Blue Atmosphere or Stellar Activity
Is the Blue Atmosphere of the Exoplanet GJ 3470 b Real?

Silvia Kunz
European Week of Astronomy and Space Science
June 27, 2017
Hot Jupiters Have Blue Atmospheres
Hot Jupiters Have Blue Atmospheres

What about low-mass planets?
Hot Jupiters Have Blue Atmospheres

What about low-mass planets?
Up to now only 3 claimed detections!
planet mass: 13.73 $M_\oplus$ ± 1.61 $M_\oplus$
planet radius: 3.88 $R_\oplus$ ± 0.32 $R_\oplus$
planet mean density: 1.18 g cm$^{-3}$ ± 0.33 g cm$^{-3}$
semimajor axis: 0.031 AU ± 0.0028 AU
orbital period: 3.3367 days

spectral type: M 1.4
distance: 28.82 pc ± 2.53 pc
stellar radius: 0.48 $R_\odot$ ± 0.04 $R_\odot$
stellar mass: 0.51 $M_\odot$ ± 0.06 $M_\odot$
Why is this planet interesting?

- orbits a relatively bright M dwarf (mag $V = 12.332$)
- transiting planet → transmission spectroscopy is possible
- good for atmospheric detections → favorable planet–to–star radius ratio
- one of the lightest planets with indications of an atmosphere
- it is still debated if atmospheres can survive in the vicinity of M dwarfs
Why is this planet interesting?

- orbits a relatively bright M dwarf ($\text{mag}_V = 12.332$)
Why is this planet interesting?

- orbits a relatively bright M dwarf ($\text{mag}_V = 12.332$)
- transiting planet $\rightarrow$ transmission spectroscopy is possible

It is still debated if atmospheres can survive in the vicinity of M dwarfs.
Why is this planet interesting?

- orbits a relatively bright M dwarf (mag$_V = 12.332$)
- transiting planet $\rightarrow$ transmission spectroscopy is possible
- good for atmospheric detections $\rightarrow$ favorable planet–to–star radius ratio
Why is this planet interesting?

• orbits a relatively bright M dwarf ($\text{mag}_V = 12.332$)
• transiting planet $\rightarrow$ transmission spectroscopy is possible
• good for atmospheric detections $\rightarrow$ favorable planet–to–star radius ratio
• one of the lightest planets with indications of an atmosphere
Why is this planet interesting?

- orbits a relatively bright M dwarf \((\text{mag}_V = 12.332)\)
- transiting planet \(\rightarrow\) transmission spectroscopy is possible
- good for atmospheric detections \(\rightarrow\) favorable planet–to–star radius ratio
- one of the lightest planets with indications of an atmosphere
- it is still debated if atmospheres can survive in the vicinity of M dwarfs
GJ 3470 b’s Blue Atmosphere

Radius ratio $k$

Wavelength (nm)

Our Data*
Nascimbeni 2013 revised
Nascimbeni 2013
Fukui 2013
Dragomir 2015
Biddle 2014
Awiphan 2016

* Chen et al. 2017
Job done?

MY JOB HERE IS DONE

Troll.me
Stars Have Activity Features
Plage Regions Are Brighter and Spots Are Darker in the Blue
Bigger Radius in the Blue than in the Red?
Bigger Radius in the Blue than in the Red?

How can we distinguish both effects?
Plage Regions are Hardly Visible in the Continuum...
but Plage Regions are Visible in a Ca II K Filter
Method

Estimate Filling Factor

- $f < 2\%$
  - No Effect Measurable

- $2\% < f < 50\%$
  - Take Spectra Of Transit

- $f > 50\%$
  - Effect Evens Out Or Is Not Measurable

Analyze Ca II H,K lines

- Decrease measurable
  - Transit Depth Could Be Influenced By Plage Regions

- No decrease measurable
  - Plage Regions Do Not Influence The Transit Depth
Filling Factor of GJ 3470 as in Fawzy et al. (2002)
Filling Factor of GJ 3470 as in Fawzy et al. (2002)

Filling factor of GJ 3470 is very roughly 20 %
Method

1. **Estimate Filling Factor**
   - **$f < 2\%$**
     - **No Effect Measurable**
   - **$2\% < f < 50\%$**
     - **Take Spectra Of Transit**
   - **$f > 50\%$**
     - **Effect Evens Out Or Is Not Measurable**

2. **Analyze Ca II H,K lines**
   - **Decrease Measurable**
     - **Transit Depth Could Be Influenced By Plage Regions**
   - **No Decrease Measurable**
     - **Plage Regions Do Not Influence The Transit Depth**
Method

- **Estimate Filling Factor**
  - \( f < 2\% \)
  - \( 2\% < f < 50\% \)
  - \( f > 50\% \)

- **No Effect Measurable**
- **Take Spectra Of Transit**
- **Effect Evens Out Or Is Not Measurable**

- **Analyze Ca II H,K lines**
  - Decrease measurable
  - No decrease measurable

- **Transit Depth Could Be Influenced By Plage Regions**
- **Plage Regions Do Not Influence The Transit Depth**
Method

- Estimate Filling Factor
  - $f < 2\%$
  - $2\% < f < 50\%$
  - $f > 50\%$

- Take Spectra Of Transit
  - No Effect
    - No Effect Measurable
  - Effect Evens Out Or Is Not Measurable

- Analyze Ca II H,K lines
  - decrease measurable
    - Transit Depth Could Be Influenced By Plage Regions
  - no decrease measurable
    - Plage Regions Do Not Influence The Transit Depth
GJ 3470 b – No Difference in Ca II H, K lines

![Graphs showing Ca K and Ca H lines for GJ 3470 b in different transit phases.](image)
Still No Difference in Sum of Ca II H,K lines

![Graph showing Sum of Ca II H,K lines of GJ3470]
Maybe we do not have to care about plage regions at all?
### GJ 1214 - Properties of the System

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>±       Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>planet mass</td>
<td>6.26 M⊕</td>
<td>± 0.91 M⊕</td>
</tr>
<tr>
<td>planet radius</td>
<td>2.80 R⊕</td>
<td>± 0.24 R⊕</td>
</tr>
<tr>
<td>planet mean density</td>
<td>1.56 g cm⁻³</td>
<td>± 0.40 g cm⁻³</td>
</tr>
<tr>
<td>semimajor axis</td>
<td>0.0141 AU</td>
<td>± 0.0003 AU</td>
</tr>
<tr>
<td>orbital period</td>
<td>1.5804 days</td>
<td></td>
</tr>
<tr>
<td>spectral type</td>
<td>M 4.5</td>
<td></td>
</tr>
<tr>
<td>distance</td>
<td>14.55 pc</td>
<td>± 0.3 pc</td>
</tr>
<tr>
<td>stellar radius</td>
<td>0.213 R☉</td>
<td>± 0.011 R☉</td>
</tr>
<tr>
<td>stellar mass</td>
<td>0.176 M☉</td>
<td>± 0.009 M☉</td>
</tr>
</tbody>
</table>
Sum of the Lines is Smaller During Transit

Sum of Ca II H,K lines of GJ1214

- Out of Transit
- In Transit

normalized flux

velocity / kms$^{-1}$
Overview of Ca II H,K S-indices in and out of transit

<table>
<thead>
<tr>
<th></th>
<th>GJ 1214</th>
<th>GJ 3470</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Transit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out of Transit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This Work was Published this Year

- **Authors:**
  G. Chen, E.W. Guenther, E. Pallé, L. Nortmann, G. Nowak, S. Kunz, H. Parviainen and F. Murgas
- **The GTC exoplanet transit spectroscopy survey**
  V. A spectrally-resolved Rayleigh scattering slope in GJ 3470 b
- **Astronomy & Astrophysics, 600:A138, 2017.**
Conclusion

• Aim: find out if the blue atmospheres are real or stellar activity?
Conclusion

• Aim: find out if the blue atmospheres are real or stellar activity?
• Method: check Ca II H,K lines as tracers of stellar activity
Conclusion

- **Aim**: find out if the blue atmospheres are real or stellar activity?
- **Method**: check Ca II H,K lines as tracers of stellar activity
- **GJ 3470 b**: no changes in Ca II H,K lines during transit
  → the blue atmosphere is most probably real

- **GJ 1214 b**: significant decrease during transit
  → increase most probably due to activity

- If Rayleigh scattering is observed follow up measurements should be made
Conclusion

- **Aim:** find out if the blue atmospheres are real or stellar activity?
- **Method:** check Ca II H,K lines as tracers of stellar activity
- **GJ 3470 b:** no changes in Ca II H,K lines during transit  
  → the blue atmosphere is most probably real
- **GJ 1214 b:** significant decrease during transit  
  → increase most probably due to activity
Conclusion

- **Aim:** find out if the blue atmospheres are real or stellar activity?
- **Method:** check Ca II H,K lines as tracers of stellar activity
- **GJ 3470 b:** no changes in Ca II H,K lines during transit
  → the blue atmosphere is most probably real
- **GJ 1214 b:** significant decrease during transit
  → increase most probably due to activity
- if Rayleigh scattering is observed follow up measurements should be made