

# Resolving the surface activities and magnetic fields of evolved stars

*ALMA Continuum and Line Polarisation observations @ band 5  
of the Red Supergiant VY CMa  
&  
Long baseline imaging of the surface of the AGB star W Hya*

Daniel Tafoya<sup>1</sup>, Wouter Vlemmings, Theo Khouri et al.

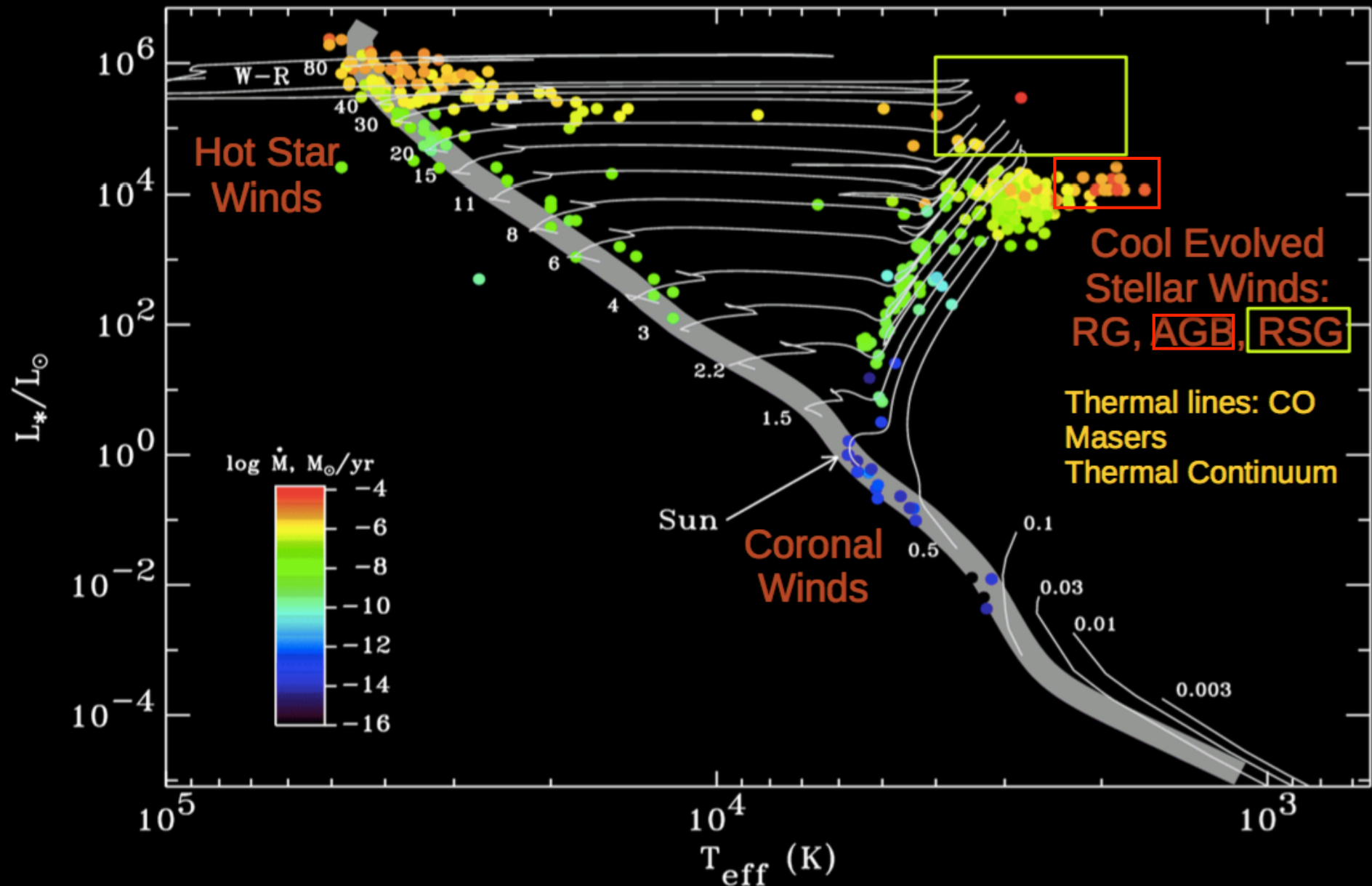
Chalmers Univ. of Technology

<sup>1</sup>Now at National Astronomical Observatory of Japan

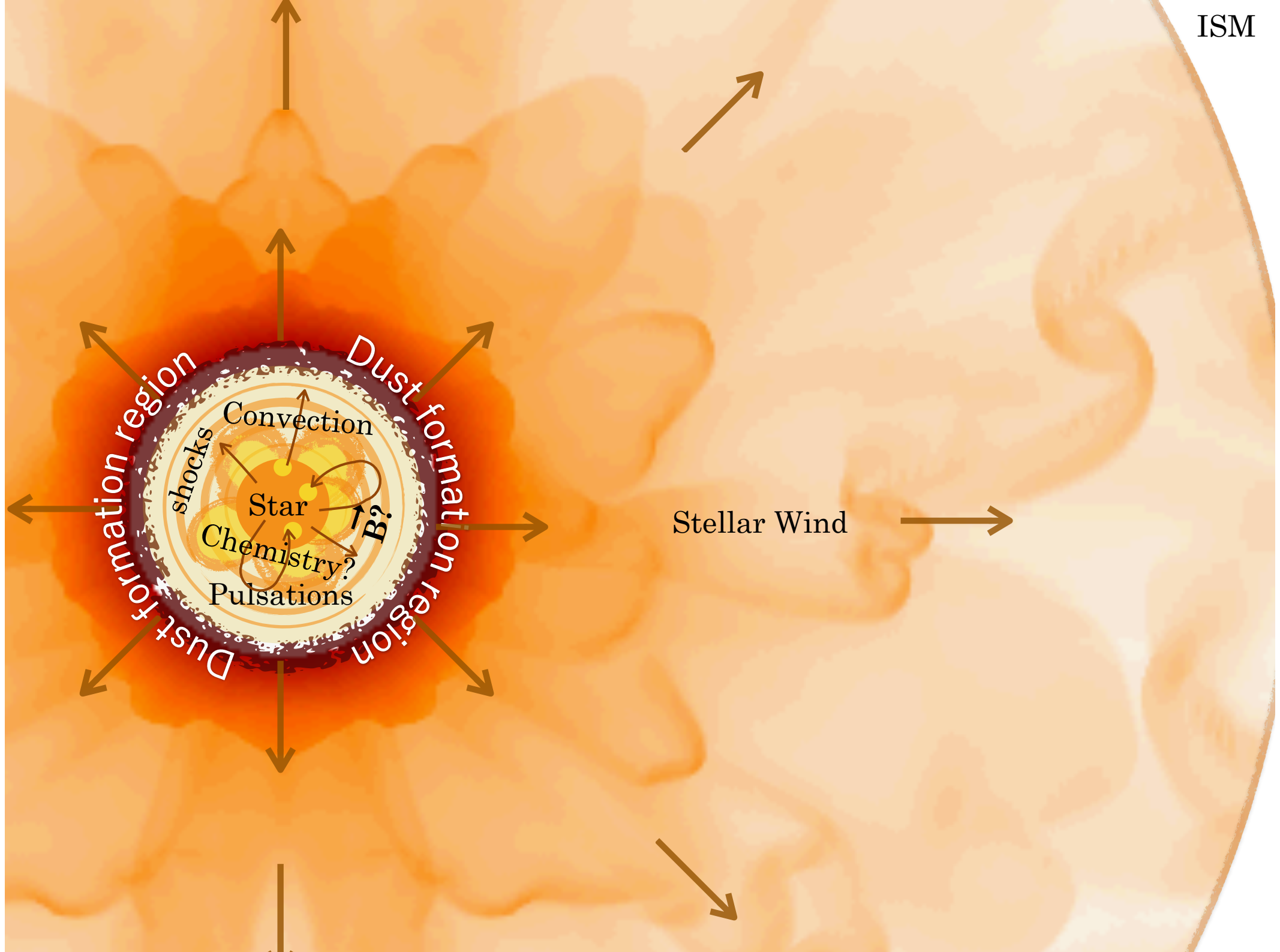


# Stellar winds from AGB and RSG stars

Main source of enrichment of the ISM with molecules and dust



ISM



# The Red Supergiant star VY CMa

Spectral Type : M5e Ia

$T_{\text{eff}} = 2800K$

$L_{\star} = 2 - 5 \times 10^5 L_{\odot}$

$M_{\star} = 25M_{\odot}$

$\dot{M} = 3 \times 10^{-3} - 10^{-4} M_{\odot} \text{ yr}^{-1}$

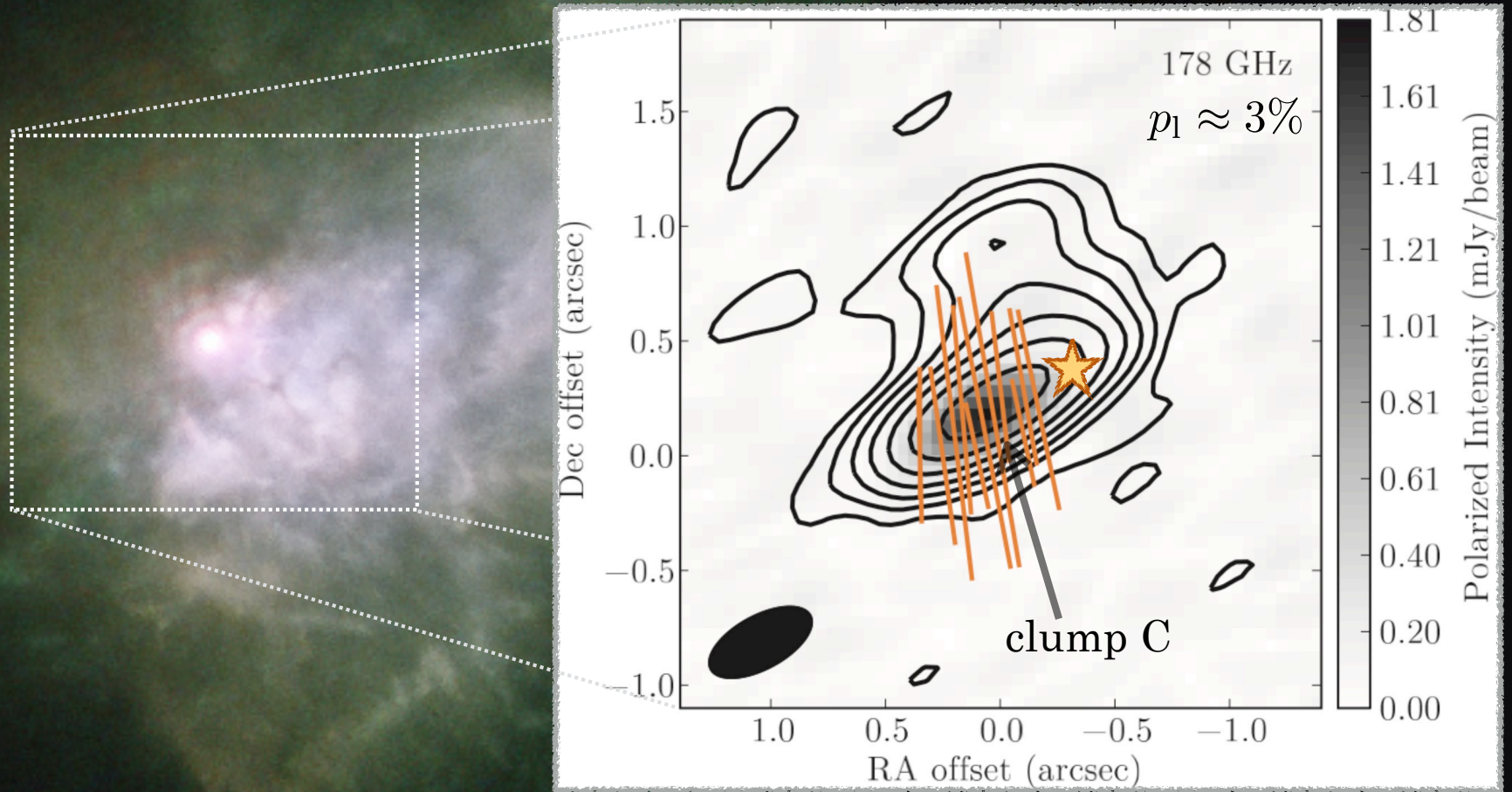
Angular diameter = 11mas

Dist =  $1200 \pm 100\text{pc}$



very complex and asymmetric CSE

# Continuum and Line Polarisation observations with ALMA @band 5 of the supergiant VY CMa



Vlemmings et al. (2017)

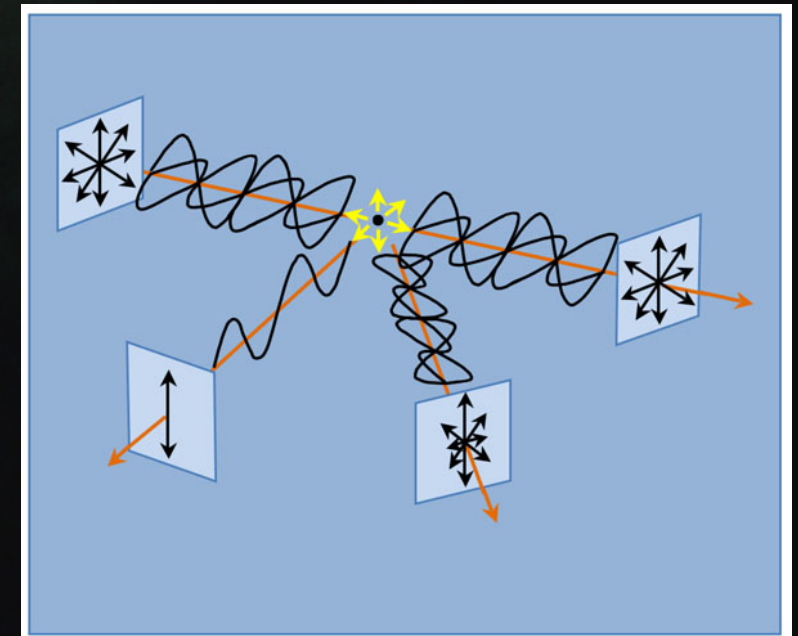
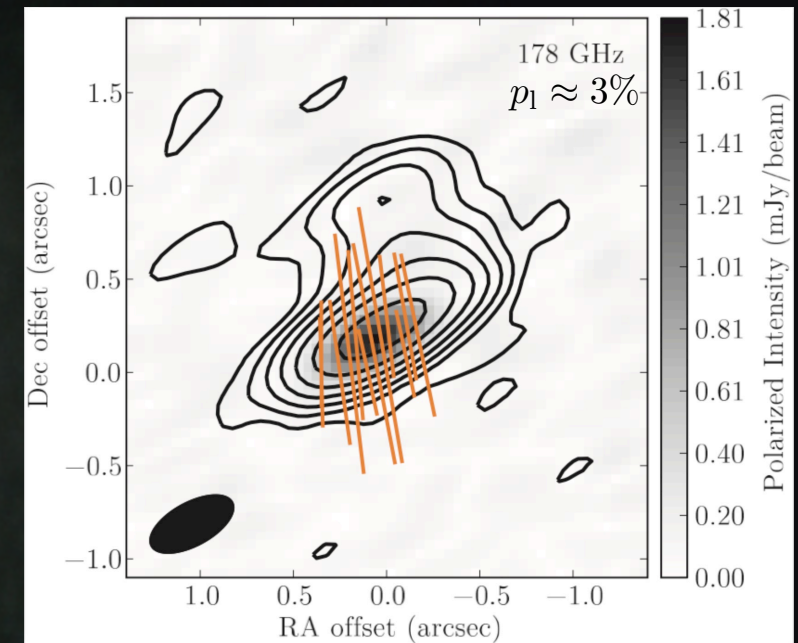
# Continuum and Line Polarisation observations with ALMA @band 5 of the supergiant VY CMa

## • Origin of the polarised emission?

### ▶ Scattering from dust grains

⇒ dust grain size  $> 100\mu\text{m}$   
very complex scattering morphology

∴ unlikely



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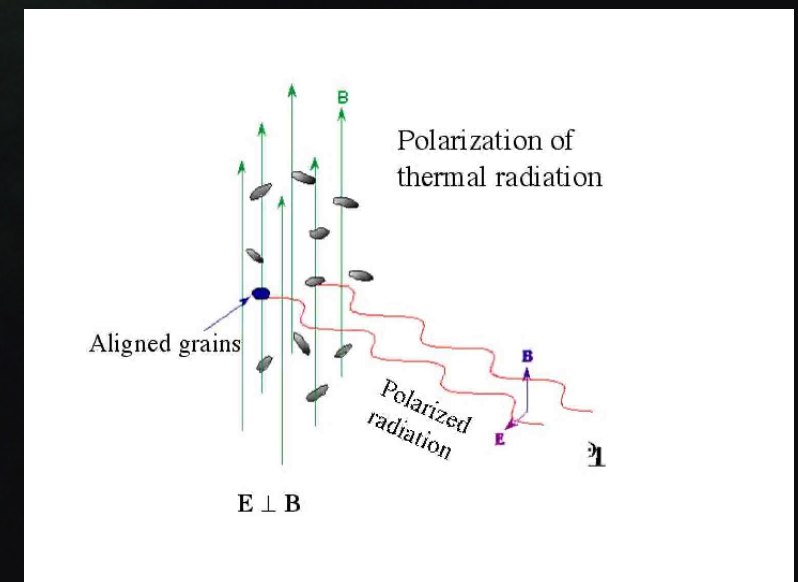
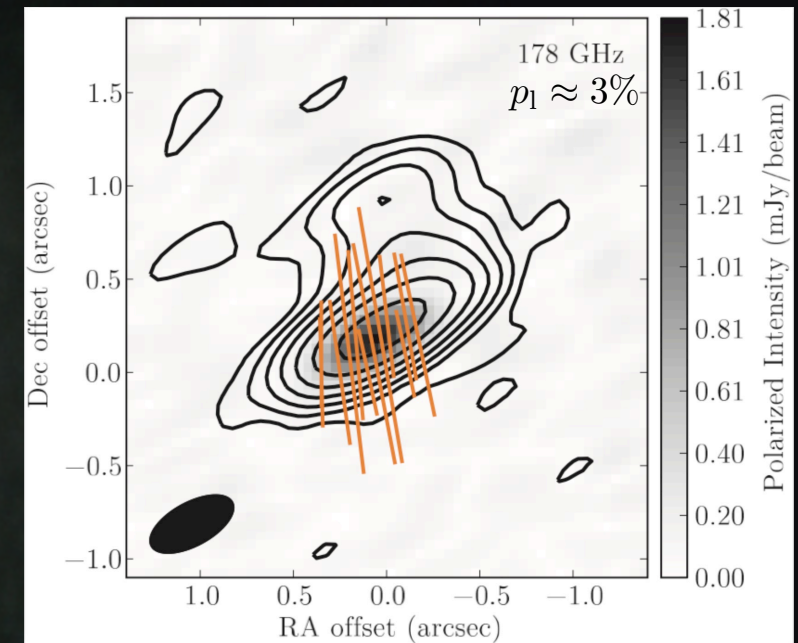
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### ▶ Emission from dust grains

Magnetically aligned silicate dust grains

Magnetic field  $\sim 15$  mGauss

Consistent with optical/IR polarisation observations



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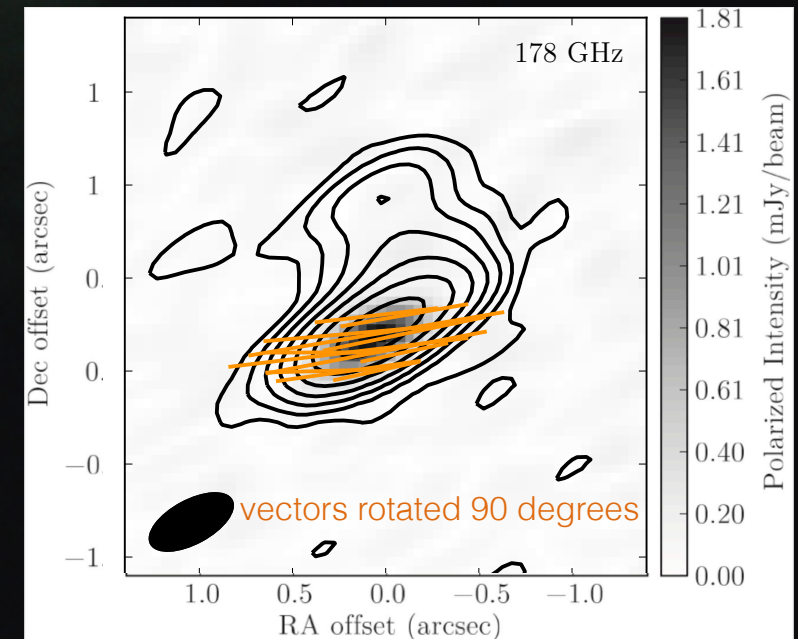
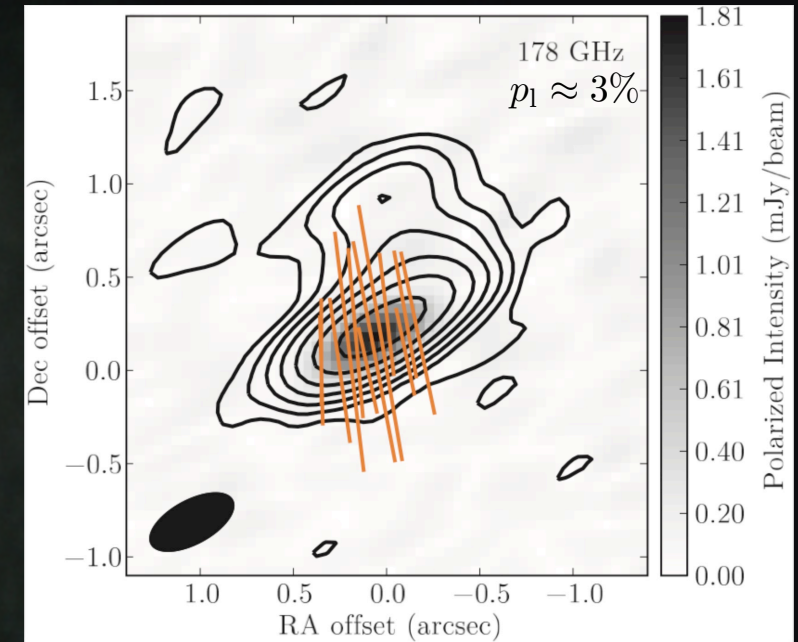
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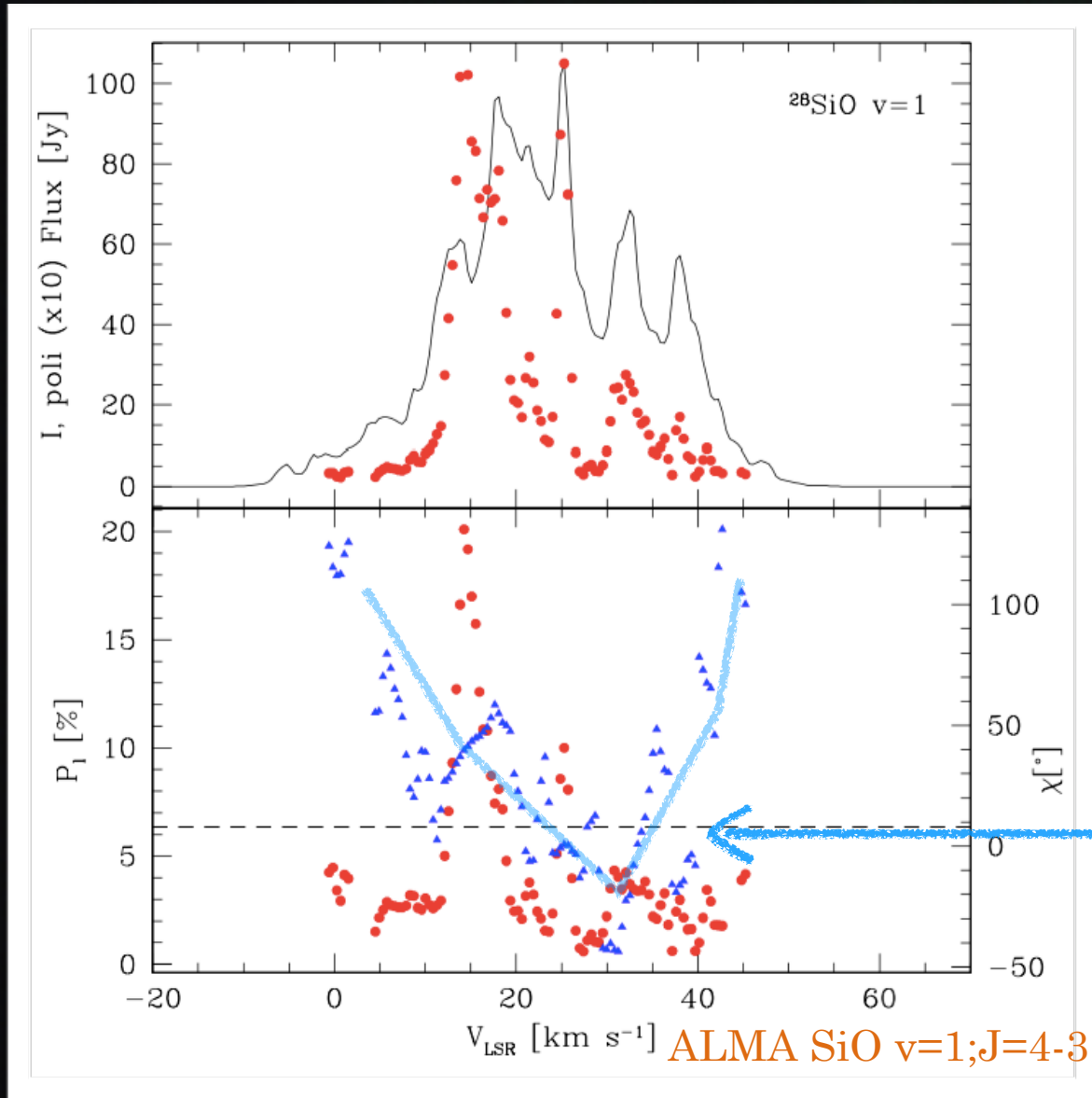
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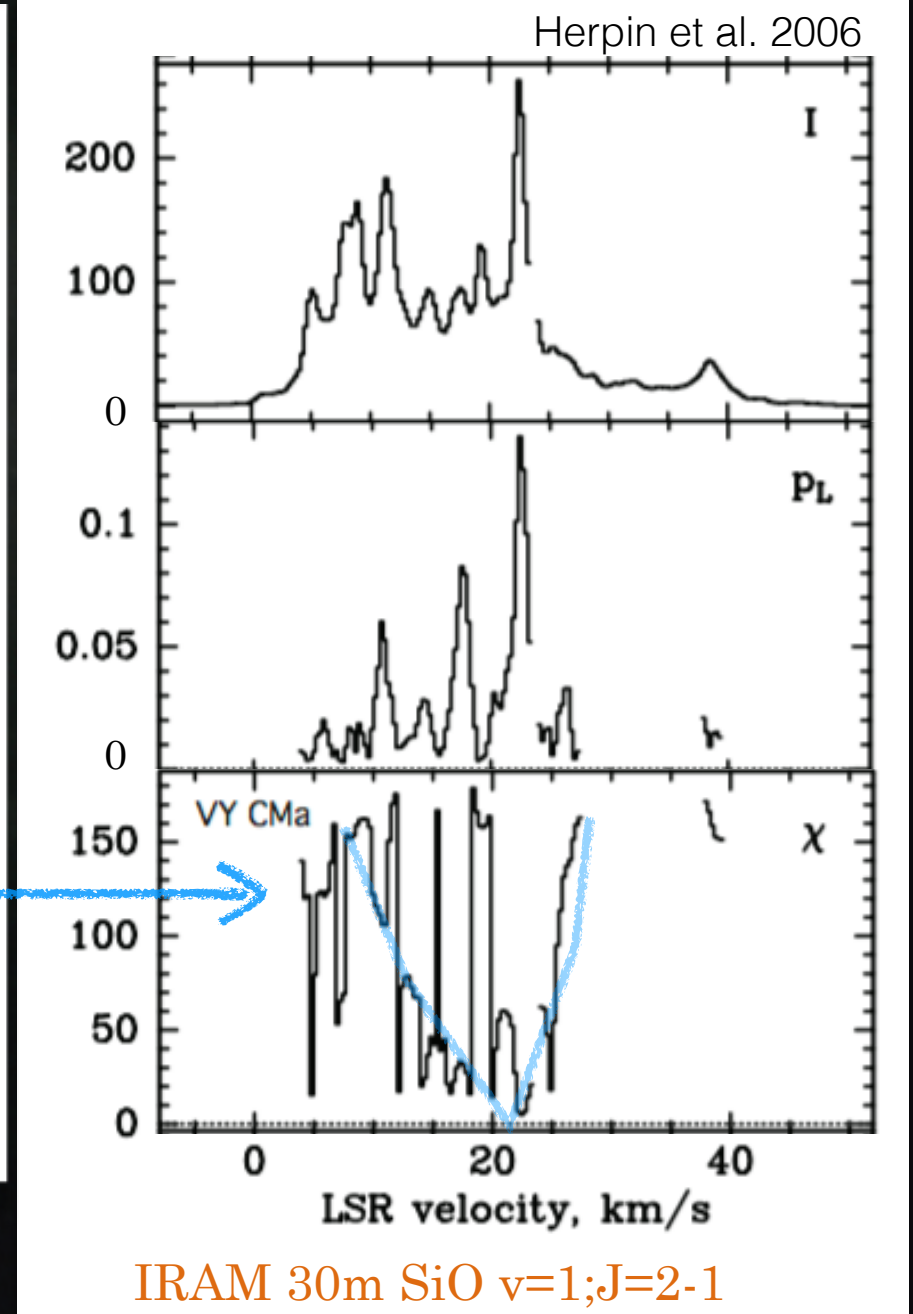




# Further evidence of magnetic alignment: SiO maser linear and circular polarisation



The horizontal dashed line indicates the EVPA observed  
in the dust continuum



# Summary I

The Continuum and Line Polarisation observations with ALMA @band 5 of the supergiant VY CMa suggest the presence of a magnetic field around the star that might be related to the launching mechanism of the stellar wind and formation of asymmetries in the CSE.

(Clump C) magnetic ejections?



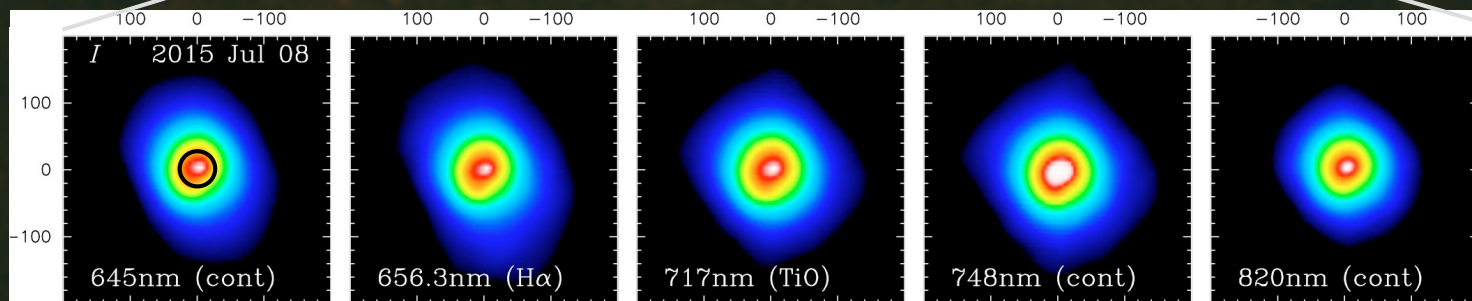
Further similar observations toward other sources will be important to determine the role of magnetic fields in the launching of stellar winds in evolved stars.

# The Asymptotic Giant Branch star W Hydrae

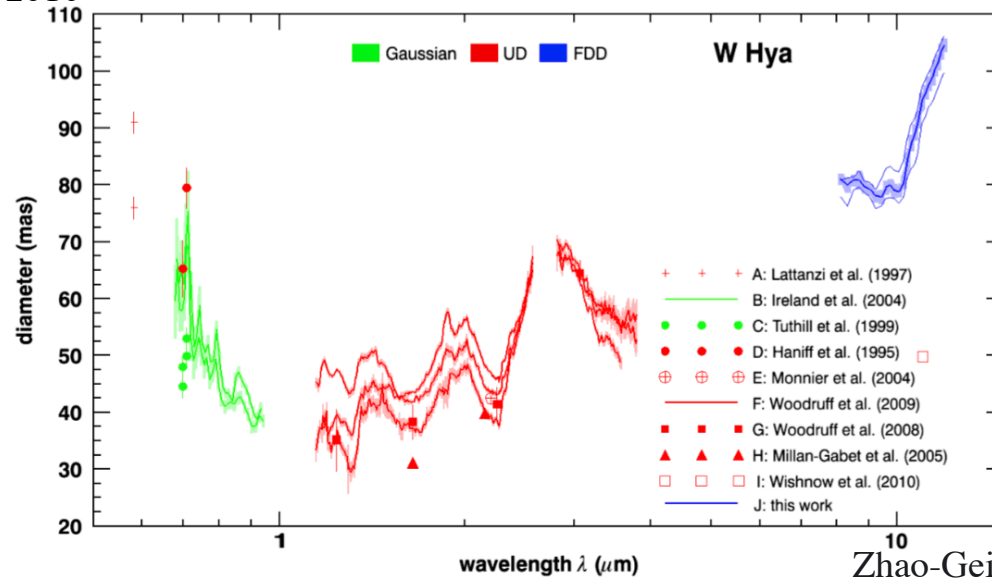
1'

$T_{\text{eff}} = 2500\text{K}$   
 $L_{\star} = 5400L_{\odot}$   
 Dist = 98pc  
 $\dot{M} = 1.3 \times 10^{-7} M_{\odot} \text{yr}^{-1}$

Cox et al. 2011

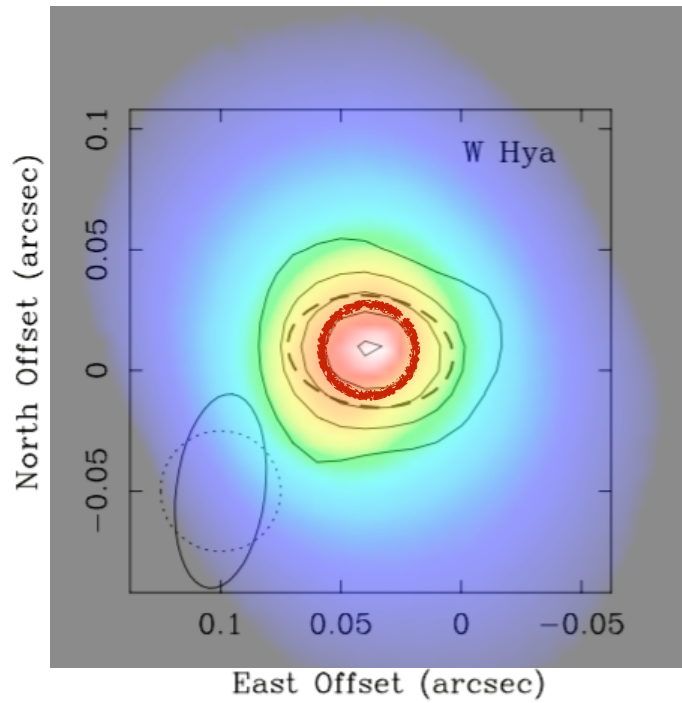


Ohnaka et al. 2016

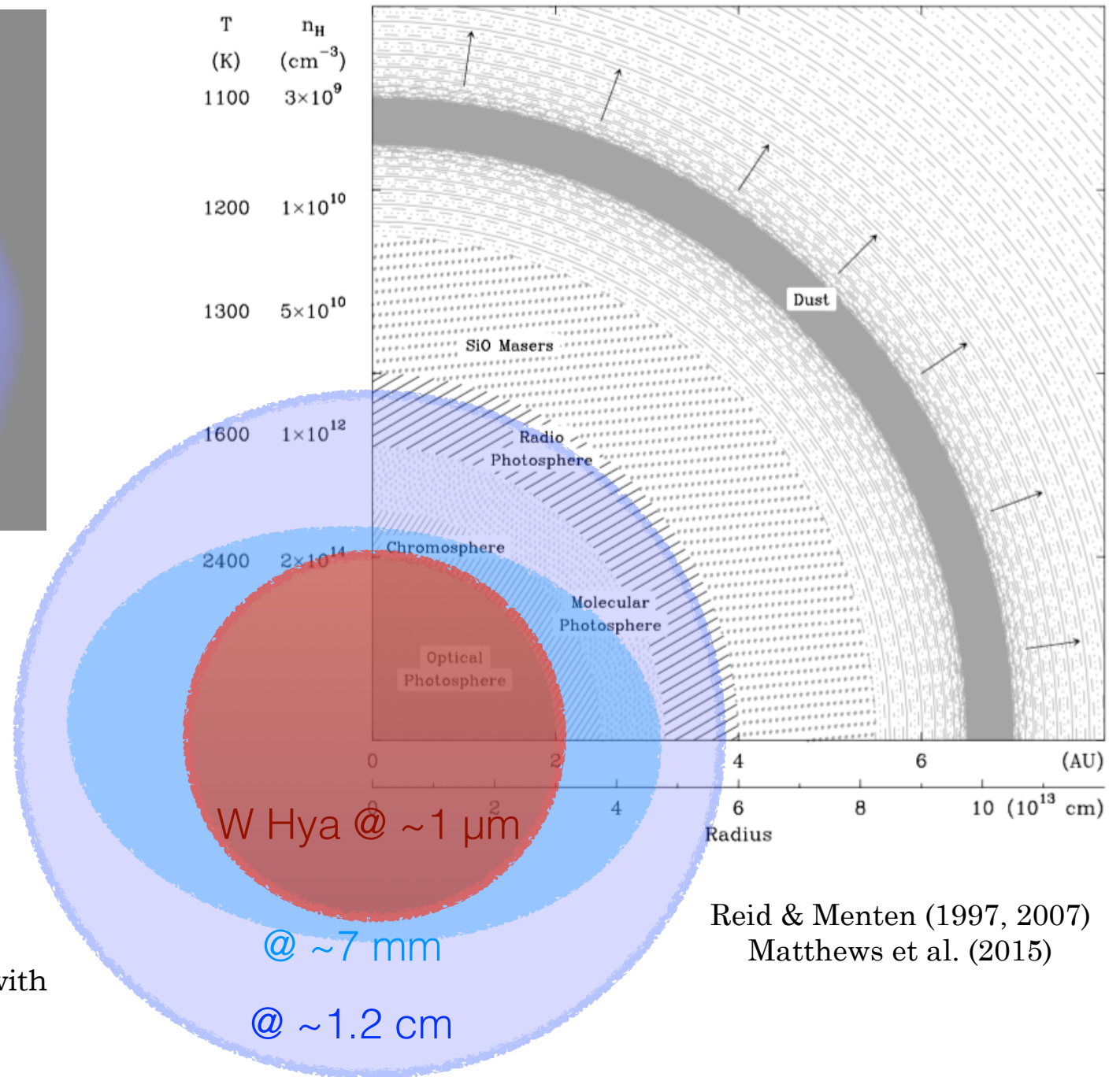


Zhao-Geisler et al. 2011

# Radio observations of W Hya



Ohnaka et al. (2016)

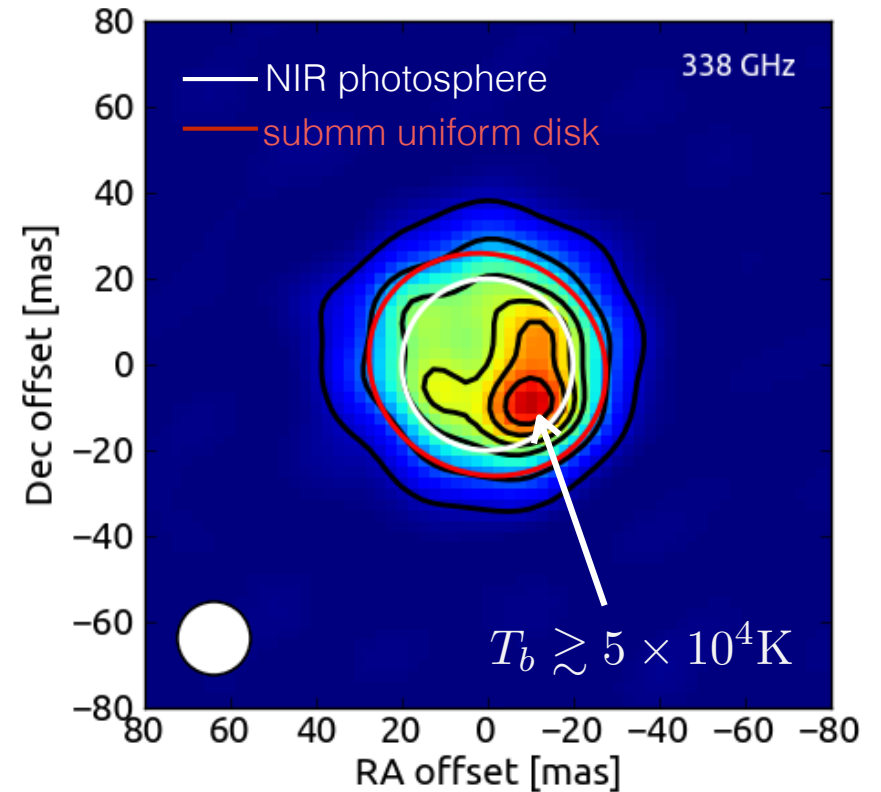
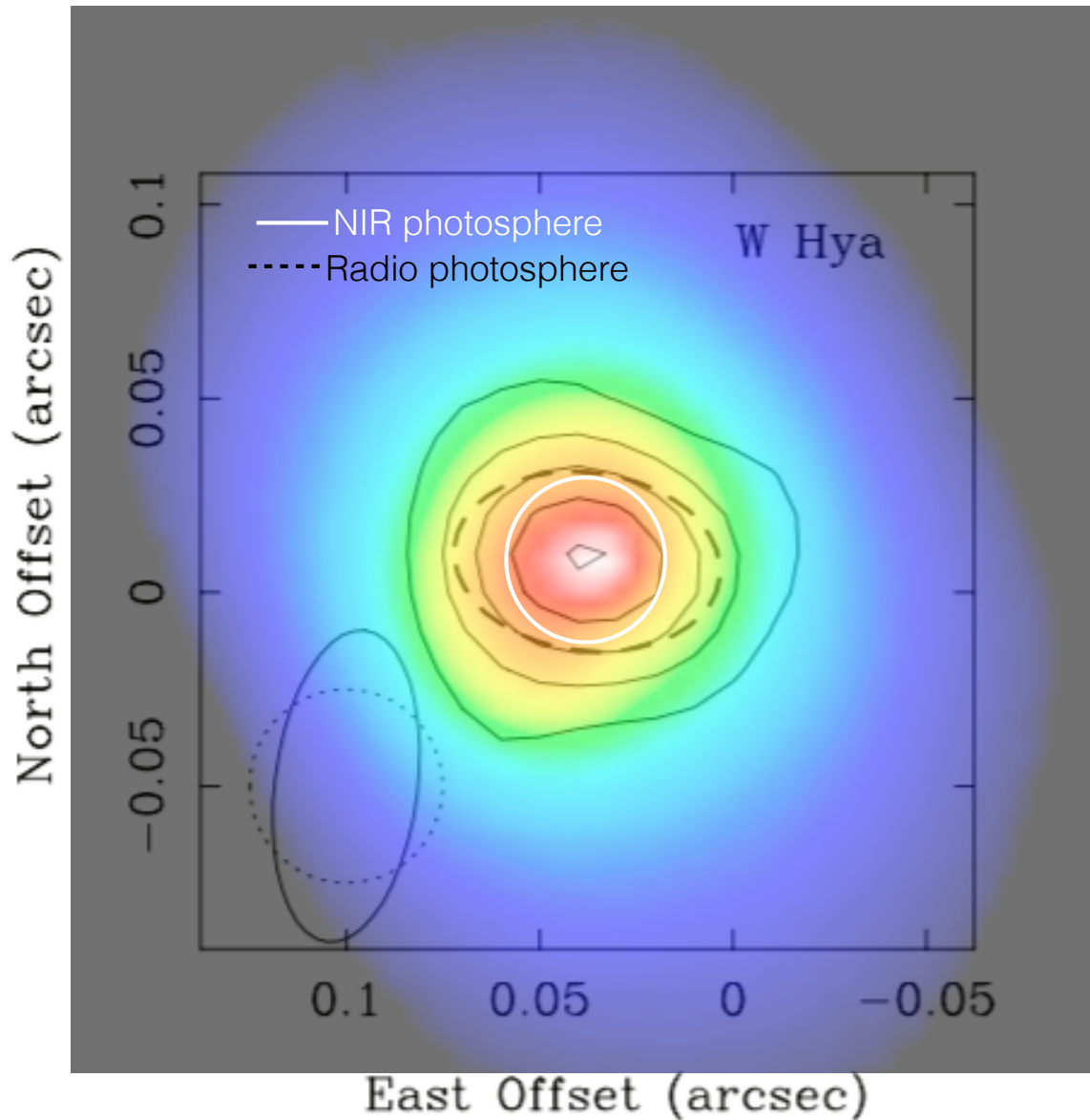


Reid & Menten (1997, 2007)  
Matthews et al. (2015)

"Radio photosphere":  
free-free emission from  
electrons interactions with  
gas. T~2400 K.

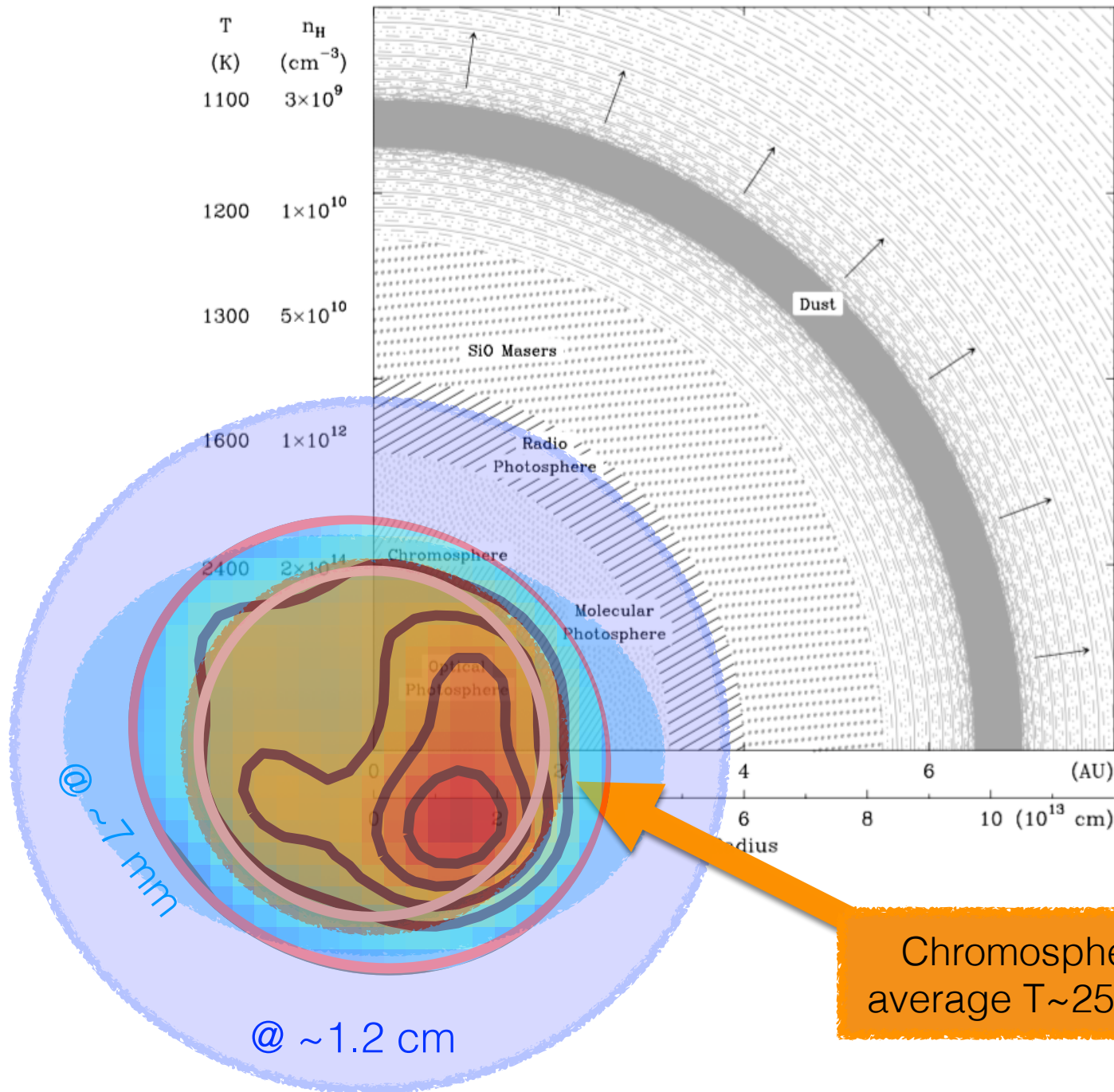
# ALMA Long baseline imaging of the surface of W Hya @ 338 GHz

- Observed Dec 2015 with 8 km baselines.
- uniform weighting: 17x24 mas beam (restored with 17 mas circular beam)



Vlemmings et al. (Nature Astronomy, 2017)

# Summary II



- Non-uniform disk with compact hotspots
- Line observations: shock heating
- Hotspots area filling factor  $< 0.2\%$  (chromosphere origin of UV emission?)

## Future with ALMA:

- longer baselines ( $< 5$  mas resolution)
- higher bands (even closer to photosphere)