The formation of the O I 1355.6 Å and C I 1355.8 Å lines in the solar atmosphere and their potential diagnostics

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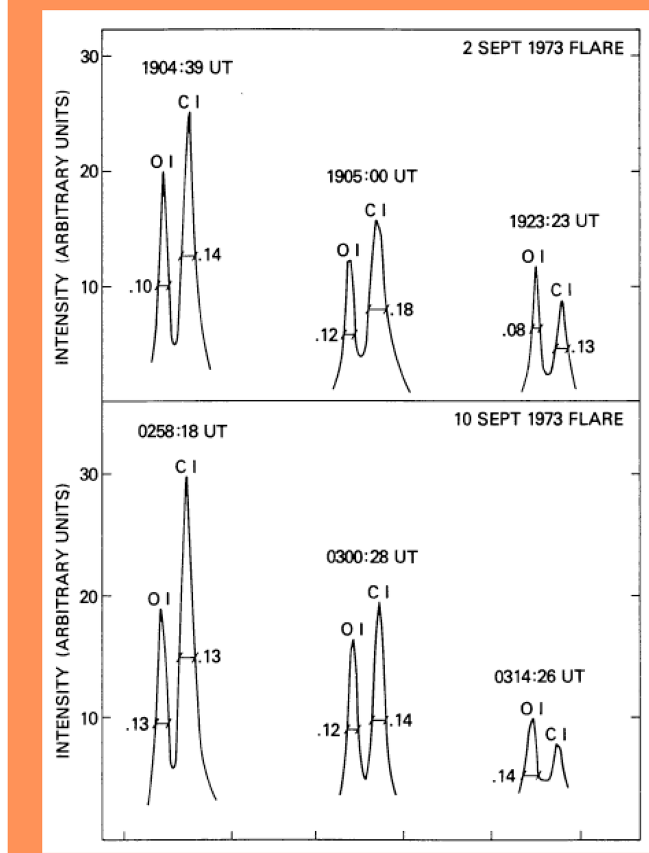
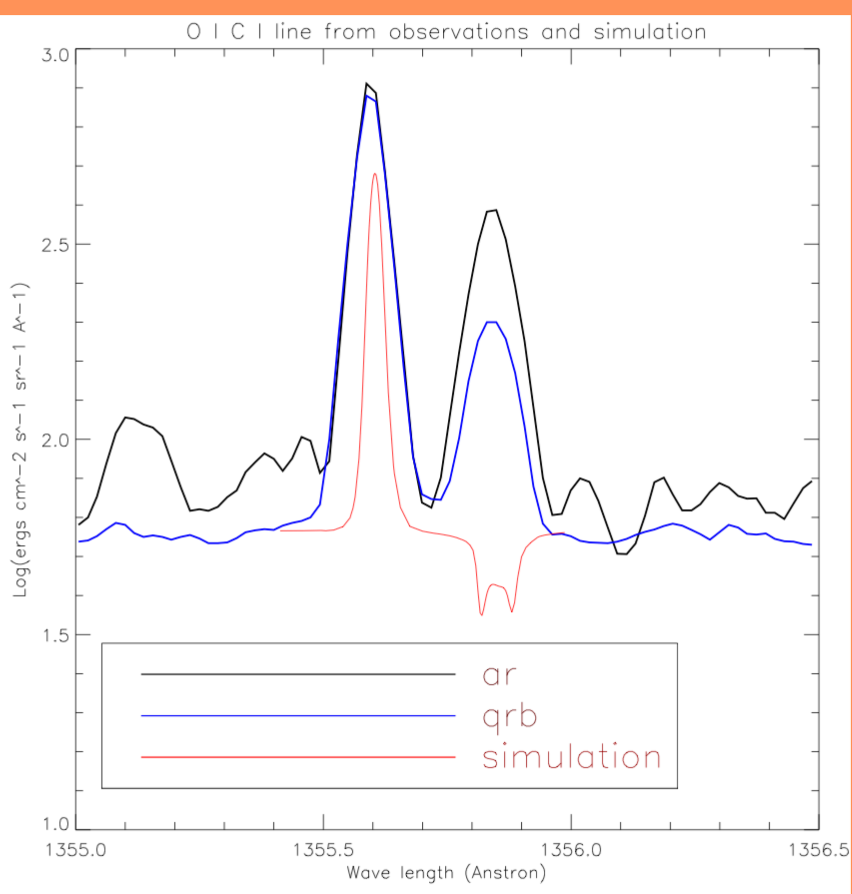
Introduction & Motivation



Skylab data from 1973: C I /O I ratio changes drastically during and after solar flare.



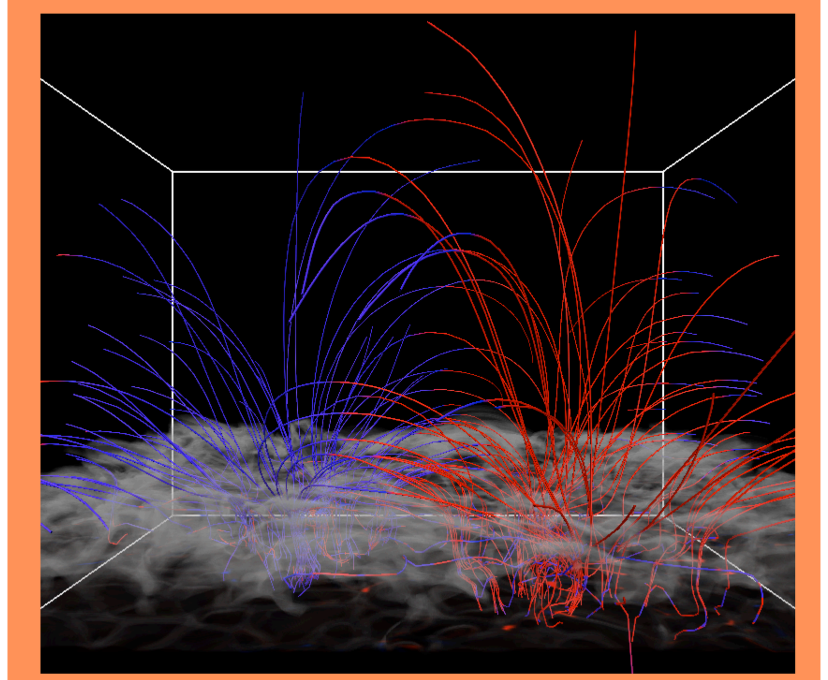
From the HRTS data[5], we also have the data for quiet sun (qrb) and active region (ar), plotted along with our simulation.

The ratio between the C I 1355.8 Å permitted line and the O I 1355.6 Å intersystem line has been reported having strong enhancement during a solar flare([1],[2]). It was suggested that the huge enhancement of the C I line indicates the flaring region where these lines originated should have high electron densities. The left plot shows the observation during a solar flare, where the C I / O I ratio exceeds one. The right plot shows the line profile of the O I and C I from quiet sun (qrb) and active region (ar), from which one can also see the difference of the line ratio. This phenomenon requires more detailed study as these two lines are observed by the NASA/SMEX mission Interface Region Imaging Spectrograph (IRIS).

We show our averaged line profile from the simulations together with HRTS data. The averaged C I absorption profile comes from the 6% of our simulation which produce very strong absorption, while 73.7% of the data is pure emission, hence dominate the averaged profile. The statistical study in this work is therefore still trust worthy.

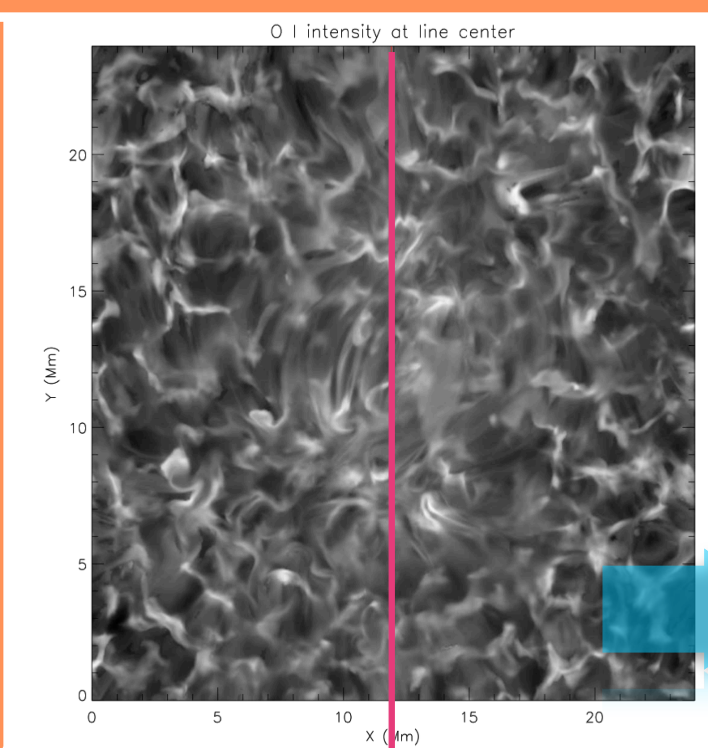
Method

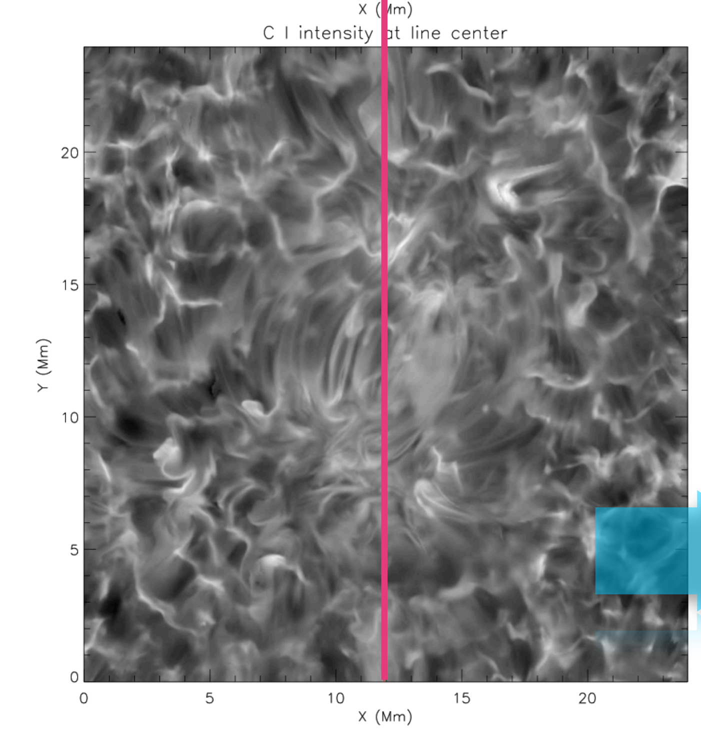
The model atmosphere is a snapshot of a 3D radiation-MHD simulation performed with the Bifrost code[6], which covers 24x24x16.8Mm^3 with 504x504x496 cells. This snapshot represents the quiet sun with two opposite magnetic poles. The picture below shows the 3D nature of such a simulation in general.



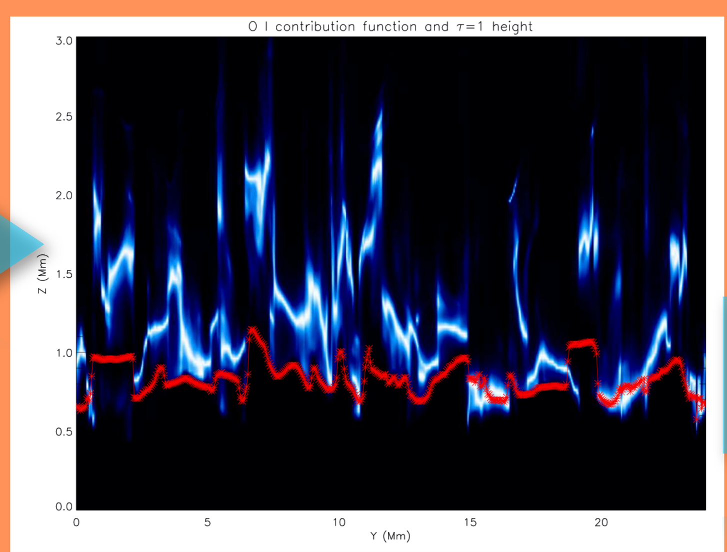
We have run a full radiative transfer simulation with the RH code [3], using O I model atom [4], and C I model atom (current work). The 1.5D simulation was performed in this work with 254016 columns.

Data analysis



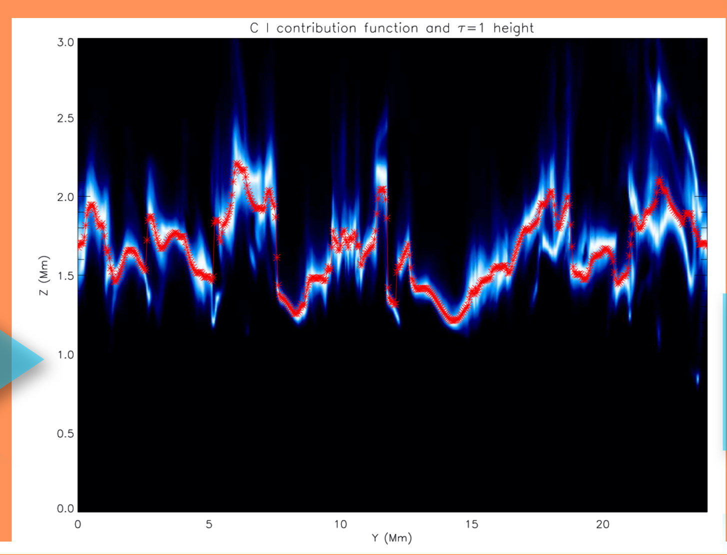


Left plots show the line core intensities of O I and C I. Along the red cut we plot the corresponding contribution function below. On top of them the red line-dots trace the optical one depth.



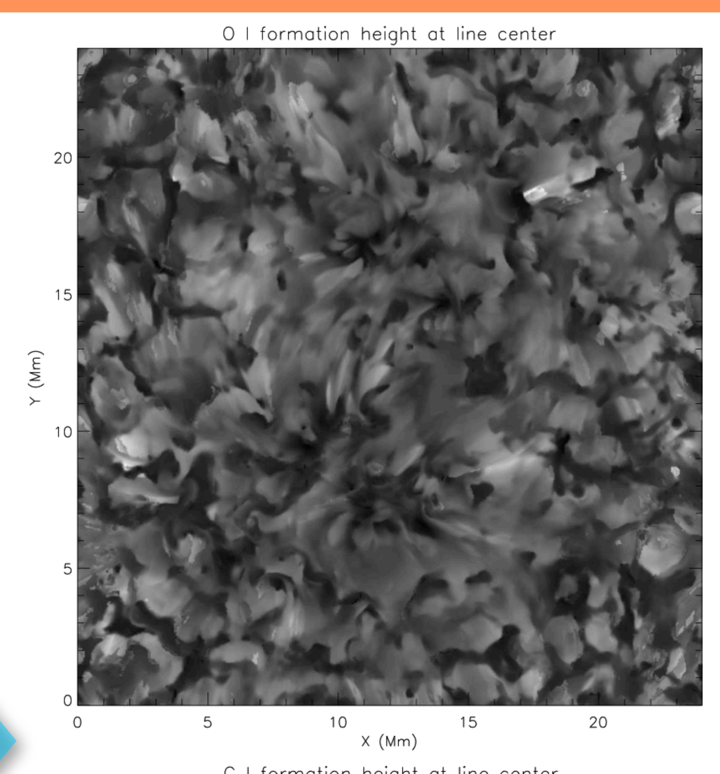
O I line is optically thin as the first moment of the contribution function departs from the optical one depth. In this case O I forms over a wilder range.

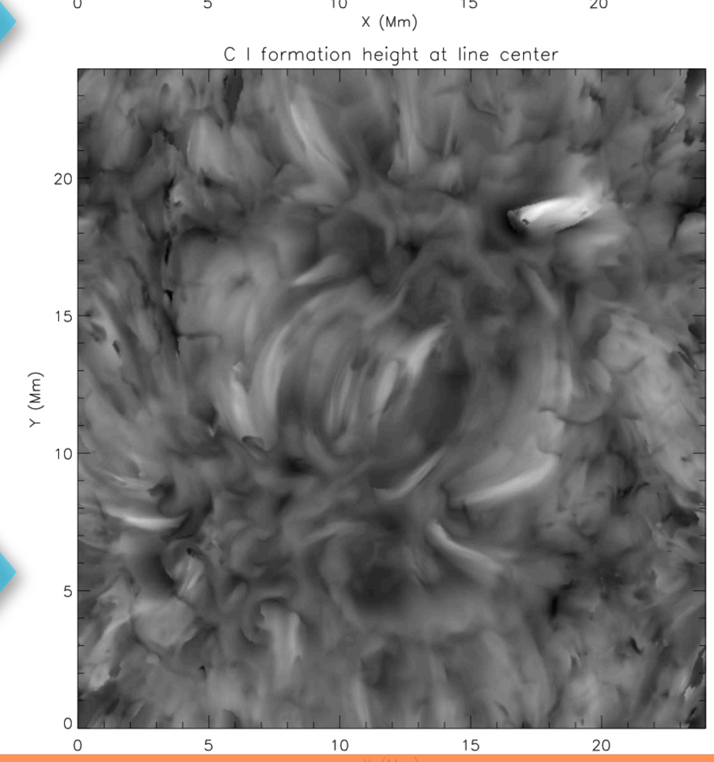
First moment of the contribution function defines formation height



C I line is optically thick as the first moment of the contribution function agrees with the optical one depth pretty well.

Optical one depth defines formation height



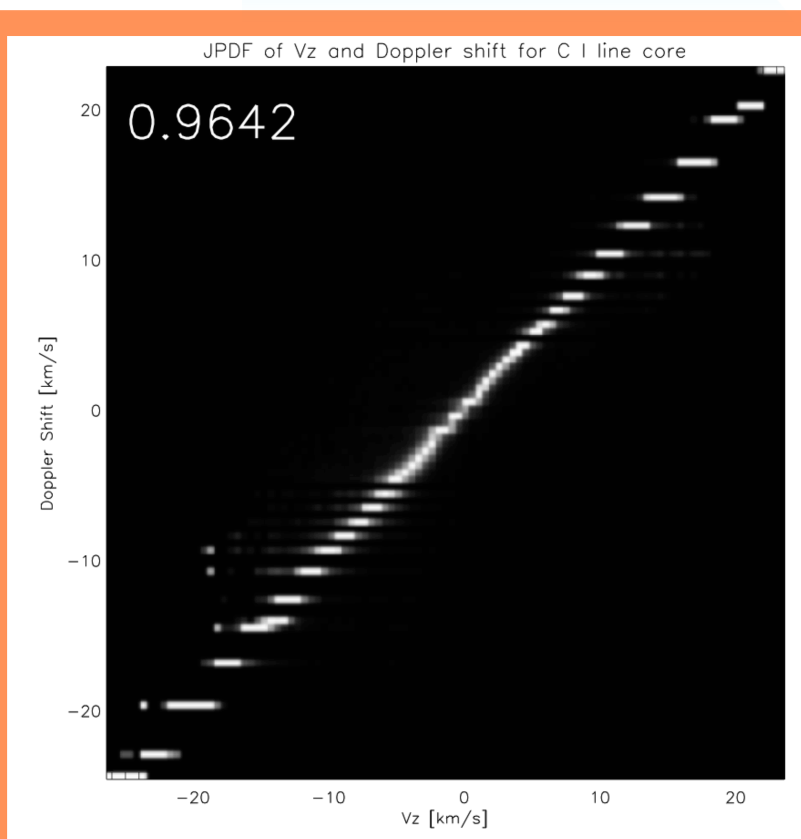


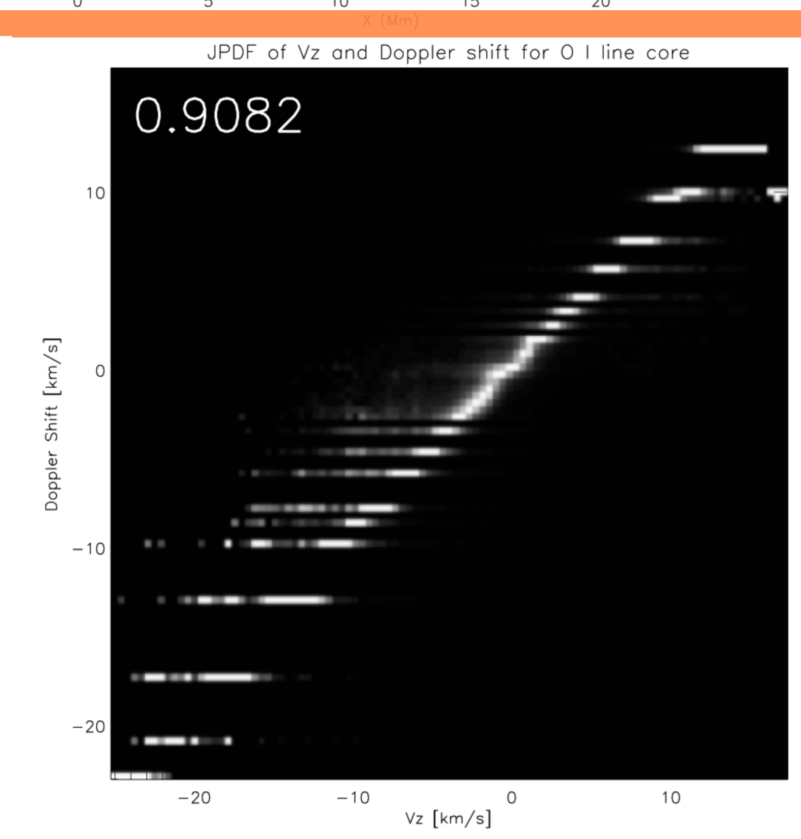
References

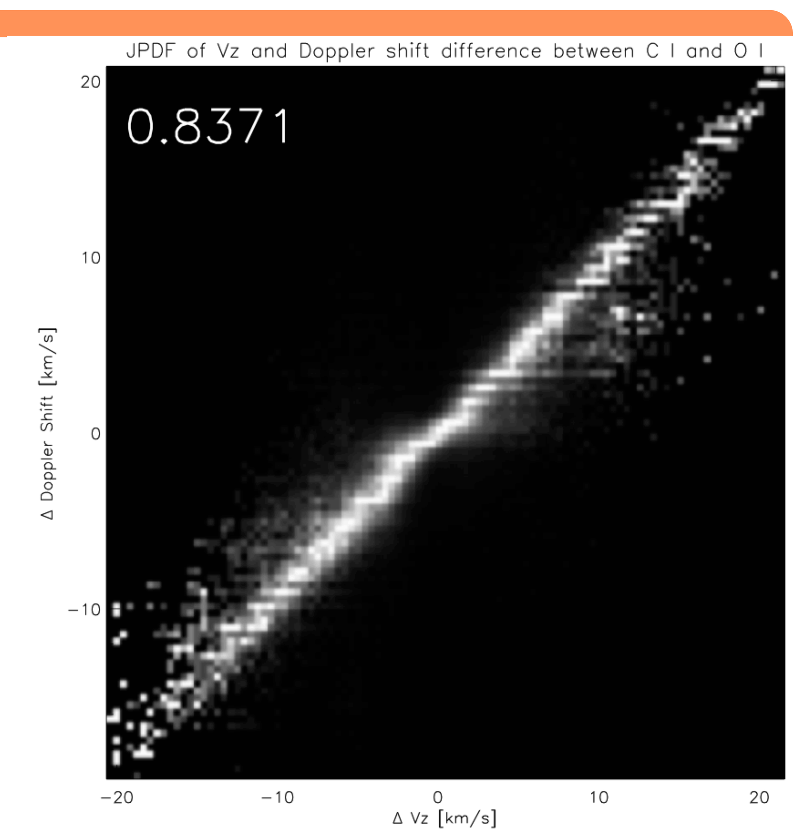
[1] Cheng, C. C. 1977 Solar. Phys. 56, 205
[2] Cheng, C. C., Feldman, U., & Doschek, F. A. 1980 Astron. Astrophys.
[3] Uitenbroek, H. 2001 ApJ. 557, 389
[4] Carlsson, M. & Judge, P.G. 1993. ApJ, 402, 344
[5] Brekke, P. Apj,1993,87:443-450
[6]Gudiksen,B. V., Carlsson, M., Hansteen, V. H., et al. 2011,A & A, 517,A49

Potential diagnostics

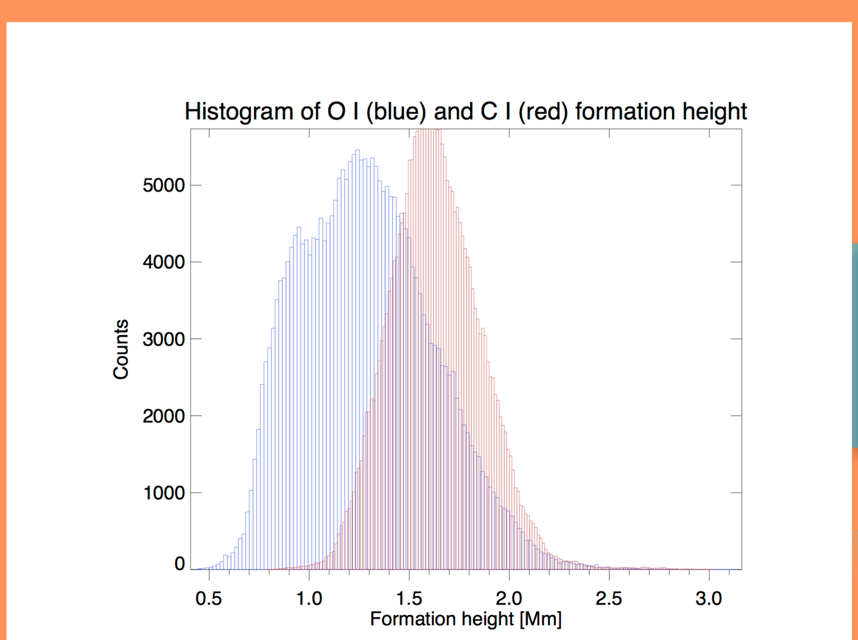
- C I and O I can be good ***velocity diagnostic*** individually.
- Tight relation between Doppler shift at line center and vertical velocity @ formation height. (correlation coefficient at left upper corner)
- C I and O I together can provide the information of the ***velocity gradient*** as they form at different height.

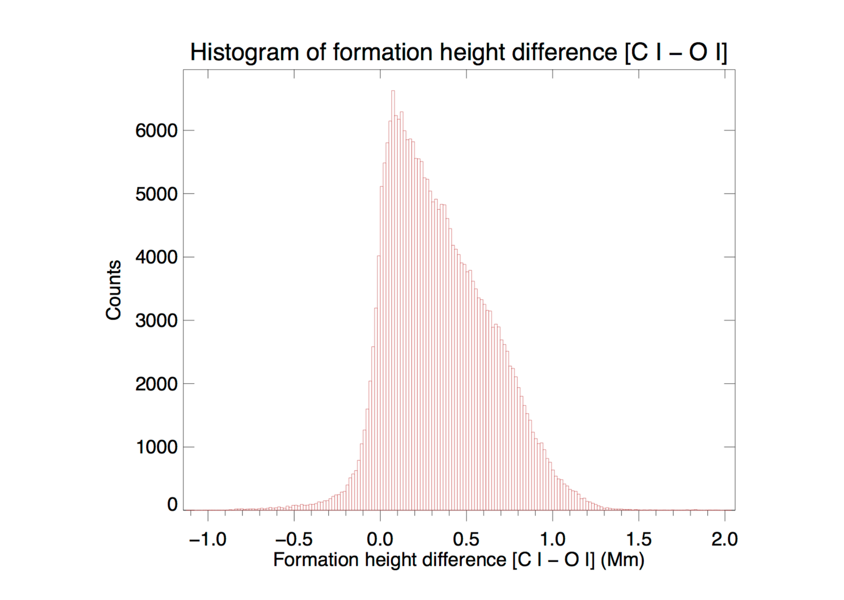






Question: where do those lines form? Can we get this information from observations?



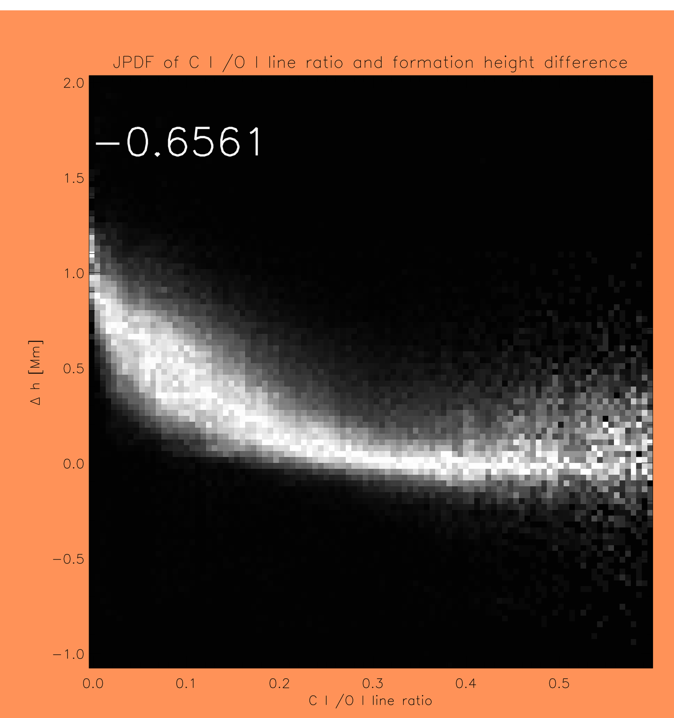


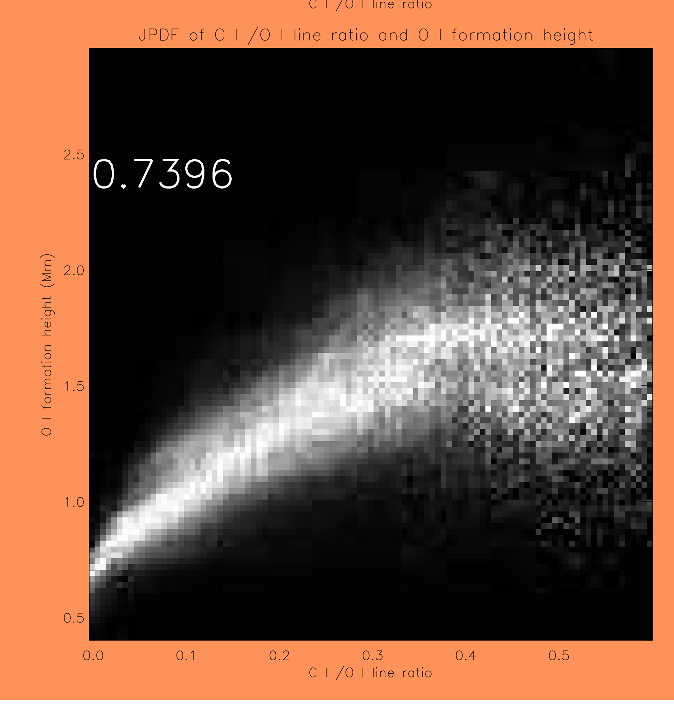
From the Histogram of the O I and C I formation height, we see C I forms generally higher than OI. The distribution of the difference between formation height also shows it is quite a distribution ranging from 0Mm to 1.5Mm.

Link between the formation height and the C I /O I line ratio if the ratio is < 0.6

Ratio C I / O I < 0.6 (97% data):

- OI formation height can be correlated with C I / O I line ratio.
- Formation height difference can also correlate with the line ratio.





General Guideline:

- Get Δ Vz from Δ Vz - Δ Doppler shift relation

If C I / O I intensity ratio < 0.6:

Get Δ h from the Ratio-formation difference relation

- Velocity gradient (Δ Vz /Δ h)

Get O I formation height from Ratio - O I formation relation

- Location of the velocity gradient