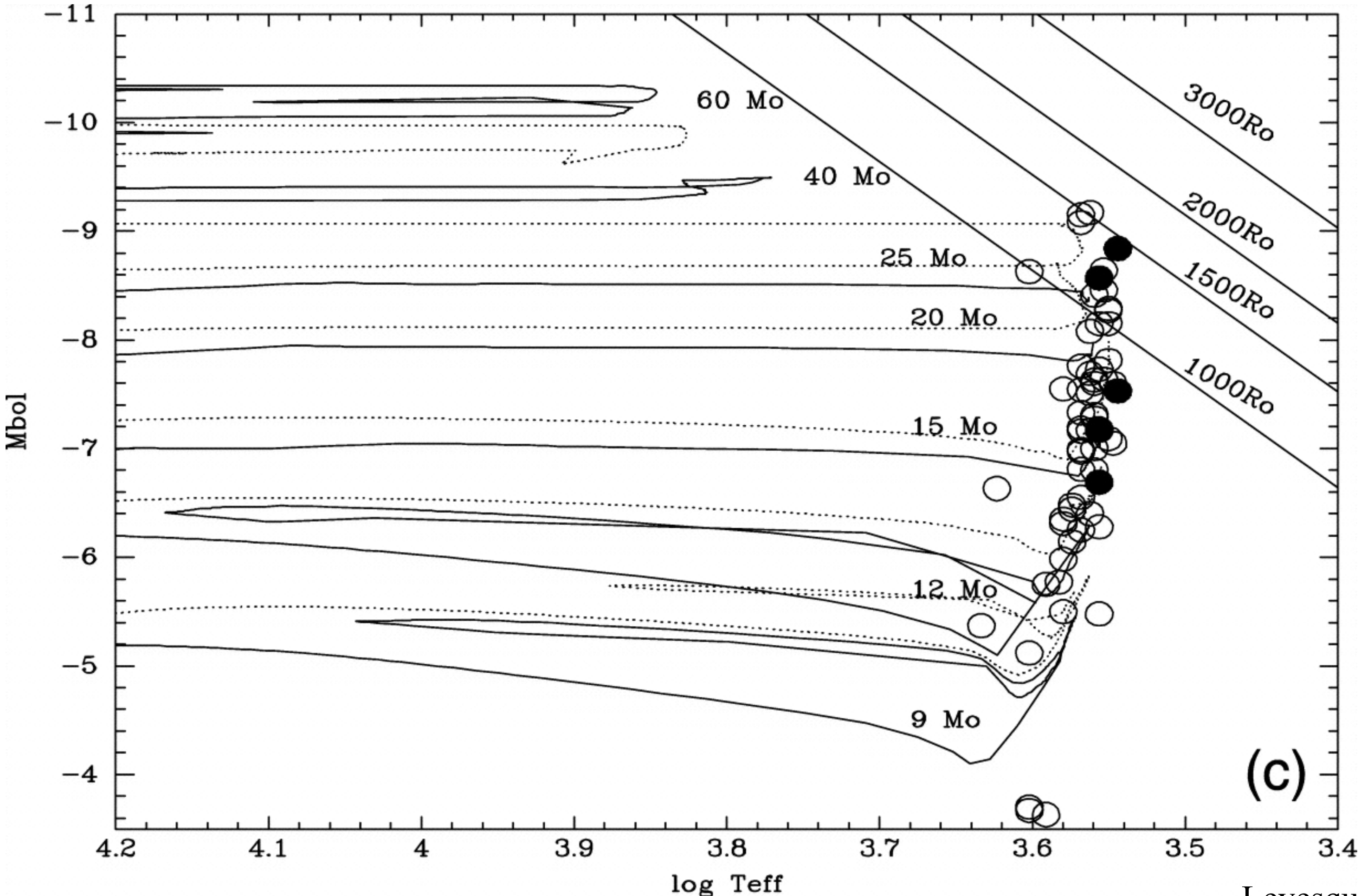
An Imaging Survey of Red Supergiants with MIRC

Ryan Norris

With Fabien Baron (GSU), Rob Parks (GSU), Andrea Chiavassa (OCA), and John Monnier (UM)

Why Study Red Supergiants?



Levesque et al. 2005

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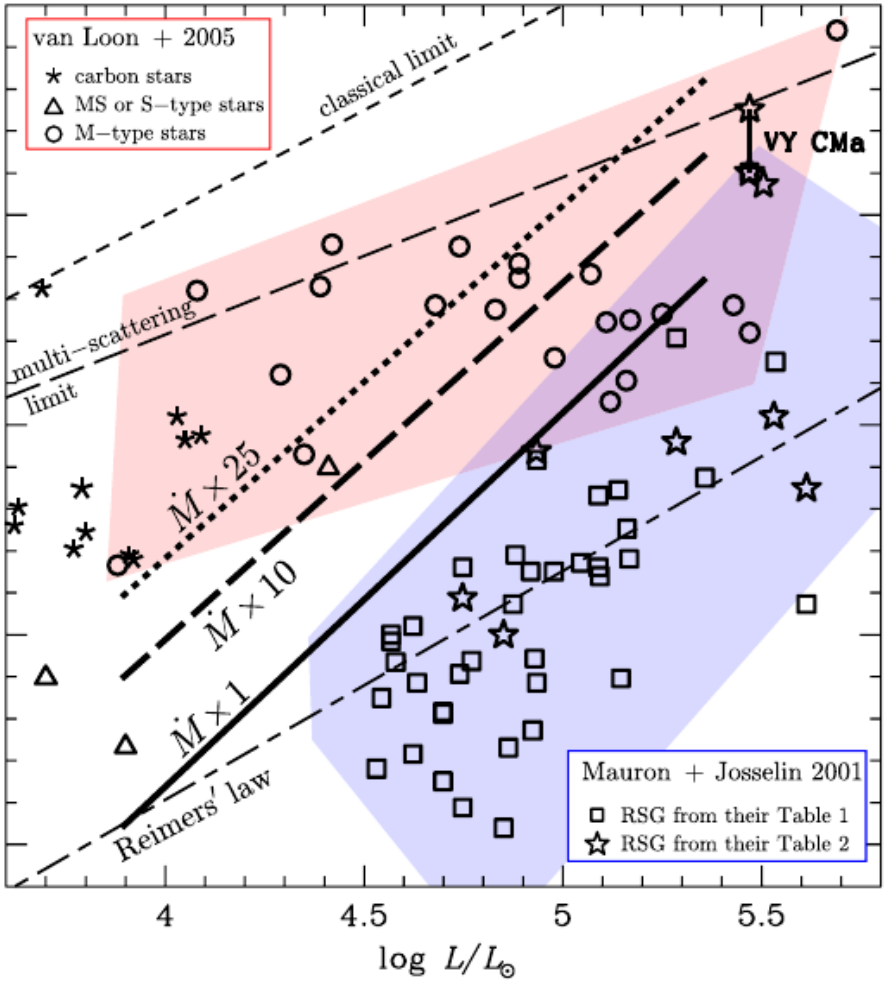

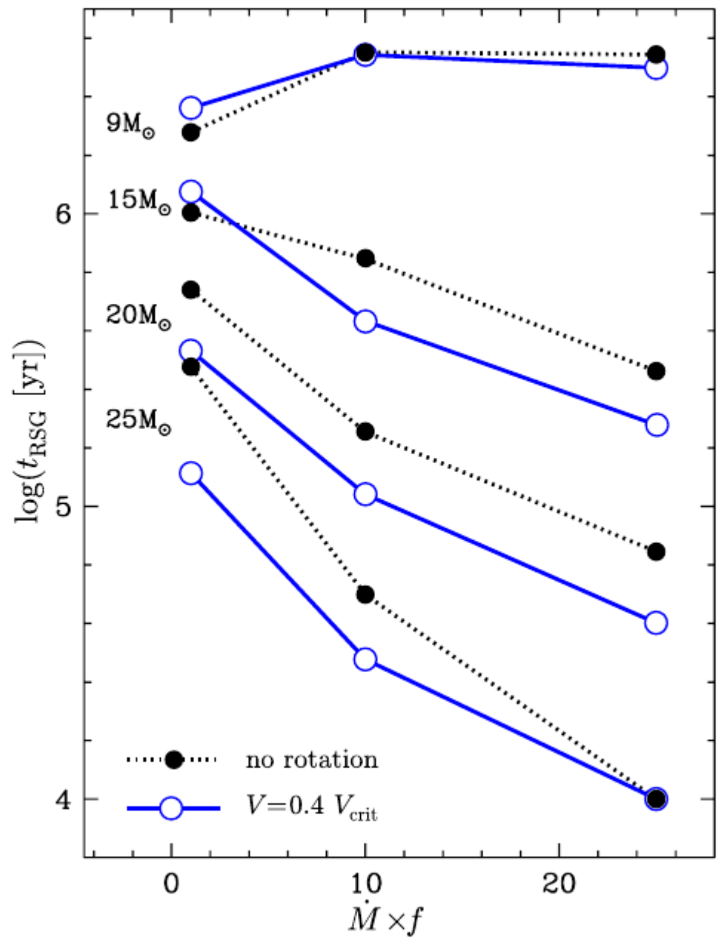

Meynet et al. 2015

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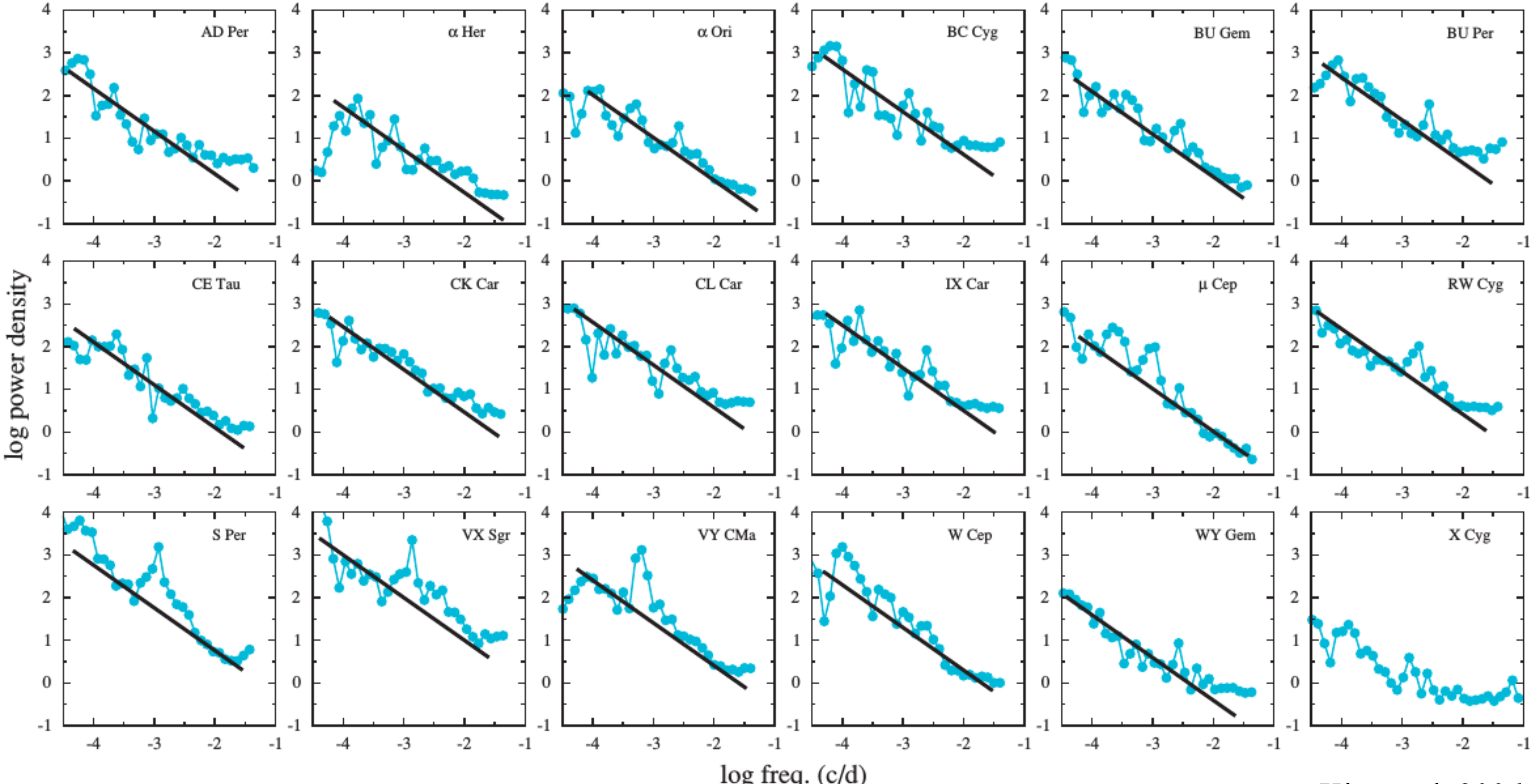

Kiss et al. 2006

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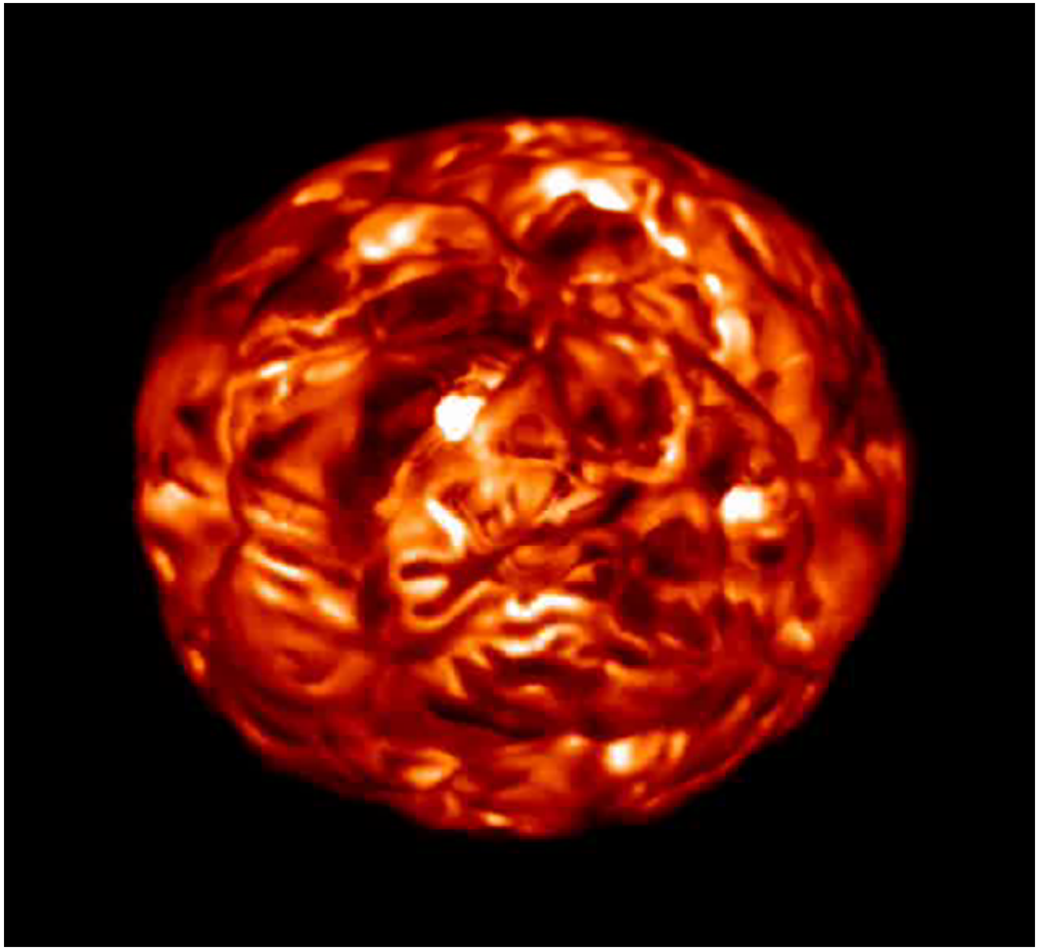
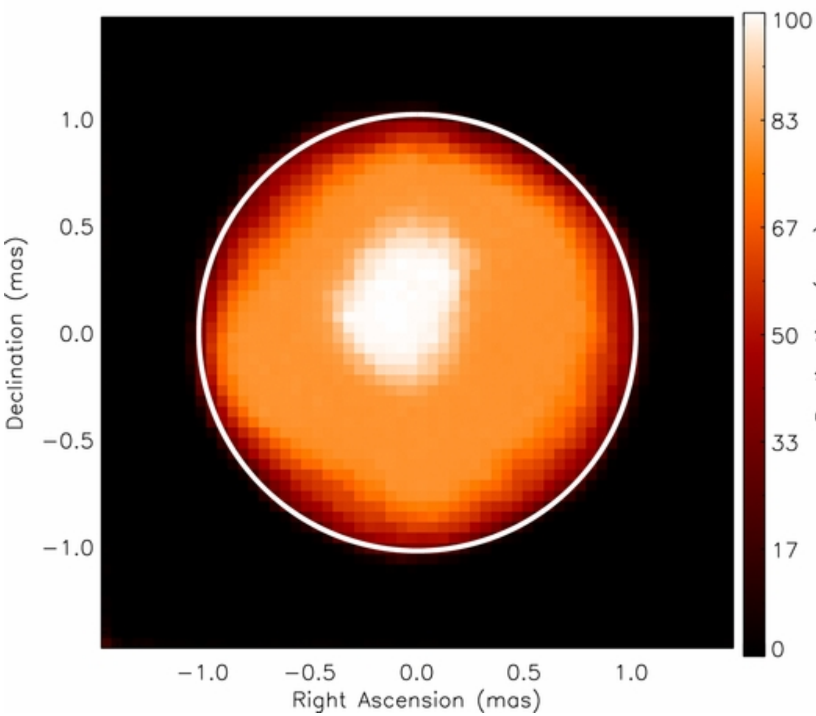


Chiavassa et al. 2011

Our Project



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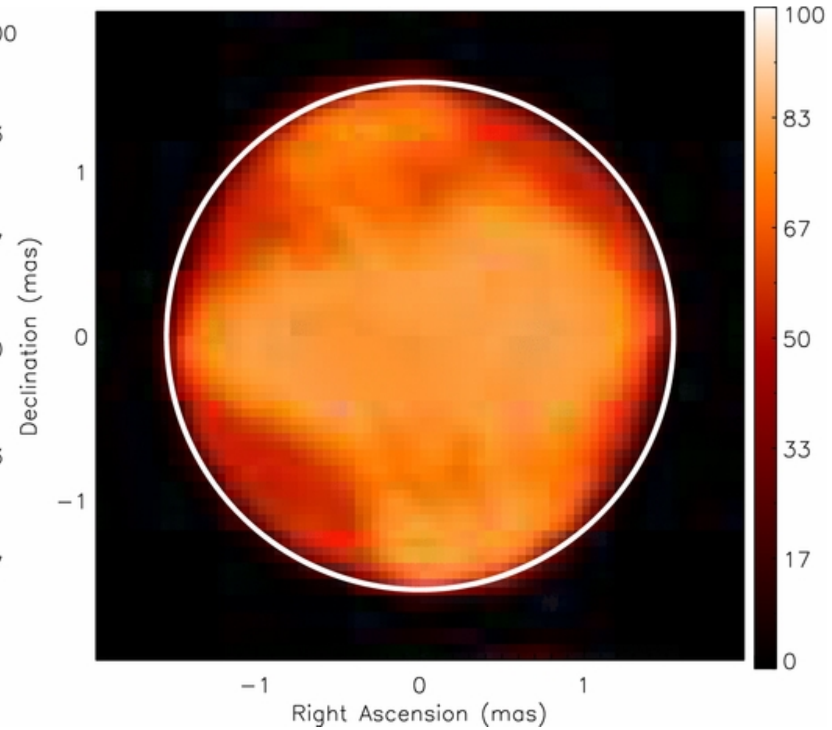

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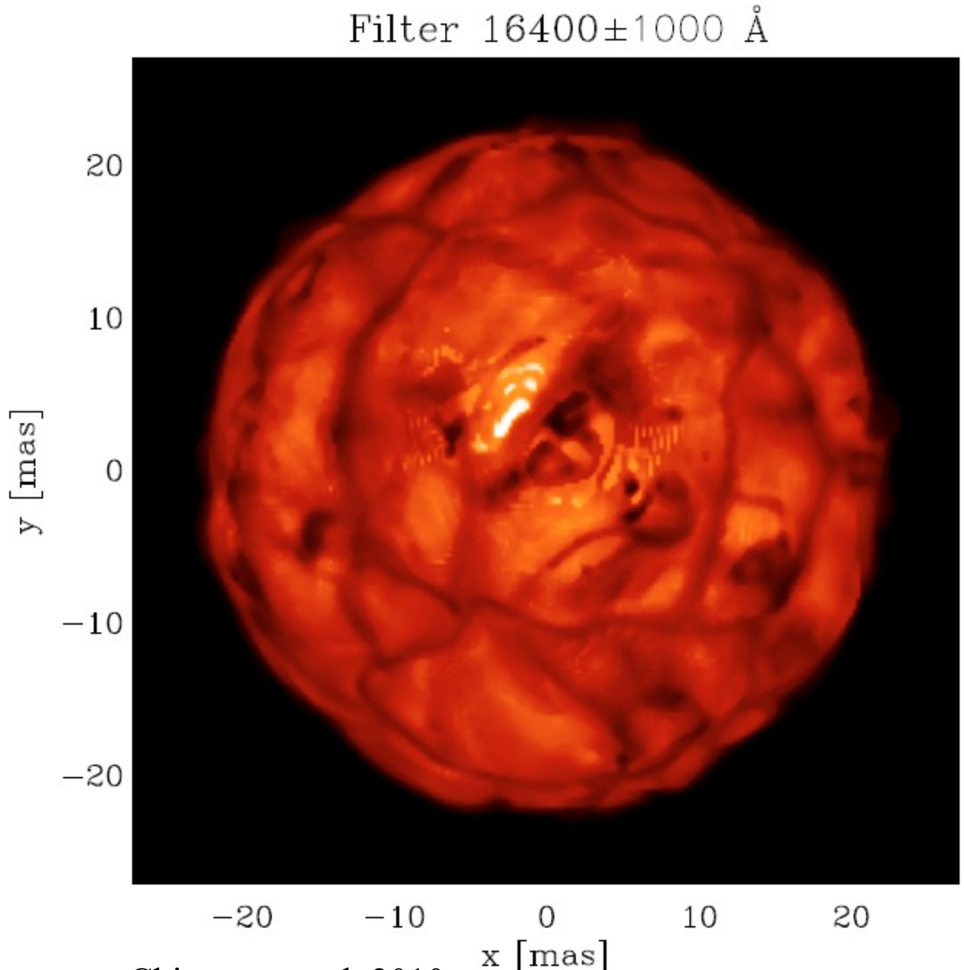
Baron et al. 2014

Our Project



Chiavassa et al. 2010

Our Project

OBSERVING

- High resolution imaging of ~21 Red Supergiants with MIRC
- Complementary Spectroscopy at Hard Labor Creek Observatory
- Follow up observations of select targets →variability of convective features on surfaces

Modeling

- SATLAS models
- Use limb darkening law to constrain stellar mass (Neilson & Lester 2012)
- Bayesian model selection of spots
- Tie observations to convection and 3D hydrodynamic models

Spectroscopy

- Hard Labor Creek Observatory
  - Rutledge, GA
- RC Optics 20'' Ritchey-Chrétien
  - V=8.5 limiting magnitude (due to guide camera)
- LHIRES III Spectrograph
  - Range: 4000-7000 (Å)
  - Resolution ($\lambda/\Delta\lambda$): 9515-26924 (2400g/ mm grating)

  (Jenkins 2011)

Interferometry

- August 17-23
- MIRC 6-T (H band)
- 21 Targets
  - Variable (Kiss et al. 2006; Josselin & Plez 2007; Percy et al. 2009)
  - Estimated θ between 3.0-7.0 mas (from published bolometric fluxes + temperatures or SED fits generated by getCal if information not available)

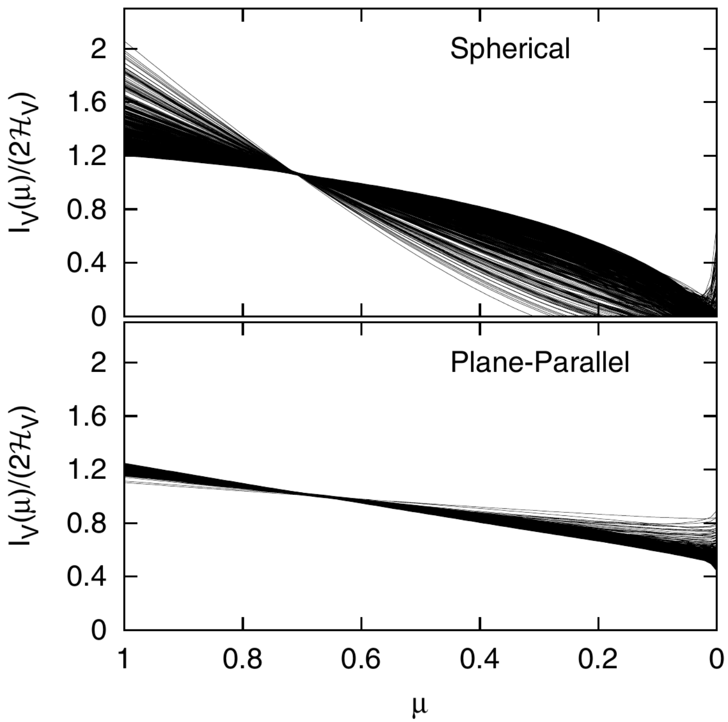
1st night

- Fast observations to get θ and look for evidence of asymmetries in closure phase

- Follow up observations in winter to test for changes in surface features

Limb Darkening and Stellar Parameters

1) $$\frac{I}{2H} = 1 - A - B + \frac{3}{2}A\mu + \frac{5}{4}B\sqrt{\mu}$$



$$\mu_1 = \frac{3\alpha(1+\alpha)+\frac{25}{16}+\sqrt{\frac{75}{8}\alpha(1+\alpha)+\frac{625}{256}}}{\frac{9}{2}\alpha^2}$$

Neilson & Lester 2012

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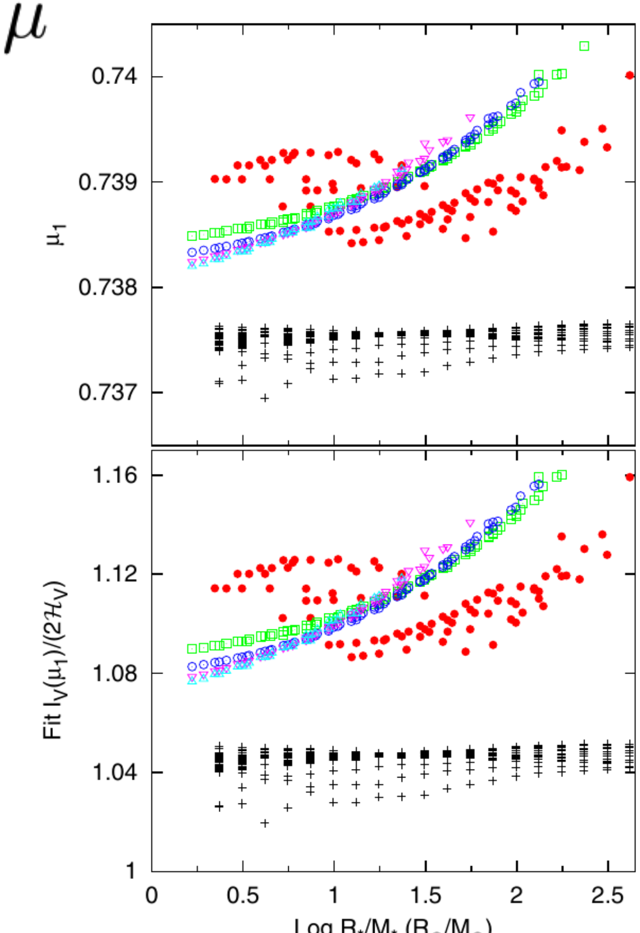
3) $$\mu_1 = C_\mu(\log\frac{R_*}{M_*})^2 + D_\mu$$

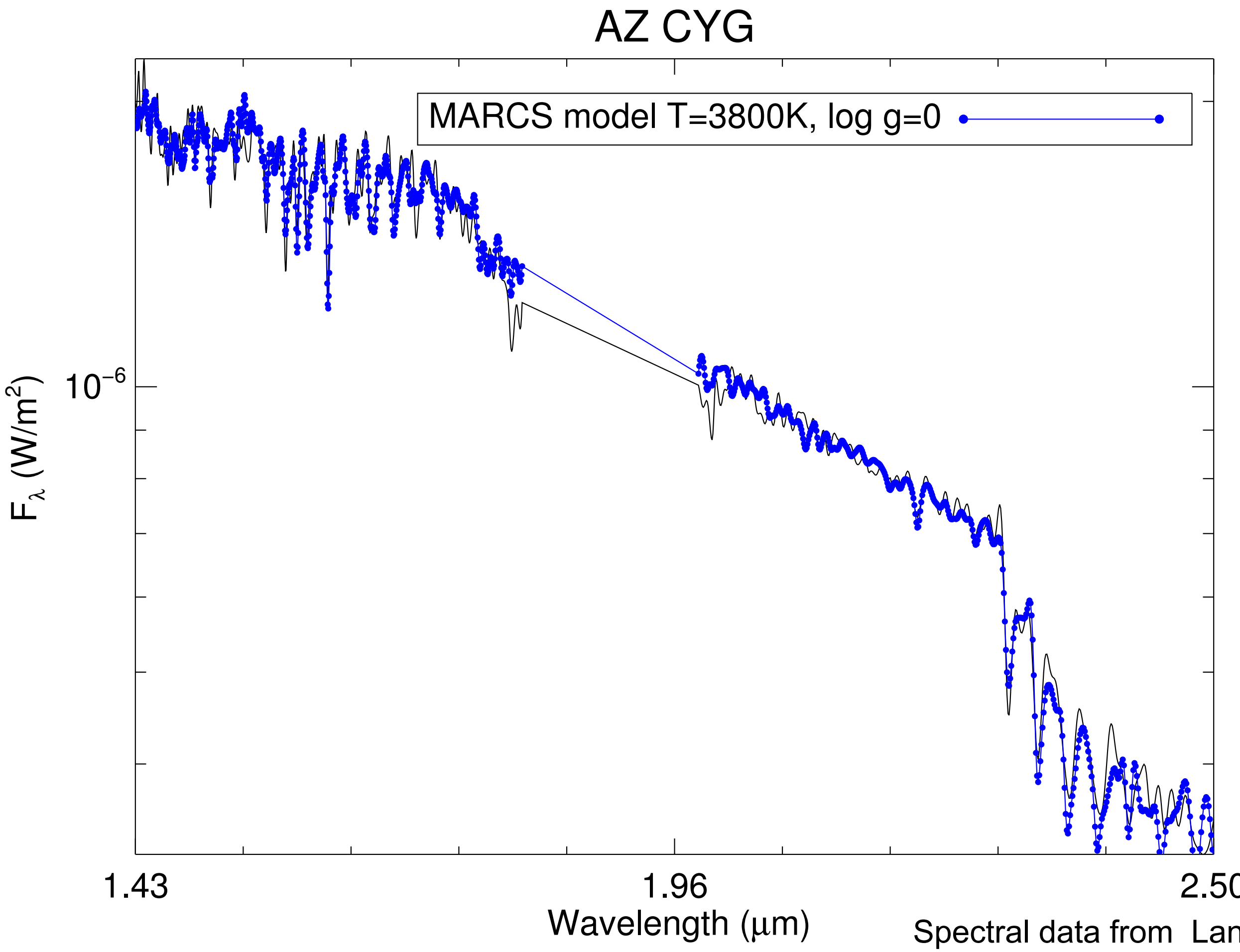
4) $$\frac{I(\mu_1)}{2H} = C_I(\log\frac{R_*}{M_*})^2 + D_I$$



Neilson & Lester 2012

- Fit law to find A & B and thus α
- Use 2), 3) and best fit coefficients from Neilson and Lester 2012 to find $\log(R_*/M_*)$
- Alternatively, iterate: start with a guess for $\log(R_*/M_*)$ and use 3) and best fit coefficients to solve 1) at μ_1 and use 4) with best fit coefficients to get new $\log(R_*/M_*)$

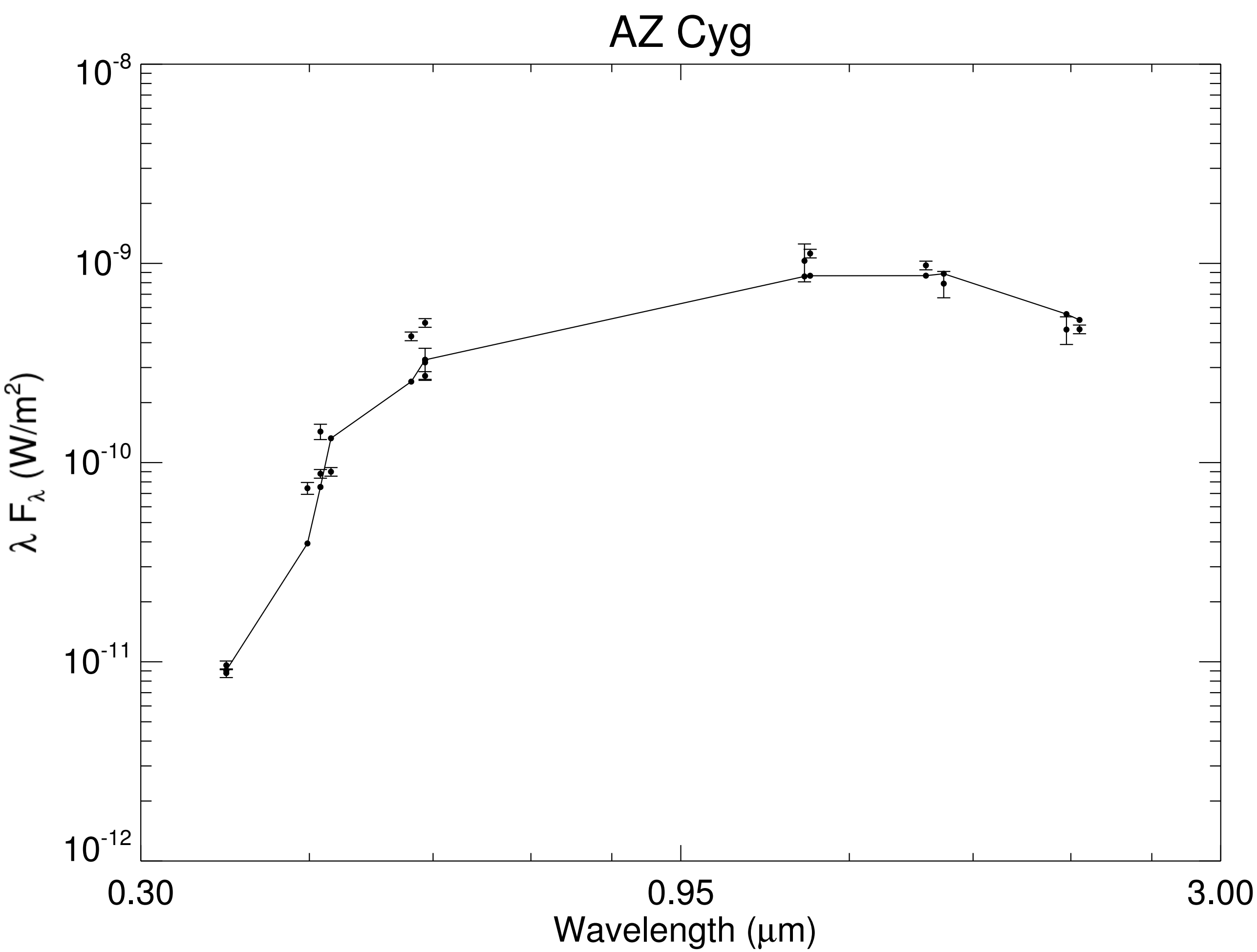
(Very) early results on AZ Cyg



- E(B-V)=0.40
- T=3800
- log(g)=0.0

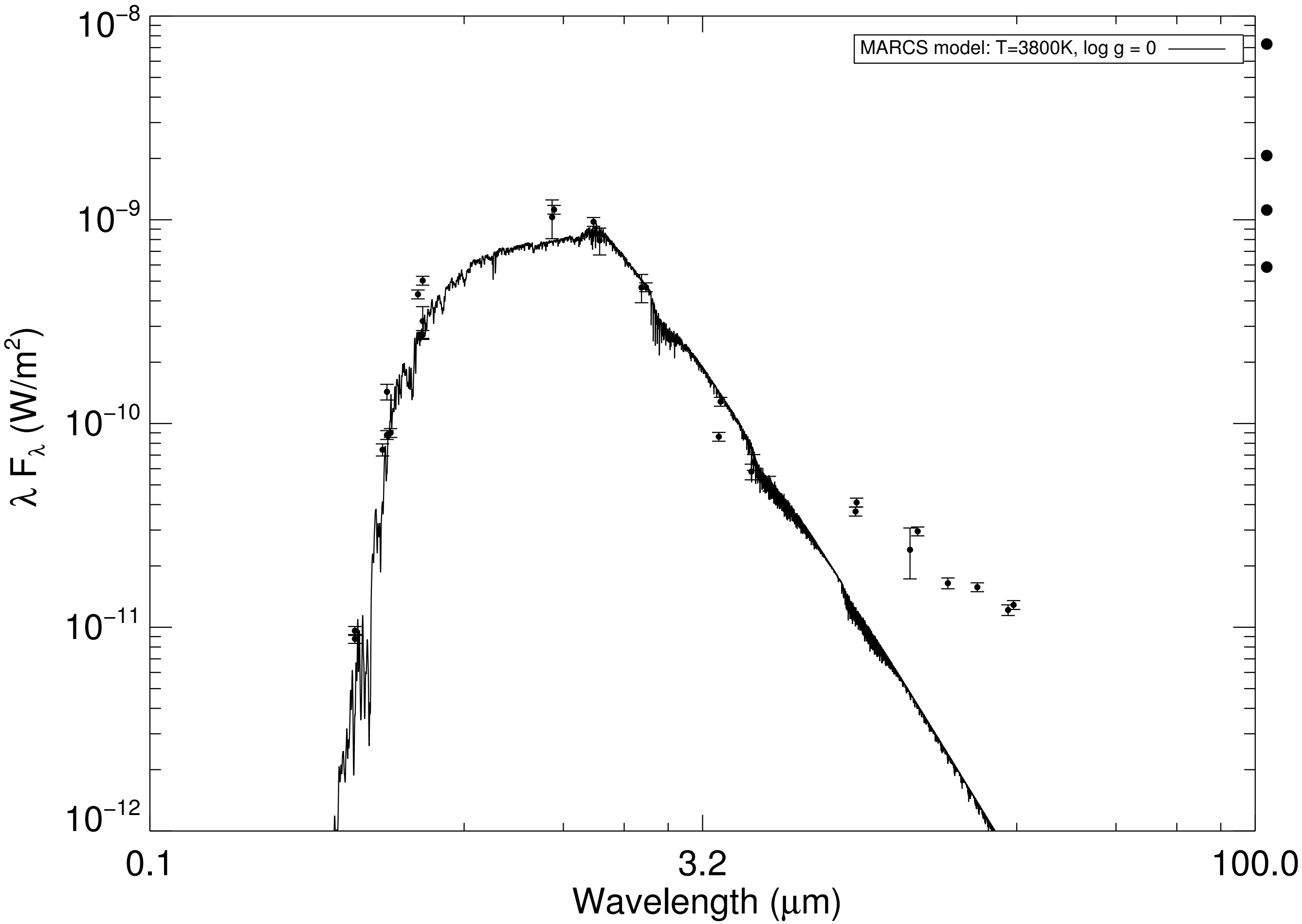
Spectral data from Lançon and Rocca-Volmerange 1992

(Very) early results on AZ Cyg

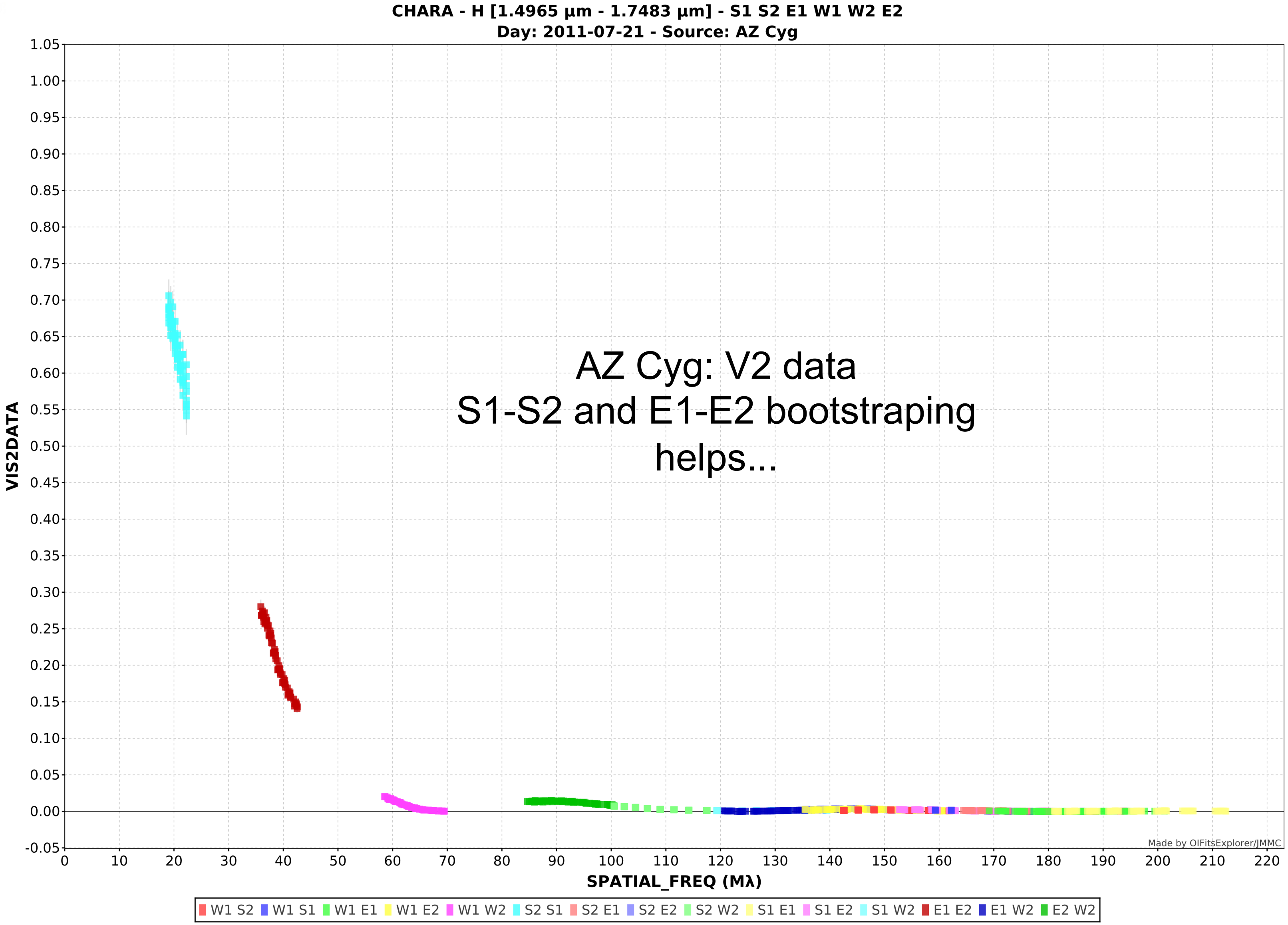


- E(B-V)=0.99
- T=3800
- log(g)=0.0

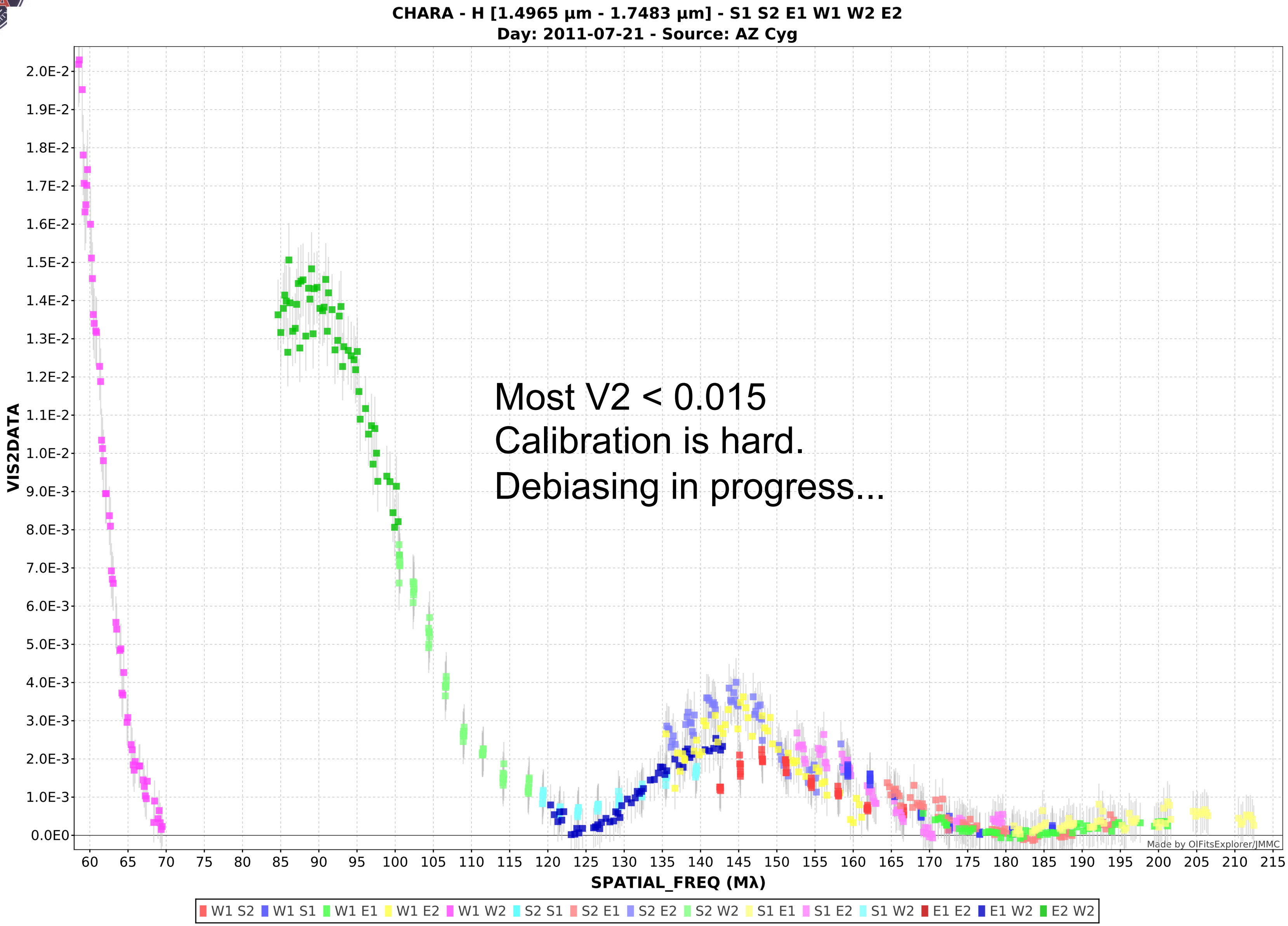
(Very) early results on AZ Cyg



- Input d=1161 pc (Pickles et al. 2010)
- Input θ=3.90±0.25 mas
- T_{eff}=3763±133 K
- R=487±58 ($R_\odot$)

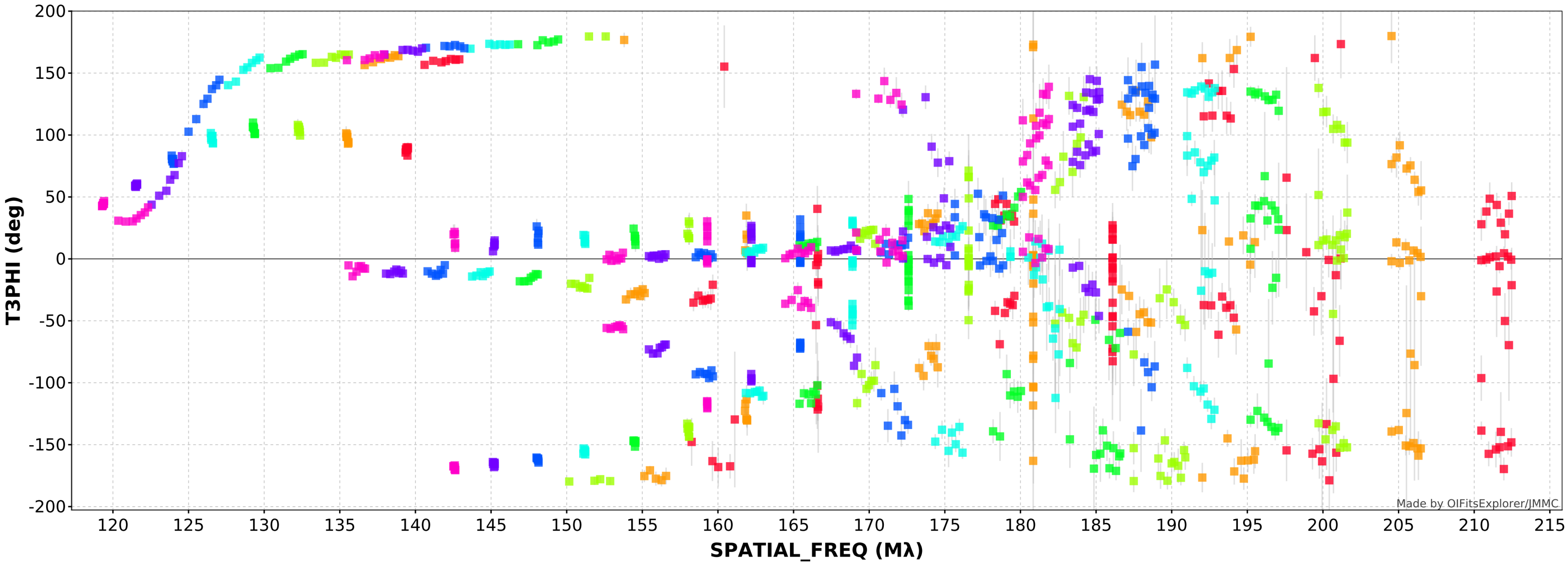


AZ Cyg: V2 data
S1-S2 and E1-E2 bootstraping helps...

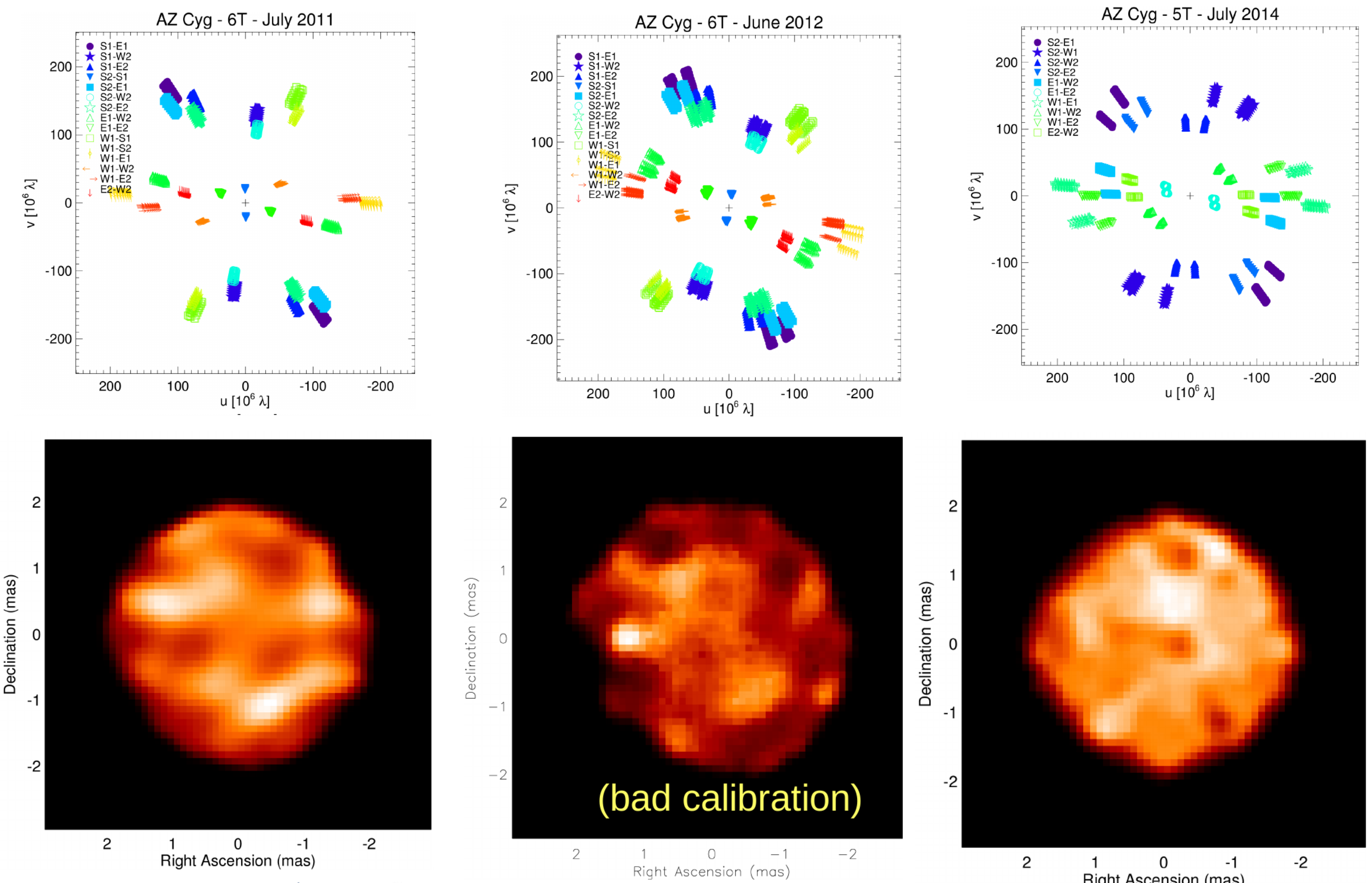


Most V2 < 0.015
Calibration is hard.
Debiasing in progress...

Strong closure phase signals :
convection pattern !



First imaging attempts



AZ Cyg belongs to the class of "evil" stars