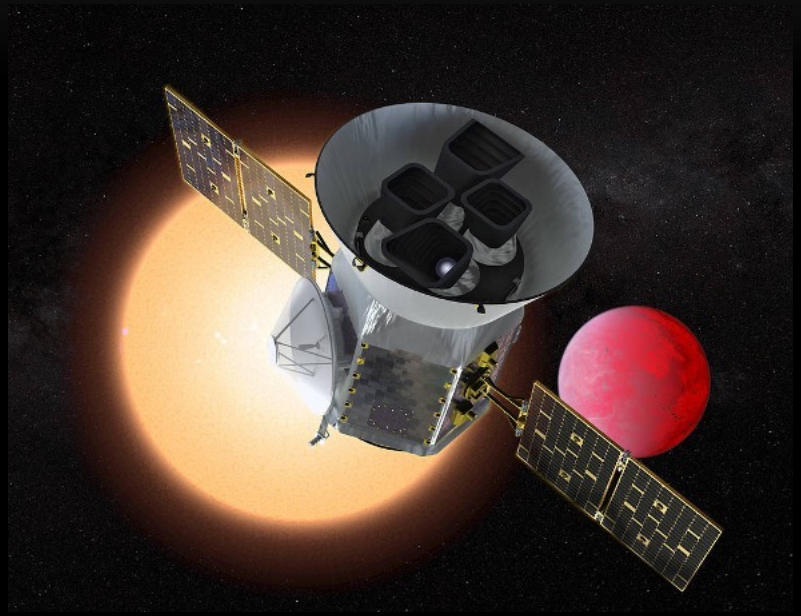
An Introduction to Alpha Cygni Variables: Space Photometry and Evolutionary Context



Joyce A. Guzik,

Claire Whitley, Nova Moore, James Kay, Brian Kloppenborg, Tom Calderwood, Madeline Marshall, Jason Jackiewicz

AGB Stars and Stellar Pulsation

October 5-7, 2026

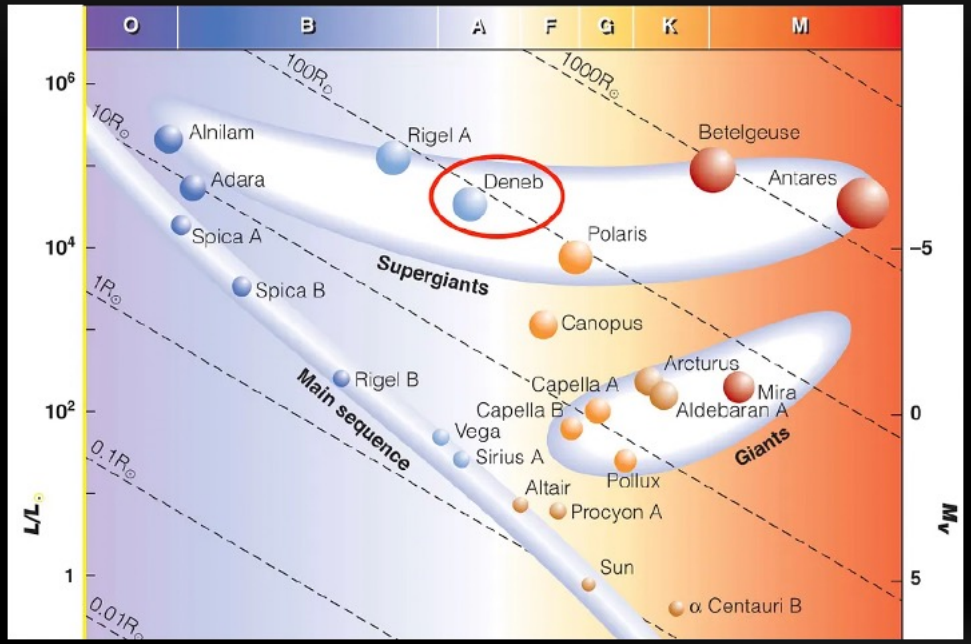
LA-UR-26-24844

https://www.nasa.gov/image-article/transiting-exoplanet-survey-satellite-tess/

Outline

- What are alpha Cygni (ACYG) variables?
- Transiting Exoplanet Survey Satellite (TESS) Observations
- Solar Mass Ejection Imager 8.6-year light curves for bright ACYG stars
- Evolution of ACYG stars—SuperAGB precursor connection?
- Conclusions and future work

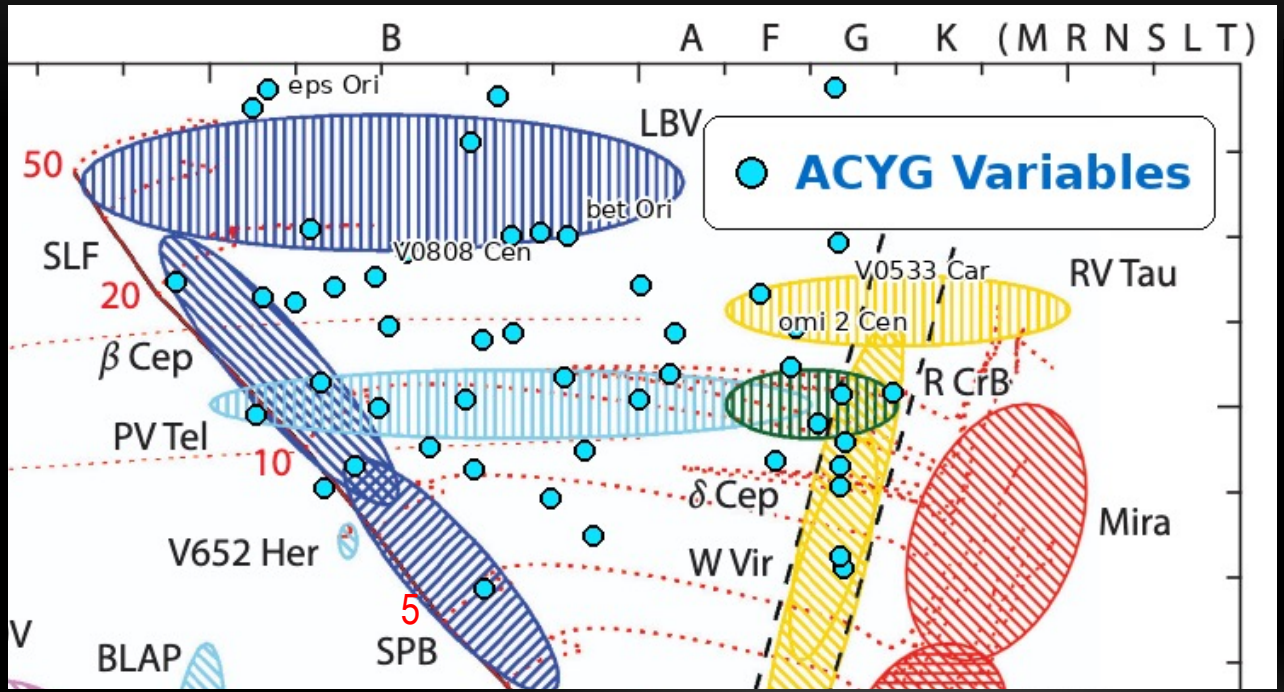
What are alpha Cygni (ACYG) Variables?



Seeds et al., Stars and Galaxies, 2011

- O, B, A spectral-type supergiants
- Prototype α Cyg (Deneb)
- 185 in AAVSO Variable Star Index (VSX)
- Small-amplitude (around 0.1 mag) photometric variations
- Quasi-periodic, timescales of days to weeks. Don't strictly repeat in period or amplitude like classical variable stars
- Evolution state and causes of variability uncertain
- May not be a homogeneous class

Attempt to place some ACYG stars on pulsating variables Hertzsprung-Russell diagram

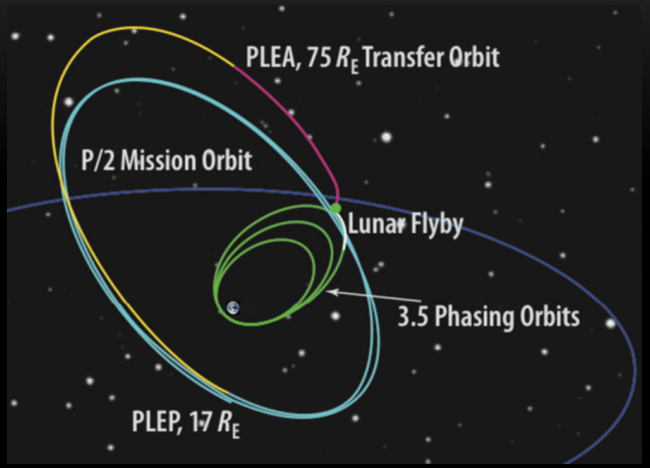


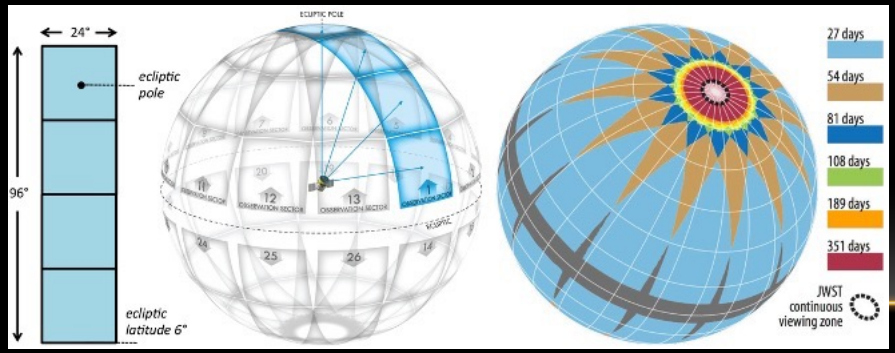
- Blue circles are ACYG variables
- Difficult to find information to calculate luminosity
- Did not account for interstellar reddening/extinction

Diagram adapted from Jeffery et al., MNRAS 447, 2836 (2025)

TESS Spacecraft Observations

Transiting Exoplanet Survey Satellite (TESS)



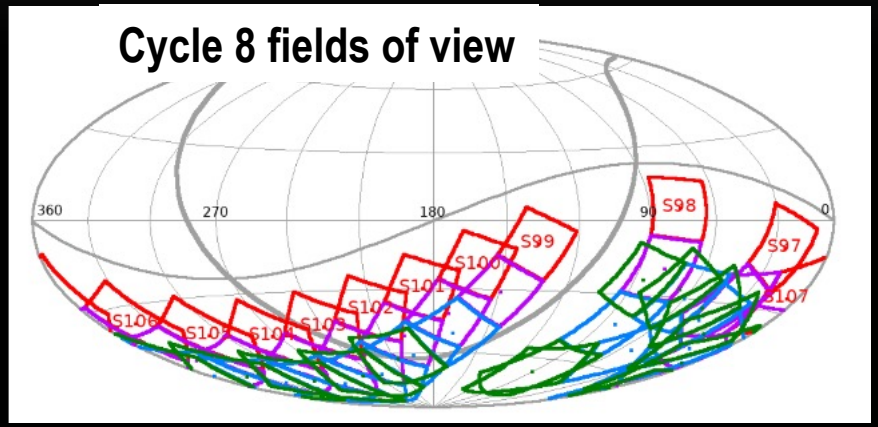


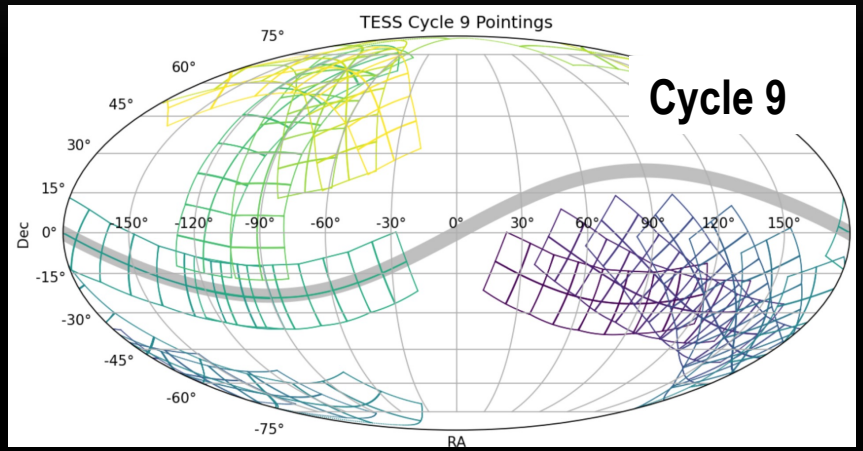
https://heasarc.gsfc.nasa.gov/docs/tess/

- Launched April 18, 2018
- Four 2048 x 2048 pixel CCD cameras
- 21 arc sec per pixel
- Observes strips of sky for 27 days
- Search for planets around nearby, mostly M-dwarf, stars
- 939 confirmed planets and 8148 candidates as of 1 October 2026

https://exoplanetarchive.ipac.caltech.edu/

117 out of 185 ACYG stars in VSX are being observed by TESS in 2025-2027



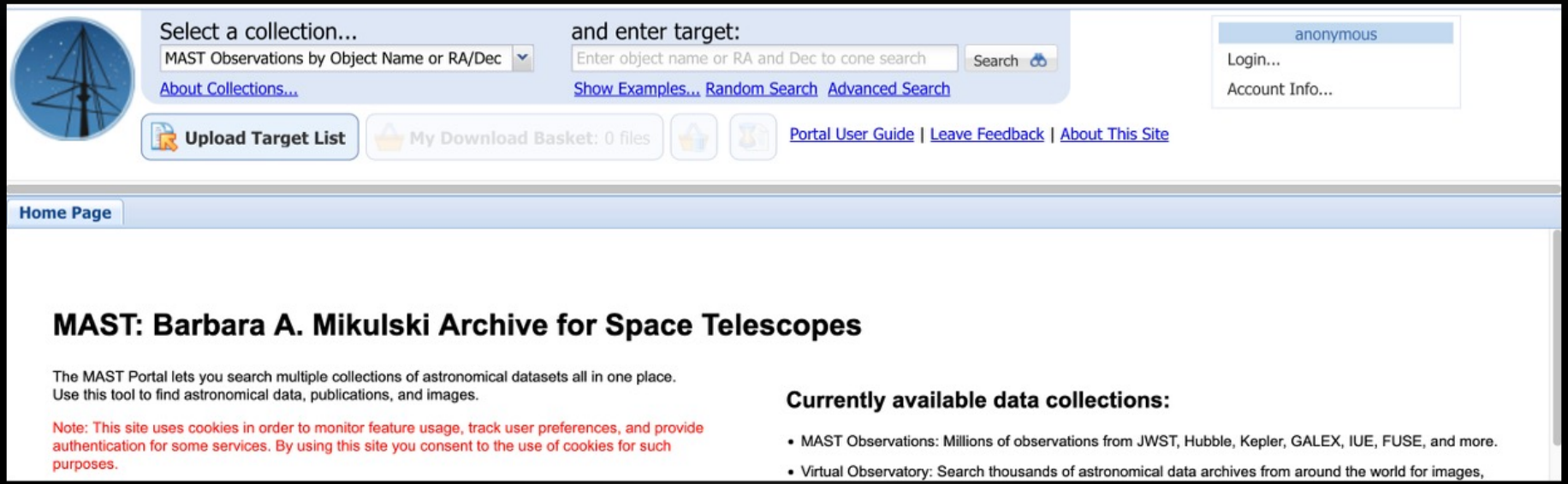


V magnitudes 0.706 (Rigel) to 12.62

75 are being observed in Cycle 8, and 74 in Cycle 9; 32 in both

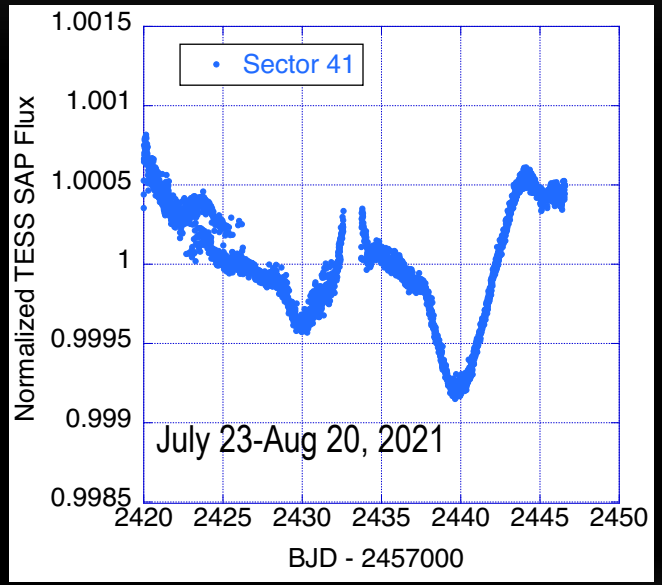
Proposed to TESS General Investigator Program

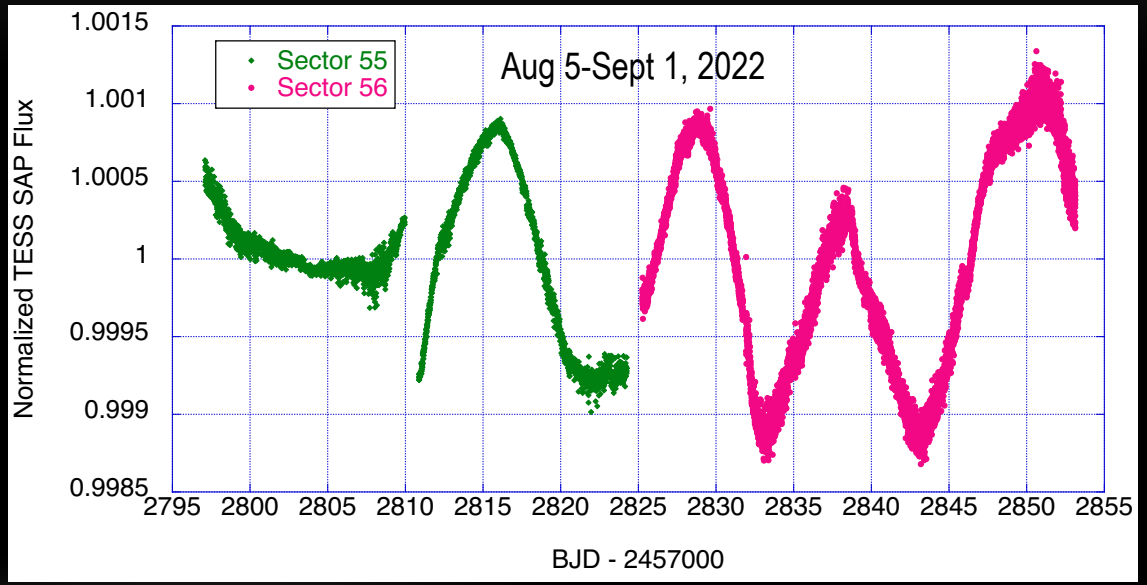
Processed TESS light curves for many ACYG stars are available on MAST database



https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html

TESS Deneb photometry shows irregular variations during 2021 and ~12-day variations in 2022

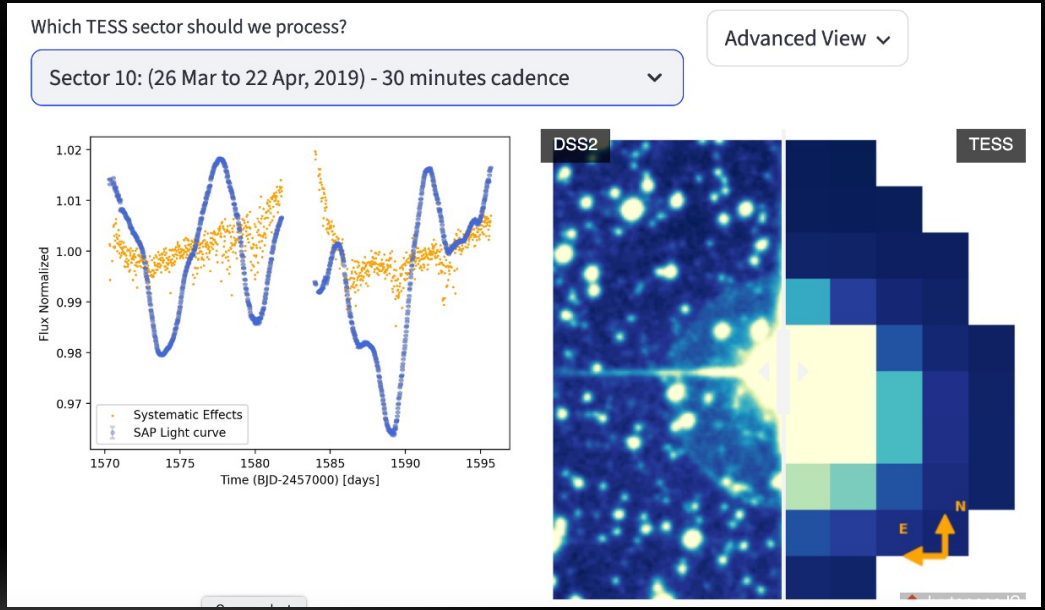




See also Abt et al. PASP 135, 2023;
Guzik et al. AAVSO 112th (2023), AAVSO 113th (2023); SAS 2024 proceedings (arXiv)

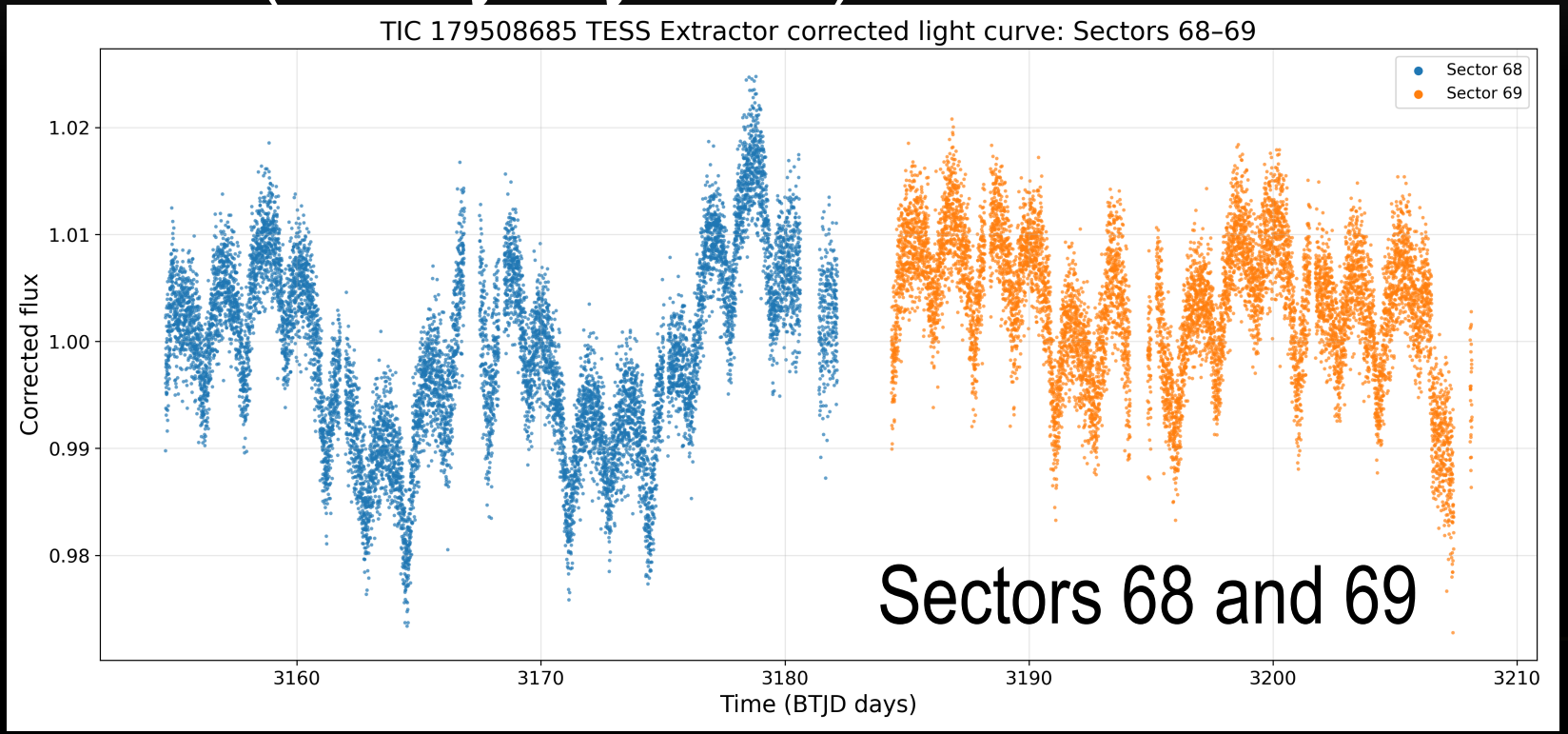
TESS Extractor is useful to extract detrended light curves from TESS full-frame images



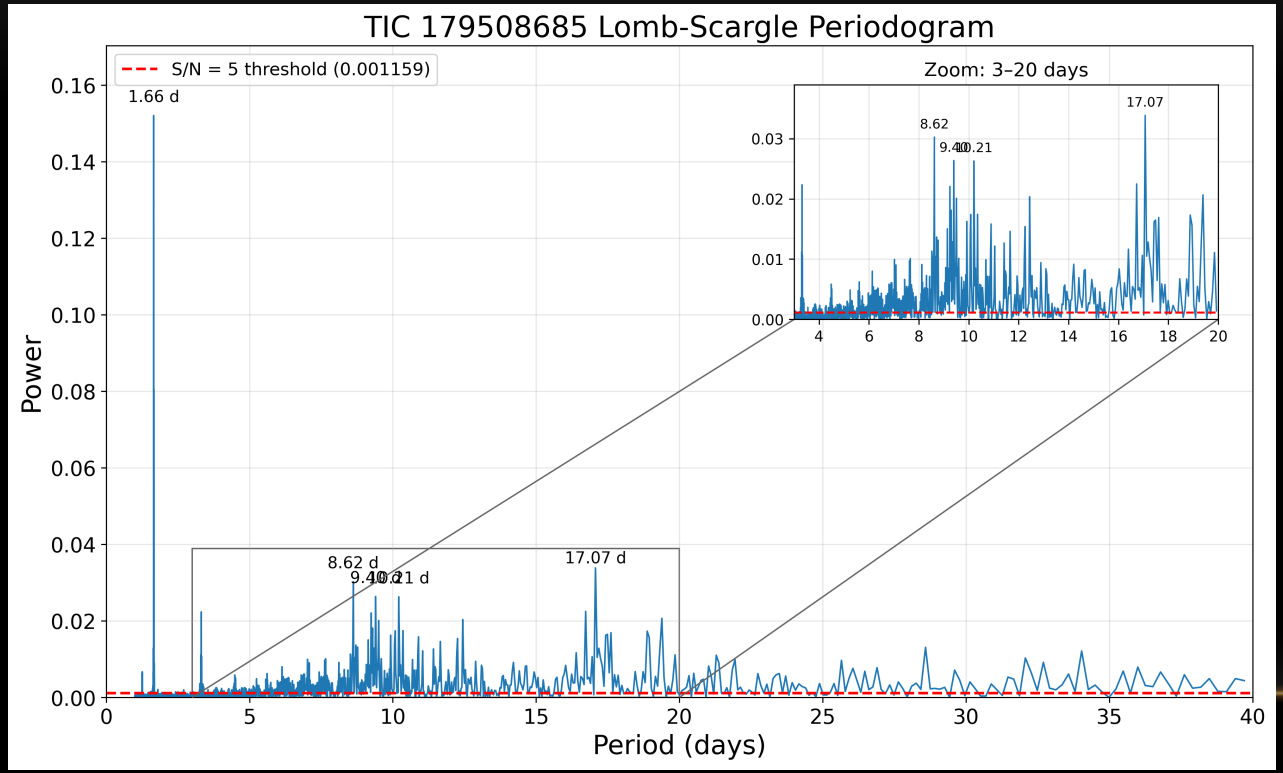


Serna et al. 2021, ApJ 923, 127
See Guzik et al. AAVSO 114th proceedings (archive/aavso.org/114)

TIC 179508685 (V mag 11.5) has 36 sectors (nearly 3 years!) of TESS data

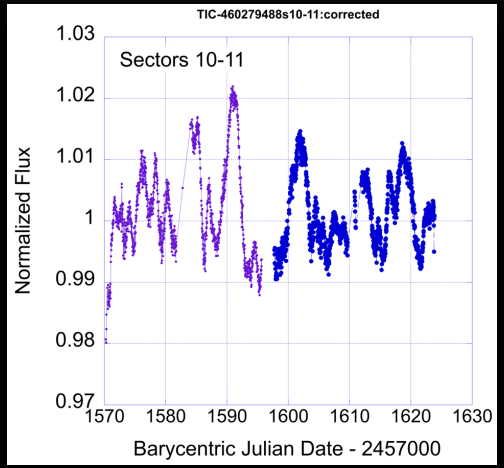


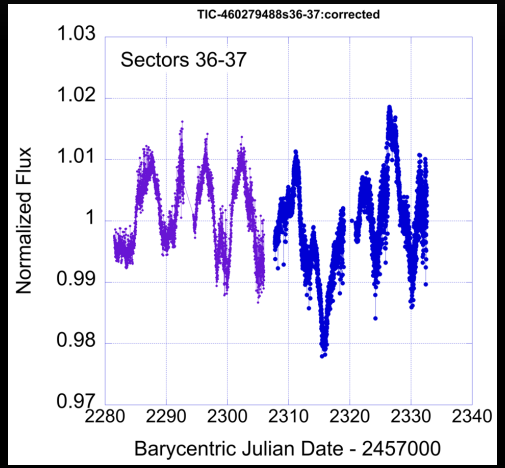
TIC 179508685 Periodogram from TESS Extractor light curves shows periodicities consistent with nonradial gravity modes and/or Rossby modes

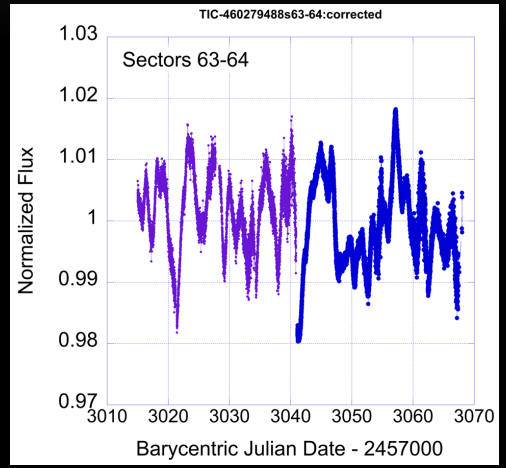


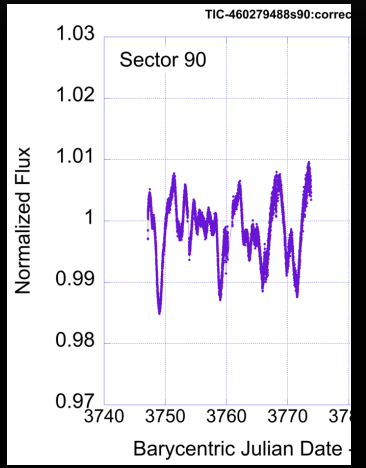
- More than 100 frequencies with S/N ratio greater than 5
- 1.66 d period might be a rotation or binary period?

Other ACYG Stars observed by TESS show more stochastic variability



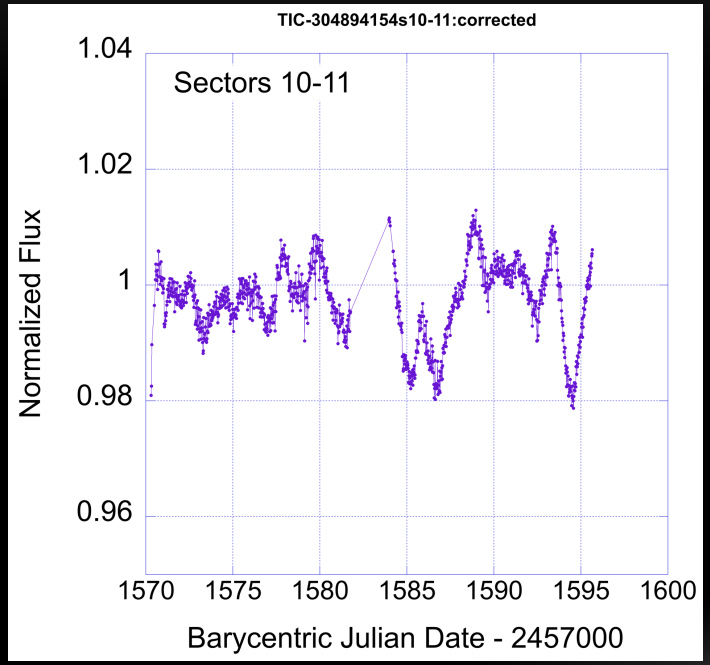


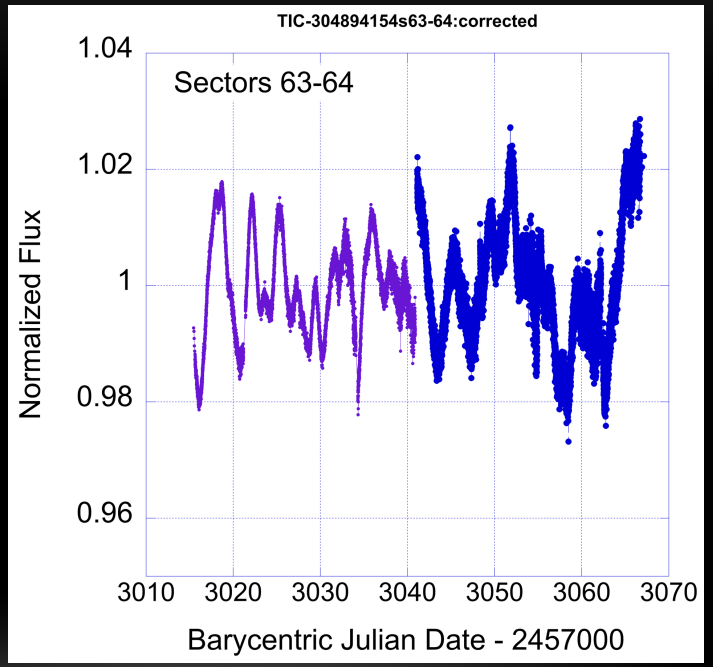


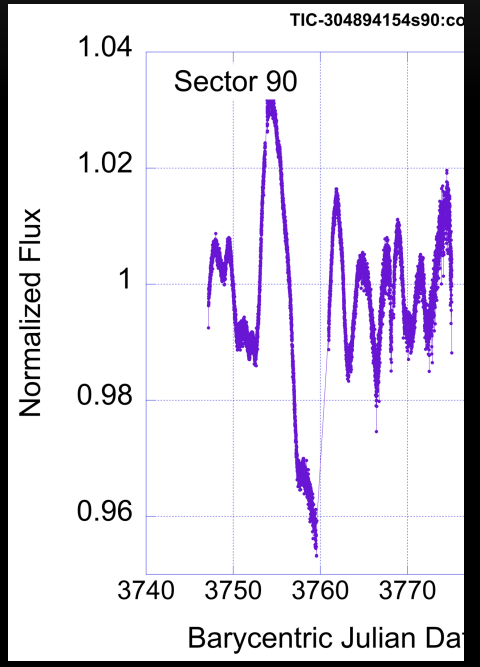


TIC 460279488, B8Iab, TESS Mag 7.32

TIC 304894154, B3Ib, TESS Mag 6.56



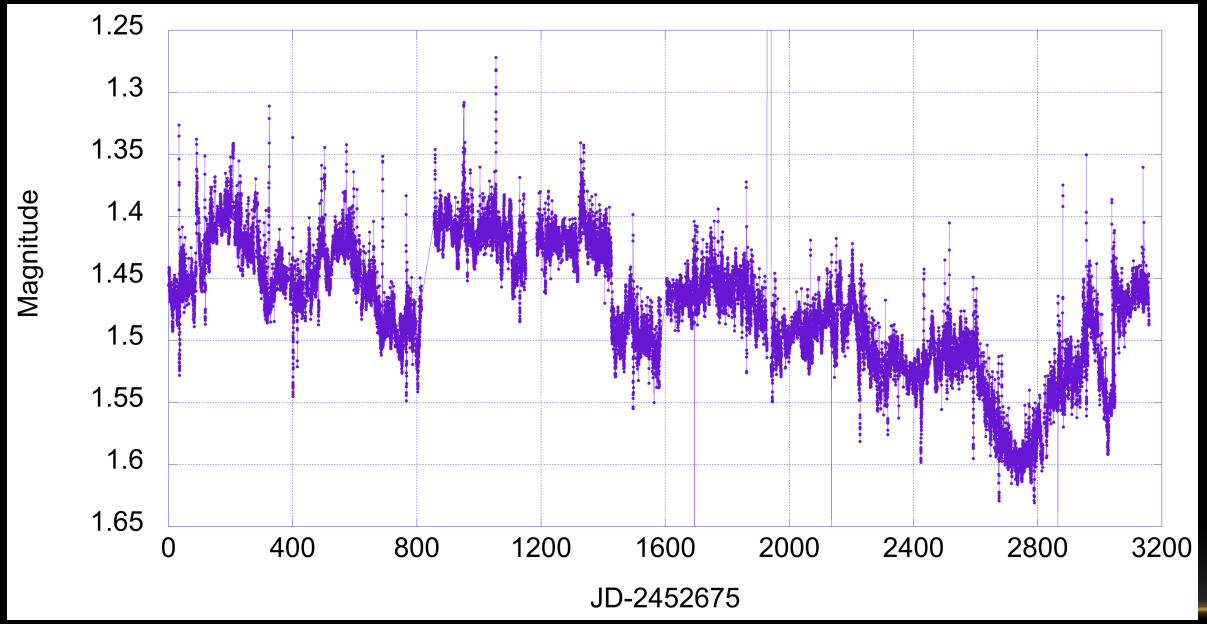




Solar Mass Ejection Imager Data



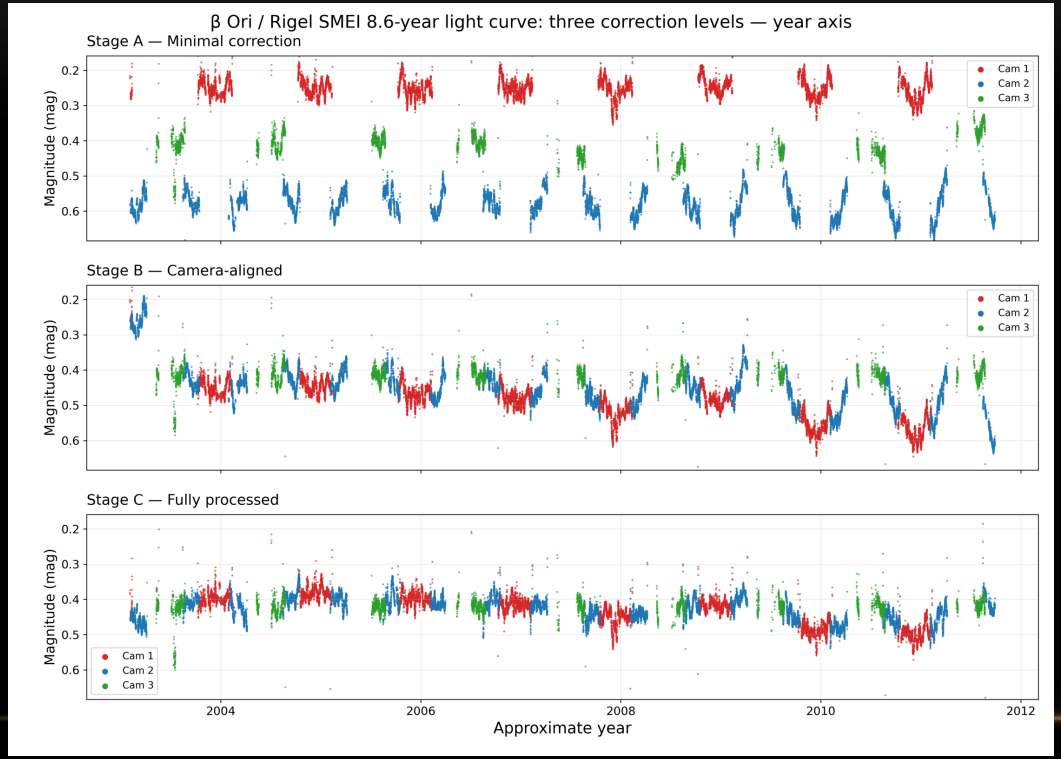
B. Kloppenborg (AAVSO) provided Deneb photometry from Solar Mass Ejection Imager (SMEI) spacecraft



- 8.6 years (2003-2011)
- SMEI data exist for nearly all bright stars with V mag < 5.5
- 1 data point per Earth orbit, 102-minute (1.7 hour) cadence

See Guzik et al. AAVSO 113 (2024) and SAS 2024 proceedings (available on arXiv)

SMEI light curves for 33 bright ACYG variables have been processed by J. Kay and B. Kloppenborg (AAVSO)

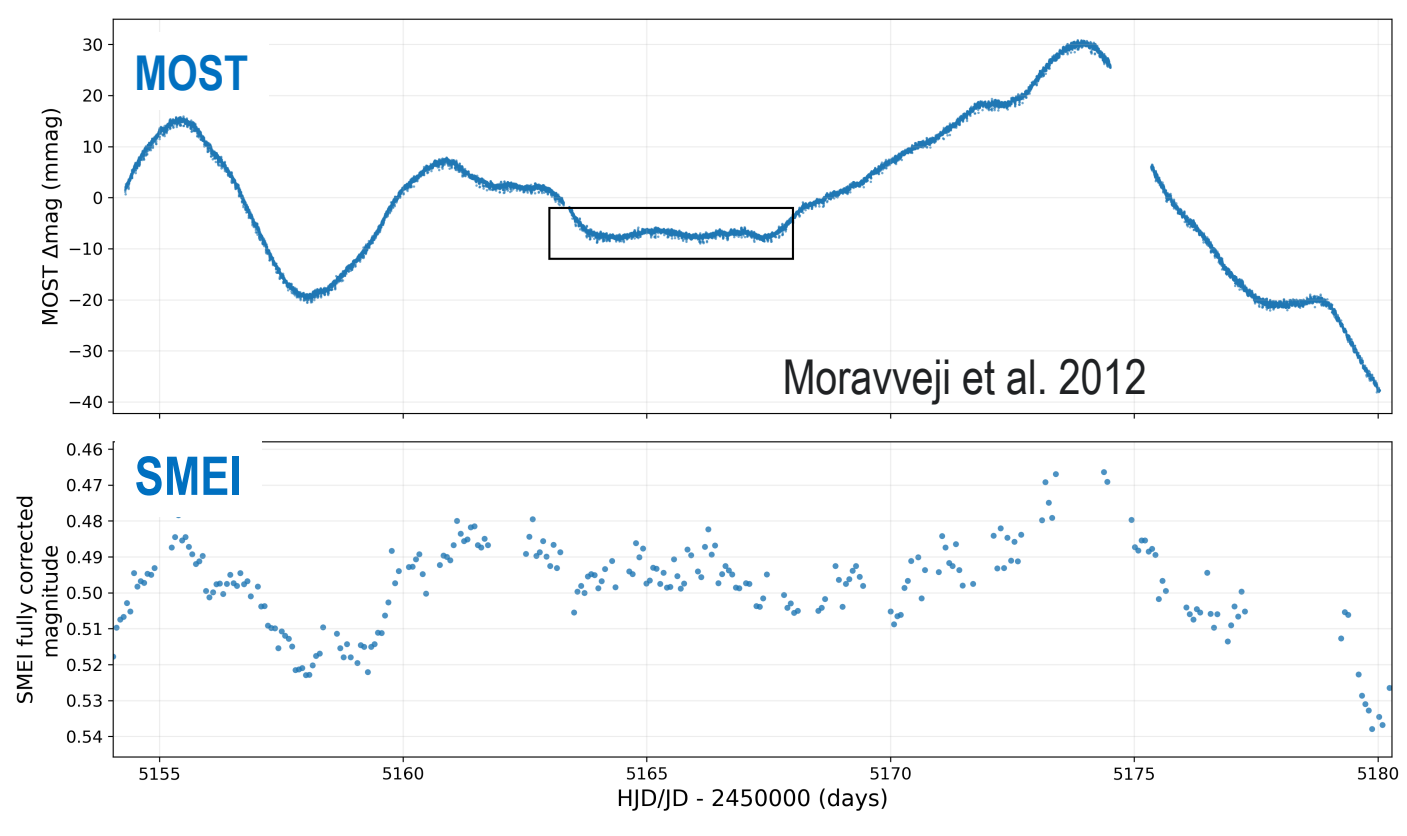


Cameras aligned

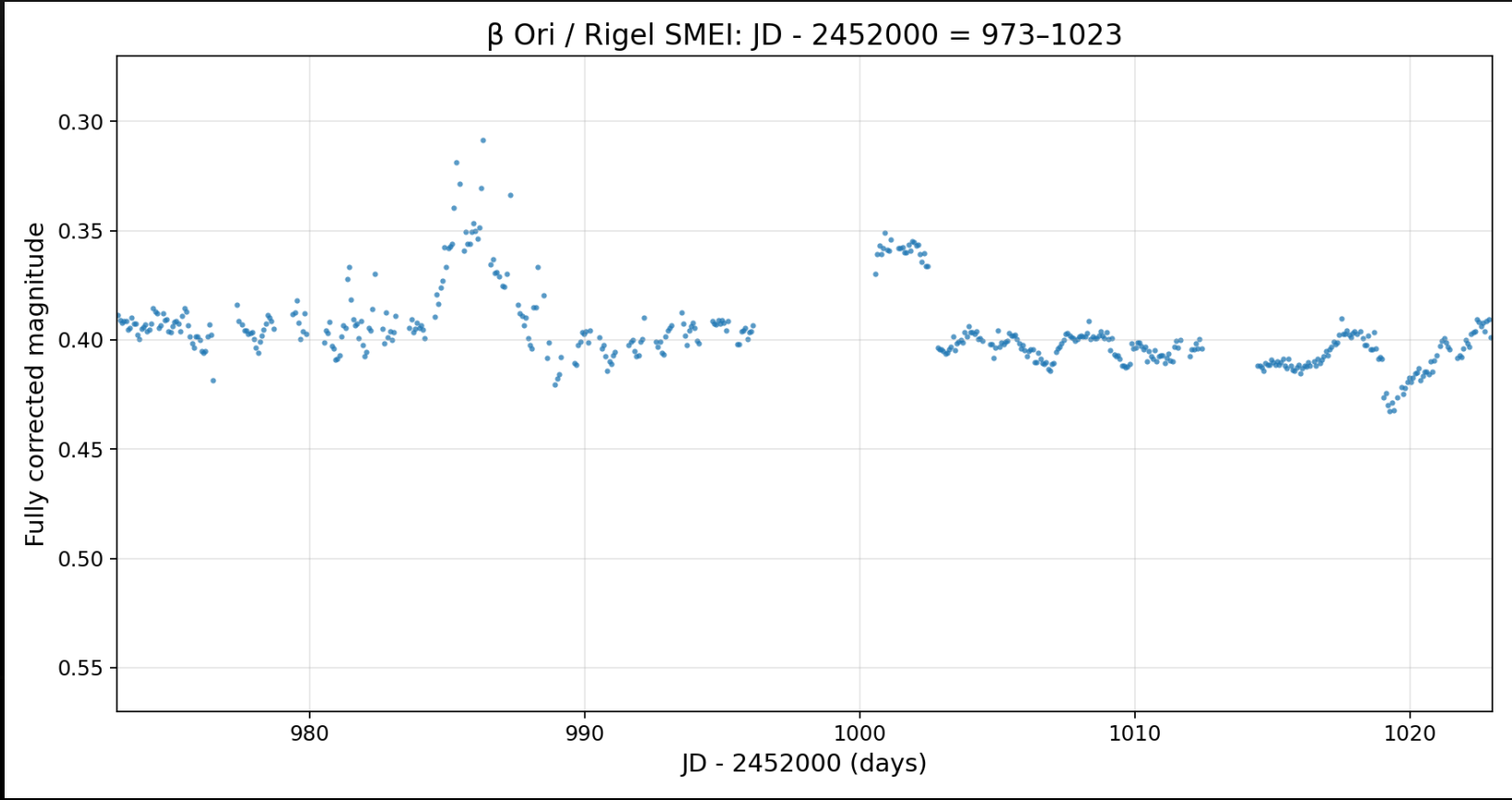
Yearly trend removed

See Guzik et al. 2026, https://socastrosci.org/wp-content/uploads/2026/07/2026-Proceedings_Ver1.3.pdf

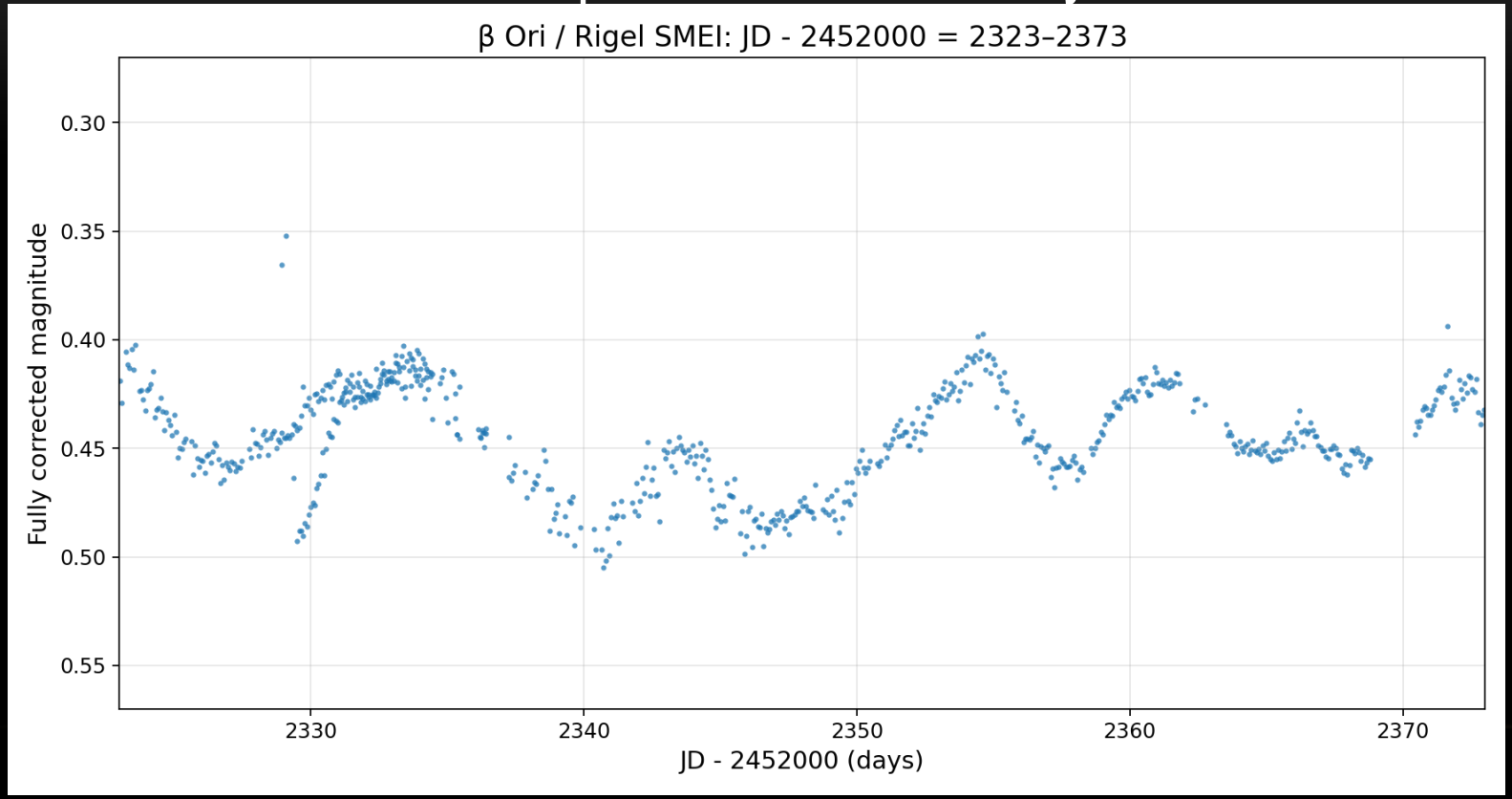
2009 SMEI vs. MOST (2003-2019) satellite light curves for Rigel show excellent correlation!



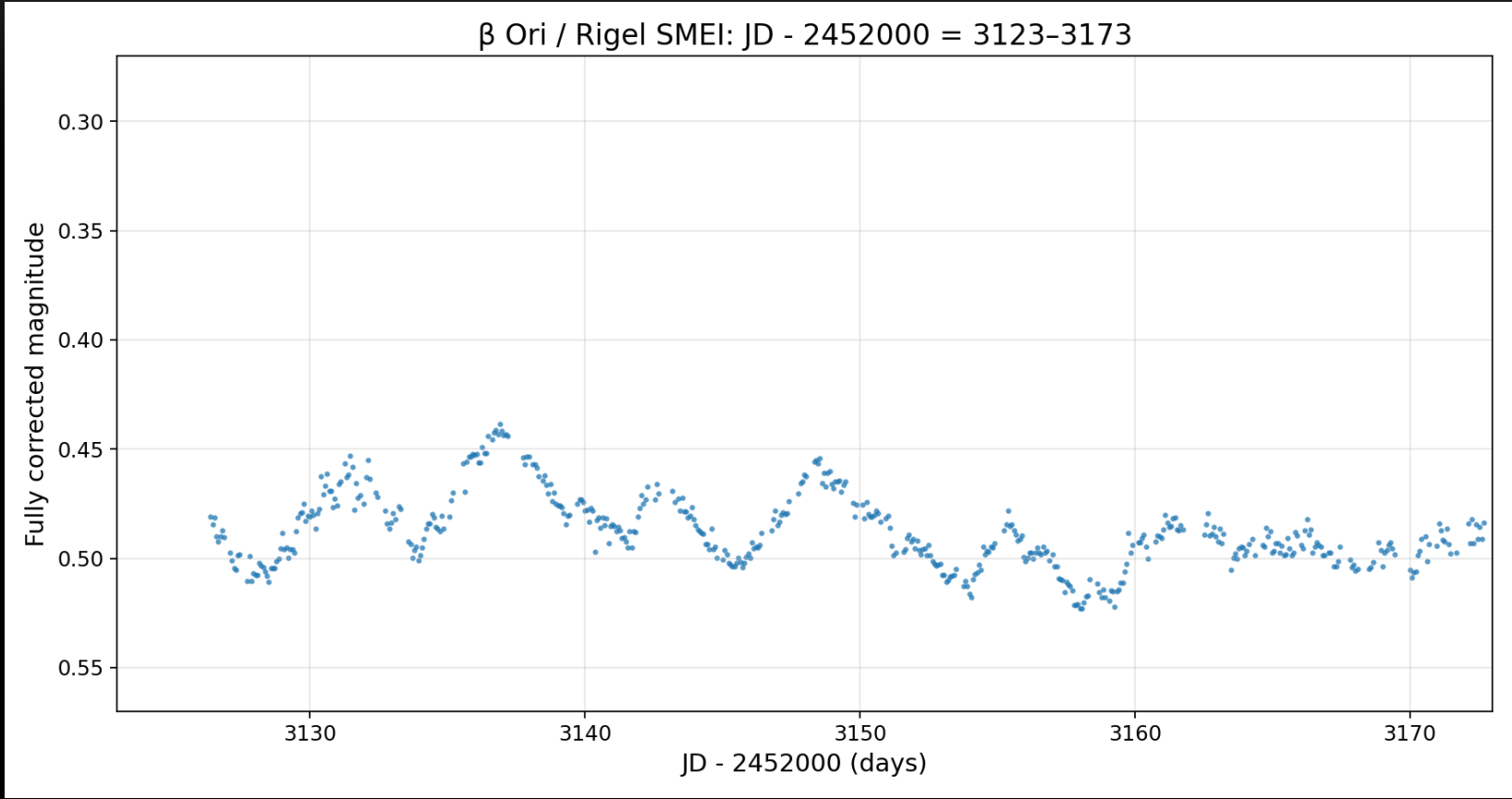
SMEI Rigel light curve shows small amplitude variations punctuated by larger amplitude variations with period ~5 days



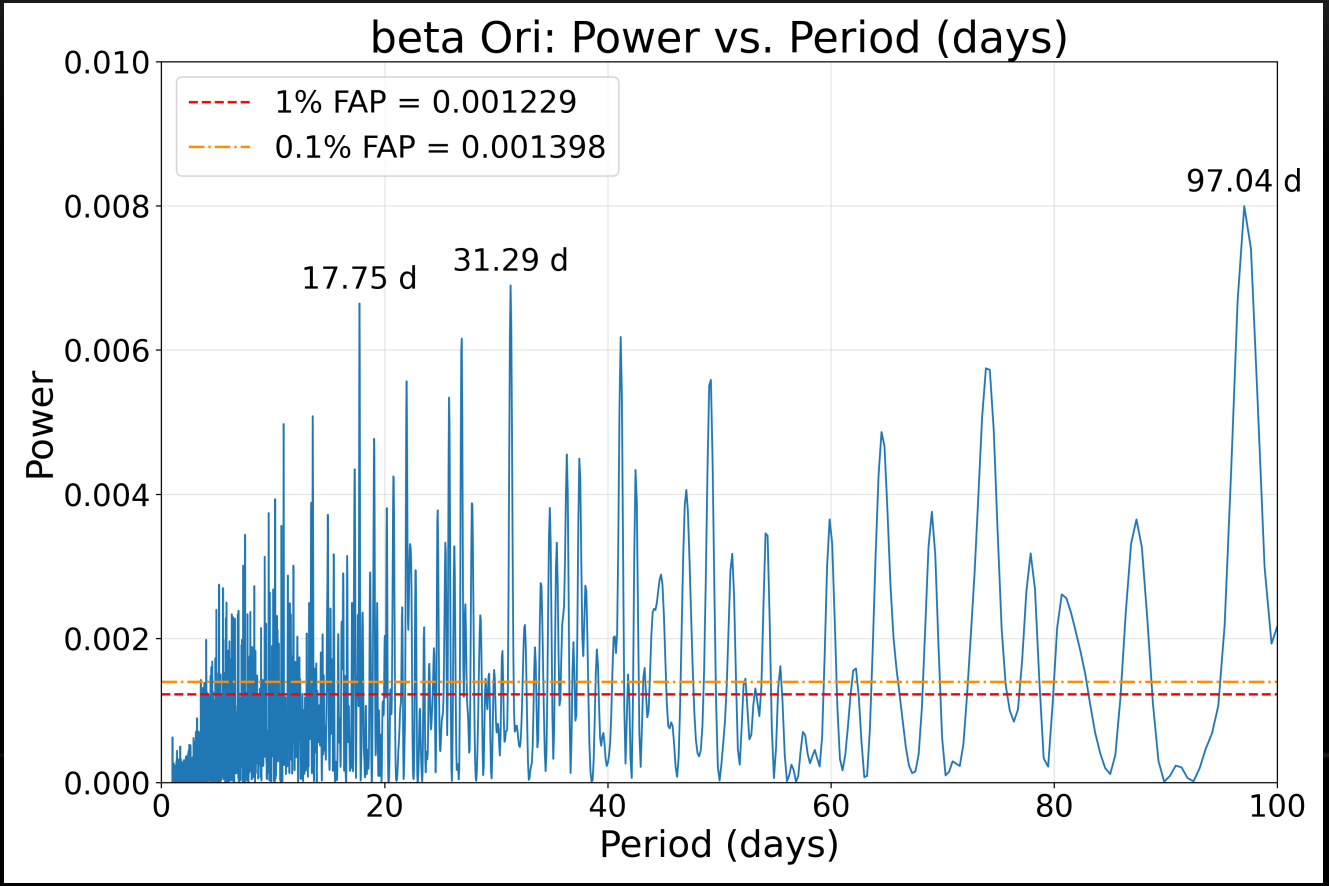
Rigel light curve sometimes shows larger amplitude variations with periods 5 to 10 days



More larger amplitude variations and transition

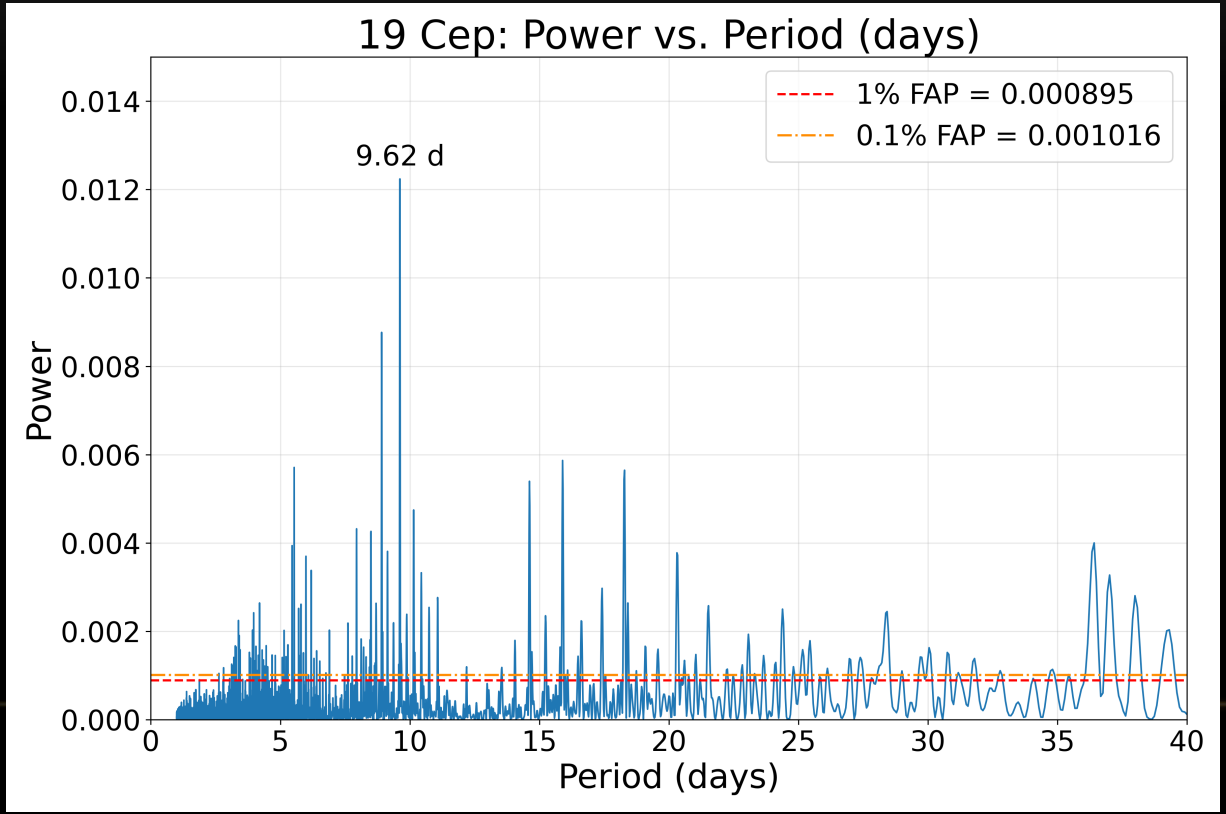


Periodogram of Rigel SMEI light curve shows most significant peaks at periods > 5 days

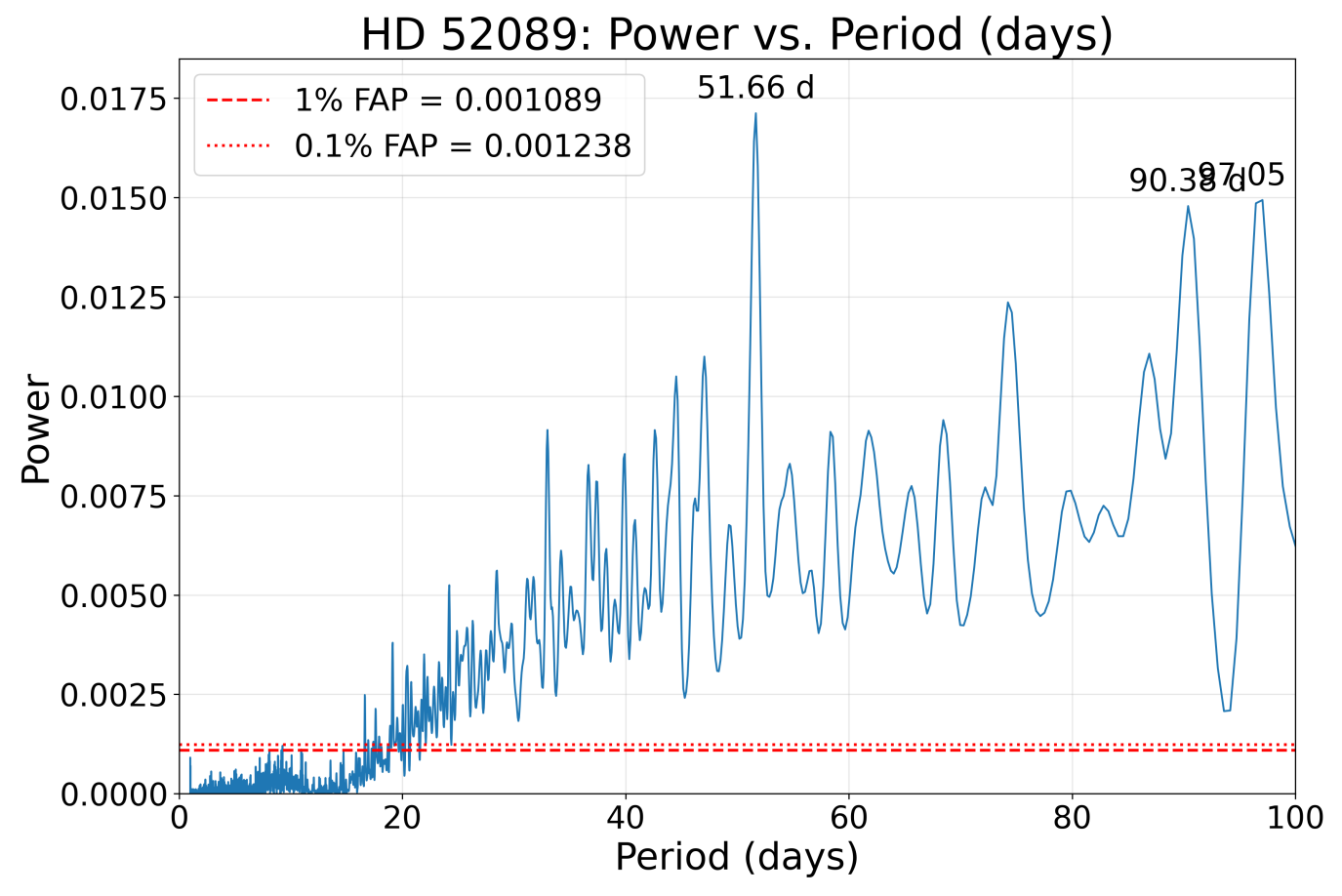


More Highlights from SMEI Periodograms

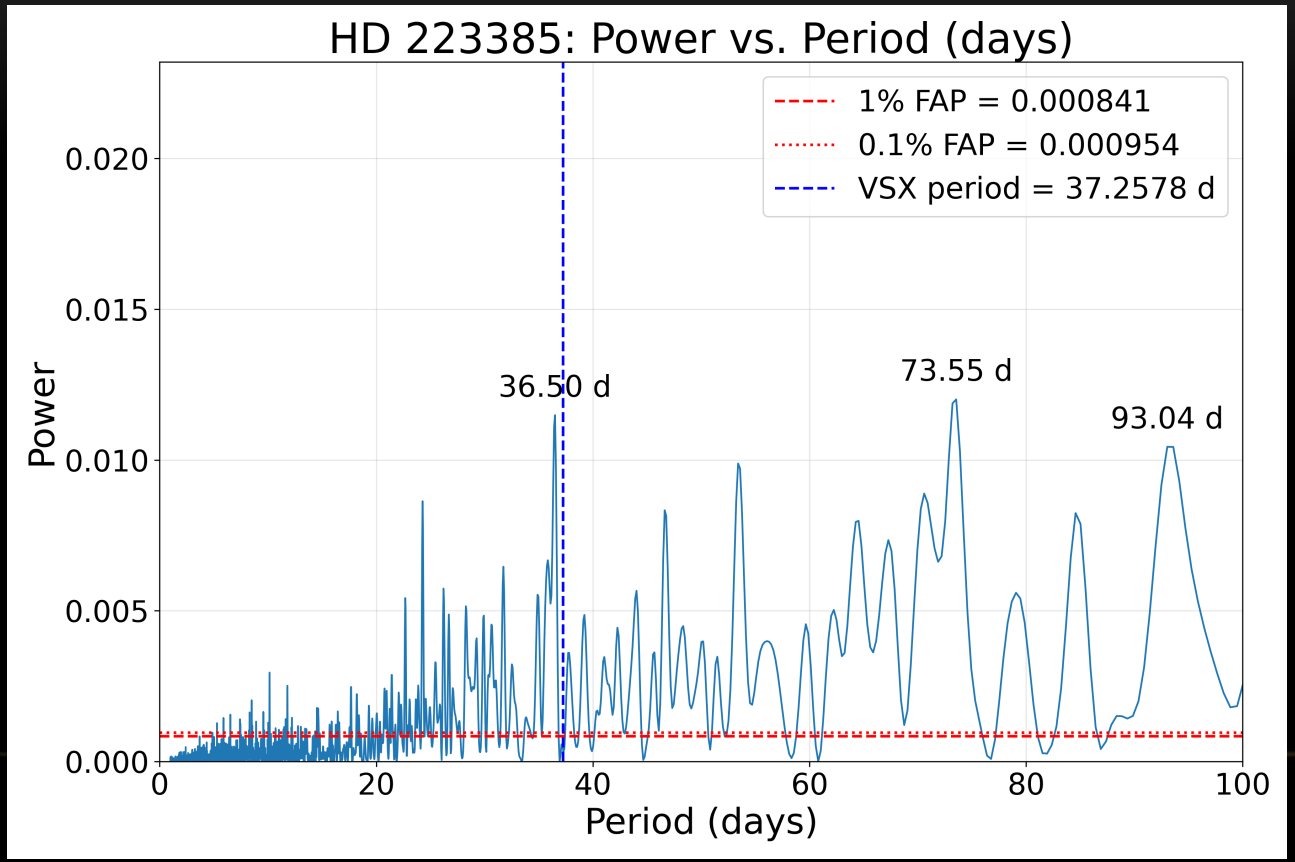
19 Cep (O9Ib, V mag 5.11) periodogram shows clumps of nearly equally spaced modes characteristic of gravity and/or Rossby modes



SMEI eps CMa (Adhara, V mag 1.5) periodogram shows a prominent 51.6-day peak

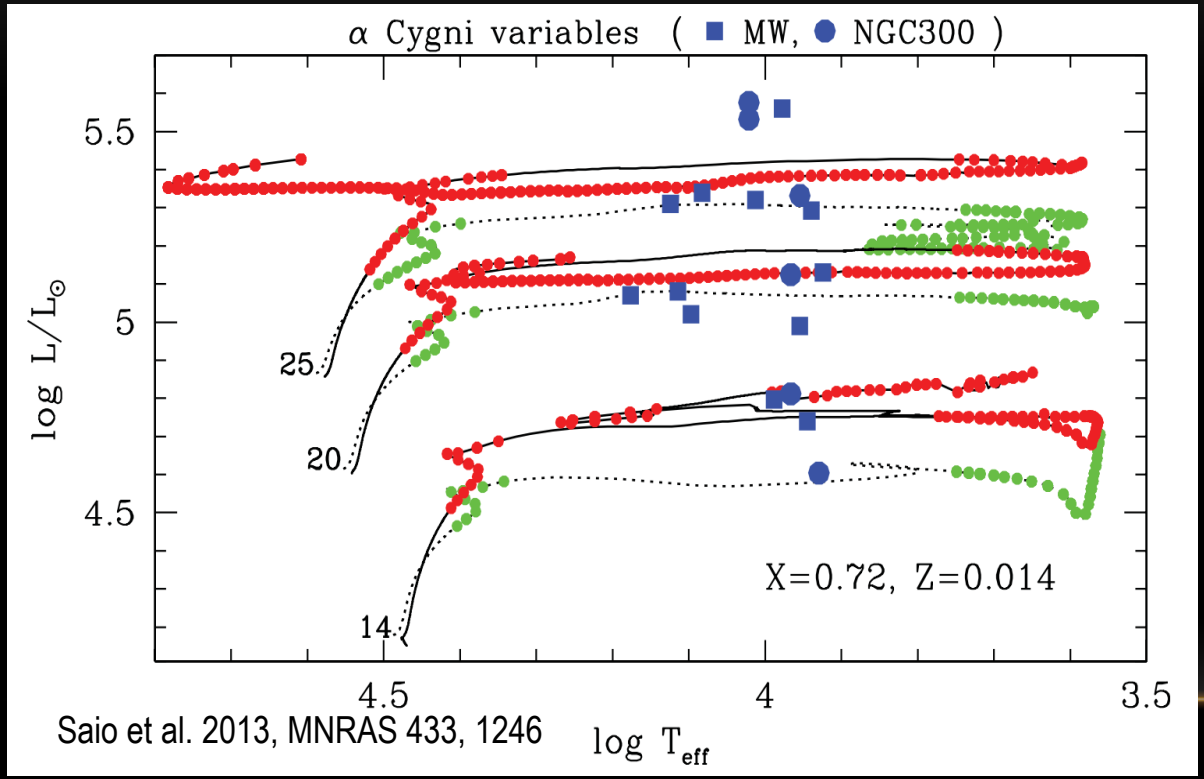


SMEI V0566 Cas (A2.5I, V mag 5.5) periodogram shows a significant peak near the period listed in VSX

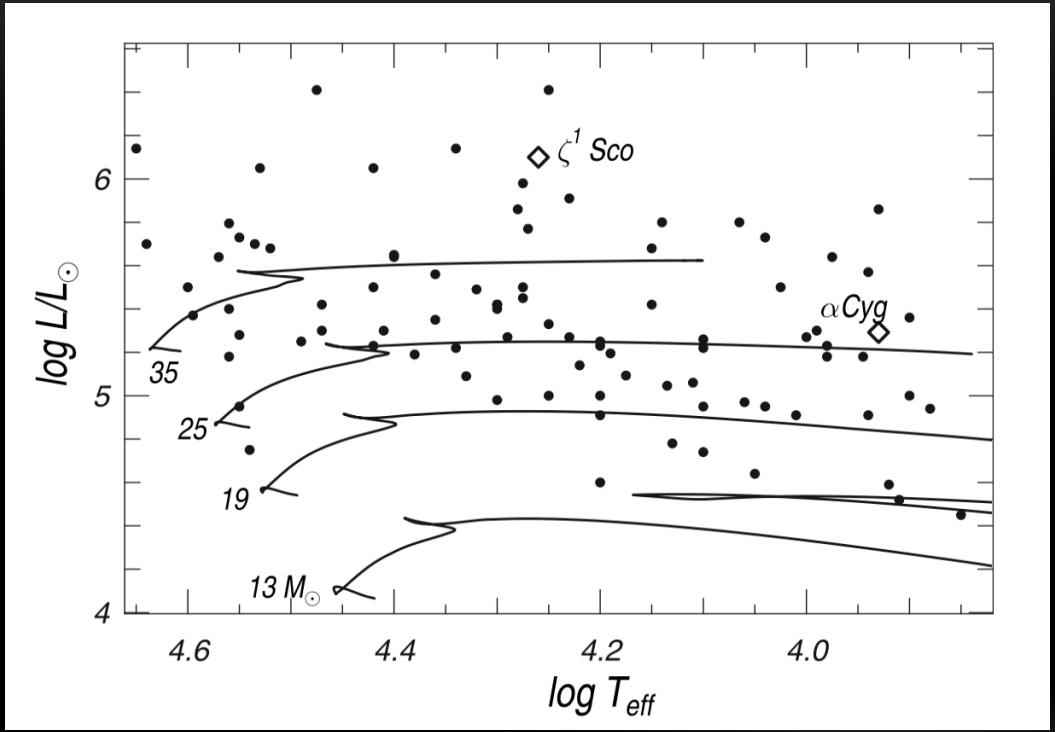


Evolution and causes of variability of ACYG stars (mostly not pulsations?)

Saio et al. find radial pulsations only for models that undergo ‘blue loops’ caused by high rotation rate (or high RGB mass loss)



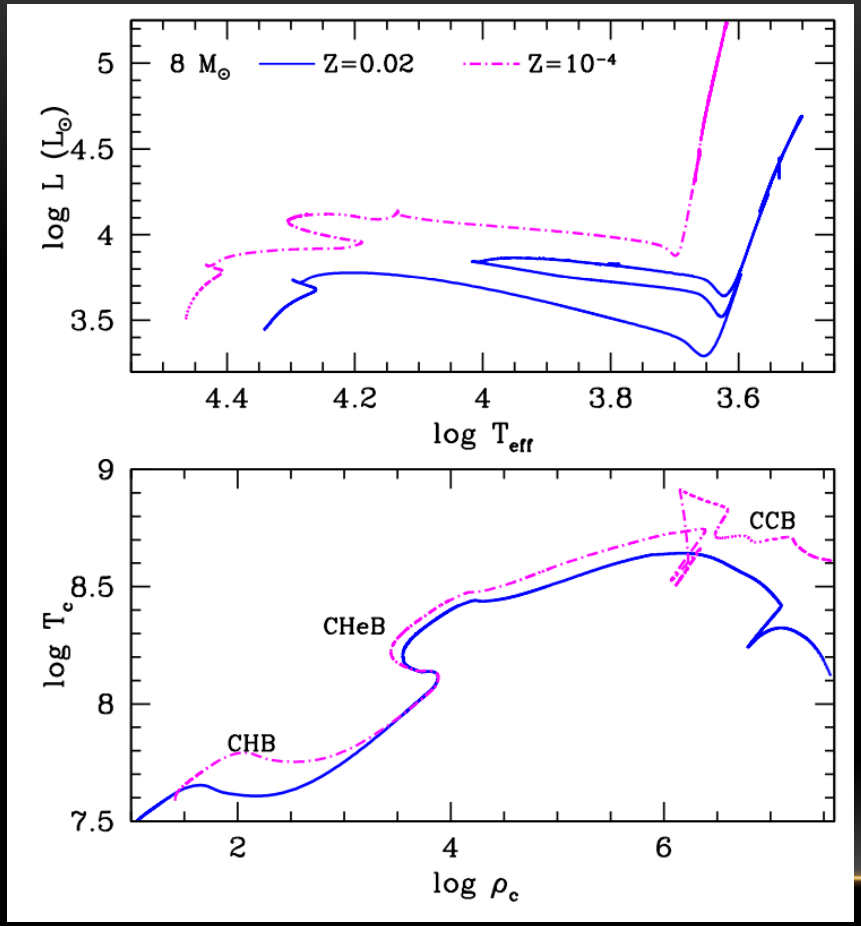
- Dash — No rotation
- Solid —ZAMS rotation at 40% breakup
- Blue dots and squares—known α Cygni variables
- Red and green dots — at least one radial pulsation mode excited



Gautschy proposed Deneb pulsations driven by a deep convection zone above H-burning shell on first crossing of HR diagram that destabilizes low-degree nonradial modes

Black dots—ACYG variables and micro-variable supergiants

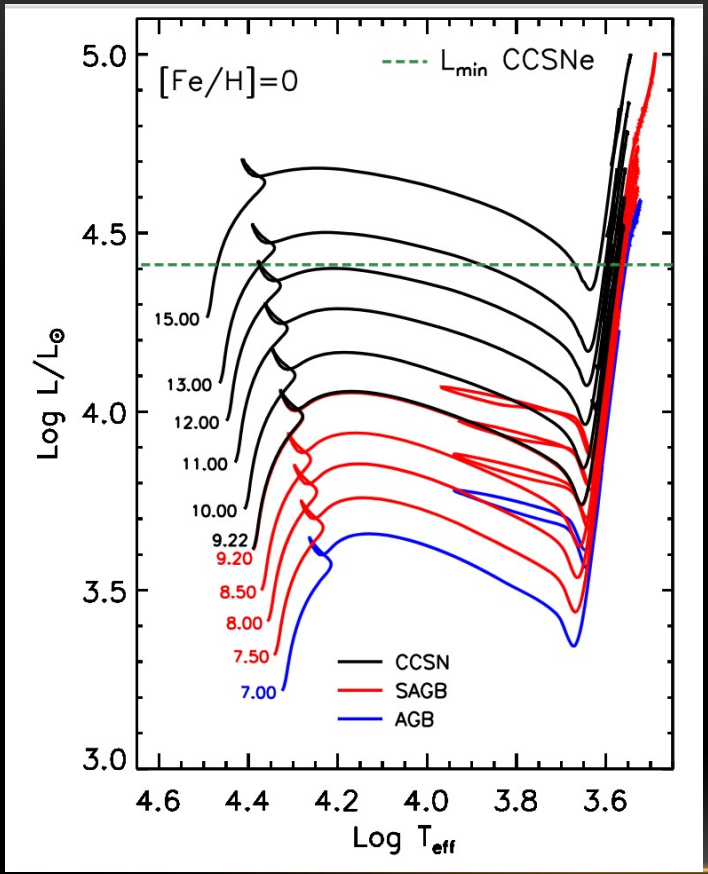
Gautschy 2009, A&A 498, 273



Models that become SuperAGB stars have different evolutionary tracks depending on metallicity

- Super-AGB star mass range ~ 6.5 -12 $M_{\odot}$
- Evolution track will affect dredge-up of elements in RGB and AGB stages

Doherty, Gil Pons, Siess, Lattanzio, 2017 PASA



For solar metallicity, SuperAGB star initial mass range ~ 7.5 -9.2 $M_\odot$

- Red lines are SuperABG stars, i.e., stars that ignite C but do not ignite Ne.
- These develop degenerate ONeMg core and enter TP phase

Limongi et al. 2024, ApJSS 270, 29

Conclusions

- 8.6-year SMEI light curves have been processed for 33 ACYG variables. Periodograms mostly show significant peaks at long periods, consistent with Stochastic Low-Frequency (SLF) variability.
- 27-day MOST satellite Rigel light curve (2009) agrees well with contemporaneous SMEI light curve, helping to validate the reductions.
- Light curves show intermittent quasi-periodic behavior that periodograms of the full data set do not capture (e.g., Deneb, Rigel).
- Found two gravity/Rossby-mode pulsators in TESS and SMEI data. These are excellent candidates for asteroseismic analysis.
- ACYG variables in VSX are not a homogeneous class!
- Long-term monitoring by amateur observers is essential.

Future Work

- Analysis of TESS light curves (sector stitching?)
- Analysis of 33 SMEI light curves
- Prewhitening and frequency analysis for two candidate gravity/Rossby mode pulsators
- Compare Rigel 6.6-year radial velocity curve discussed by Moravveji et al. (2012) with SMEI light curve
- Continue ground-based monitoring of ACYG stars and compare with TESS light curves taken at same time, when available
- Modeling of evolution and variability mechanisms for ACYG variables

Acknowledgments

- This work makes use of data from NASA's Transiting Exoplanet Survey Satellite (TESS), obtained from the Mikulski Archive for Space Telescopes (MAST).
- We also acknowledge use of Gaia DR3 and SIMBAD databases.
- We made use of open-source software including *astropy* and *TESS Extractor.*
- We thank the AAVSO Photoelectric Photometry (PEP) observing team.
- This work has made use of data from the BRITE Constellation satellites.
- We acknowledge support from Los Alamos National Laboratory, managed by Triad National Security, LLC for the U.S. DOE's NNSA, Contract #89233218CNA000001.
- We acknowledge use of ChatGPT v5.5 and Claude Sonnet for assistance with data analysis and figures.