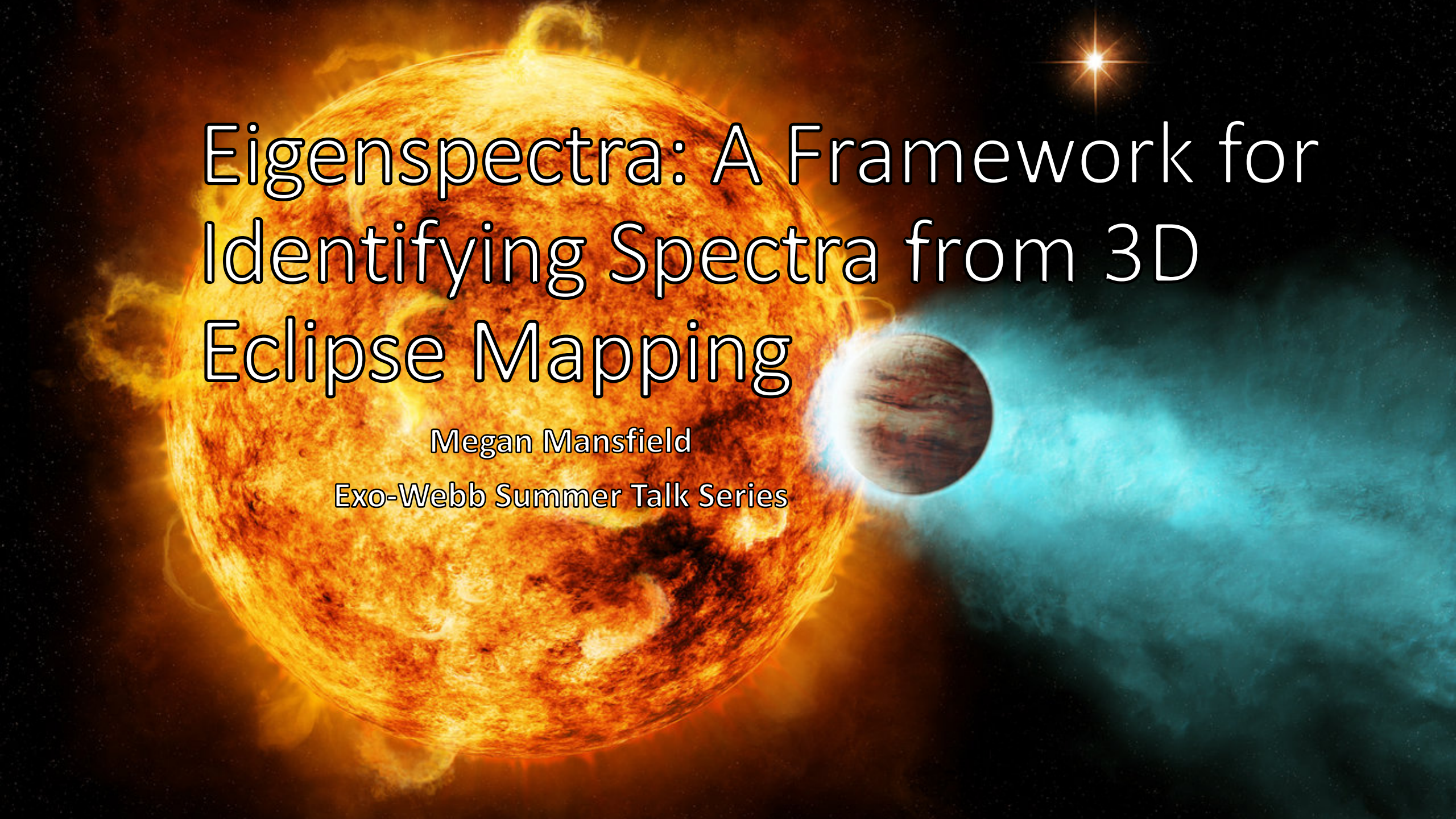


Eigenspectra: A Framework for Identifying Spectra from 3D Eclipse Mapping

Megan Mansfield

Exo-Webb Summer Talk Series

Acknowledgements

- Co-Authors: Everett Schlawin, Jacob Lustig-Yaeger, Arthur D. Adams, Emily Rauscher, Jacob Arcangeli, Y. Katherina Feng, Prashansa Gupta, Dylan Keating, Kevin B. Stevenson, and Thomas G. Beatty
- University of Michigan Institute for Research in Astrophysics

Photometric eclipse mapping produces a 2D map of the planet's dayside

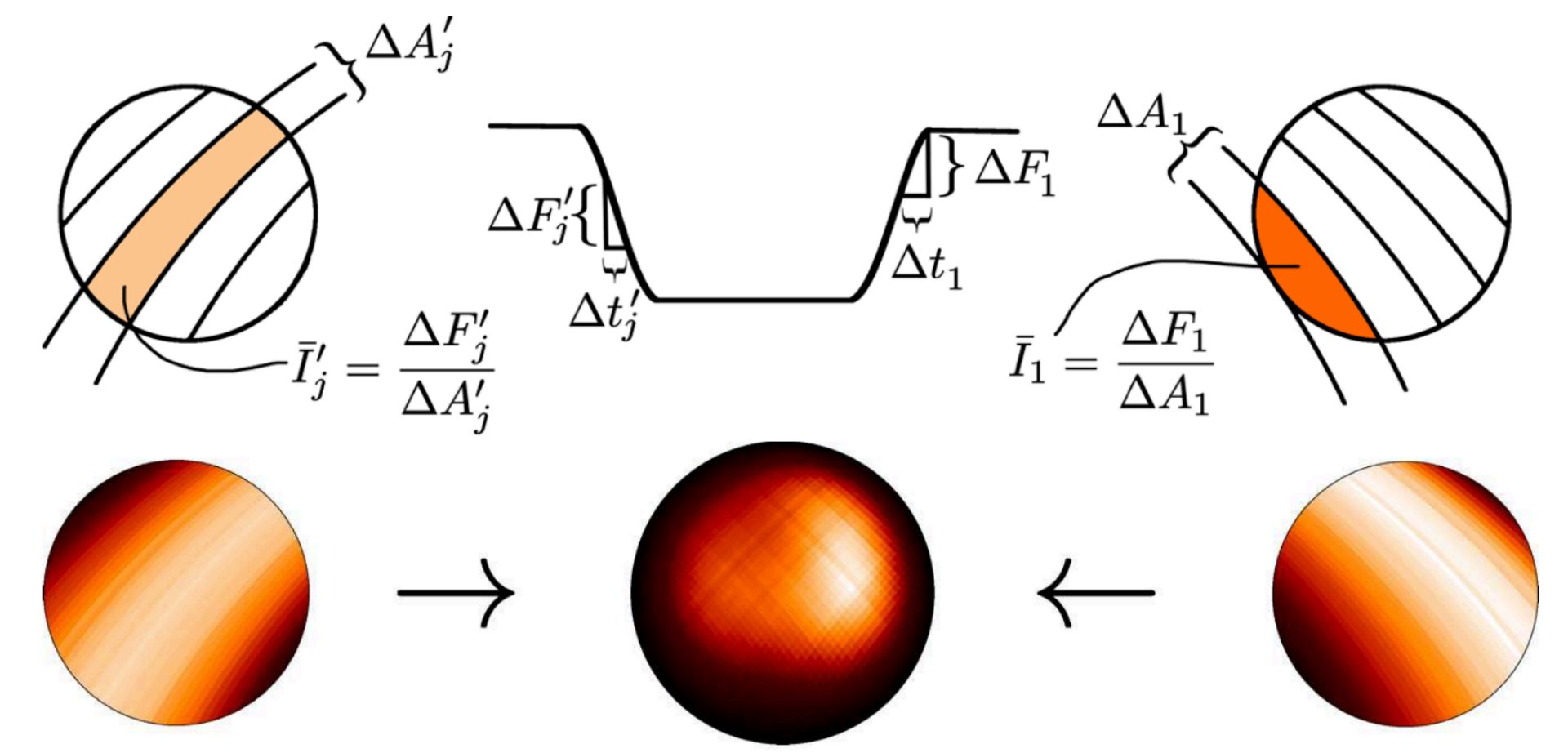


Figure from Majeau et al. (2012)

Photometric eclipse mapping has produced one map of one planet (HD 189733b at 8 microns)

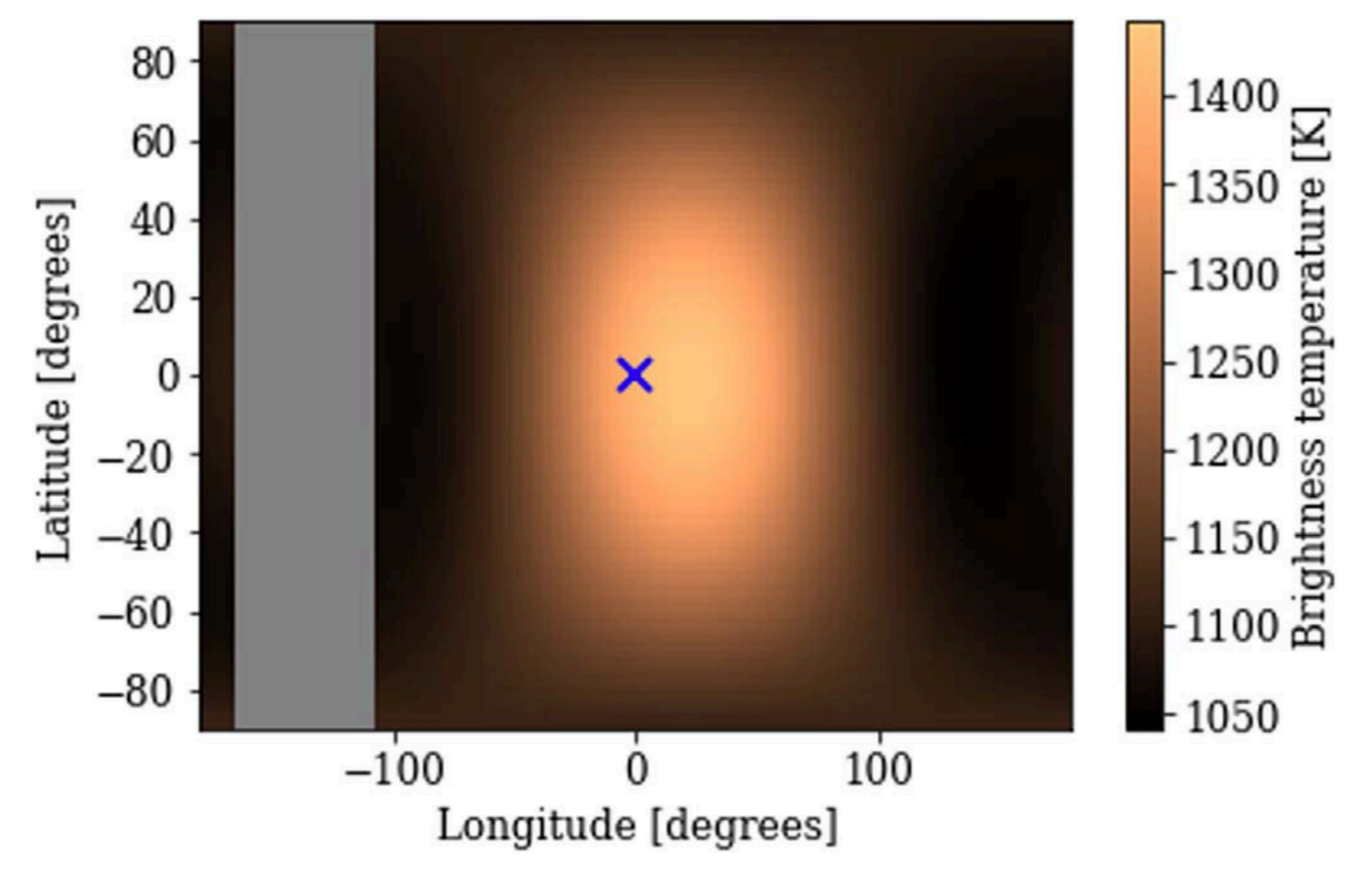
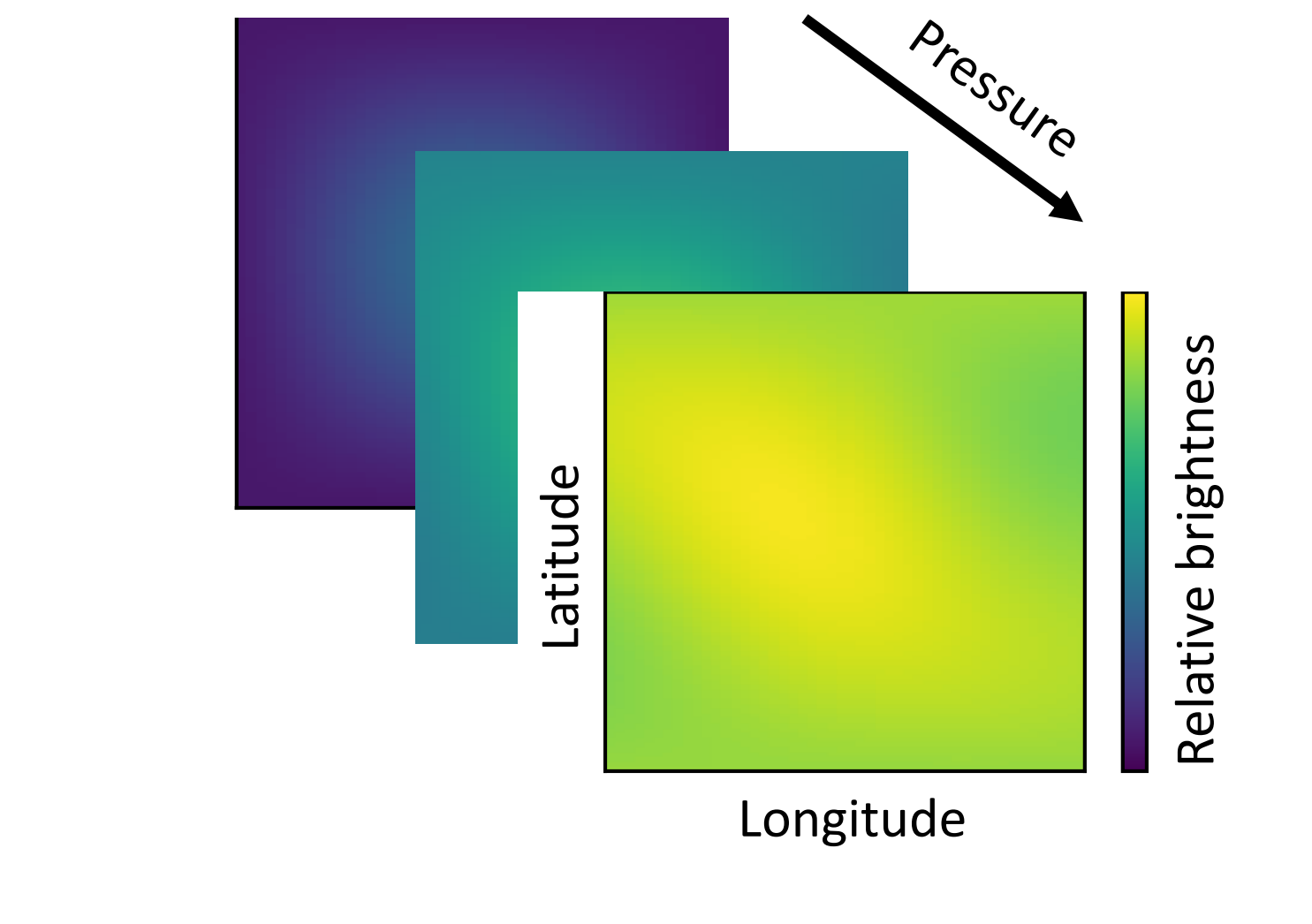


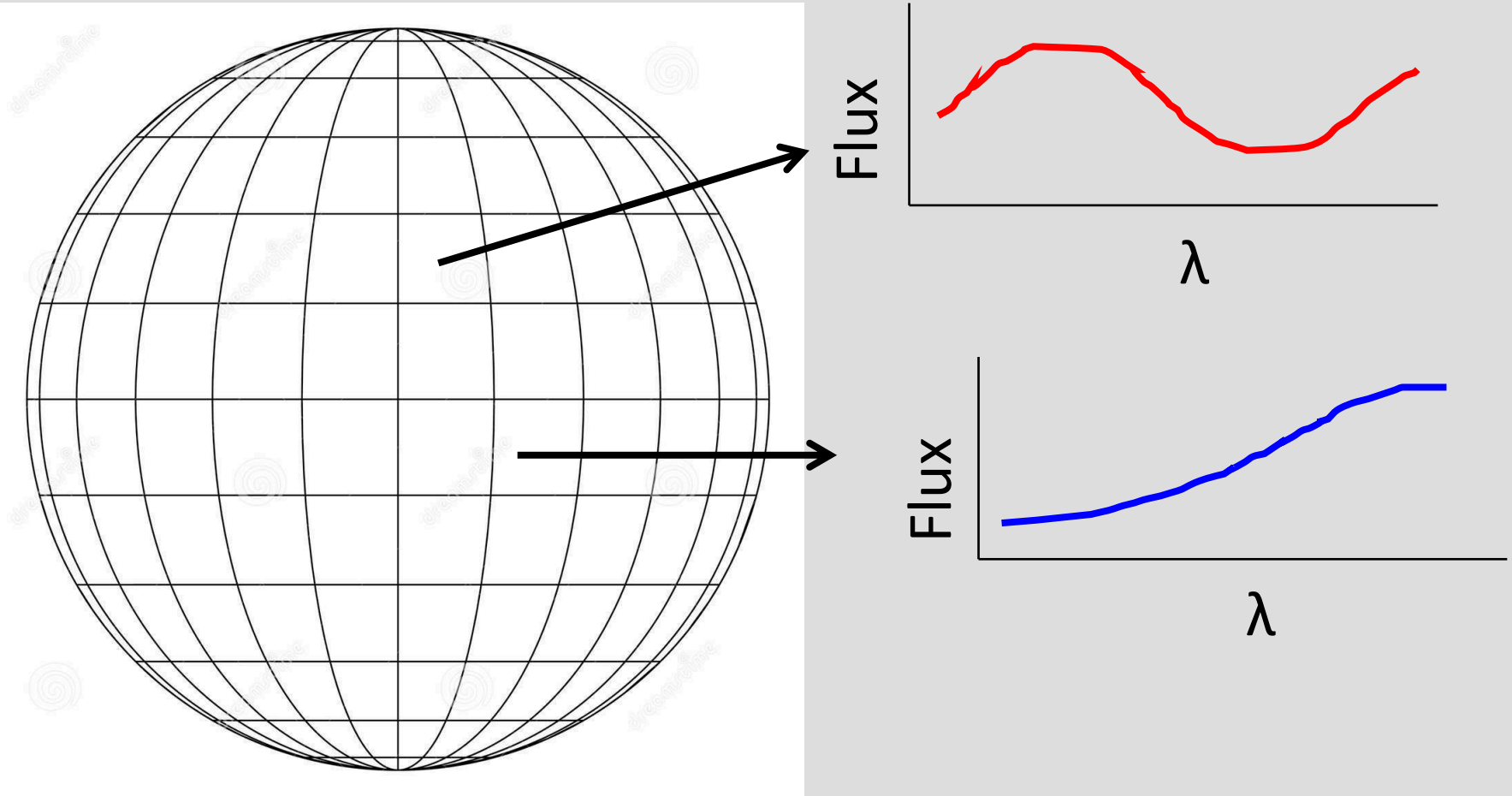
Figure from Rauscher et al. (2018)

JWST = spectroscopic eclipse mapping: one map at each wavelength/altitude/pressure



There are degeneracies in information encoded in eclipse maps. How best to extract the maximum information?

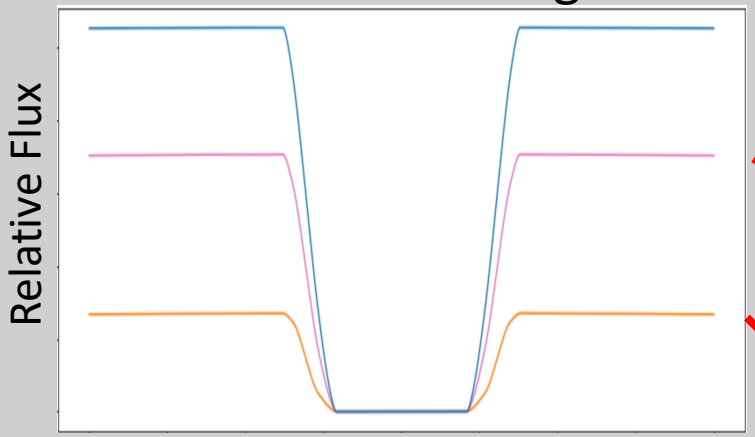
No perfect proxies for spatial dimensions: because you only get lightcurve out there are degeneracies with planetary parameters



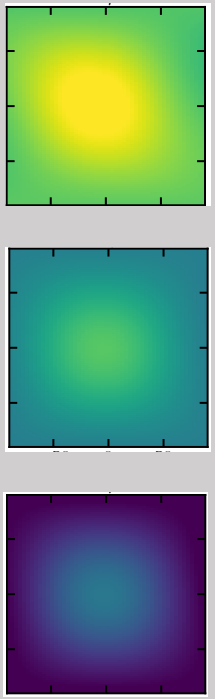
Eigenspectra mapping method developed to address these degeneracies

Eigenspectra mapping identifies flux patterns without a priori assumptions

1. Eclipse light curve at each wavelength

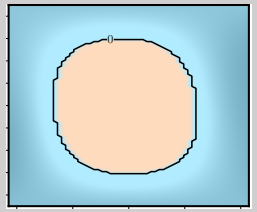


2. Use “eigencurves” (Rauscher et al., 2018) to make map at each wavelength



3. Combine into 3D spatial + spectral map

4. Use clustering to identify similar regions (“groups”) and their representative spectra (“eigenspectra”)



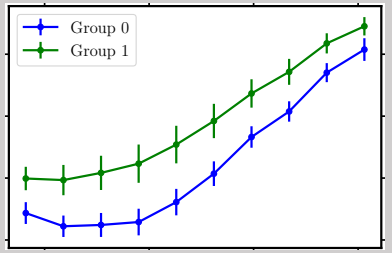
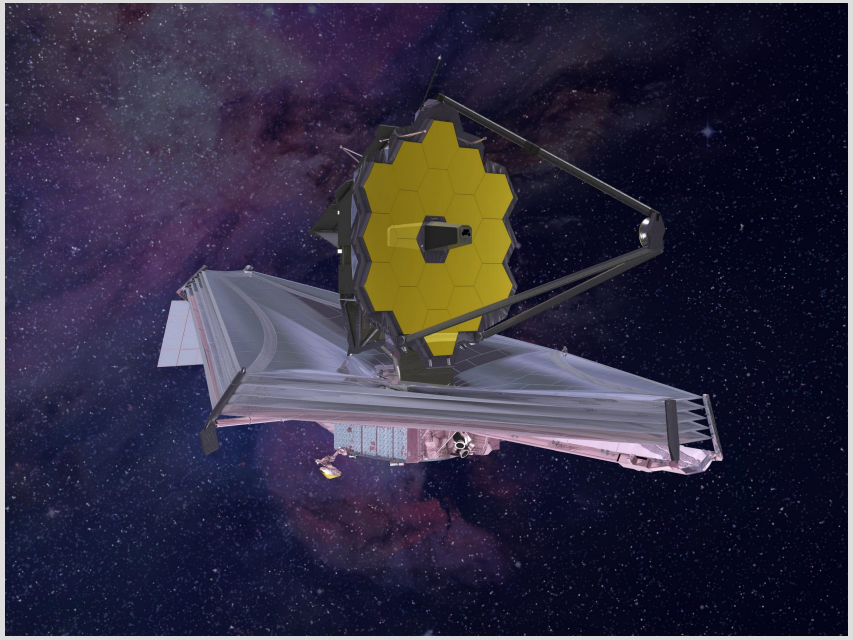
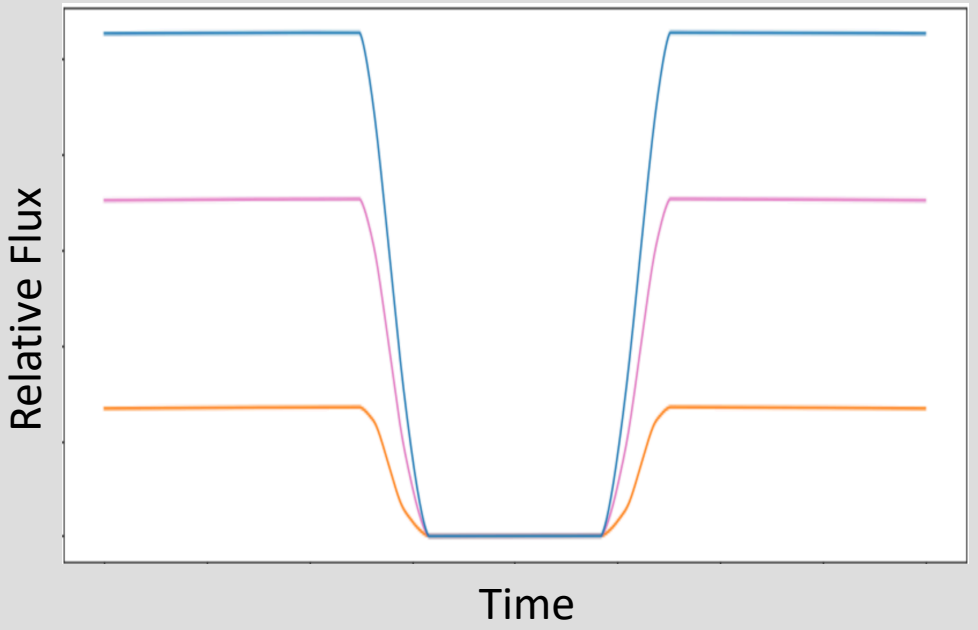


Figure from Mansfield et al. (submitted)

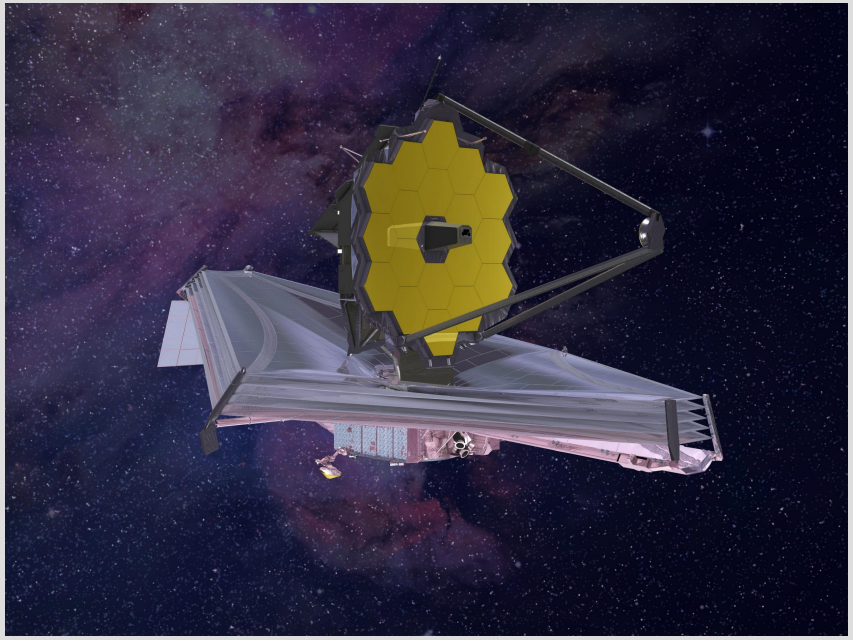
Step 1: JWST gives you beautiful eclipse data



Each curve is at a different wavelength



Goal: look for flux patterns in this data without assuming the flux pattern follows any one physical model



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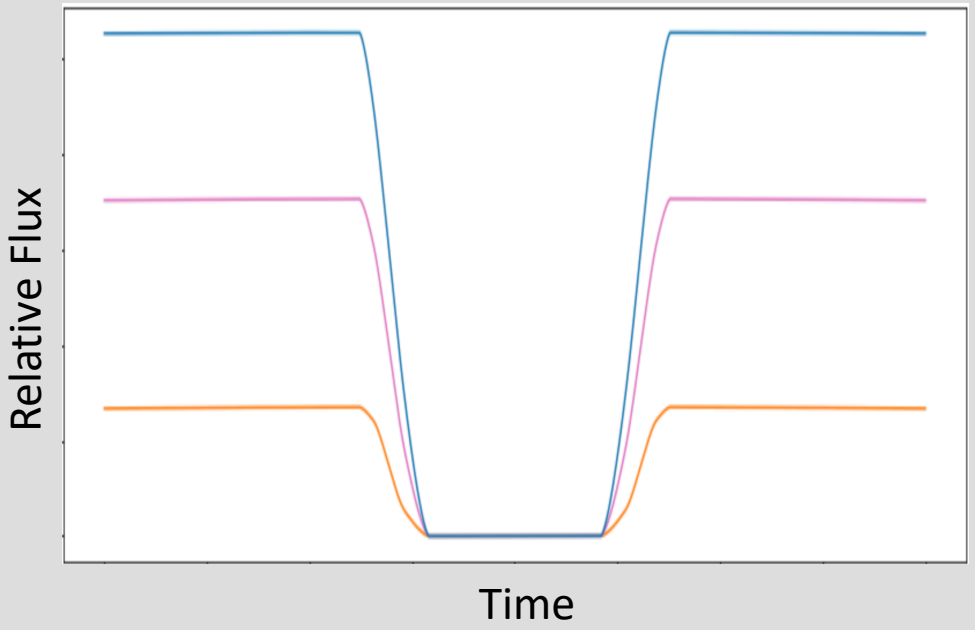
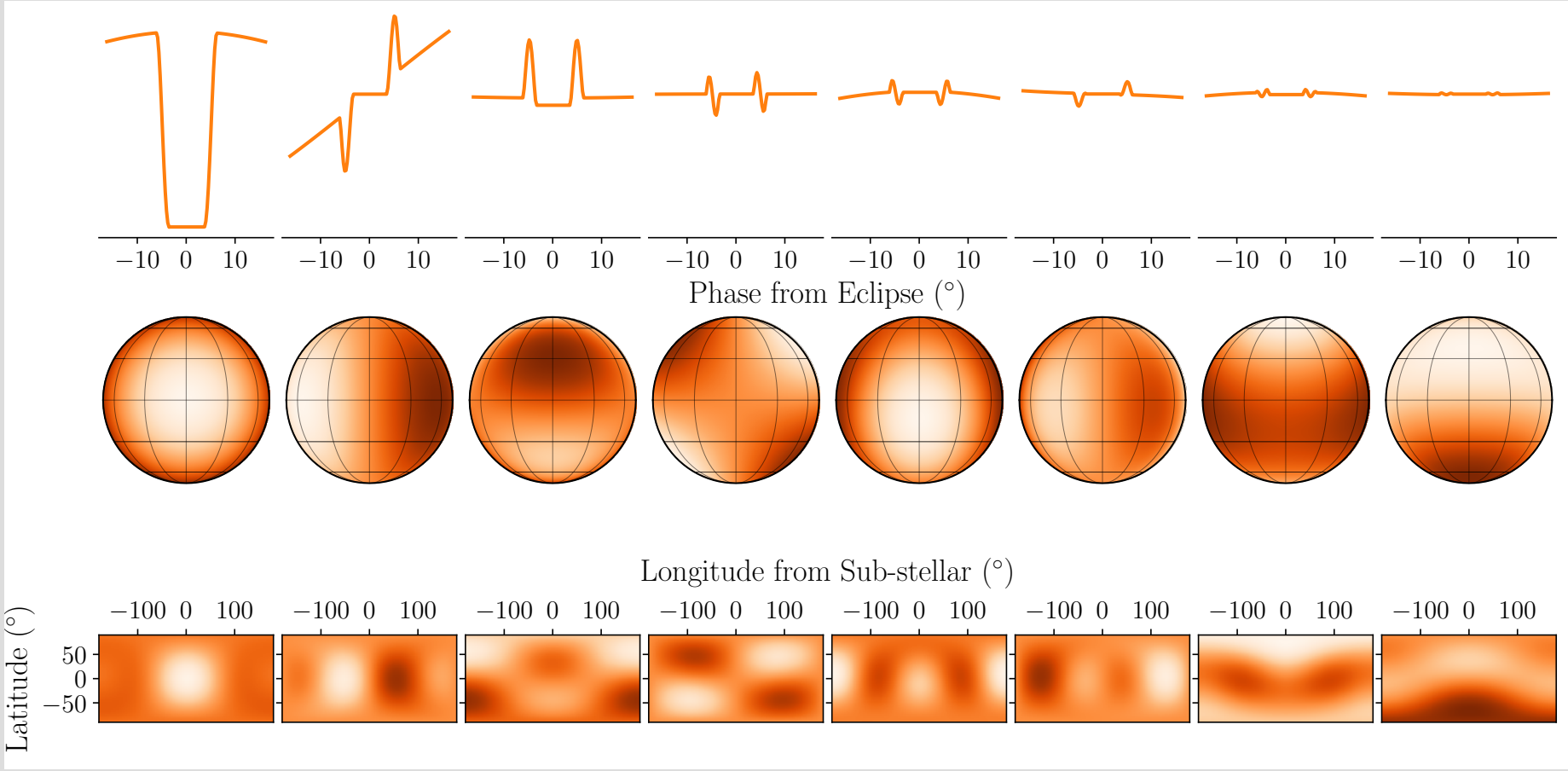


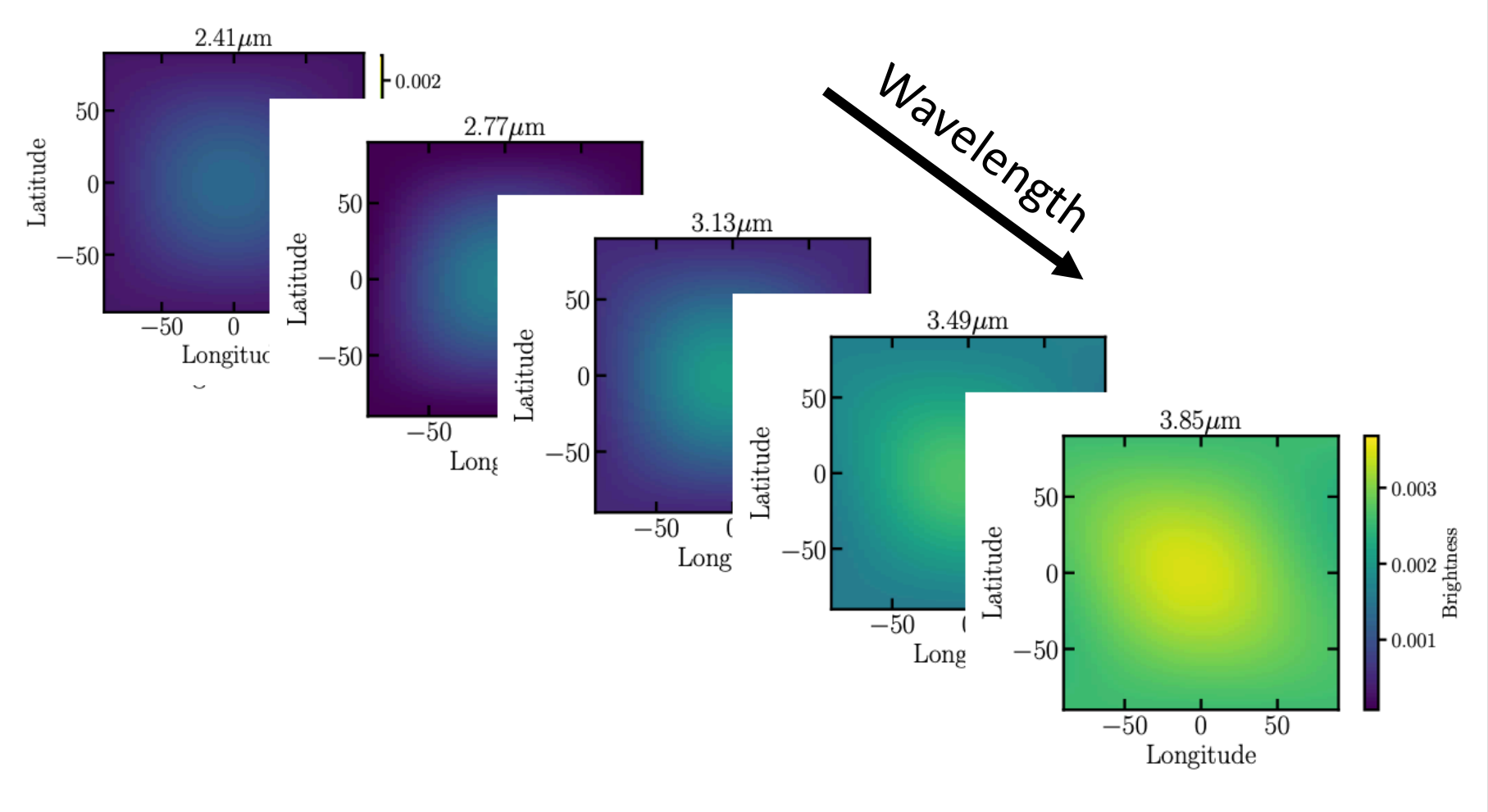
Step 2: Use the “eigencurves” method of Rauscher et al. (2018) to make a map at each wavelength



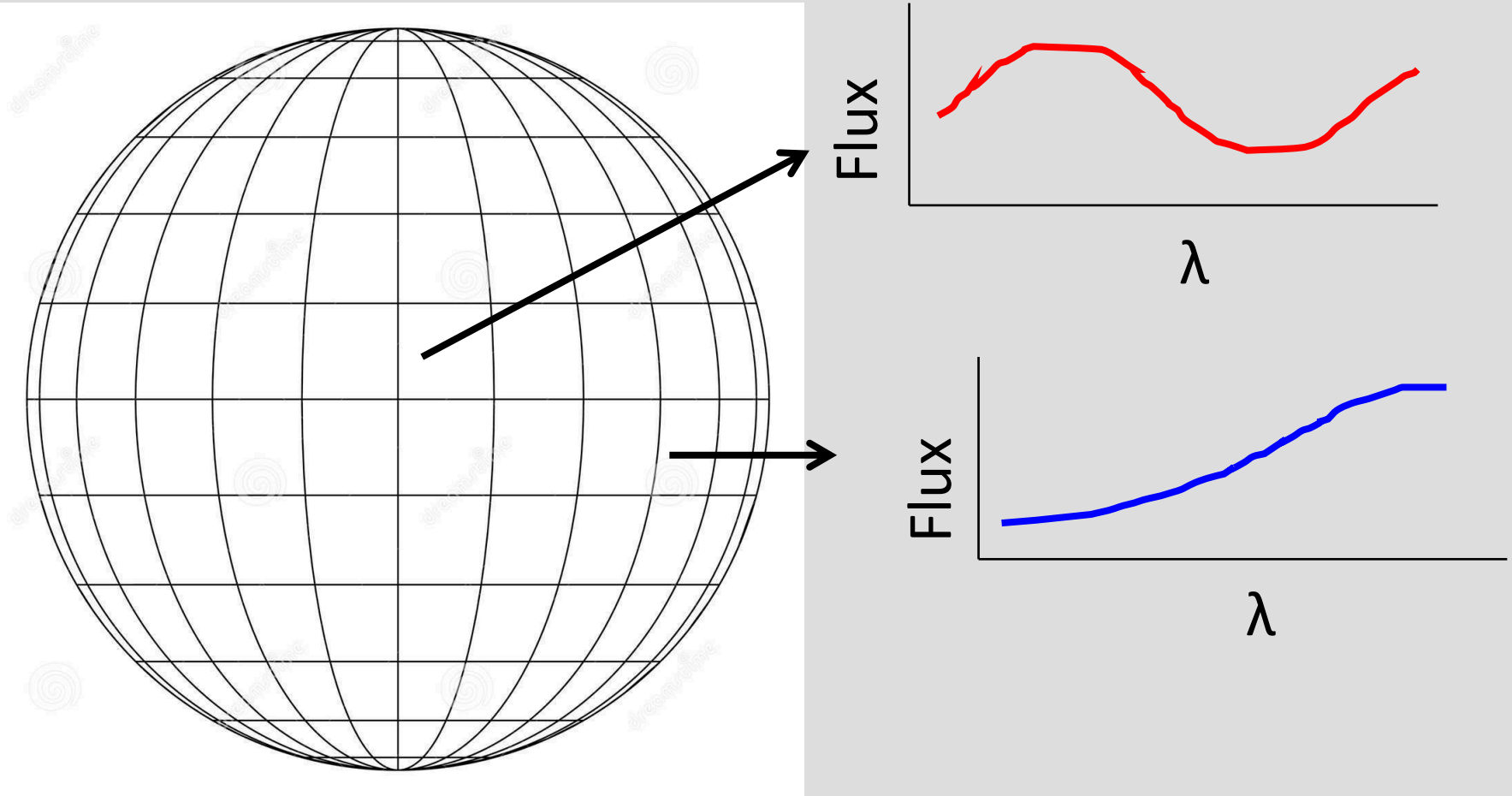
PCA creates orthogonal basis of lightcurves (*not* orthogonal maps)

Figure from Mansfield et al. (submitted), designed by Arthur Adams

Step 3: Combine maps at each wavelength to make one spatial+spectral map



Step 4: Use k-means clustering to identify similar regions (“groups”) and their representative spectra (“eigenspectra”)



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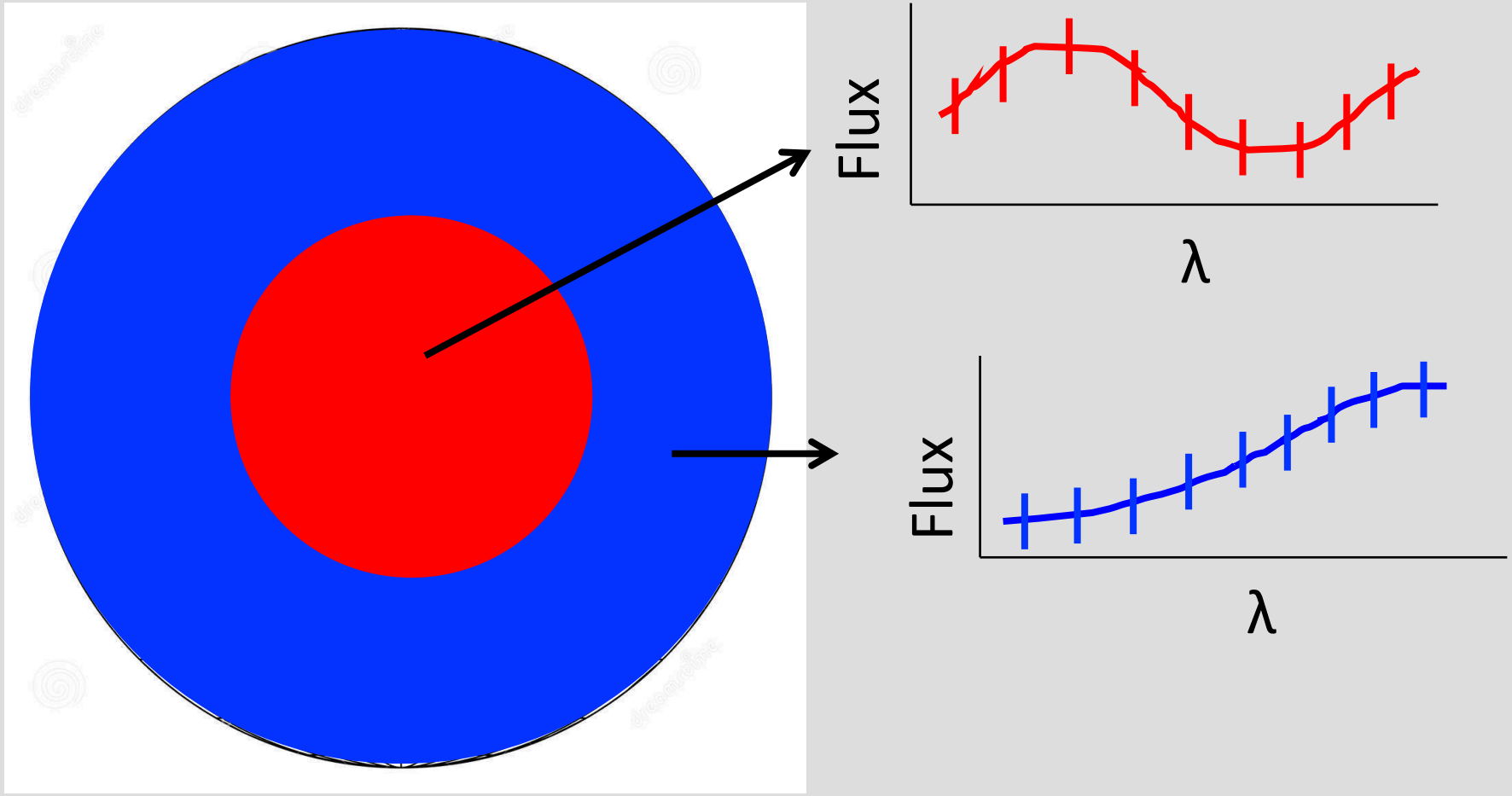
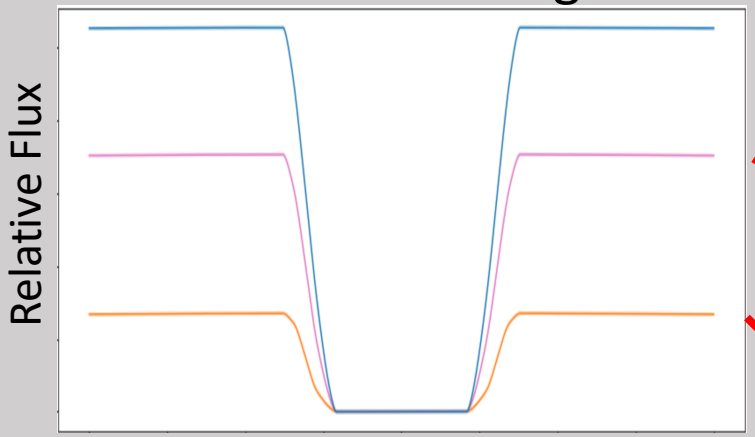


The eigenspectra mapping method in practice: the gradient hotspot

1. Eclipse light curve at each wavelength



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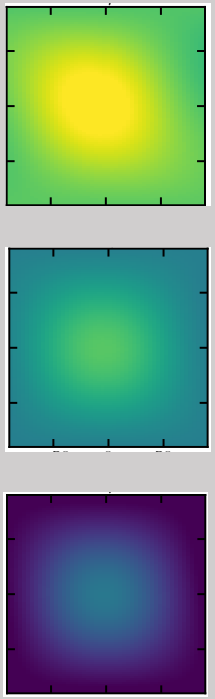
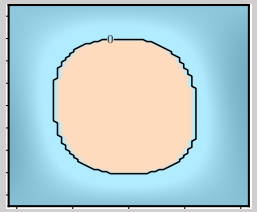


3. Combine into 3D spatial + spectral map

4. Use clustering to identify similar regions (“groups”) and their representative spectra (“eigenspectra”)



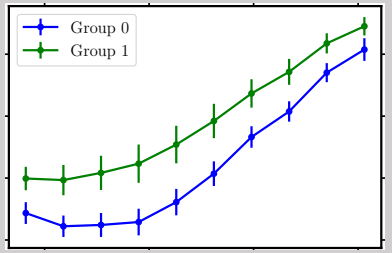
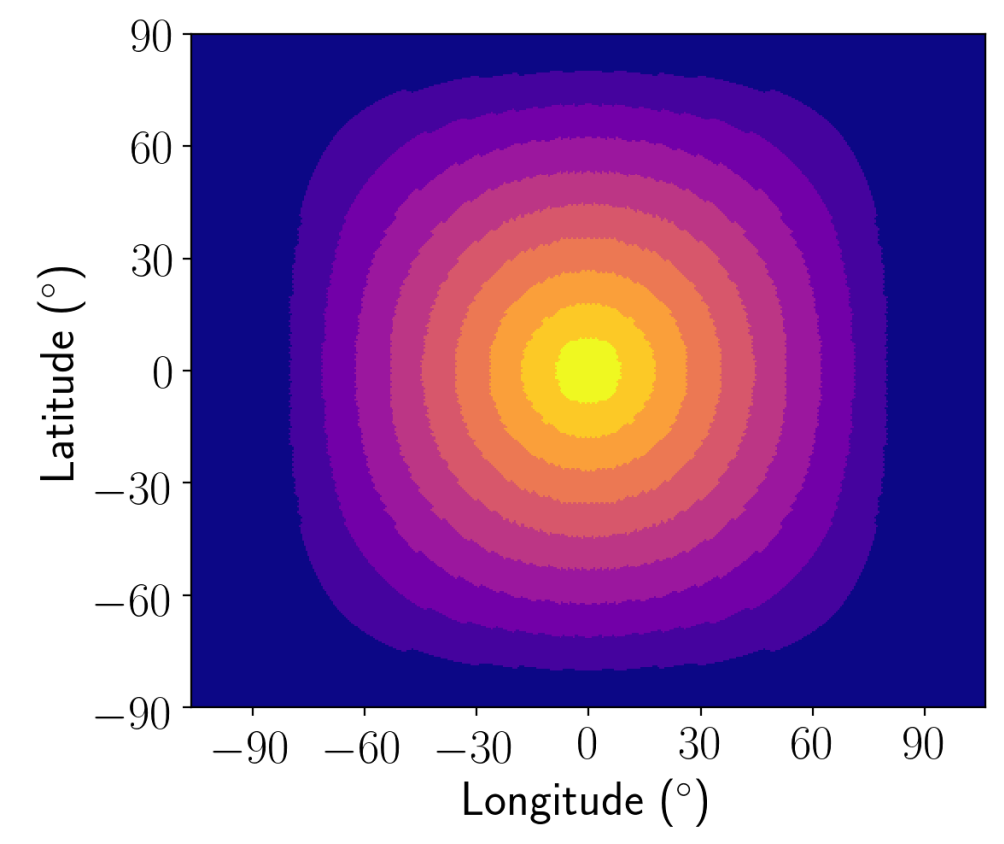
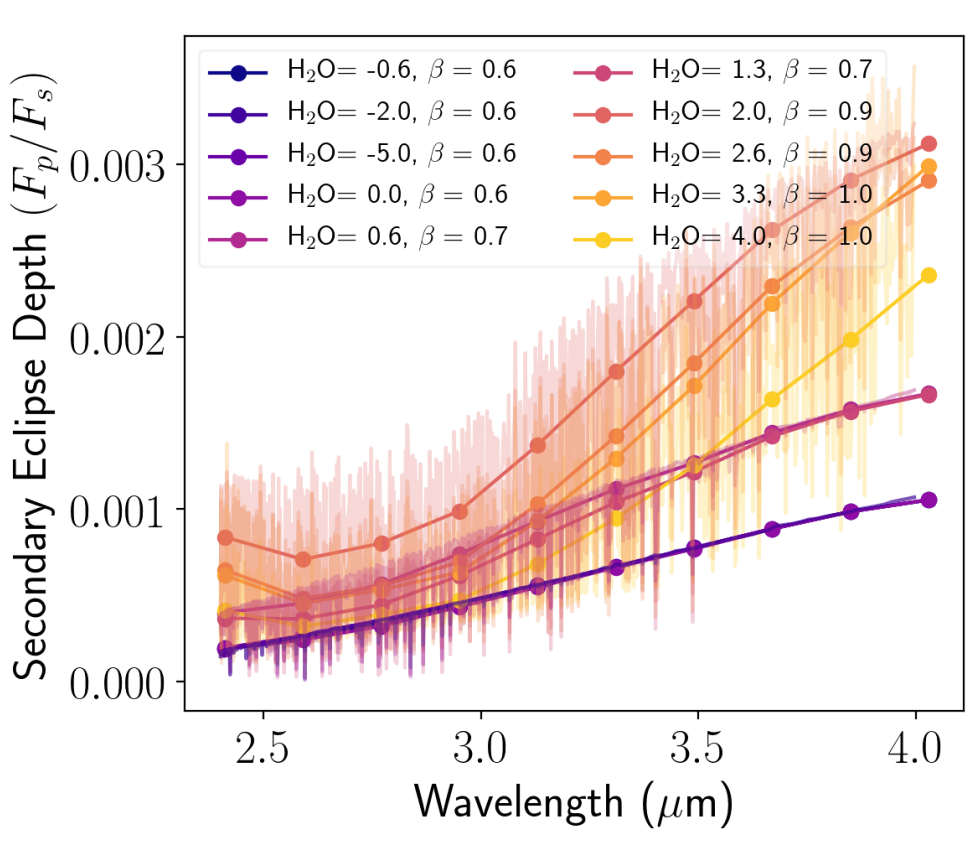


Figure from Mansfield et al. (submitted)

The eigenspectra mapping method in practice: the gradient hotspot

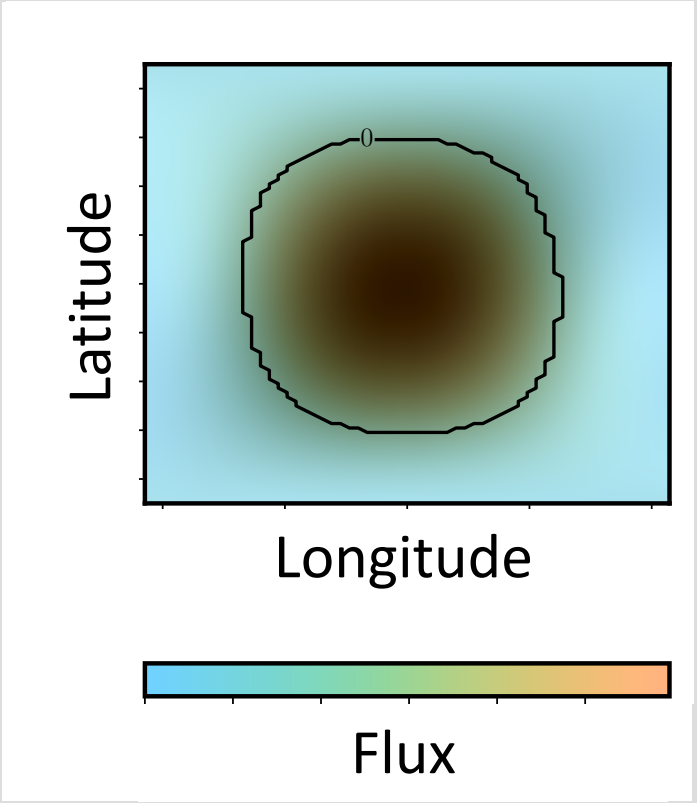


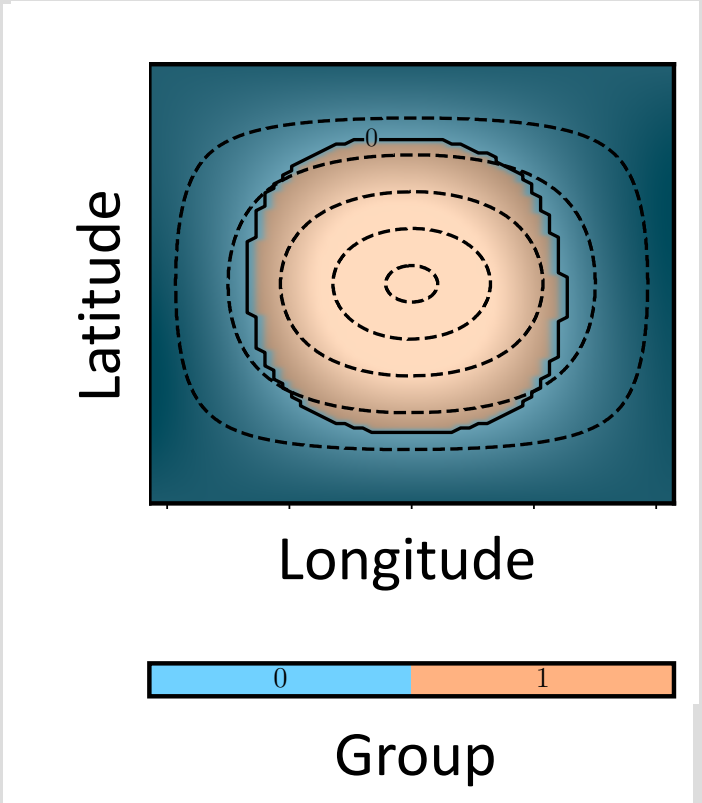


Figures from Mansfield et al. (submitted), designed by Jacob Lustig-Yaeger

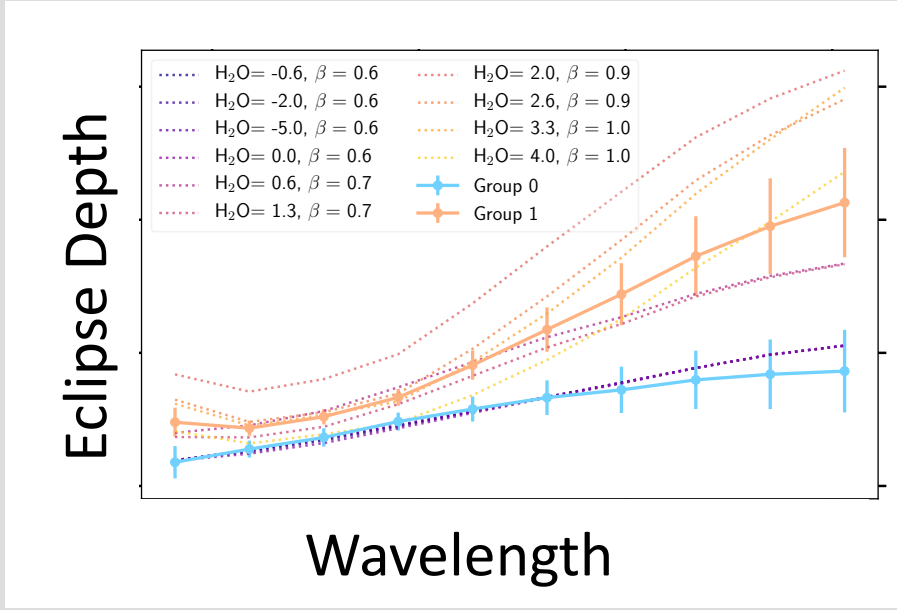
Eigenspectra method identifies large-scale gradients and overall shape of planet map

Output Maps





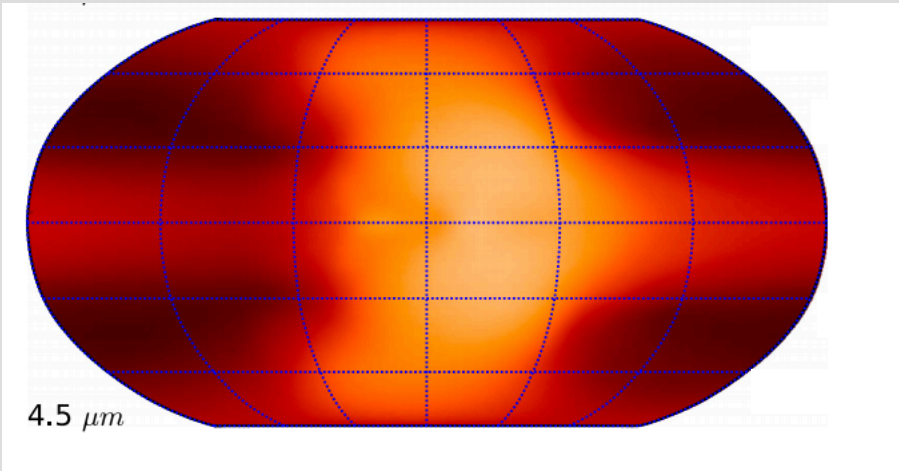
Comparison of “Eigenspectra”



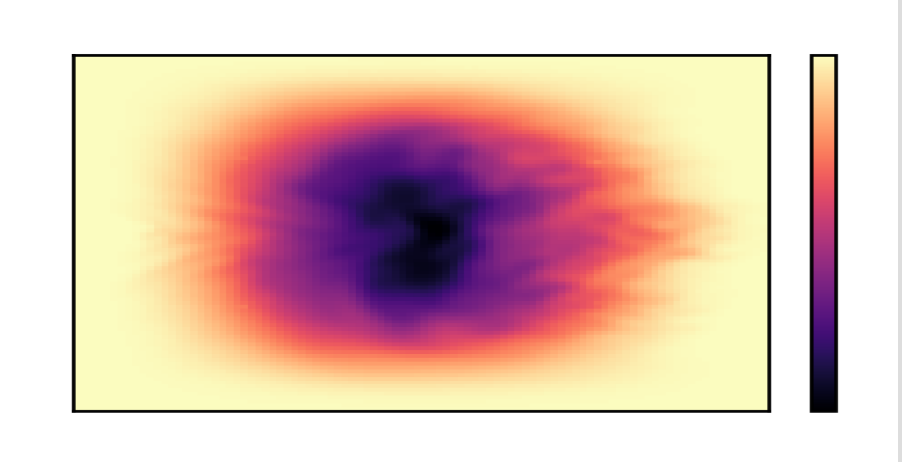
Figures from Mansfield et al. (submitted), designed by Everett Schlawin, Arthur Adams, Jacob Lustig-Yaeger

Limitations to the Eigenspectra mapping method

- Can’t model sharp discontinuities, but we expect realistic planet maps to be smooth
- Best at identifying maps symmetric about the substellar point



WASP-43b (T_{eq}~1400 K) brightness temperature, adapted from Stevenson et al. (2017)



KELT-20b (T_{eq}~2200 K) water mixing ratio, from Thaddeus Komacek

Eigenspectra method can be used to determine observability of features in circulation models

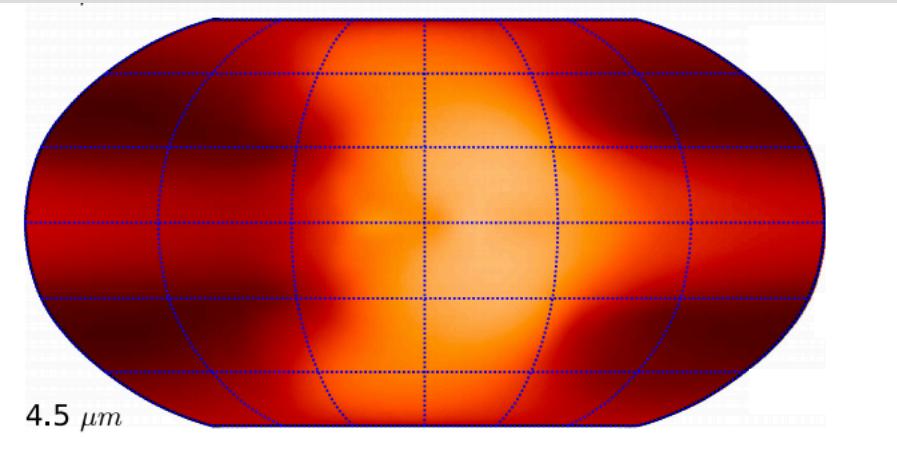


Figure adapted from Stevenson et al. (2017)

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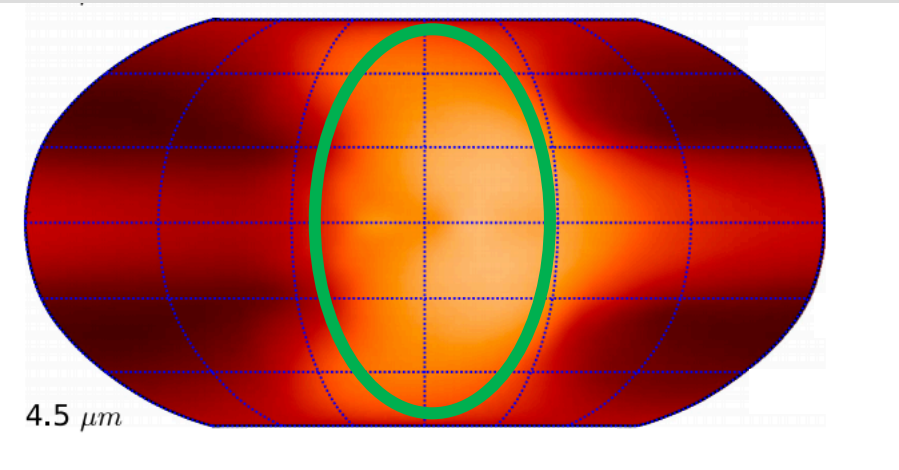
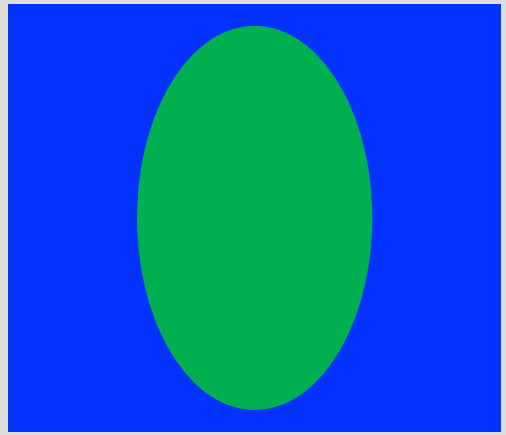




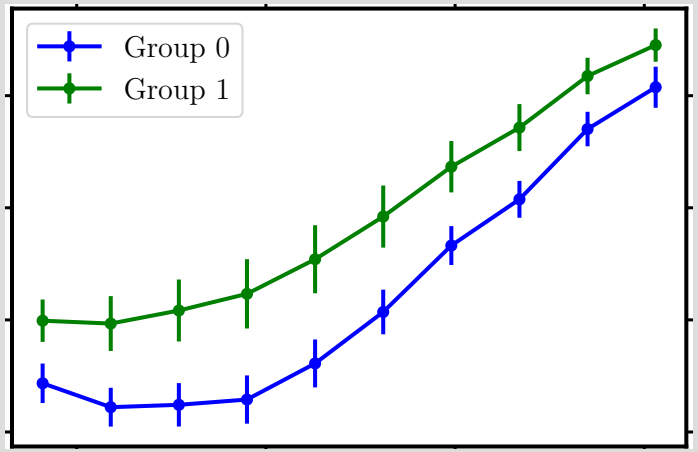
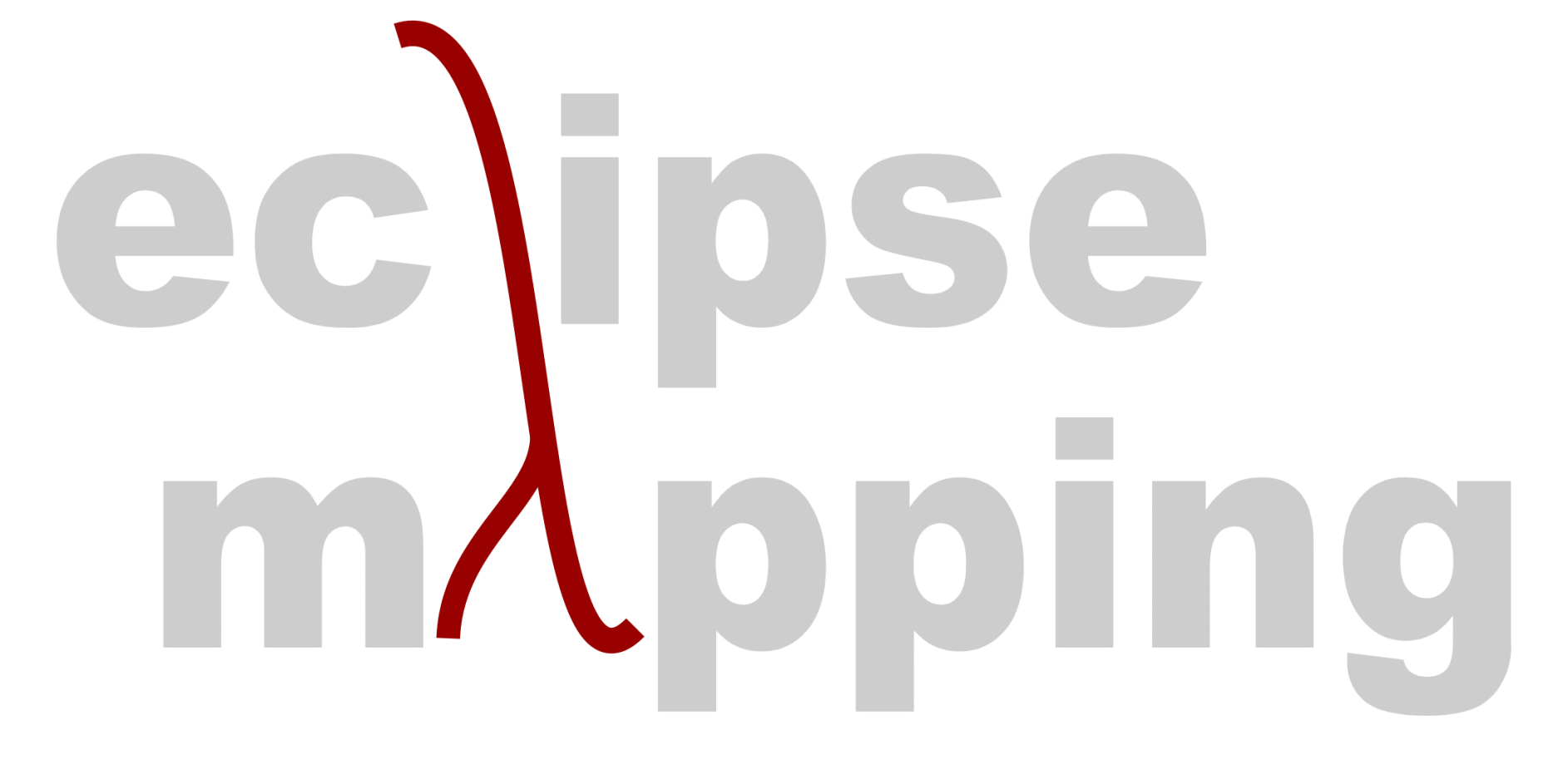


Figure adapted from Stevenson et al. (2017)

Conclusions

- Developed the “eigenspectra” method to extract information from spectroscopic eclipse maps without relying on expected flux patterns from circulation models
- Eigenspectra method generally identifies broad shape of flux pattern but struggles with discontinuities and asymmetric maps
- Two uses for eigenspectra method:
    1. Identify large-scale gradients and flux patterns for further analysis
    2. Evaluate which patterns in circulation models would be observable

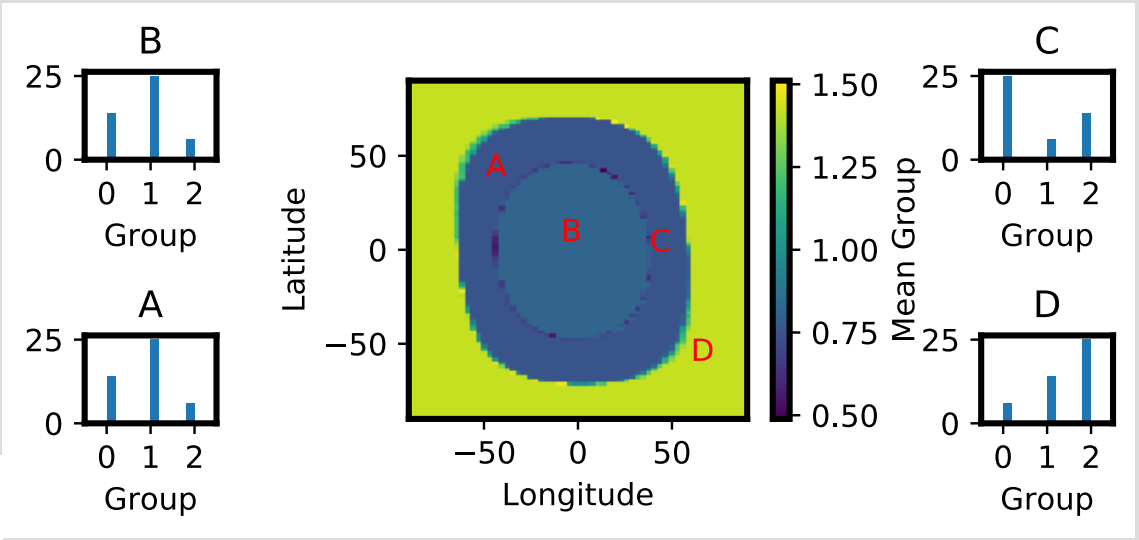
Eigenspectra mapping code will be available on GitHub (github.com/multidworlds/eigenspectra)

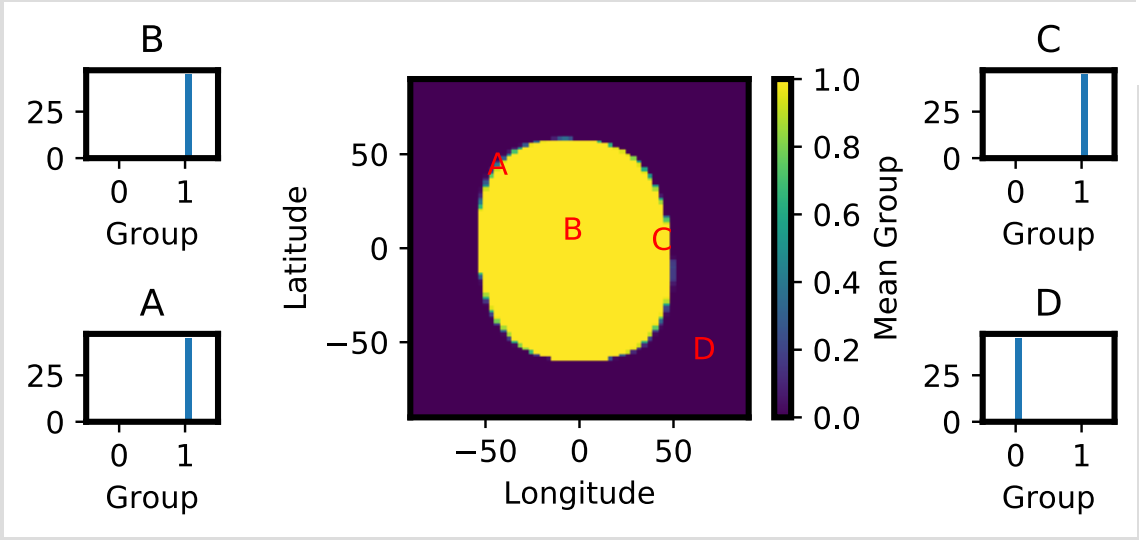


References

- Mansfield, M. et al. 2020, MNRAS submitted
- Majeau, C. et al. 2012, ApJL, 747, 20.
- Rauscher, E. et al. 2018, AJ, 156, 235.
- Stevenson, K. B. et al. 2017, AJ, 153, 68.

Different numbers of groups

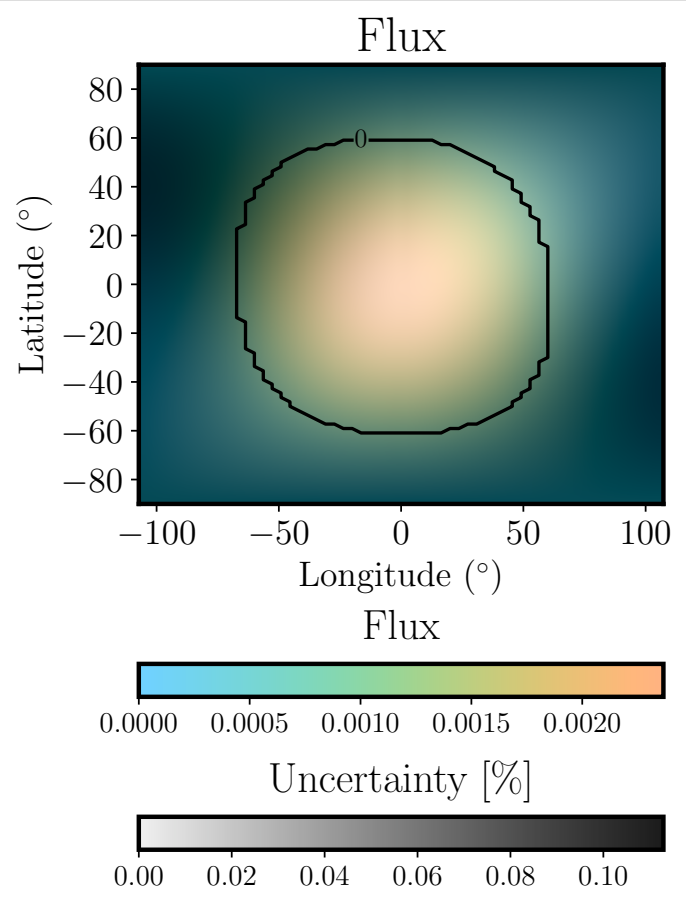


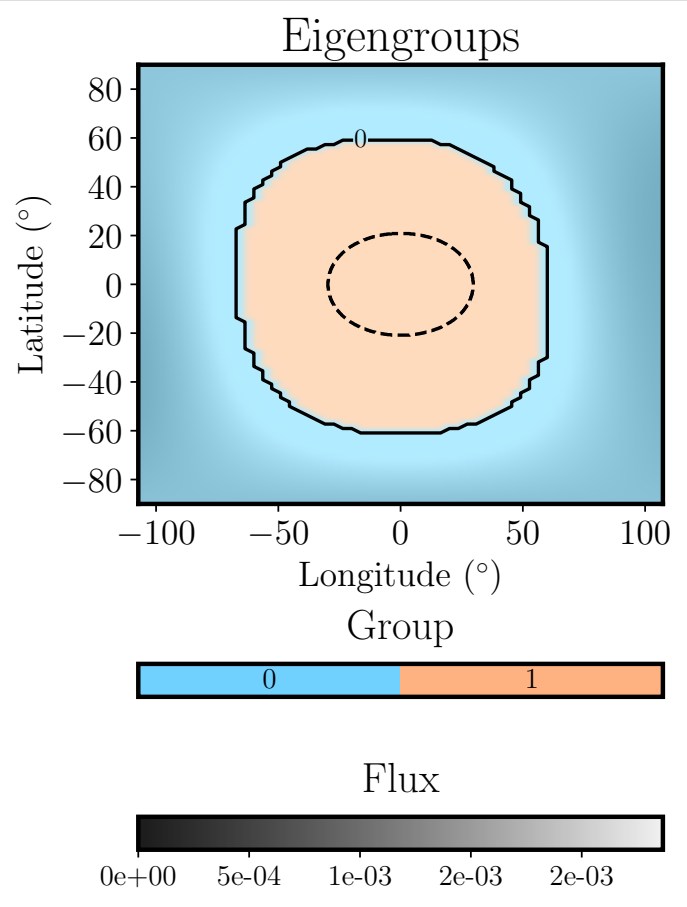


Figures from Mansfield et al. (submitted), designed by Everett Schlawin

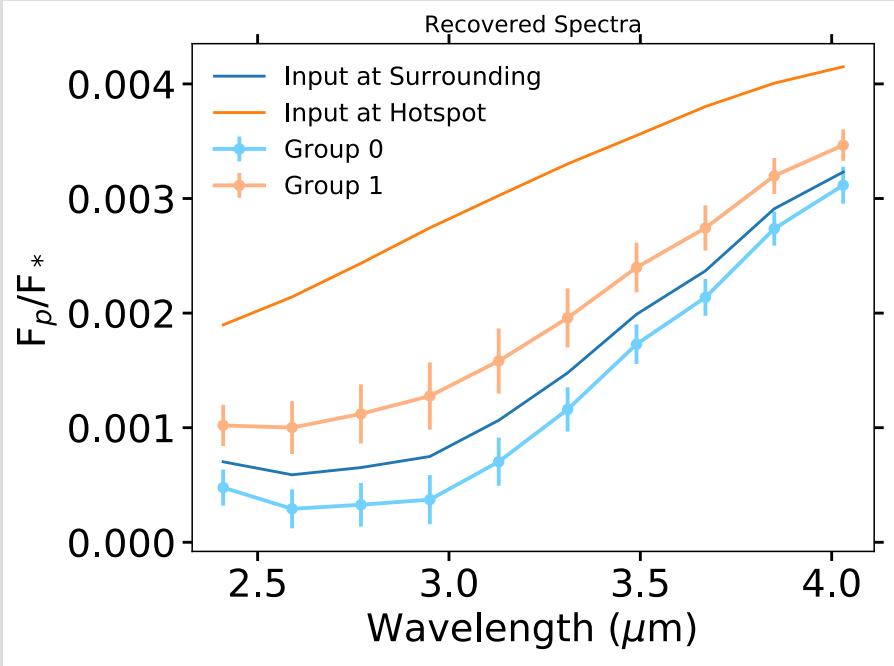
The simplified hotspot

Output Maps





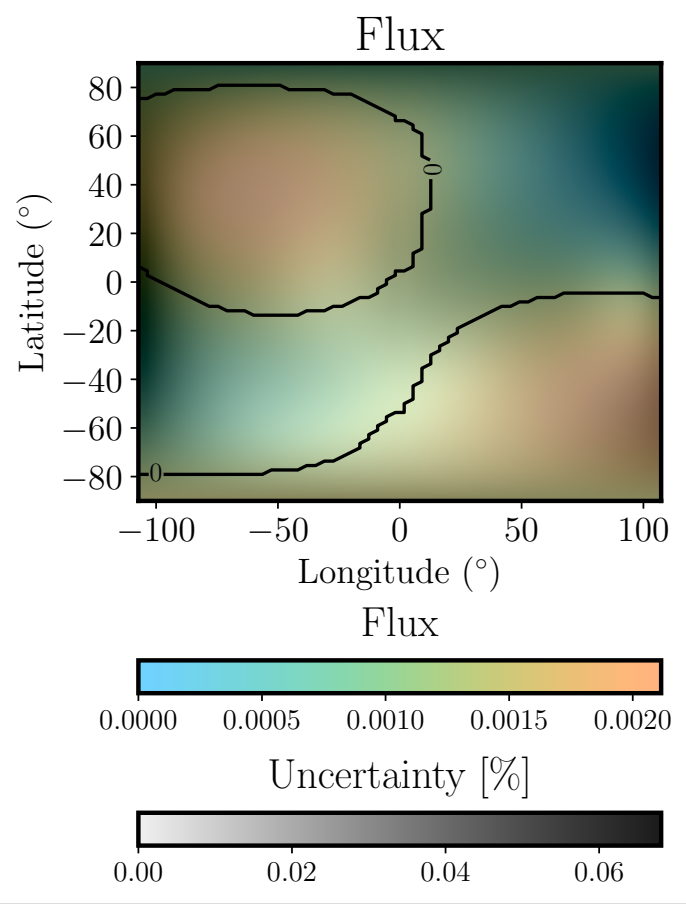
Comparison of “Eigenspectra”

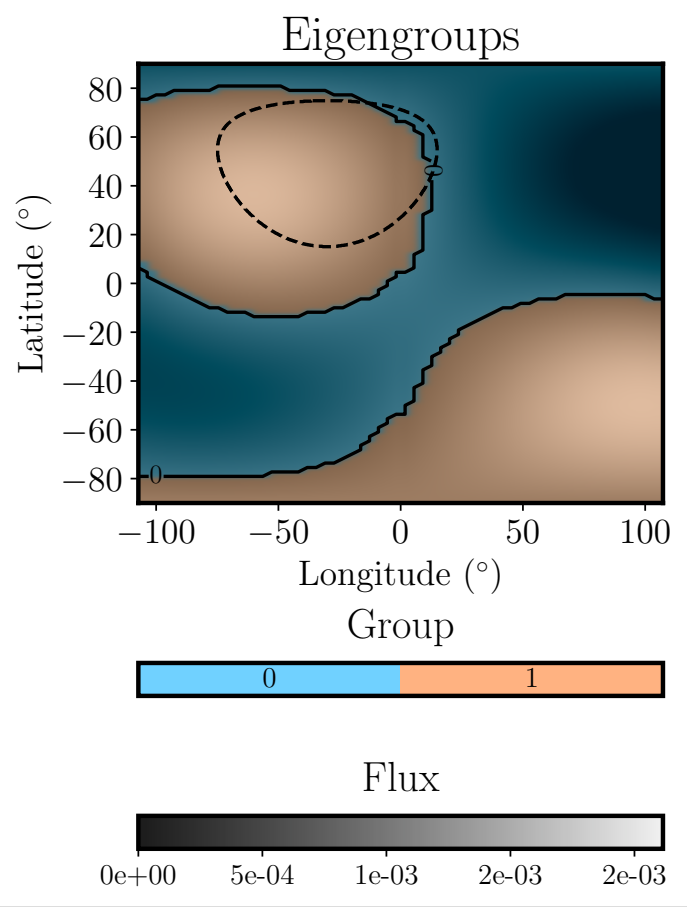


Figures from Mansfield et al. (submitted), designed by Everett Schlawin, Arthur Adams, Jacob Lustig-Yaeger

The asymmetric hotspot

Output Maps





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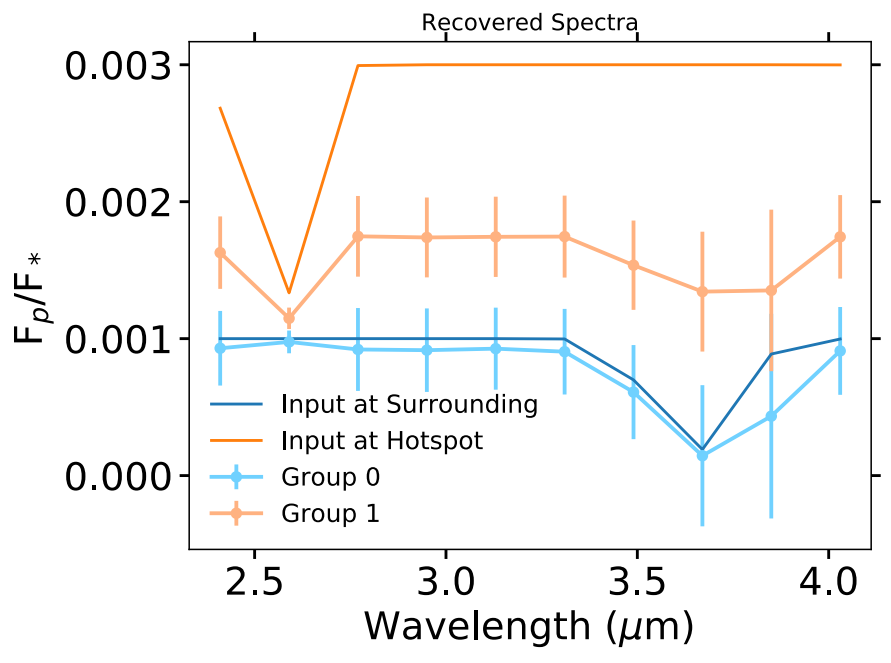

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