Inhomogeneous eclipses in the UX Ori type stars

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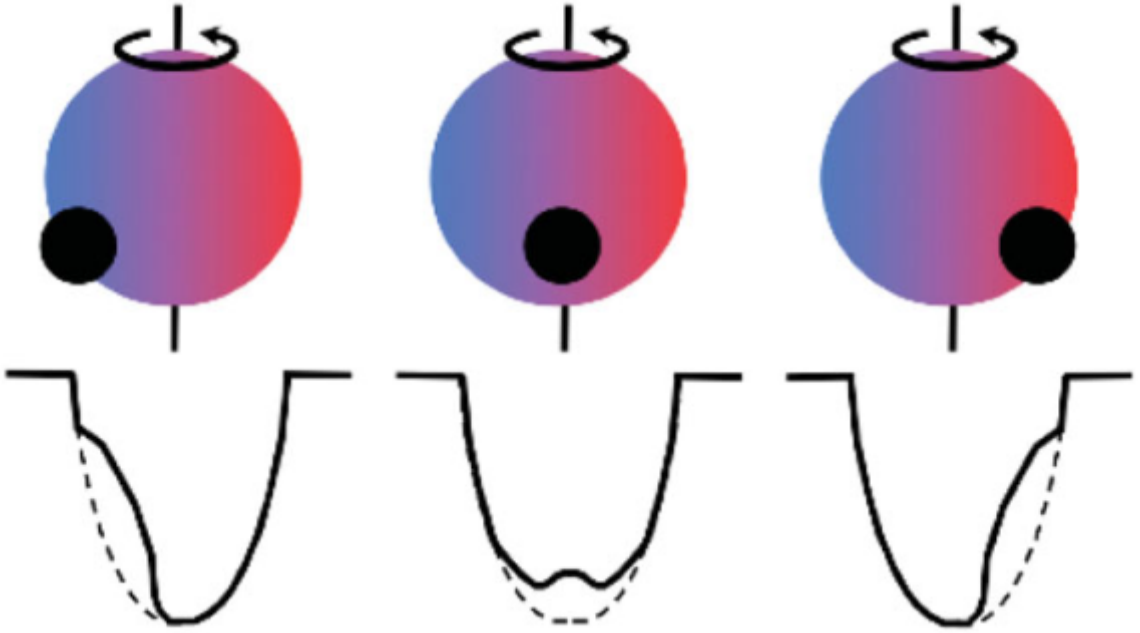
Rossiter-McLaughlin (RM) effect

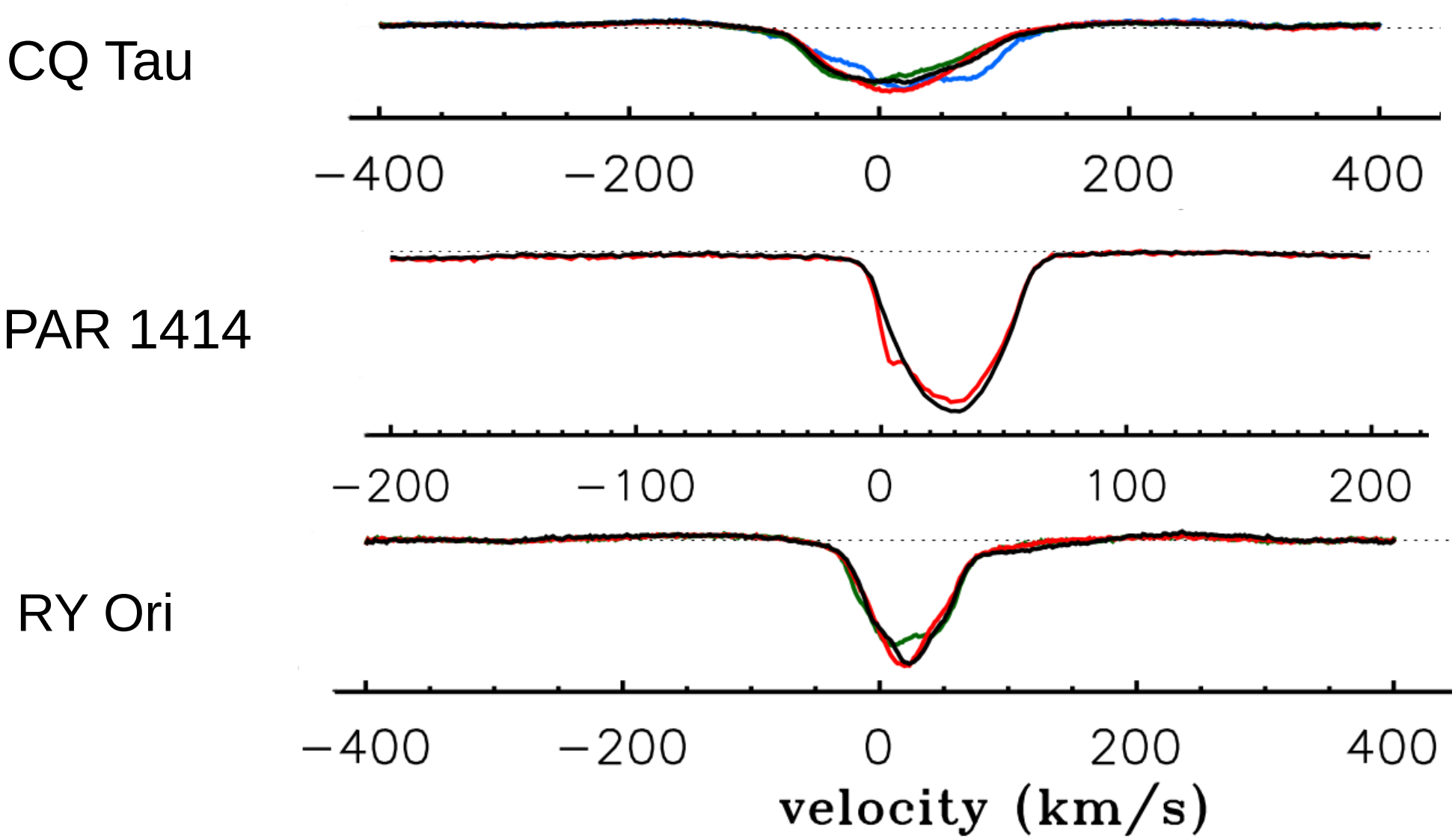
All lines undergo the same kind of the distortion
(up to the variations of the limb darkening law in different lines)



J. Winn, 2011

UX Ori: V. Grinin, I. Potravnov, 2013 for RZ Psc

Variability of LSD profiles

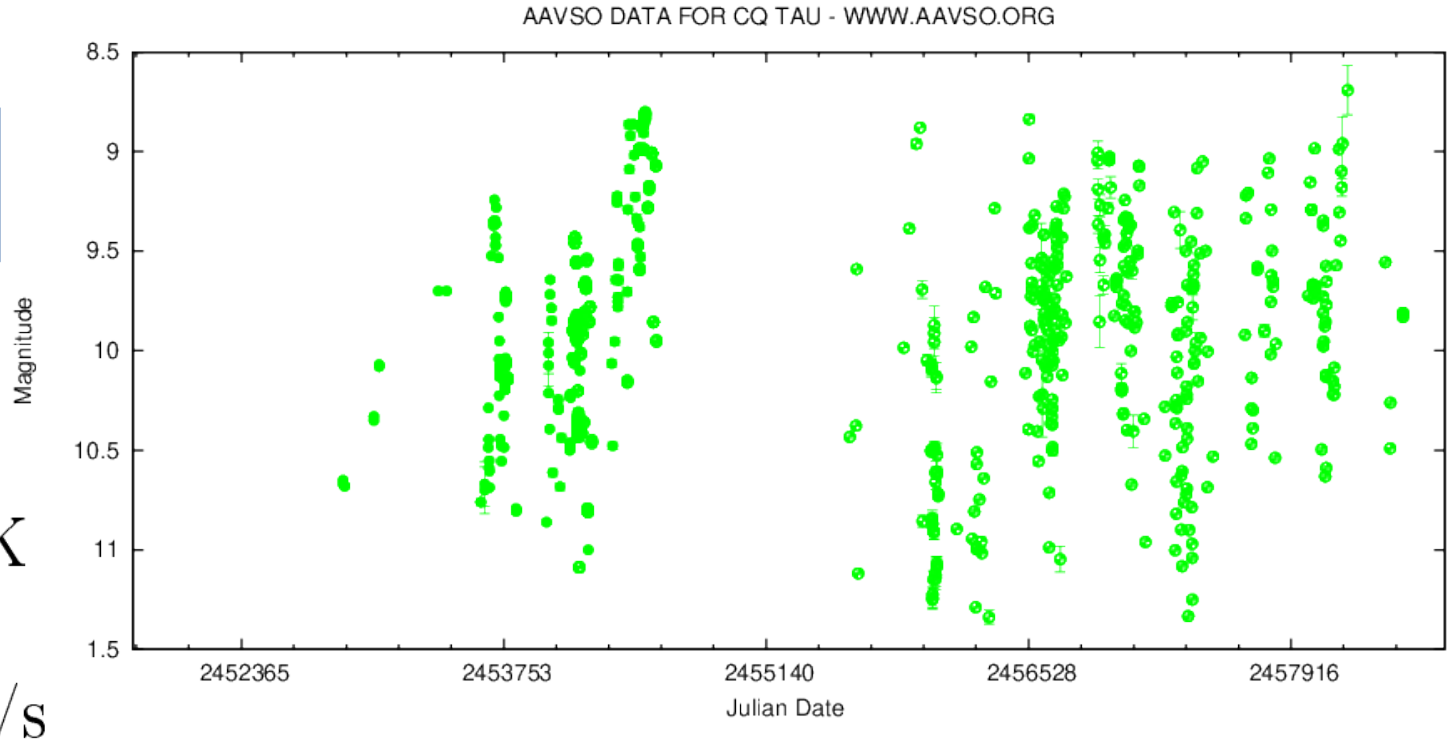


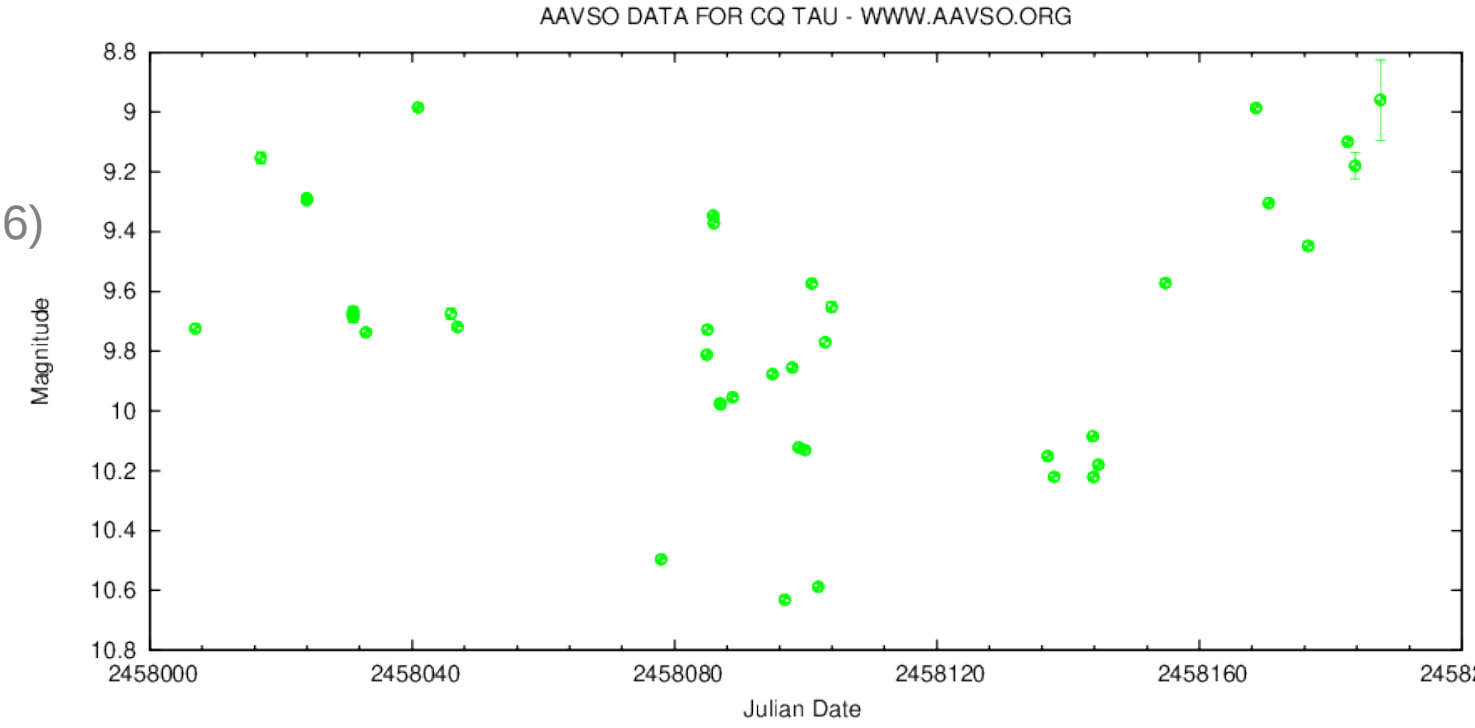
F. Villebrun et al., 2019

CQ Tau

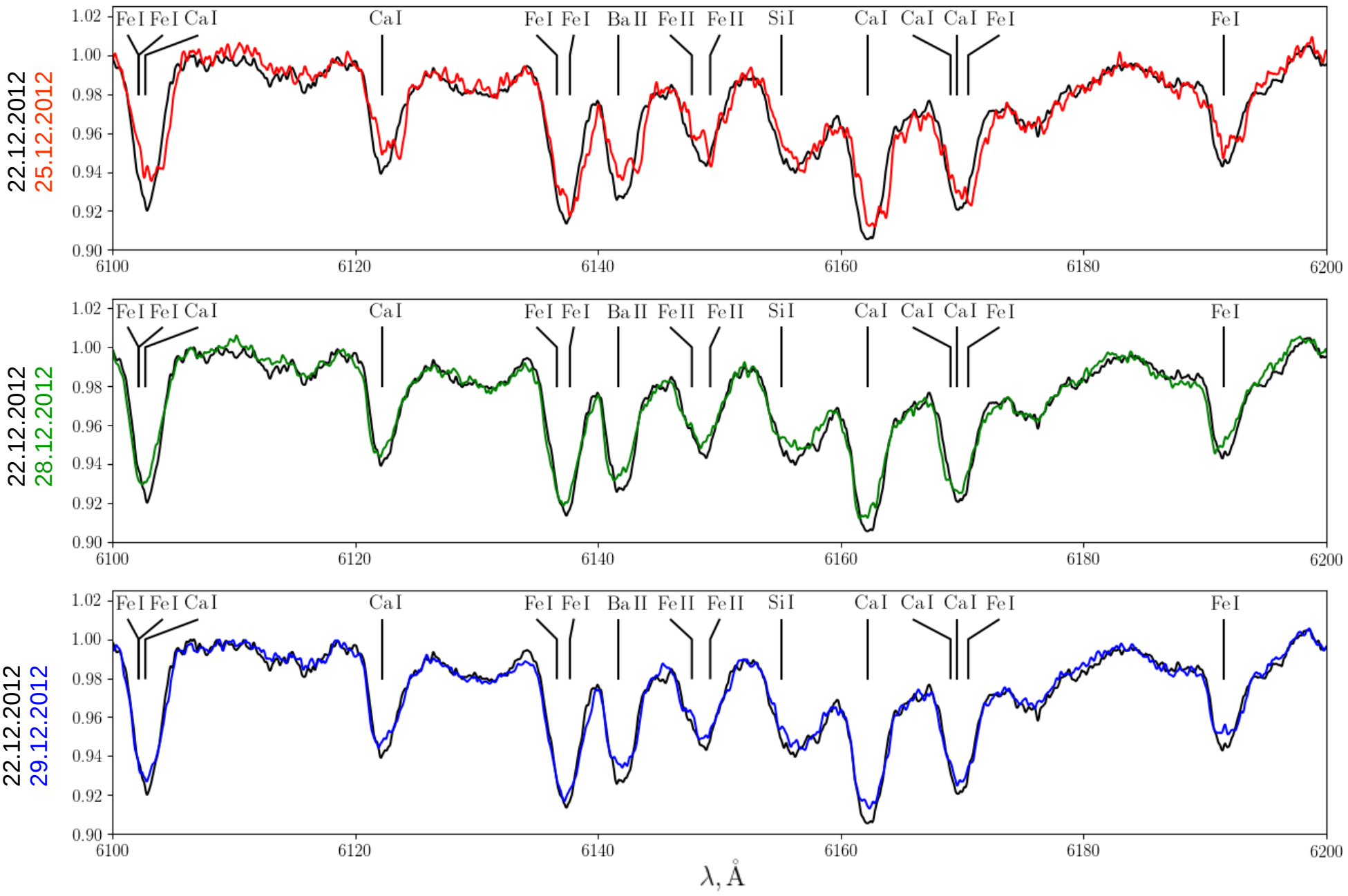
T_{eff}	6850 ± 100 K
$\log g$	4.2 ± 0.2
v_{mic}	3.2 ± 0.9 km/s
v sini	98 km/s
v_{rad}	12.6 km/s

SME (Piskunov, Valenti, 2016)





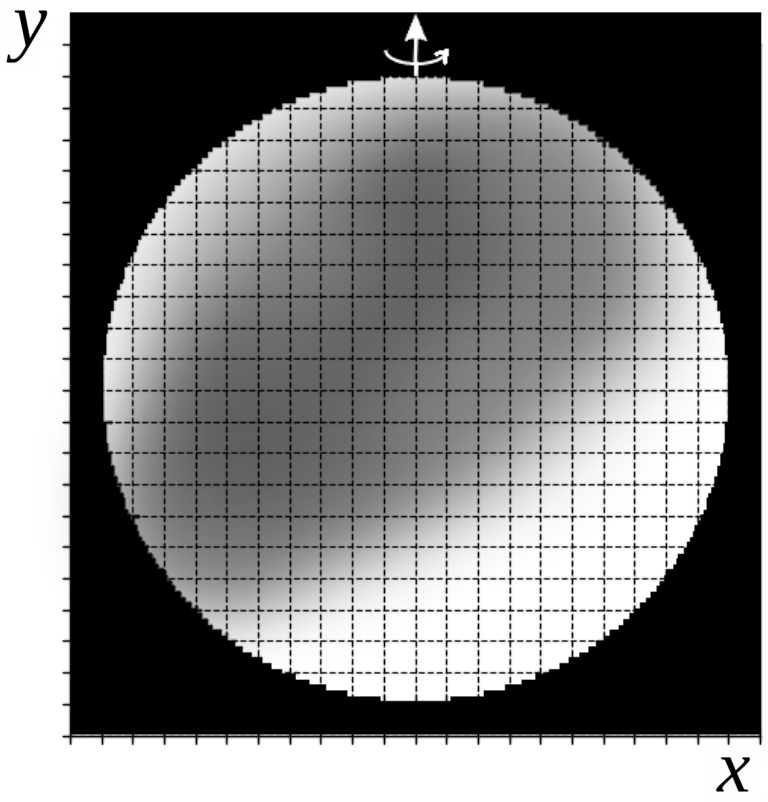
All lines show the same kind of distortion, as expected for RM effect:



ESPaDOnS

Modelling

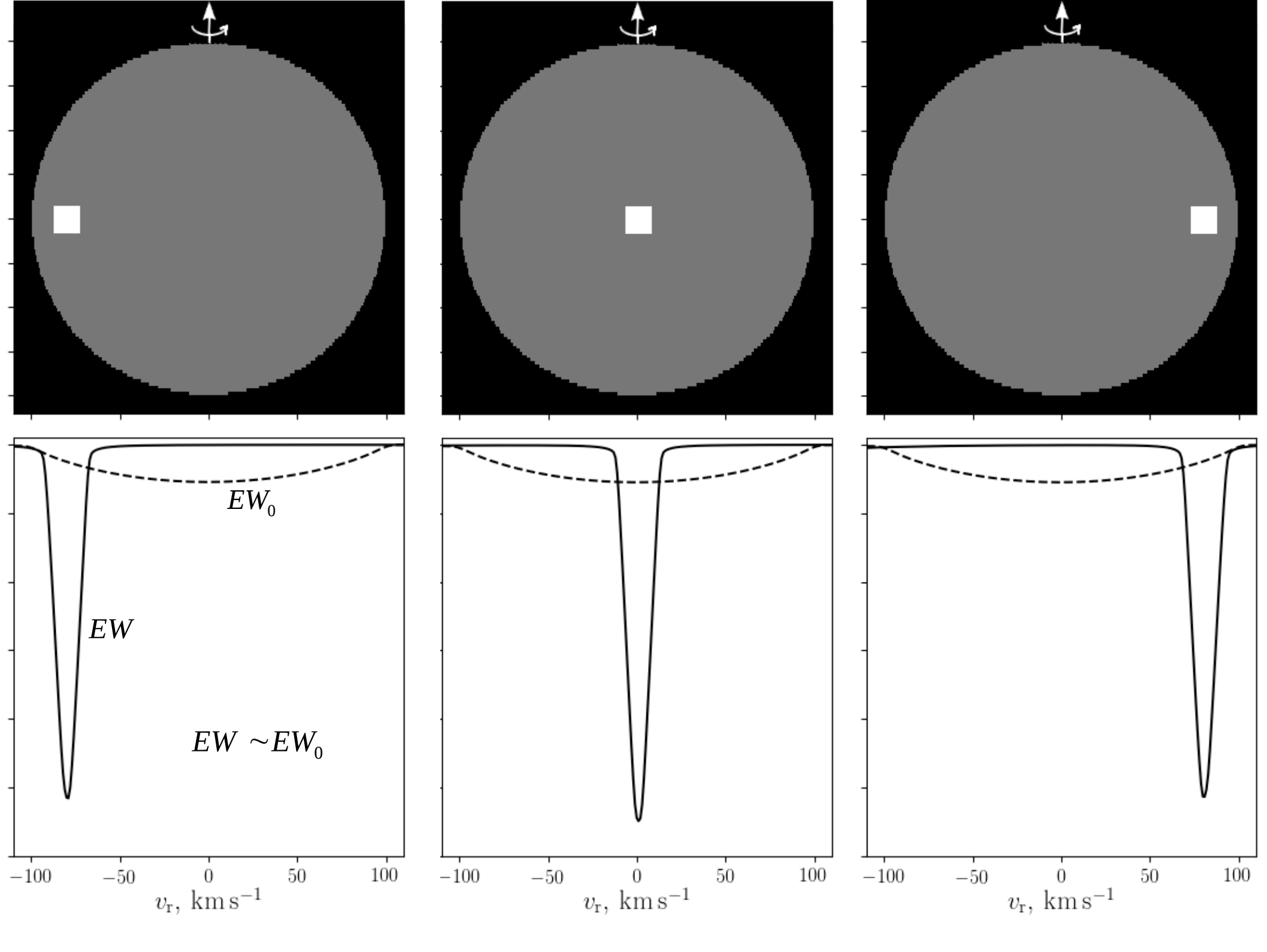
$$f = \frac{\int I\left[\lambda\left(1+\frac{V_{\rm r}(x)}{c}\right),\mu(x,y)\right] e^{-\tau_\lambda(x,y)} dxdy}{\int I_{\rm c}\left[\lambda,\mu(x,y)\right] e^{-\tau_\lambda(x,y)} dxdy}$$

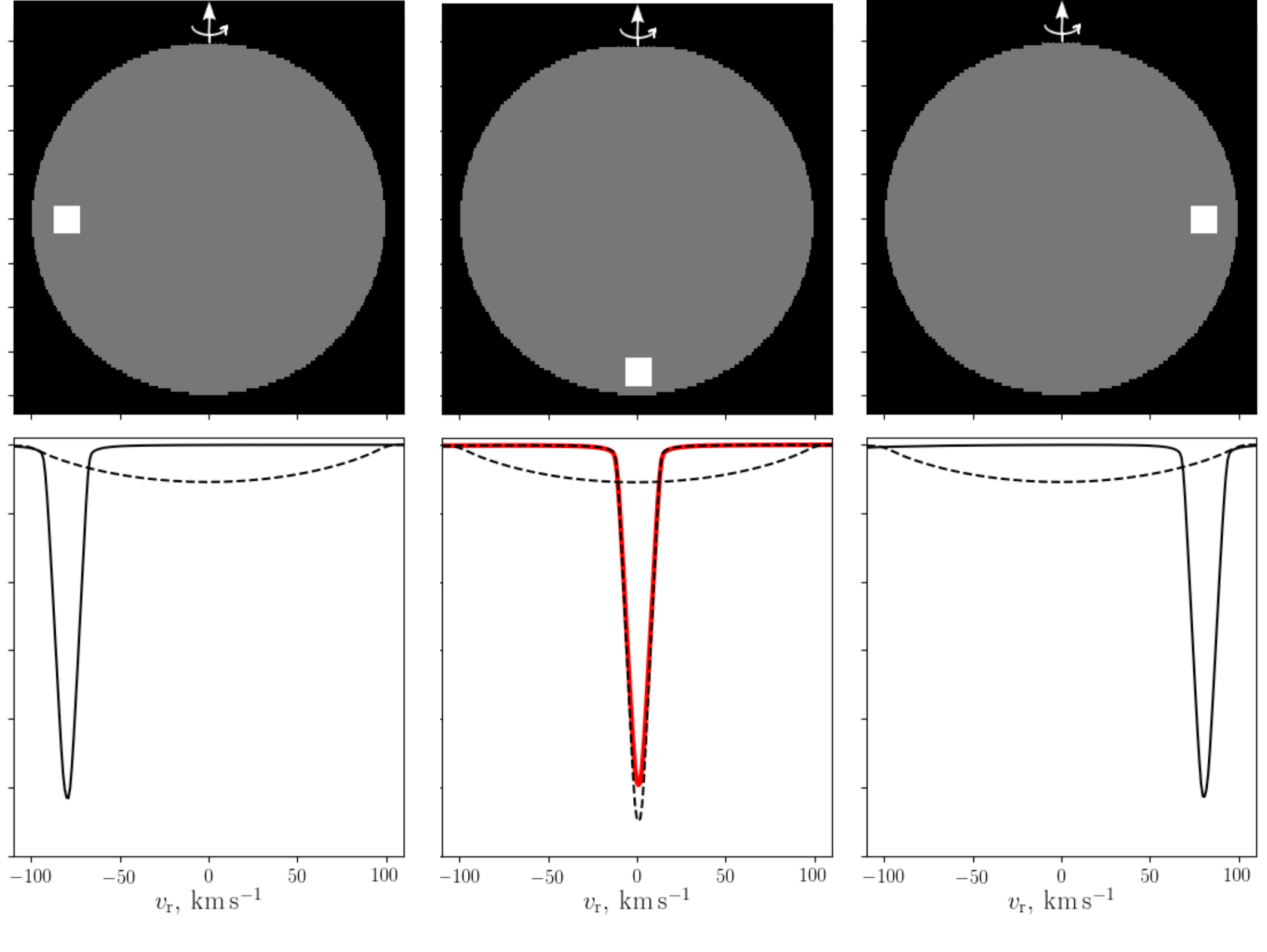


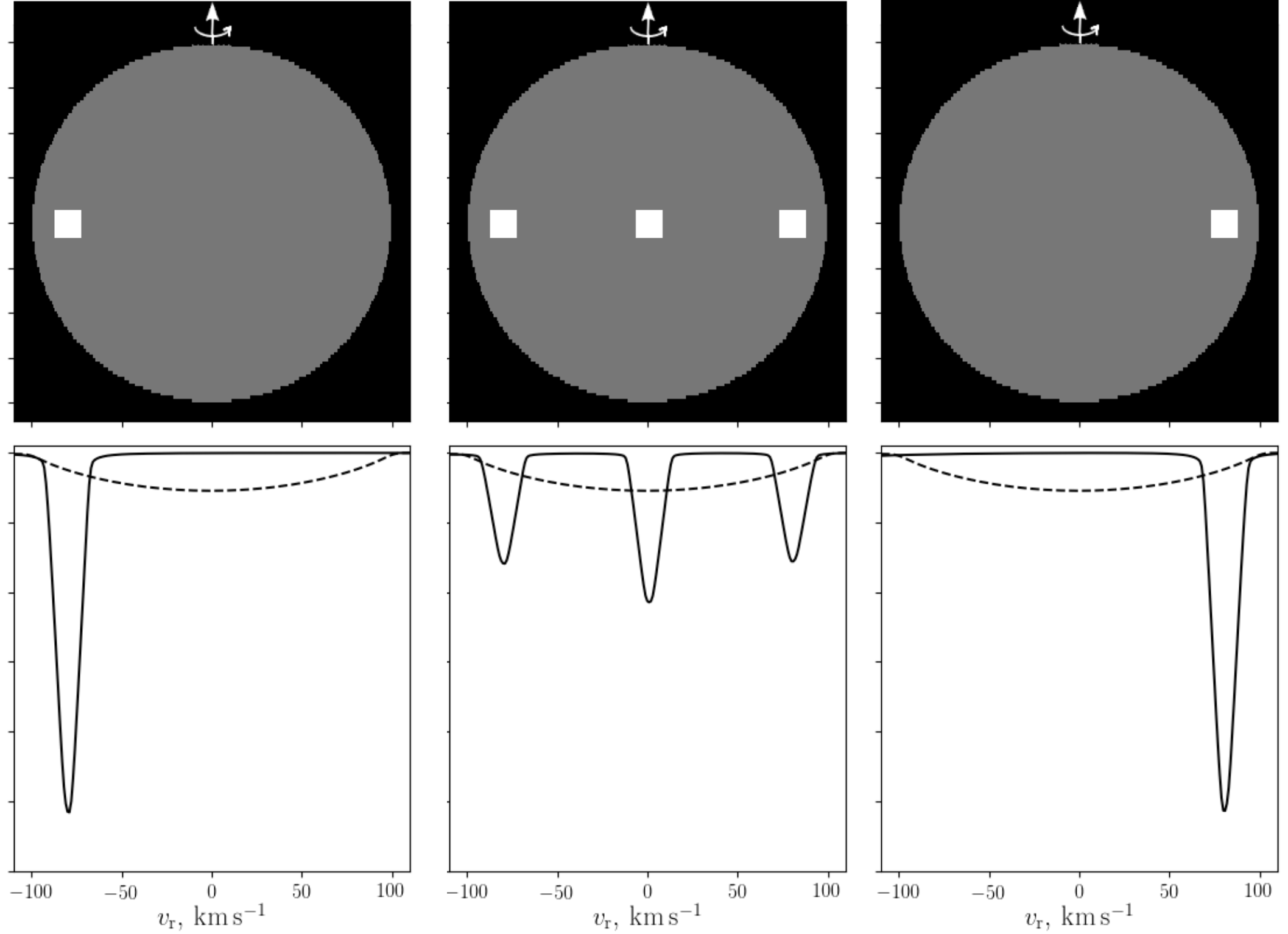
$I(\lambda,\mu)$ – SME

$V_{\rm r} = V_{\rm r}(x)$ – rigid rotation of spherical star

τ_λ – standard extinction law


EW_0
EW
$EW \sim EW_0$
−100
−50
0
50
100
v_r, km s^{-1}


−100
−50
0
50
100
v_r, km s^{-1}
−100
−50
0
50
100
v_r, km s^{-1}
−100
−50
0
50
100
v_r, km s^{-1}


−100
−50
0
50
100
v_r, km s^{-1}
−100
−50
0
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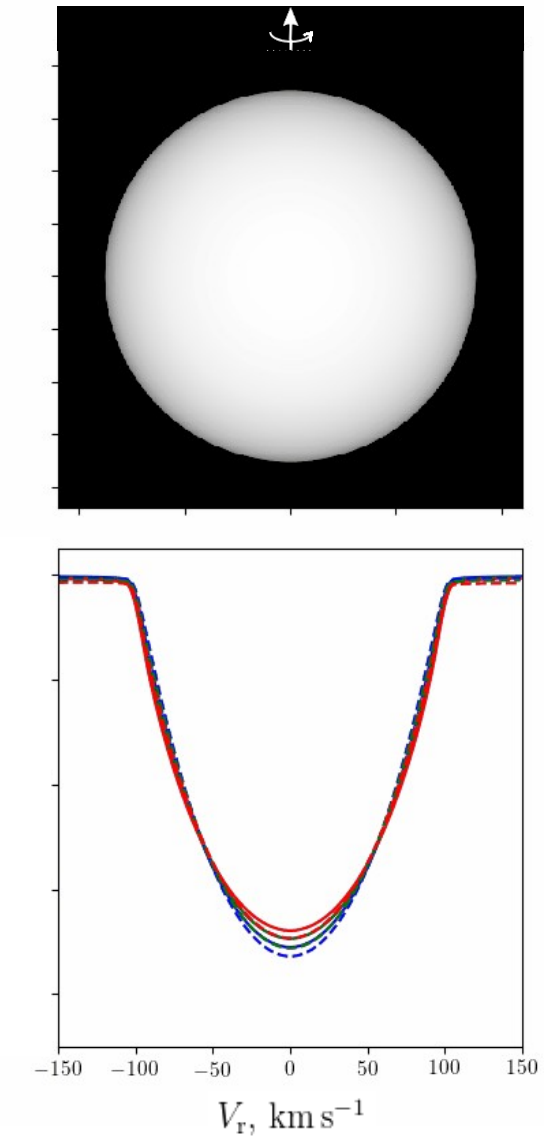
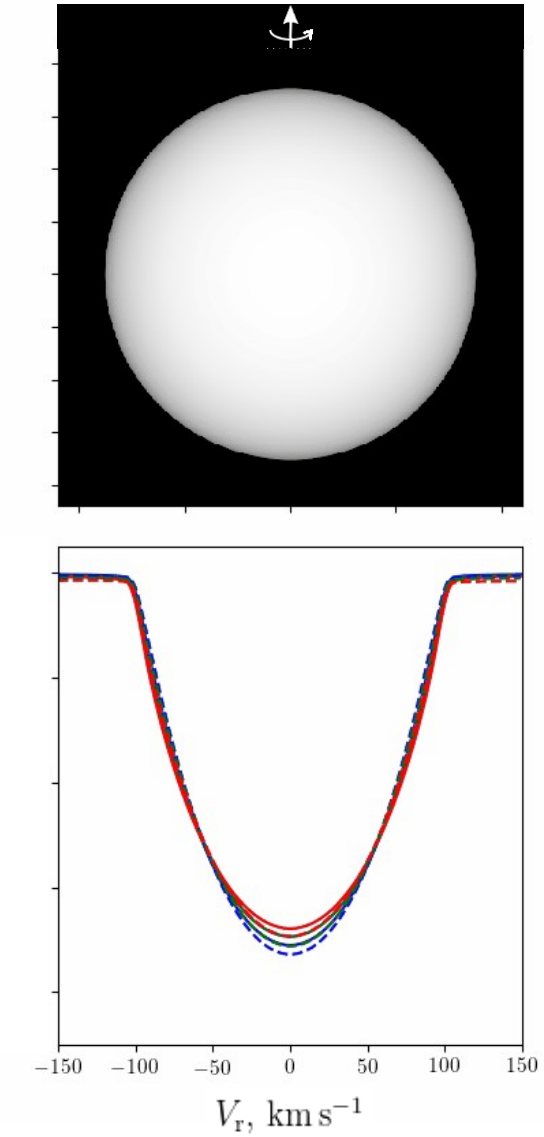
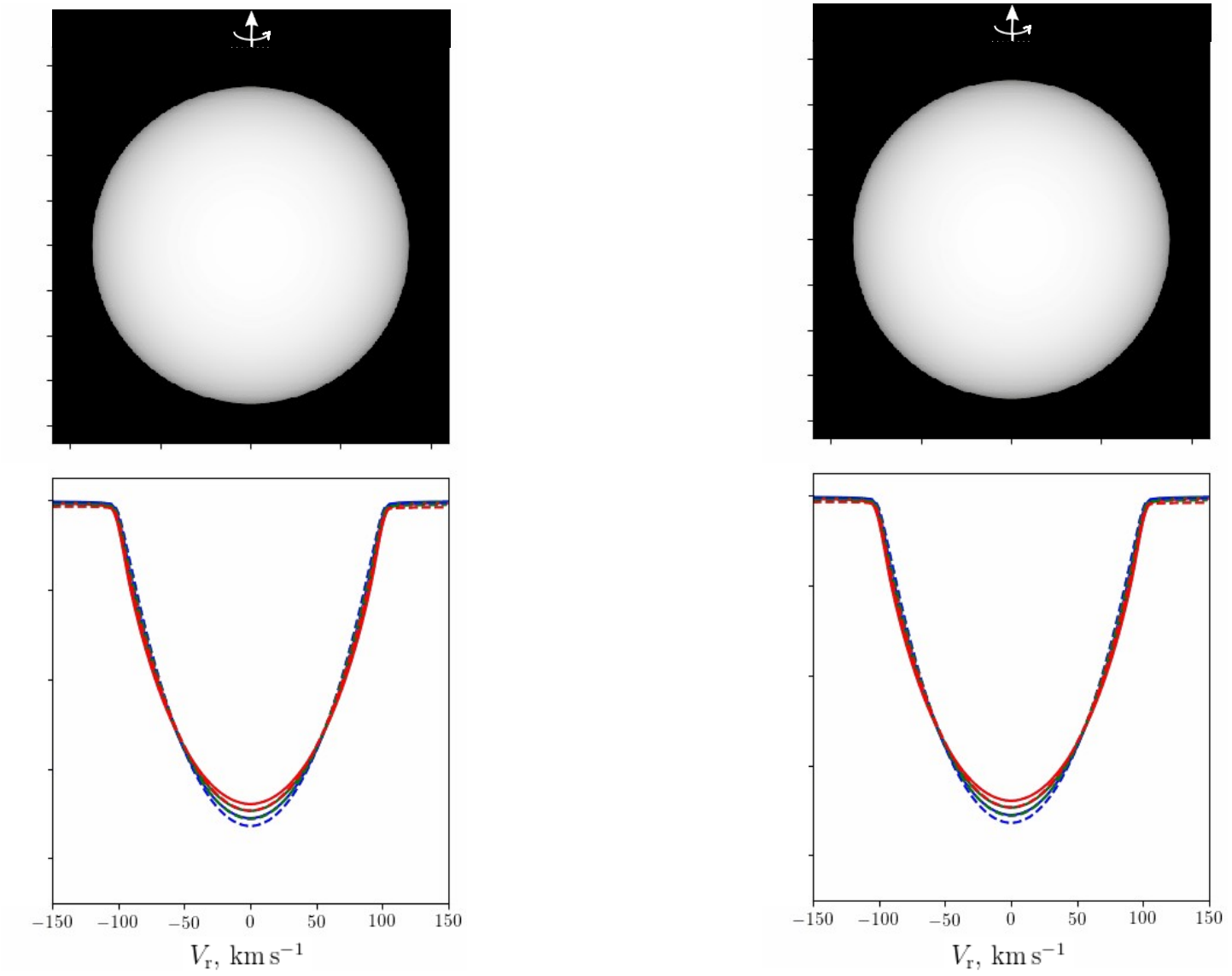
v_r, km s^{-1}
−100
−50
0
50
100
v_r, km s^{-1}


−150
−100
−50
0
50
100
150
$V_{\rm r}$, km s^{-1}


−150
−100
−50
0
50
100
150
$V_{\rm r}$, km s^{-1}

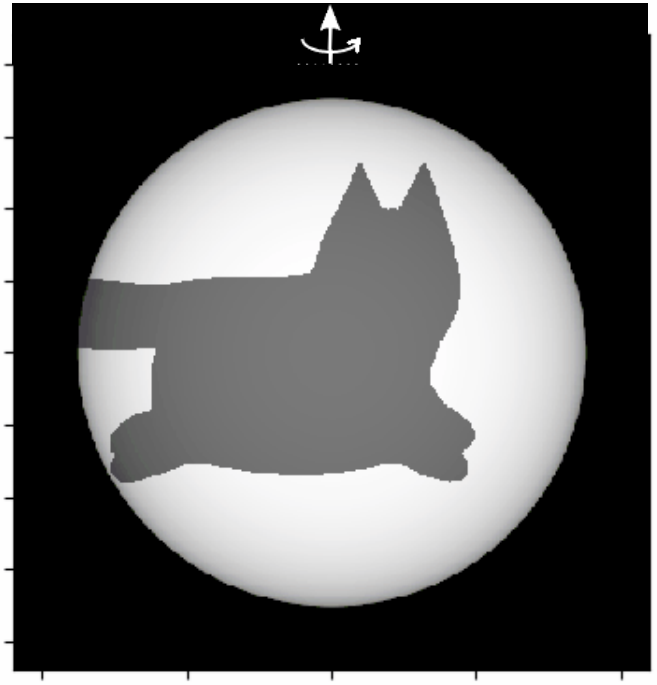


The differences in lines give the information about cloud's shape

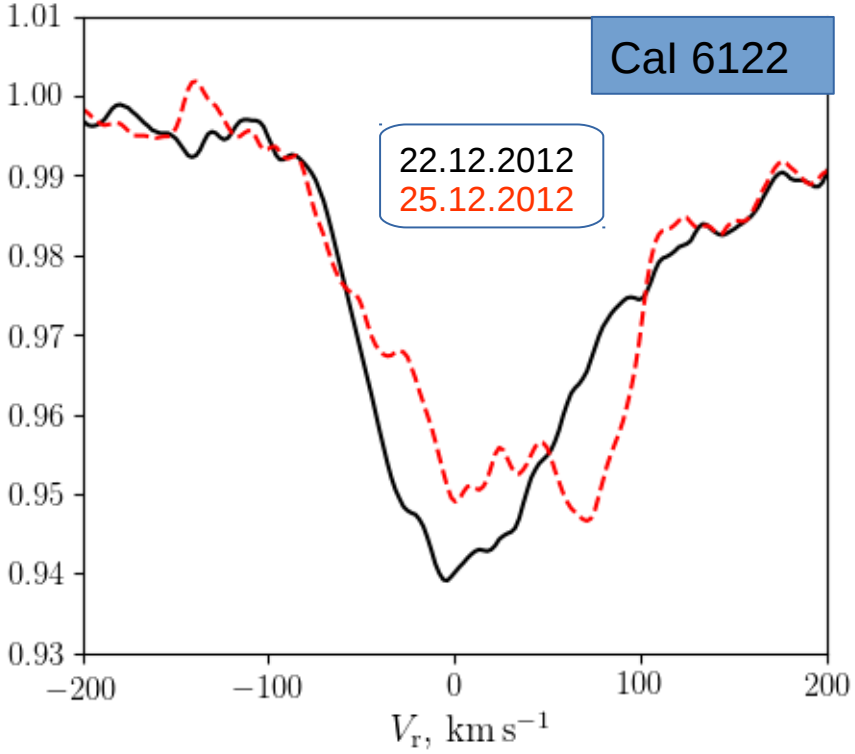
The pattern of variability gives information about the direction of movement

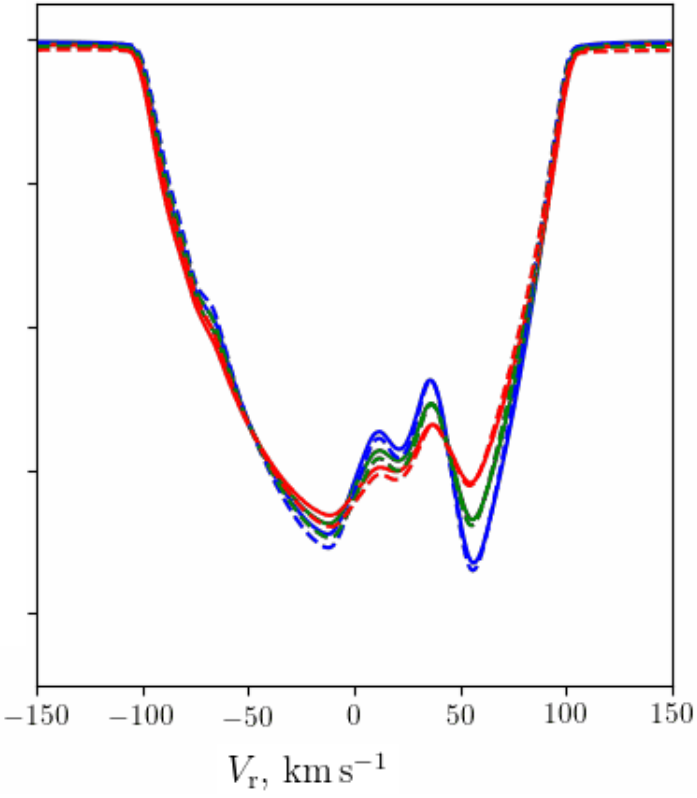
Modelling

Due to the inhomogeneous eclipses the line profiles show complex shape with narrow features – as was observed



CQ Tau:

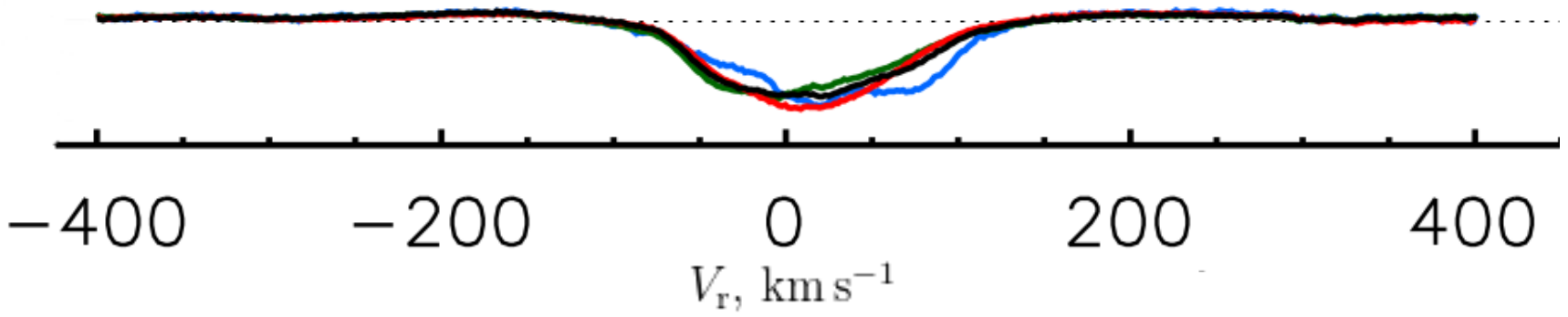




Consequences of inhomogeneity

Star's properties are affected:

- Radial velocity and v sin i distortion



- Parameters of the star (T_{eff} ,log$g$,V_{mic}) are slightly distorted due to differences in limb darkening in weak and strong lines:

$$\left(\frac{EW_{weak}}{EW_{strong}}\right)_0 \neq \left(\frac{EW_{weak}}{EW_{strong}}\right)_{eclipse}$$

Consequences of inhomogeneity

Dust properties:

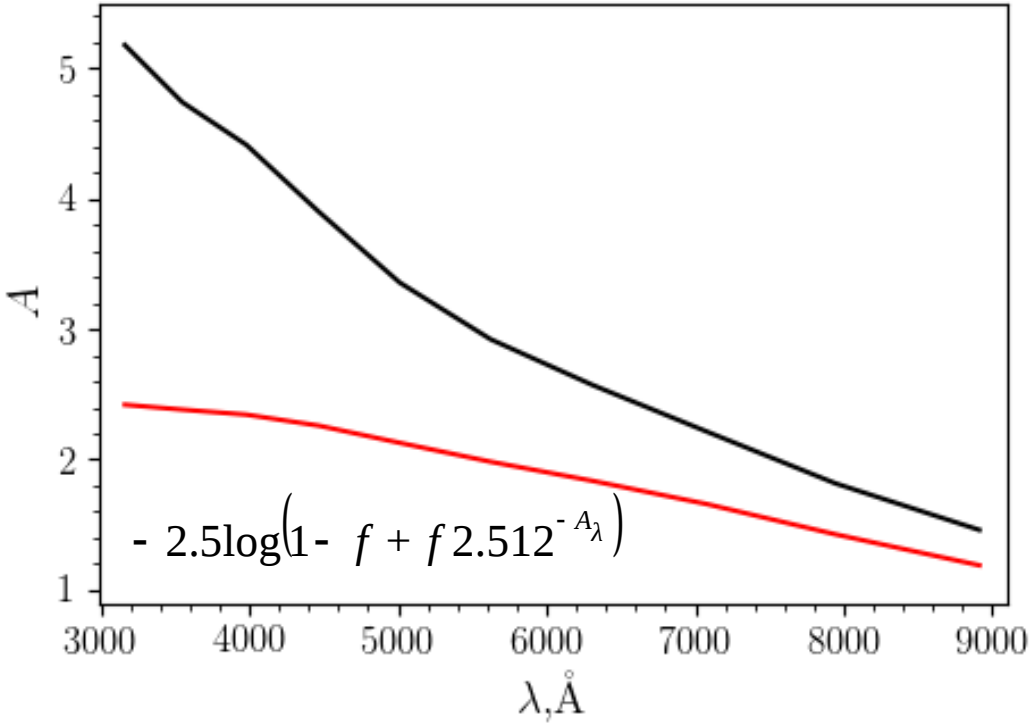
- Inhomogeneous eclipses are tend to be more grey, leading to incorrect conclusion about the mean size of dust grains:

(Natta, Panagia, 1984)

$f = 0.9$

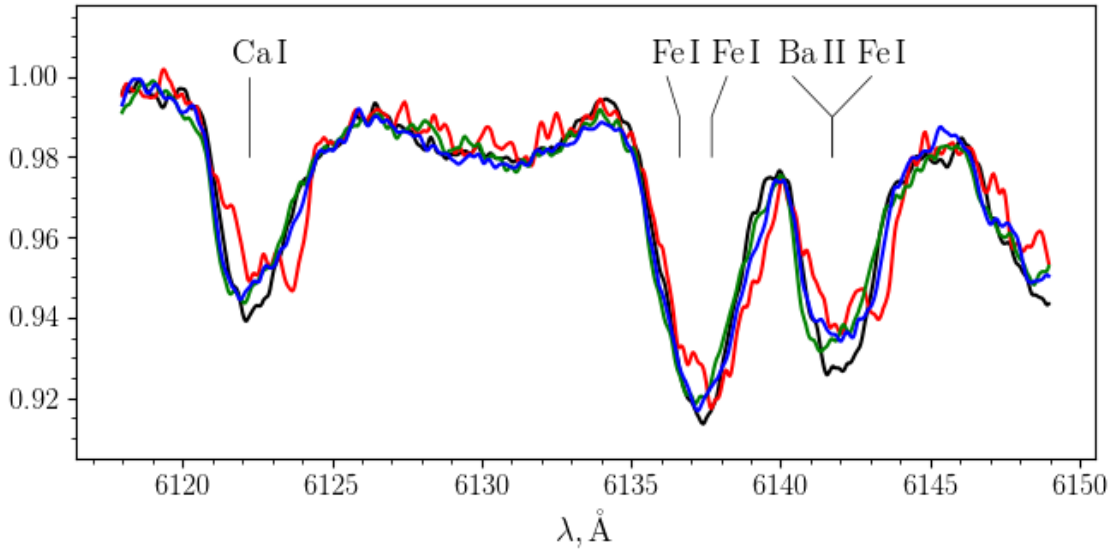
$A_V = 3$, for standard extinction

Cardelli, Clayton & Mathis, 1989

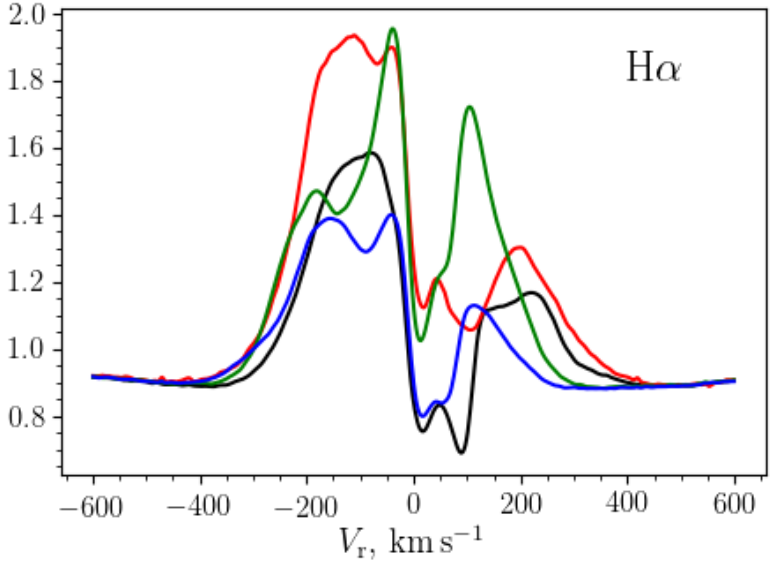


Consequences

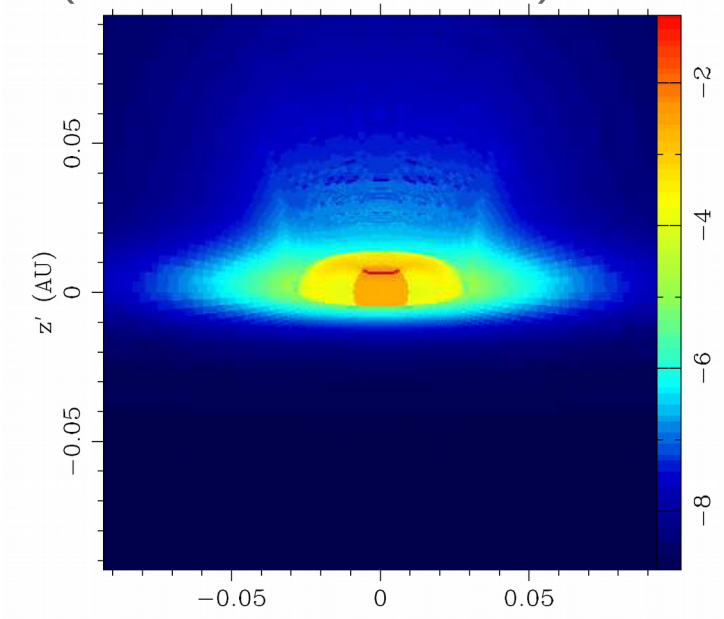
Distortions observed in absorption lines



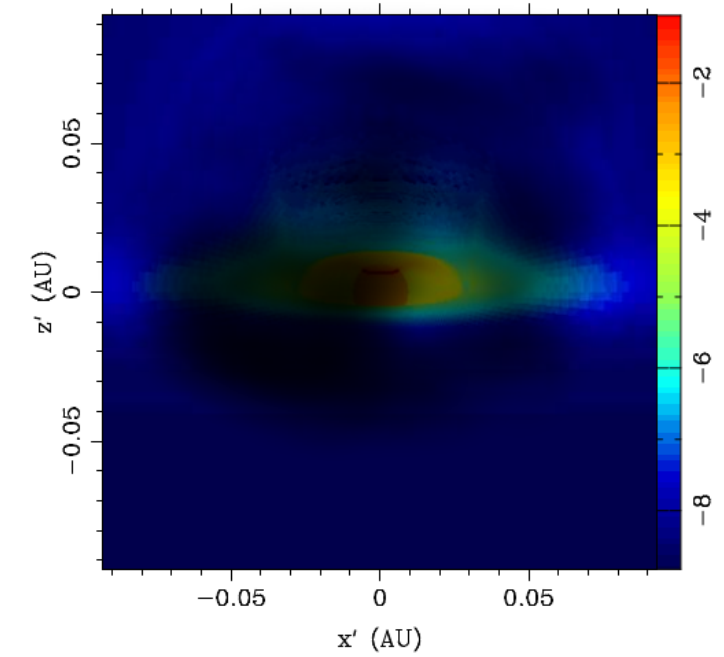
should be present in the emission lines:



A simulated Ha image of accreting CTTS with an outflow (Kurosawa et al., 2006):

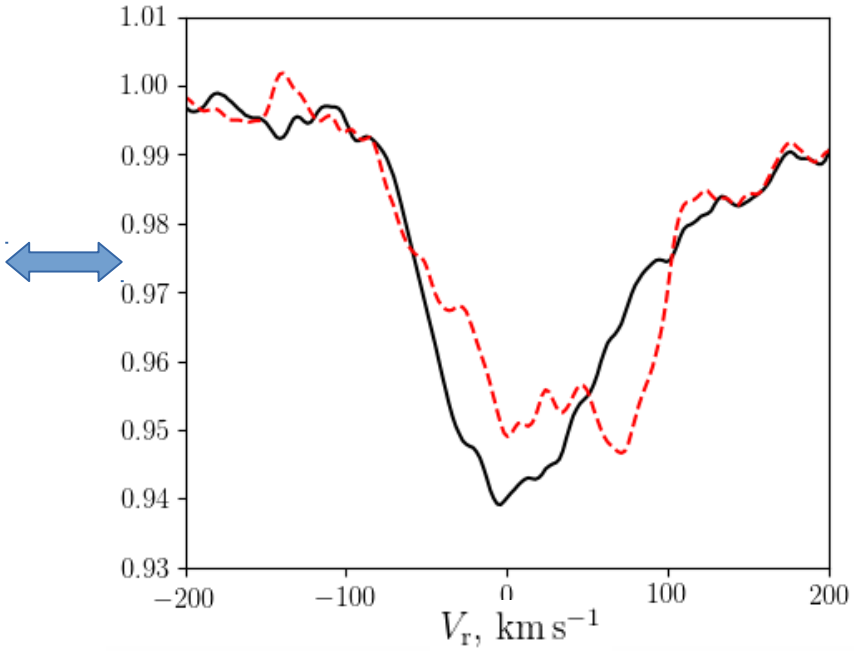


The same, but with clouds:

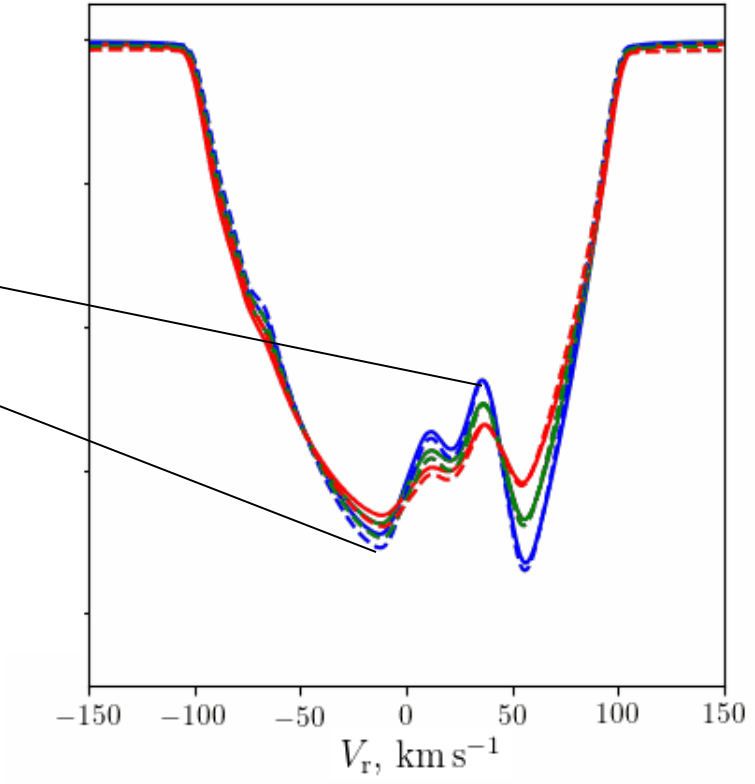


Conclusions

1. Obscuring clouds are structured on the scales of stellar radii



2. Differences in line profiles give an opportunity to map the clouds



3. Series of observations within one night will make the study of clouds movements possible

Thank you for your attention!

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