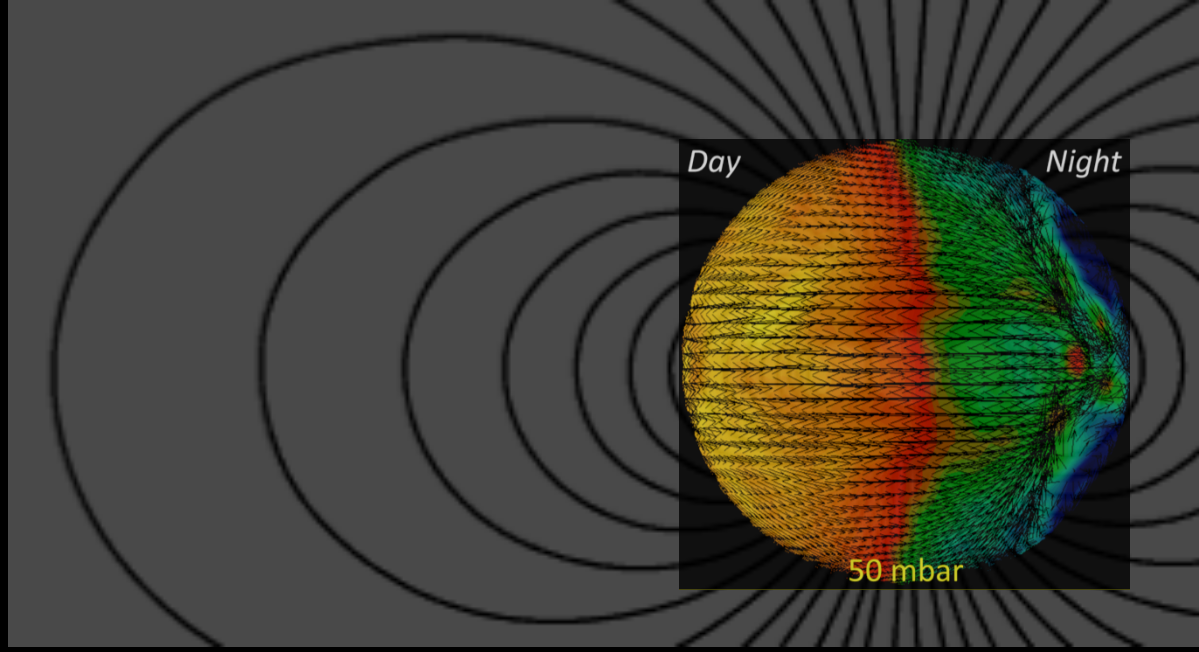
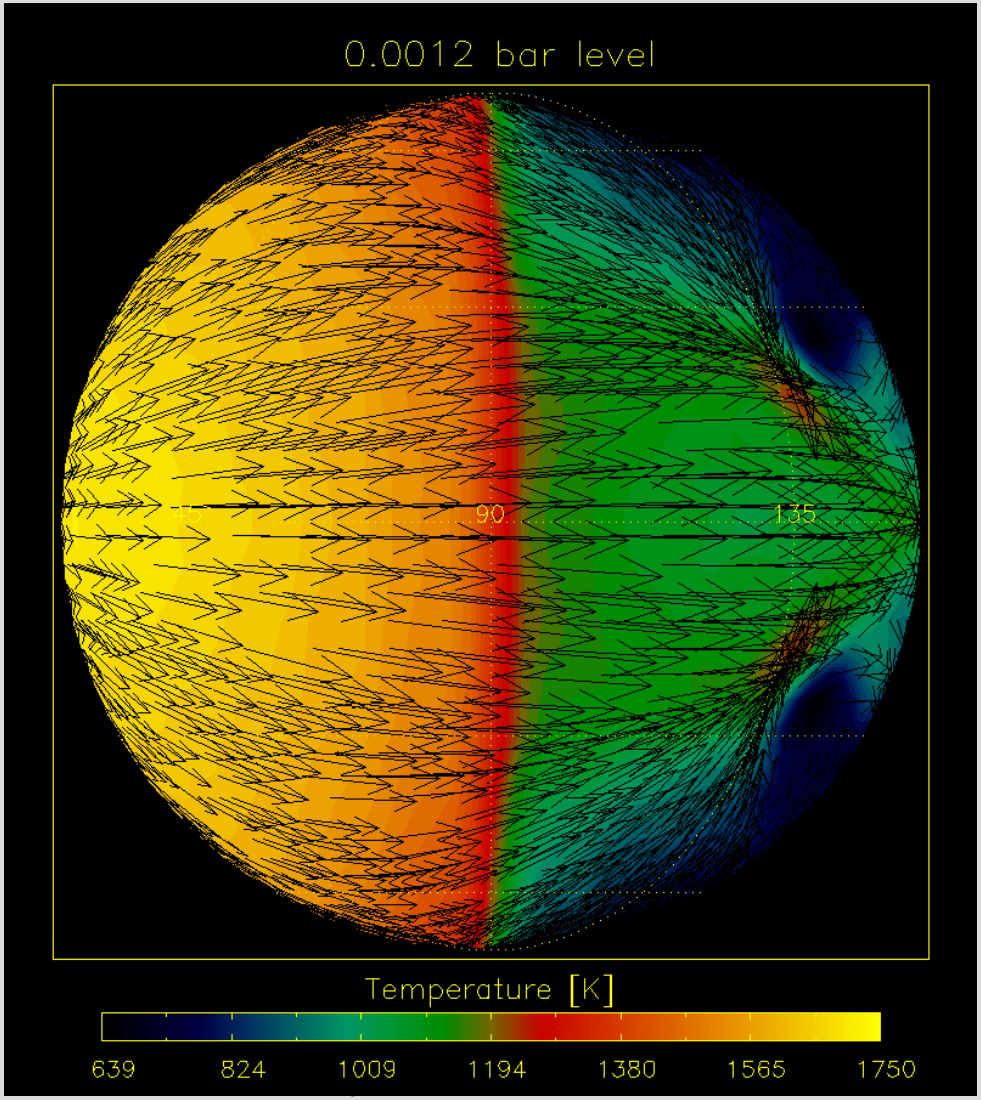


Emily Rauscher
Princeton

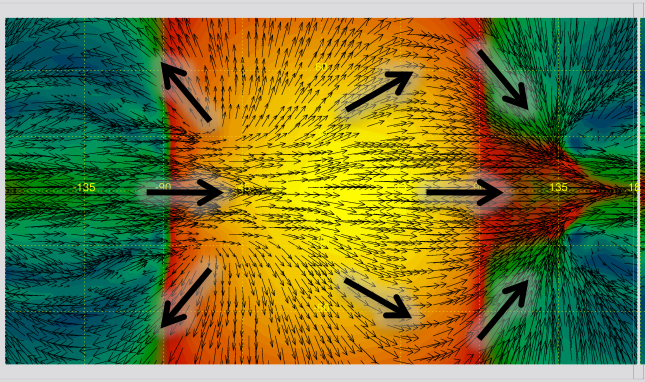
Hot Jupiter Atmospheric Circulation with Magnetic Drag and Ohmic Heating

Hot Jupiter atmospheres



Hot Jupiter atmospheres

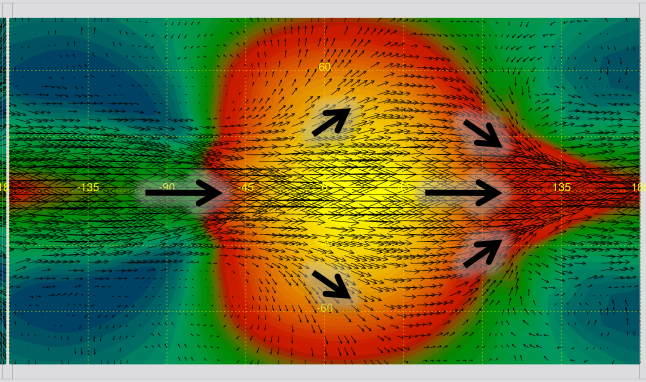
Upper atmosphere: 2 mbar



698 874 1050 1226 1402 1578 1754

Temperature [K]

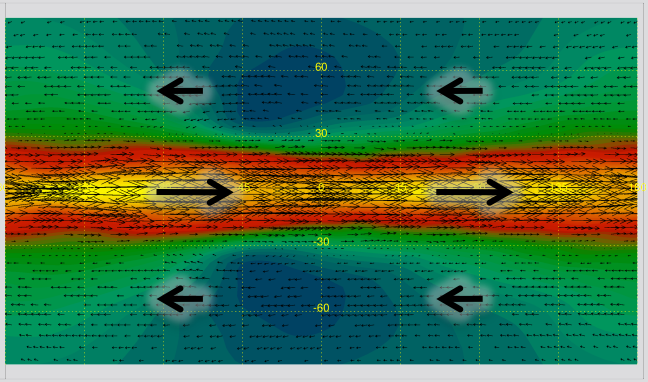
200 mbar



1002 1196 1389 1583 1776 1970 2163

Temperature [K]

Lower atmosphere: 20 bar



2007 2079 2151 2222 2294 2366 2438

Temperature [K]

Max winds: 10 km/s

Max winds: 7 km/s

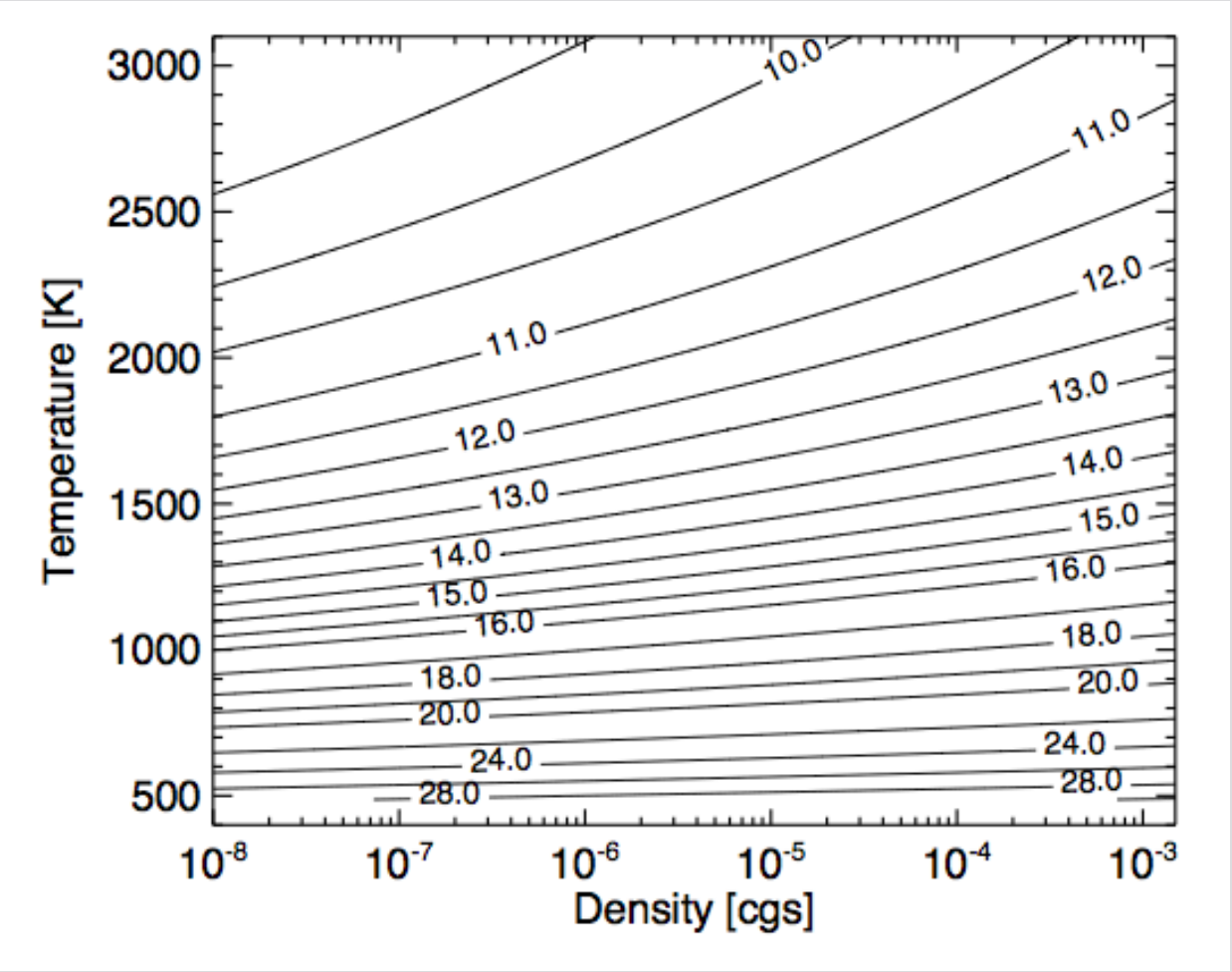
Max winds: 2 km/s

Radiation dominated and Supersonic winds

Advection dominated and Subsonic winds

The strength of magnetic effects

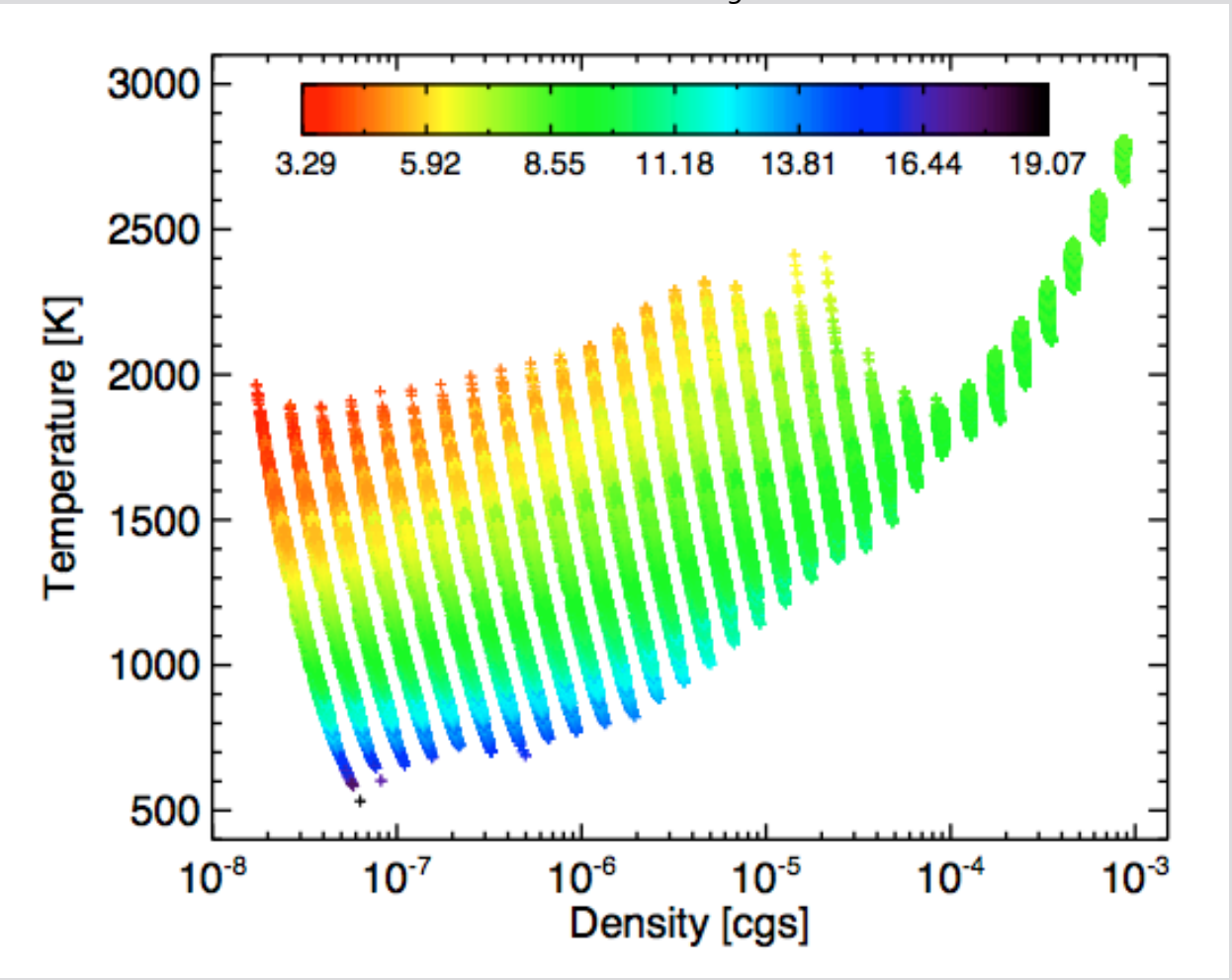
$\log_{10}$(resistivity) [cgs]



- Resistivities are calculated from the first ionization potential of all elements from hydrogen to nickel

Rauscher & Menou (2012b)

The strength of magnetic effects



- Resistivities are calculated from the first ionization potential of all elements from hydrogen to nickel

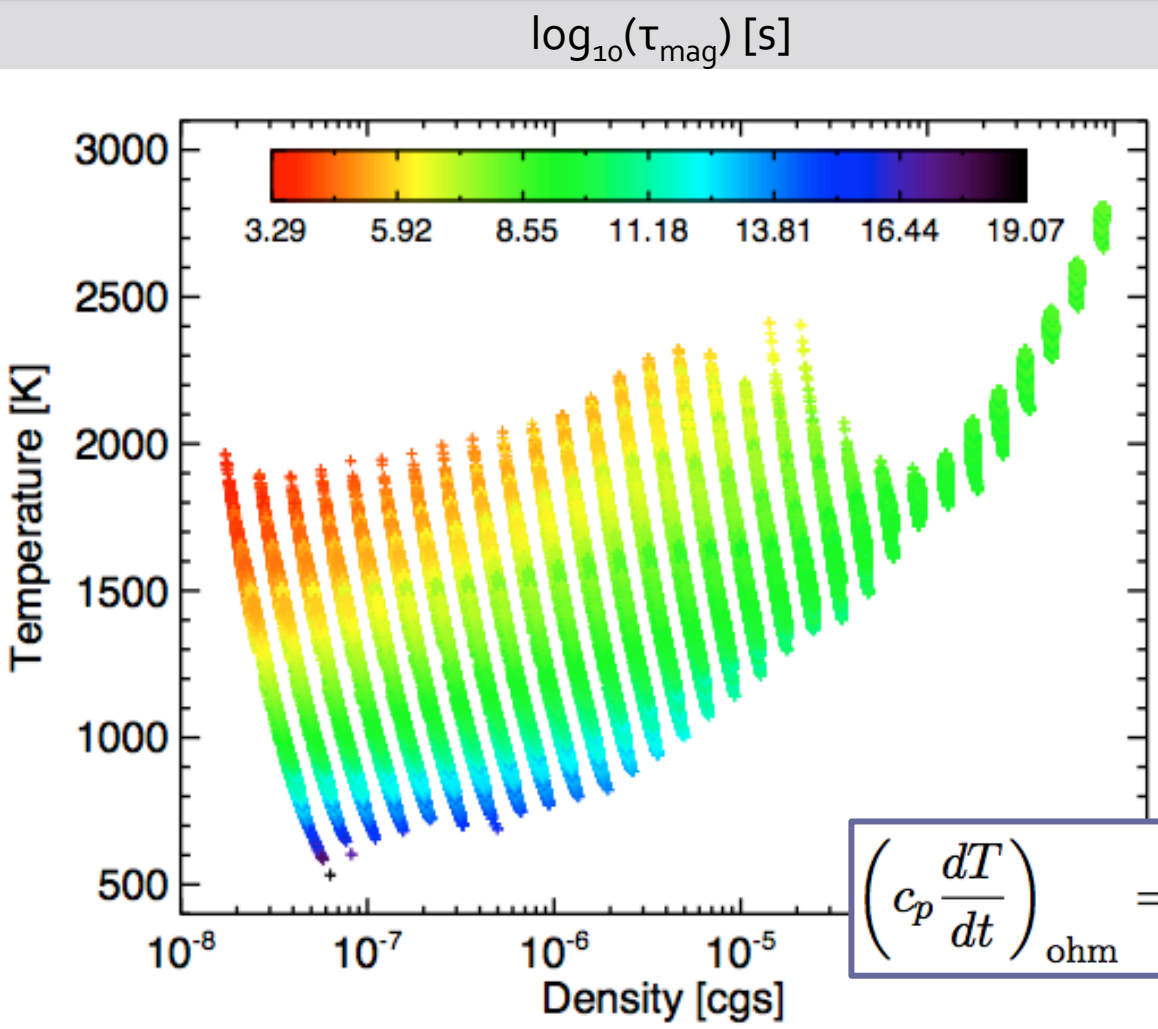
- The magnetic timescales are calculated as:

$$\tau_{\rm mag}(B,\rho,T,\phi) = \frac{4\pi\rho\ \eta(\rho,T)}{B^2\ |\sin\phi|}$$

Rauscher & Menou (2012b)

see Zhu+05; Liu+08; Perna, Menou, & Rauscher 10a,b; Menou 12

The strength of magnetic effects



- Resistivities are calculated from the first ionization potential of all elements from hydrogen to nickel

- The magnetic timescales are calculated as:

$$\tau_{\rm mag}(B,\rho,T,\phi) = \frac{4\pi\rho\ \eta(\rho,T)}{B^2\ |\sin\phi|}$$

- The drag and heating are:

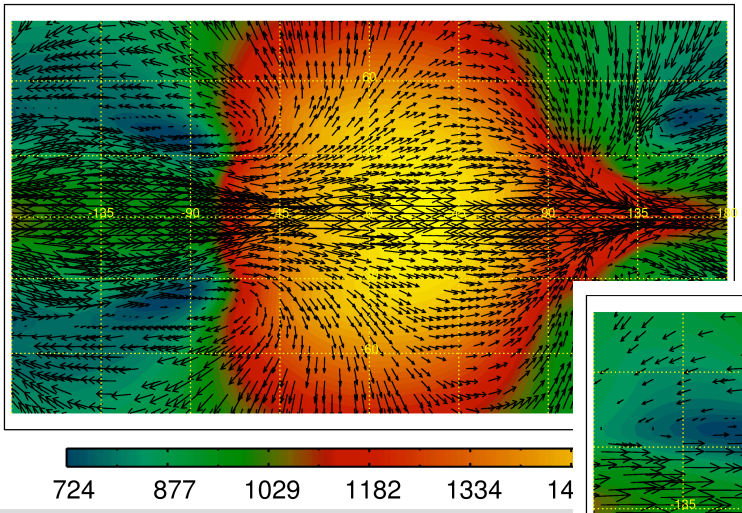
$$du/dt = -u/\tau_{\rm mag}$$

$$\left(c_p \frac{dT}{dt}\right)_{\rm ohm} = \frac{1}{\rho}\frac{4\pi\eta}{c^2} j^2 = u^2 \frac{B^2|\sin\phi|}{4\pi\eta\rho} = \frac{u^2}{\tau_{\rm mag}}$$

Rauscher & Menou (2012b)

see Zhu+05; Liu+08; Perna, Menou, & Rauscher 10a,b; Menou 12

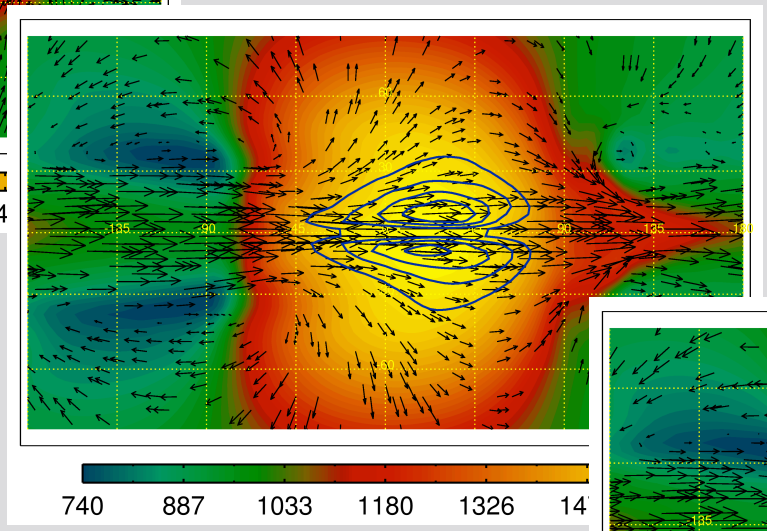
HD 189733b (T_{eq} = 1200 K)



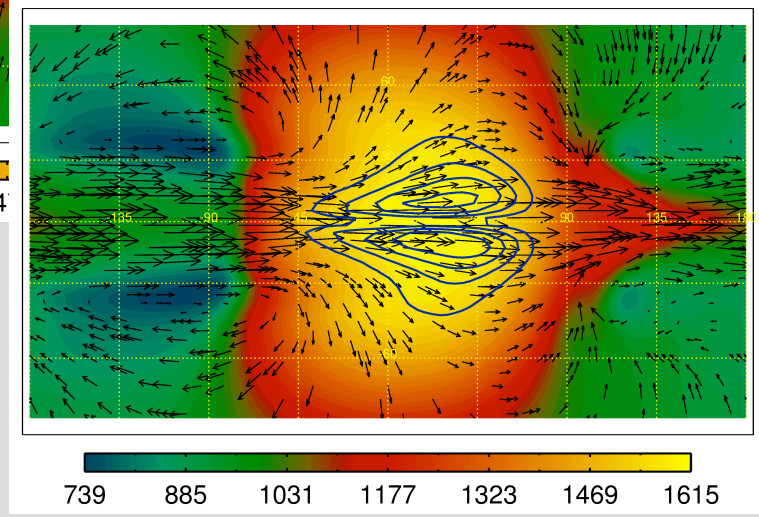
B = 0 G

The IR photosphere:

B = 30 G



B = 30 G,
metallicity 3x solar

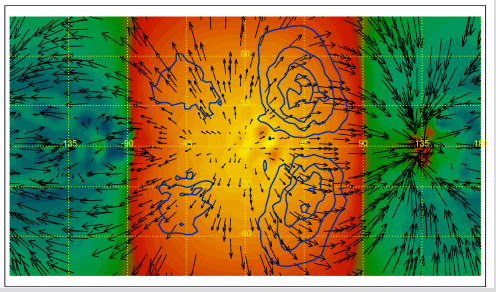


Magnetic effects do not matter on this planet

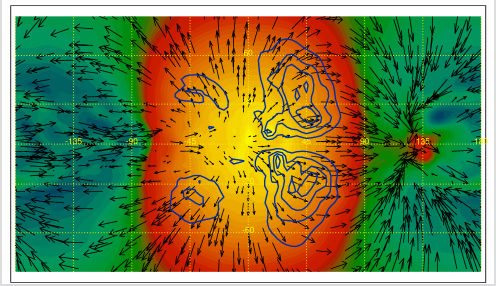
B = 3 G

HD 209458b (T_{eq} = 1500 K)

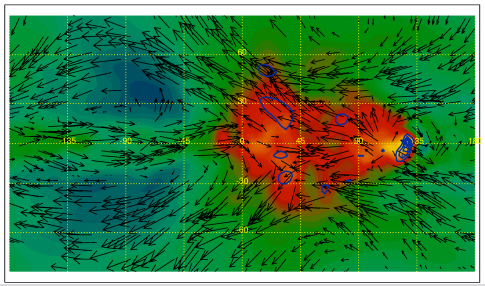
8 mbar



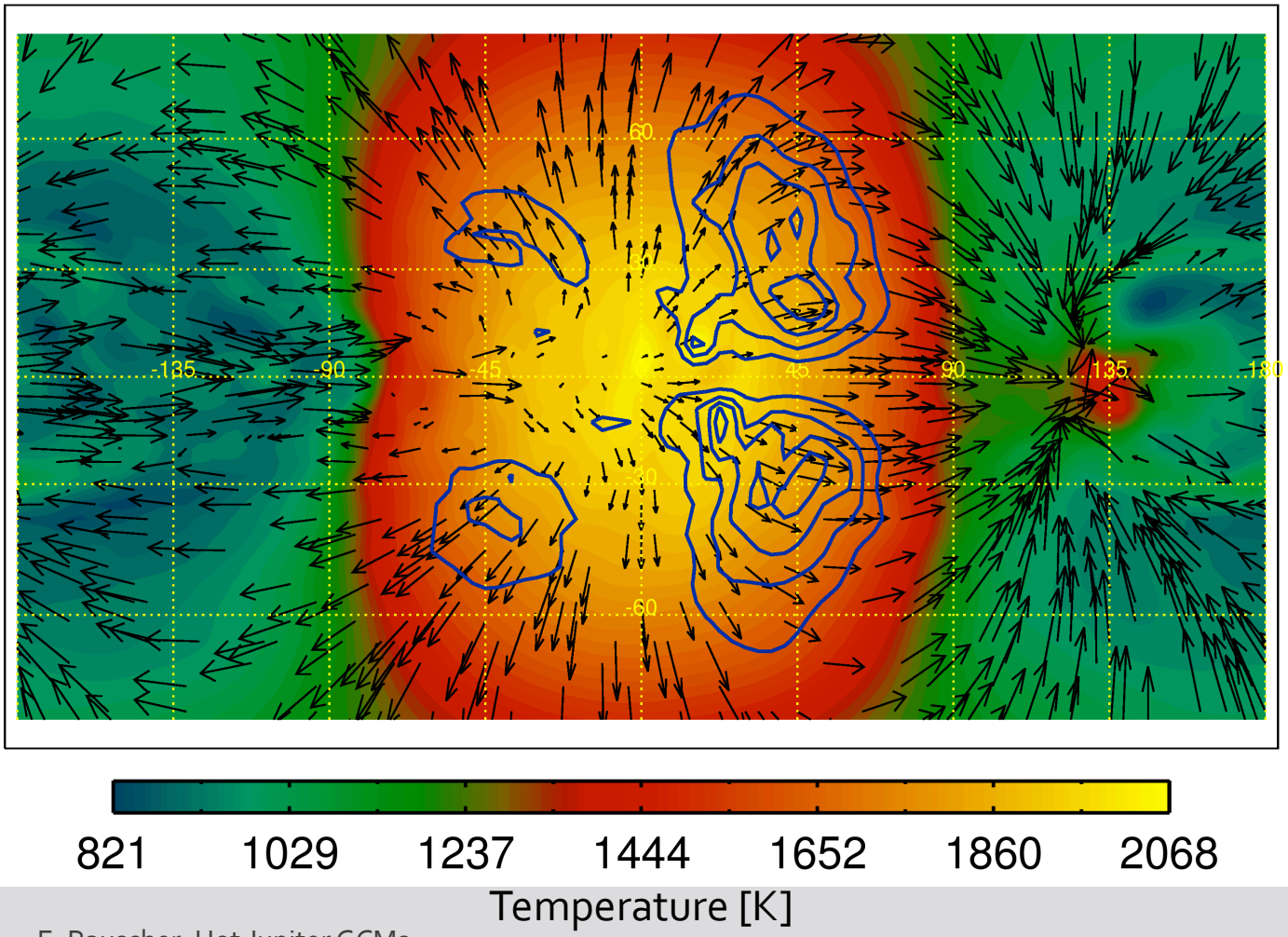
56 mbar



2 bar

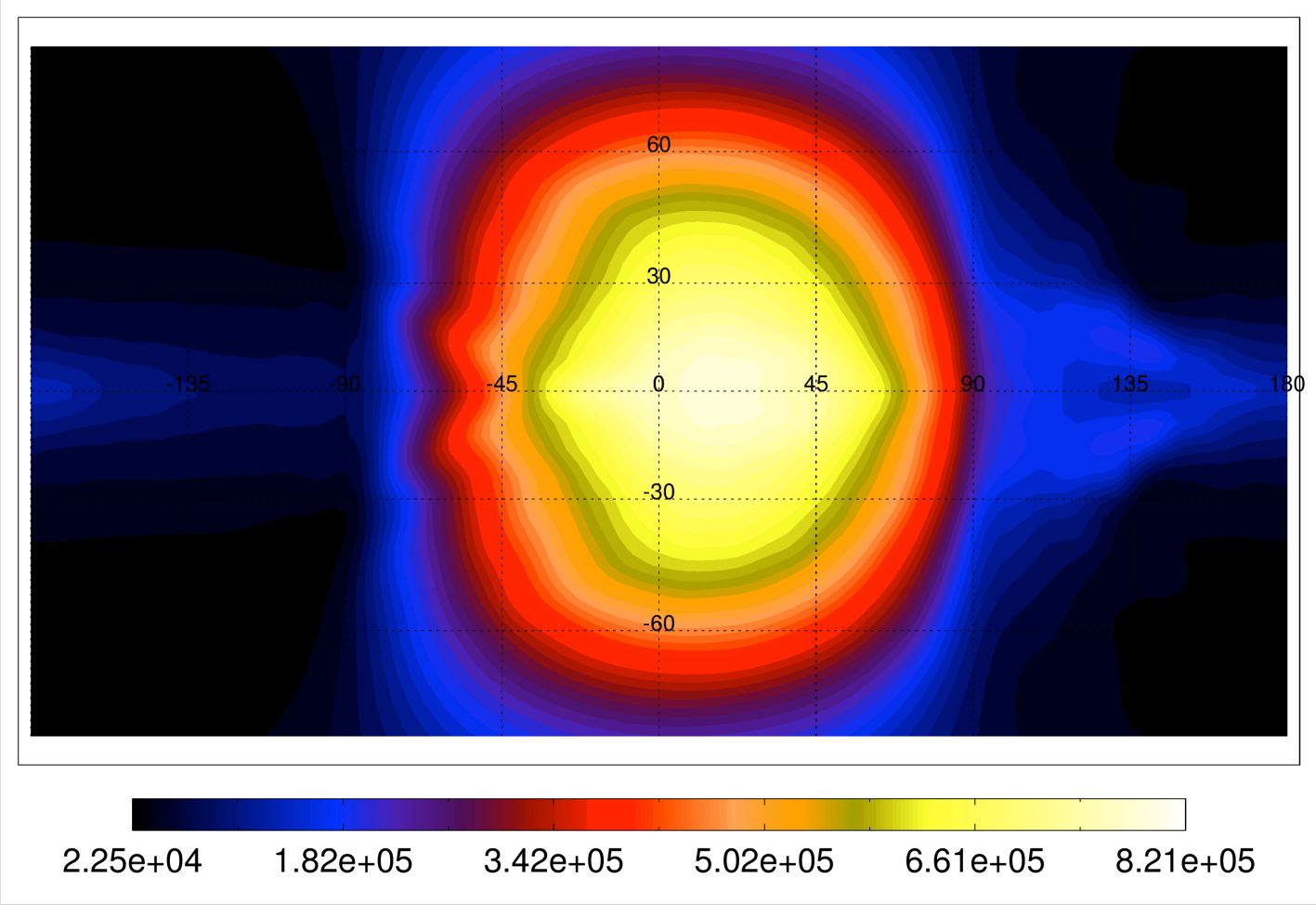


56 mbar level (IR photosphere)



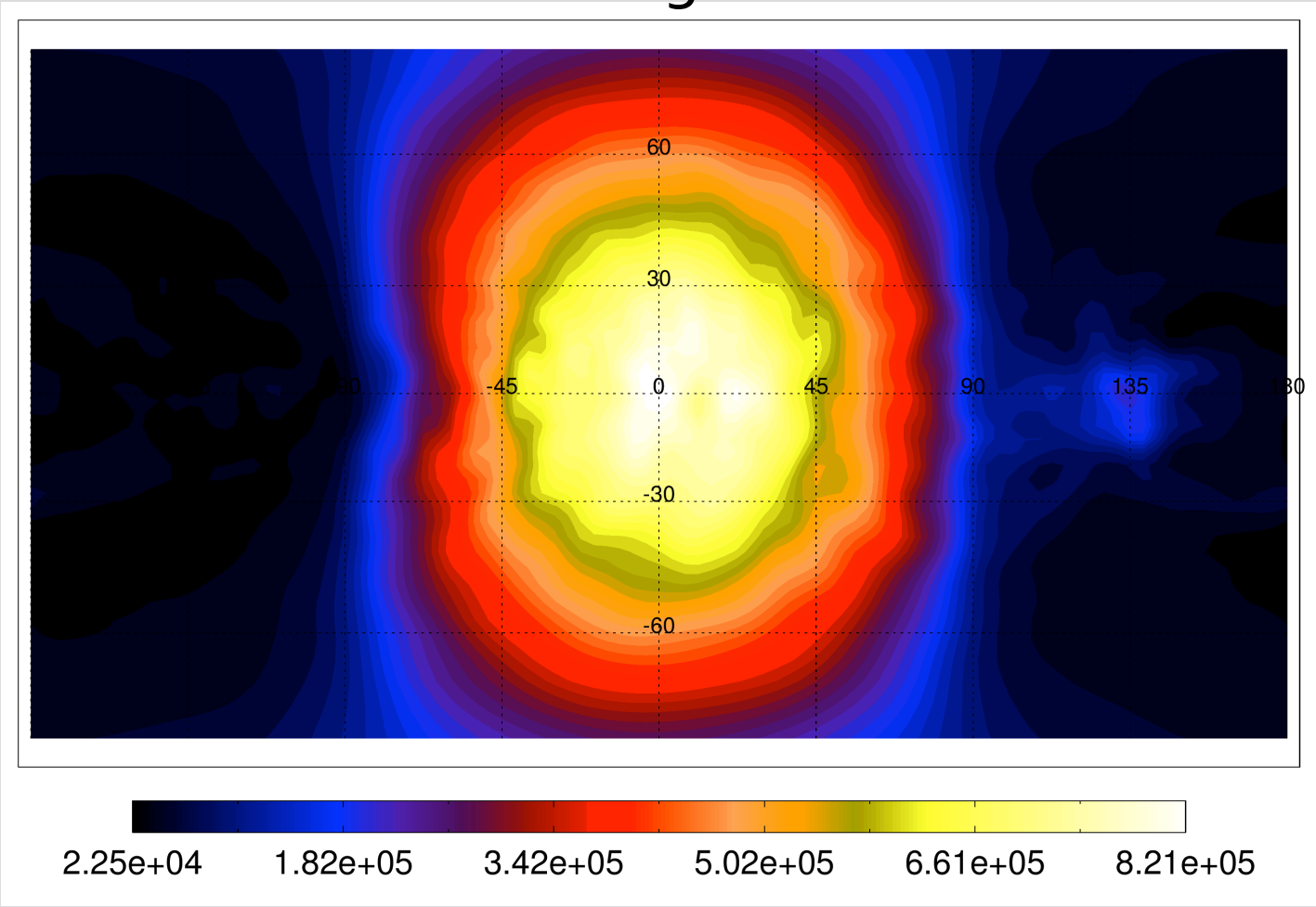
Map of flux emitted by HD 209458b

B = 0 G



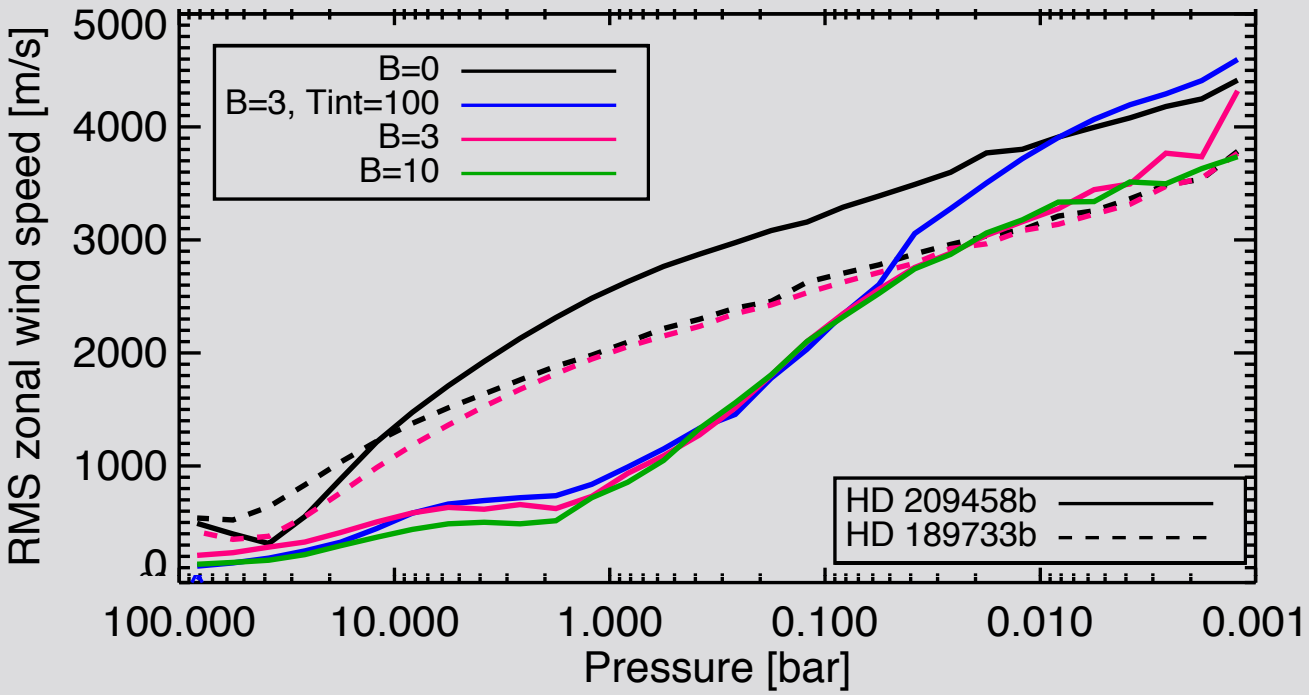
Map of flux emitted by HD 209458b

B = 3 G



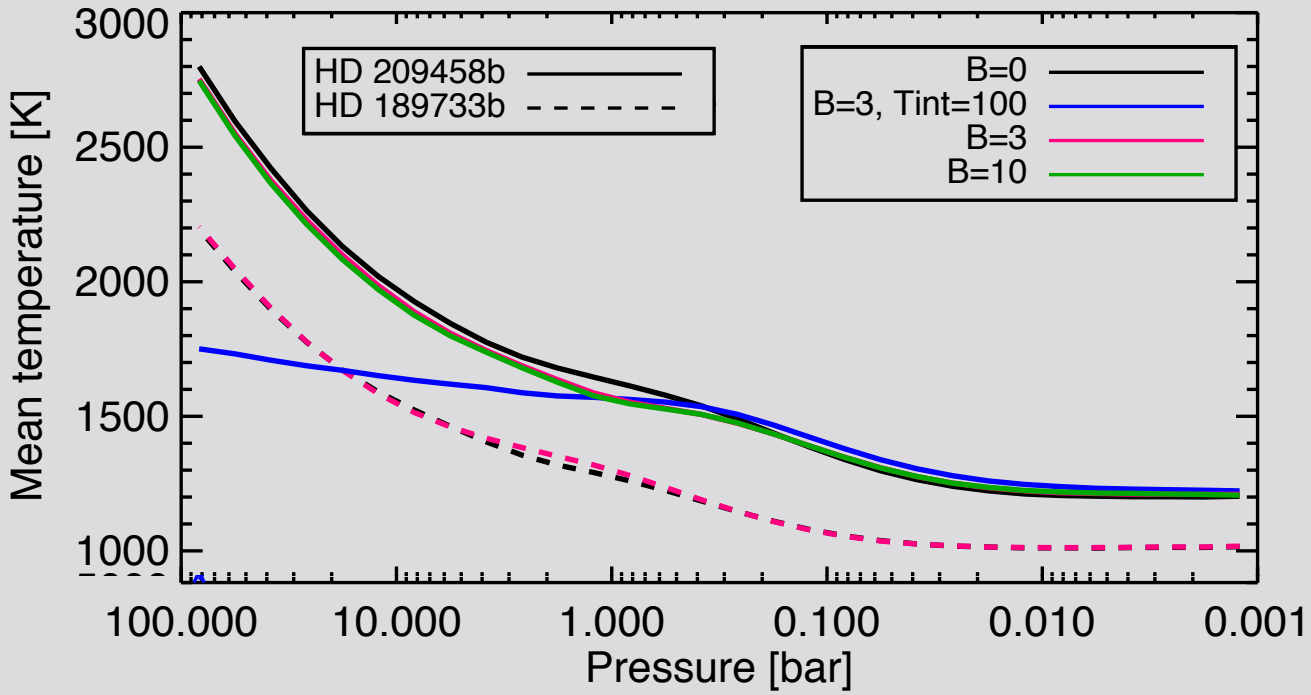
Globally averaged wind profiles

The winds are strongly suppressed (on HD 209458b) but are non-zero at 100 bar.

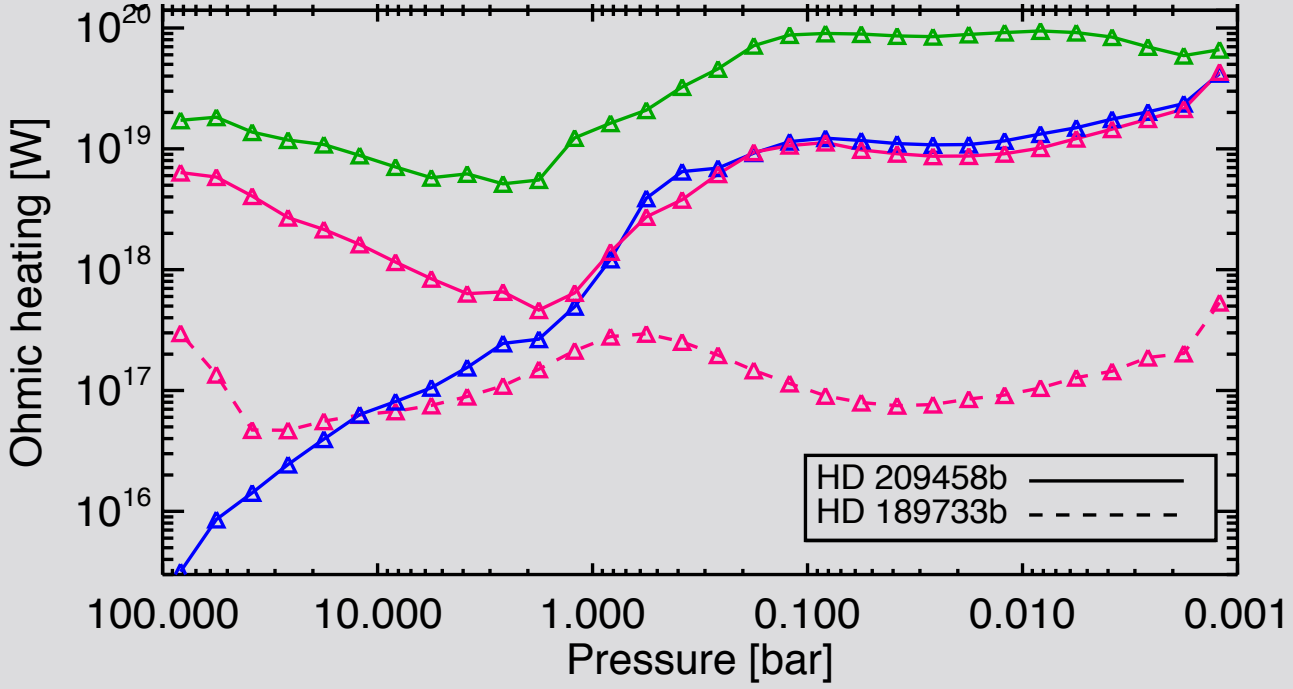


Globally averaged temperatures

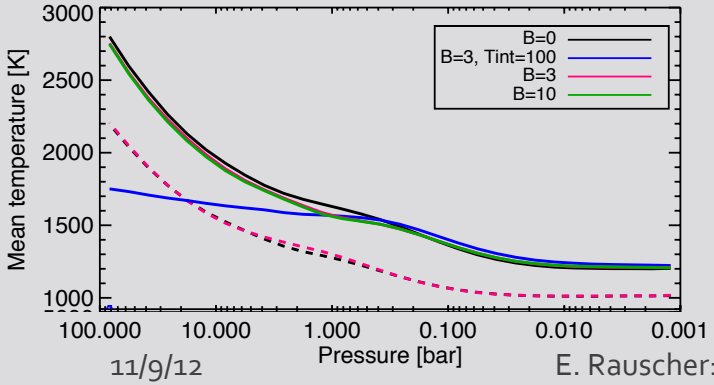
The global profiles are largely unchanged by the magnetic heating and are not useful for calculating the heating rates.

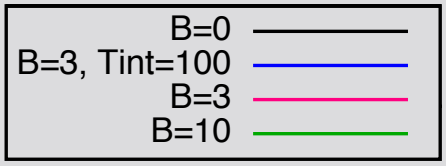


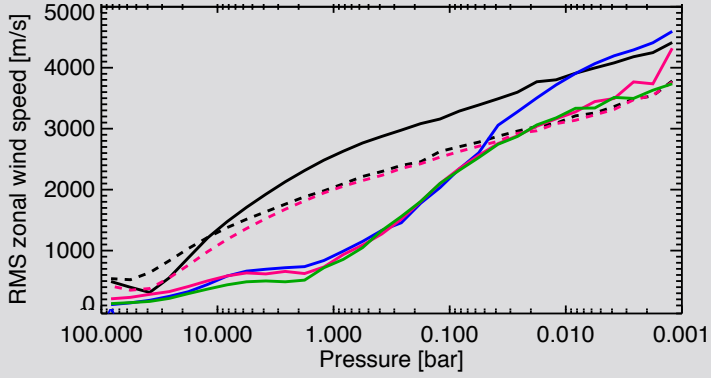
Global ohmic heating rates



Given a hot deep atmosphere, there should be enough ohmic heating to inflate HD 209458b.







Results (subject to caveats)

- The hot Jupiter HD 189733b is too cold for magnetic effects to matter
- However, HD 209458b is hot enough that magnetic effects should:
  - Disrupt the circulation
  - Alter the orbital phase curve
  - Keep the planet inflated