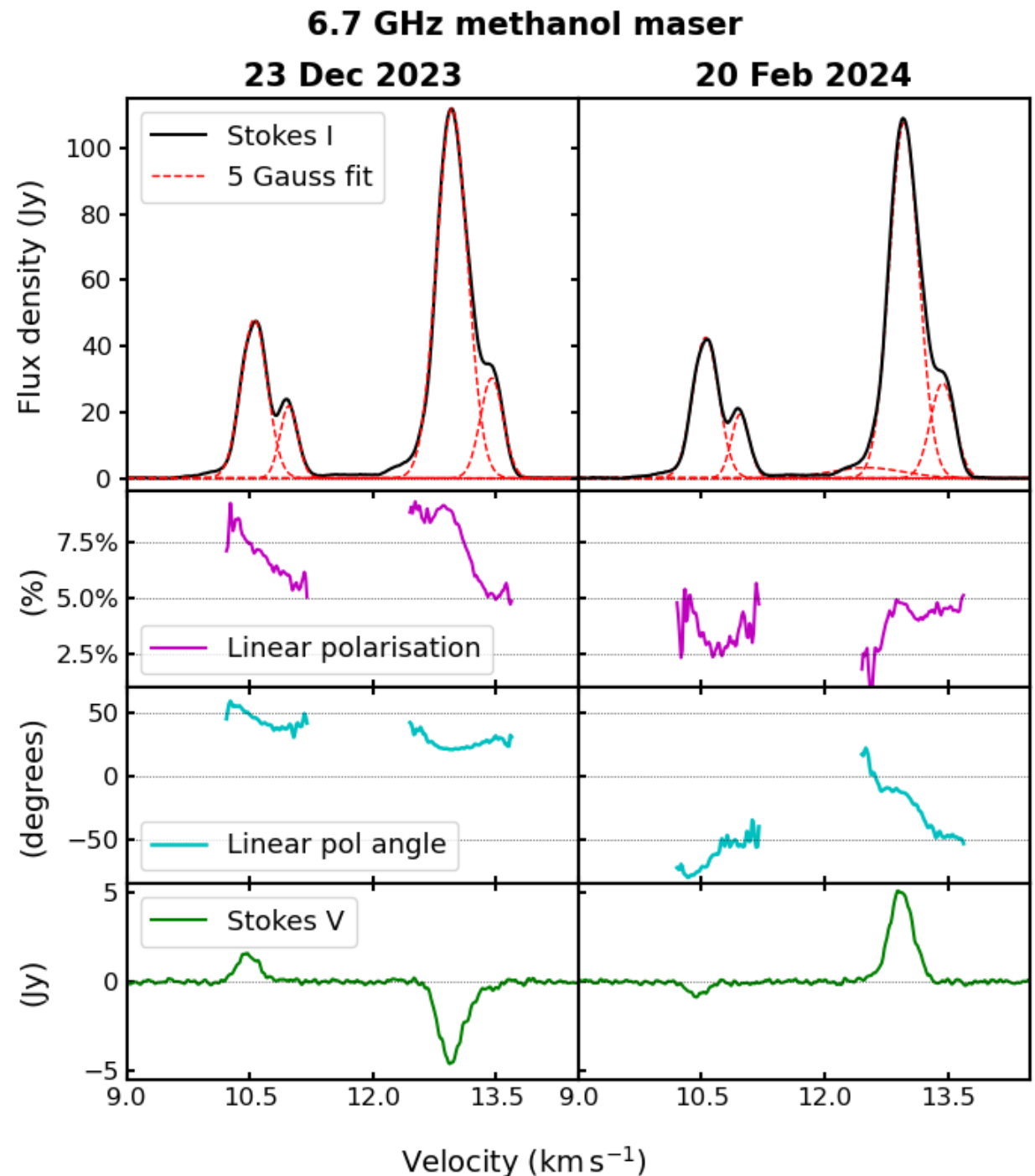
# GBT observations 4.765 GHz exOH maser in Mon R2

- Maser signal – Stokes I  
(intensity does vary!)
- 4.7 GHz exOH maser polarisation
- Changing linear polarisation  
(not generally known)
- Circular polarisation (unique shape)  
*Smits & Fallon 2025*
- Zeeman splitting  
LOS magnetic field  $\sim 80$  mG

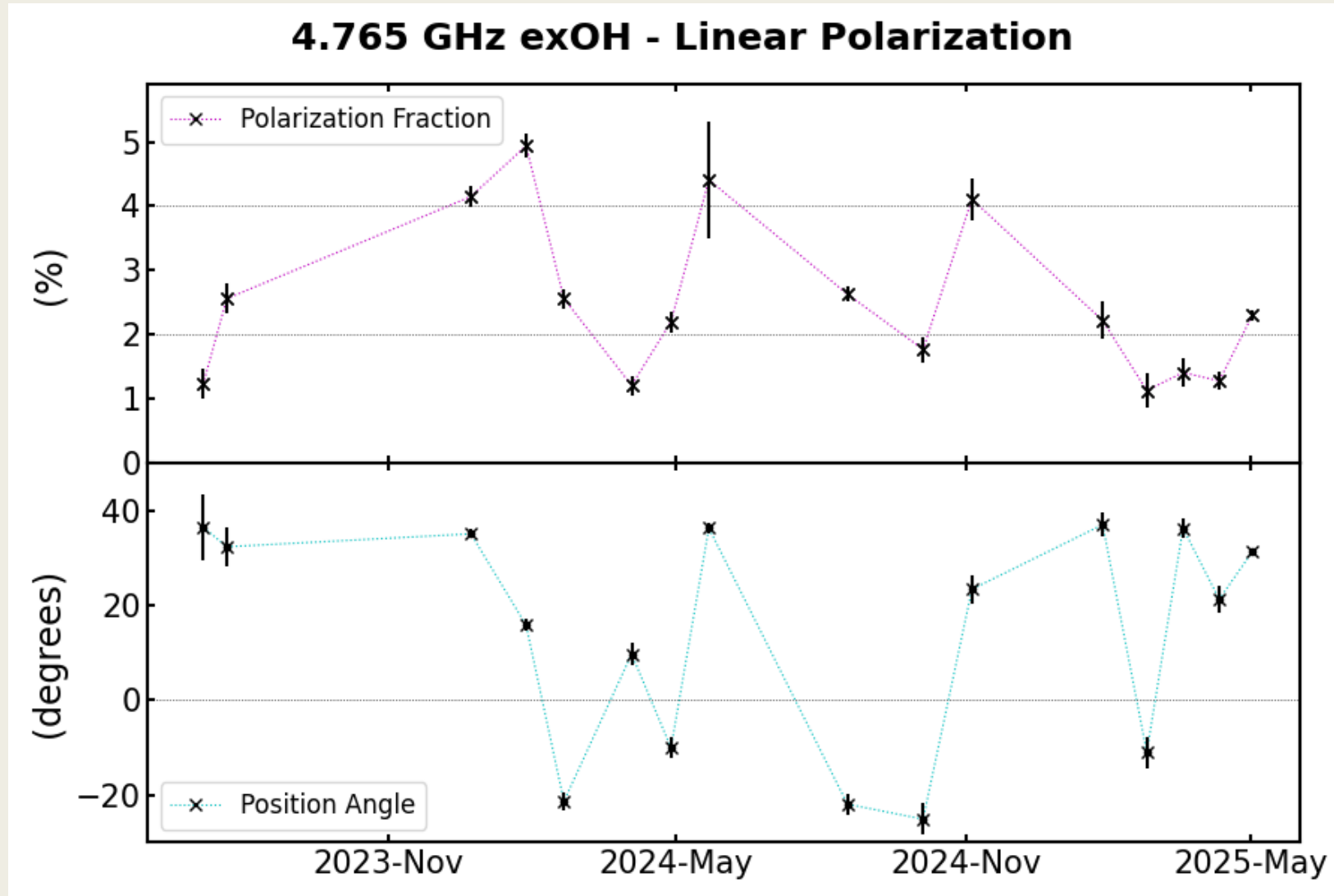


## 6.7 GHz methanol maser (in Mon R2)

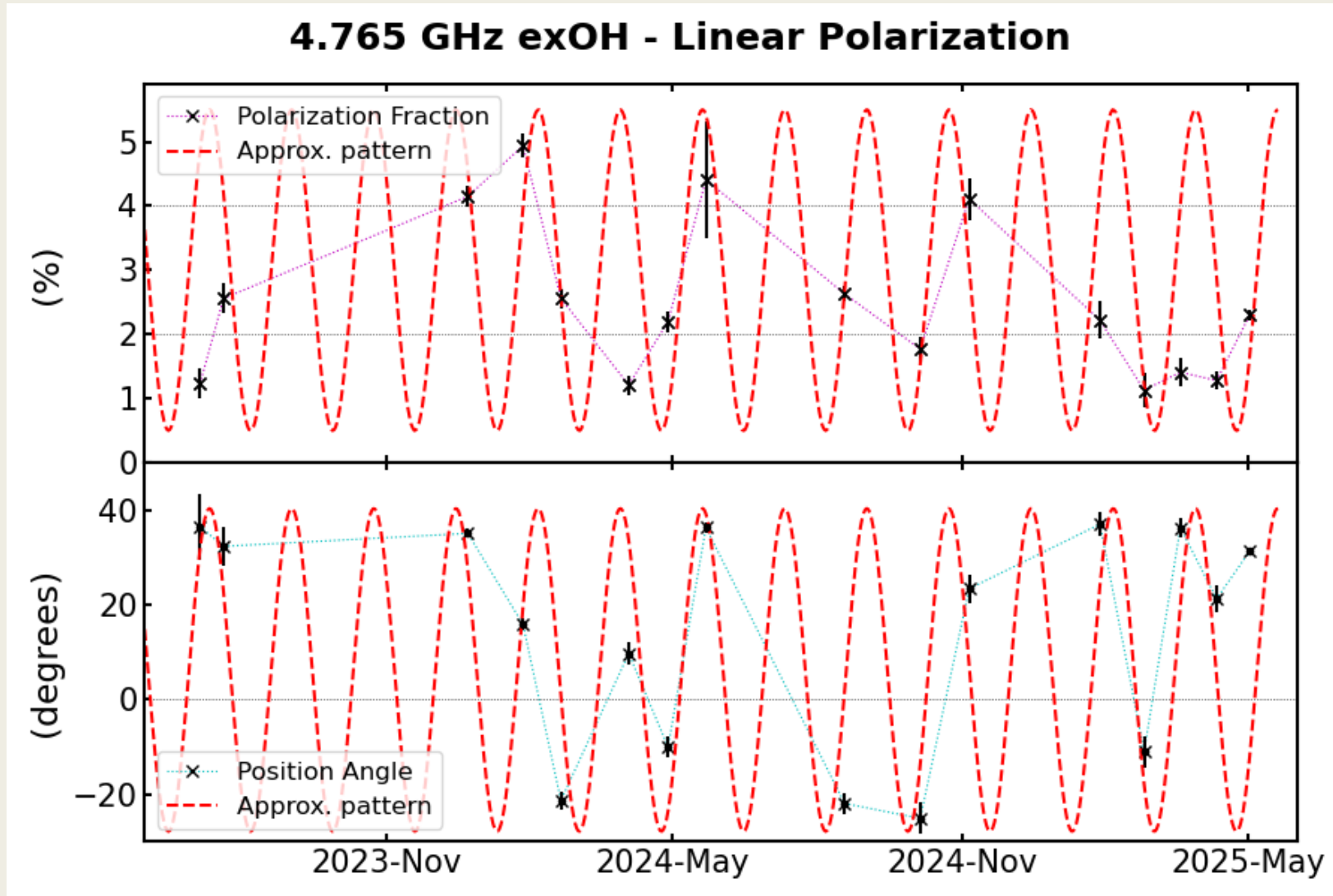
- Little change in maser intensity
- Expect both linear and circular polarisation for 6.7 GHz methanol
- Linear polarization changes similar to exOH maser (separated by  $\sim 200$  AU)
- Zeeman splitting detected  
Dec 2023: 46mG & 21mG  
Feb 2024: -71mG & -13mG  
(Fallon & Smits 2026, submitted)  
Changes with polarization variations



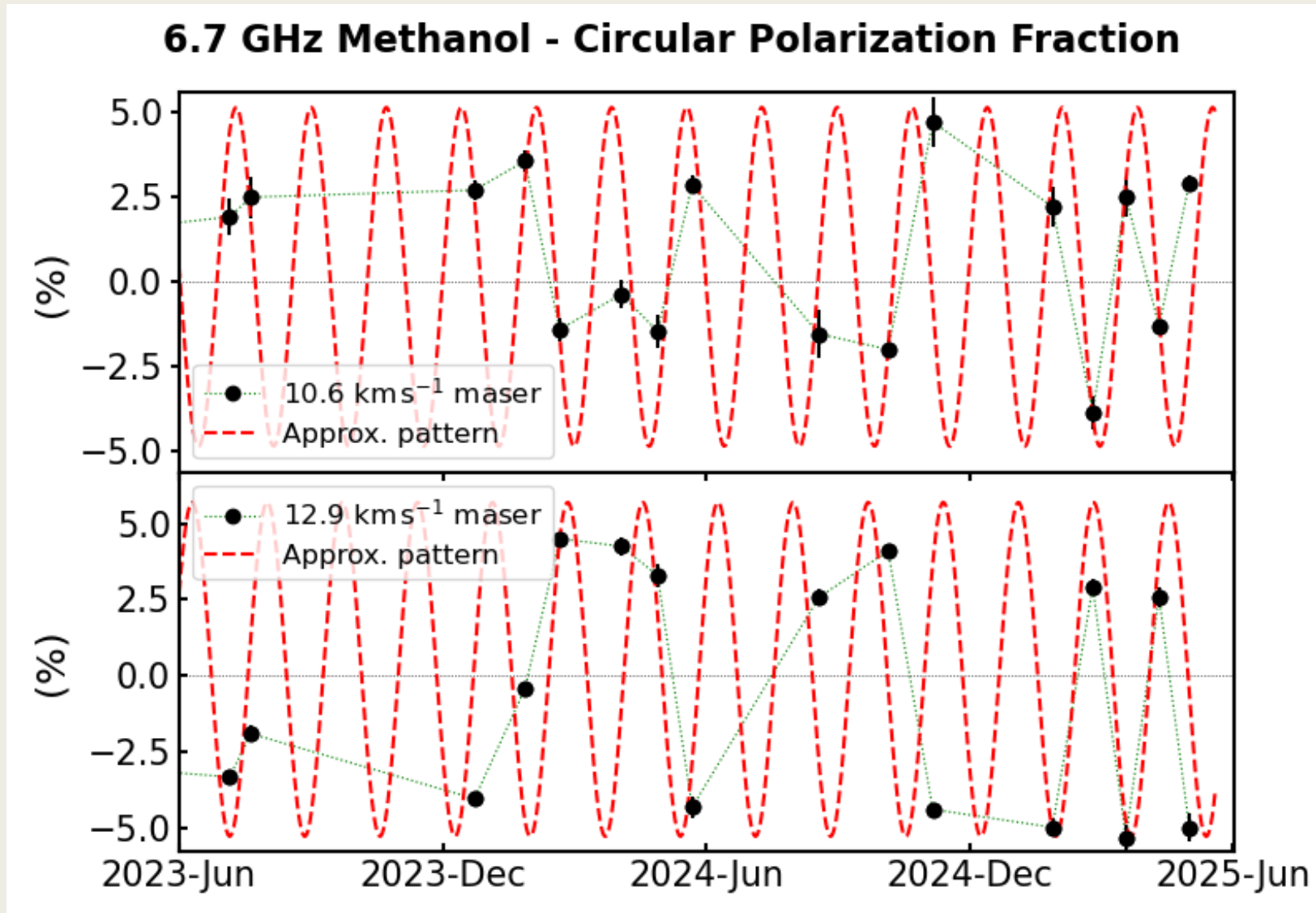
We have a series of 18 observations showing varying polarization



Ongoing observation suggest periodic changes in polarization



Ongoing observation suggest periodic changes in polarization



## Observation

- Polarization due to magnetic fields
- Changing/cycling linear polarization  
Rotating in the (x'y') sky plane
- Changing/cycling circular polarization  
Rotating in the (x'z') plane

## Hypothesis

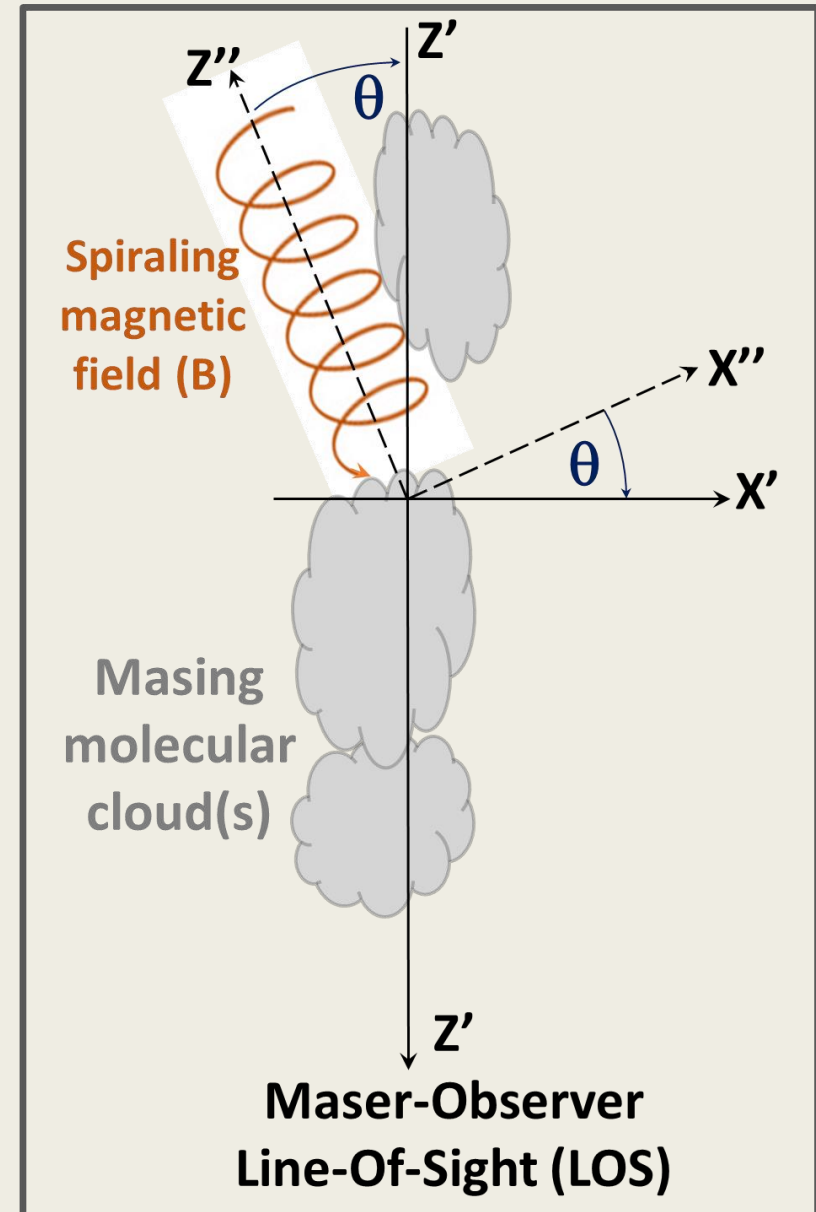
- So, a spiralling magnetic field?

## Model in x''y''z'' plane

$$\hat{\mathbf{B}}_{\parallel} = B_{\parallel} \hat{\mathbf{z}}''$$

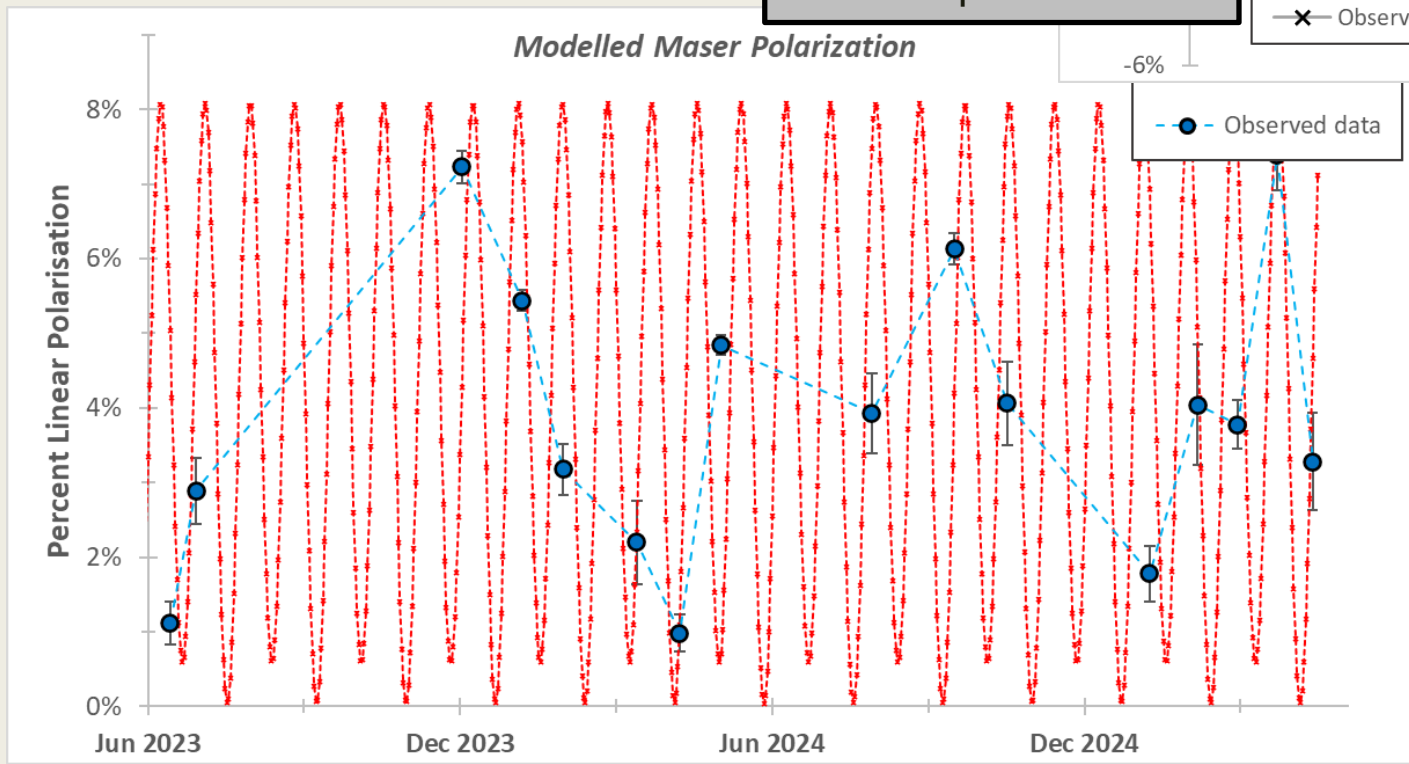
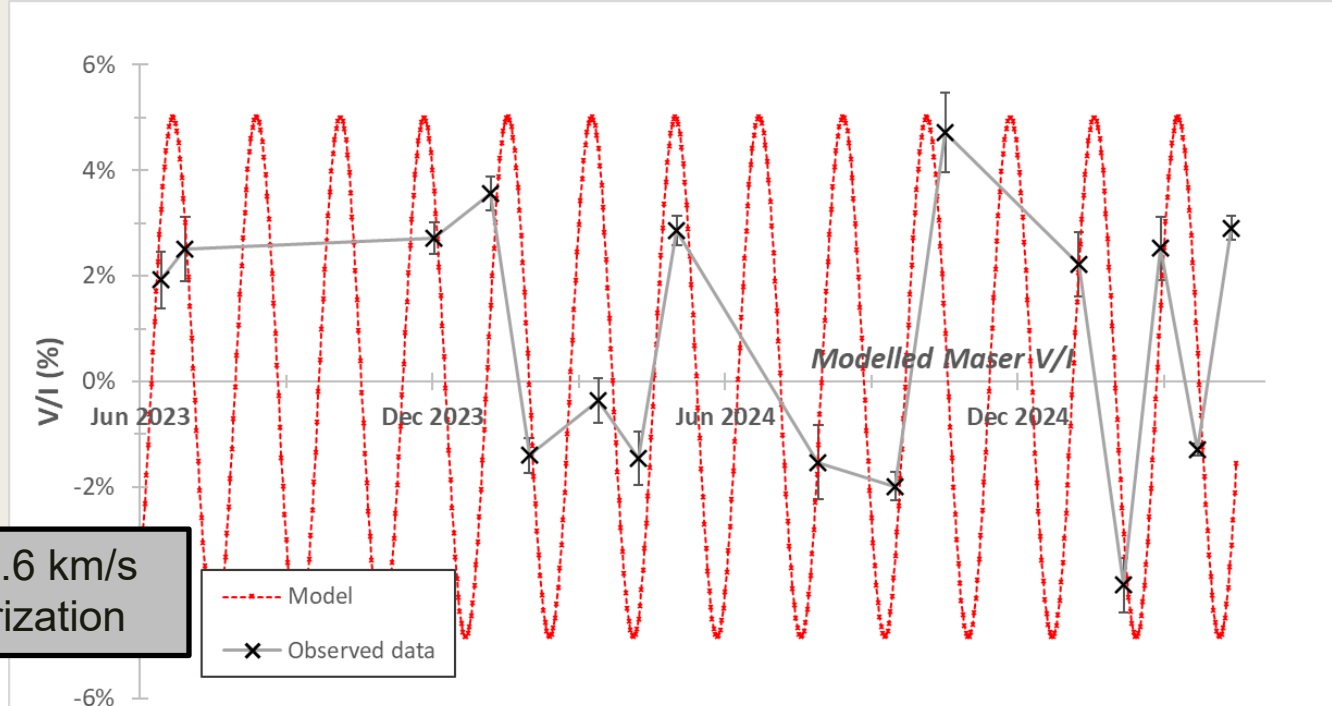
$$\hat{\mathbf{B}}_{\perp} = B_{\perp} (\hat{\mathbf{x}}'' \cos \omega t + \hat{\mathbf{y}}'' \sin \omega t)$$

- Rotate by  $\theta$  into x'y'z' plane and  
twist by  $\phi$  into observer xyz plane
- Fit to the data



# Fitting the model is progressing . . .

- Spiralling period ~ 52 or 26 days?
- Same/similar period for all masers in this source?
- Fit spiral period, elongation, and orientation to observer



- Magnetic field spiral may be changing/uneven?
- GBT project: Nov 2025 – Jan 2026, suggest changed pattern?

- **Summary**
  - *Periodic variations in maser polarization*
  - *Suggest a spiraling or helical magnetic field in the protellar accretion disk*
  - *Magnetic field orientation varies within weeks to months*
  - *Not unexpected from MHD simulations of turbulent disk winds, but a first observation*
- **Our model explains the observed polarization pattern**
  - *Why the linear polarization fraction is periodic*
  - *Why the data is not a perfect sine curve cycle*
  - *Provides magnetic field orientation relative to observes line-of-sight*
- ***Analysing further observations***

# *Questions*