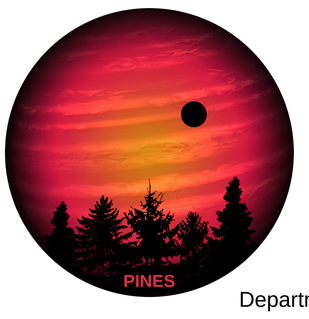
Modeling the Surface Features of SIMP 0136



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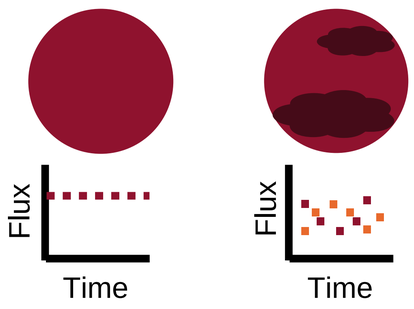
Surface Features Can Be Predicted From Light Curves

Measuring Flux

Surface features block the inherent light of the dwarf, and decrease the overall flux. By recording the flux over time, we can work backwards to predict what these surface features look like.



Different Wavelengths

Observing a dwarf in different wavelengths, using different filter bands, allows us to probe different depths of the atmosphere. This allows us to see different surface features.

SIMP 0136[a]

- SpT = T2.5
- R ≈ 1.22 R_J
- M ≈ 12.7 M_J
- T_{eff} ≈ 1098 K
- Age ≈ 200 Myr
- Period*
  - *J*-band ≈ 2.54 h, *Ks*-band ≈ 2.48 h
- Amplitude*
  - *J*-band ≈ 4%, *Ks*-band ≈ 2%

SIMP 0136 Displays Significant *J-Ks* Color Variation Over Time

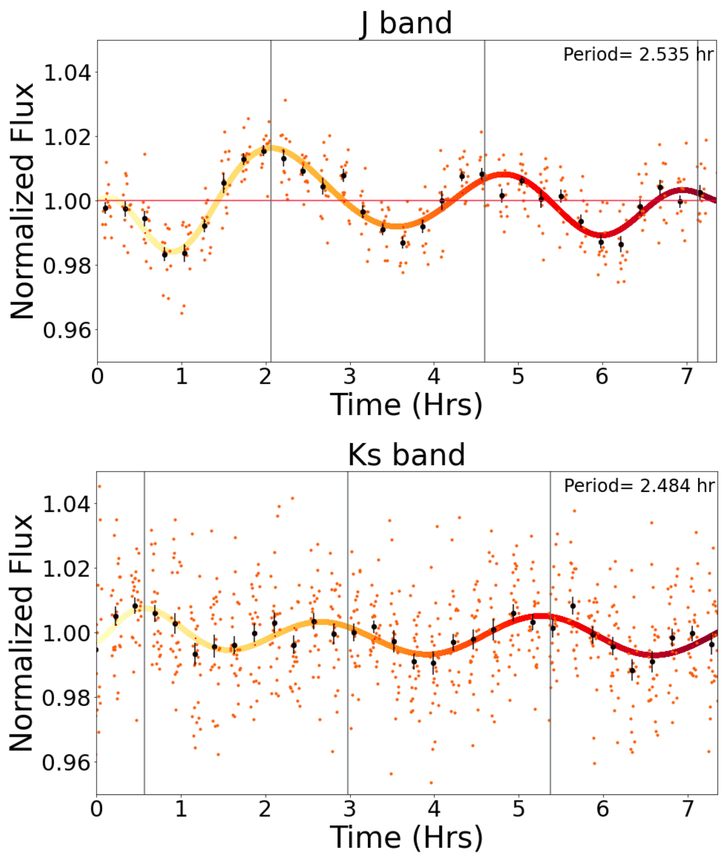
Observations

- Data obtained using Perkins Telescope Observatory in Flagstaff, Arizona, USA
- November 2015
- Exposure Times: 30s in *J*, 15s in *Ks*
- 6 minutes per band

Analysis

- `PINES Analysis Toolkit`[b]
  - (See poster 275 W/F by P. Tamburo)
- Used `Lightkurve` to determine the period in each band
- Lew et al. 2021[c] found no *J-H* color variation for SIMP 0136

Figure 1 (right): Light curve of SIMP 0136 in *J*-band (top) and *Ks*-band (bottom). Gray vertical lines are placed to show the peak to peak rotation. The periods were determined via Lomb-Scargle Periodogram.



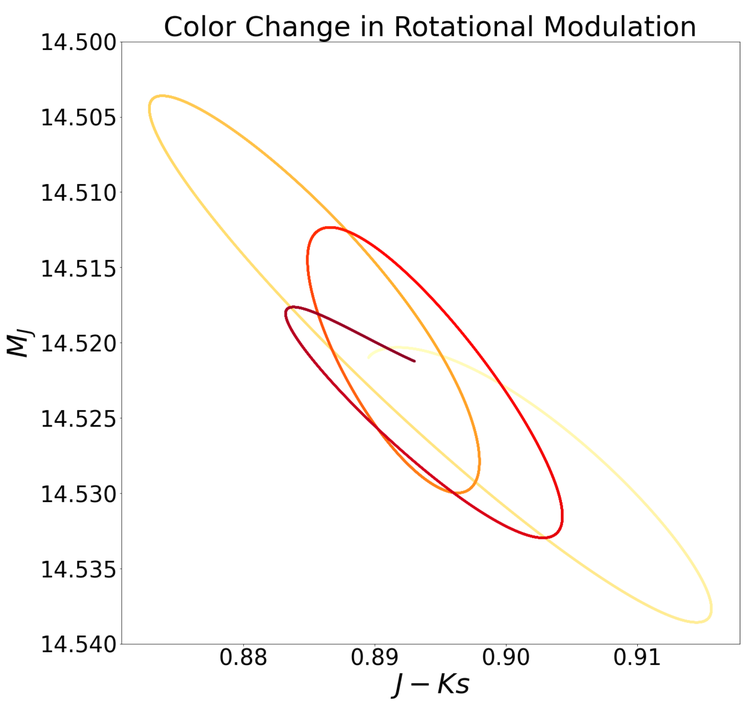


Figure 2: Color modulation of SIMP 0136 over ~7 hours. Color coding matches the time domain in Figure 1. There is a strong color modulation with variability. As SIMP 0136 becomes brighter, it also becomes bluer.

SIMP 0136 *J-Ks* Color Modulations Can Be Modeled With Two Cool Zones

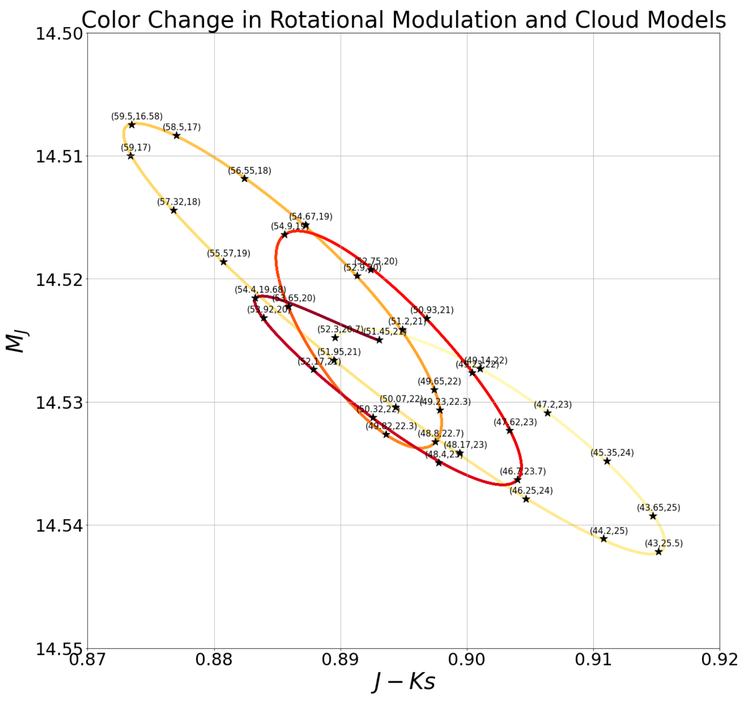


Figure 3: Color modulation of SIMP 0136 with the 1200K photosphere, and 1000K and 800K cool zone coverage model overlaid. Each label represents the fraction of the visible surface covered by (1000K, 800K) cool zones, respectively.

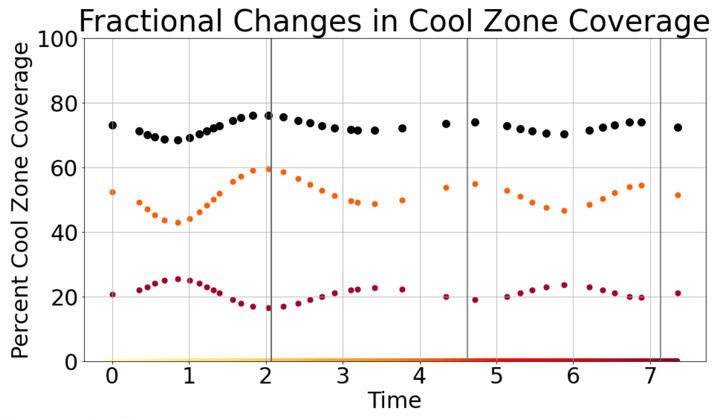


Figure 4: The fraction of the visible surface of the dwarf covered with each cool zone. The 800K cool zone fluctuates between ~16.5 - 25.5% coverage. The 1000K cool zone fluctuates between ~43 - 59.5% coverage. The total cool zone fraction fluctuates between ~68.5 - 76% coverage. At any given point, only ~24 - 31.5% of the 1200K photosphere is visible.

Model Details

BT-Settl Models (Allard et. al 2011) were used to model the surface features. A 1200K photosphere, with 1000K and 800K cool zones. Two cool zones were sufficient to model the surface features of SIMP 0136.

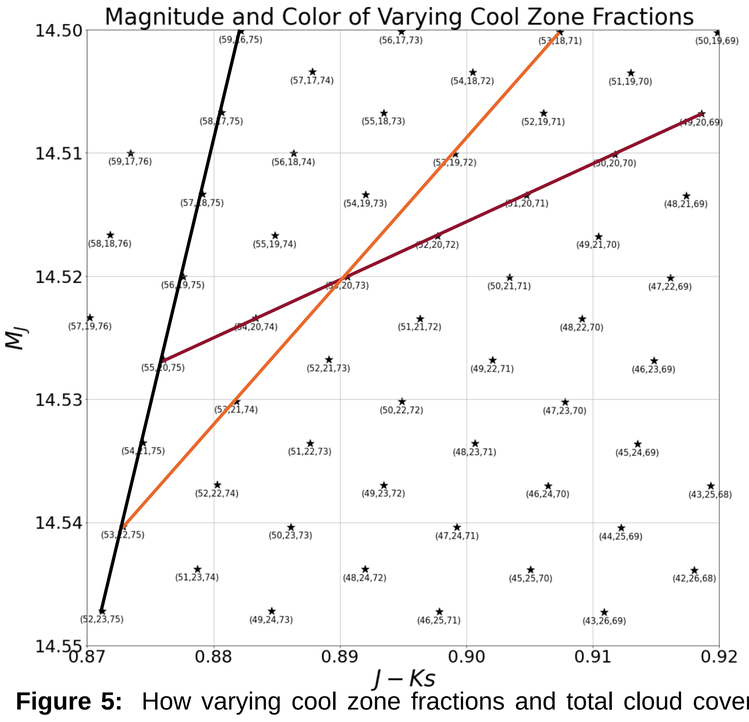


Figure 5: How varying cool zone fractions and total cloud cover affect *J-Ks* magnitude and absolute *J* Magnitude. Constant 1000K cool zone coverage is shown in orange, and constant 800K cool zone coverage is shown in maroon. The black line and associated slope represents constant overall cool zone coverage. The labels are the coverage of (1000K, 800K, TOTAL).

References

[a] Gagné, J., Faherty, J. K., Burgasser, A. J., et al. 2017, ApJL, 841, L1, doi: 10.3847/2041-8213/aa70e2

[b] Tamburo, P., Muirhead, P. S., McCarthy, A. M., et al. 2022, AJ, 163, 253, doi: 10.3847/1538-3881/ac64aa

[c] Lew, B. W. P., Apai, D., Zhou, Y., et al. 2020, AJ, 159, 125, doi: 10.3847/1538-3881/ab5f59

* This work

Conclusion

At least two cool zones must be present and vary at different rates to display the *J-Ks* color modulation we detect in SIMP 0136.

Future Work

- Observe objects across the L/T transition in *J*, *H*, and *Ks*
- *i'*-, *z'*-, *J*-, *H*-, *Ks*-band simultaneous photometry of SIMP 0136

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