

*Omicron Ceti (Mira) in the UV*

# **Atmospheric Dynamics in Mira Stars: A Spectropolarimetric Insight**

**Nicolas Fabas**  
**07/05/2014**

Meeting of the Working Group 2 on

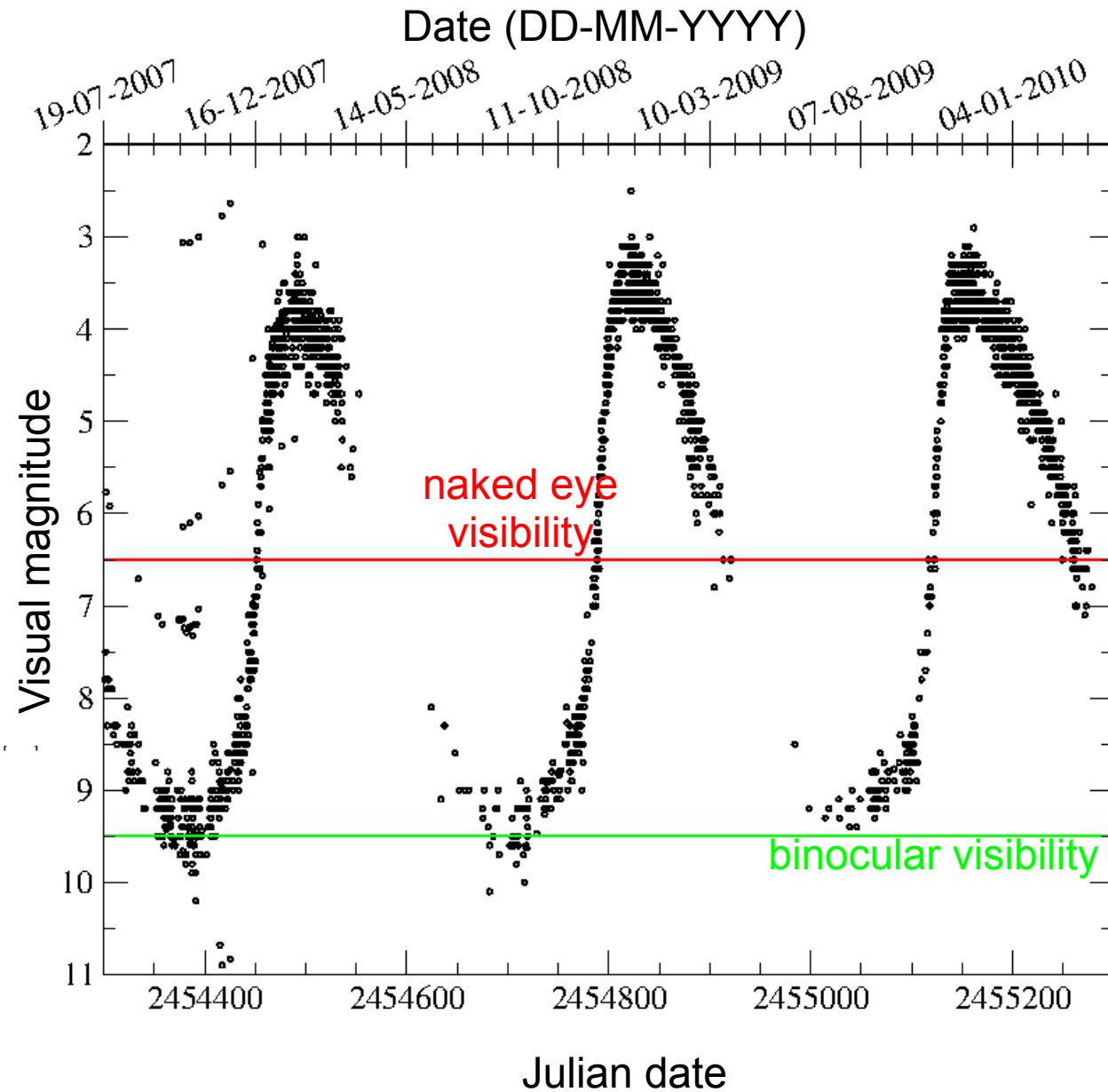
**Theory & Modelling  
of polarisation in astrophysics**

Prague, Czech Republic, 5-8 May, 2014

1. Mira stars
2. Spectropolarimetric Survey of Mira Stars
3. Learning from Solar Spectropolarimetry
4. Conclusions and Perspectives

# Mira stars

Light curve  
from the  
*American  
Association of  
Variable Stars  
Observers*



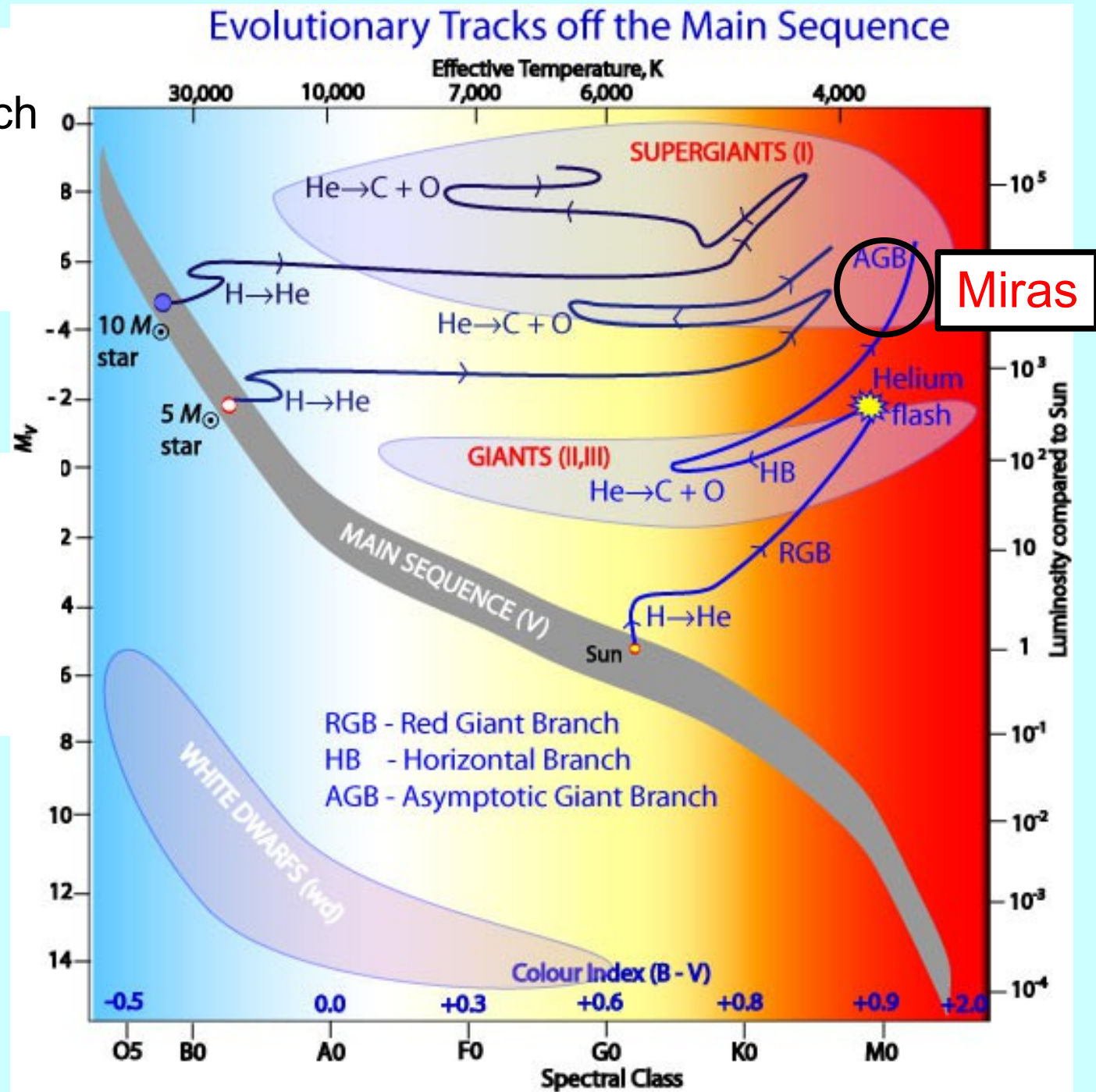
**Light curve of omicron Ceti**

## Mira Stars:

- Asymptotic Giant Branch
- $T_{\text{eff}} \approx 3000 \text{ K}$
- $\log(g) \approx 1$

## Spectral Type:

- $C/O < 1 \rightarrow$  M type
- $C/O \approx 1 \rightarrow$  S type
- $C/O > 1 \rightarrow$  C type

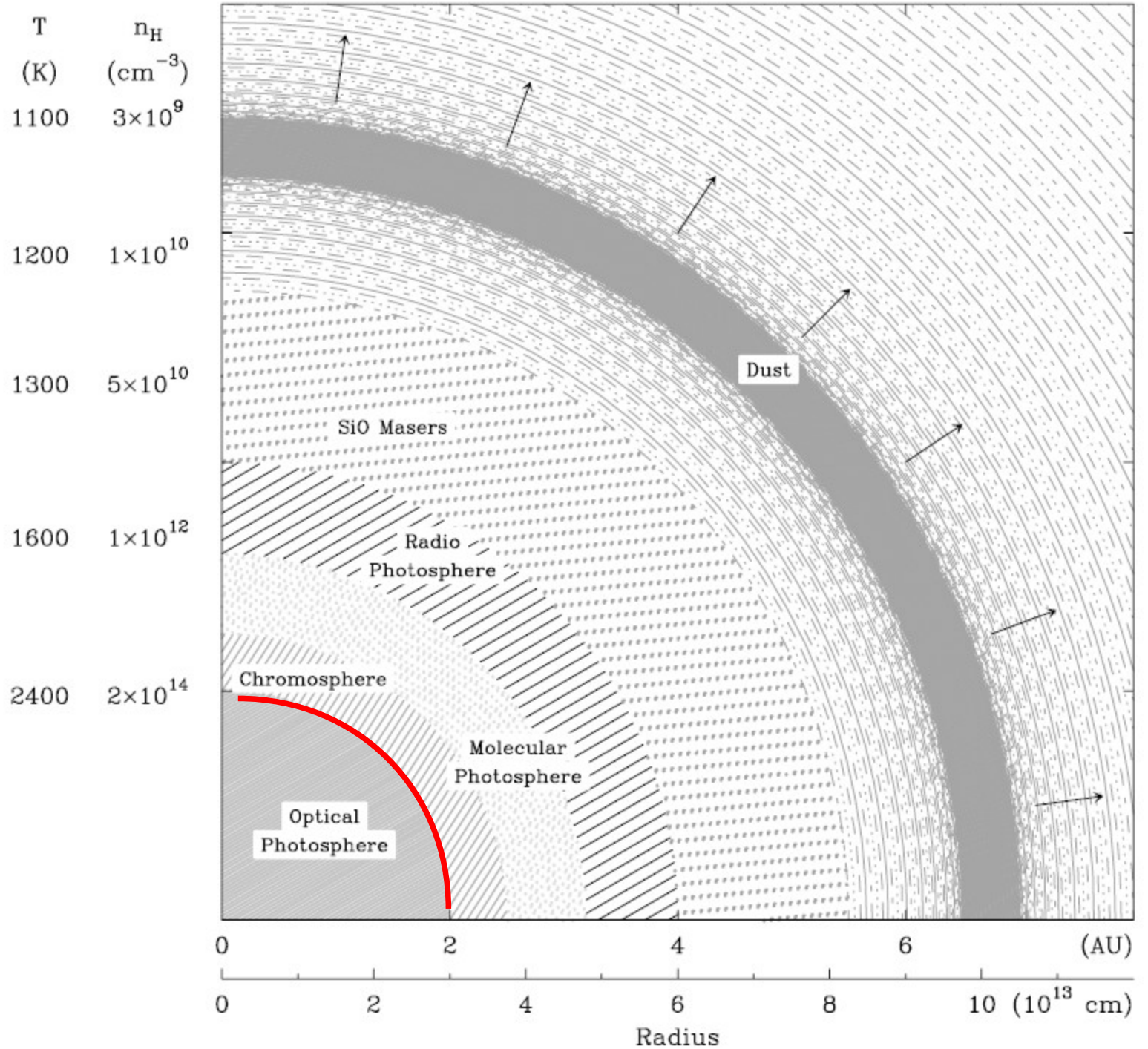




**Extended atmosphere**

**Strong molecular presence**

**Atmospheric dynamics with shocks**



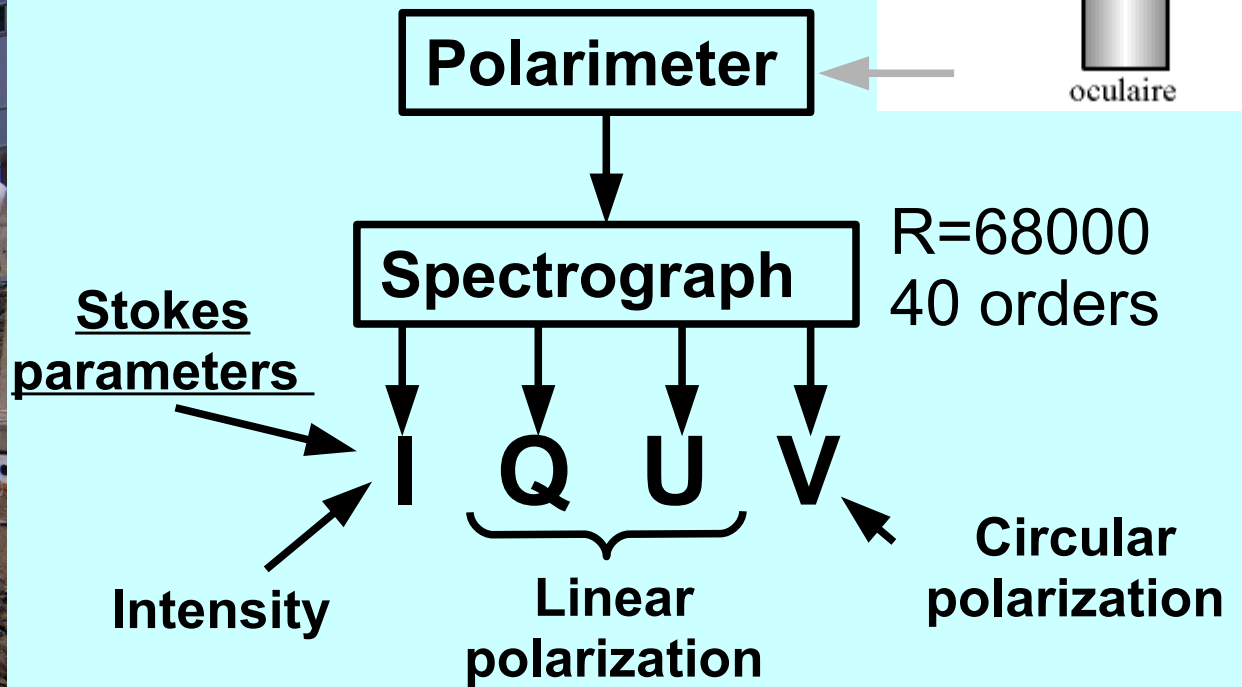
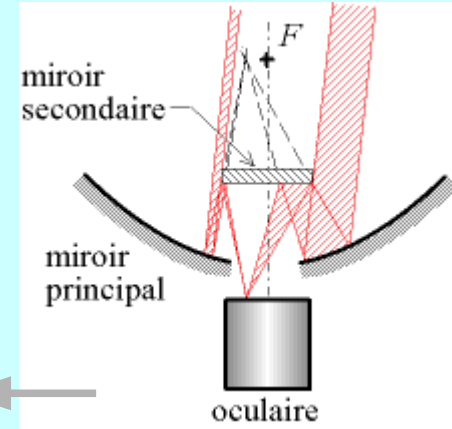
**Reid & Menten 1997**

# **Spectropolarimetric Survey of Mira Stars**

# The NARVAL spectropolarimeter



**Bernard Lyot Telescope  
(Cassegrain type)**

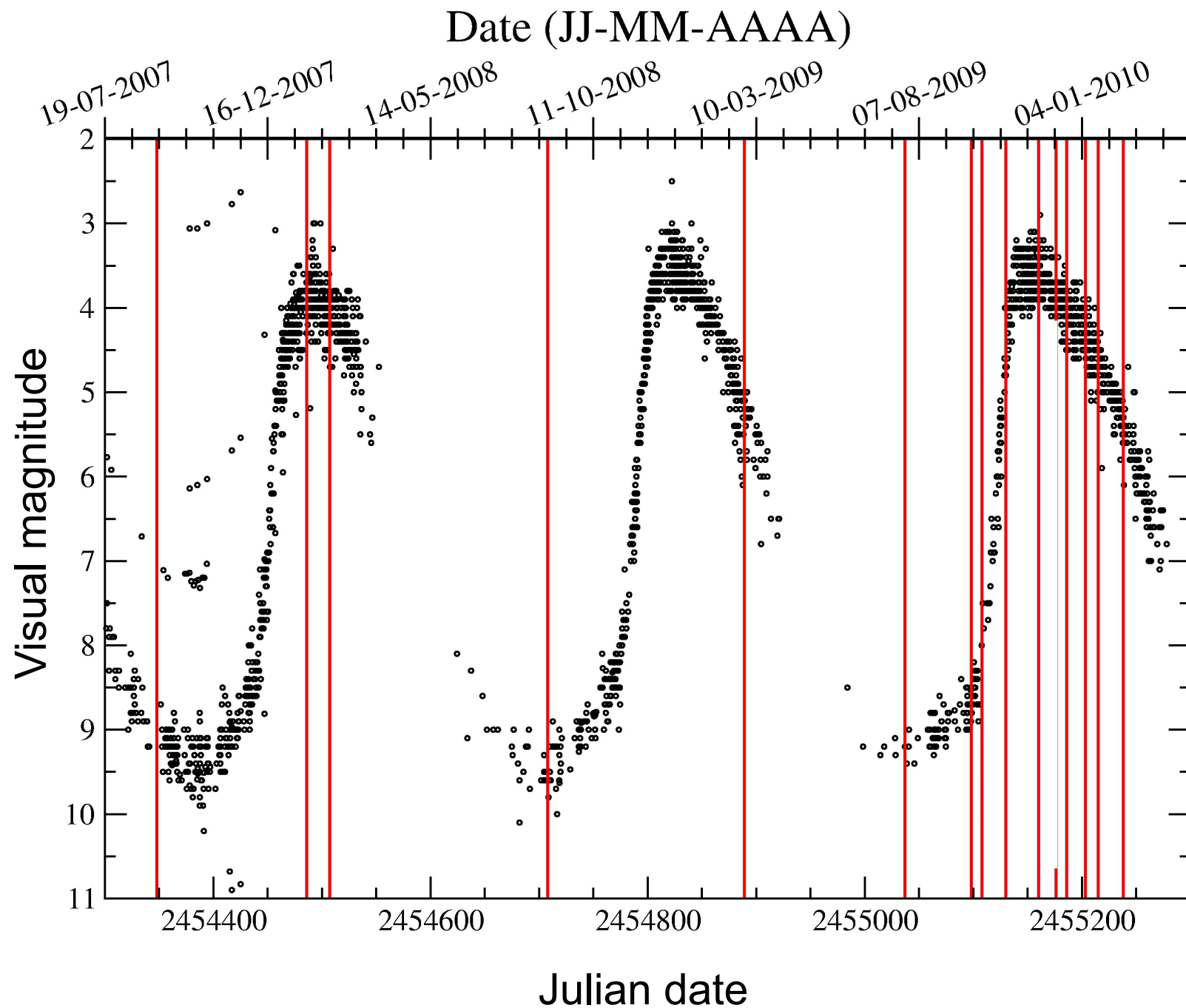


$$Q = I_{0^\circ} - I_{90^\circ}$$

$$U = I_{45^\circ} - I_{135^\circ}$$

$$V = I_{\text{circ left}} - I_{\text{circ right}}$$

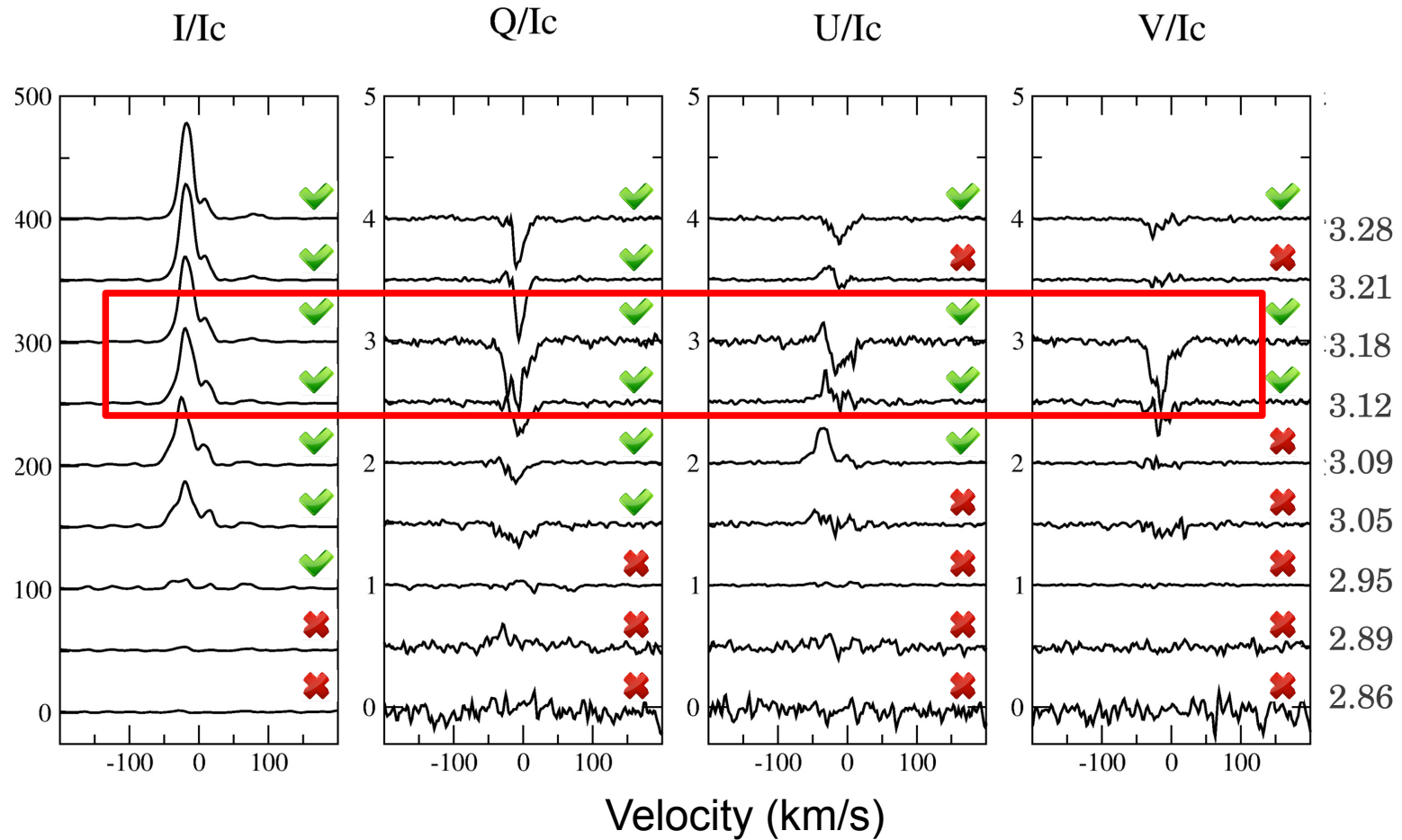
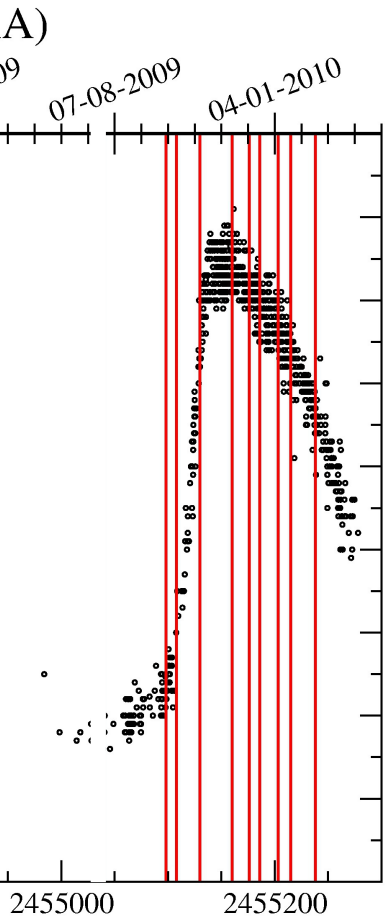




**Light curve : July 2007 to February 2010 (AAVSO)**

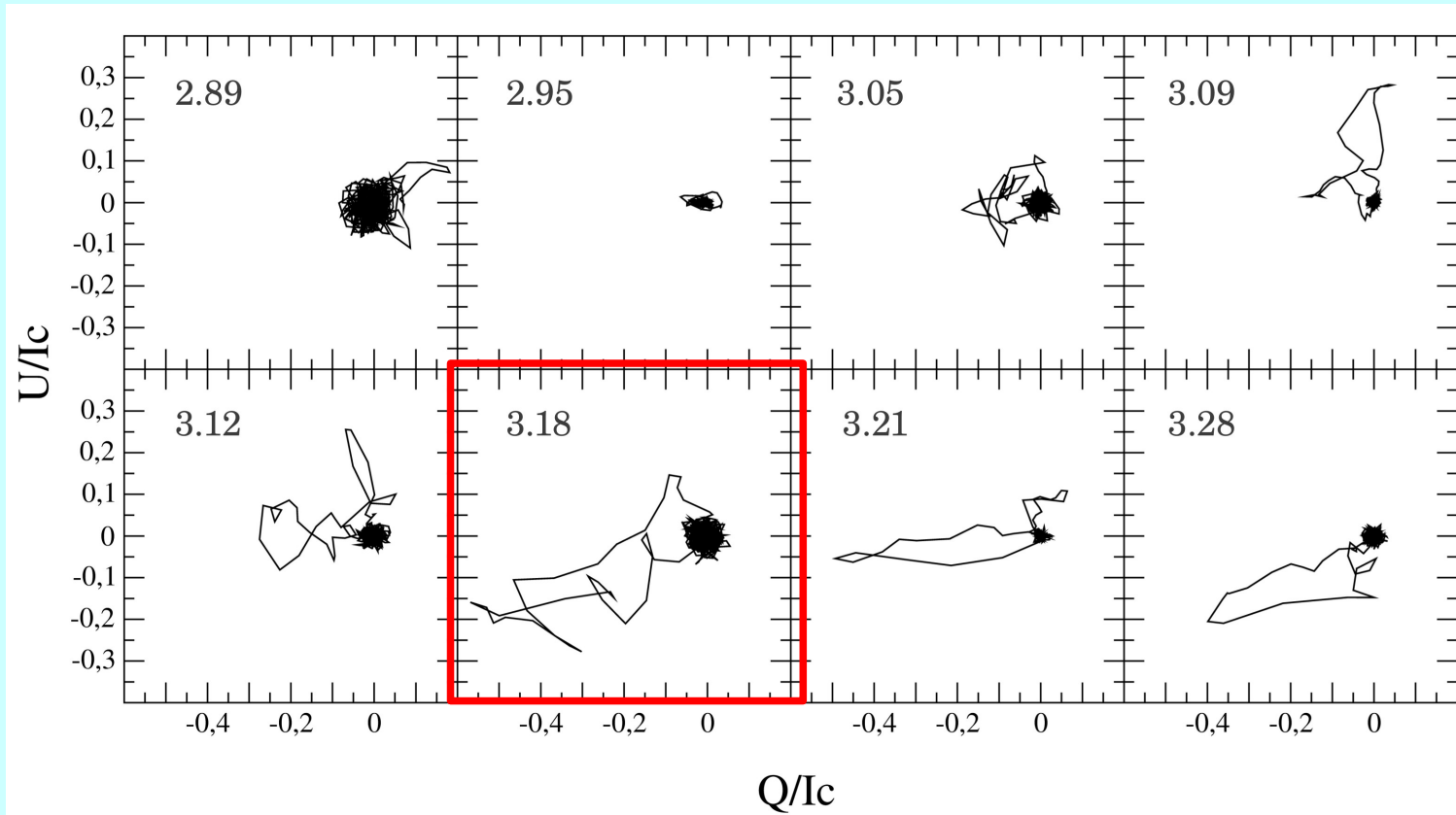
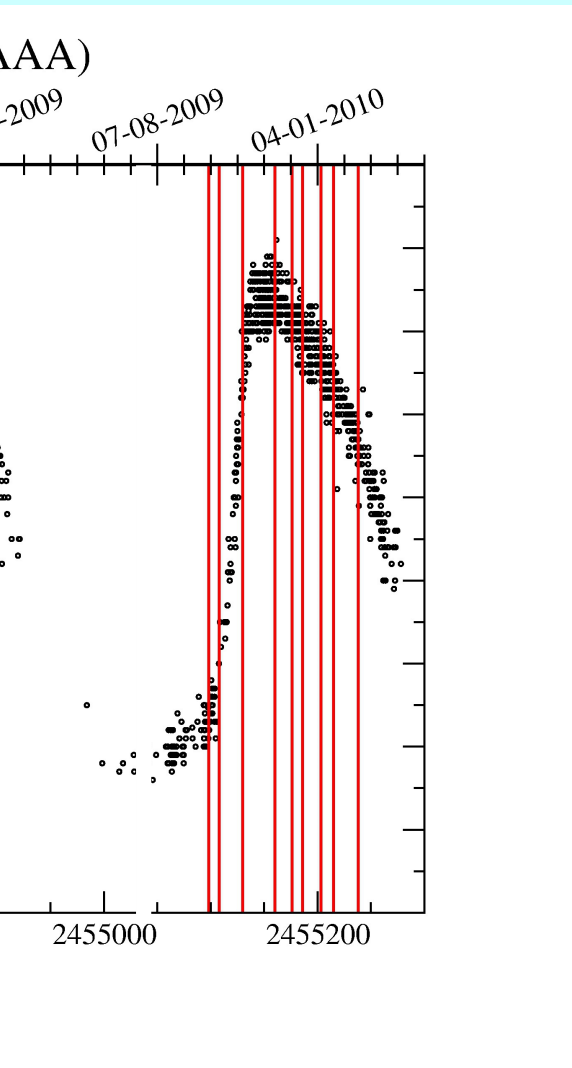
# 3rd cycle : H $\delta$

Detection :  $3^*\sigma$  



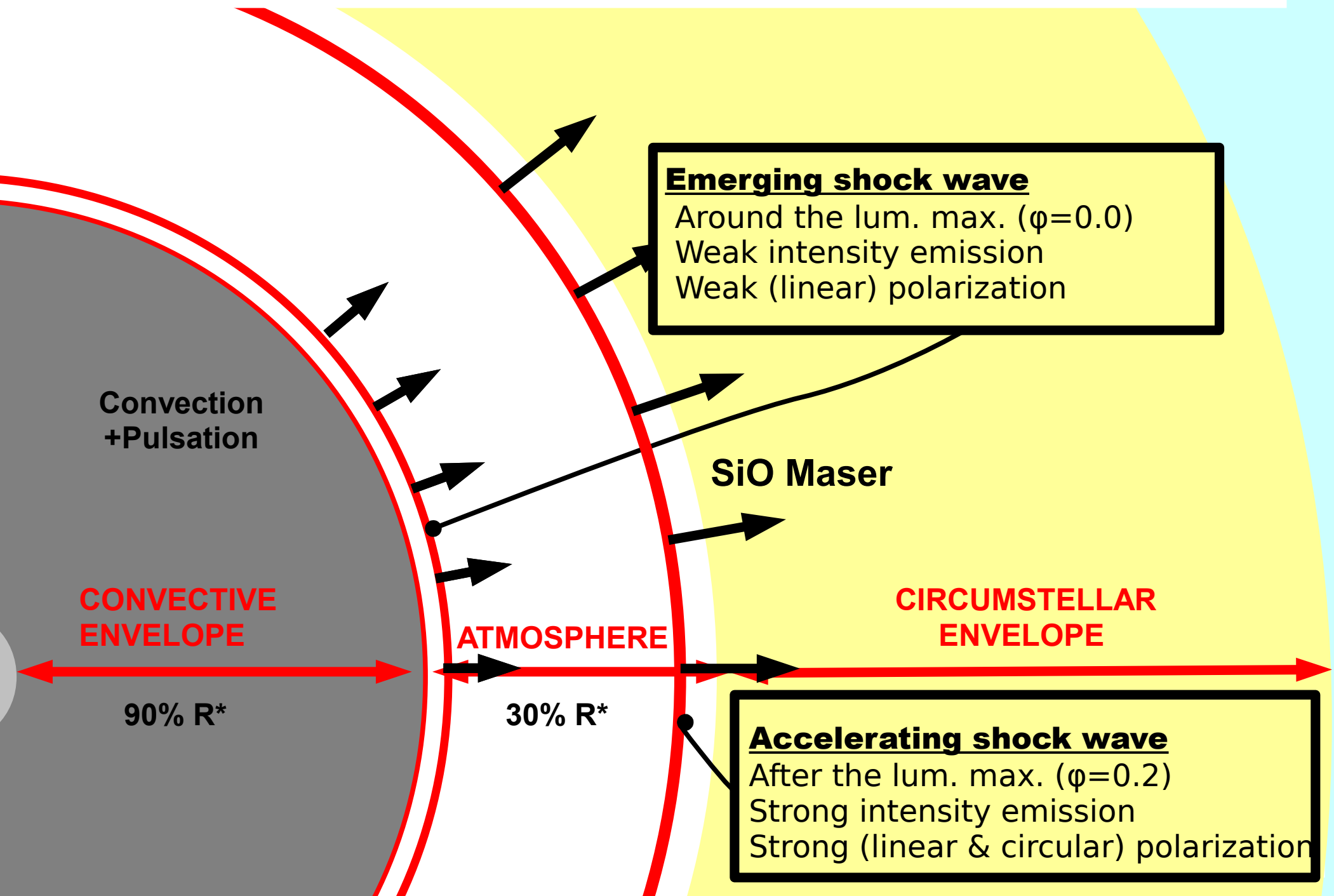
**Fabas et al. 2011**

# 3rd cycle : H $\delta$



**Fabas et al. 2011**

# Link polarization-shock wave





1 – PhD work: we realize that there is a link between shock/atm.dyn. and the polarization

2 – Next step: how solar physics can help: influence of atm.dyn. and MF on the linear polarization, Hanle effect, results in Fabas et al. 2014

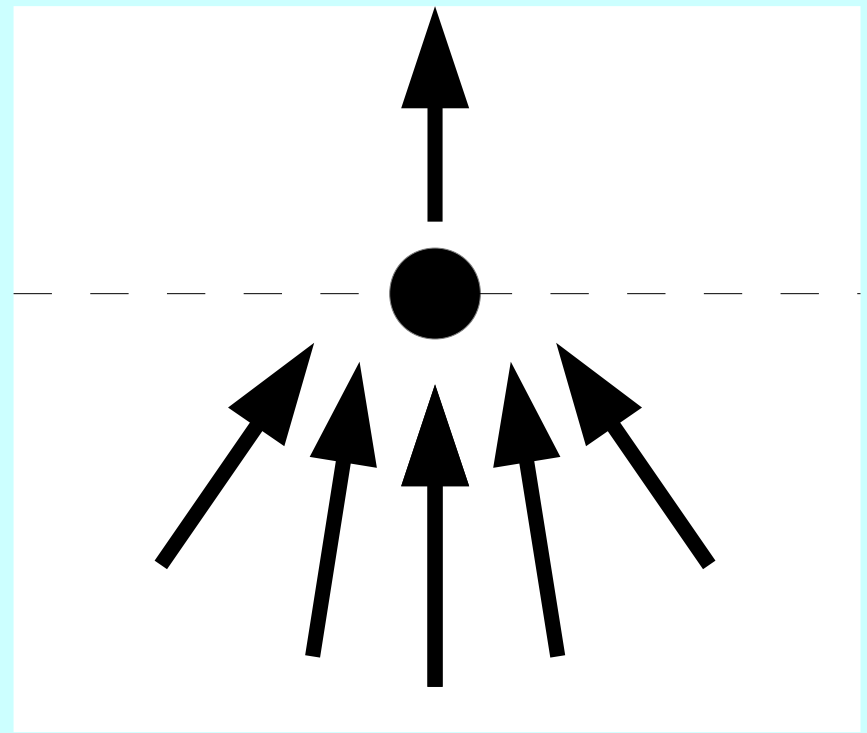
3 – Detection of MF in Mira stars that are related to shocks Lebre et al 2014

# **Learning from Solar Spectropolarimetry**

## Anisotropic illumination

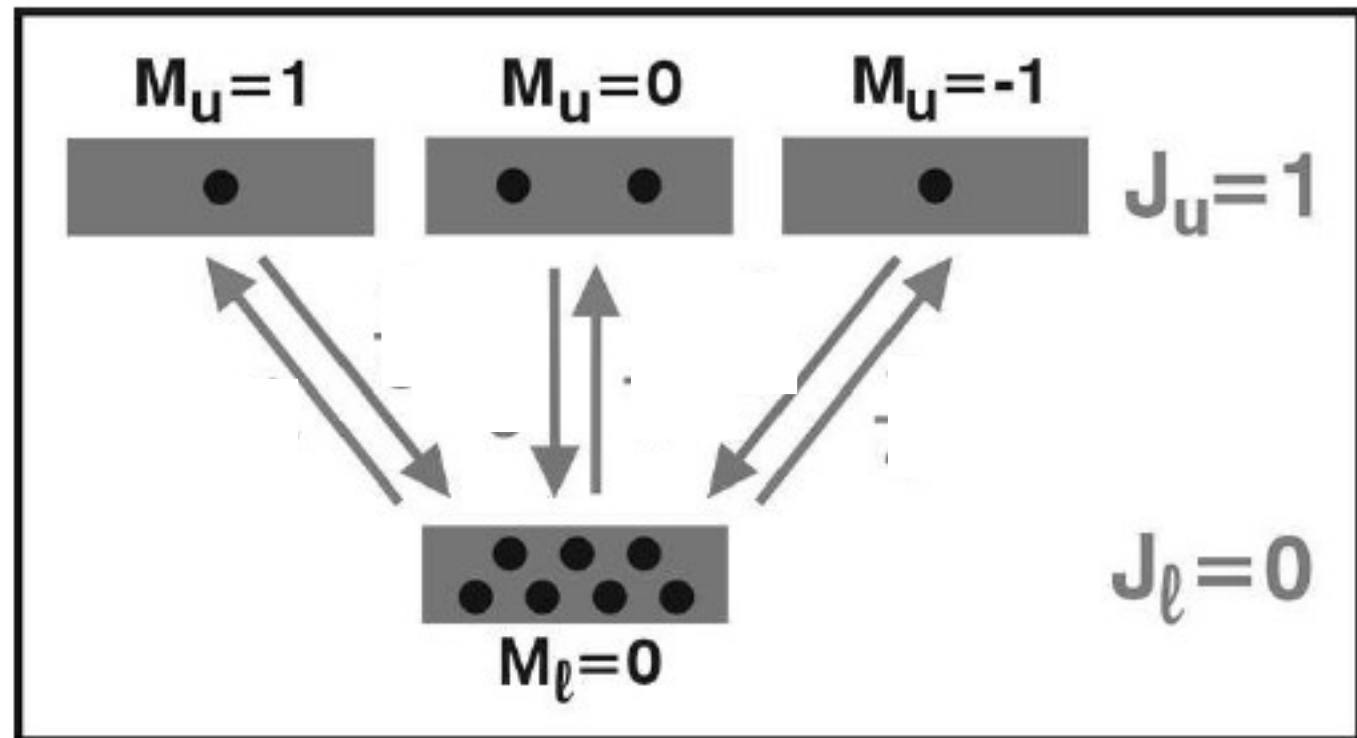
→ imbalance in the sublevels of one given transition

→ **linear polarization**



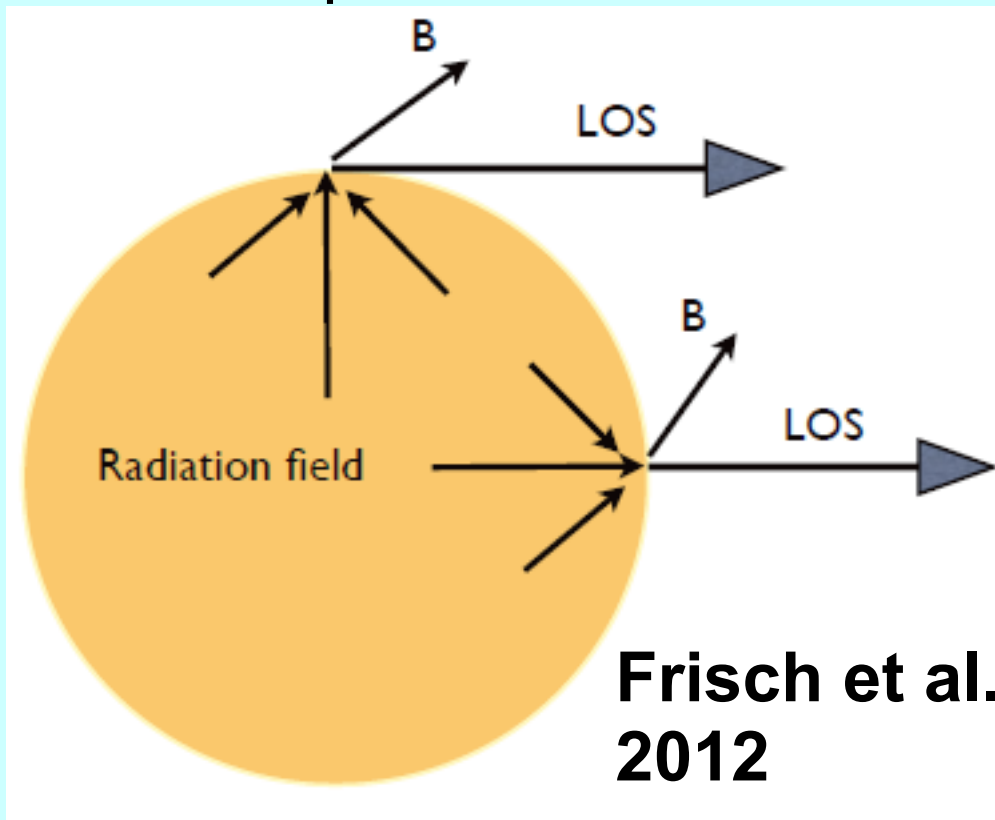
## Hanle effect:

A magnetic field can modify these populations and thus the polarization in the spectral lines.

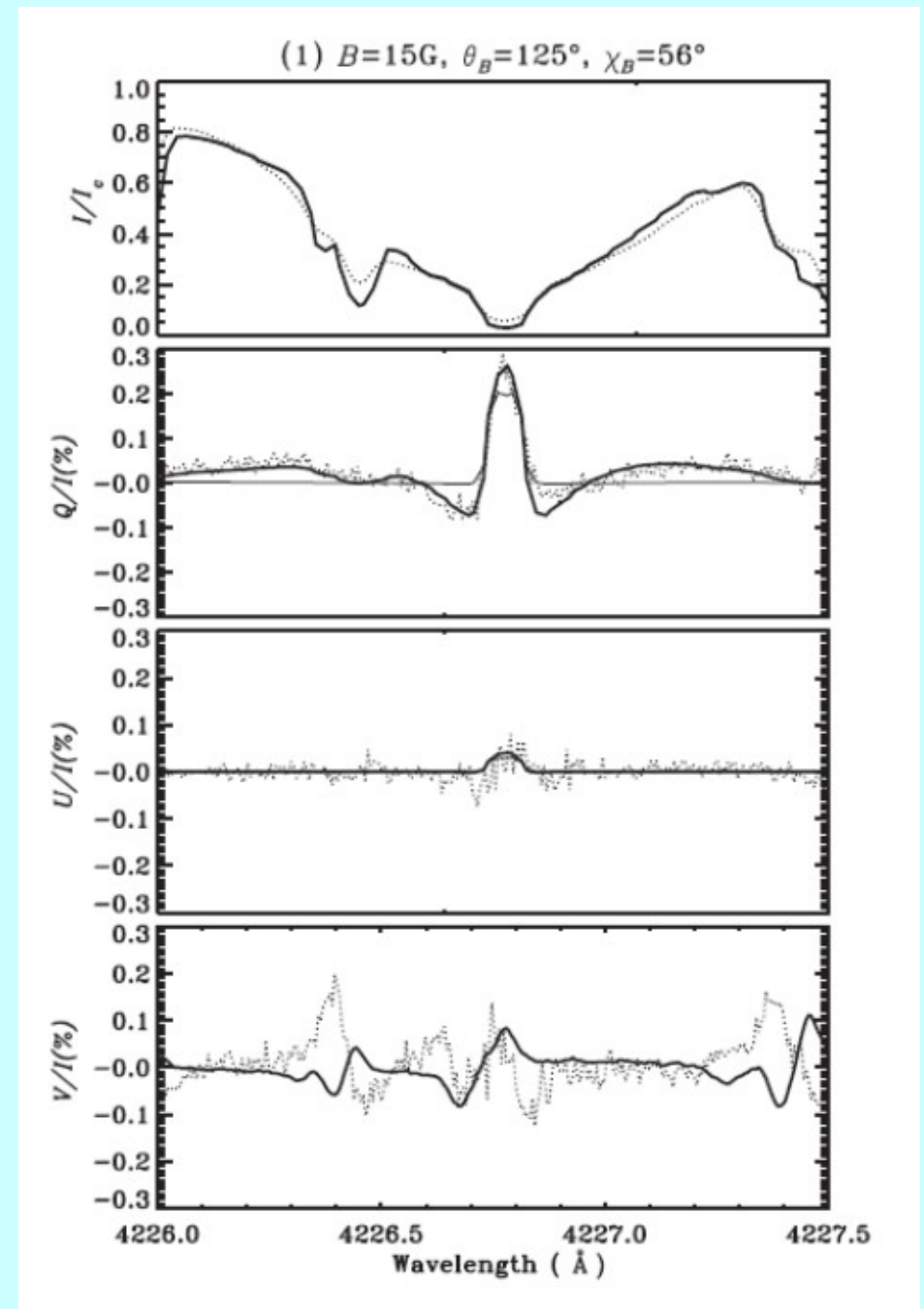


# The case of the CaI 4227Å line

Used to study the solar  
chromosphere



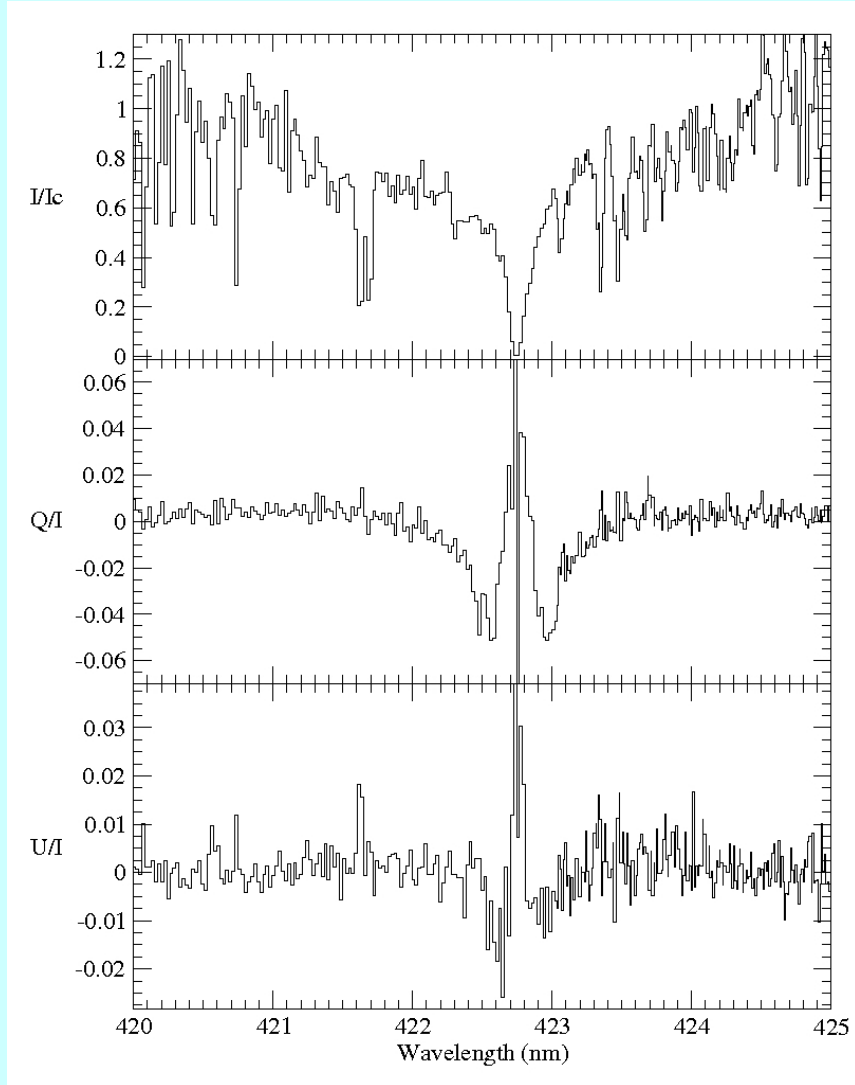
Scattering + Hanle effect



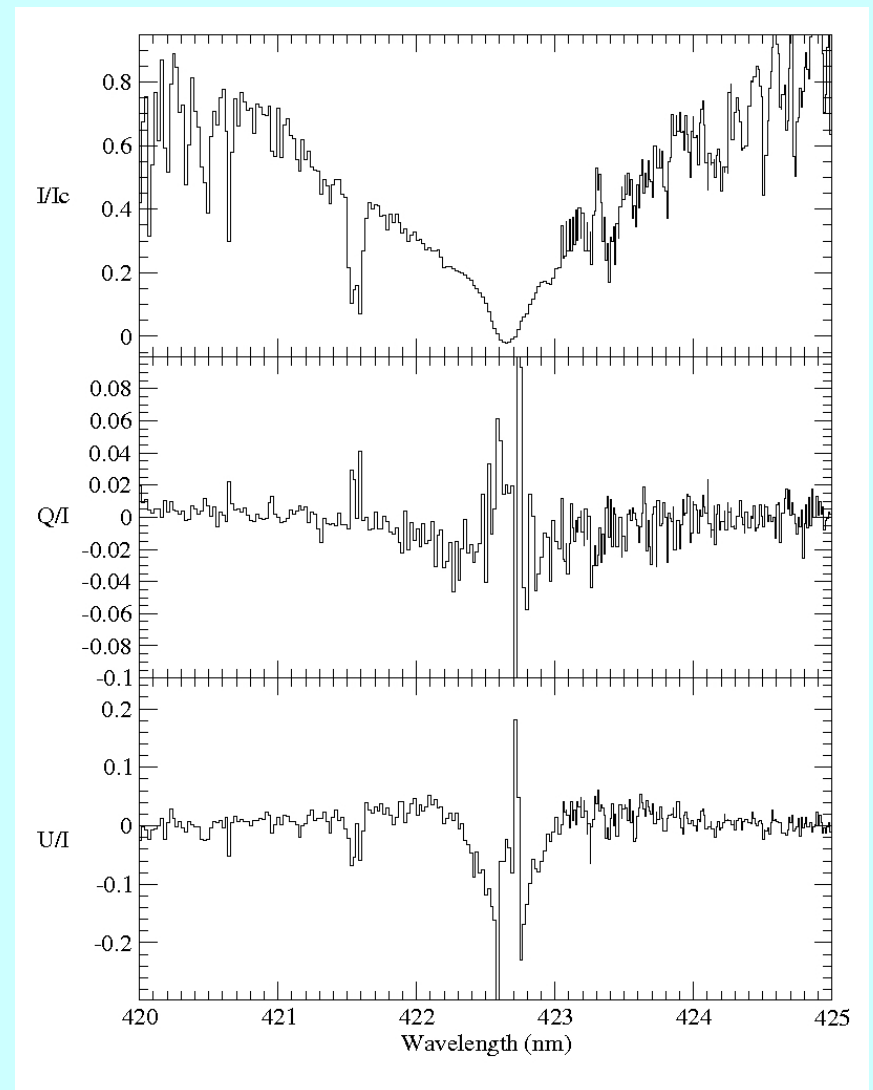
Anusha et al. 2011



# The CaI 4227Å line in Mira stars



Omicron Ceti ( $\phi=1.00$ )



Chi Cygni ( $\phi=0.94$ )

**Fabas et al. 2014 (to be published)**

## Solar case

Scattering region not extended:

- negligible curvature
- low anisotropy

→ linear polarization rate:  
~0.1%

Thousands of small convective cells

## Mira case

Scattering region very extended:

- important curvature
- high anisotropy

→ linear polarization rate: 1 to 10 %

Few giant convective cells (Hoefner et Freytag 2008) → global non-sphericity, non-cancellation of linear polarization

# First detection of a surface magnetic field in the Mira star chi Cygni

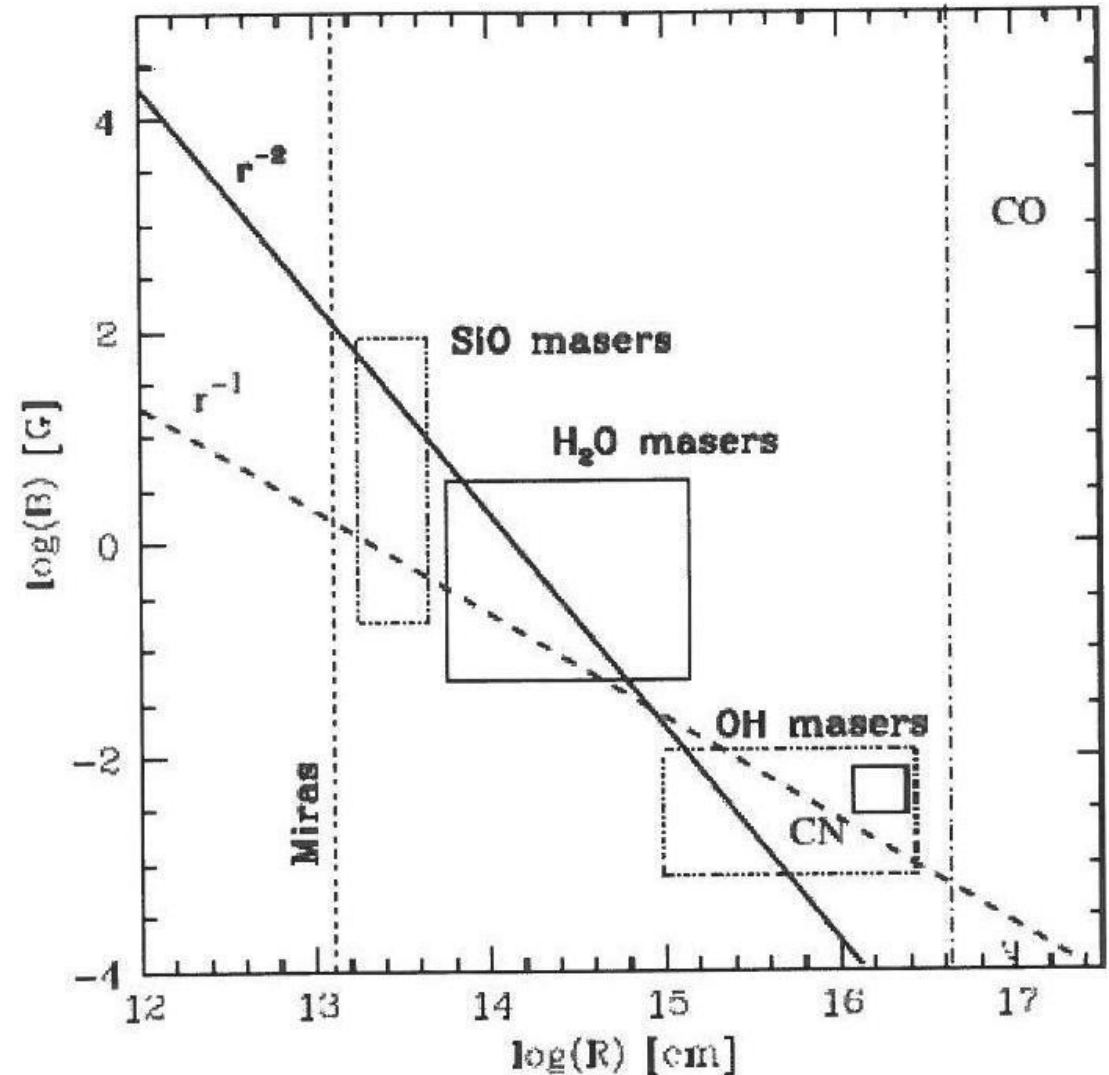
Spectral type:

S6 to S10

Pulsating period:

400 days

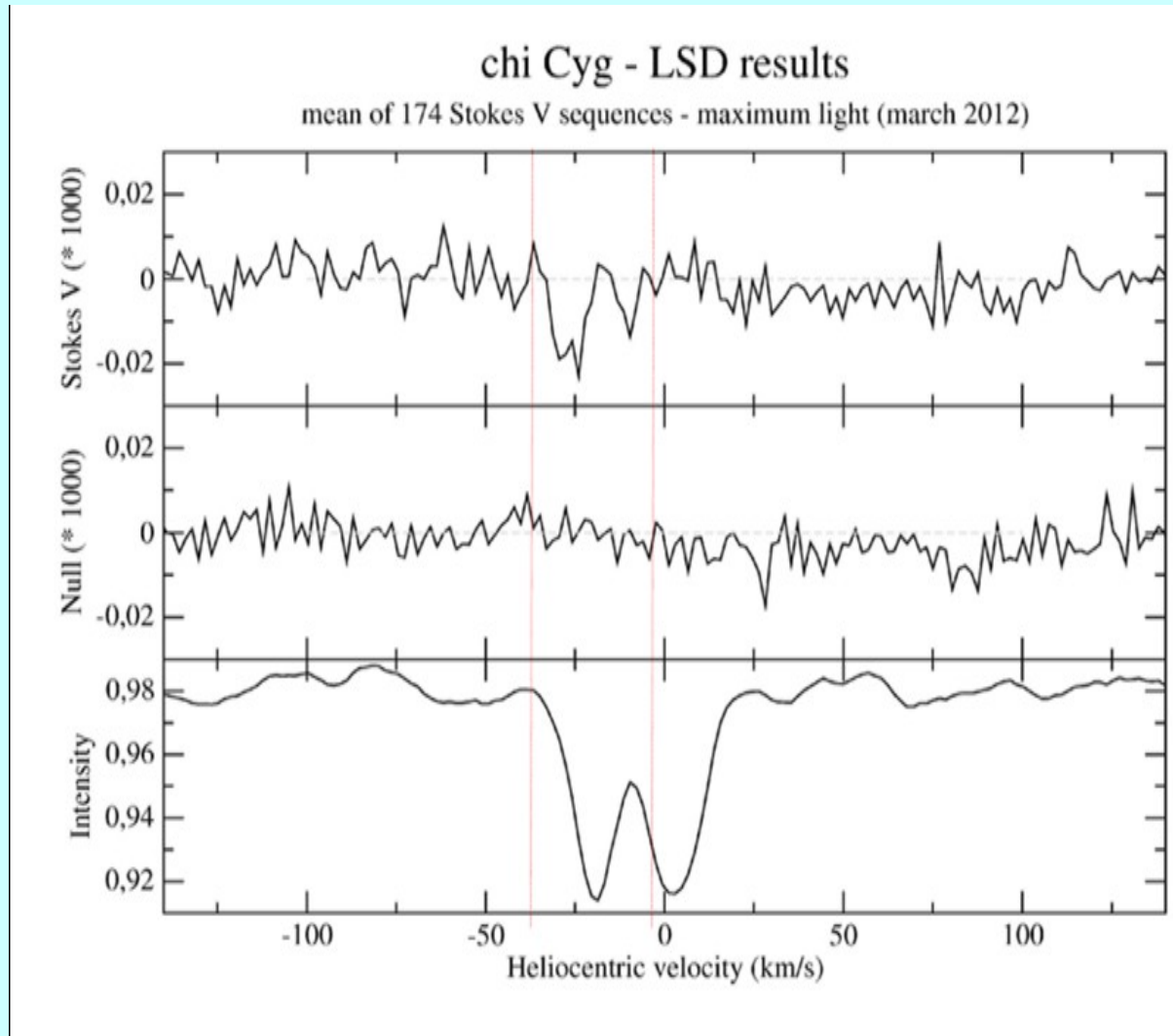
So far, magnetic field measured in the circumstellar envelope with masers.



LSD method:  
averaging over  
14,000 atomic  
lines per  
sequence, with  
174 V sequences

$$|B_L|=0.25 \text{ G}$$

Previous detection  
in the CSE of chi  
Cyg by  
Herpin et al. 2006



**Lèbre et al. 2014**



- ★ **Link with Atmospheric Dynamics**
- ★ **Presence of Surface Magnetic Field**
- ★ **Potential of Linear Polarization  
to be Exploited**
- ★ **Molecular lines to be considered**
- ★ **Complementarity with Interferometry**