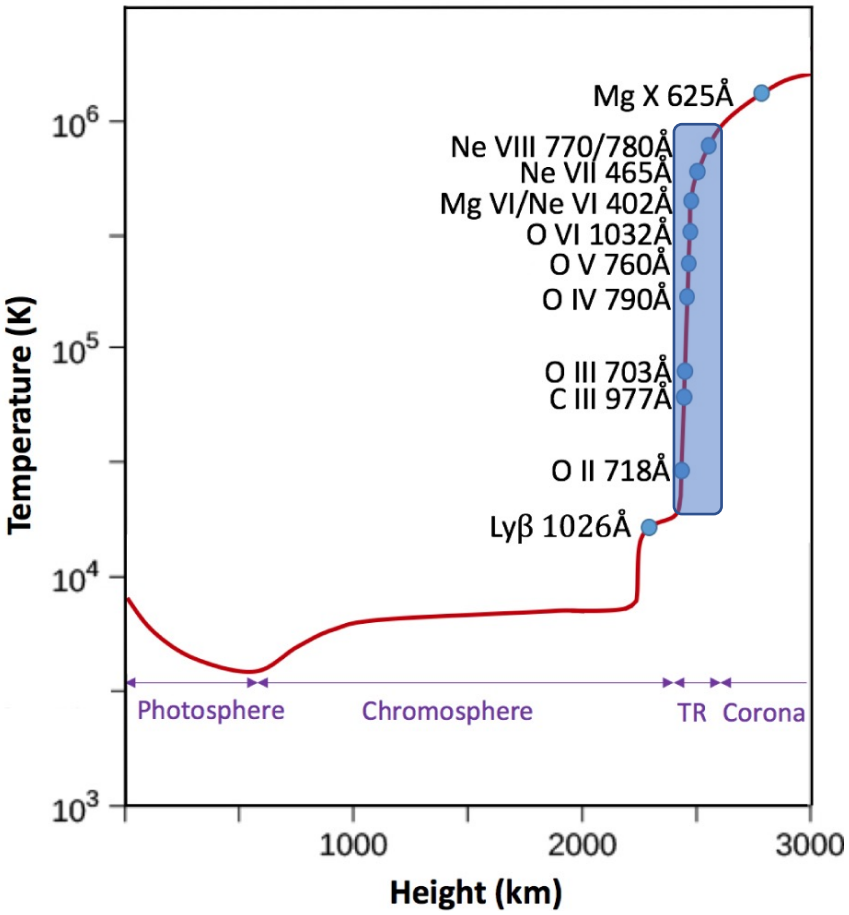
Doppler shifts of spectral lines formed in the solar transition region and corona

Yajie Chen[1,2], Hardi Peter[1], Damien Przybylski[1], Hui Tian[2], Jiale Zhang[2]

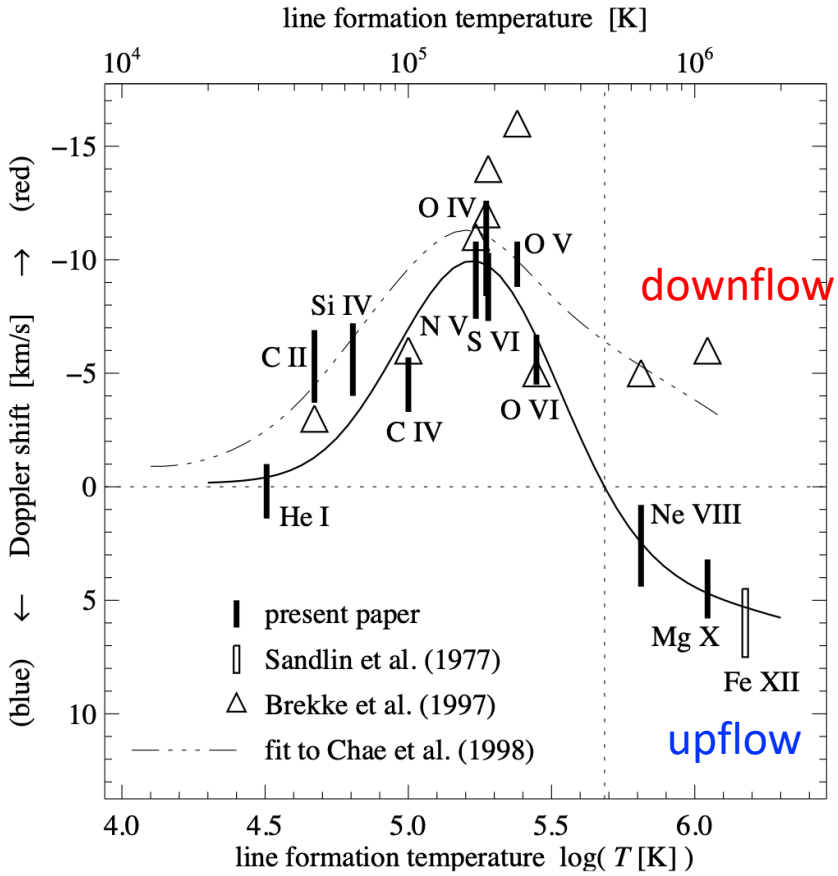
[1]Max Planck Institute for Solar System Research

[2]School of Earth and Space Sciences, Peking University

Solar transition region

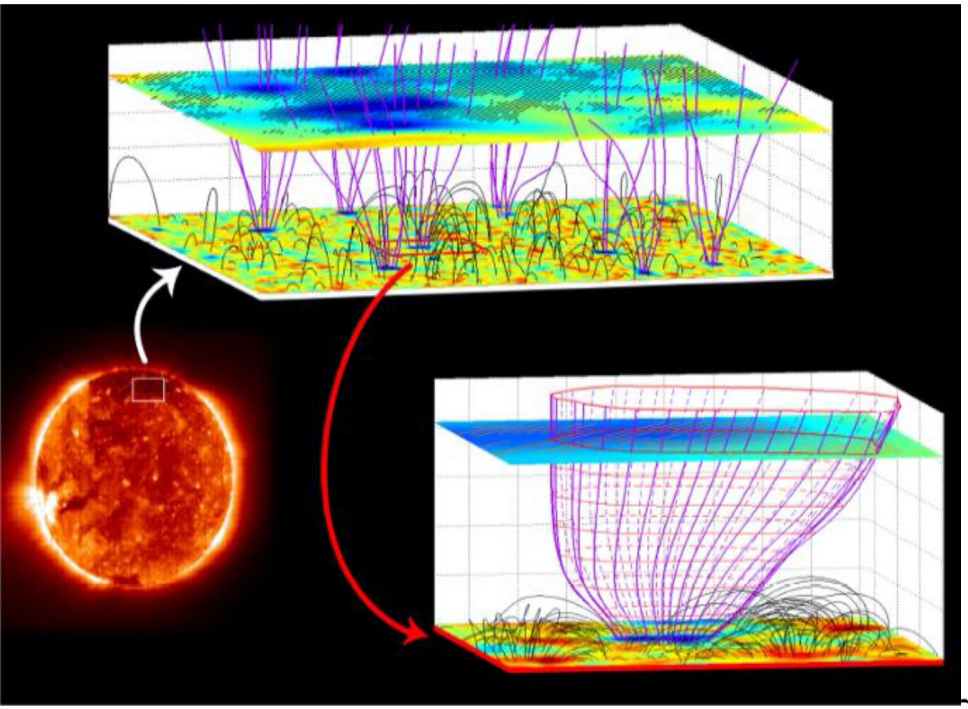


Tian 2017, RAA

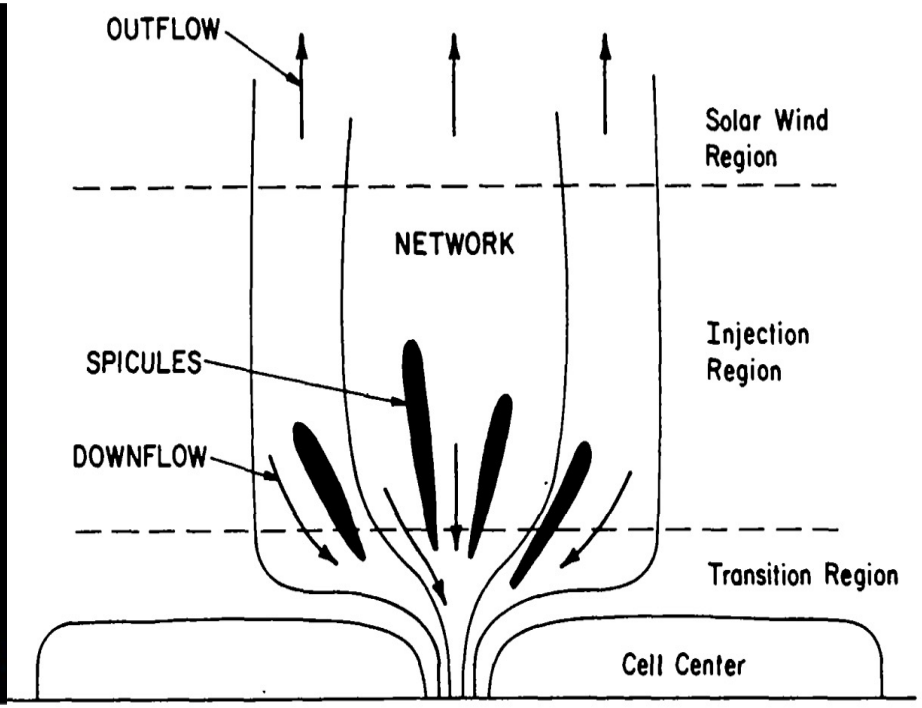


Peter & Judge 1999, ApJ

Doppler shifts of the transition region line

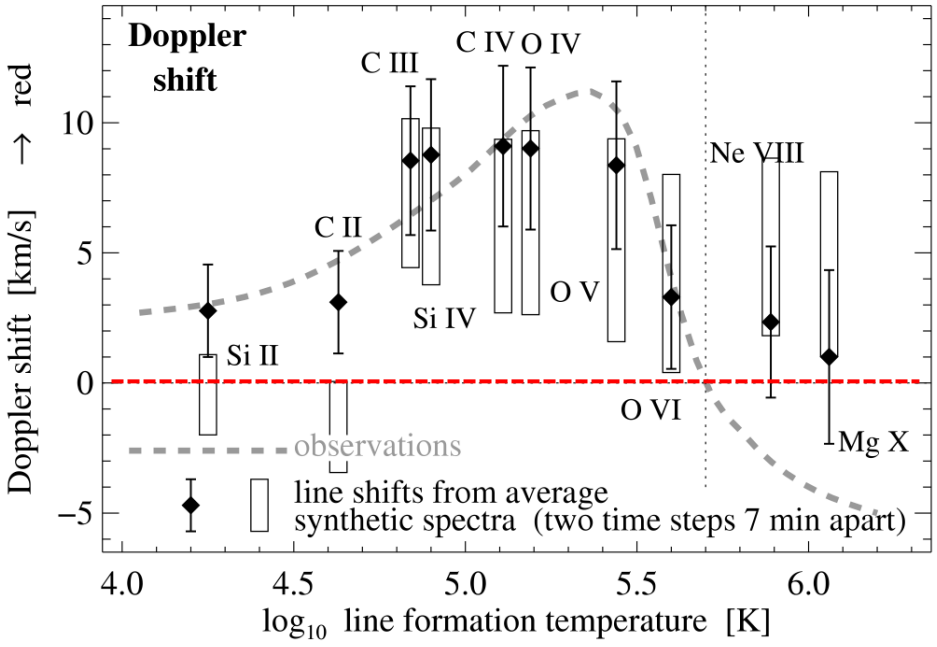


Tu et al. 2005, Science

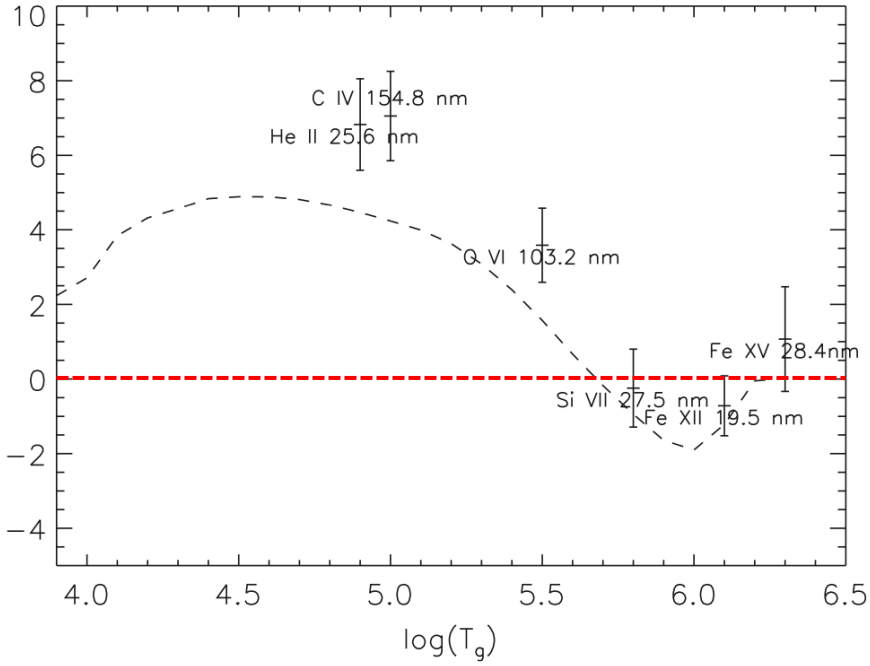


Pneuman & Kopp 1978, Solar Physics

Doppler shifts of spectral lines in previous 3D models



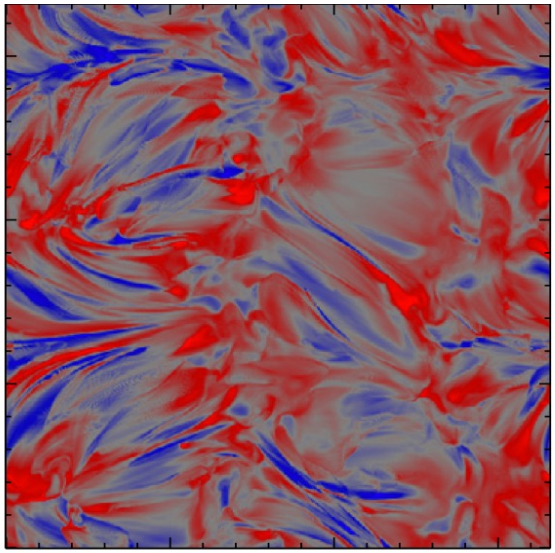
Peter et al. 2006, ApJ



Hansteen et al. 2010, ApJ

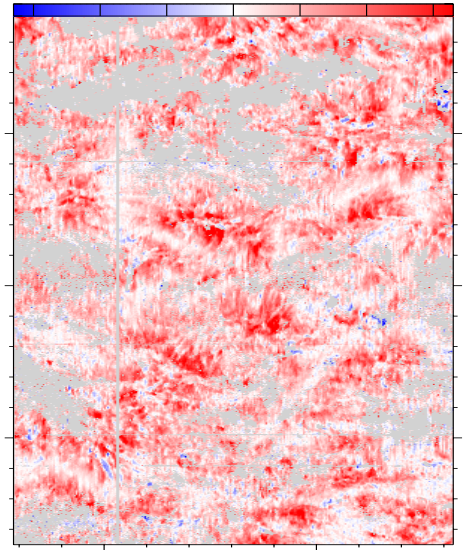
Doppler shifts of the transition region line

Previous model

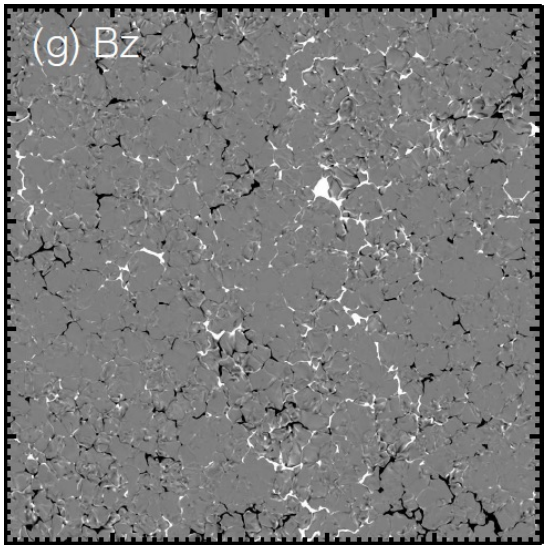


Hansteen et al. 2010, ApJ

IRIS observations



Current model

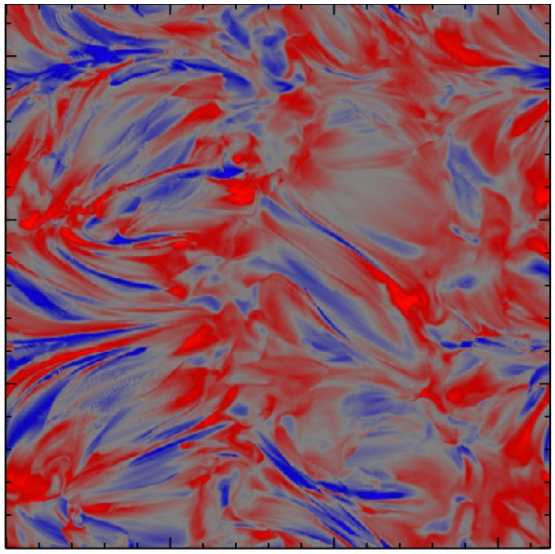


Chen et al. 2022, A&A

- We constructed a 3D radiation MHD model extending from the upper convection zone to the lower corona.
- Our model self-consistently maintains network fields and allows a steady corona of 1 MK.

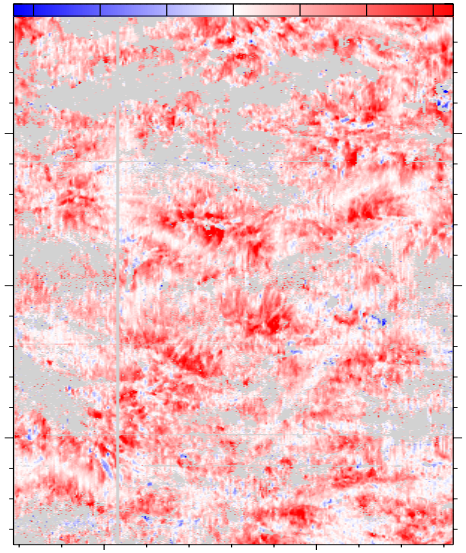
Doppler shifts of the transition region line

Previous model

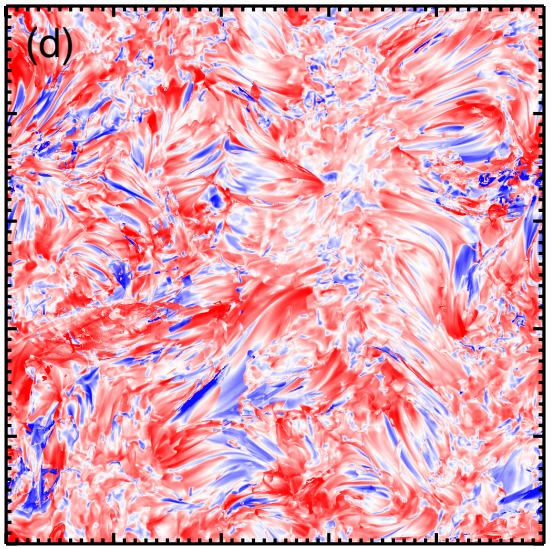


Hansteen et al. 2010, ApJ

IRIS observations



Current model



Chen et al. 2022, A&A

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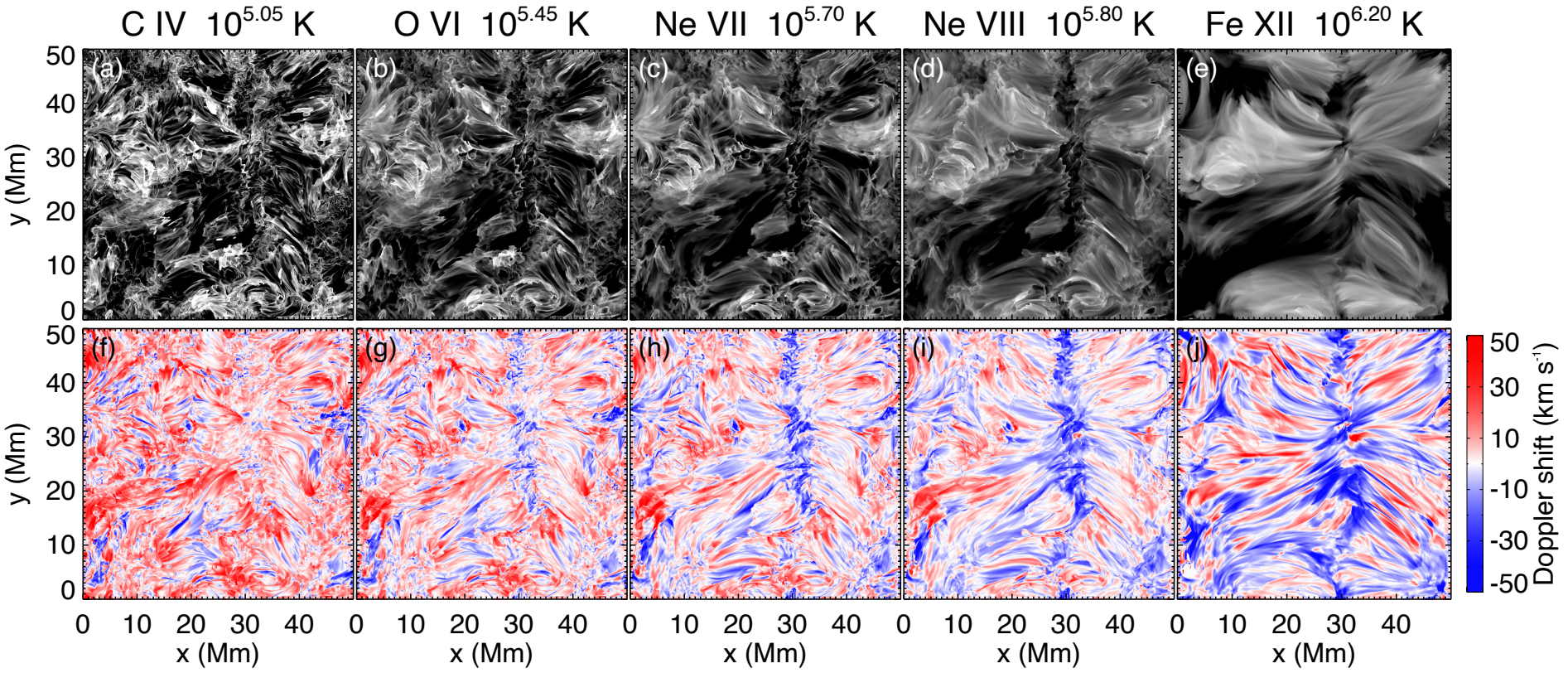
- Our model self-consistently maintains network fields and allows a steady corona of 1 MK.
- The model shows a clear imbalance of area coverage of redshifts in the transition region.

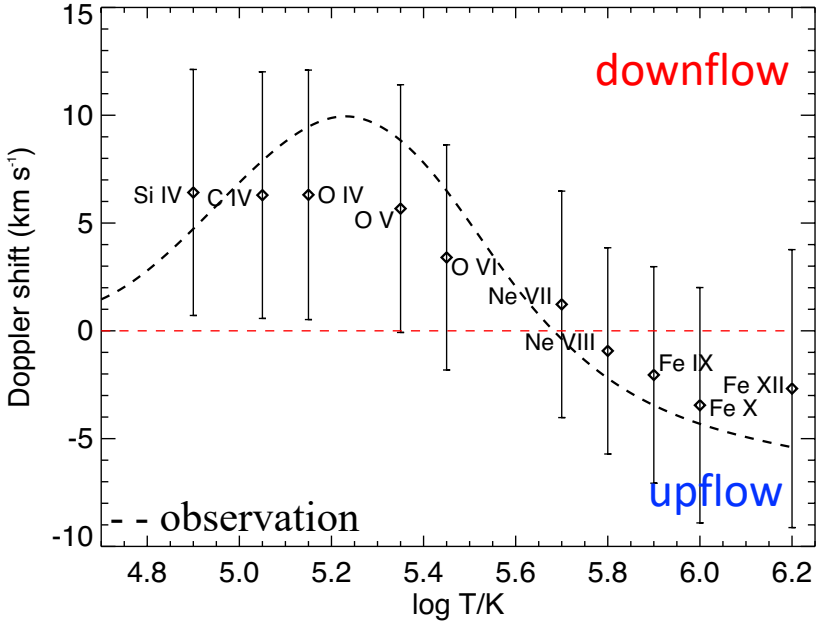
Maps of intensity and Doppler shifts for different lines

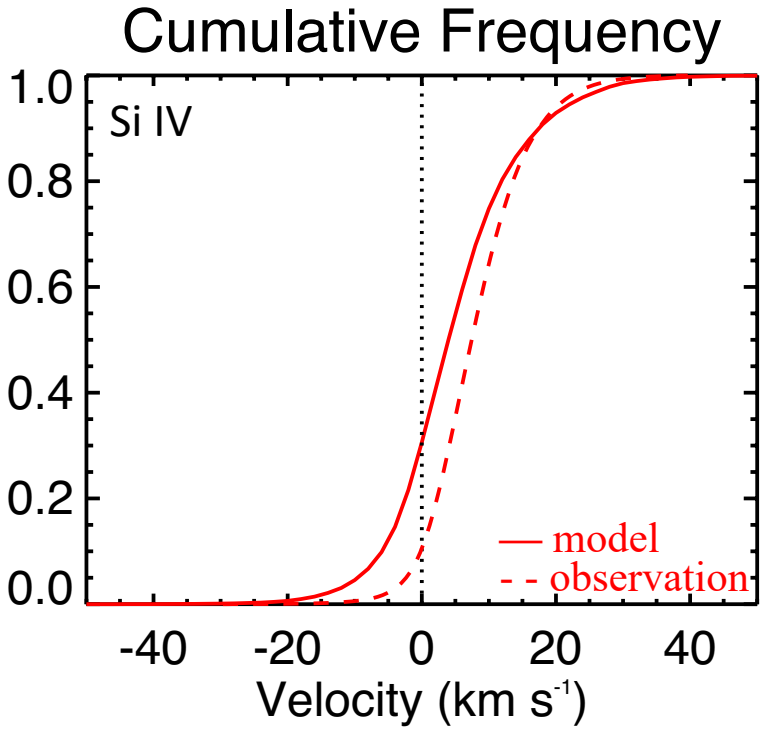


Transition region → Corona

redshifts → blueshifts

Doppler shifts of spectral lines in our model

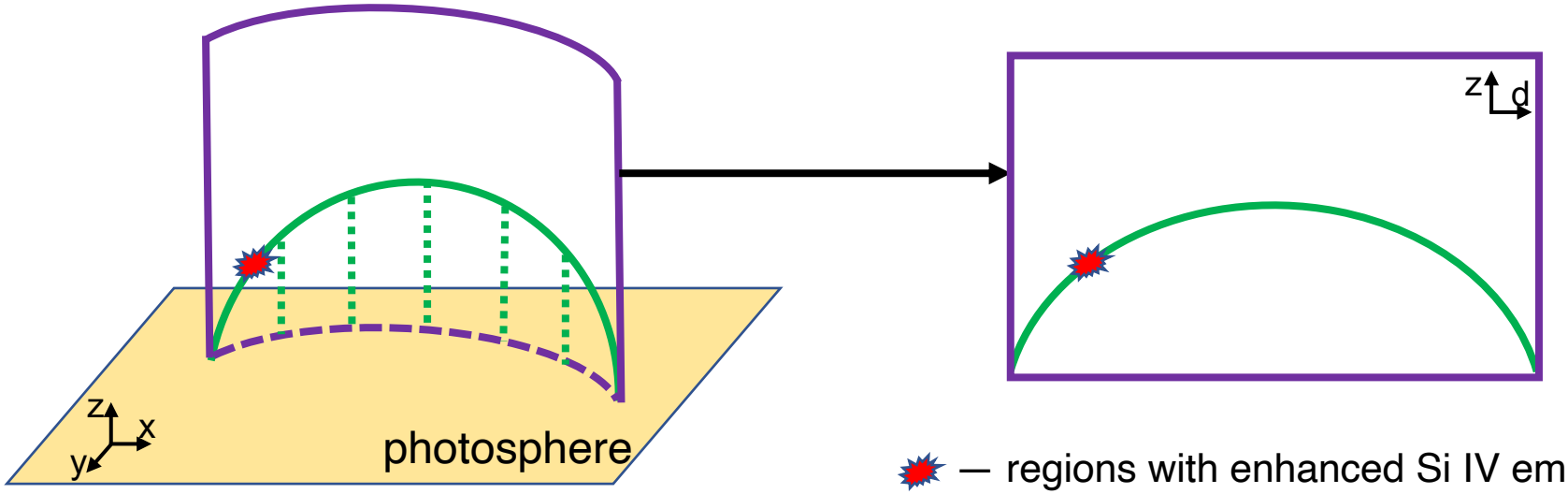




- Transition region lines show an average net redshift (✓)
- The net Doppler shifts change from red in the transition region to blue in the corona (✓)
- Transition region lines show redshifts almost exclusively (✓), and only ca. 10% of the quiet Sun is covered by blueshifts (✗)
- Doppler maps show patterns reminiscent of nests of spicules (✗)

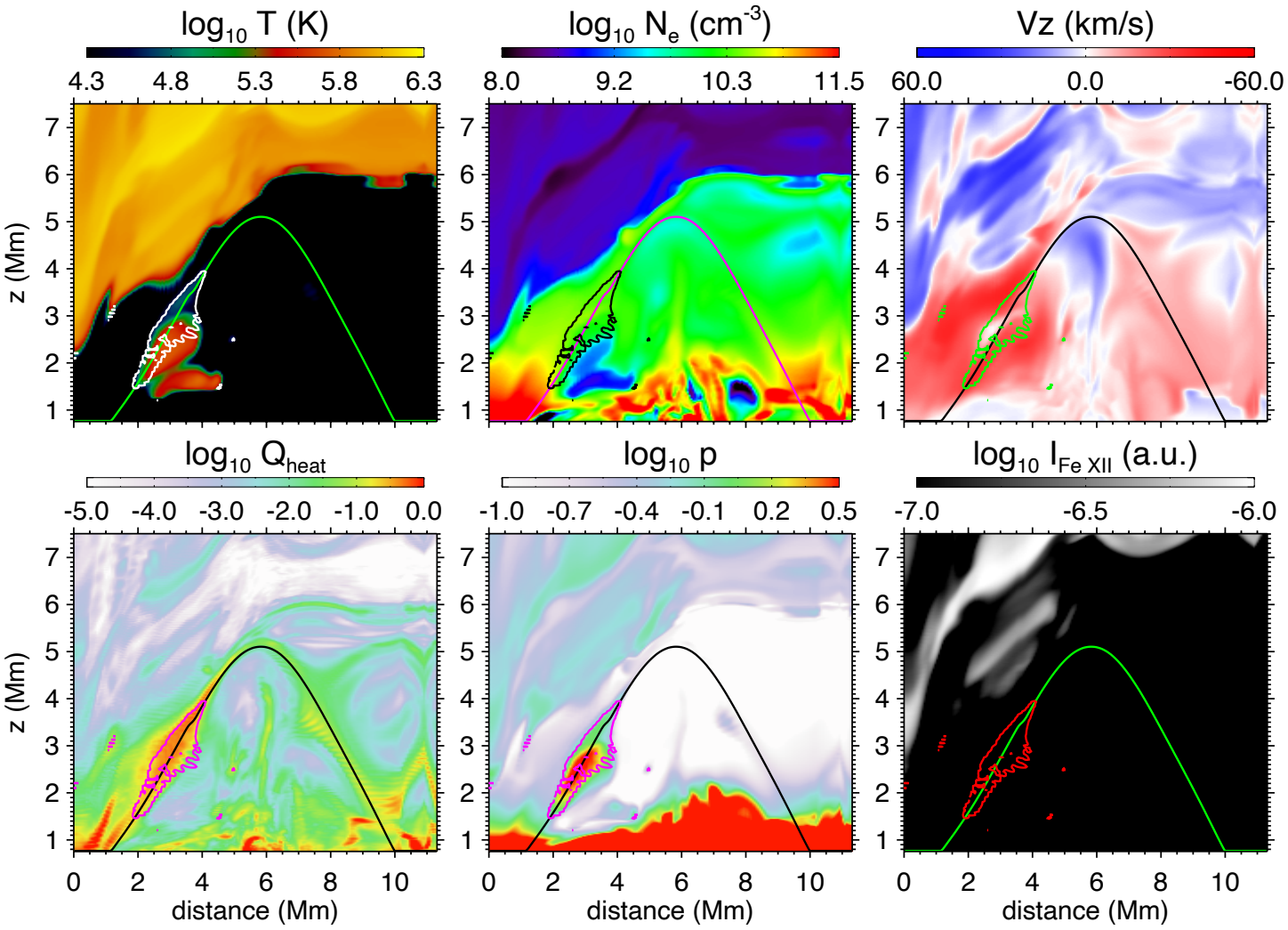
Missing physics? Limited spatial resolution?

Doppler shifts of spectral lines in our model



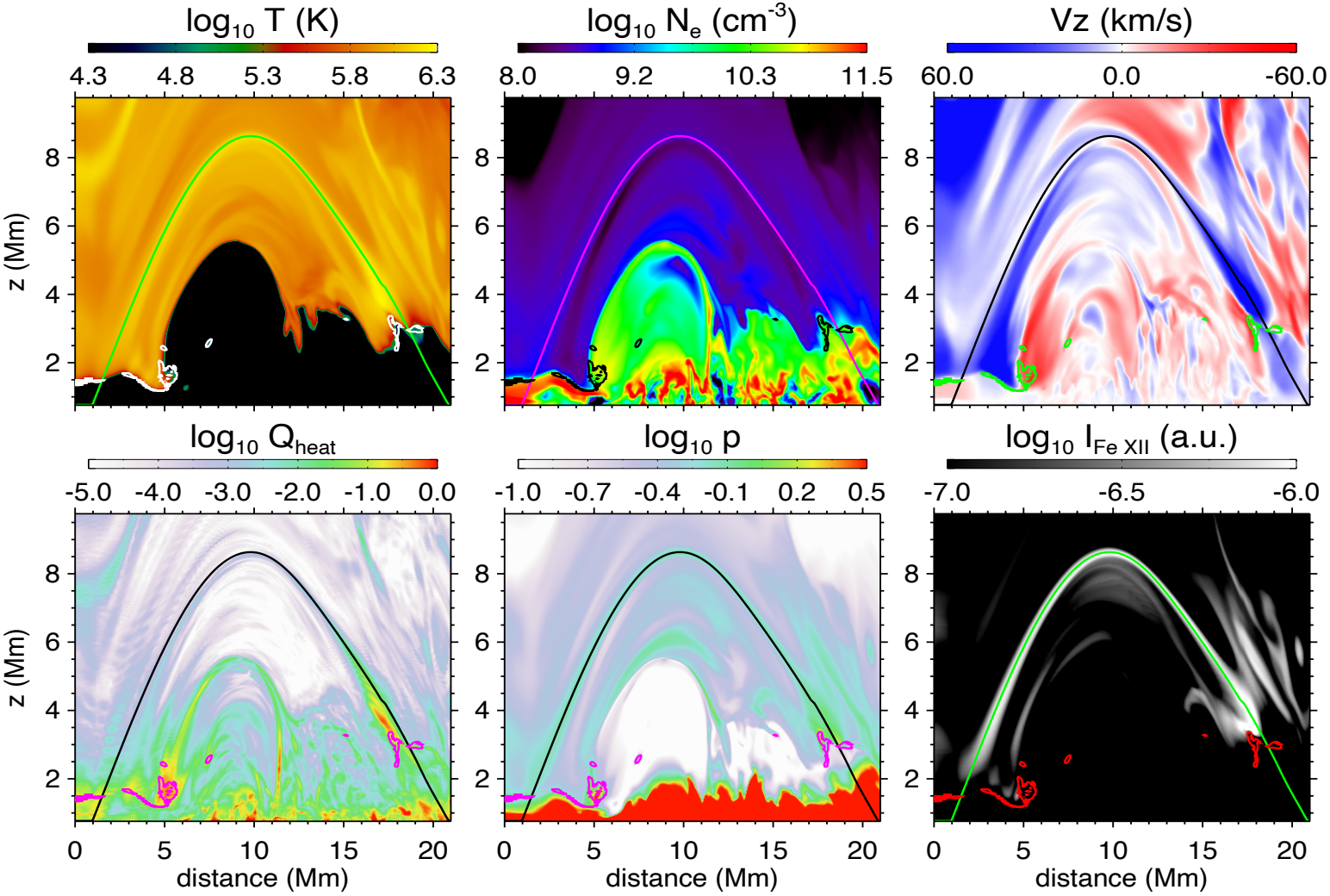
- Vertical maps of various properties in and around selected loops
- Processes contributing to Doppler shifts
  - ① transition region brightenings unrelated to coronal emission
  - ② pressure enhancement in the transition region
  - ③ siphon-type flows
  - ④ boundaries between cold and hot plasma

Processes contributing to Doppler shifts



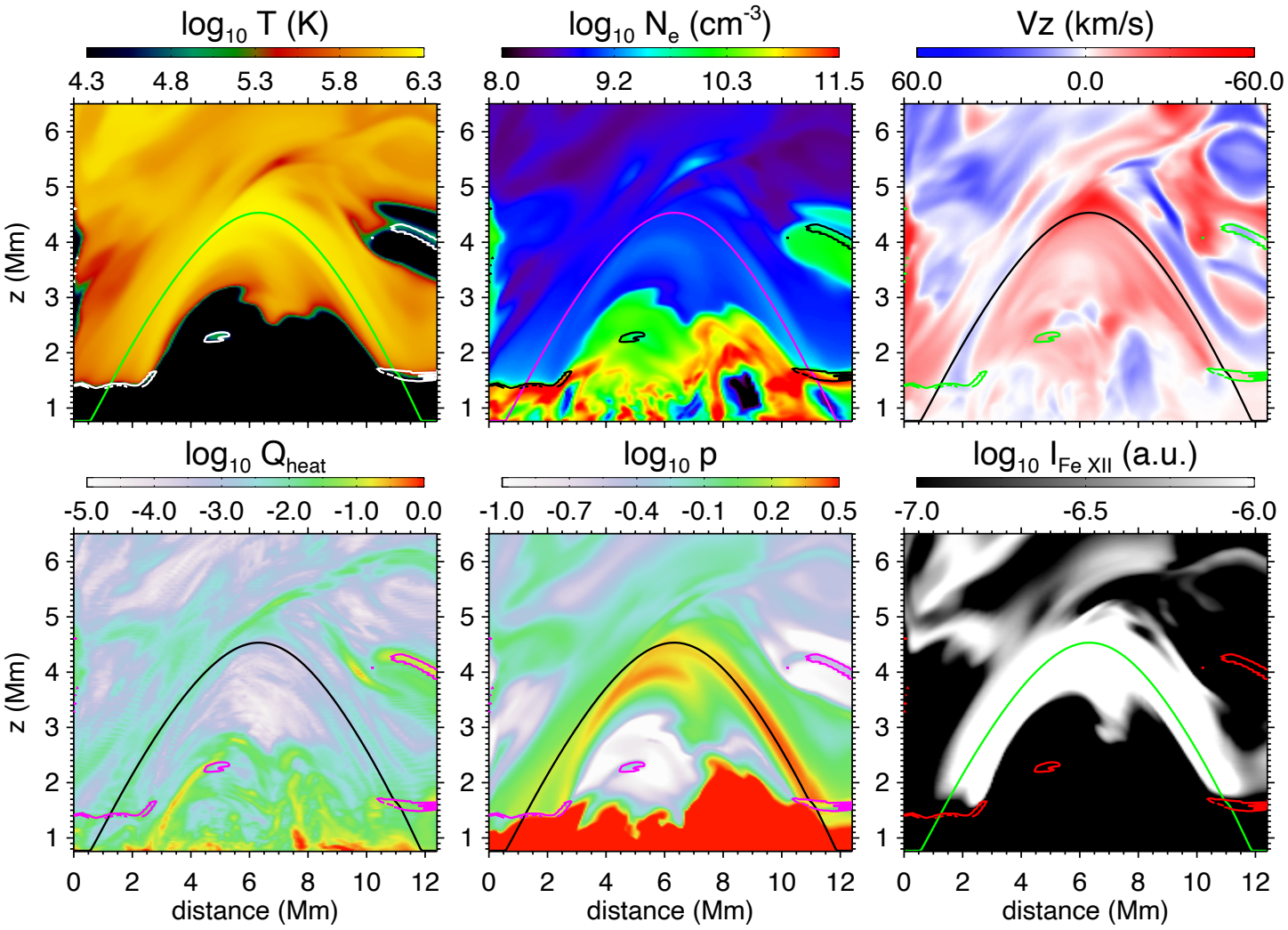
① transition region brightenings unrelated to coronal emission (30%)

Processes contributing to Doppler shifts



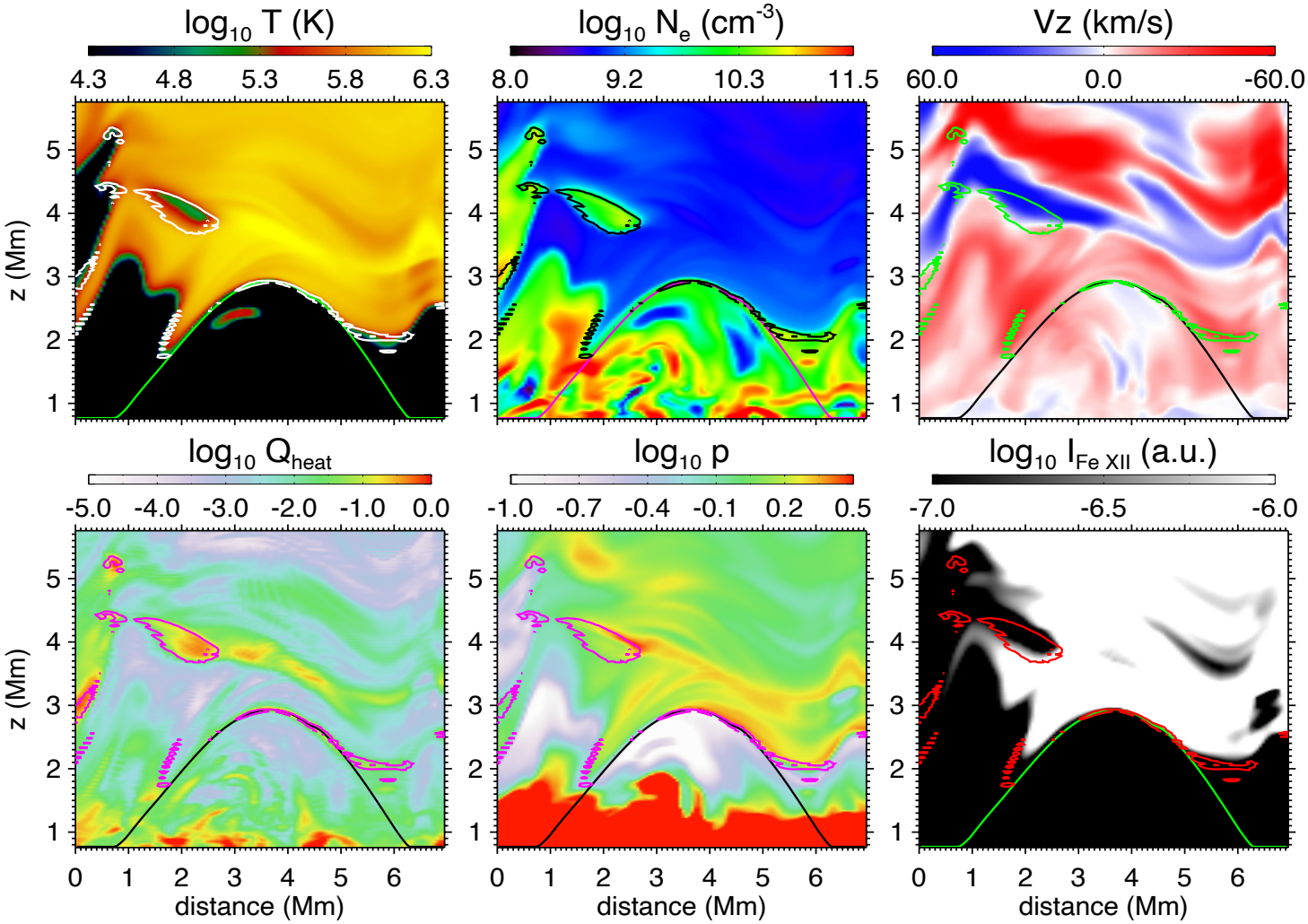
② pressure enhancement in the transition region (>50%)

Processes contributing to Doppler shifts



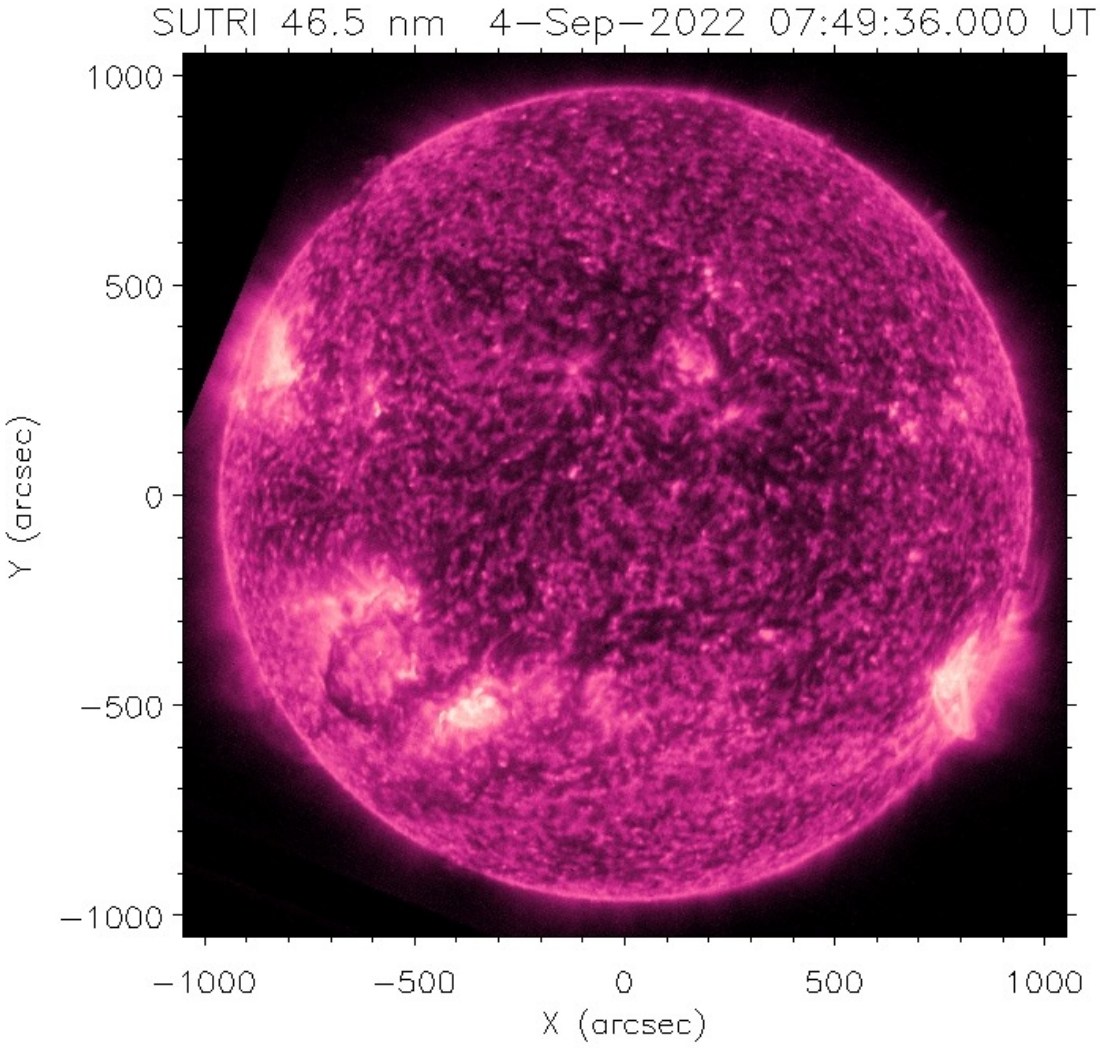
③ siphon-type flows (a few examples)

Processes contributing to Doppler shifts



④ boundaries between cold and hot plasma (14%)

Imaging observations of the Ne VII 465 Å line



Credit to Hui Tian (huitian@pku.edu.cn)

Conclusions

- We constructed a 3D MHD model, in which network fields and a steady corona of 1 MK is self-consistently maintained.
- Our model reproduces the observed change of average Doppler shifts from redshift in the transition region to blueshift in the corona.
- The model shows a clear imbalance of area coverage of redshifts versus blueshifts in the transition region.
- We determine that (at least) four processes generate the systematic Doppler shifts
  - pressure enhancement in the transition region (50%)
  - transition region brightenings unrelated to coronal emission (>30%)
  - boundaries between cold and hot plasma (14%)
  - siphon-type flows (a few examples)

Thanks!