Spectropolarimetric Imaging of the photosphere of Betelgeuse

A. López Ariste

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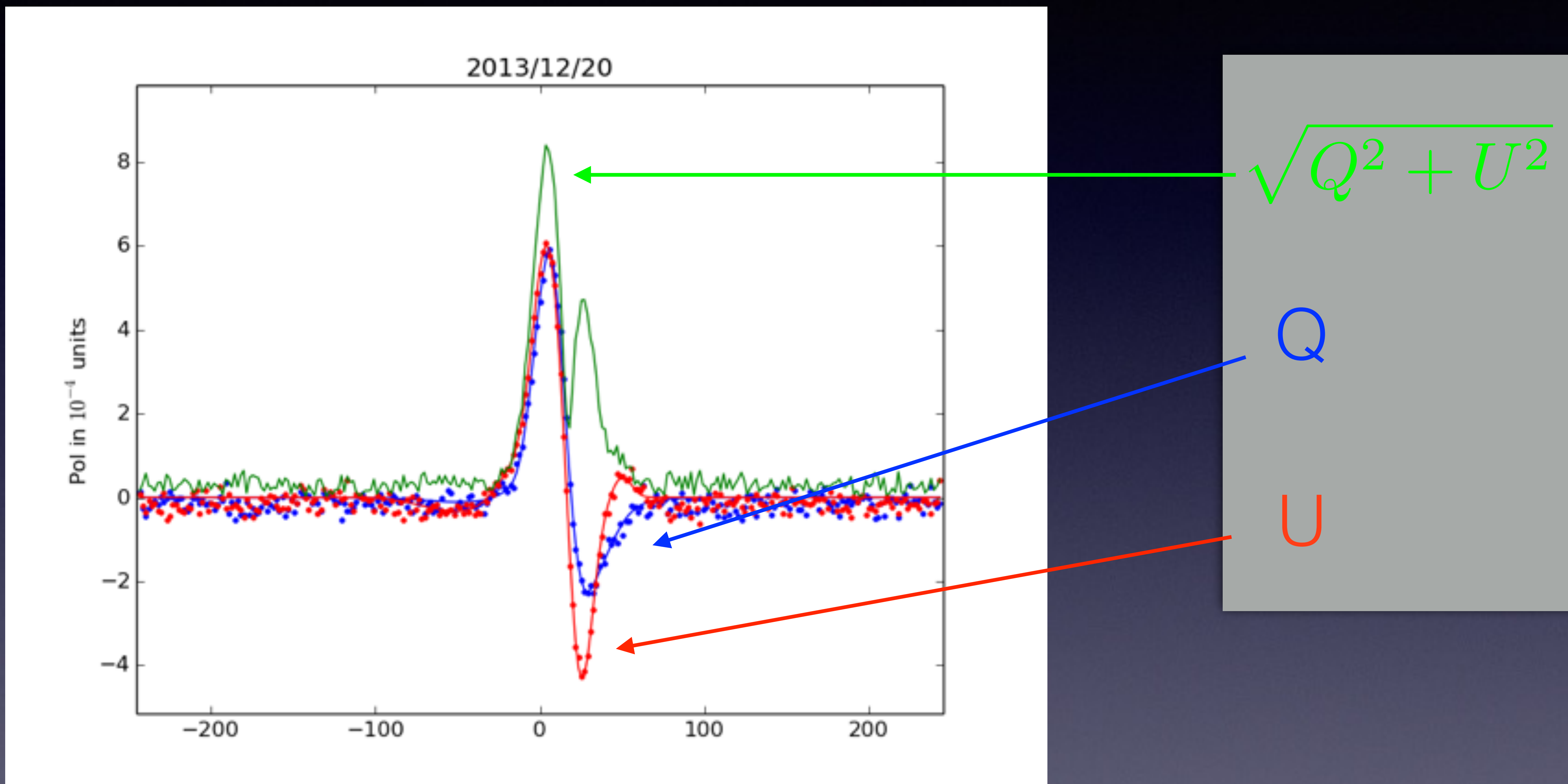
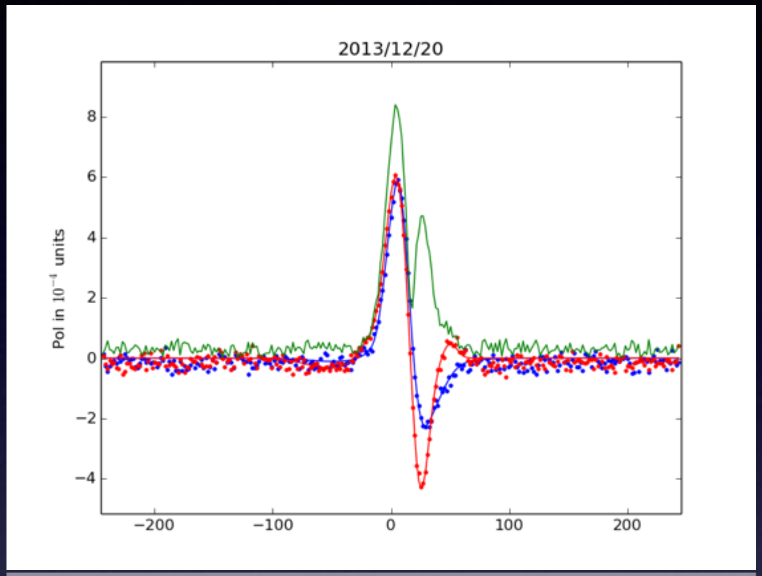
LSD profiles of Linear Polarisation from Betelgeuse



LSD profiles of Linear Polarisation from Betelgeuse

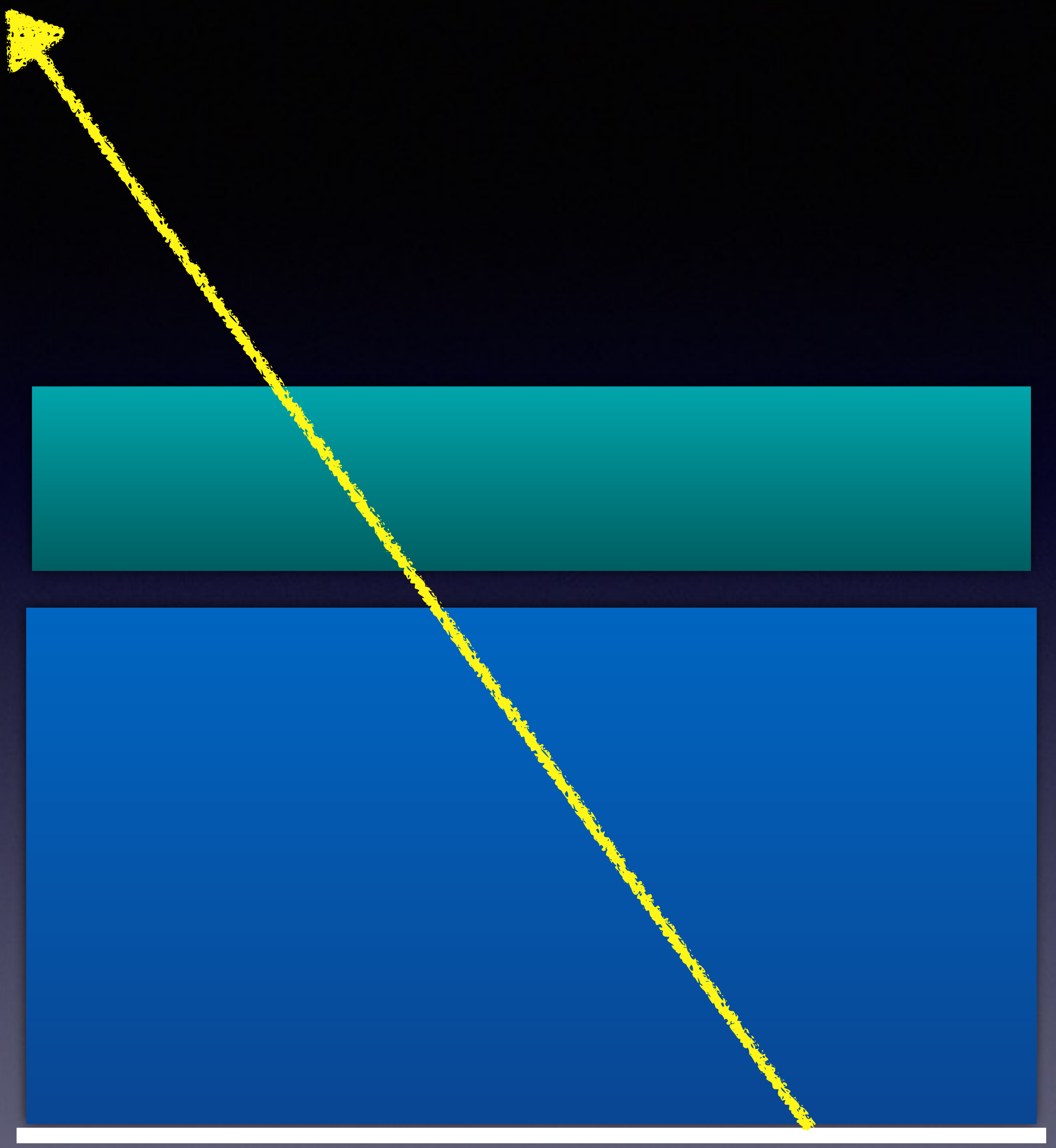


- Continuum is polarised (Rayleigh)
- Spectral lines form while and after this polarisation of the continuum
- They depolarise the continuum
- We see as signal this depolarisation

Forming lines absorb polarised photons and re-emit unpolarised ones

Rayleight scattering polarises continuum

Continuum forms



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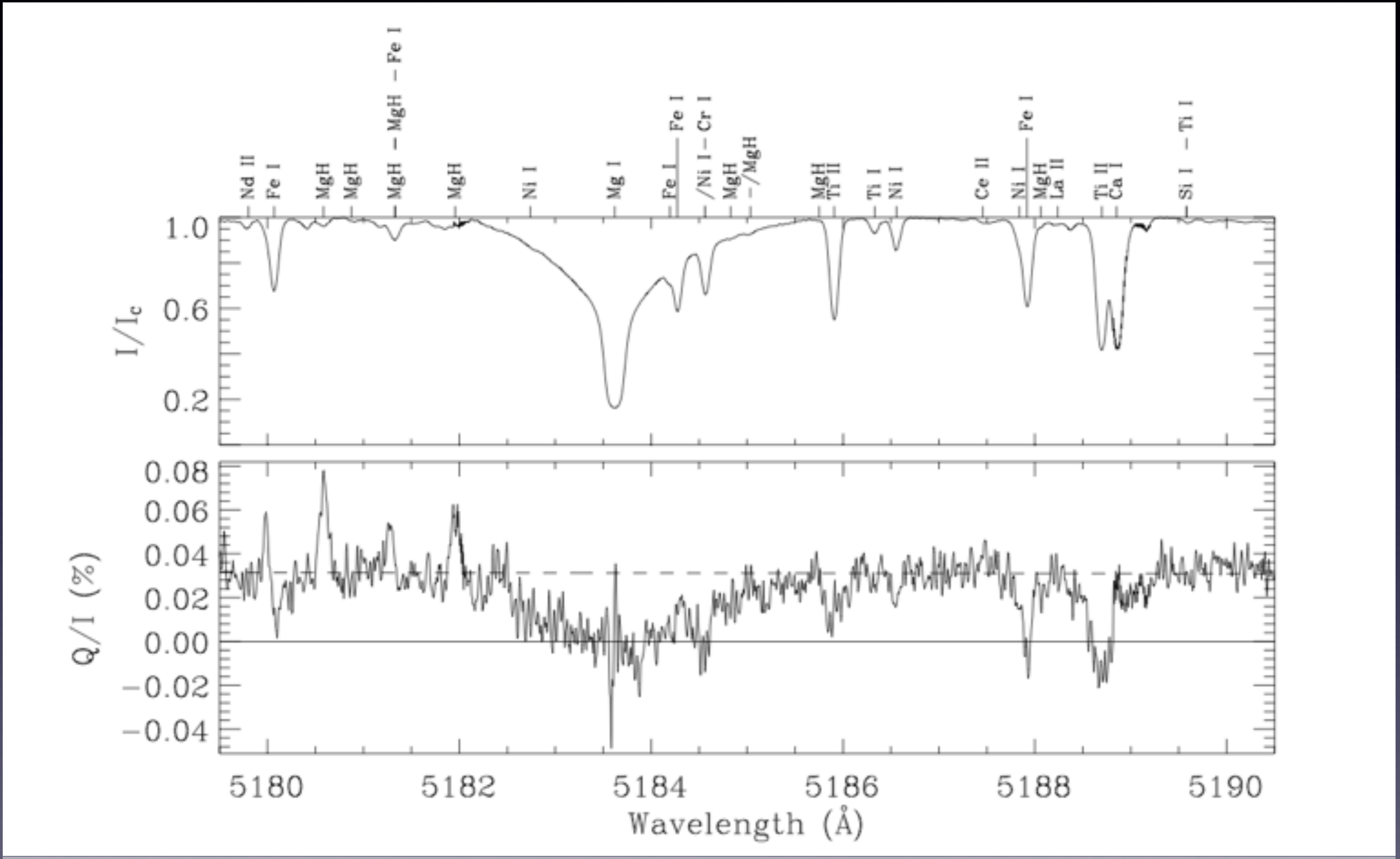
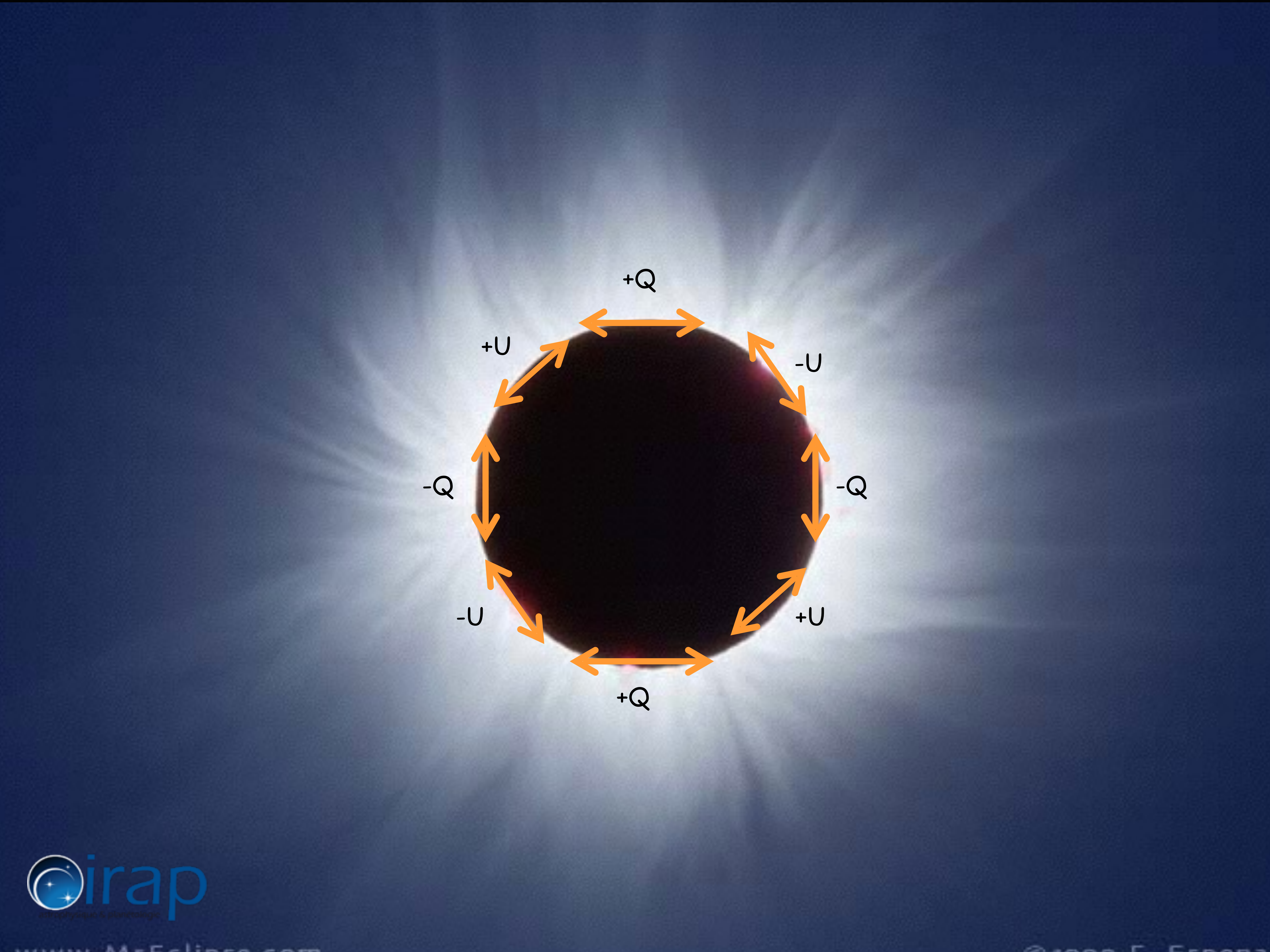
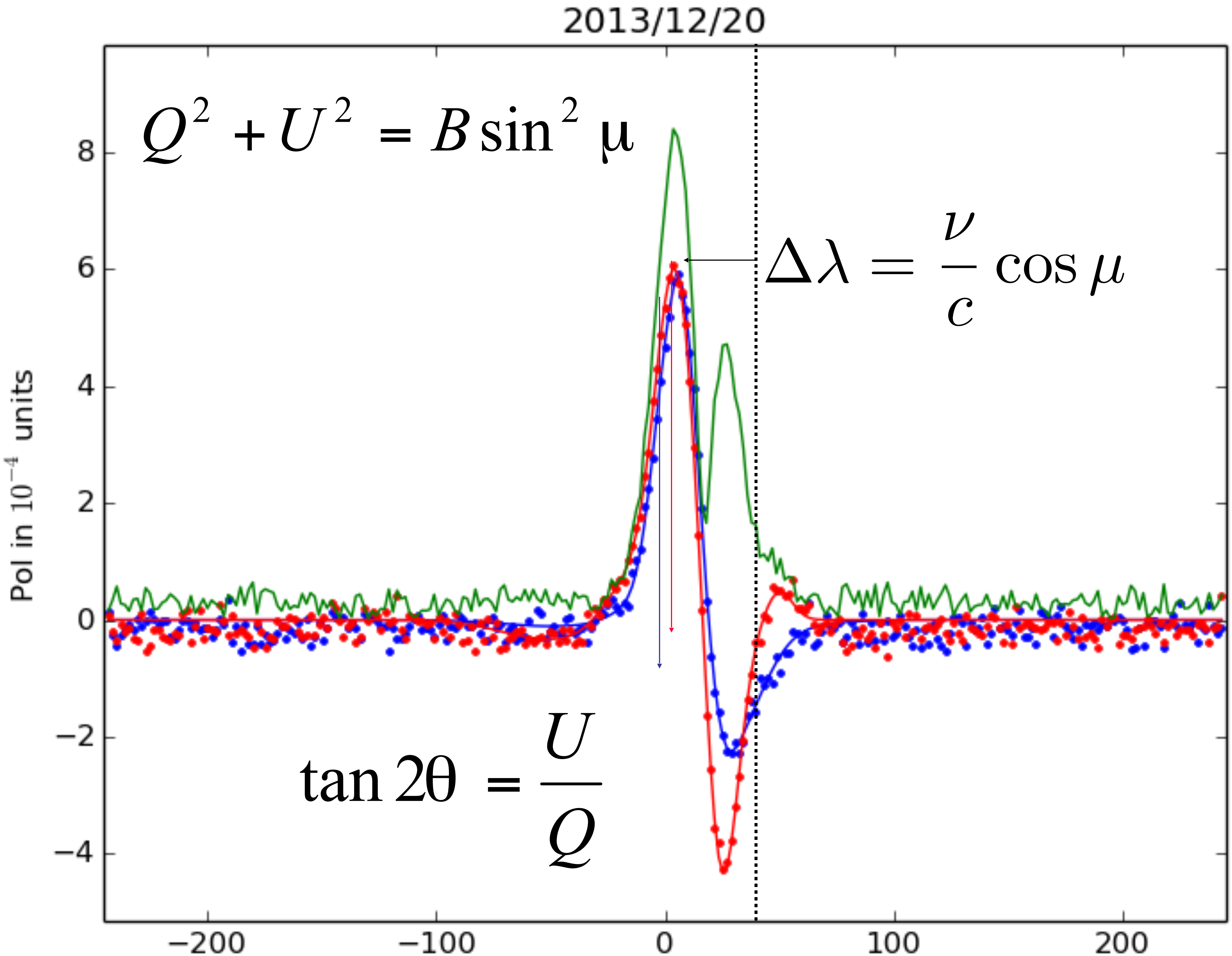
Depolarisation of the continuum in the Solar spectrum



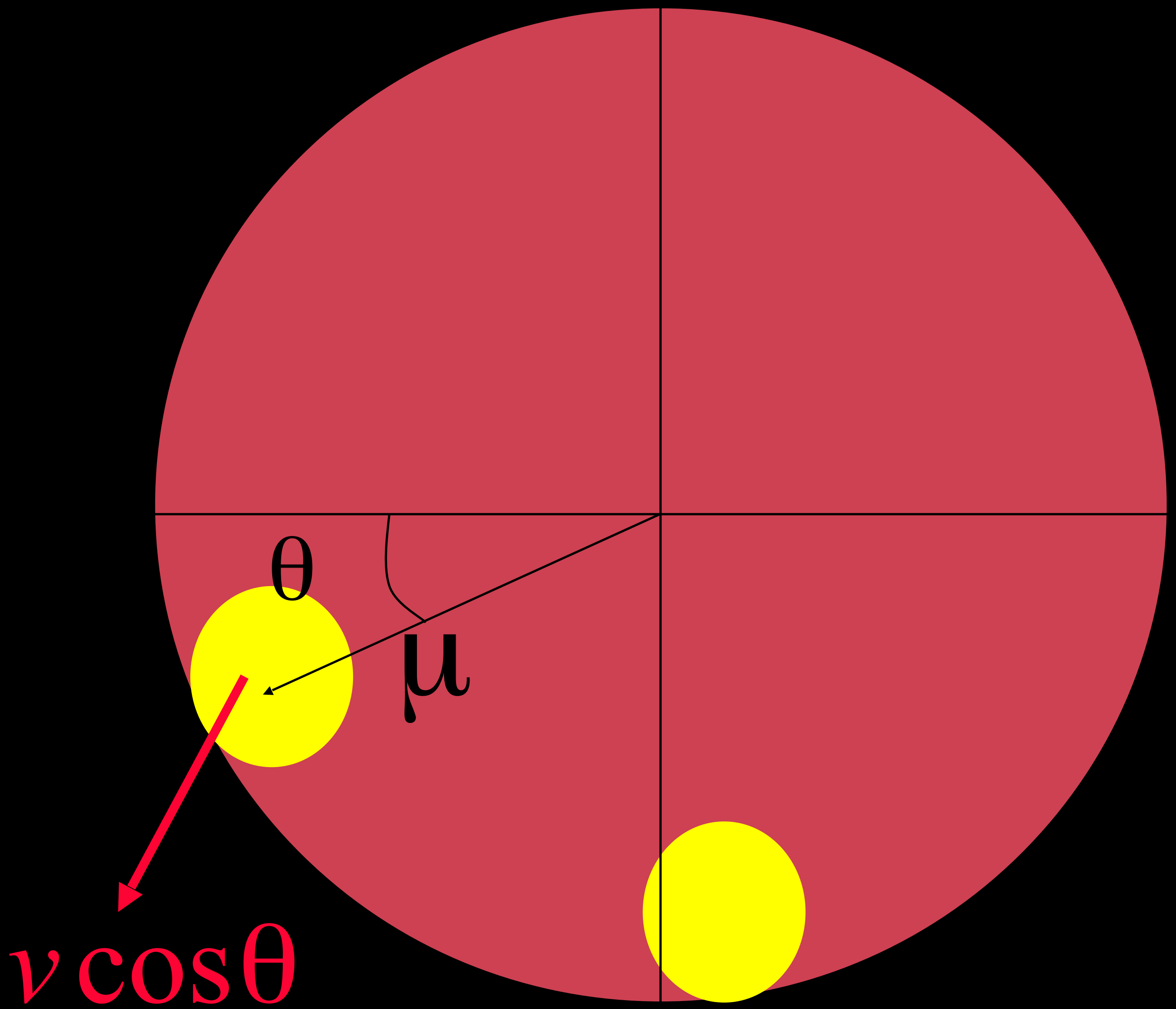

+Q
+U
-U
-Q
-Q
-U
+U
+Q

First approximation:

One wavelength, one spot



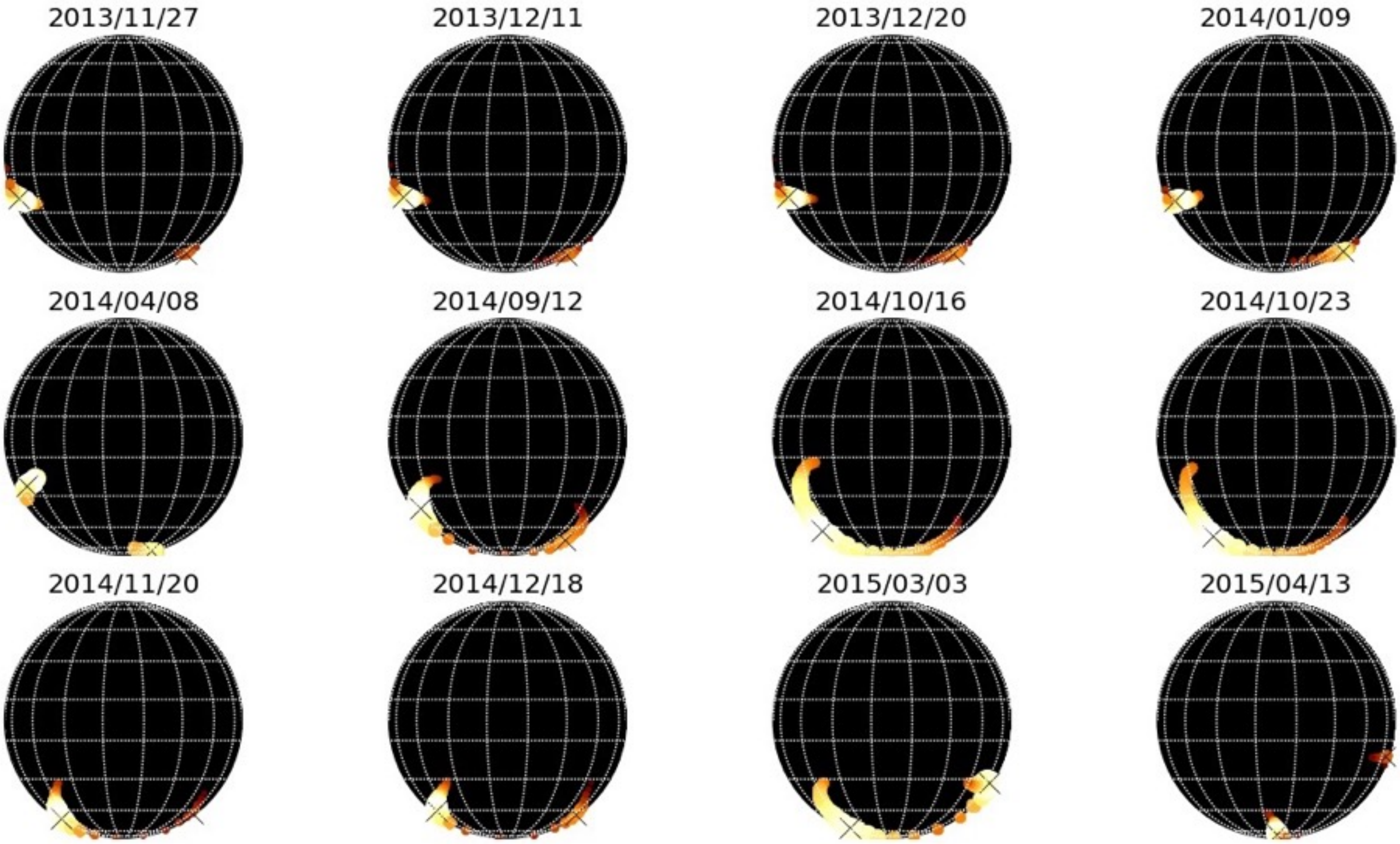
2013/12/20
$Q^2 + U^2 = B \sin^2 \mu$
$\Delta\lambda = \frac{\nu}{c} \cos\mu$
$\tan 2\theta = \frac{U}{Q}$
Pol in 10^{-4} units
8
6
4
2
0
−2
−4
−200
−100
0
100
200



$$\tan 2\theta = \frac{U}{Q}$$

$$Q^2 + U^2 = B \sin^2 \mu$$

$$\Delta\lambda = \frac{v}{c} \cos\theta$$



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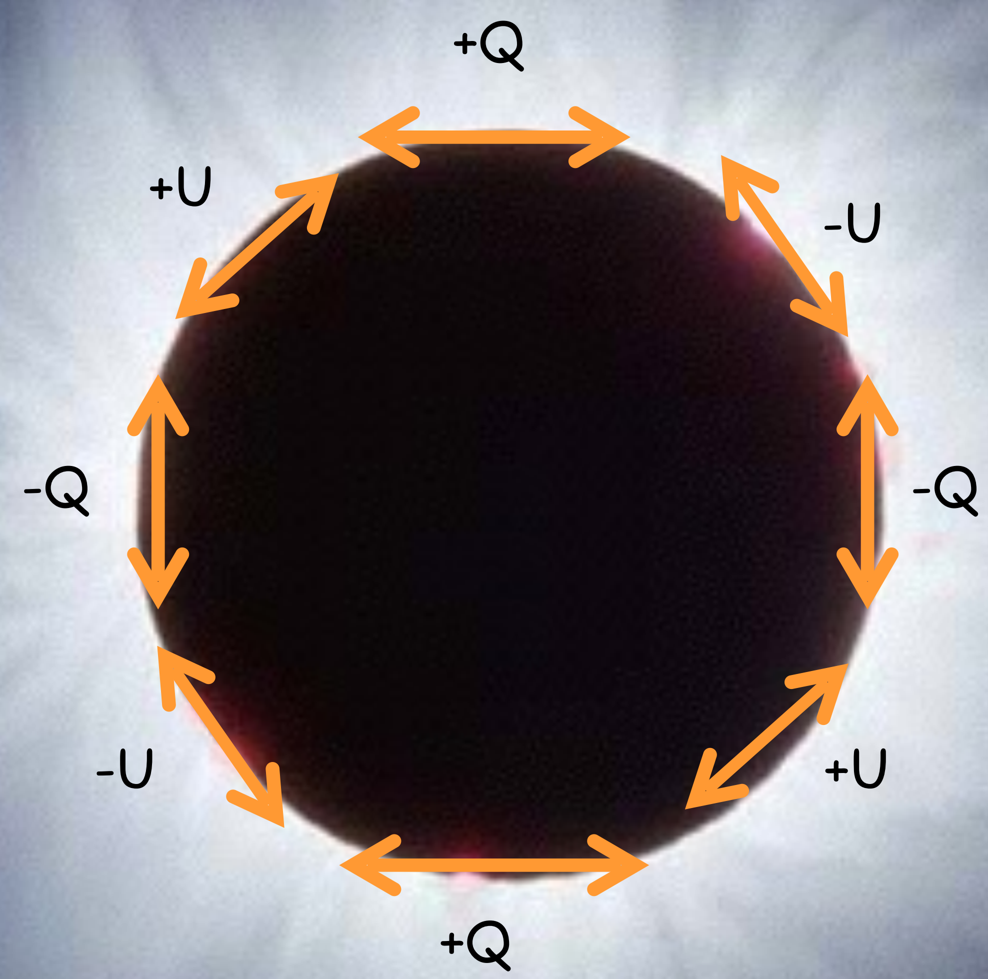
Aurière et al. (2016)

Second approximation:

Disk-integrated brightness distribution

$$Q = \int_S B \cdot P \cdot (\sin^2 \mu) d\mu d\theta$$



Either B or P or both are not homogeneous over the disc

$$Q = \int_S B \cdot P \cdot (\sin^2 \mu) d\mu d\theta$$

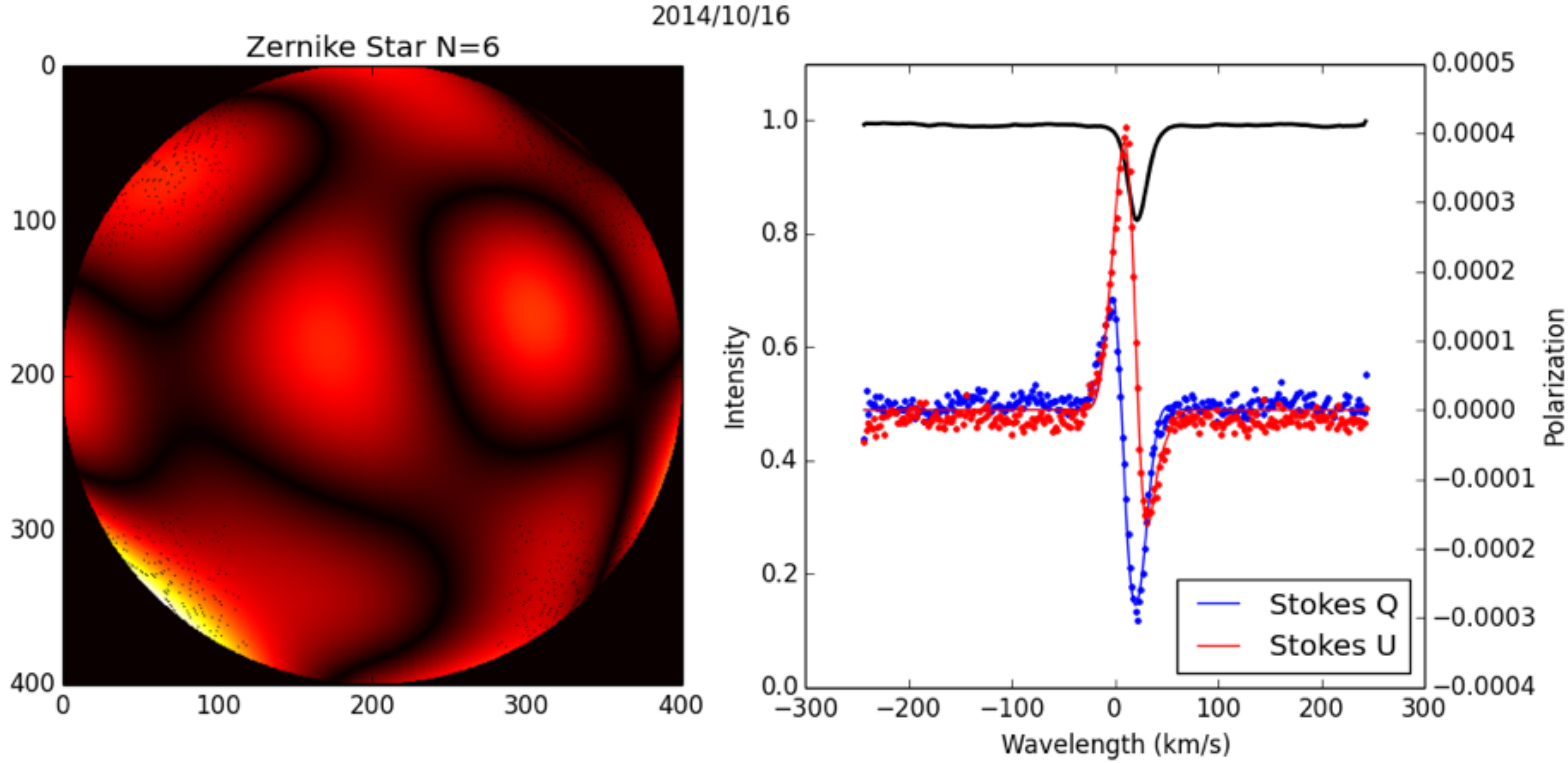
- Either B or P or both are not homogeneous over the disc. Which one?
- Brilliance cannot be homogeneous elsewhere
- The observed total polarisation amplitude is 10 times lower than the expected local polarisation

$$Q = \int_S B \cdot P \cdot (\sin^2 \mu) d\mu d\theta$$

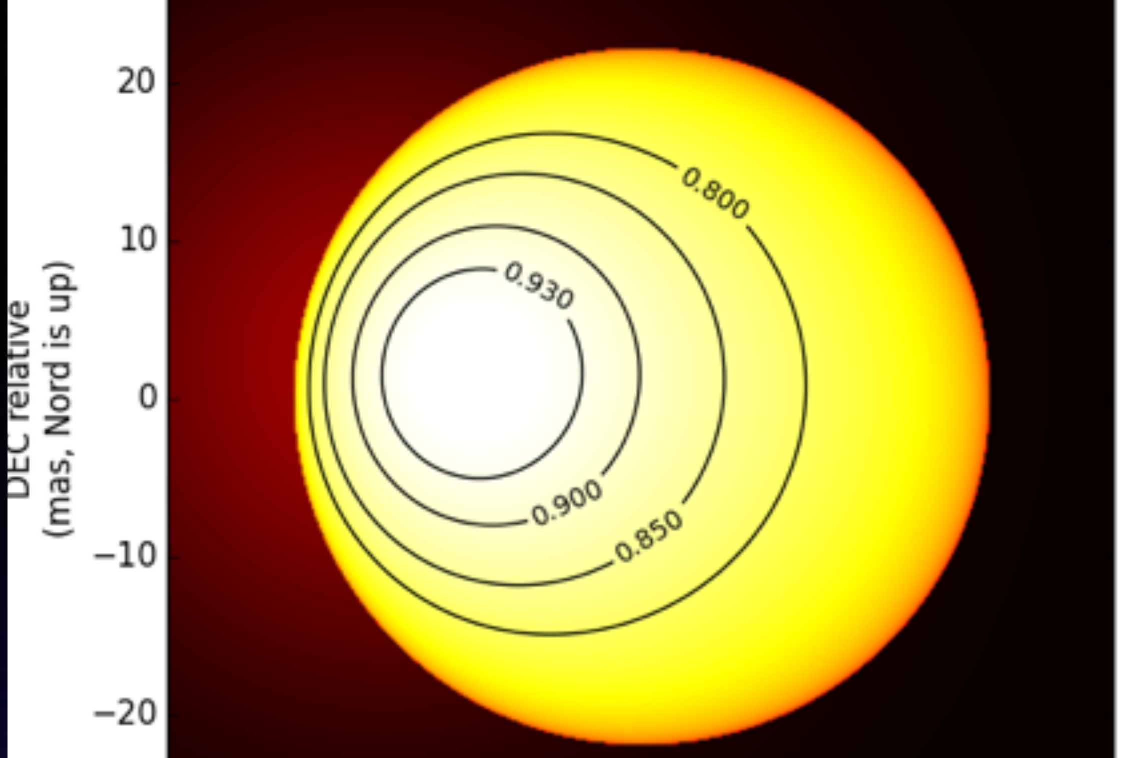
We propose a continuous distribution ….

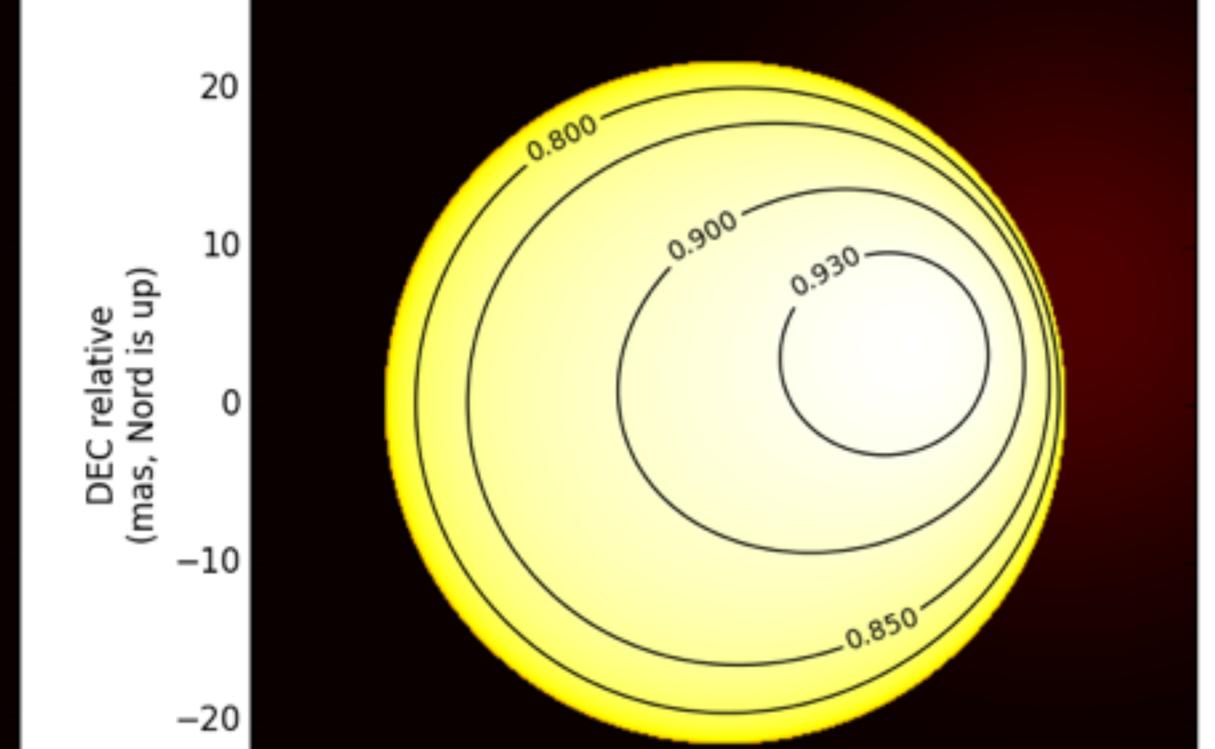
$$B \cdot P(r, \theta) = \sum c_j Z_j(r, \theta)$$

From which we can derive synth profiles and invert the data (PCA + NLLS)

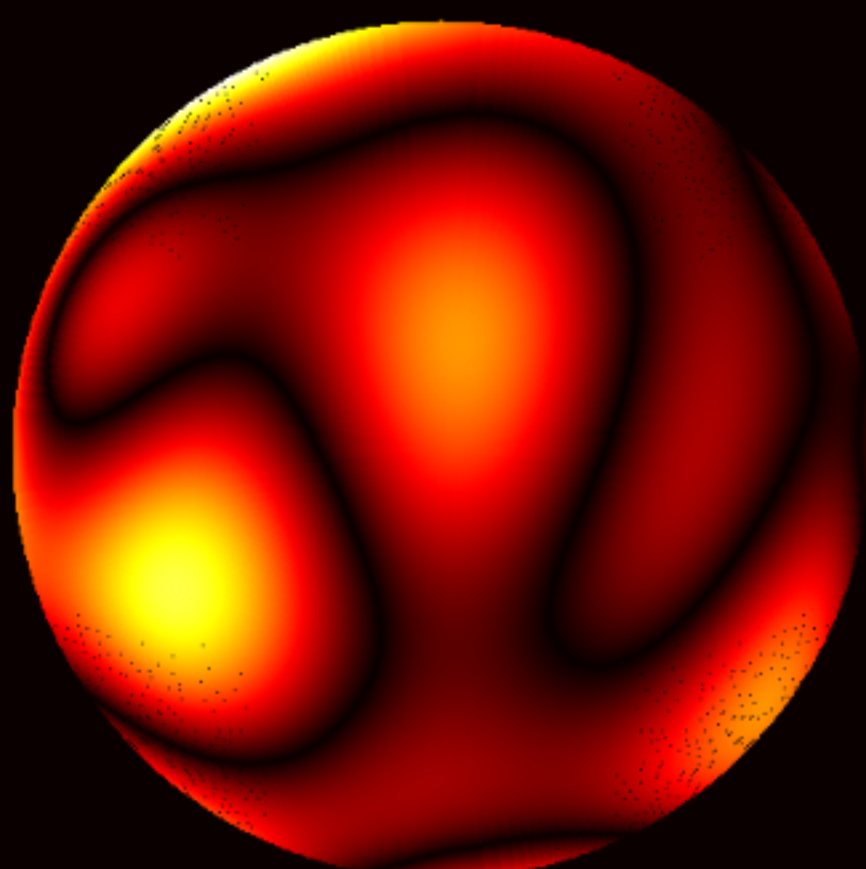


2014/10/16
Zernike Star N=6
0
100
200
300
400
0
100
200
300
400
1.0
0.8
0.6
0.4
0.2
0.0
Intensity
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
−0.0001
−0.0002
−0.0003
−0.0004
Polarization
−300
−200
−100
0
100
200
300
Wavelength (km/s)
Stokes Q
Stokes U

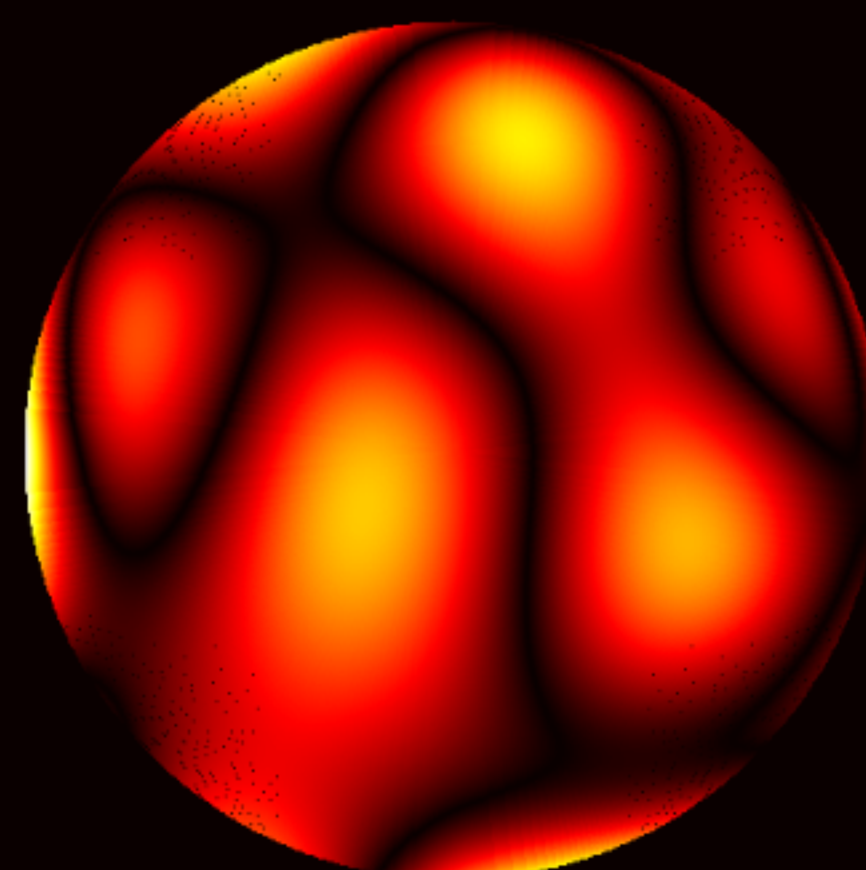




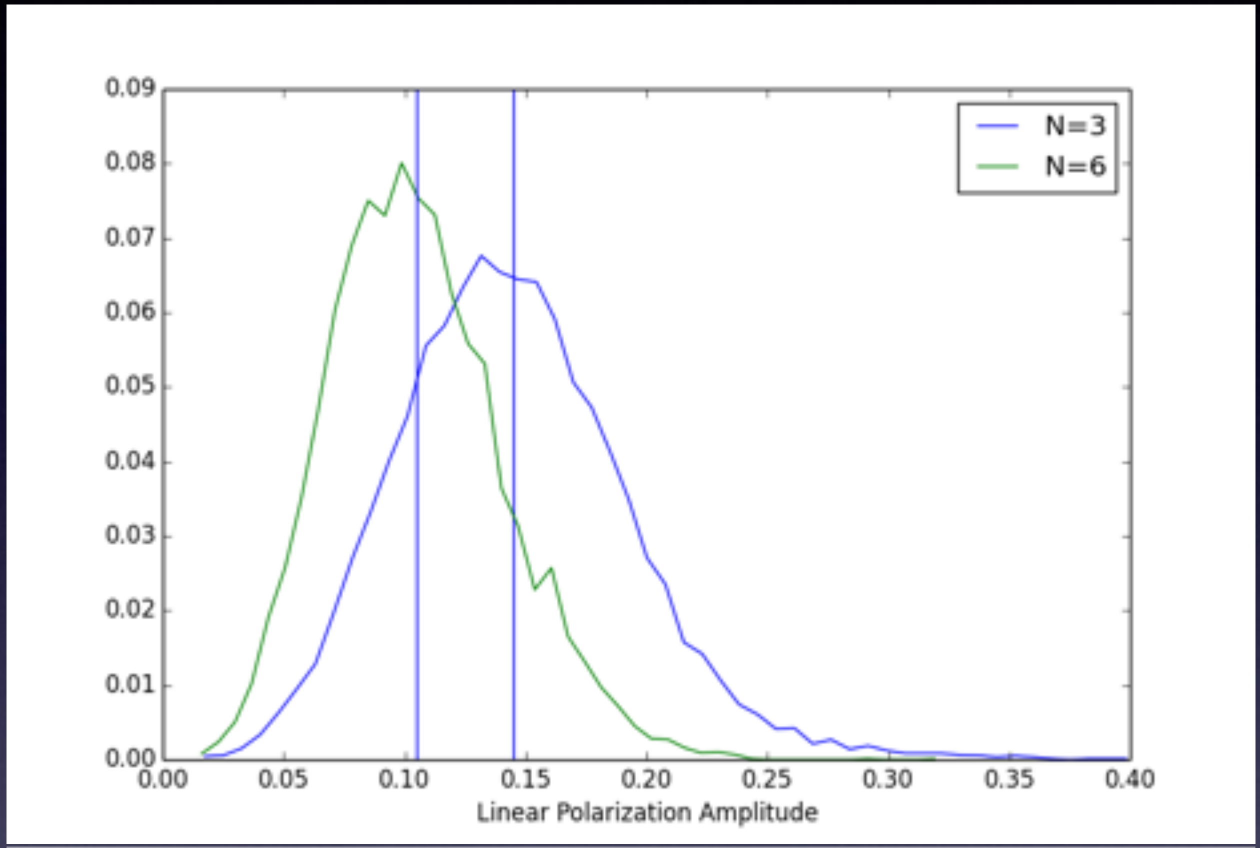
2014/01/09



2014/11/20



First result



Local continuum polarisation gets divided by 10

From RT calculations, this local polarisation is about 1%

We post-dict a polarisation amplitude of ~ 0.1%

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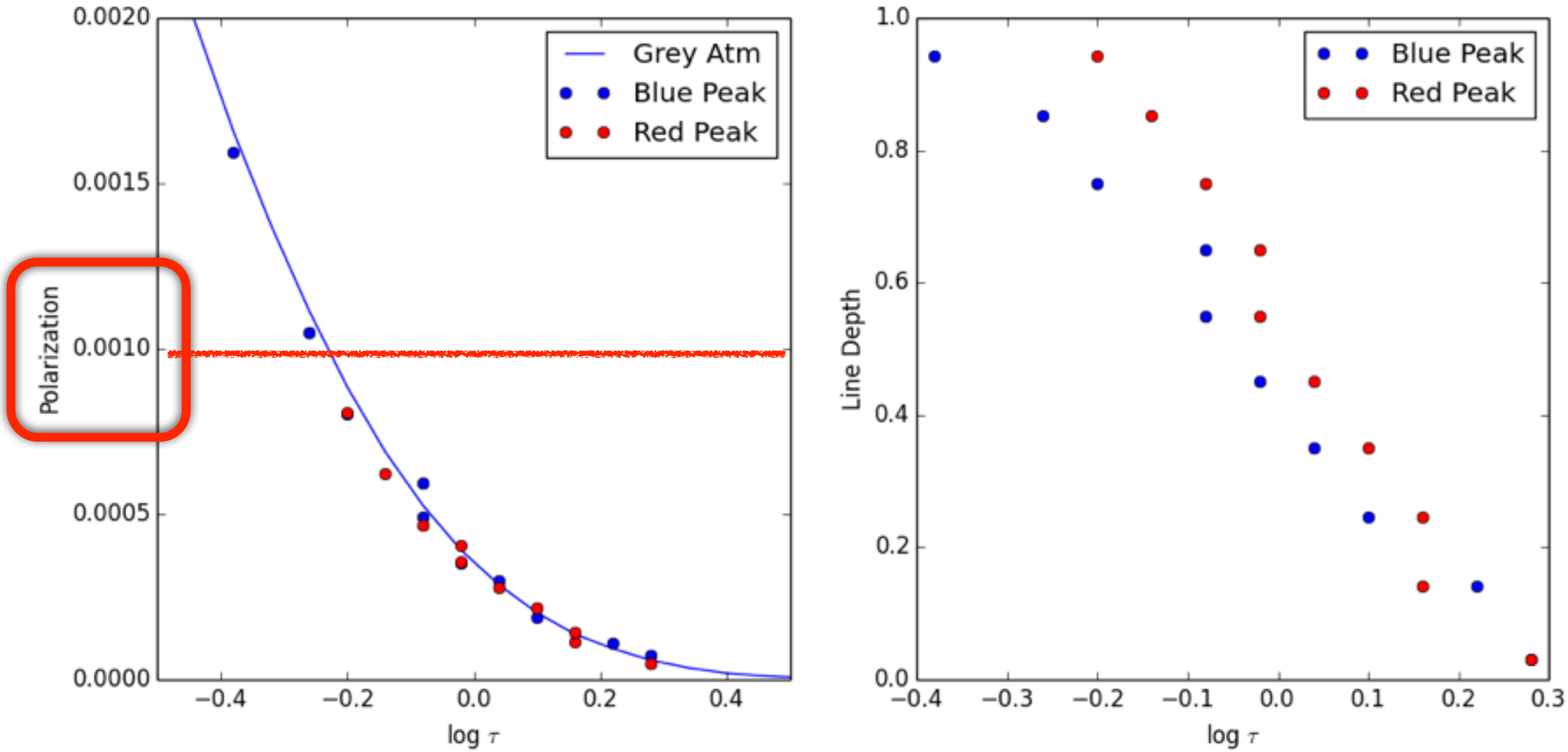

We post-dict a polarisation amplitude of ~ 0.1%

Second result

$$B \cdot P(r,\theta) = \sum_{j=1,N} c_j Z_j(r,\theta)$$

Bigger N means smaller structures

We test N=3 and N=6

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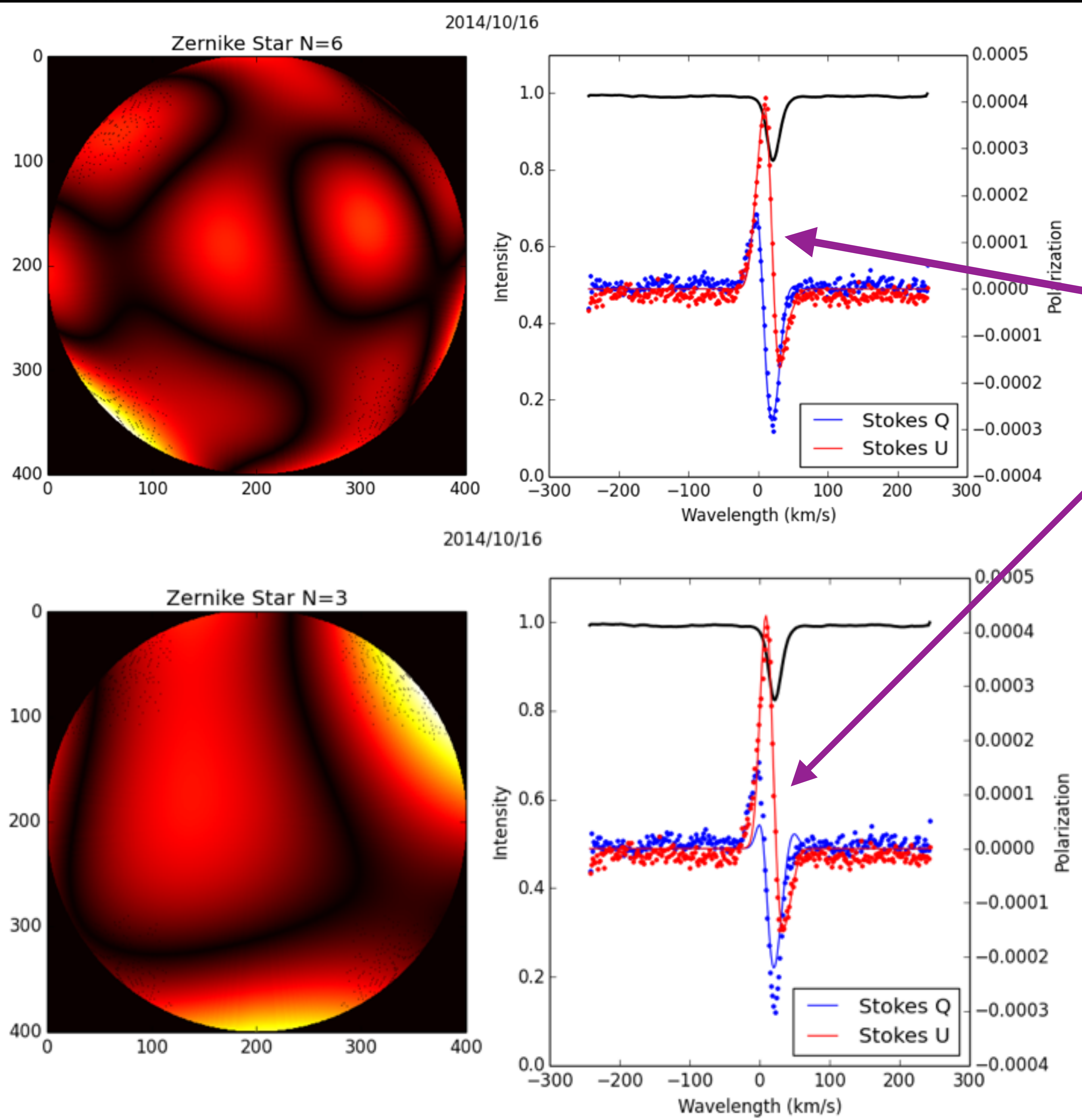
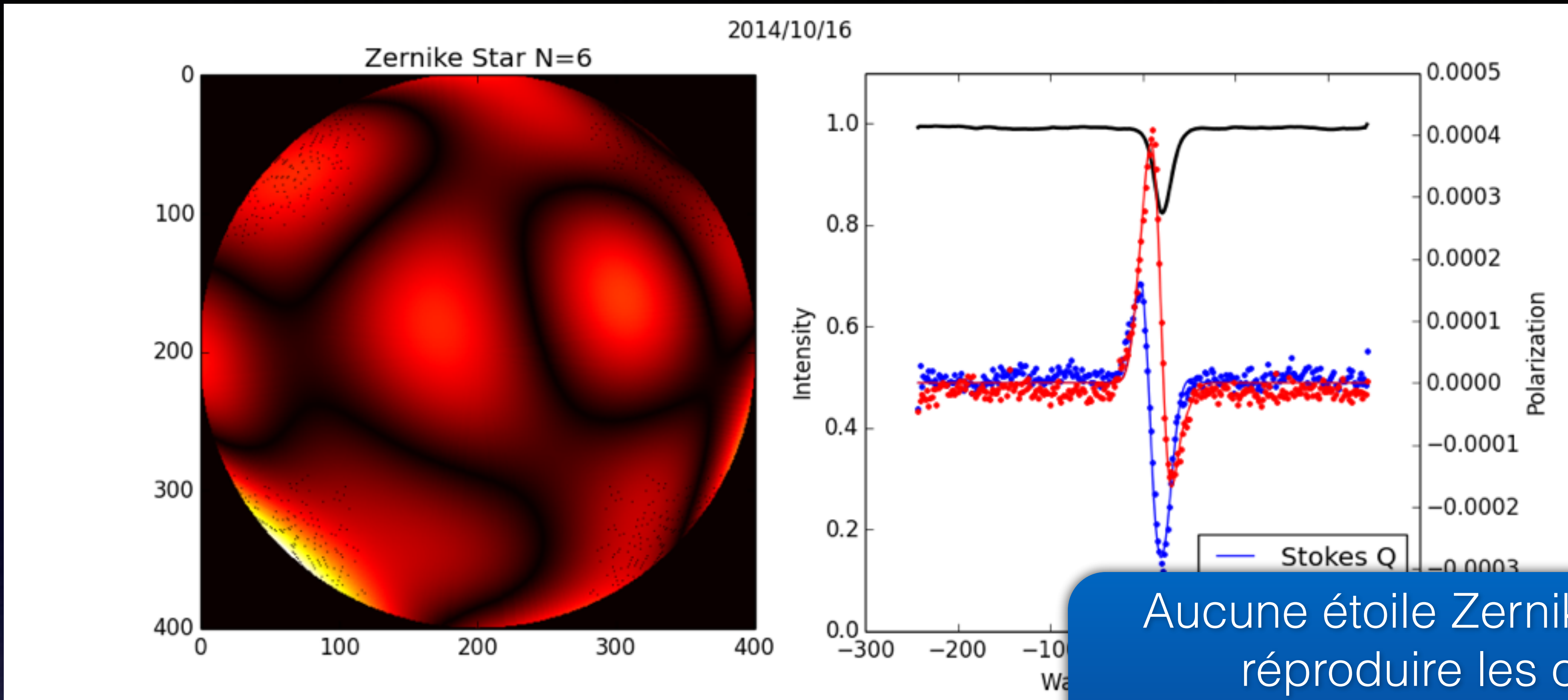
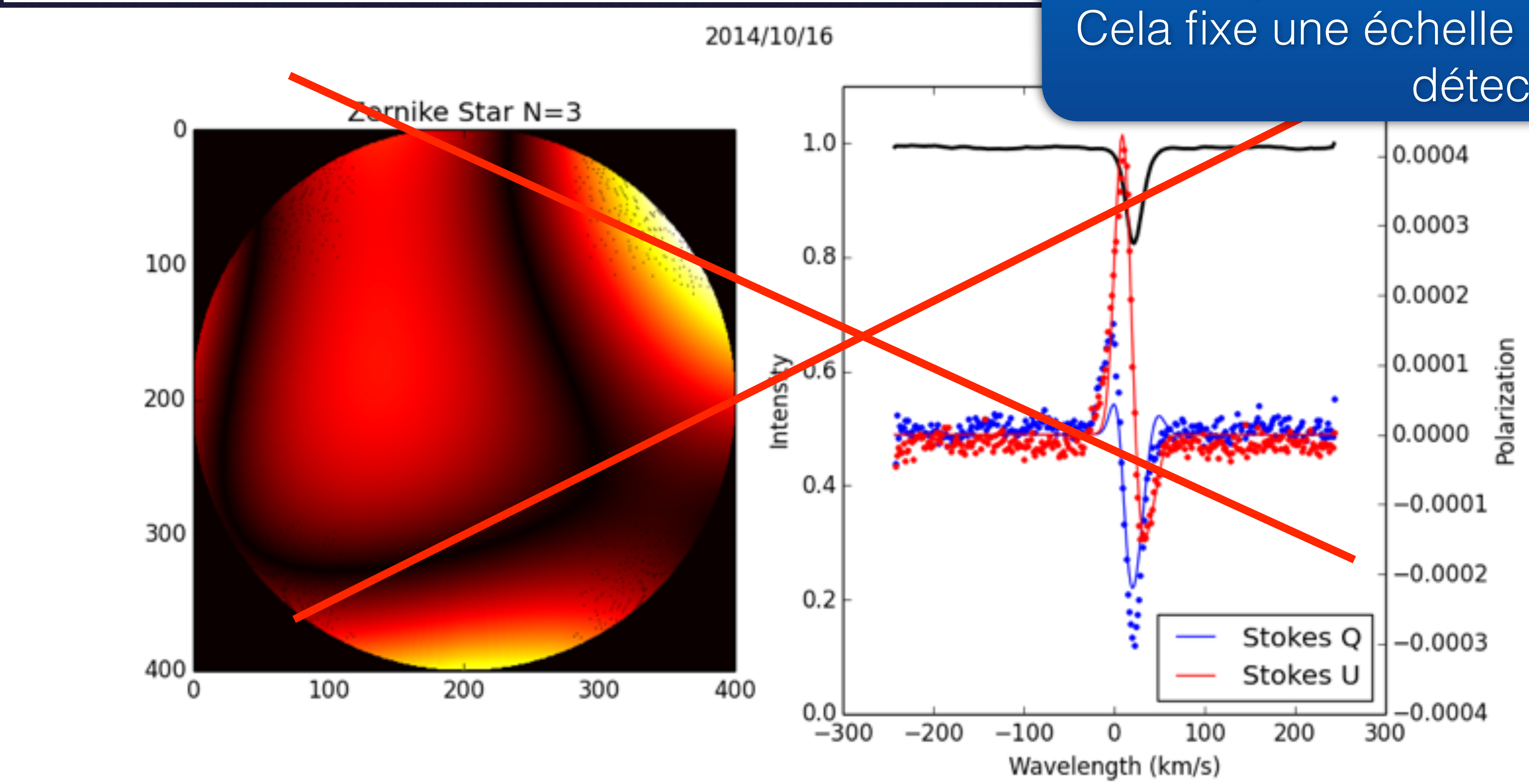


Réproduction
avec N=6,
mais pas possible
avec N=3



Aucune étoile Zernike avec n=3 peut réproduire les observations.
Cela fixe une échelle max des structures détectés

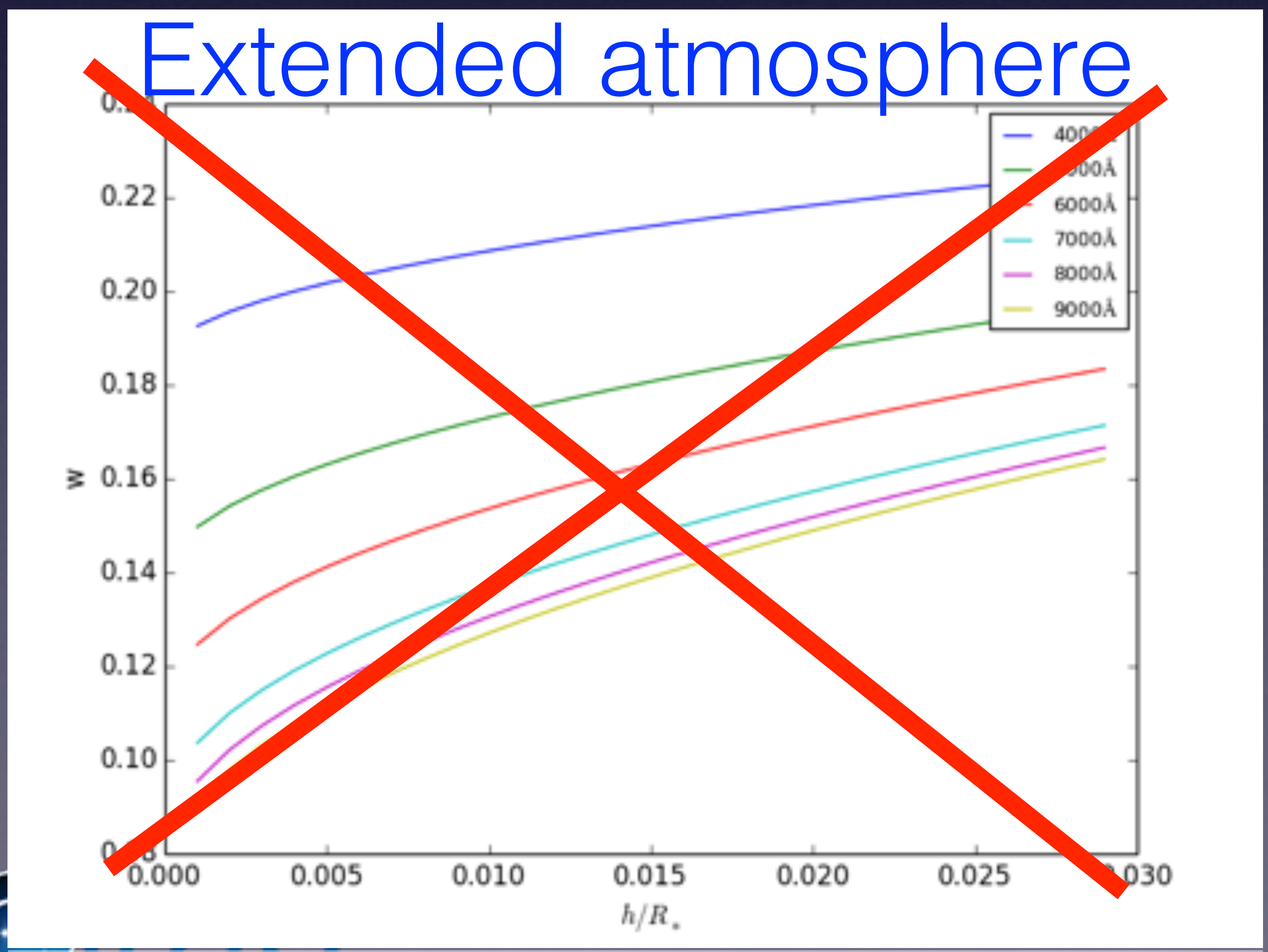


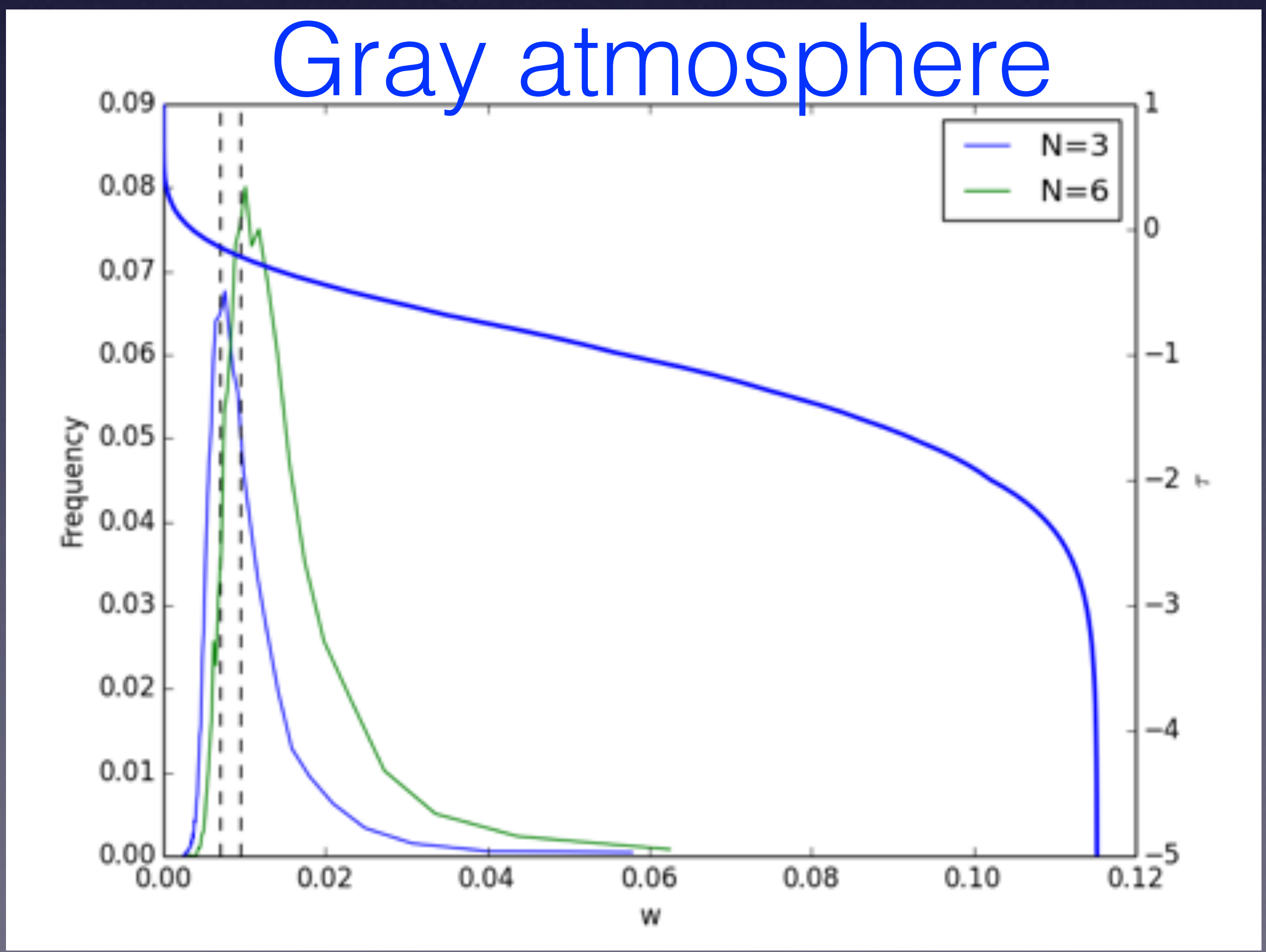
Second result

Observed structures have typical scales of 0.5 R

Third result

If the local continuum polarisation is 1%
and it is due to the radiation field anisotropy
we can determine the atmospheric model



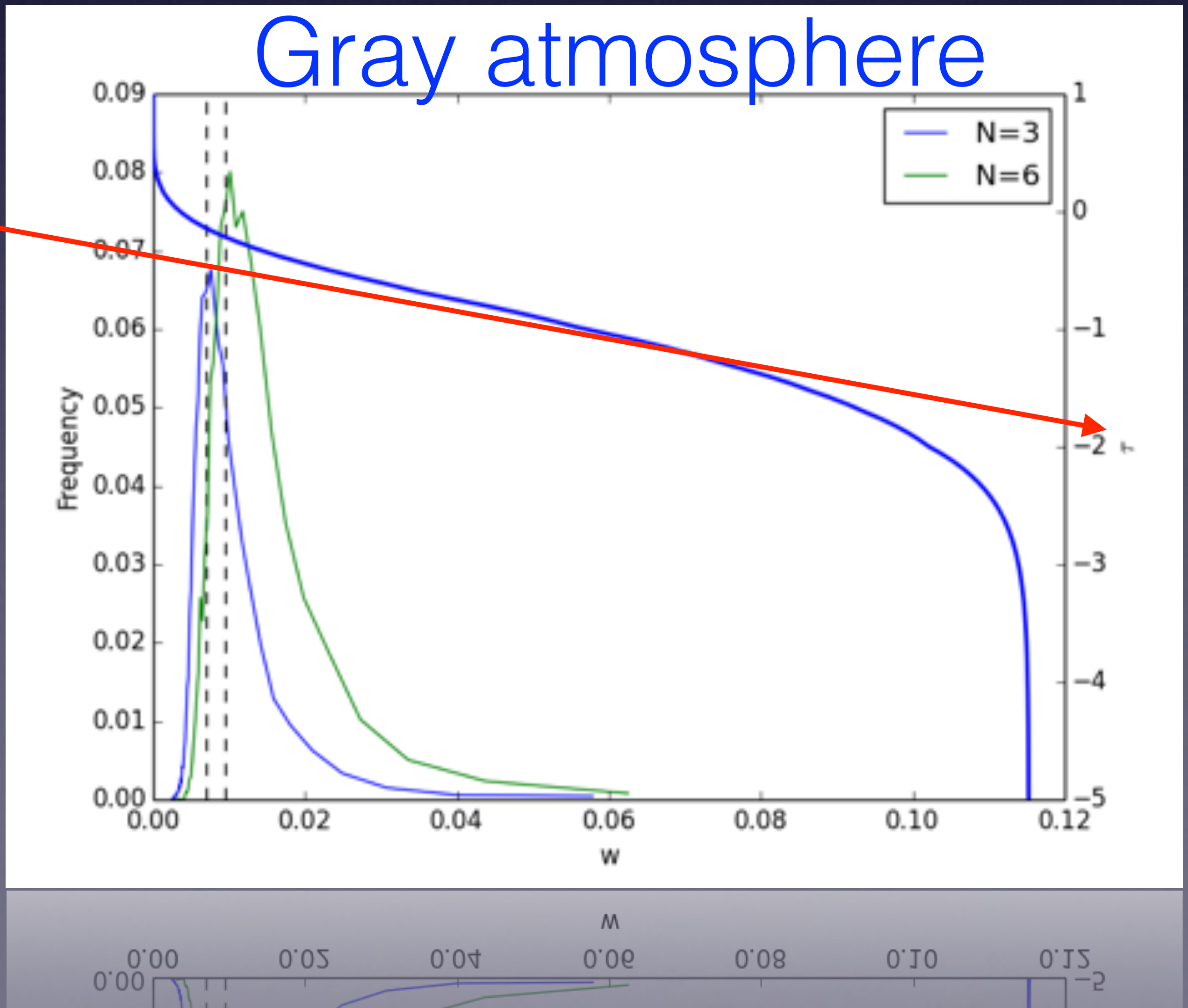


Third result

If the local continuum polarisation is 1%
and it is due to the radiation field anisotropy
we can determine the atmospheric model

then fix the opacity scale

and go over every single line



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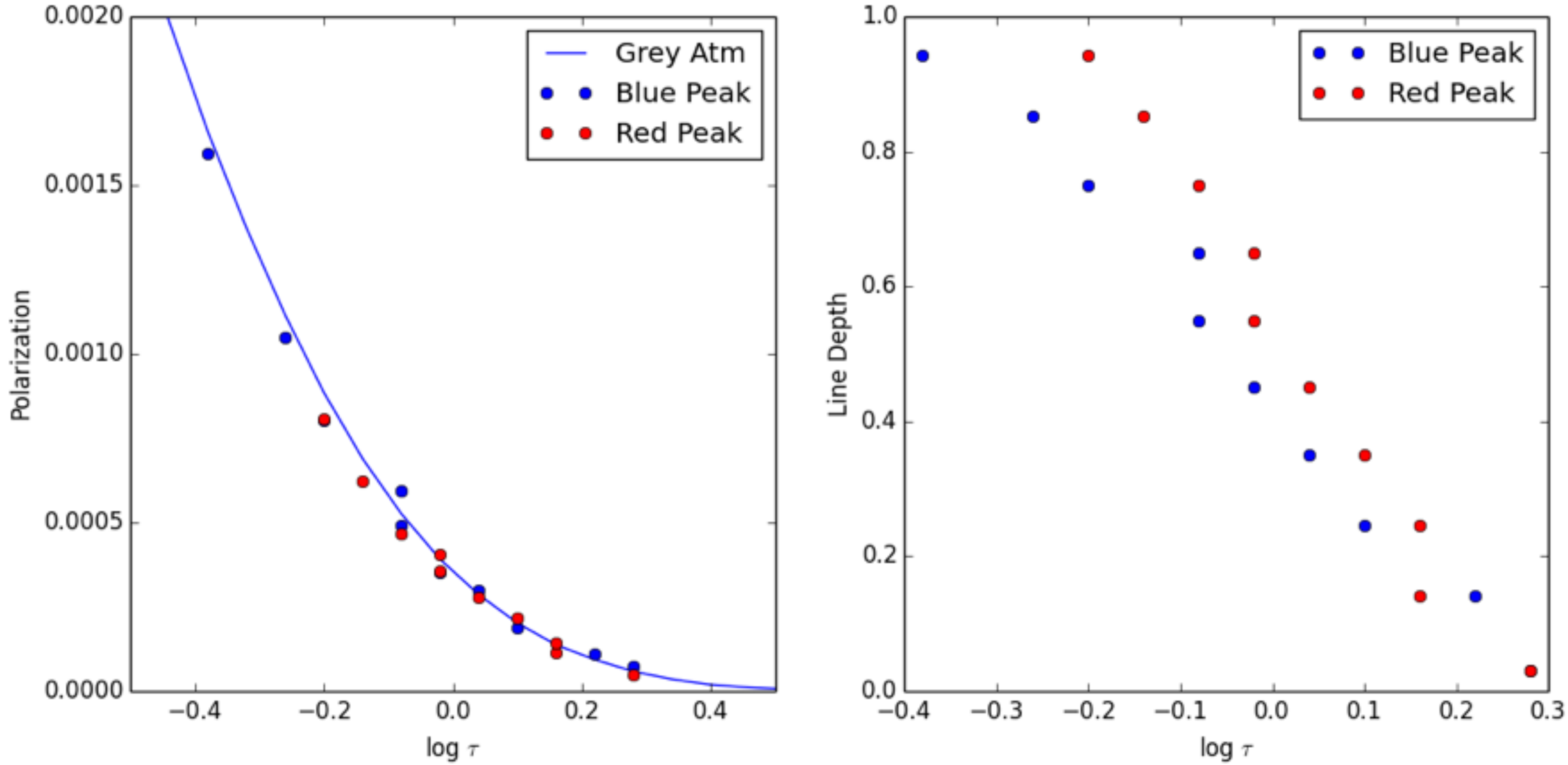
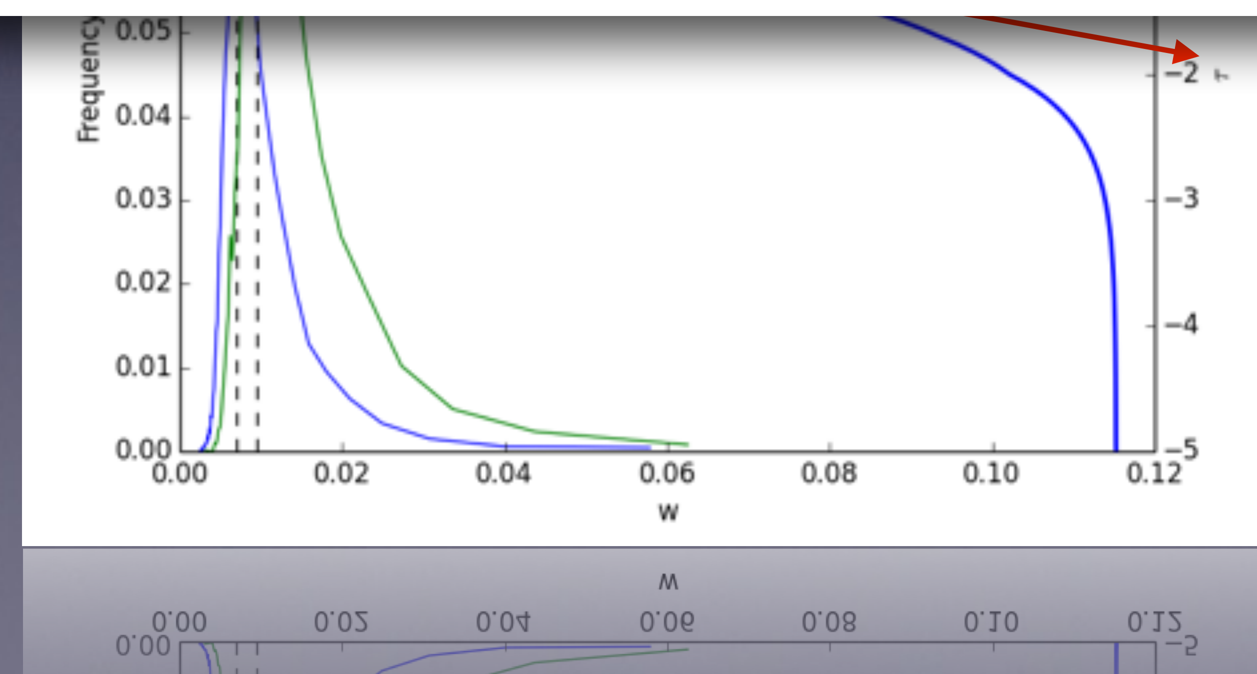
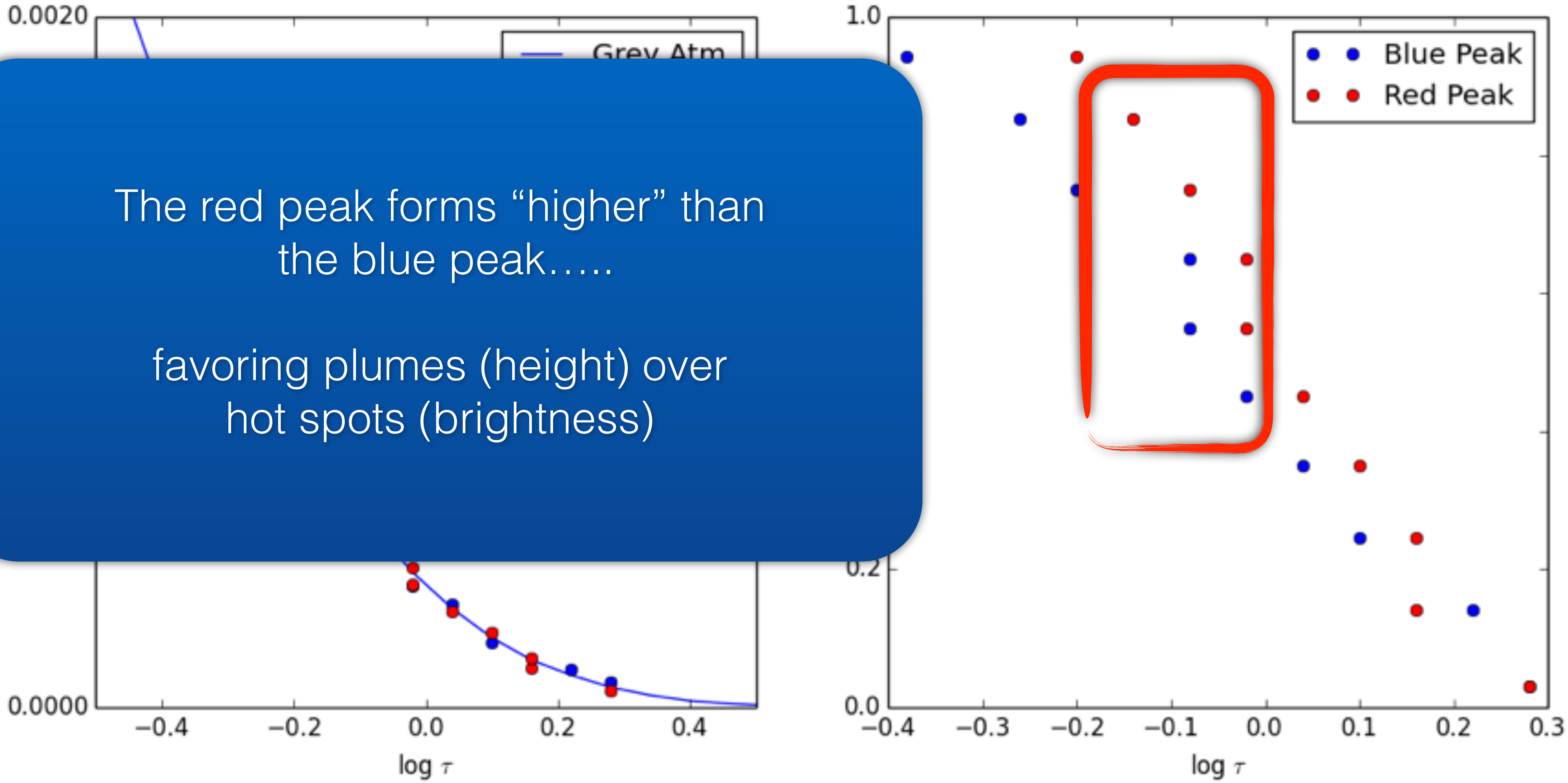


and go over every single line

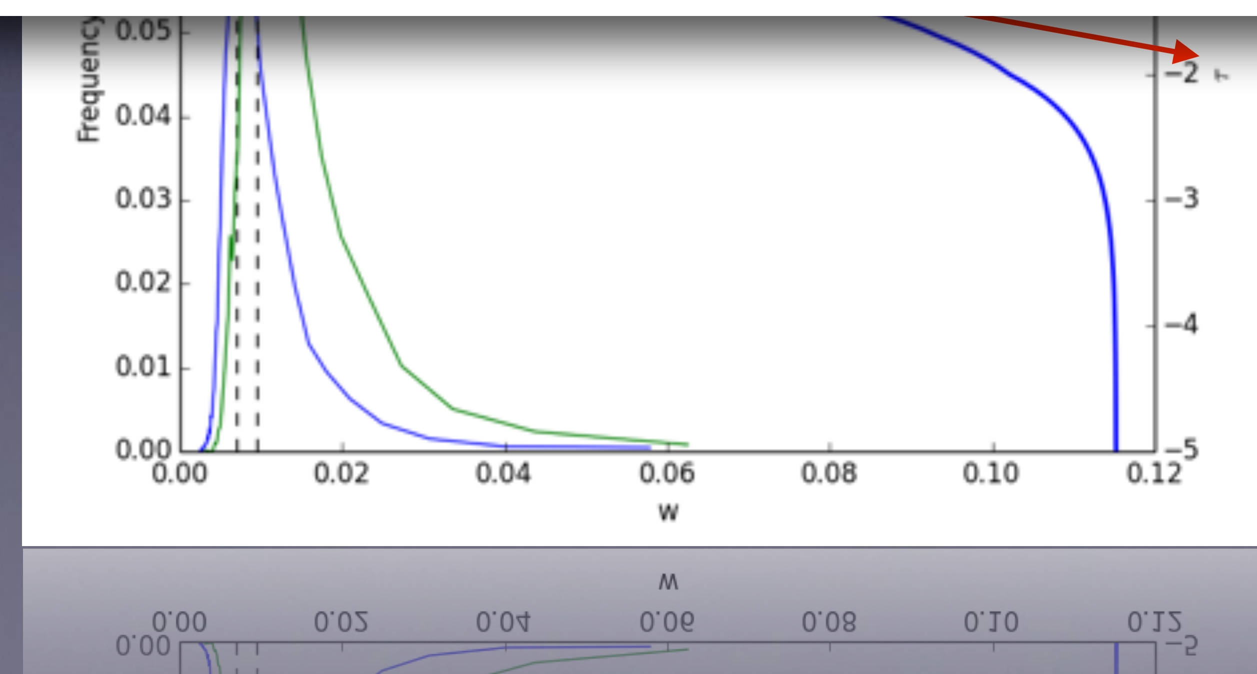


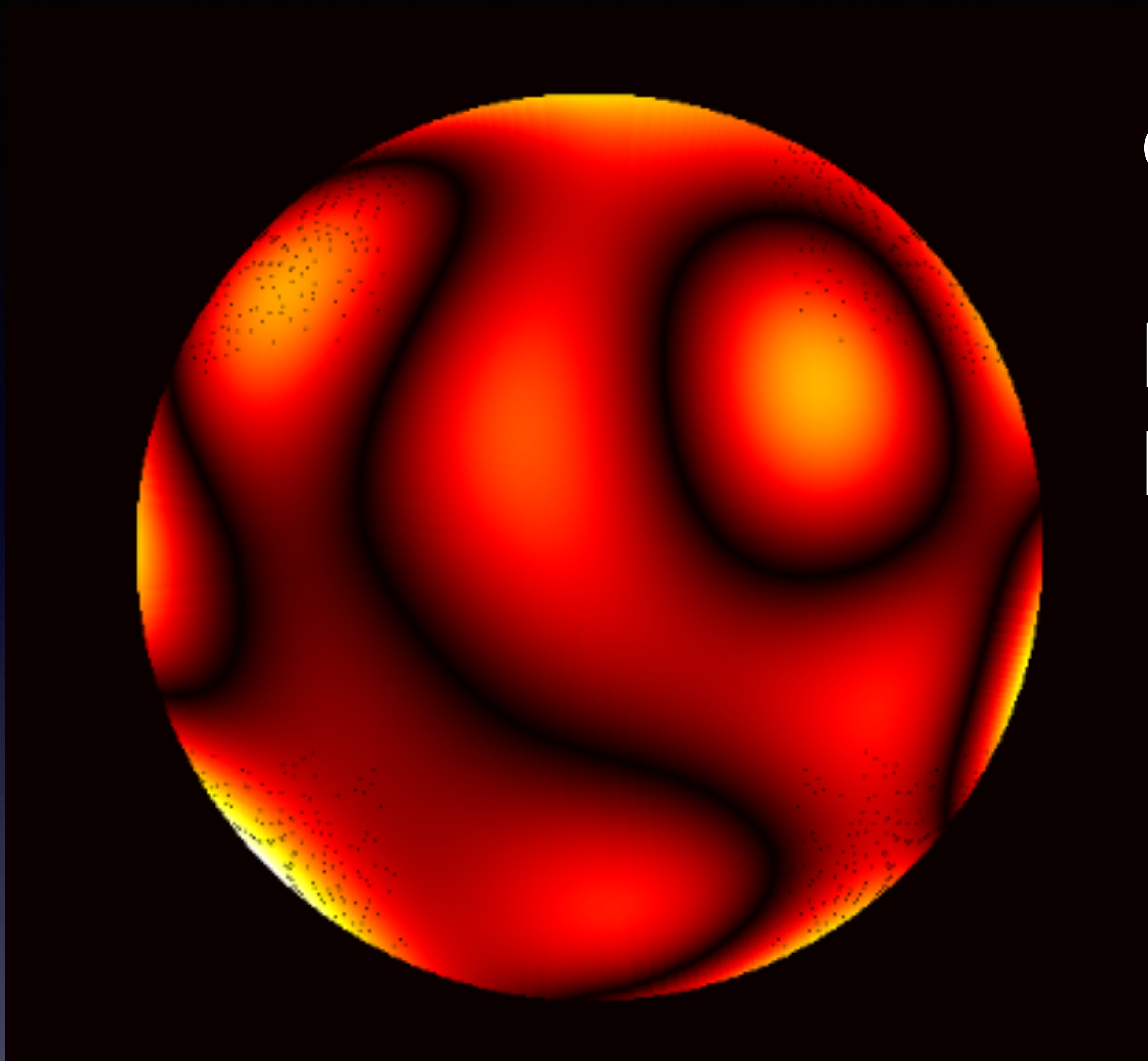


The red peak forms “higher” than the blue peak…..

favoring plumes (height) over hot spots (brightness)

and go over every single line





I'm showing brightness distributions….

How is velocity related to brightness?

1. Bright=Hot=Raising

2. Bright=High…raising or sinking

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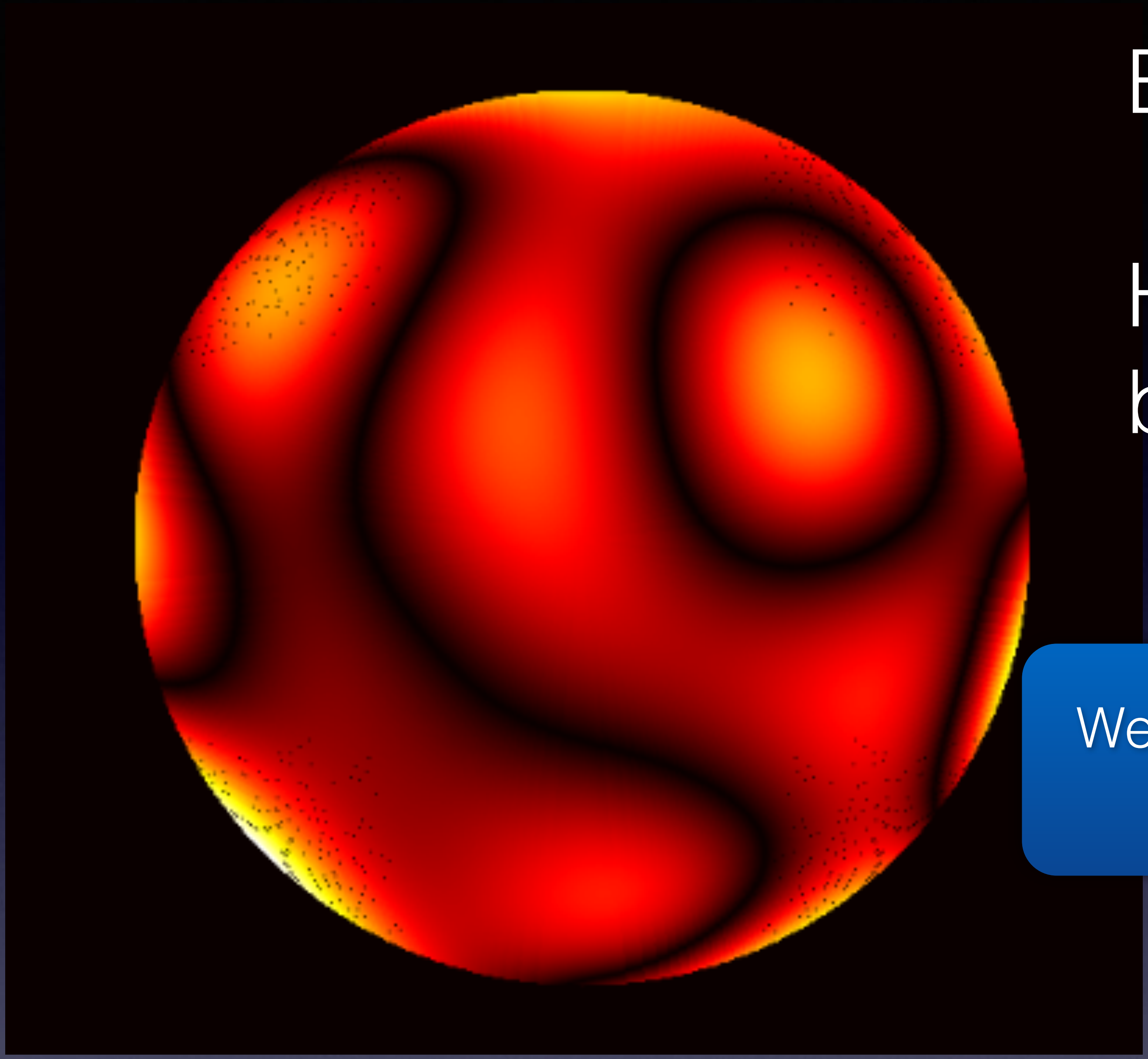

Brightness or height?

How is velocity related to brightness?

We see convective plumes as bright colors

1. ~~Bright=Hot=Raising~~

2. Bright=High…raising or sinking

27/11/2013