# Atmospheric Dynamics of Two Eccentric Transiting Planets: GJ436b and HD17156b

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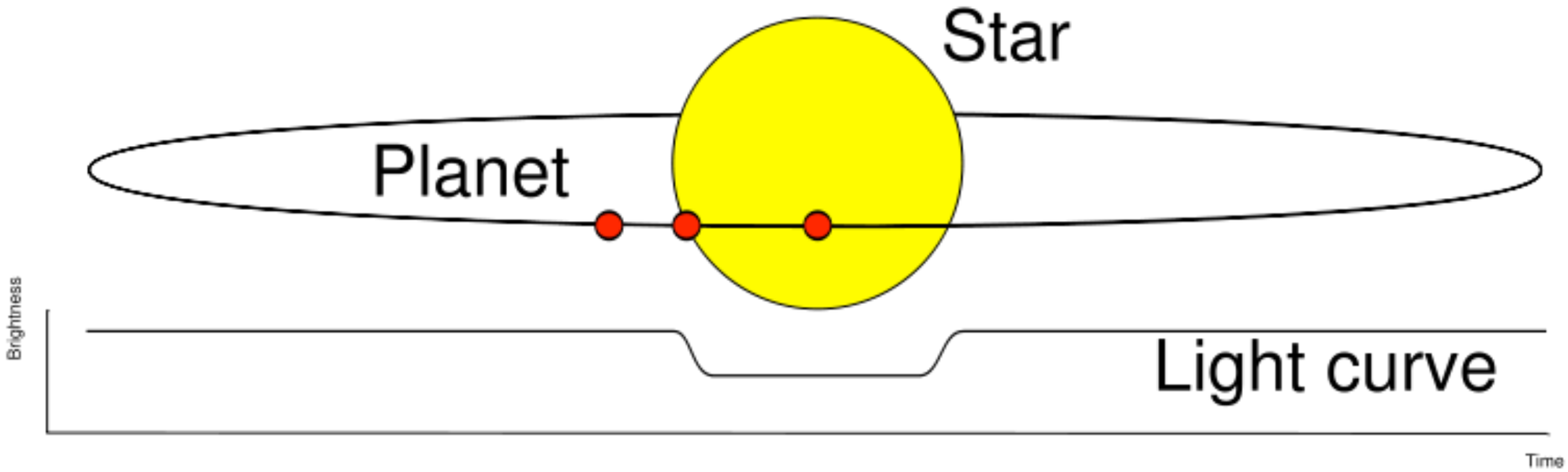
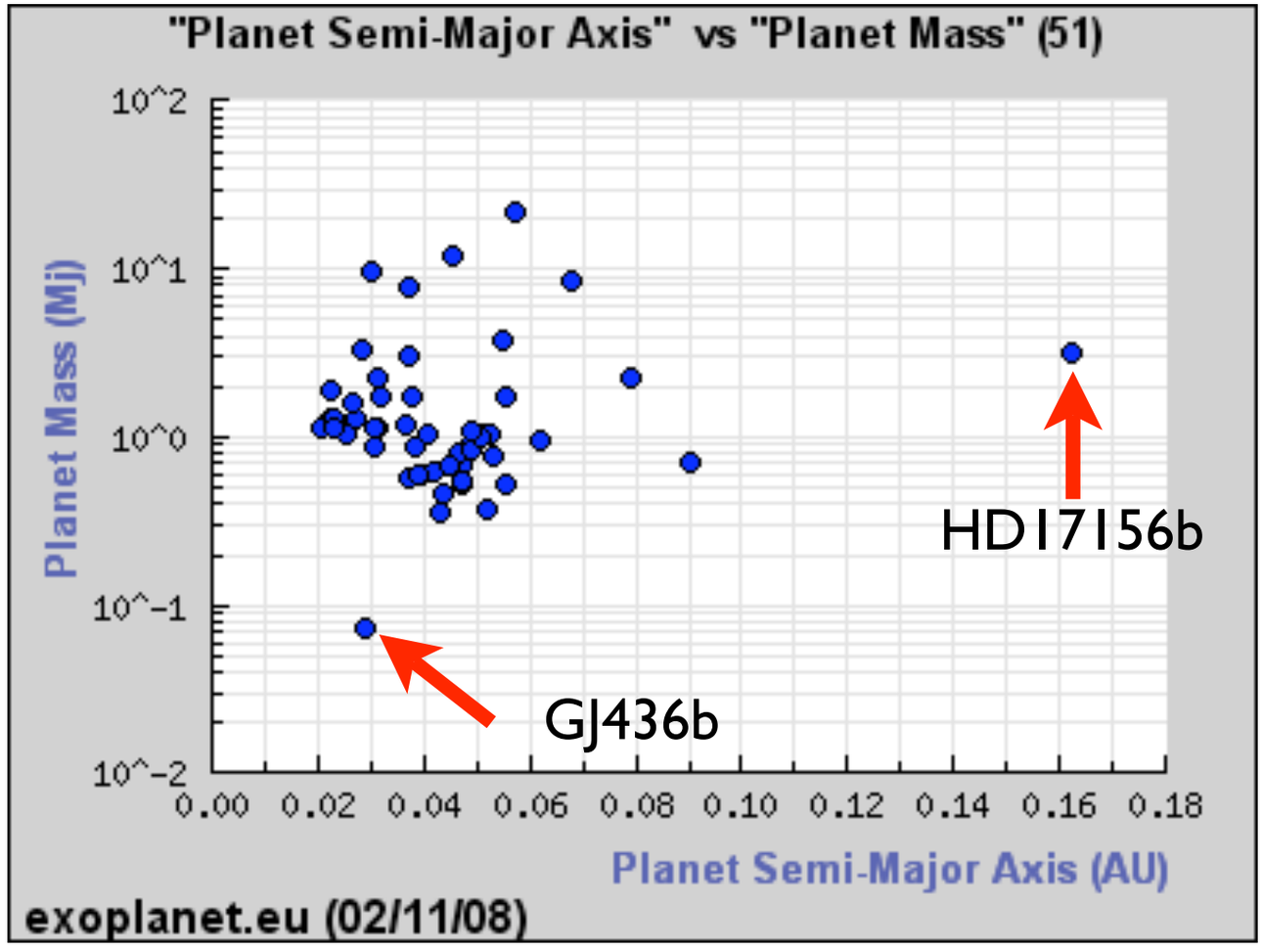
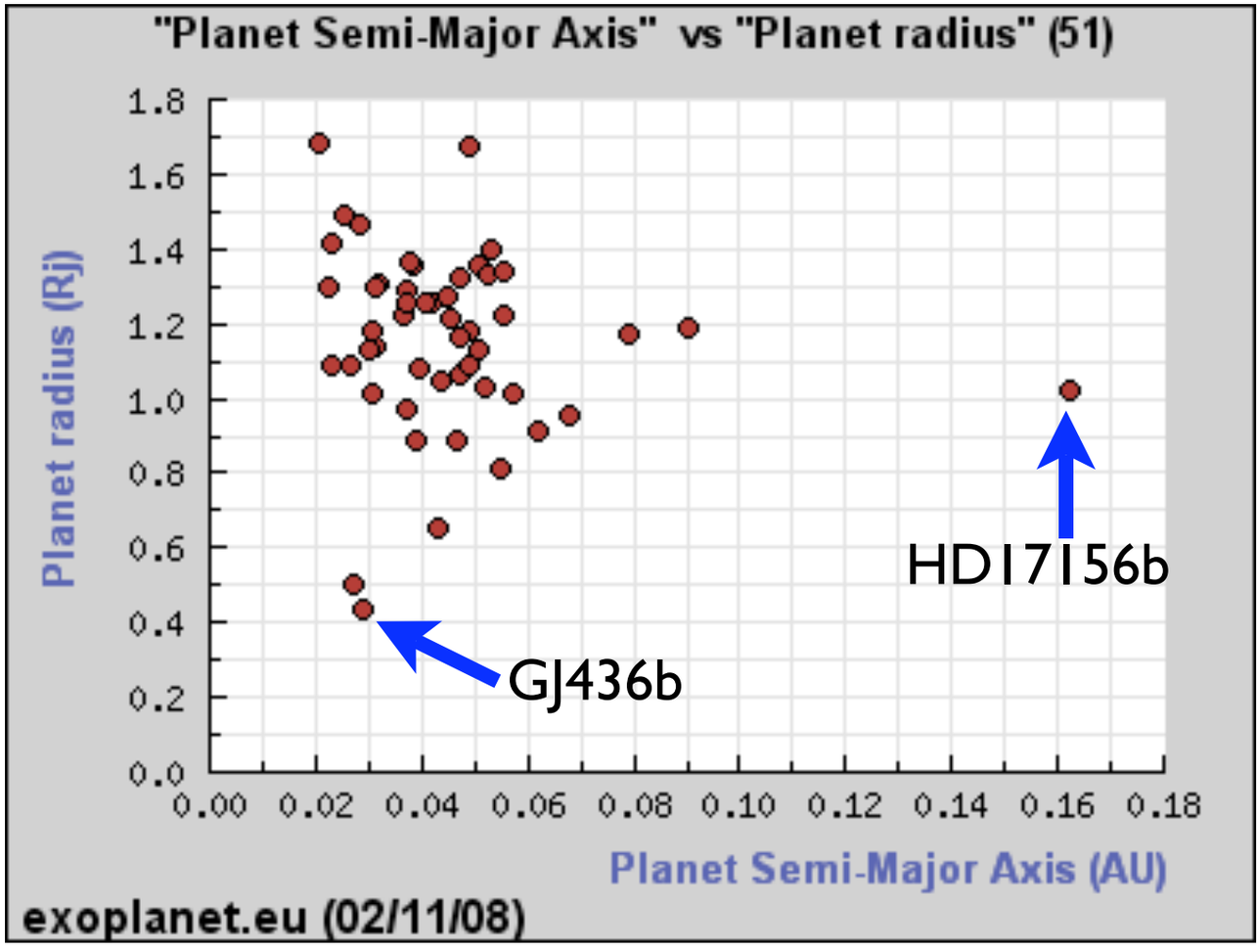
# Motivation

- Studying weather on extrasolar planets can help us understand current observations
- Chance to test unusual atmospheric forcing regimes and broaden our understanding of atmospheric dynamics
- The goal of this study is to test the effects of eccentric orbits on the atmospheric dynamics of extrasolar planets

# Transiting Extrasolar Planets



# SPARC Model Atmosphere

## (Substellar and Planetary Atmospheric Radiation and Circulation Model)

## MITgcm

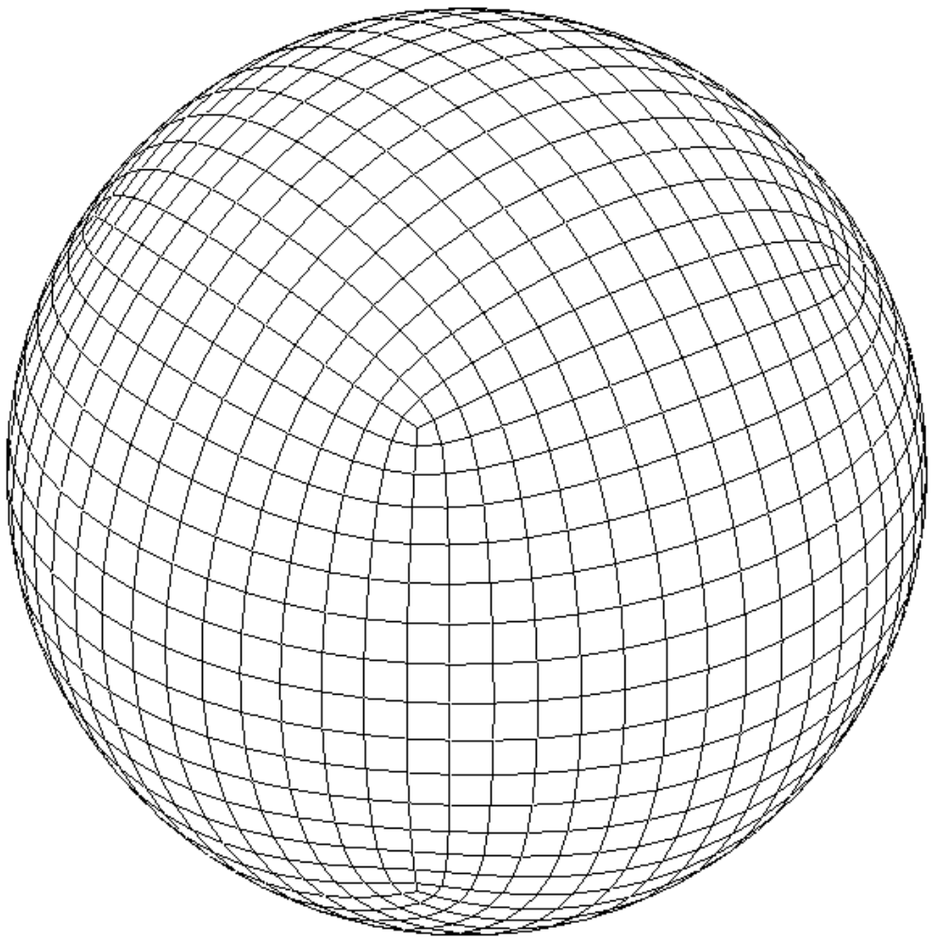
- Solves 3D primitive equations

$$\frac{d\mathbf{v}}{dt} = -\nabla\Phi - f\mathbf{k}\times\mathbf{v}$$

$$\frac{\partial\Phi}{\partial p} = -\frac{1}{\rho}$$

$$\nabla\cdot\mathbf{v} + \frac{\partial\omega}{\partial p} = 0$$

$$\frac{dT}{dt} = \frac{q}{c_p} + \frac{\omega}{\rho c_p}$$



Cubed-sphere grid

## Radiative Transfer

- Based on Marley & McKay (1999) radiative transfer model
- Plane-parallel two-stream radiative transfer scheme
- Opacities determined using correlated-k method
- Heating ($q$) determined from the divergence of calculated wavelength-dependent radiative fluxes

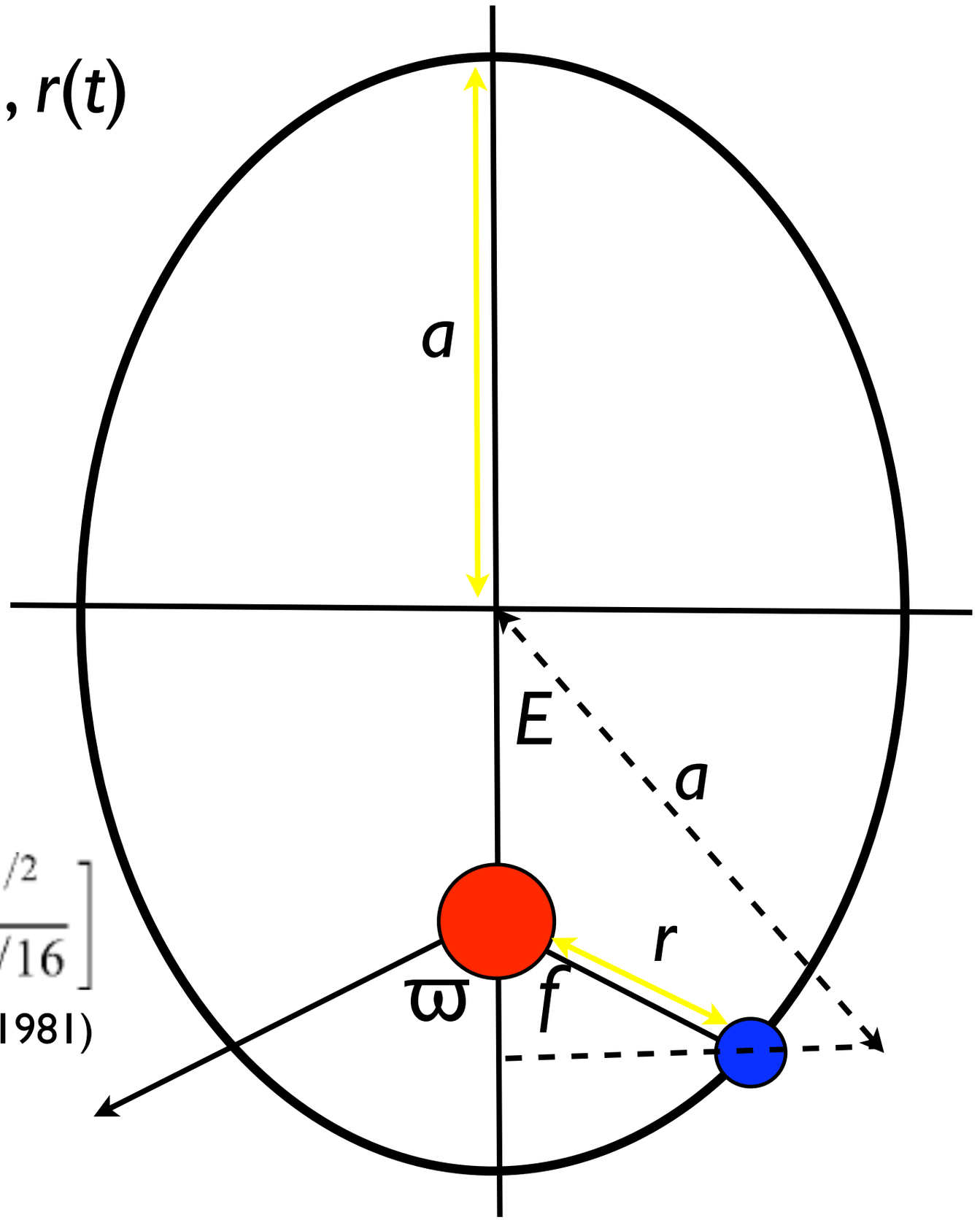
# Eccentric Exoplanet Considerations

- Distance varies with time, *r*(*t*)

$$r(t) = a(1 - e\cos E(t))$$

$$M(t) = E(t) - e\sin E(t)$$

$$M(t) = n(t - \tau)$$




- Planetary rotation rate is likely non-synchronous

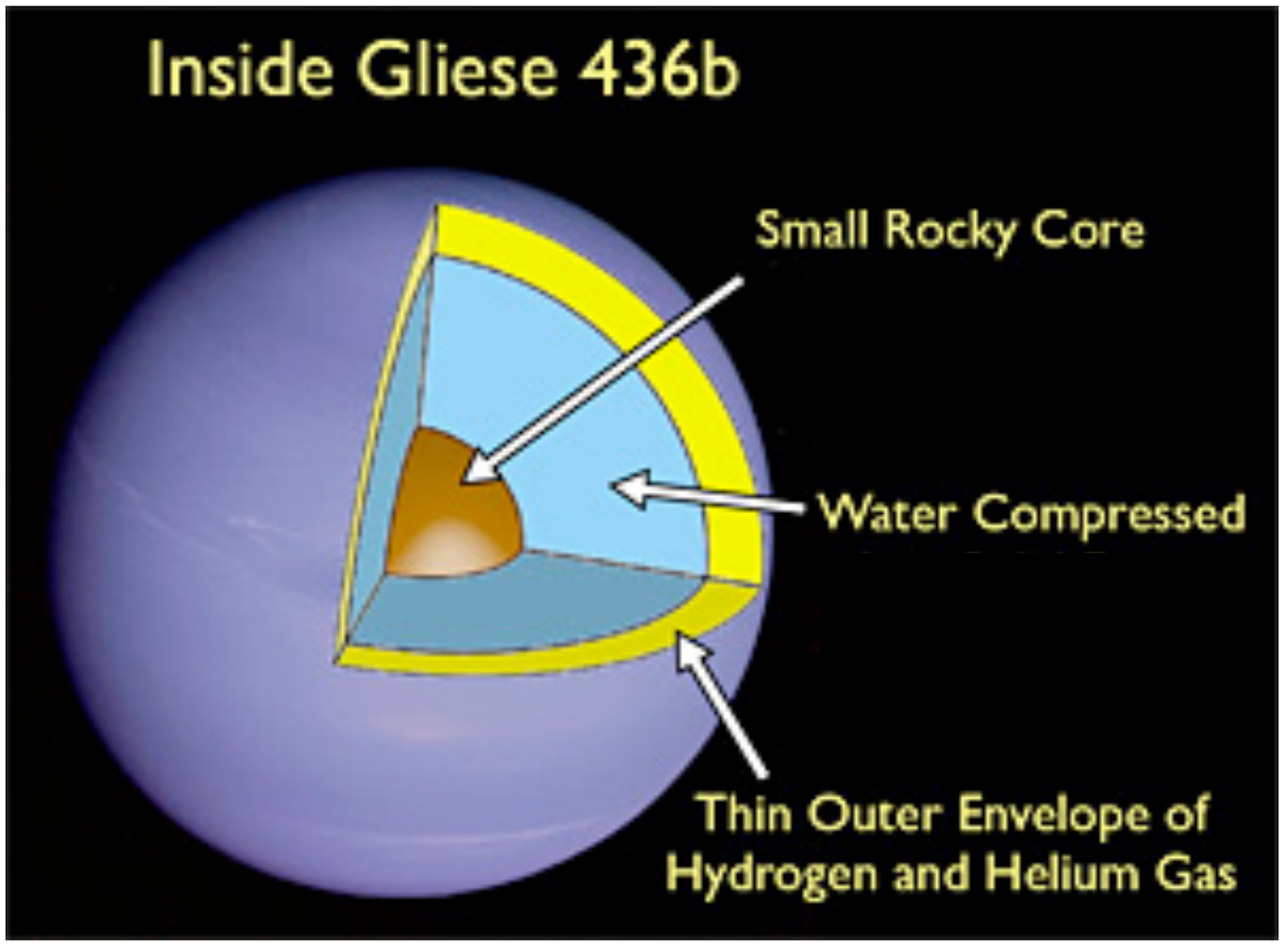
$$\tau_{\rm rot} = \tau_{\rm orb}\left[\frac{(1 + 3e^2 + 3e^4/8)(1 - e^2)^{3/2}}{1 + 15e^2/2 + 45e^4/8 + 5e^6/16}\right]$$

Hut (1981)

# GJ436b: Hot Neptune

## Planetary Parameters

- $M_p$ = 0.071±0.006 $M_J$
- $R_p$ = 0.437±0.035 $R_J$
- a = 0.028 AU
- e = 0.15
- g = 9.22 $m/s^2$
- $P_{orb}$ = 2.643904 days
- $P_{rot}$ = 2.328553 days

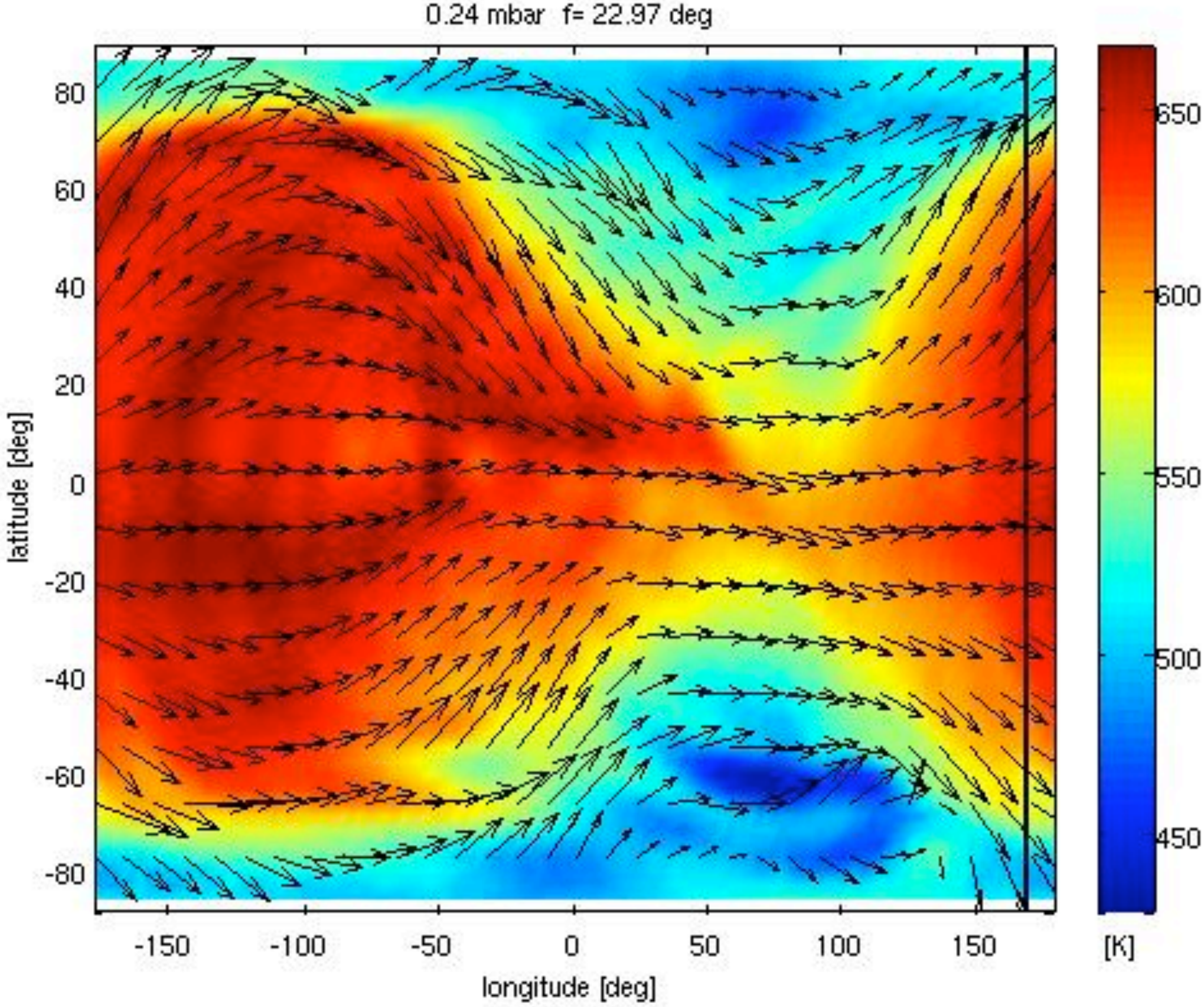



Credit: Jason Wright/UC Berkeley

## Stellar Parameters

- M2.5 ($T_{eff}$ ~ 3200-3700 K)
- [Fe/H] < 0.0

# GJ436b 1x Solar



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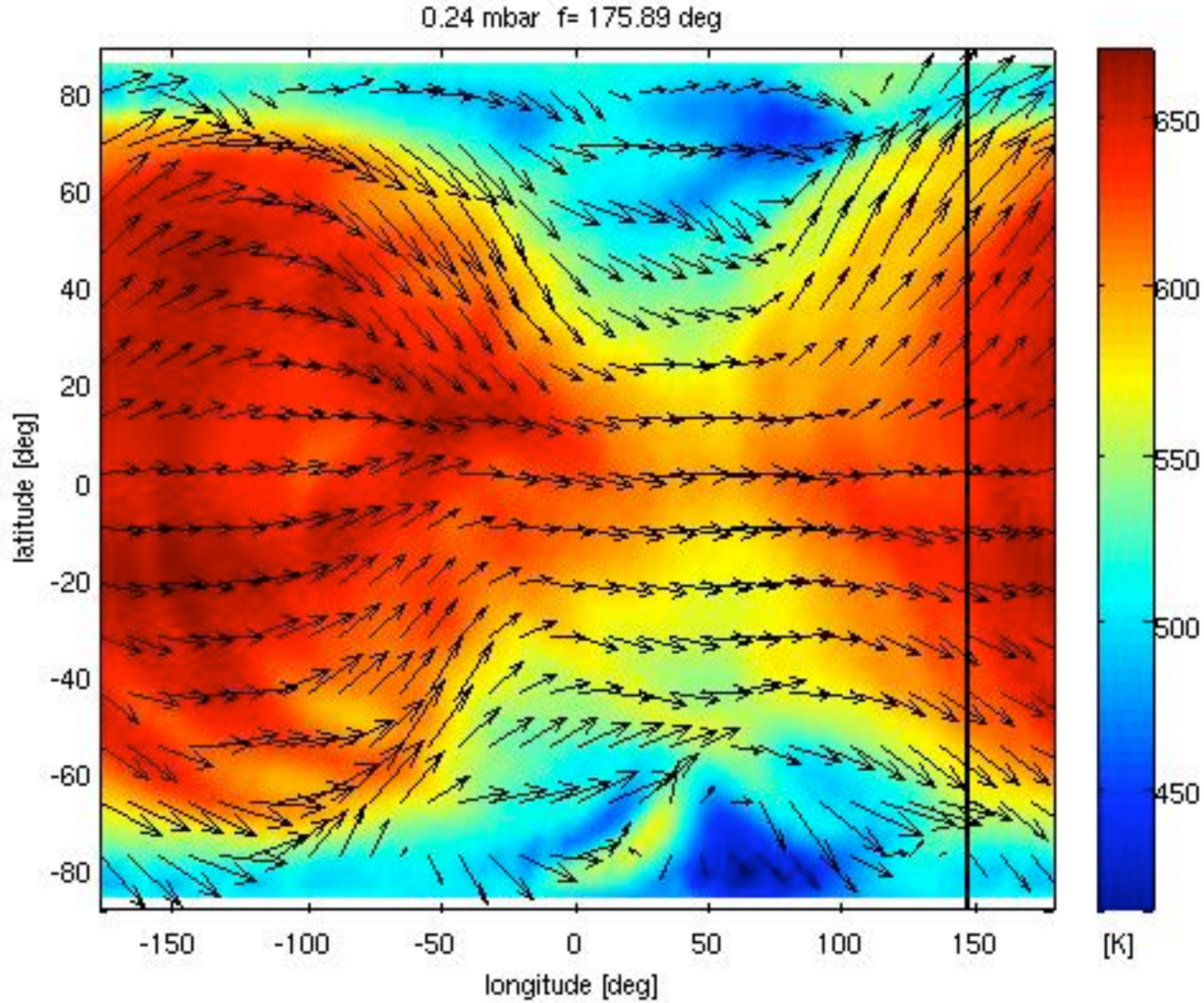
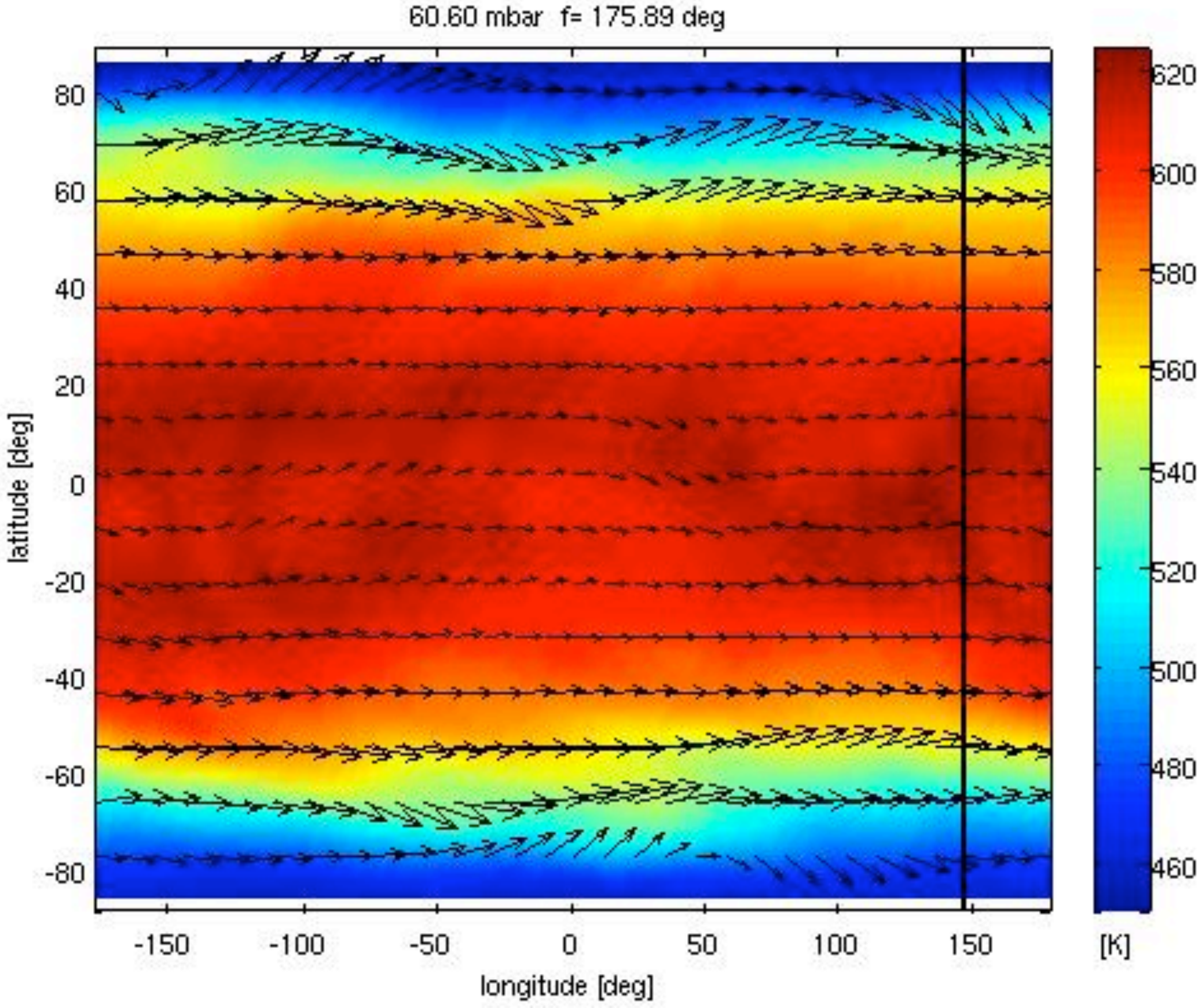
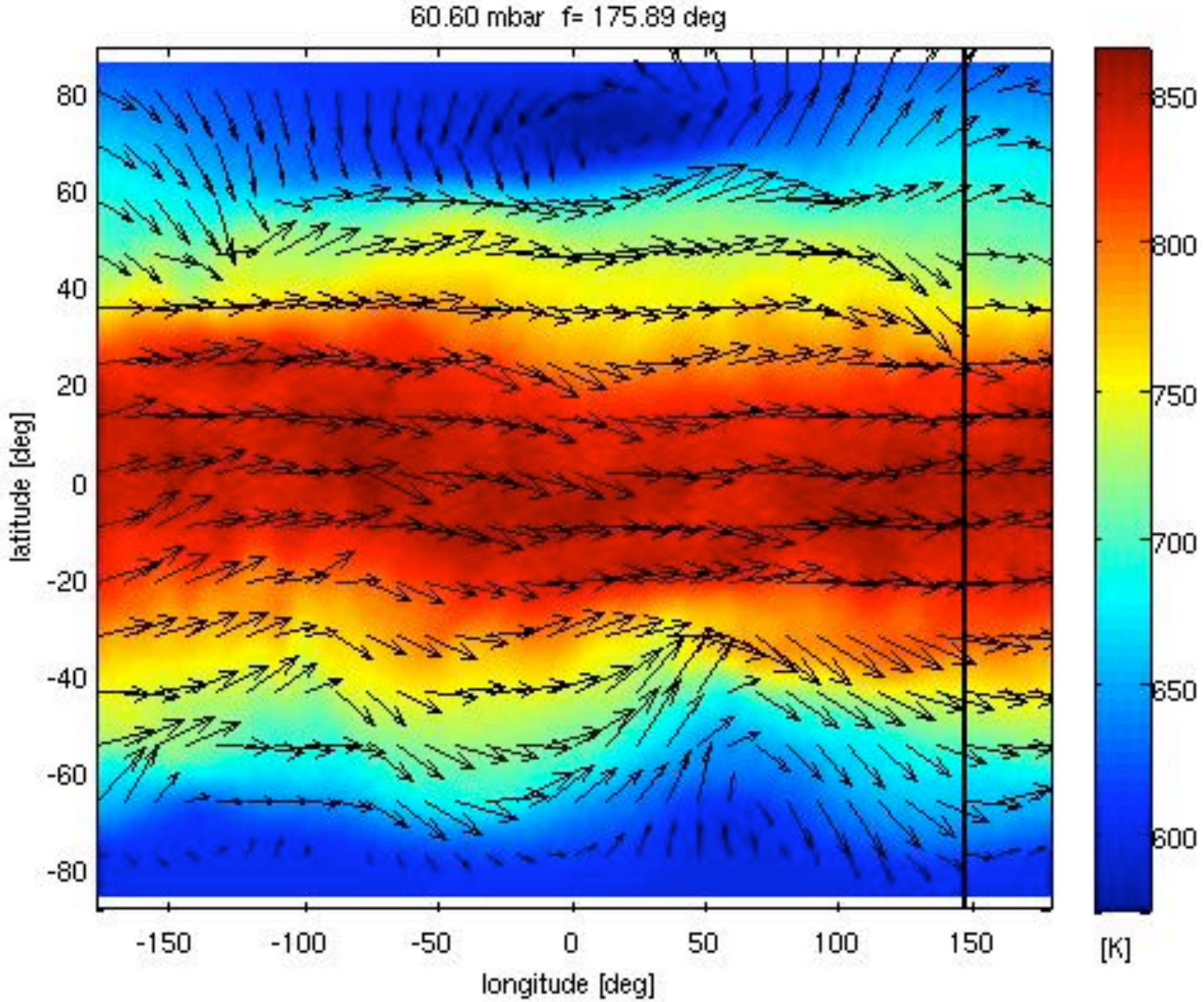


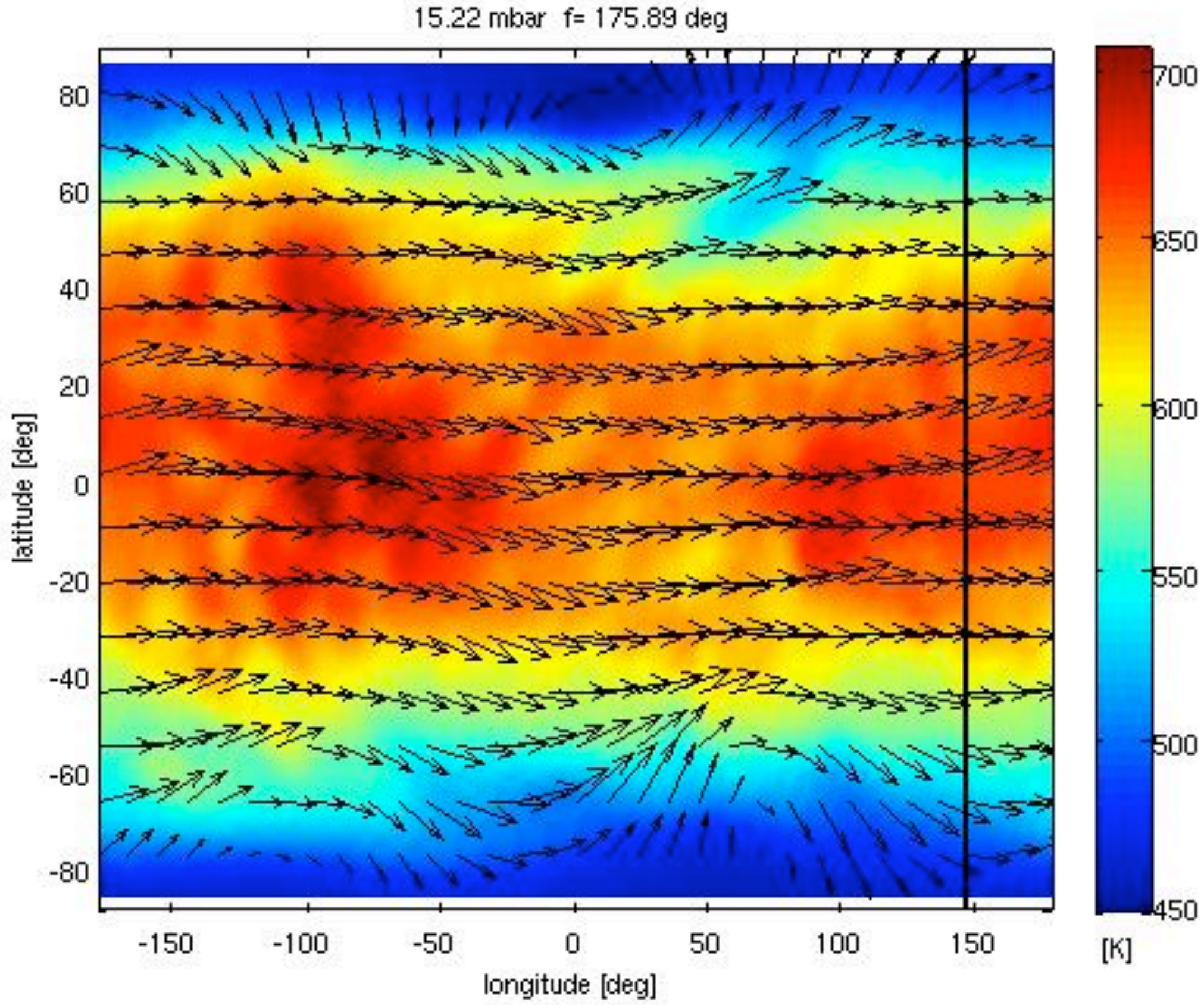
# GJ436b 1x Solar



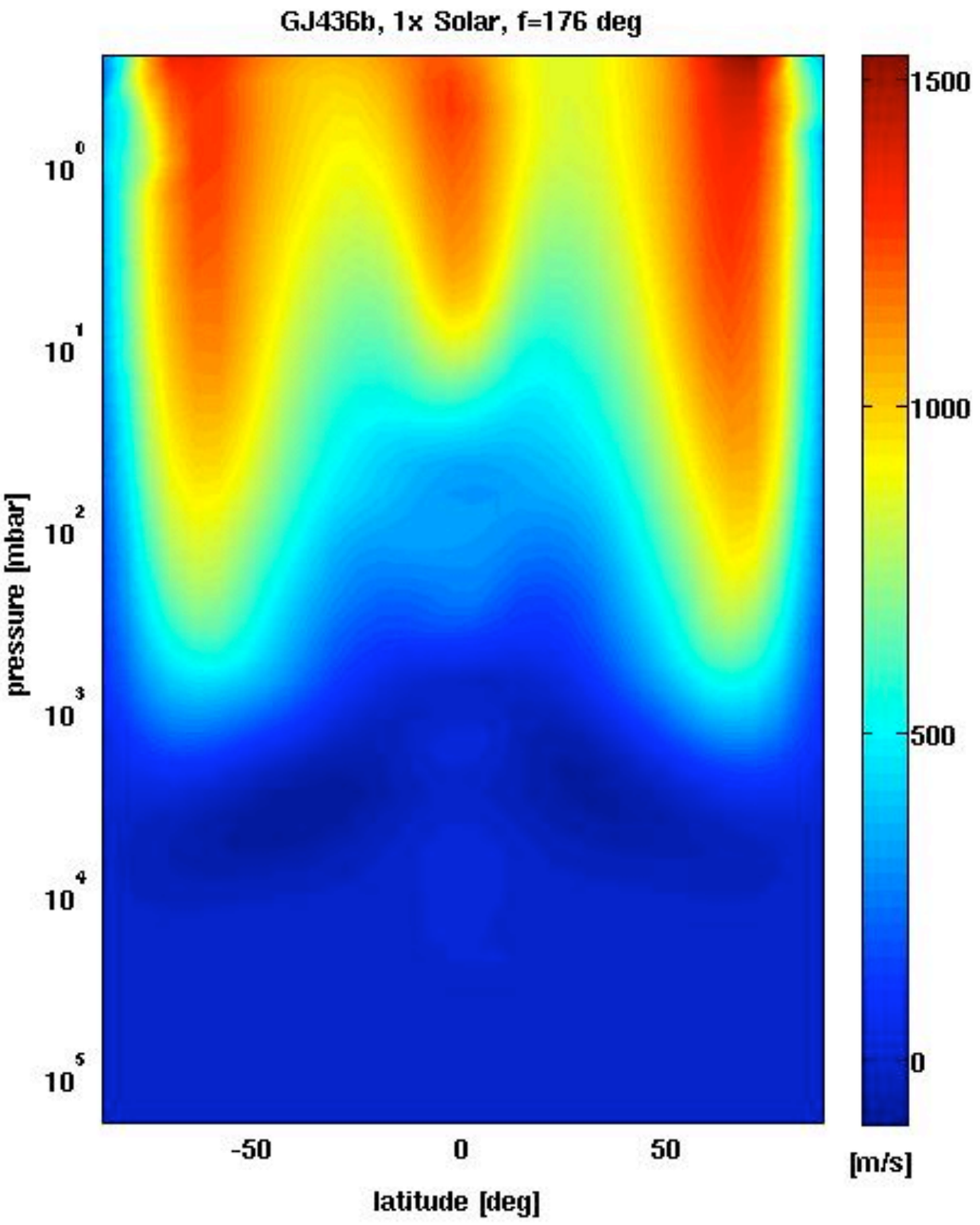
# GJ436b 30x Solar

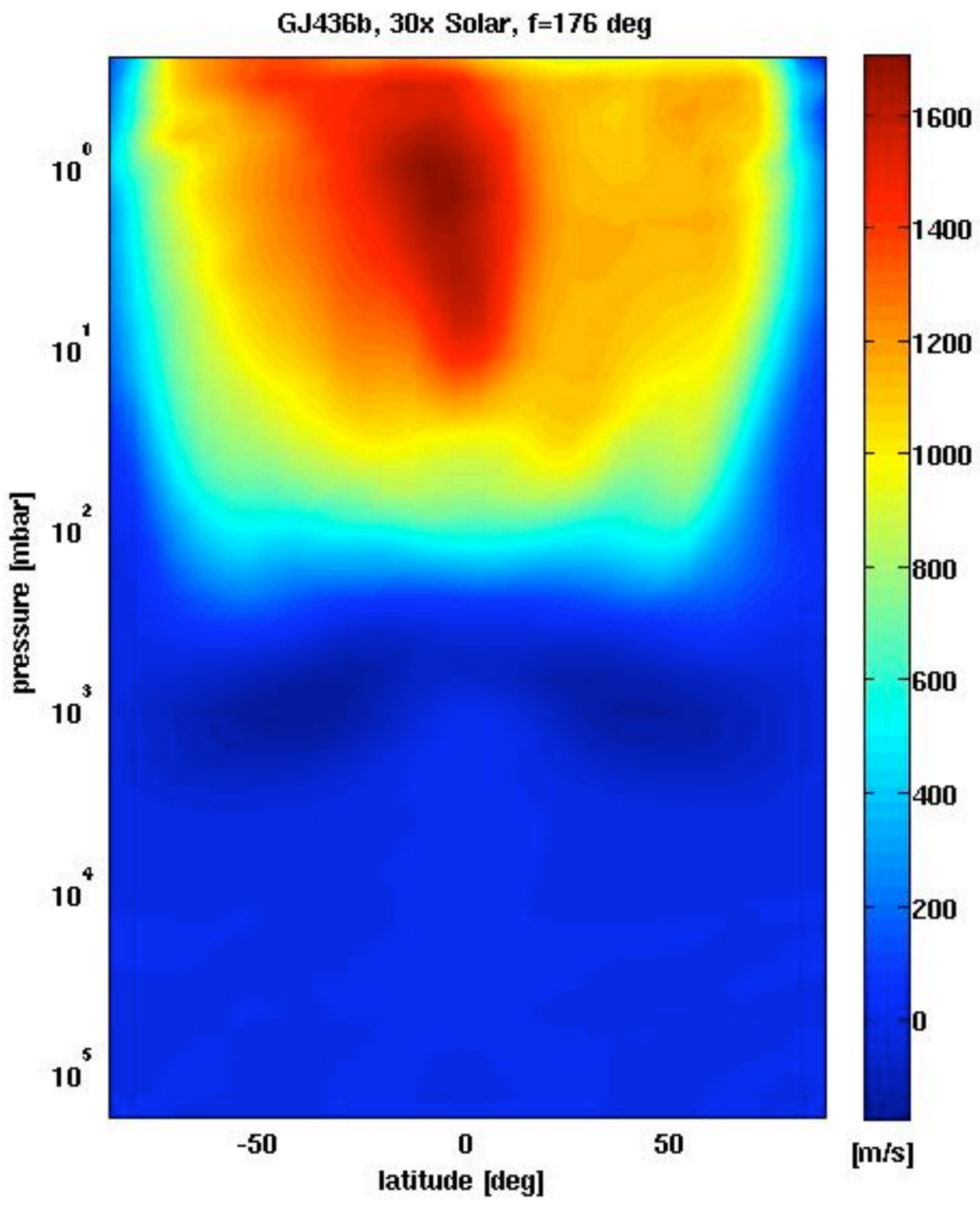


# GJ436b 30x Solar



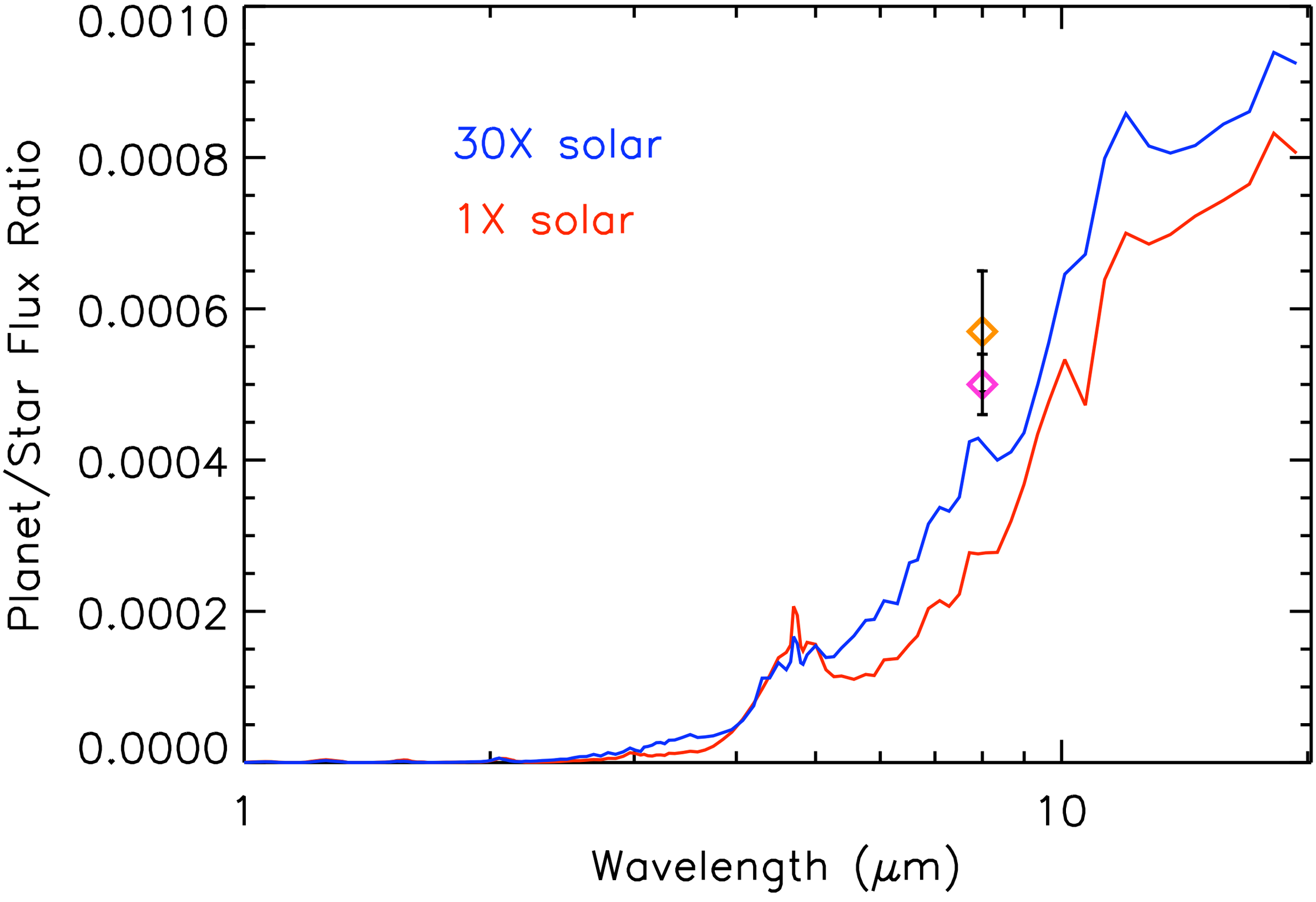
# GJ436b Zonal Mean Zonal Winds



# GJ436b 8 μm Observations

## Secondary Eclipse



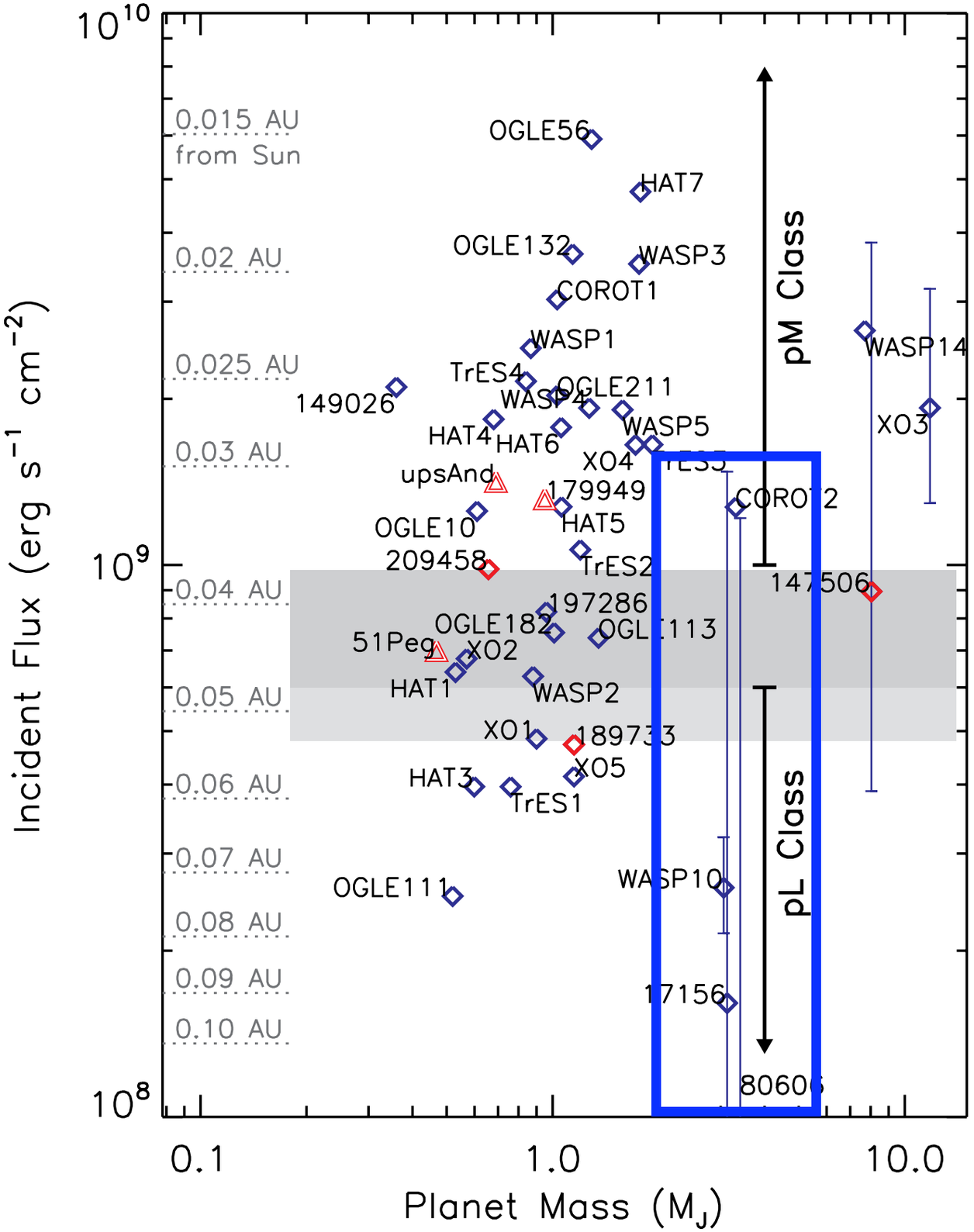
# HD17156b: Eccentric Hot Jupiter

## Planetary Parameters*

- $M_p$ = 3.09 $M_J$
- $R_p$ = 1.23 $R_J$
- a = 0.1589 AU
- e = 0.6719
- g = 50.6 $m/s^2$
- $P_{orb}$ = 21.21747 days
- $P_{rot}$ = 3.76797 days

## Stellar Parameters

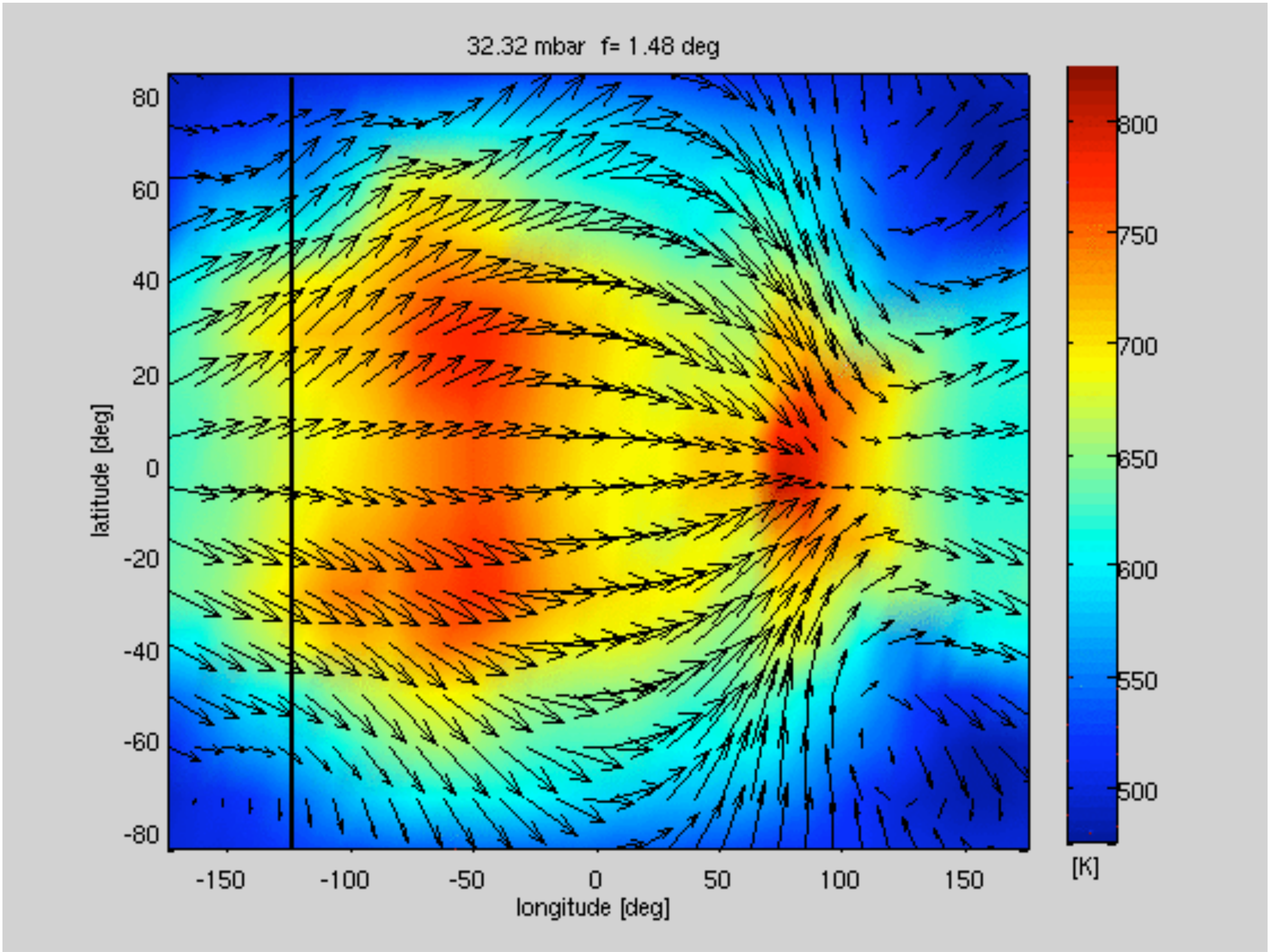
- G0 ($T_{eff}$ ~ 6079 K)
- [Fe/H] = 0.24±0.05



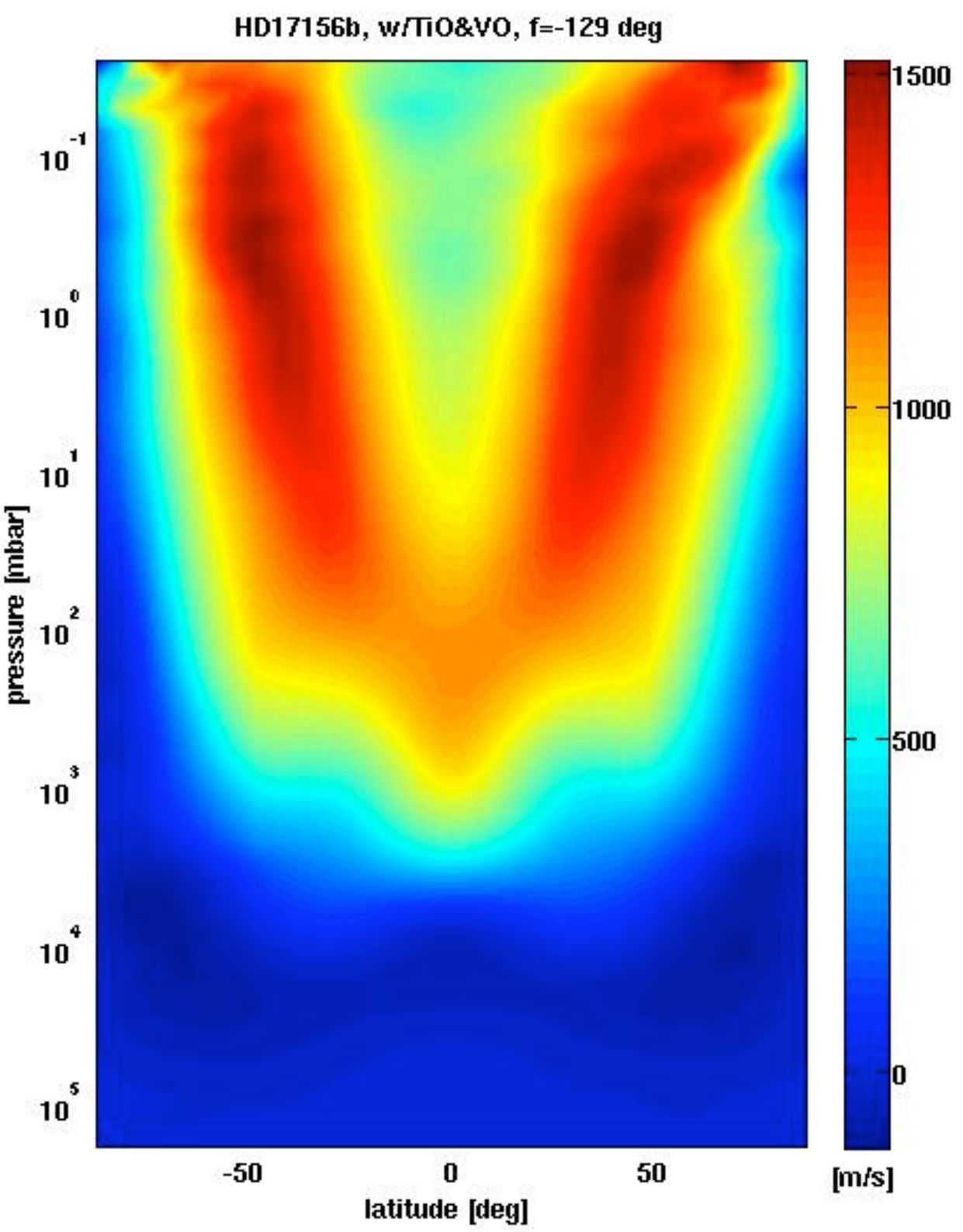

Fortney et al. (2008)

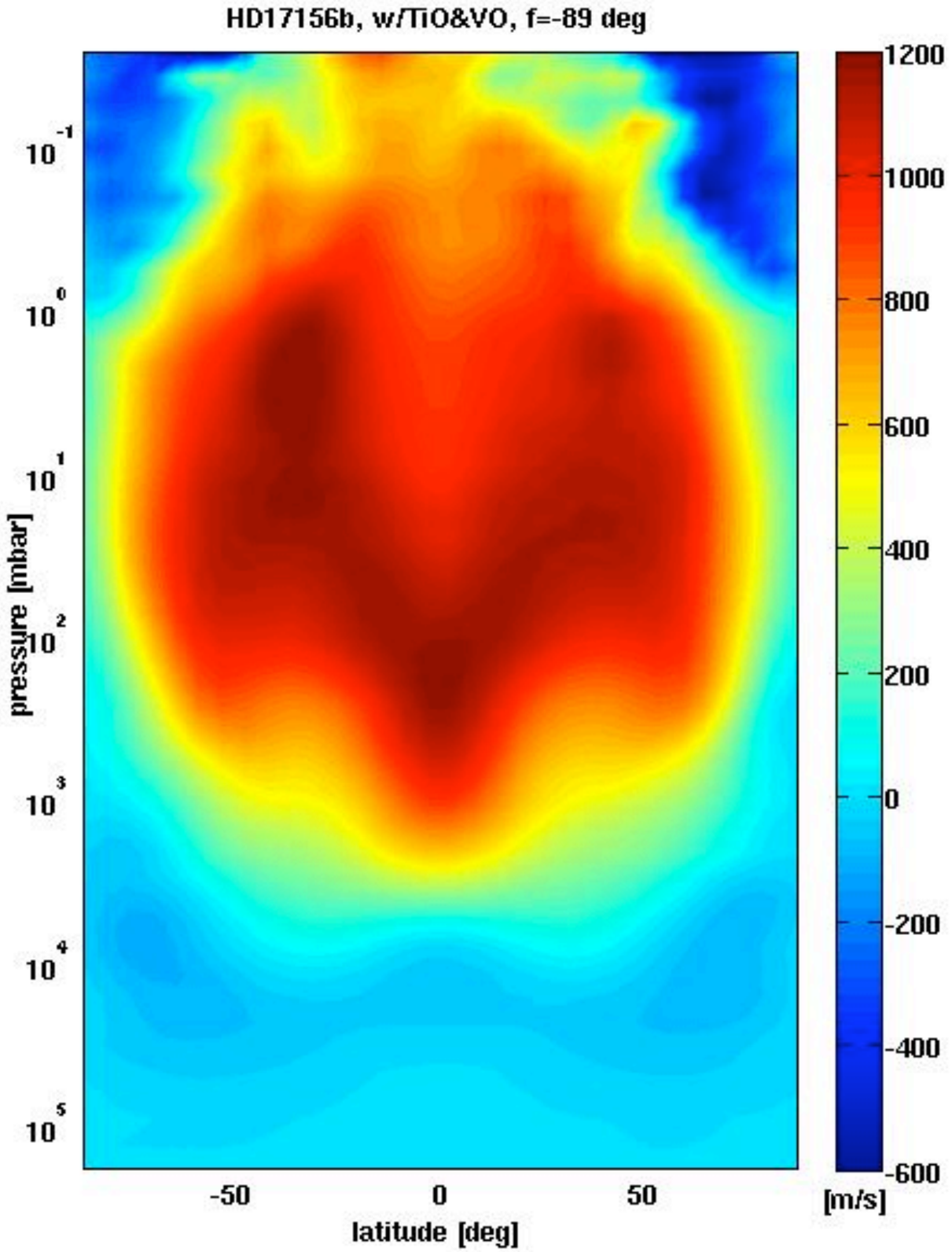
*Gillon et al. (2008)

# HD17156b 1x Solar w/TiOVO, ~30 mbar



# HD17156b 1x Solar w/TiOVO



## Conclusions

- Non-synchronous rotation favors the development of mid to high latitude jets.
- Increasing chemical abundances in the atmosphere relative to solar tends to produce strong winds near the equator and increase temperatures near the level of the photosphere.
- Weather on eccentric planets will produce light curves that will be exhibit peak flux timing different from that of non-eccentric planets.

## Future Work

- Explore the effects of tidal heating on atmospheric dynamics.
- Tackle the dynamics of other transiting extrasolar planets with *Spitzer* multi-wavelength data.

# Questions?