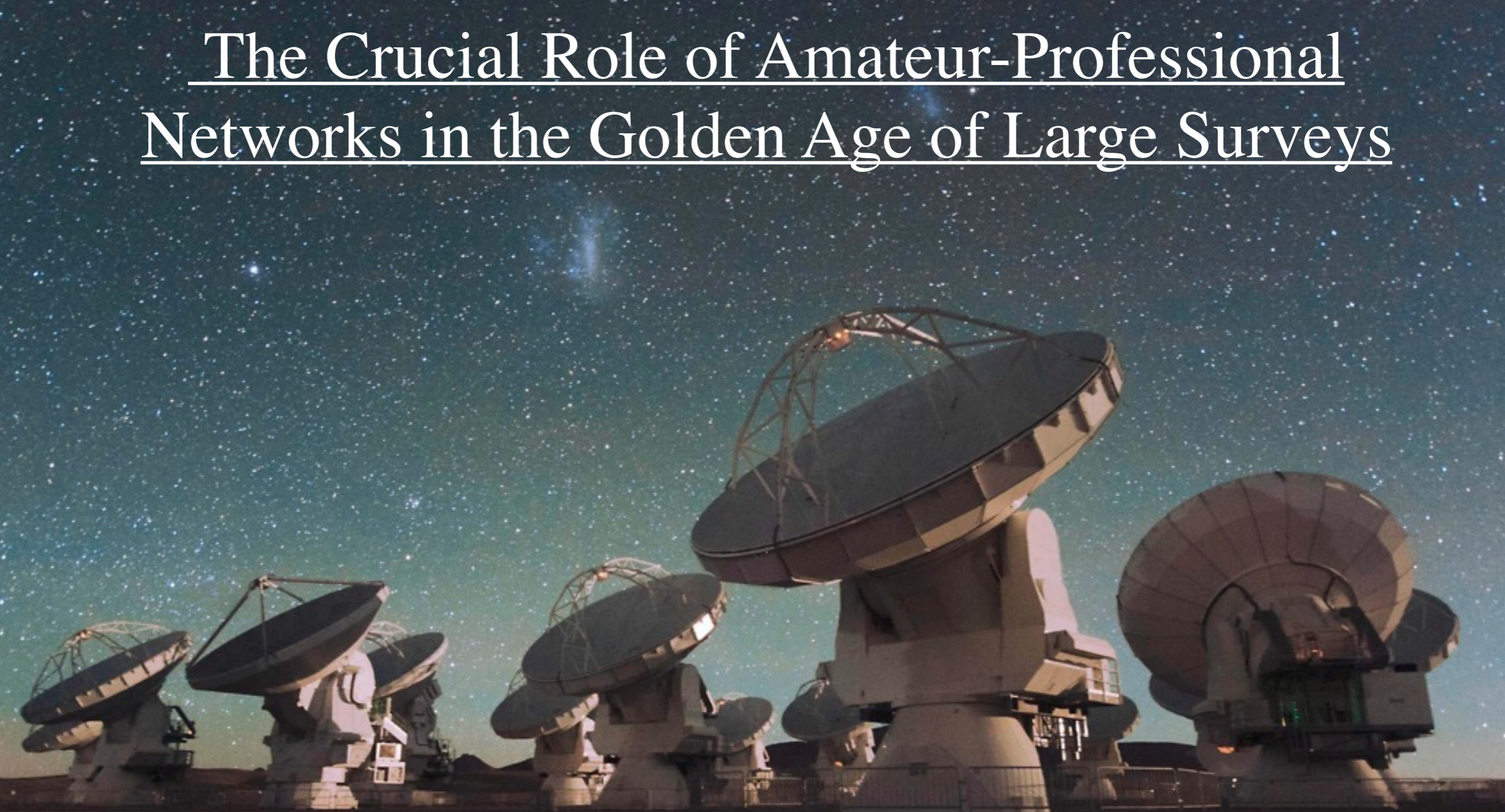


# The Crucial Role of Amateur-Professional Networks in the Golden Age of Large Surveys



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Harvard-Smithsonian Center for Astrophysics



# Past, Current, & Future Contribution

- Confirmation of the longest period EB -> Guinness Record (Rodriguez et al. 2016b)
- Studying the Complex environment of RW Aur (Rodriguez et al. 2013, 2016a; Petrov et al. 2015; Bozhinova et al. 2016; Facchini et al 2016)
- 2016 outburst of V694 Mon (Munari et al. 2016, NA)
- Refining Exoplanet Ephemerides for HST (See Dennis Conti's Talk)
- Confirmation of Giant planet candidates from TESS (See Ryan Oelker's talk)
- Follow-up for K2 (See David Ciardi's talk)
- Transients from LSST and Gaia (See Meredith Rawls's talk)
- Variability Follow-up for Evryscope (See Octavi Fors's talk)
- Confirmation and Follow-up of DESK discoveries, single transit exoplanet discoveries, and Dippers

# Age of Large Surveys

## Current

- Ground based Surveys: KELT, MEarth, SuperWASP, HAT-Net/HATS, Qatar, EvryScope, ASAS-SN, NGTS
- Space Missions: Kepler/K2, HST, Spitzer, Gaia
- Radio: SMA, ALMA



## Future

- Ground based: LSST, GMT/ELT/TMT
- Space Missions: TESS, JWST, PLATO, WFIRST



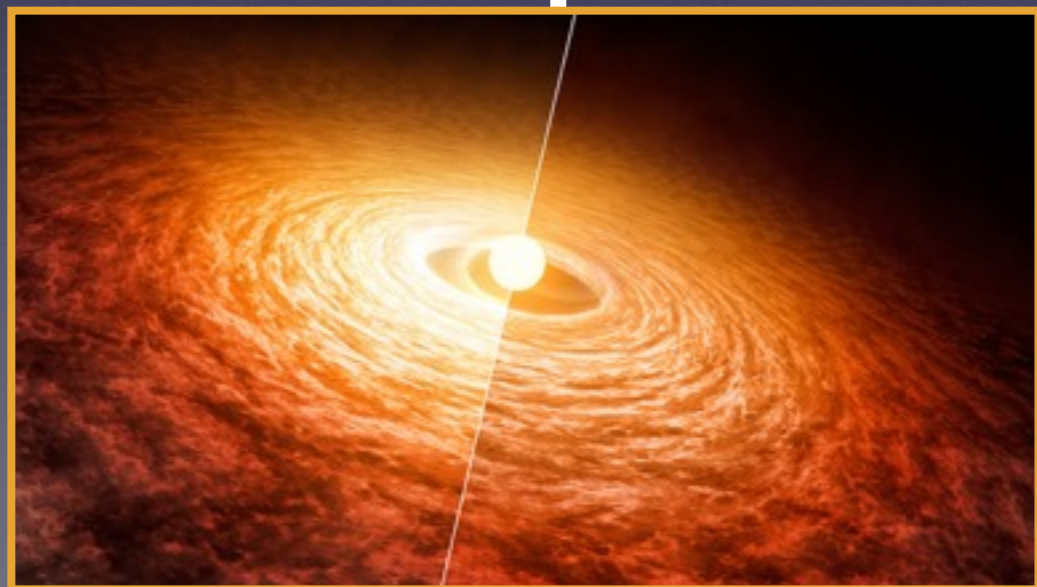
# Planet Formation and Evolution

- Exoplanet Discovery
- Characterization
- Demographics



- Remnant Planet formation
- Epsilon Aur
- TYC 2505-672-1

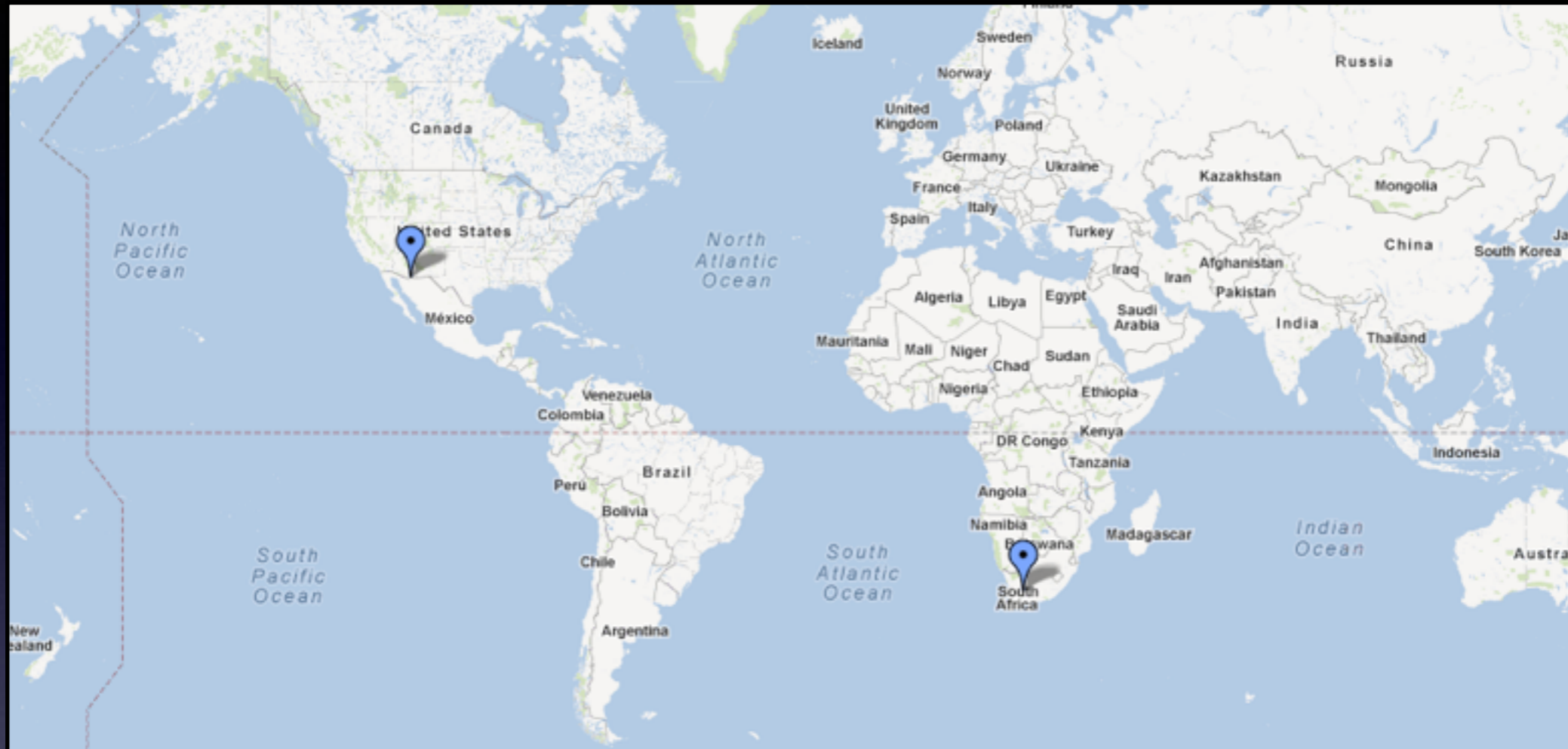
Time



- DESK
- Dipper/Bursters
- Planet formation processes



# Kilodegree Extremely Little Telescope



- Exoplanet Survey of Bright Stars  
( $V = 8-11$  mag, 1% Photometry)
- Locations: Sutherland South Africa  
(KELT-South) and Sonoita, AZ  
(KELT-North)



# Kilodegree Extremely Little Telescope

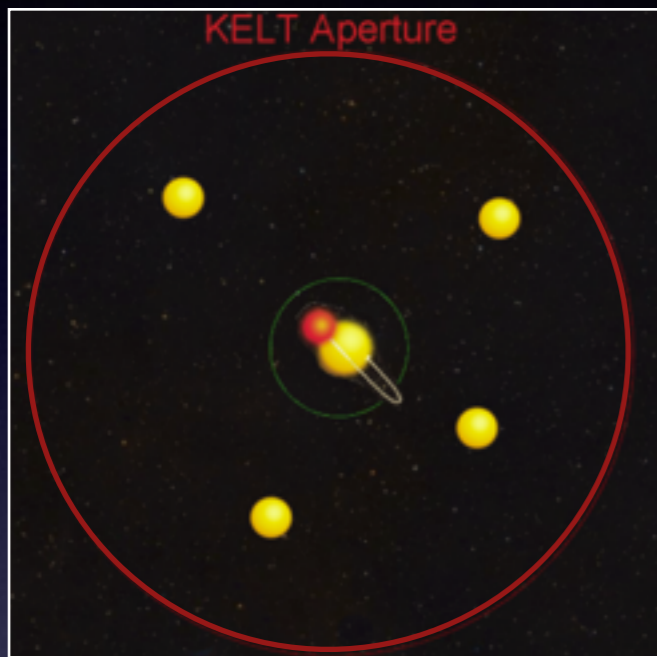


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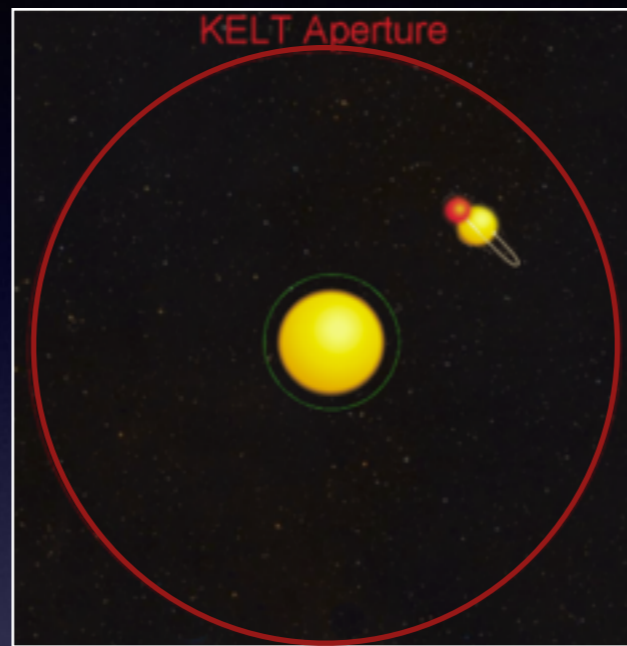


# What Causes a Light Curve Dip?

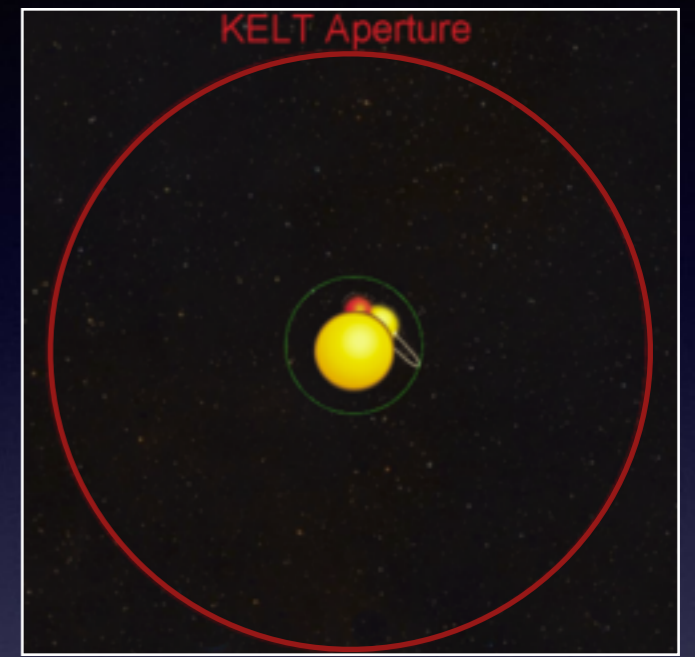
Target EB +  
blended neighbor stars



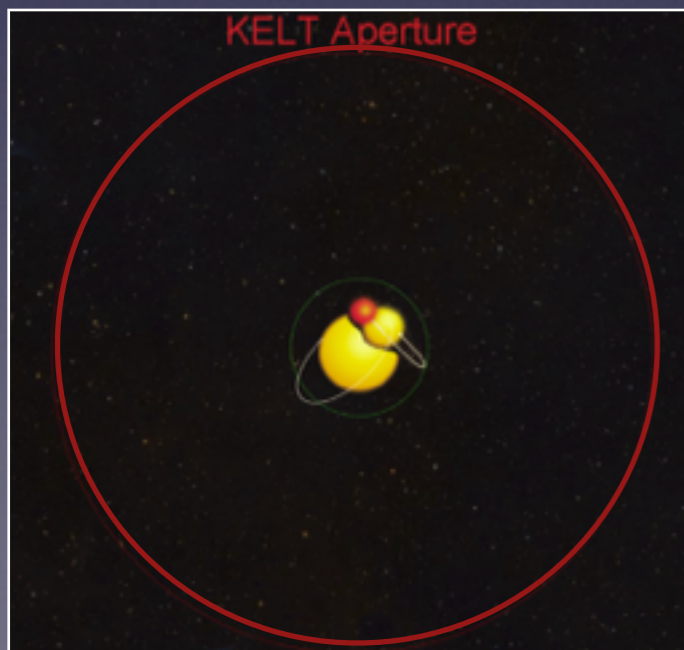
Neighbor EB (NEB)  
blended with target



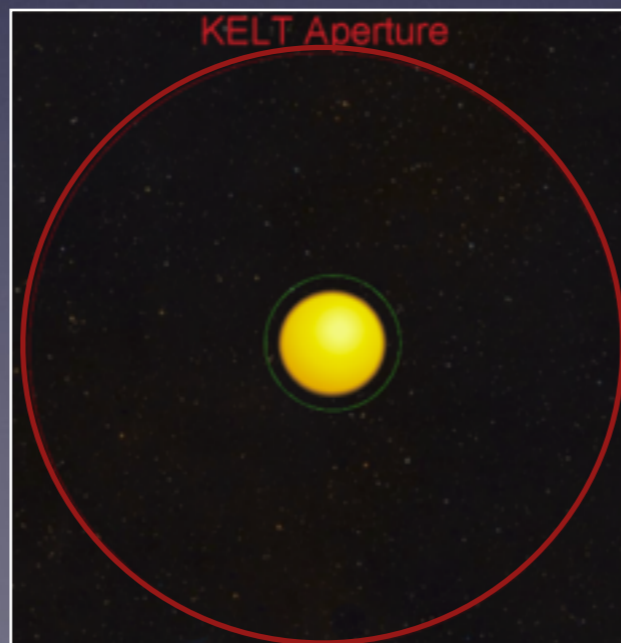
Blended EB



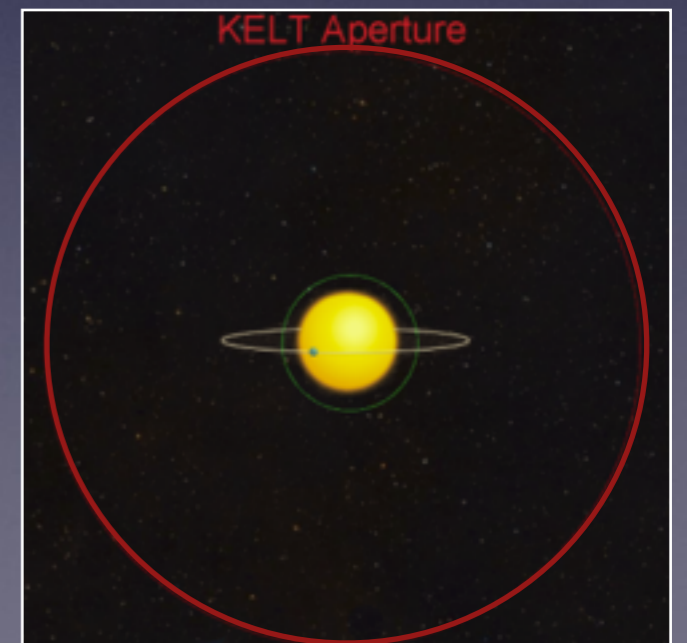
Hierarchical triple



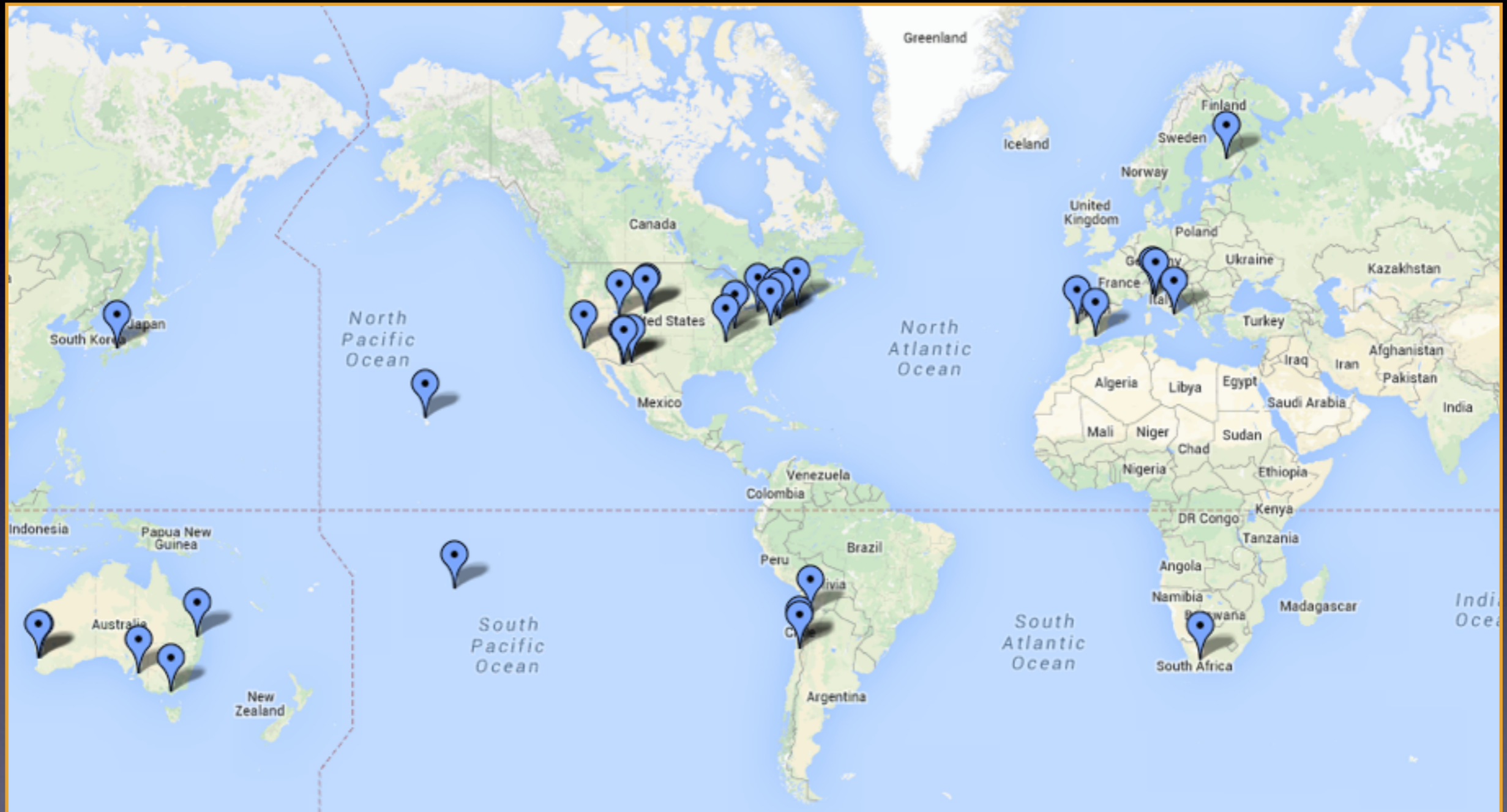
Artifact



Planet!



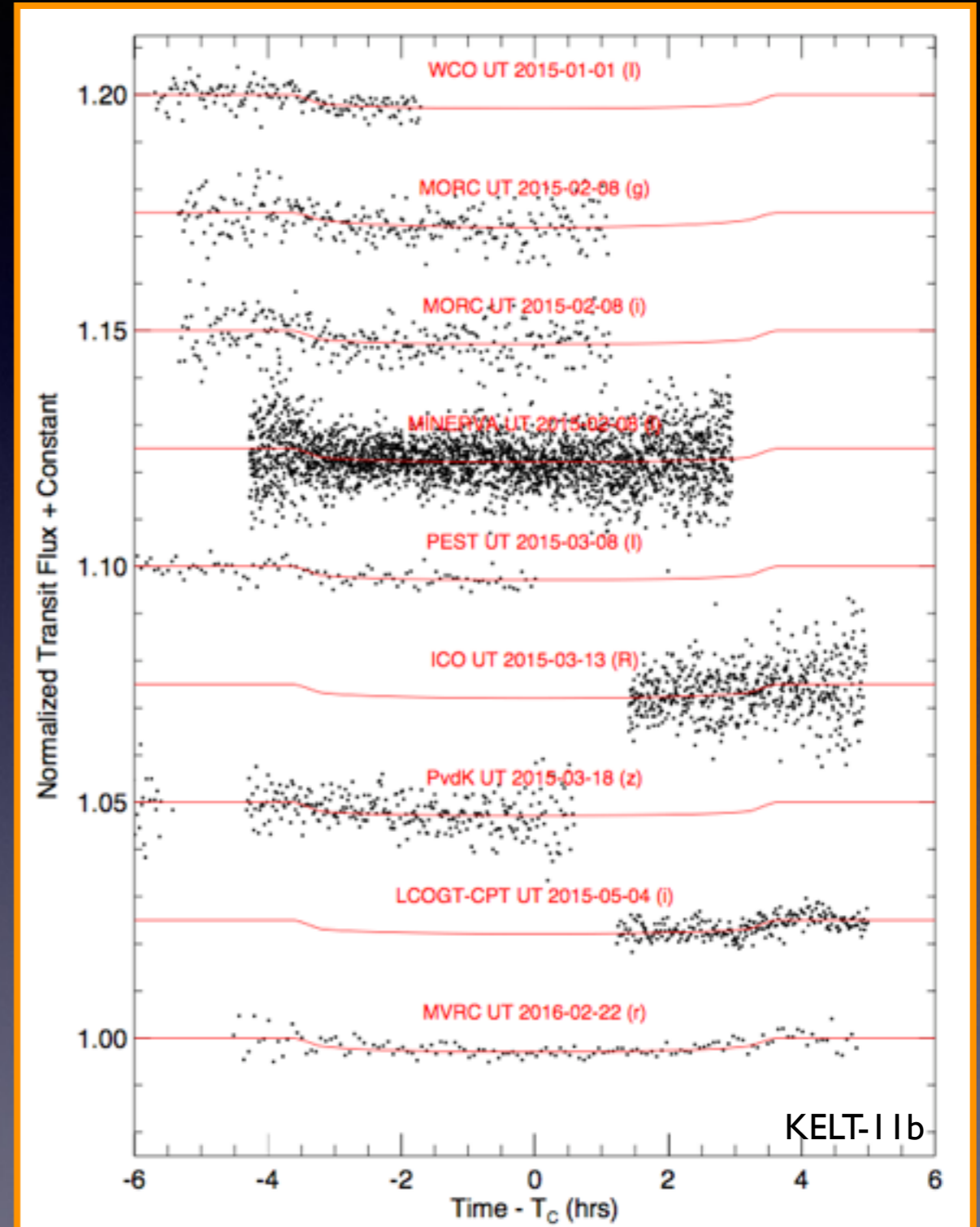
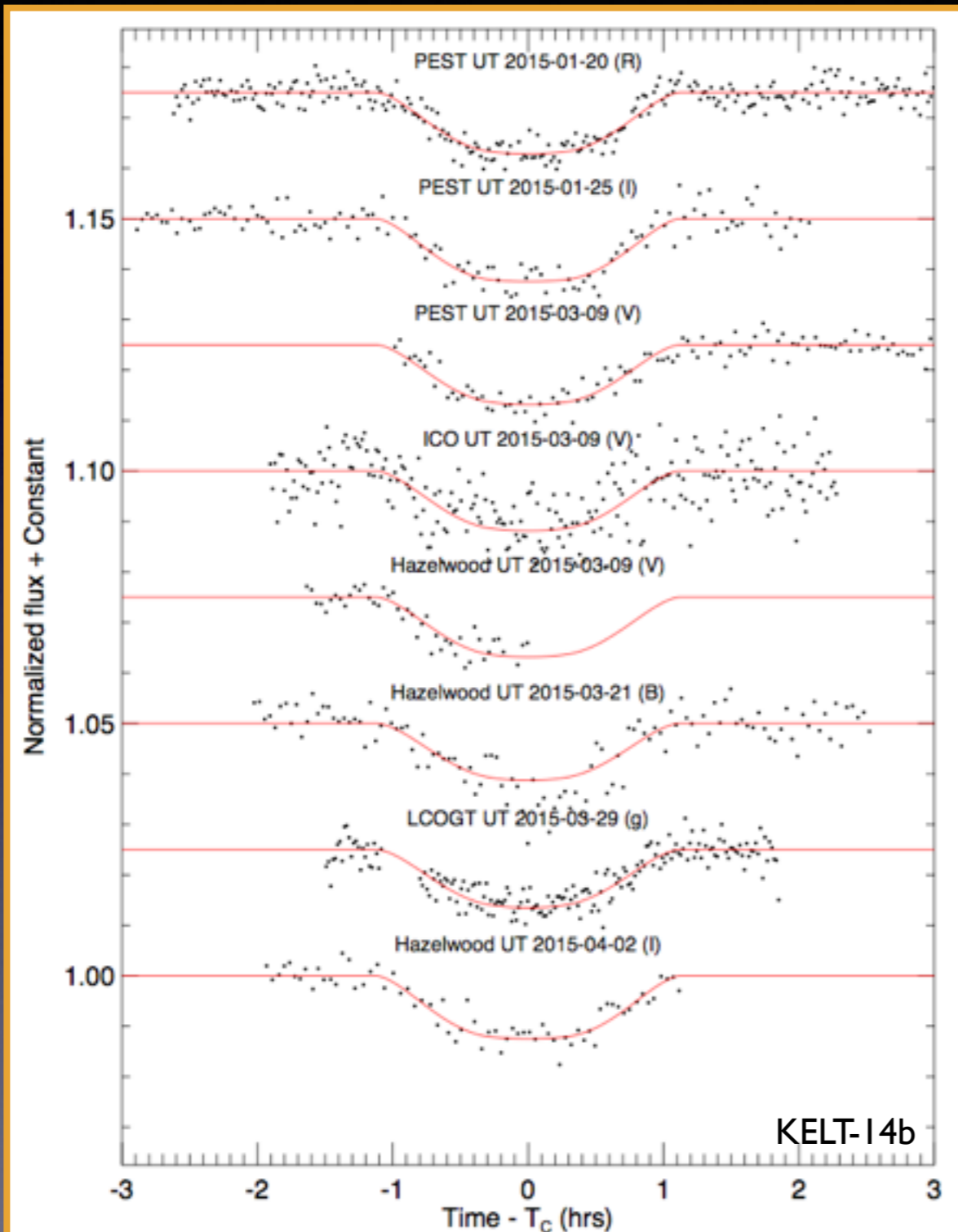
# KELT Follow-Up Network (KELT-FUN)



- Amateur Astronomers
- Skynet and LCOGT Networks
- Small colleges and universities
- 10 inch to 2 meter telescopes

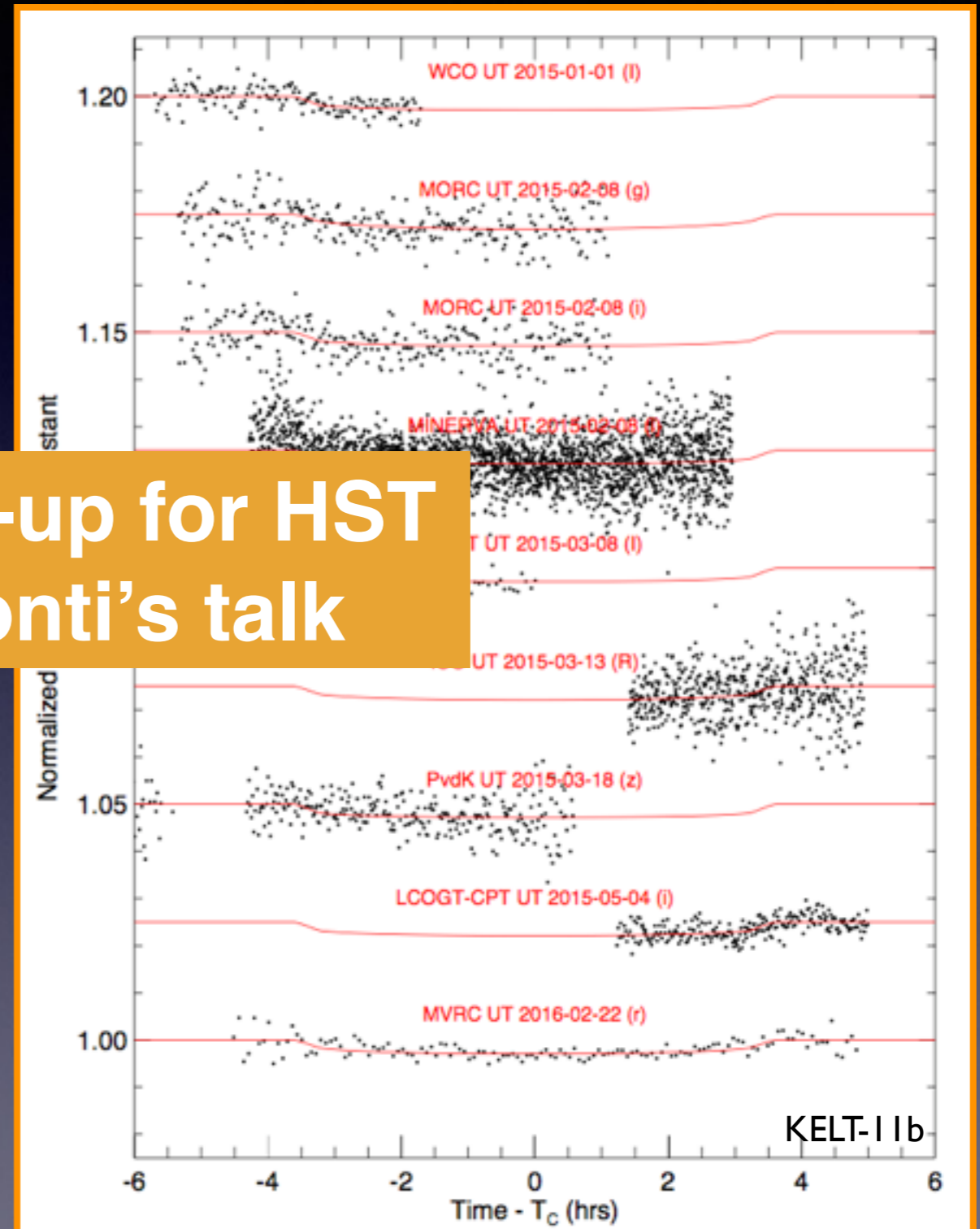
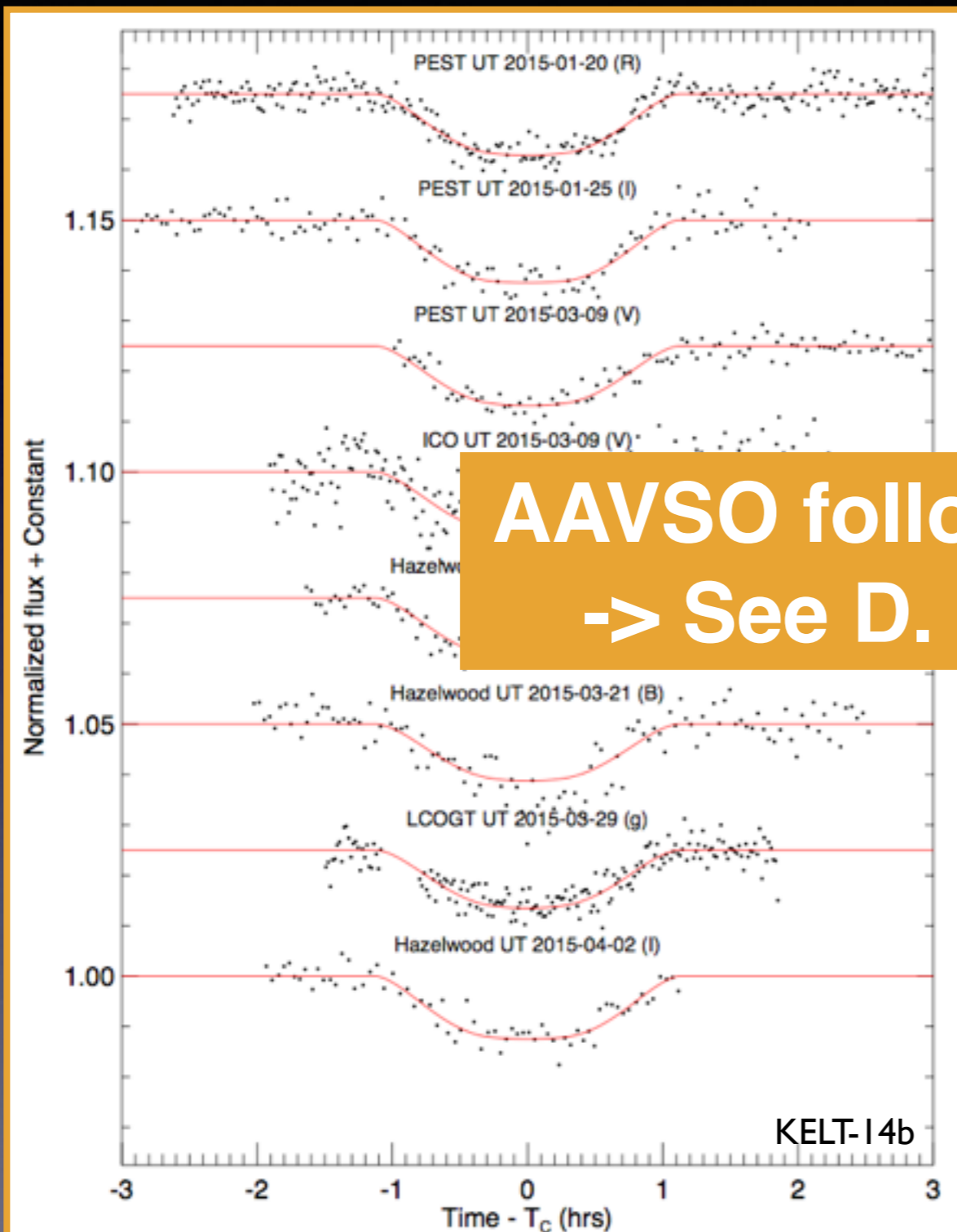


# KELT-FUN Followup



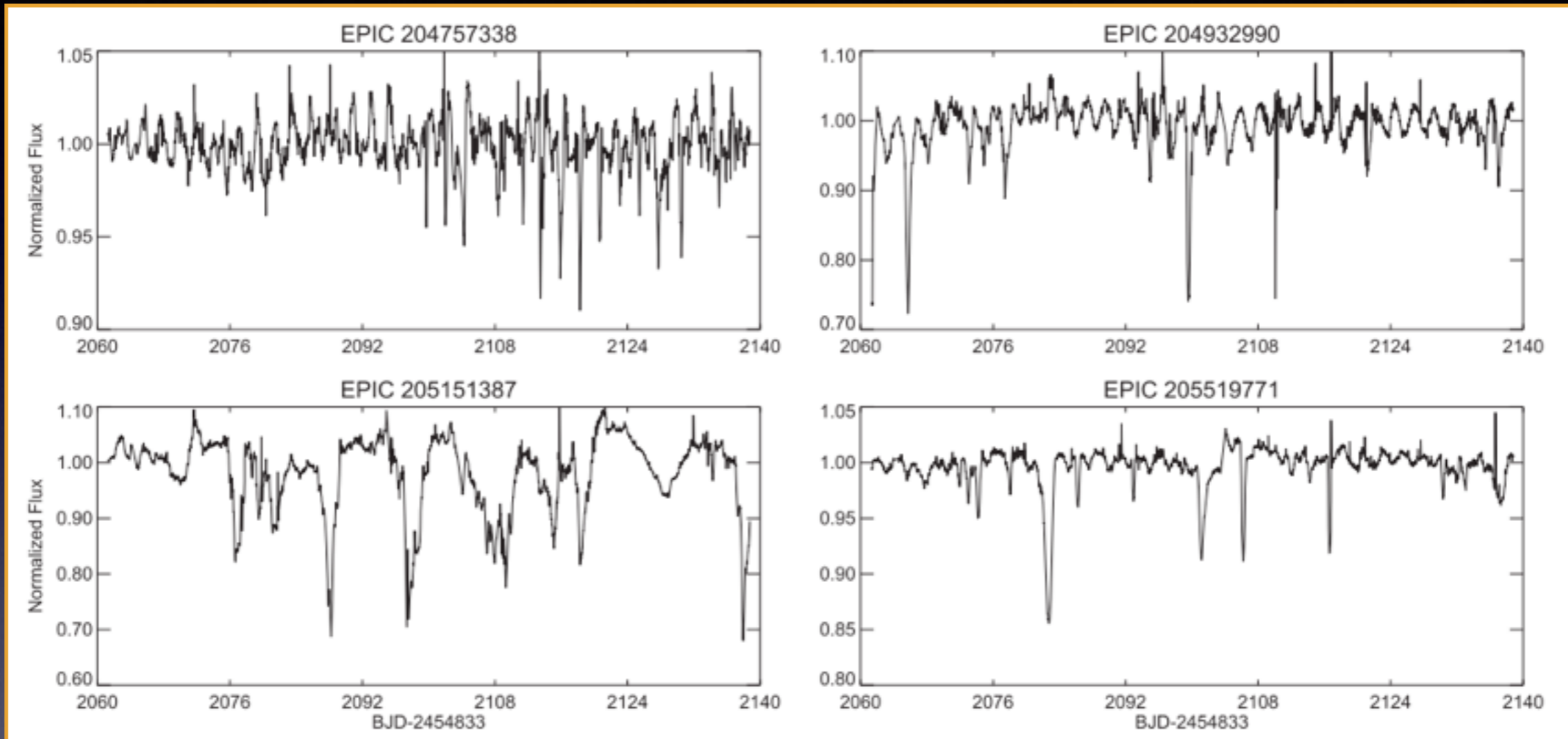
Rodríguez, Colón, Stassun et al. 2016, AJ  
Pepper, Rodríguez, Collins et al. 2016, AJ

# KELT-FUN Followup



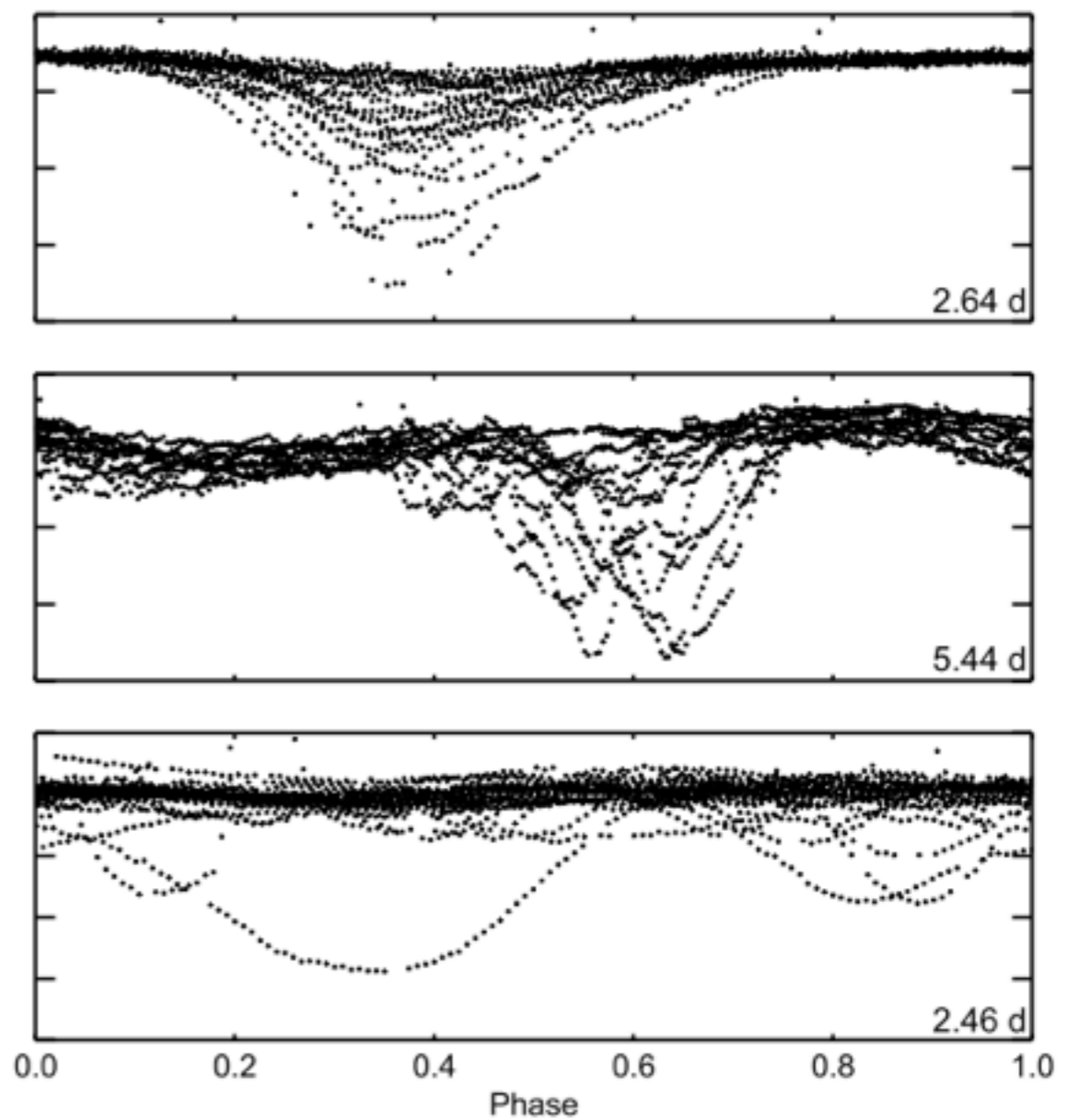
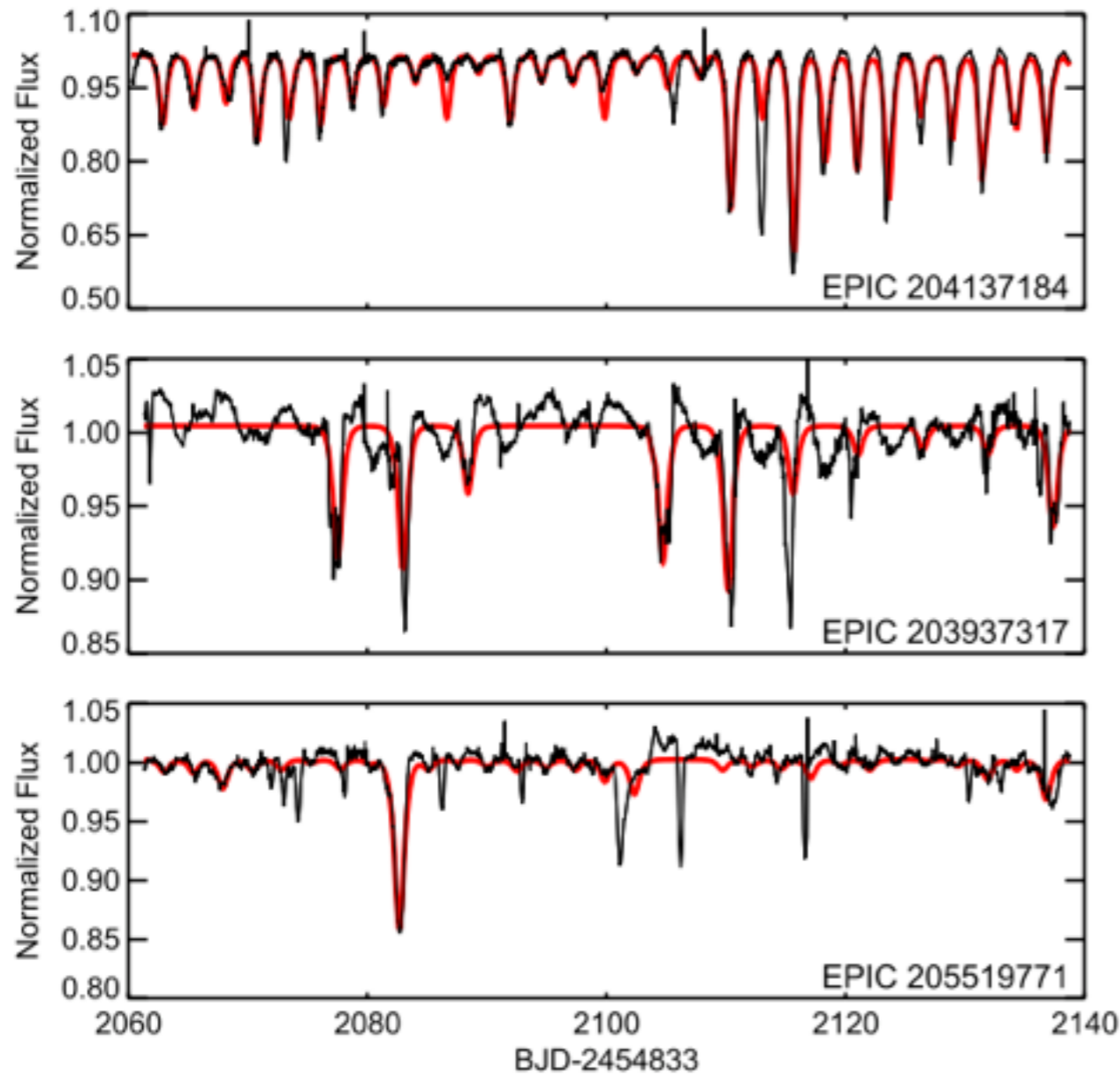
AAVSO follow-up for HST  
-> See D. Conti's talk

# Dippers: The Early Stages of Planet Formation?



- YSOs with Disks
- >10% dips for 0.5-2 days
- occulting structures in the inner disk - > planet formation?
- Warps or over-dense regions

# Dippers: The Early Stages of Planet Formation?

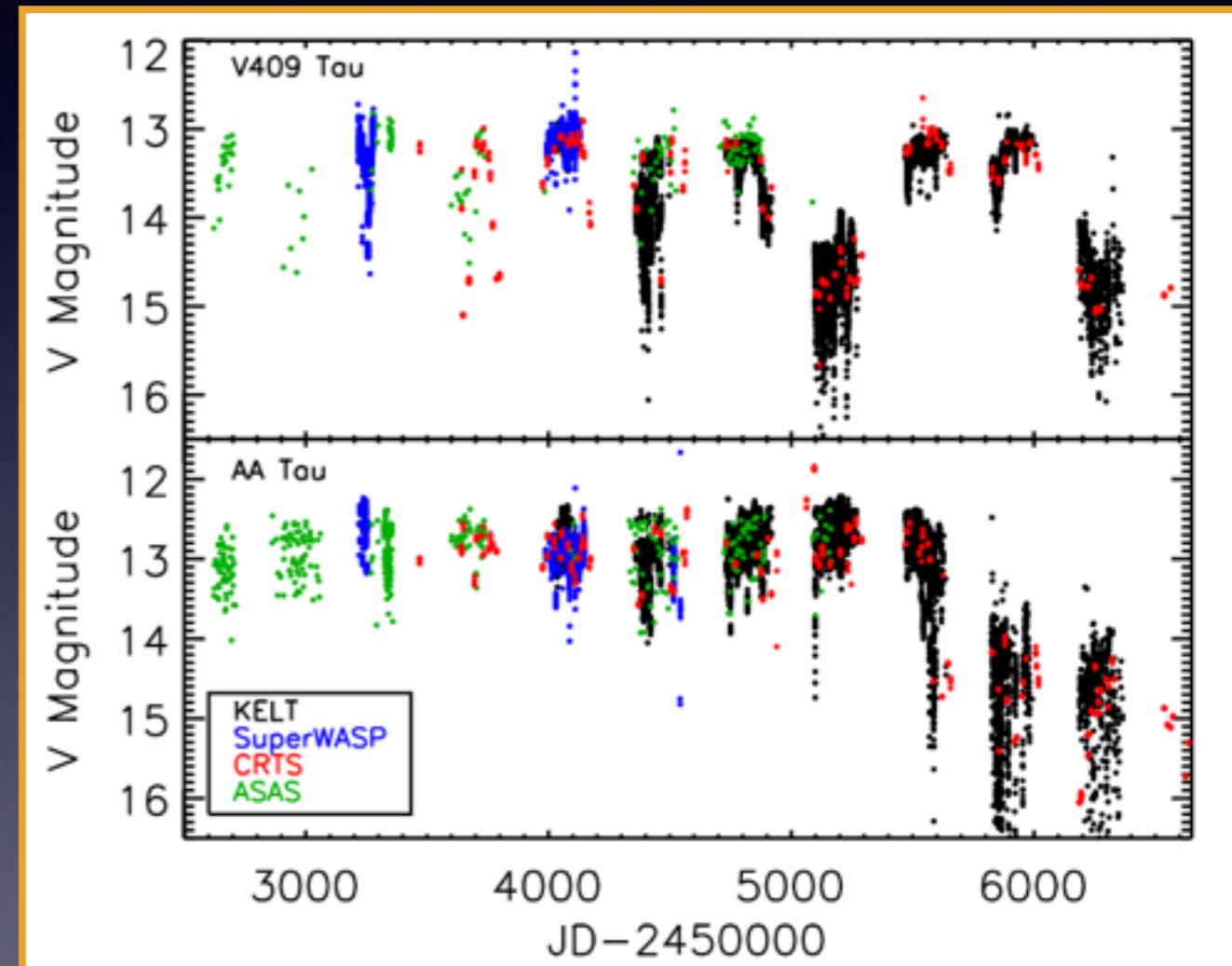




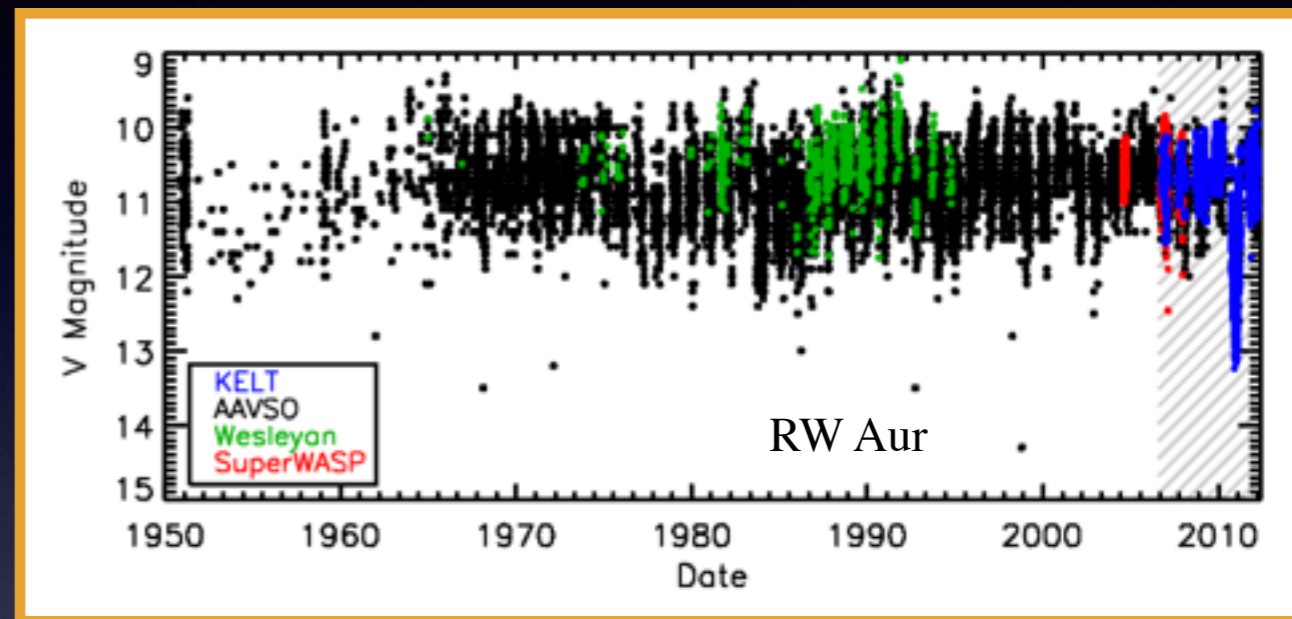
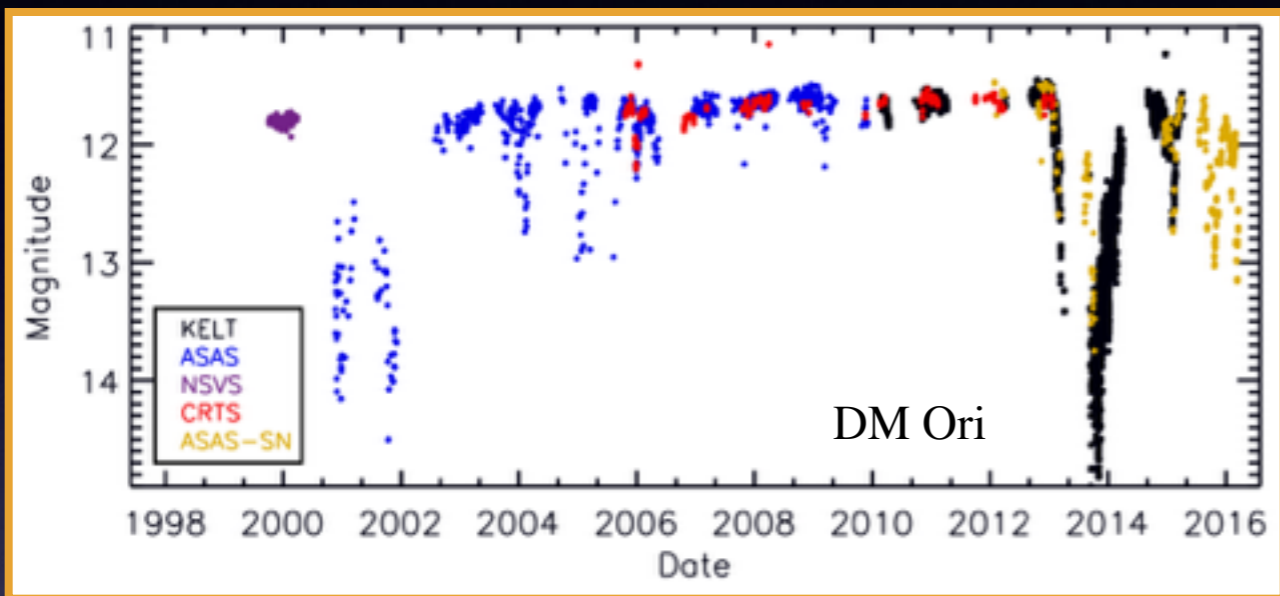
# DESK Survey



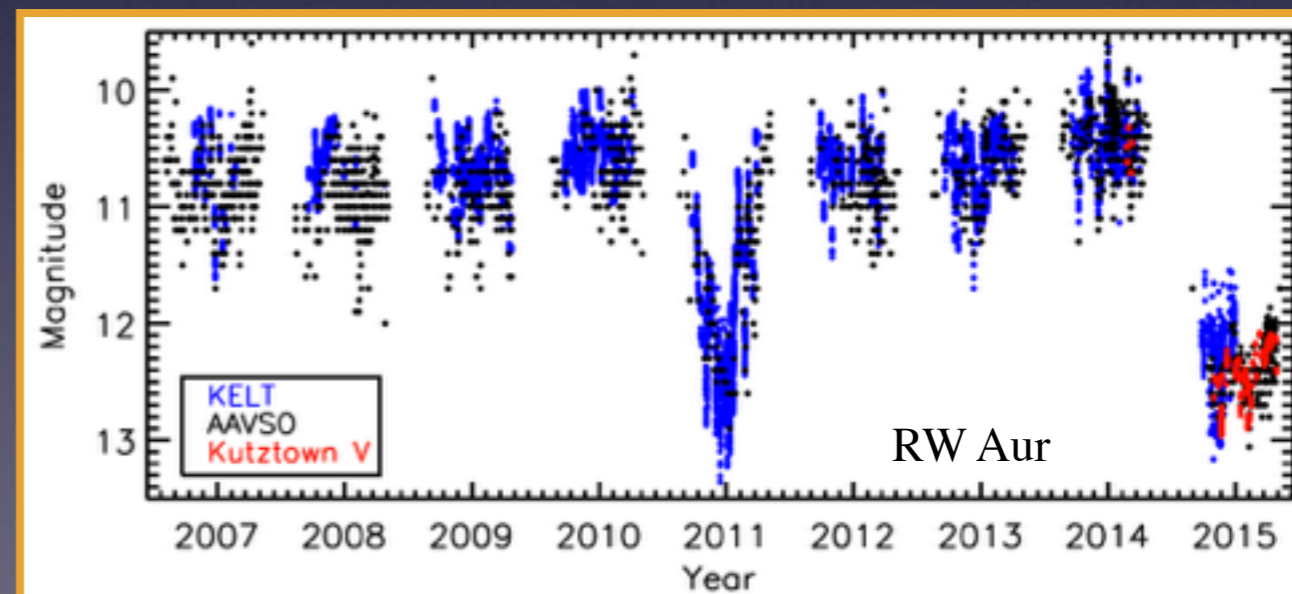
- Disk Eclipse Search with KELT (DESK)
- Archival search of >3 million stars for large occultations in collaboration with ASAS-SN and SuperWASP
- RW Aur, V409 Tau, AA Tau, TYC 2505-672-1, DM Ori, PDS 110, V1334 Tau, V773 Tau
- ALMA Cycle 3 & 4 for RW Aur
- 5 published papers (2 w/ AAVSO) and 3 in prep



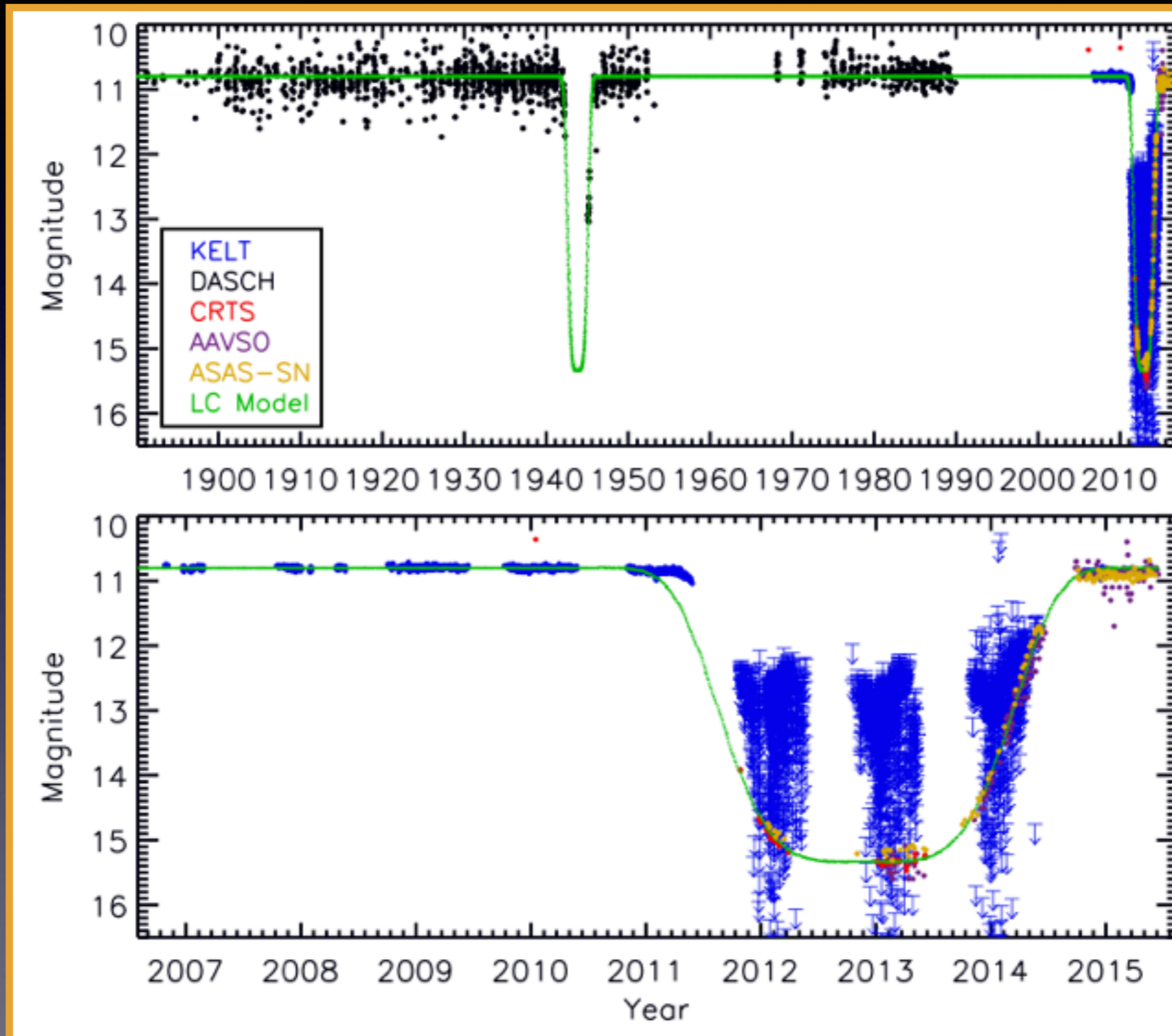
# Multiple Fadings: RW Aur and DM Ori



- DM Ori: Orbiting disturbance in its circumstellar disk.
- RW Aur: Tidally disrupted circumstellar environment, Disk winds, or warped inner disk.



# TYC 2505-672-1: An Extreme Epsilon Aurigae Analogue:

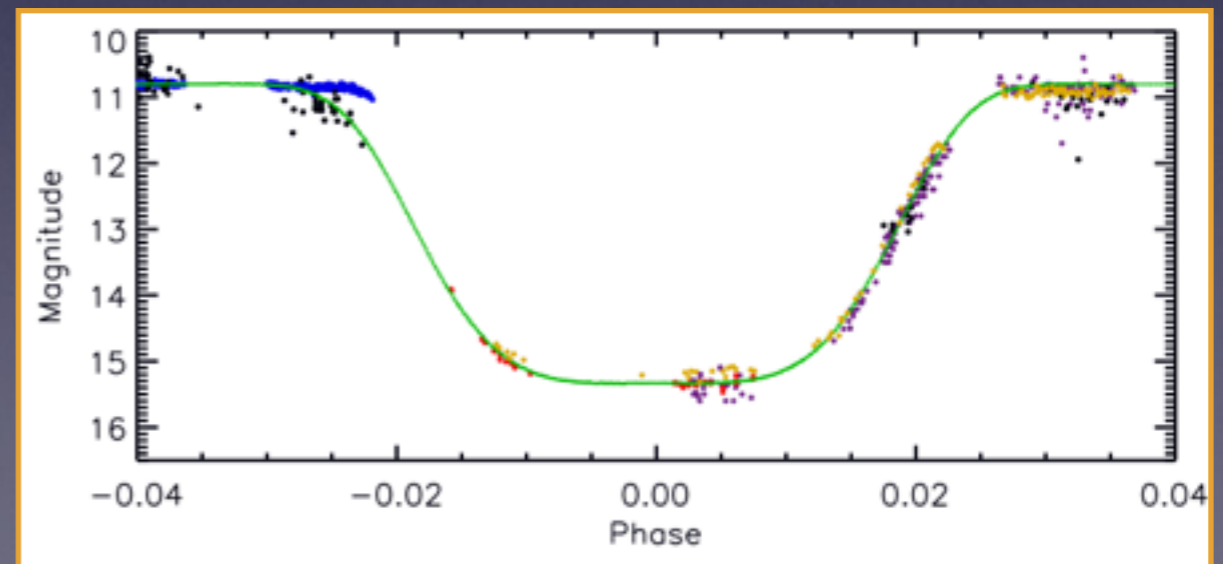
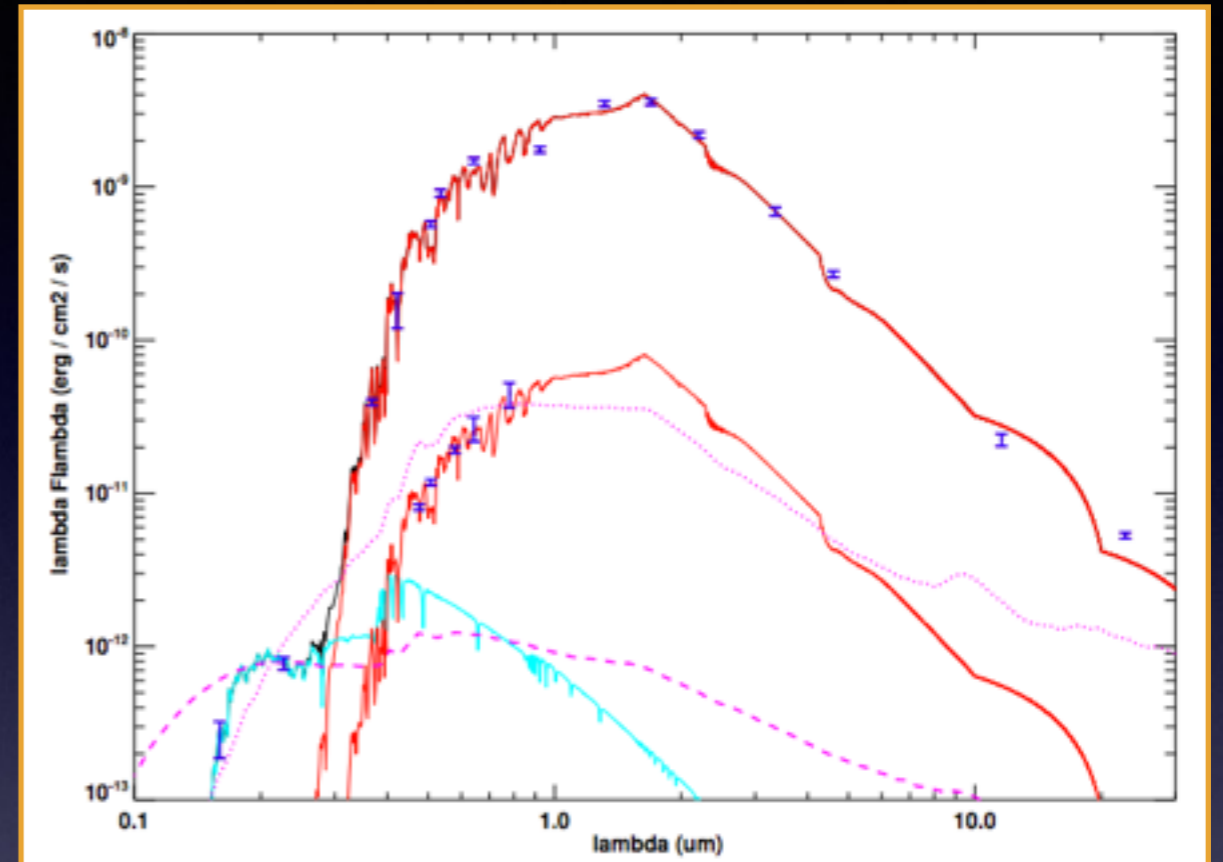


Rodriguez, Stassun, Lund et al. 2016, AJ

Lipunov, Gorbovskoy, Afanasiev et al. 2016, A&A

# TYC 2505-672-1: An M-Giant Eclipsed Every 69.1 Years

- M-giant (M2 III) primary eclipsed by a hot ( $T_{\text{eff}} \sim 8000\text{K}$ ), optically dim companion
- $\sim 4.5$  mag depth,  $\sim 3.5$  year duration
- Occulter = 1-6 AU in Width
- $R_{\text{comp}} = 0.1 - 0.5 R_{\text{sun}}$ ,  
 $\gg \text{WD}$ ,  $\ll \text{MS A-star}$
- Possible stripped red-giant with a large, opaque disk around it.
- Guinness World Record

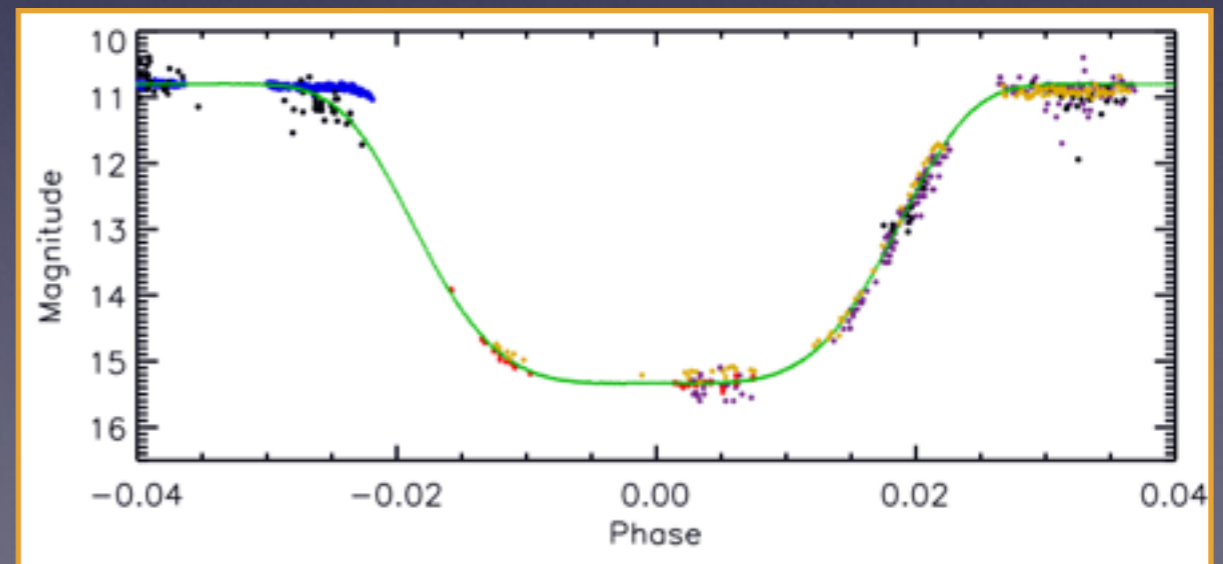
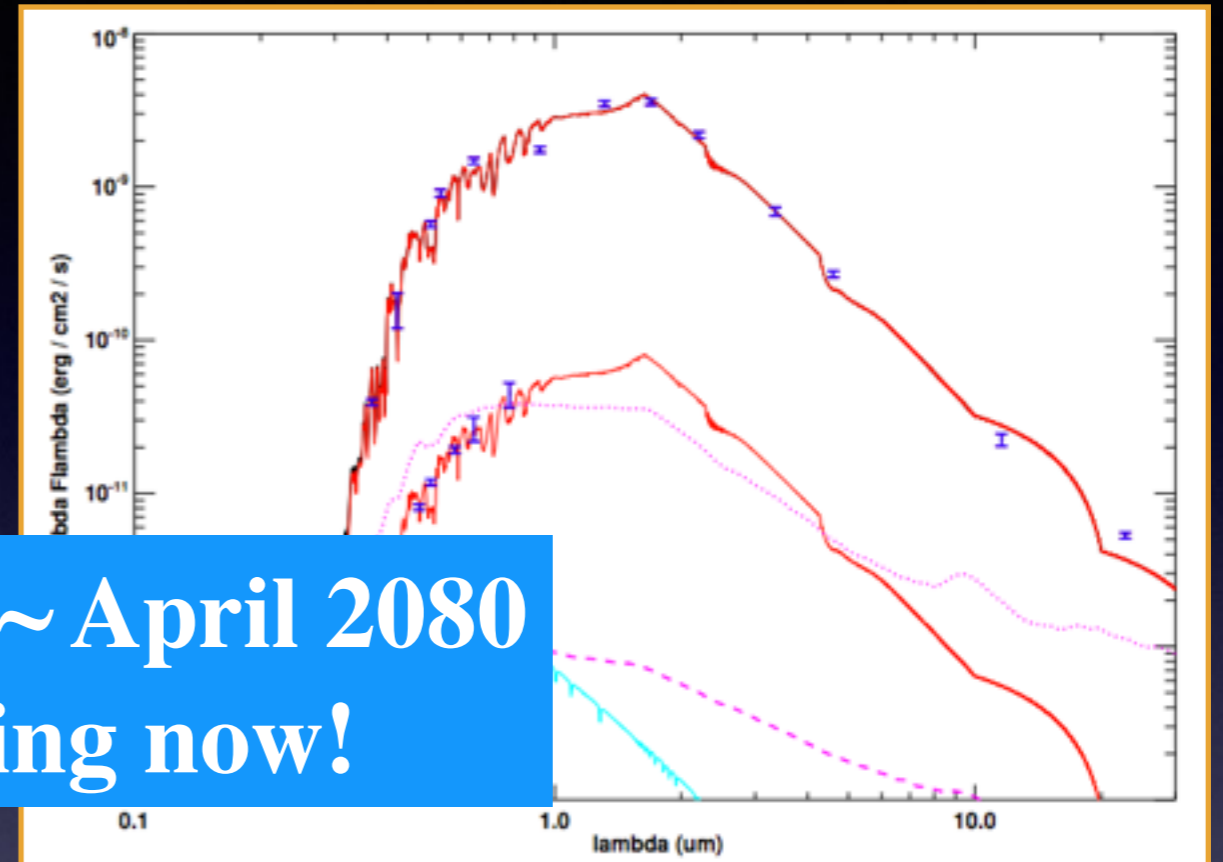




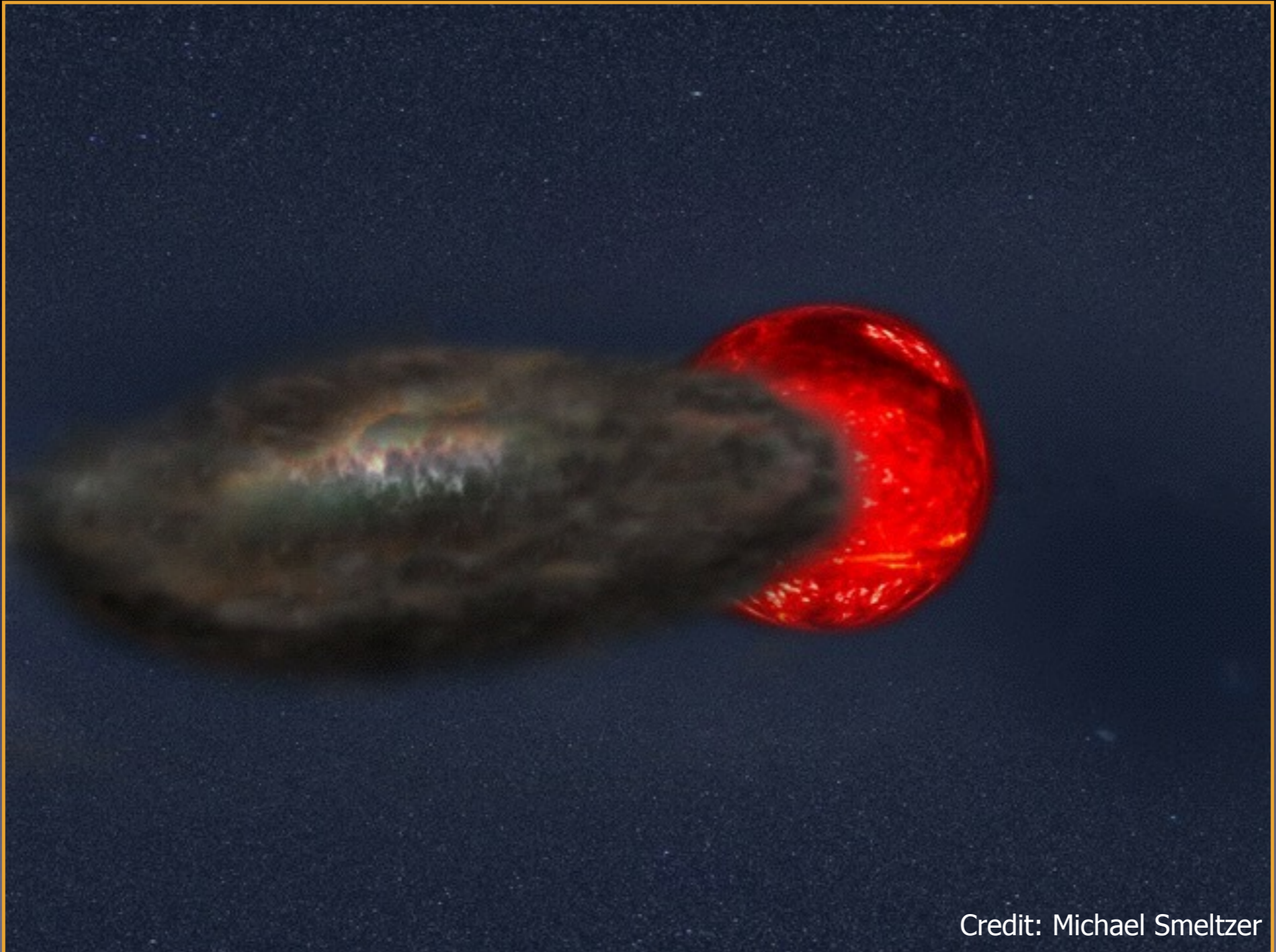
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**NEXT Eclipse: ~ April 2080**  
**Start planning now!**



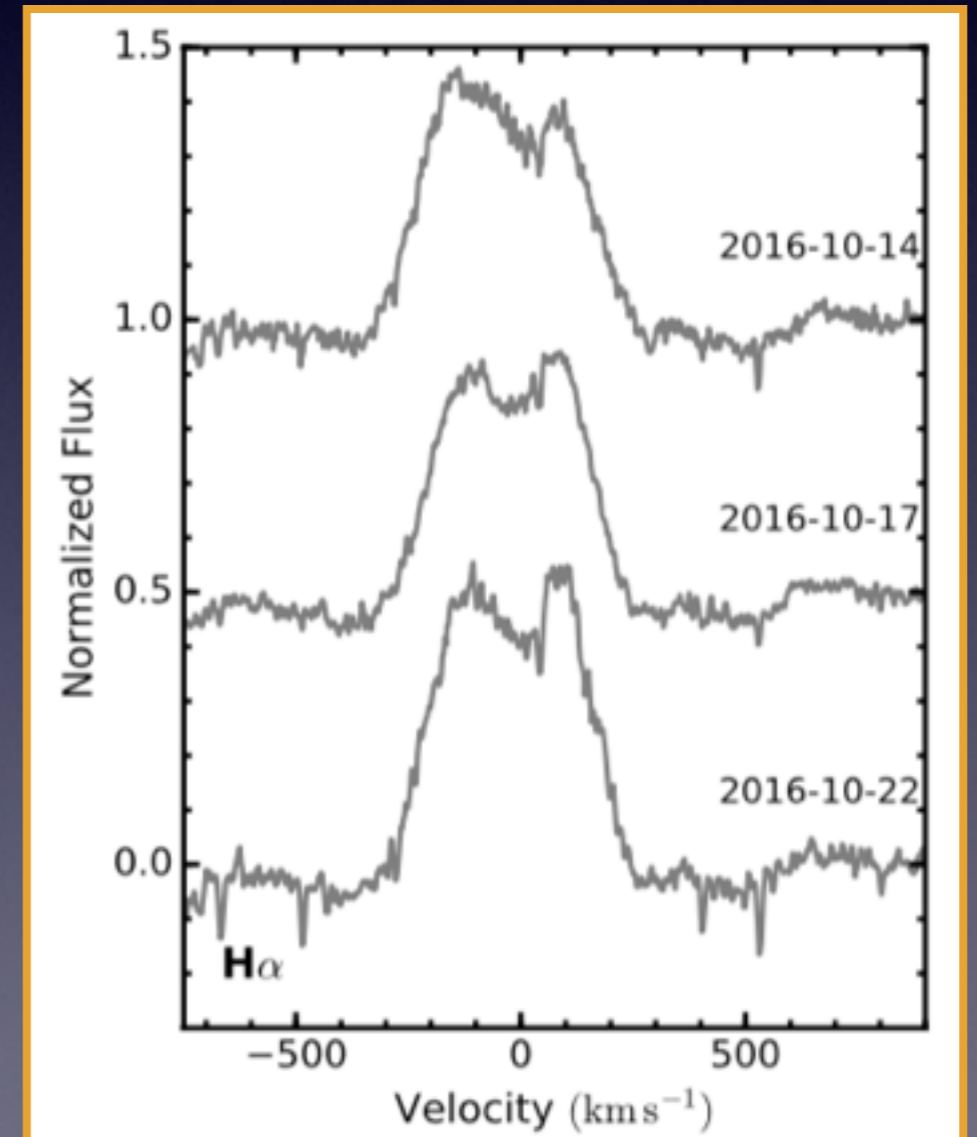
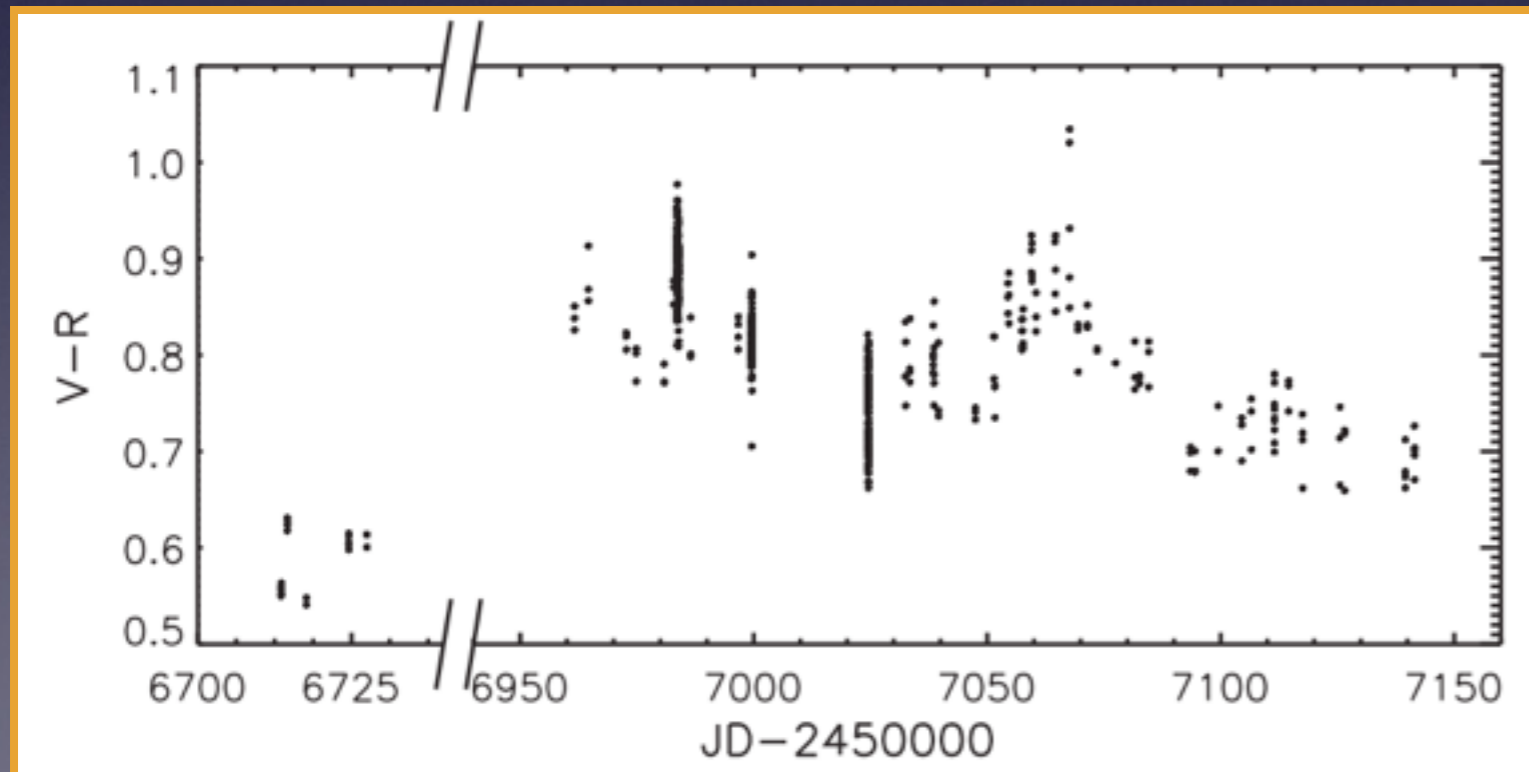
# Epsilon Aurigae Analogue: A 69.1 Year Period Eclipsing Binary



# AAVSO Contribution for YSOs

- Continued follow-up of DESK and Dipper discoveries
- Multiband observations to study grain growth

- Low-resolution spectroscopy



# Some Final Thoughts

- LSST will increase the number of “Disk Eclipsing” systems known by  $\sim 2$  orders of magnitude.
- K2 dippers may be the beginning stages of planet formation
- $\sim 17,000$  Jupiters expected from TESS FFIs
- TESS and PLATO will provide high precision photometry for a large fraction of the sky in the next 5-10 years.
- JWST, Gaia, and ALMA will allow for detailed characterization.

