Introduction to Imaging Stellar Surfaces

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51 Peg b Fellow

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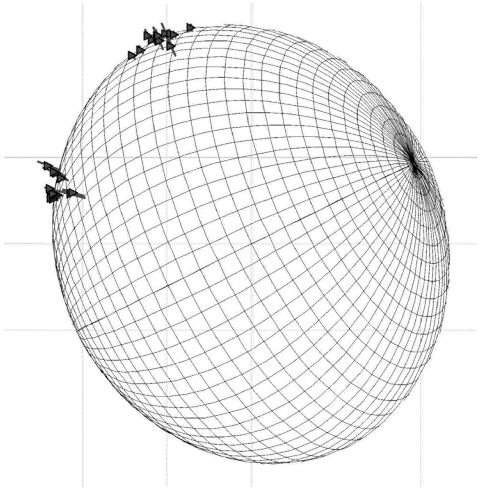
Rapid Rotators

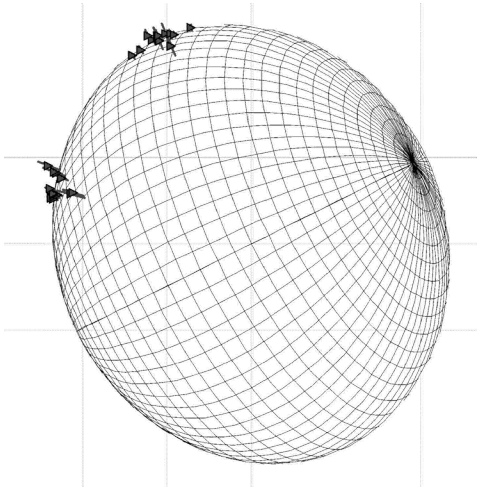
Altair



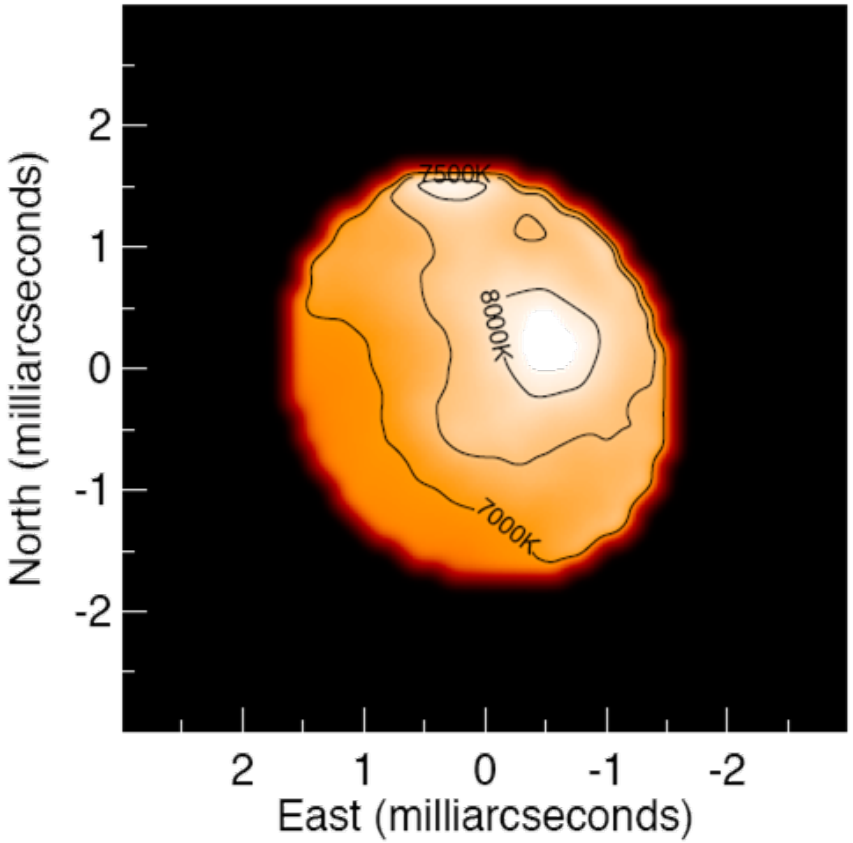
van Belle et al. 2001

Rapid Rotators

Altair

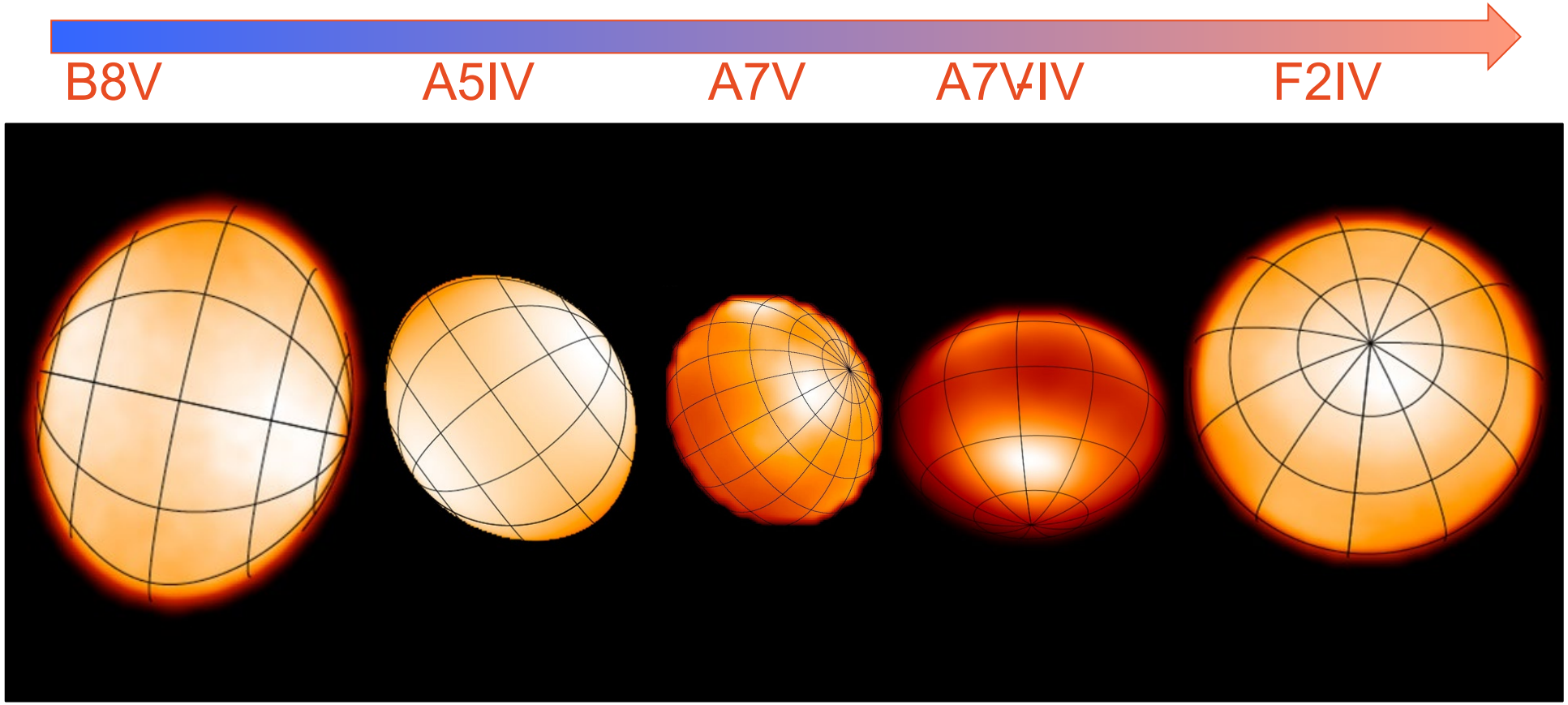


van Belle et al. 2001



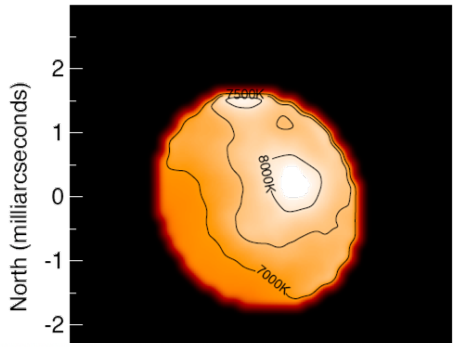
Monnier et al. 2007

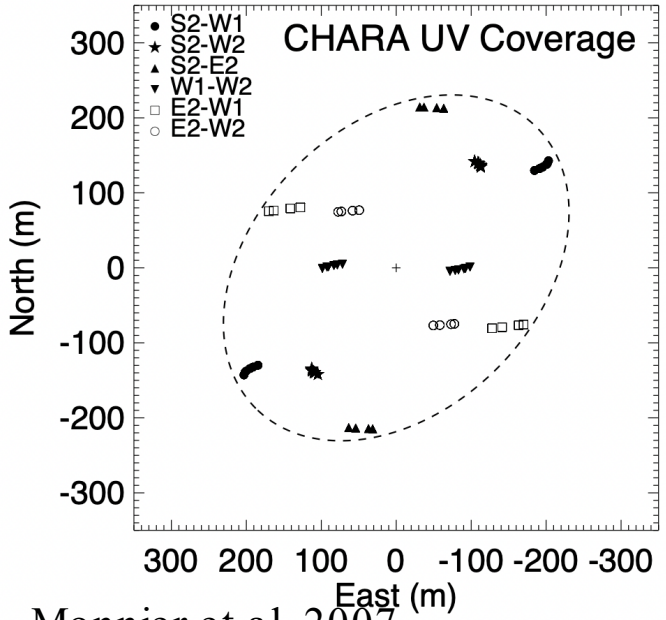
Rapid Rotators

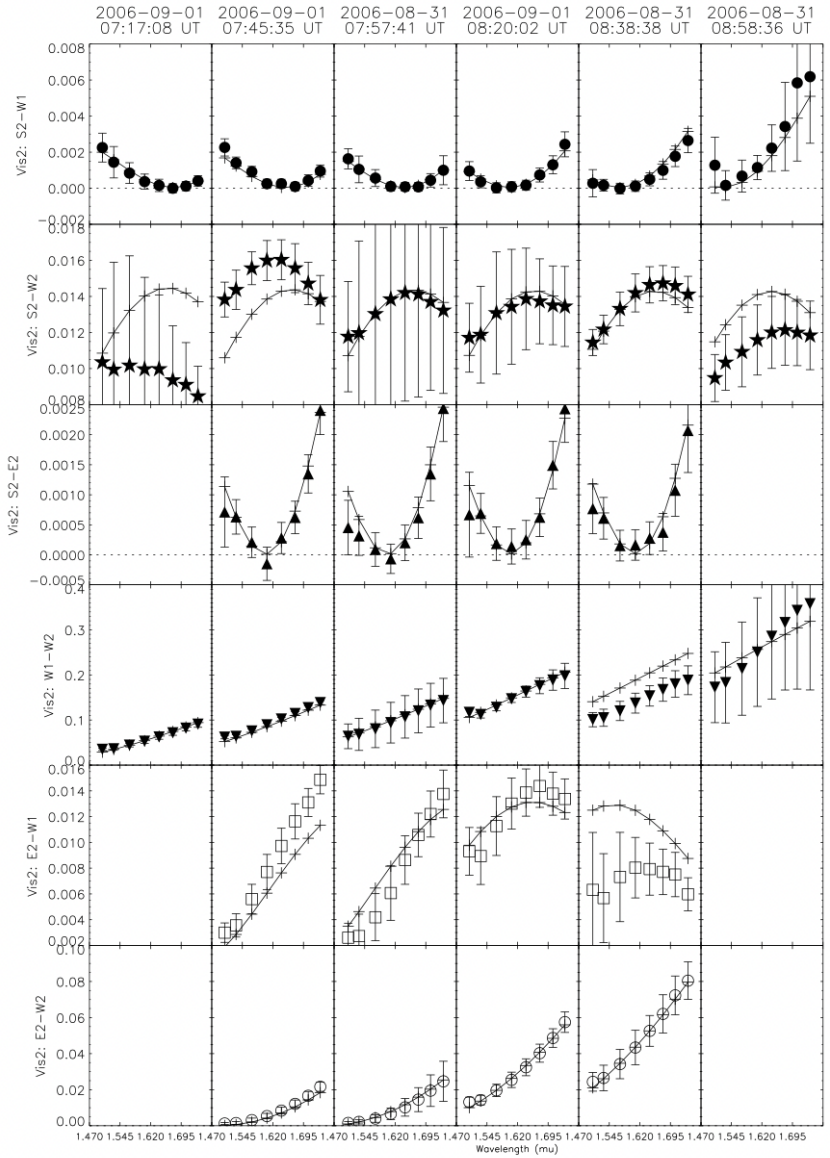


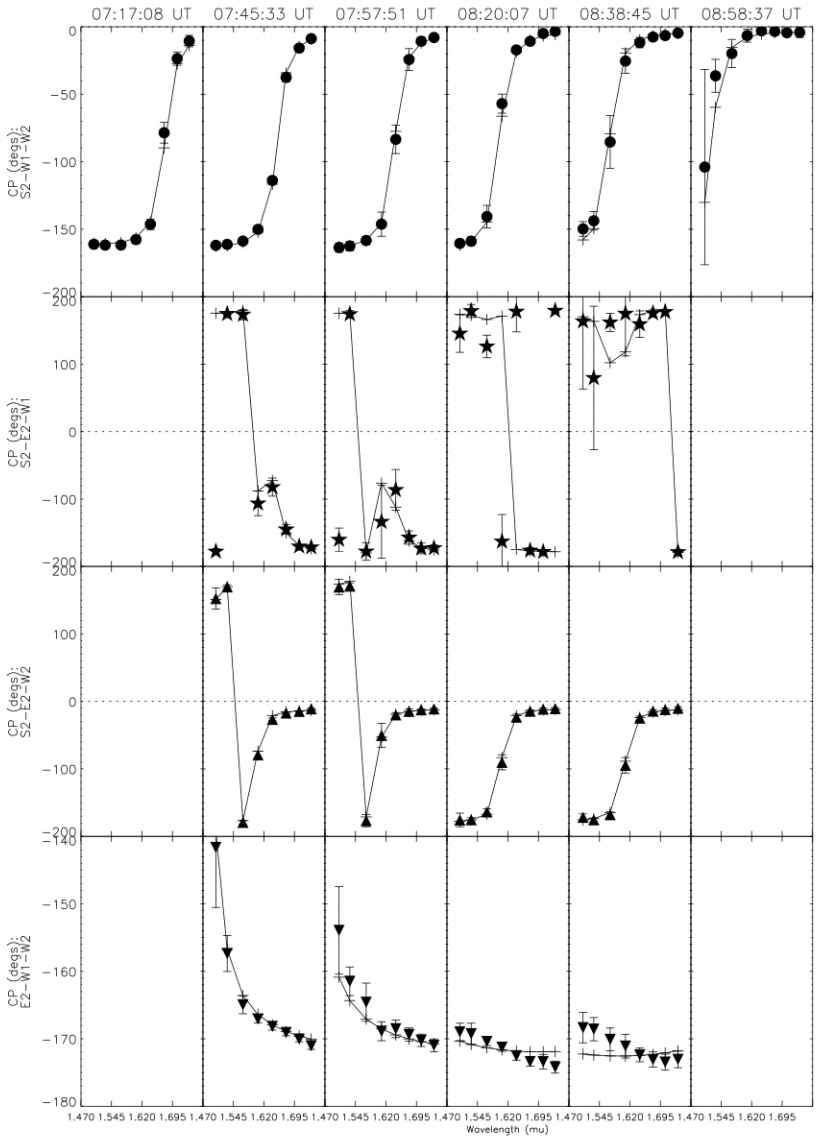
From review by Ming Zhao

Altair





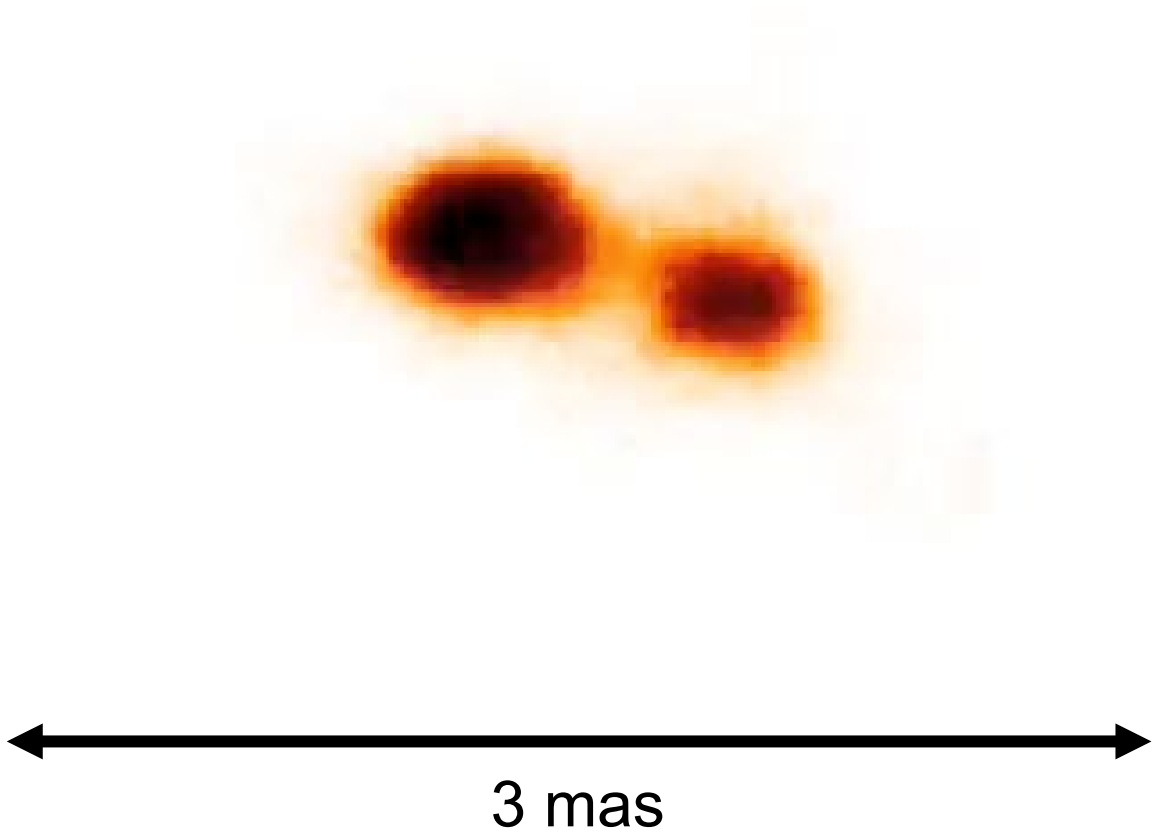




Monnier et al. 2007

Interacting Binaries

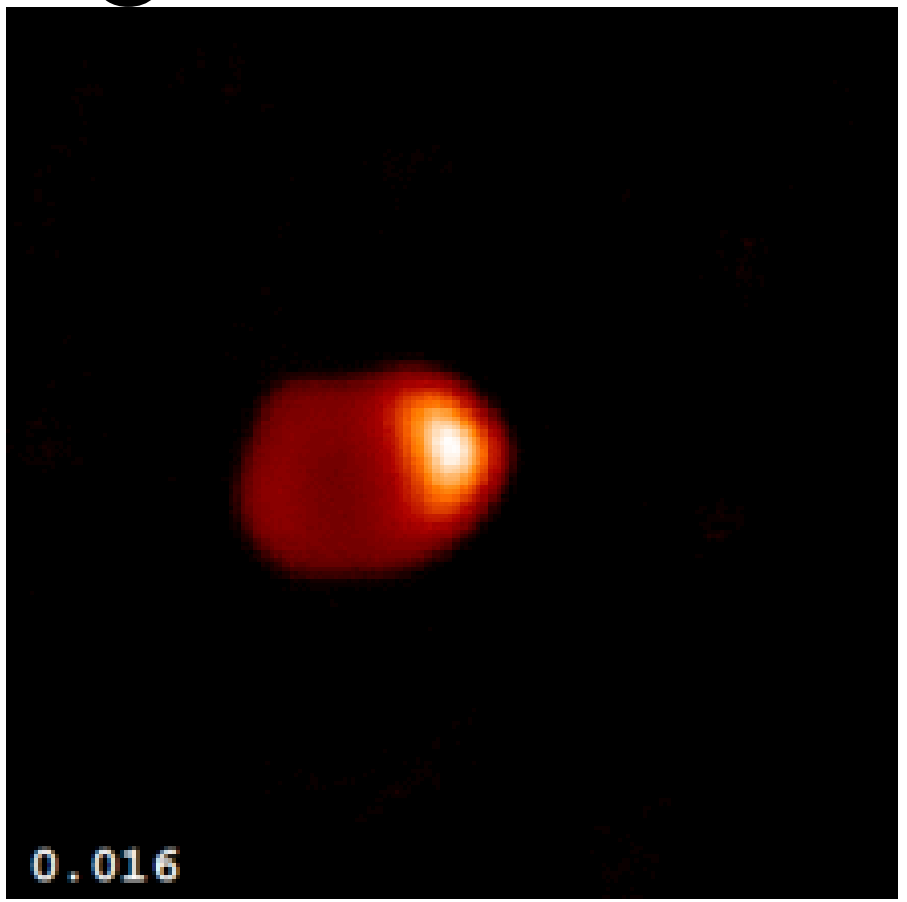
β Lyrae



Zhao et al. 2008

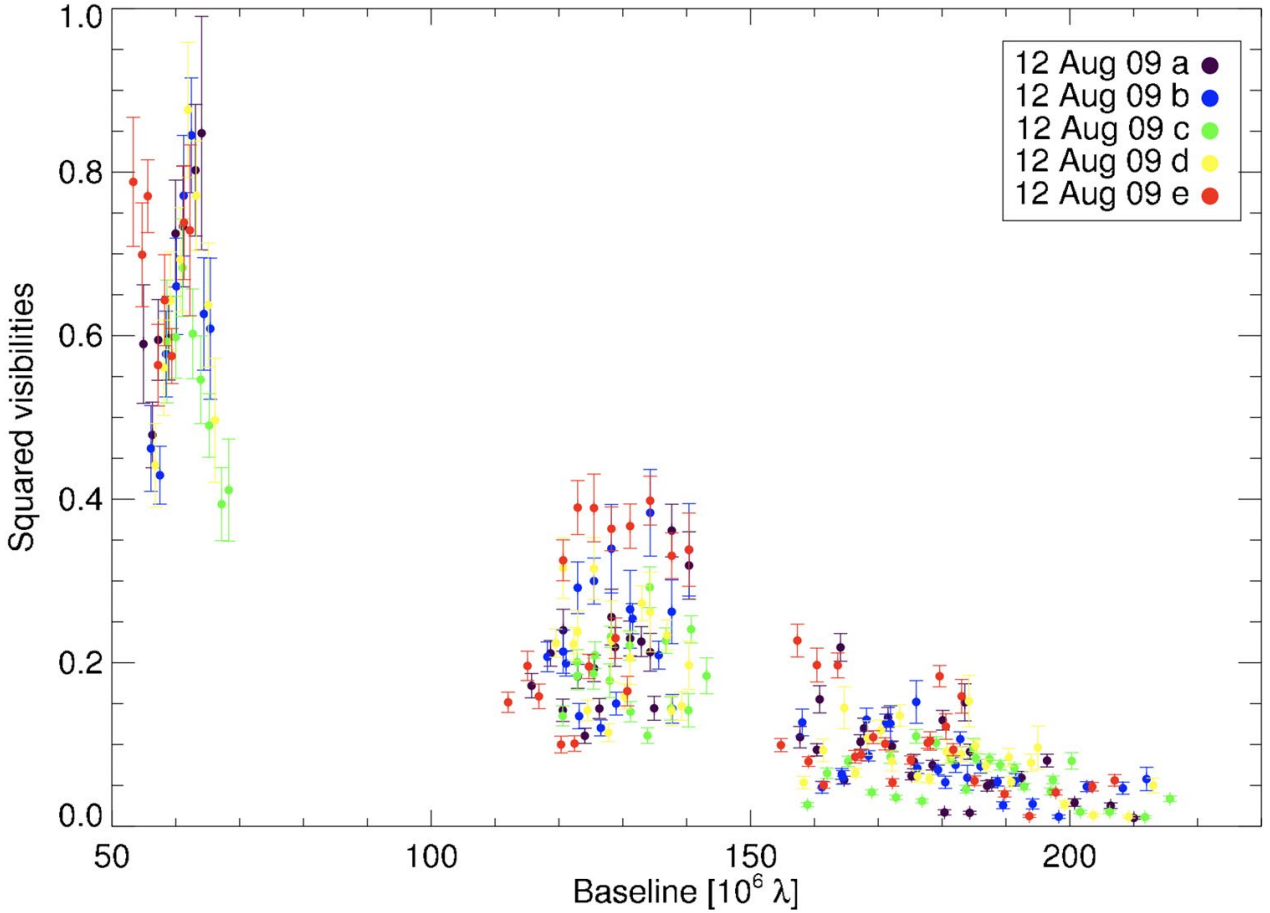
Interacting Binaries

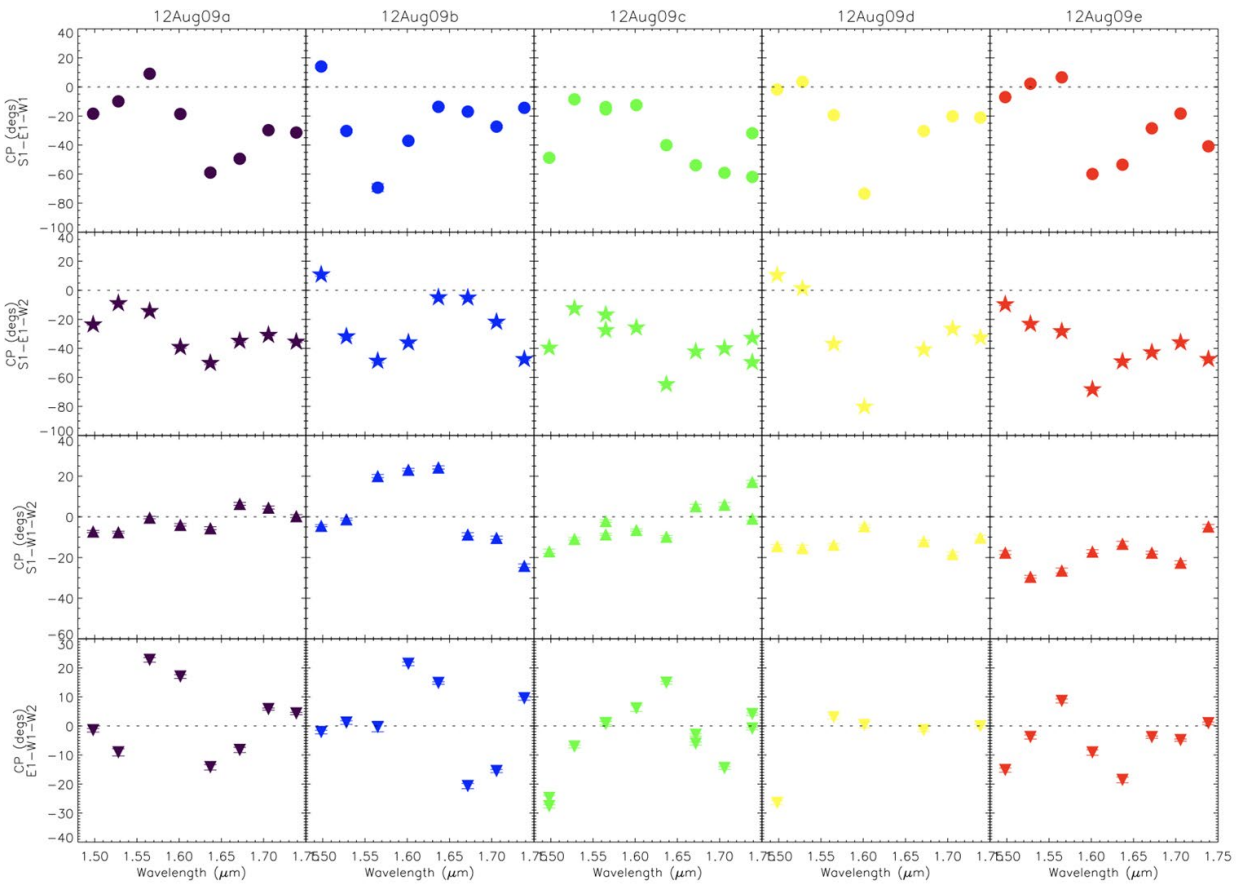
Algol



Baron et al. 2012

Algol

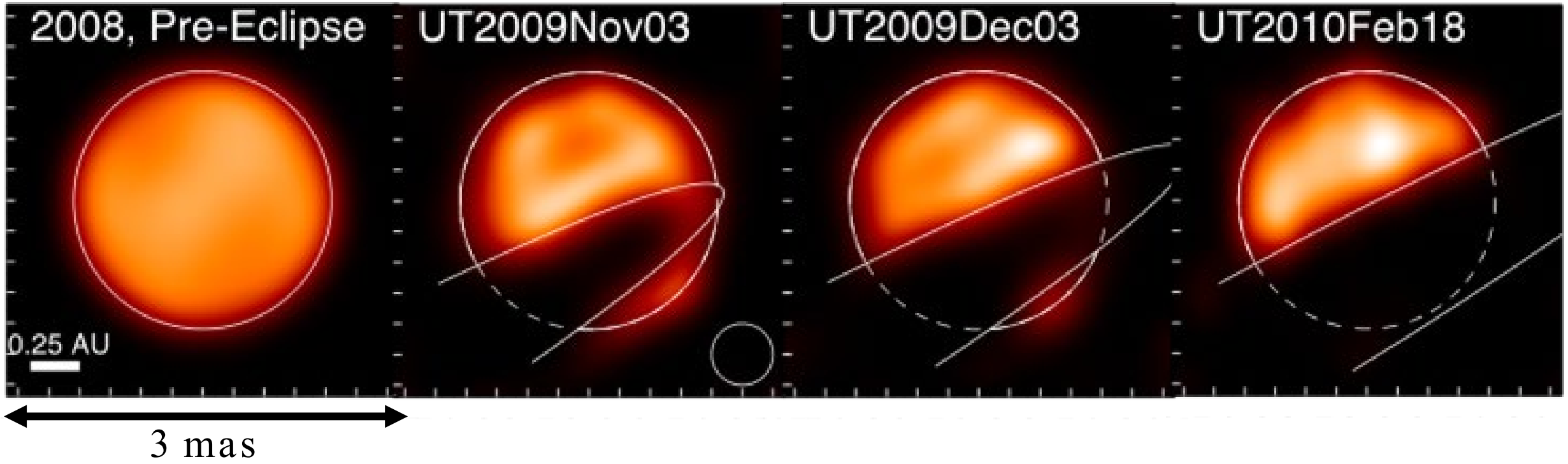




Baron et al. 2012

Transiting Disk

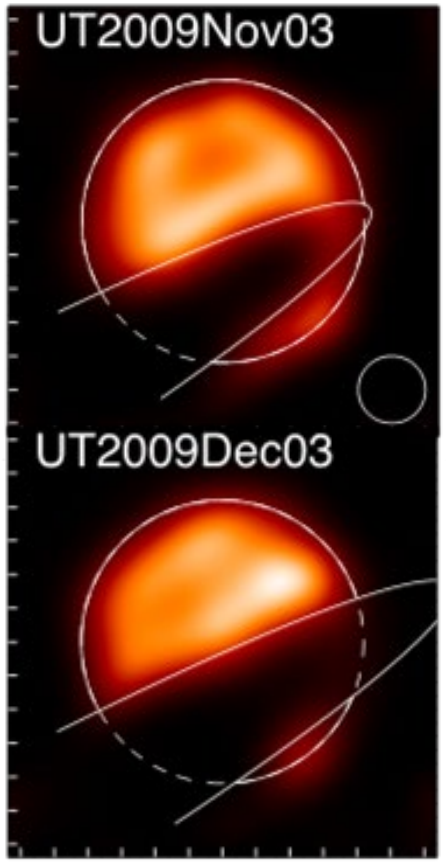
ε Aur

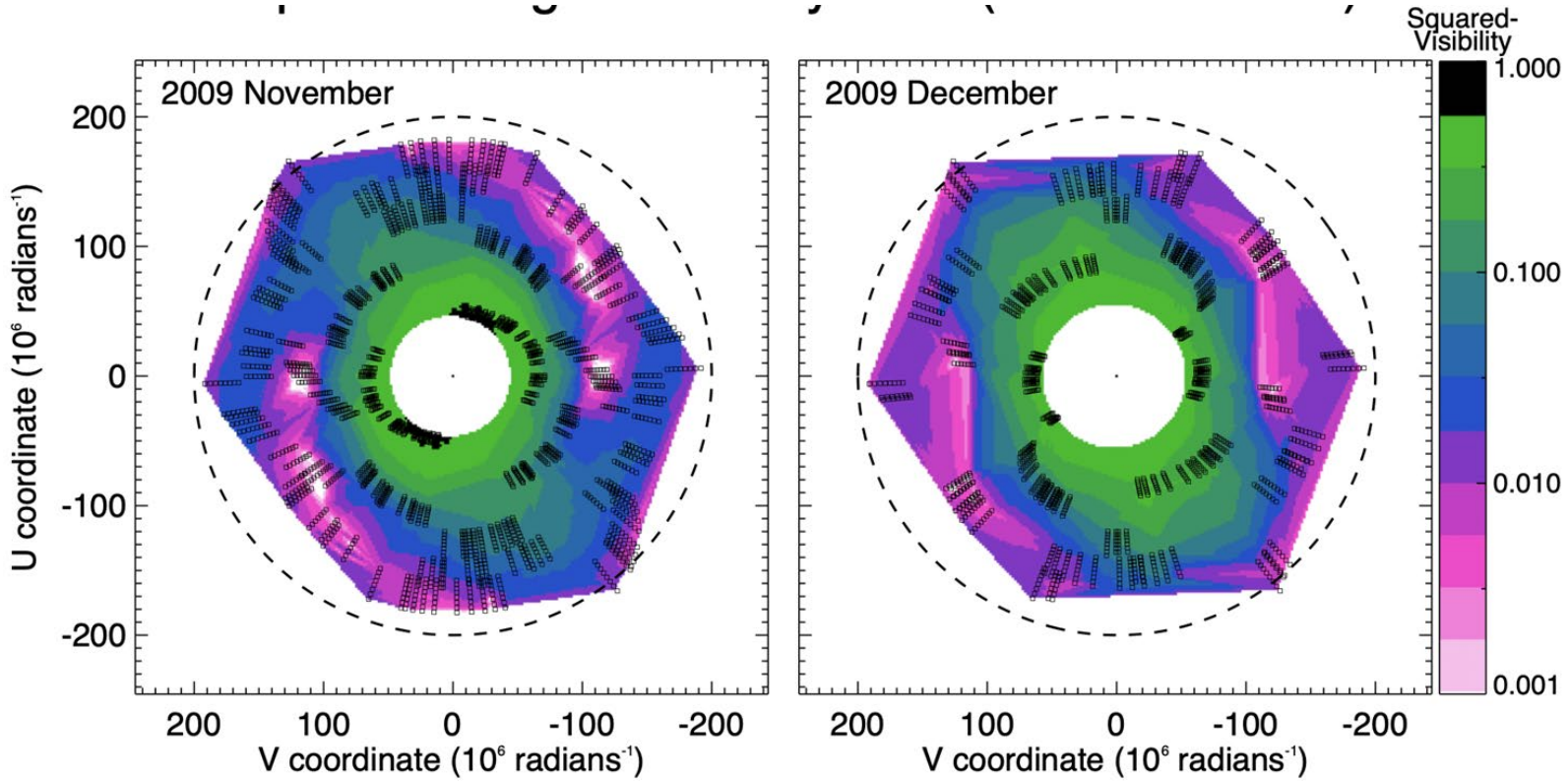


Kloppenborg et al. 2010

Transiting Disk

ε Aur

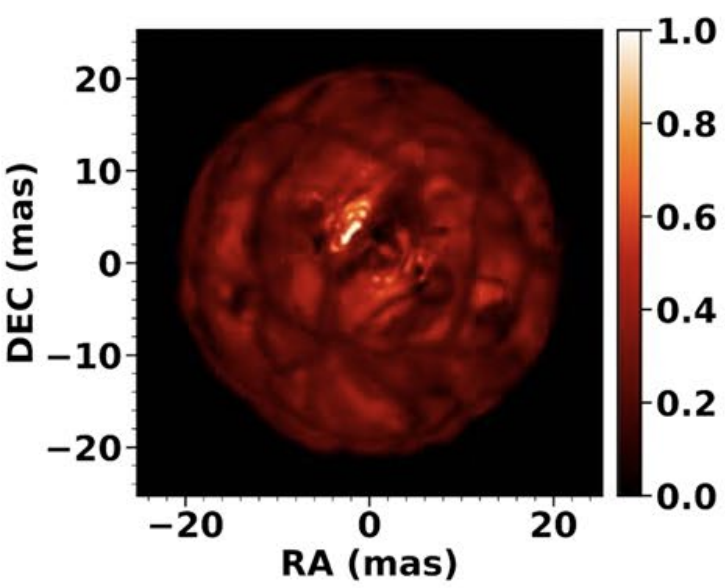




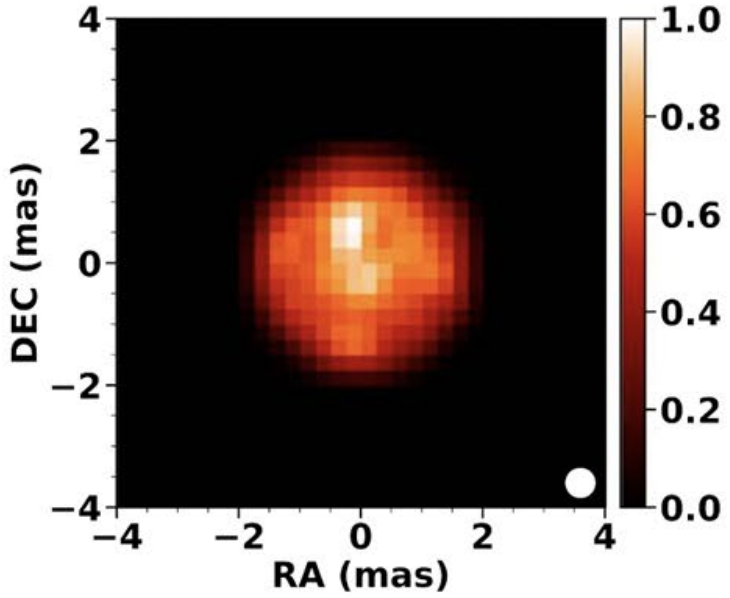
Kloppenborg et al. 2010

Supergiants

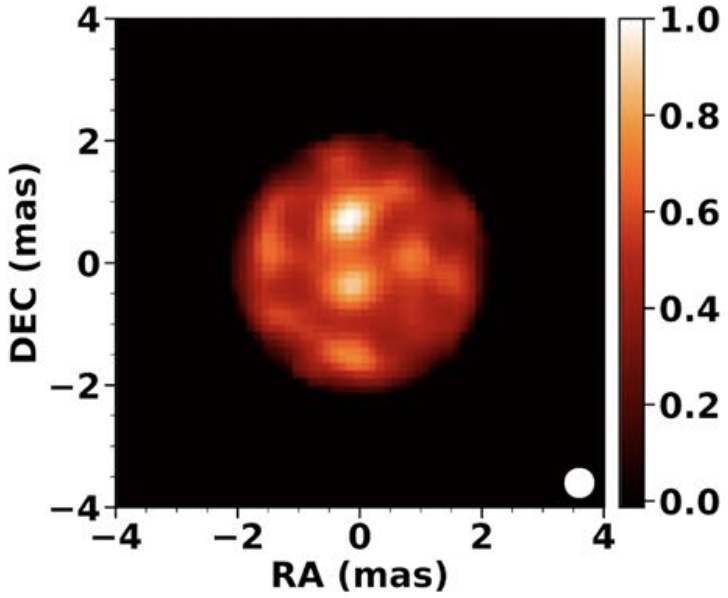
AZ Cyg



Unconvolved Source Image



Scaled down, convolved Source Image

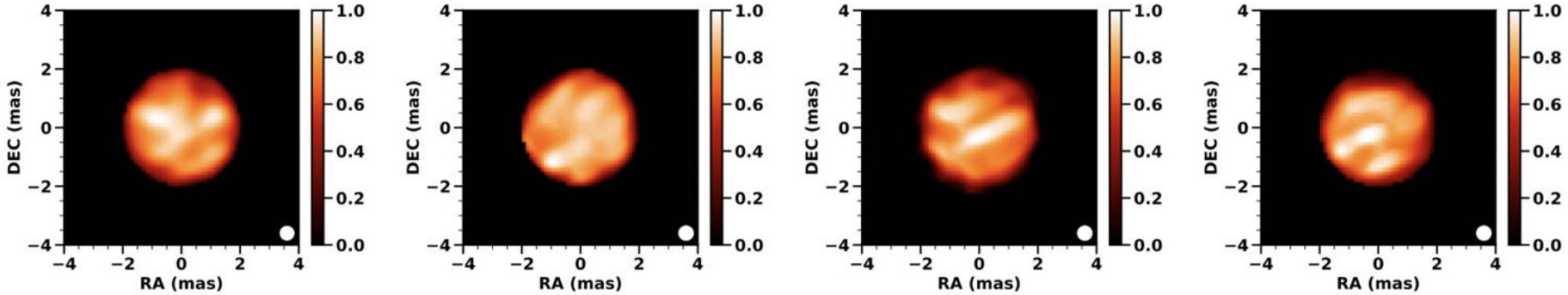


Best fitting reconstruction

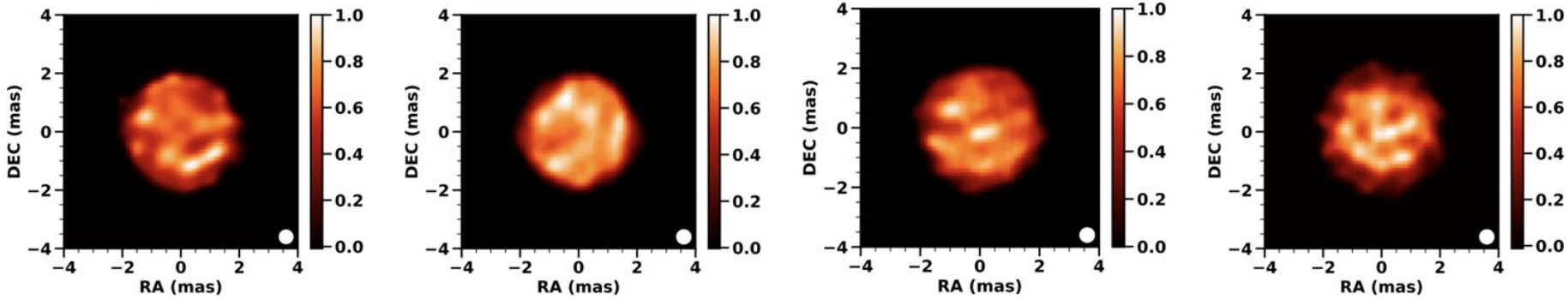
Norris et al. 2021

Supergiants

AZ Cyg

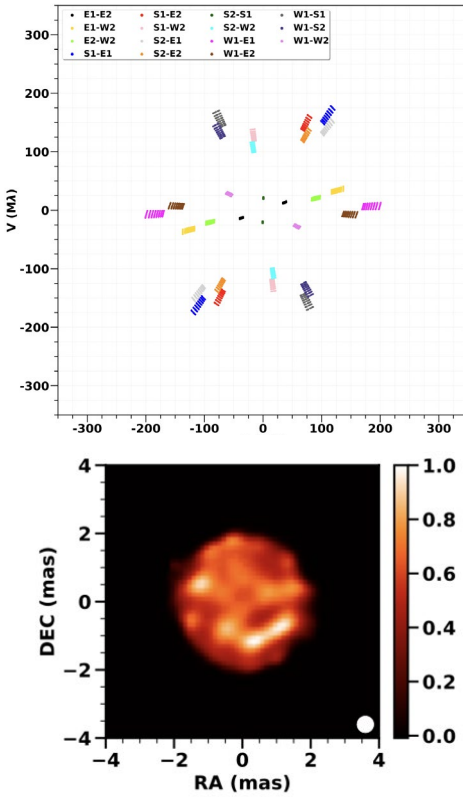


AZ Cyg (OITOOLS.jl) 2011 AZ Cyg (OITOOLS.jl) 2014 AZ Cyg (OITOOLS.jl) 2015 AZ Cyg (OITOOLS.jl) 2016

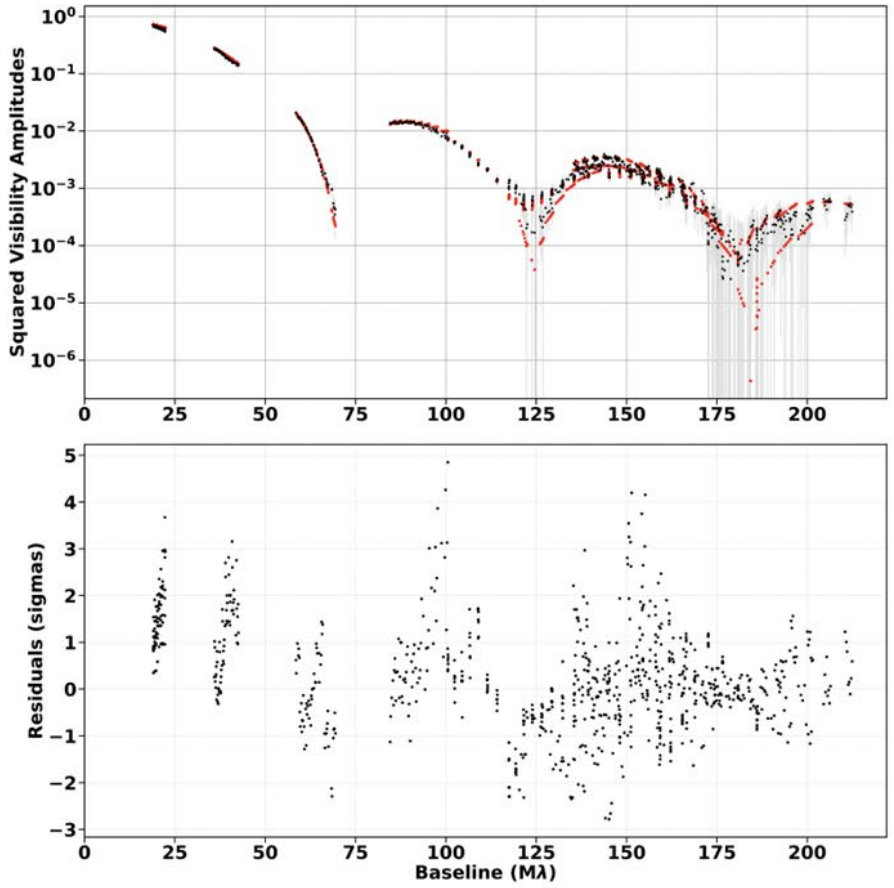


AZ Cyg (SQUEEZE) 2011 AZ Cyg (SQUEEZE) 2014 AZ Cyg (SQUEEZE) 2015 AZ Cyg (SQUEEZE) 2016 Norris et al. 2021

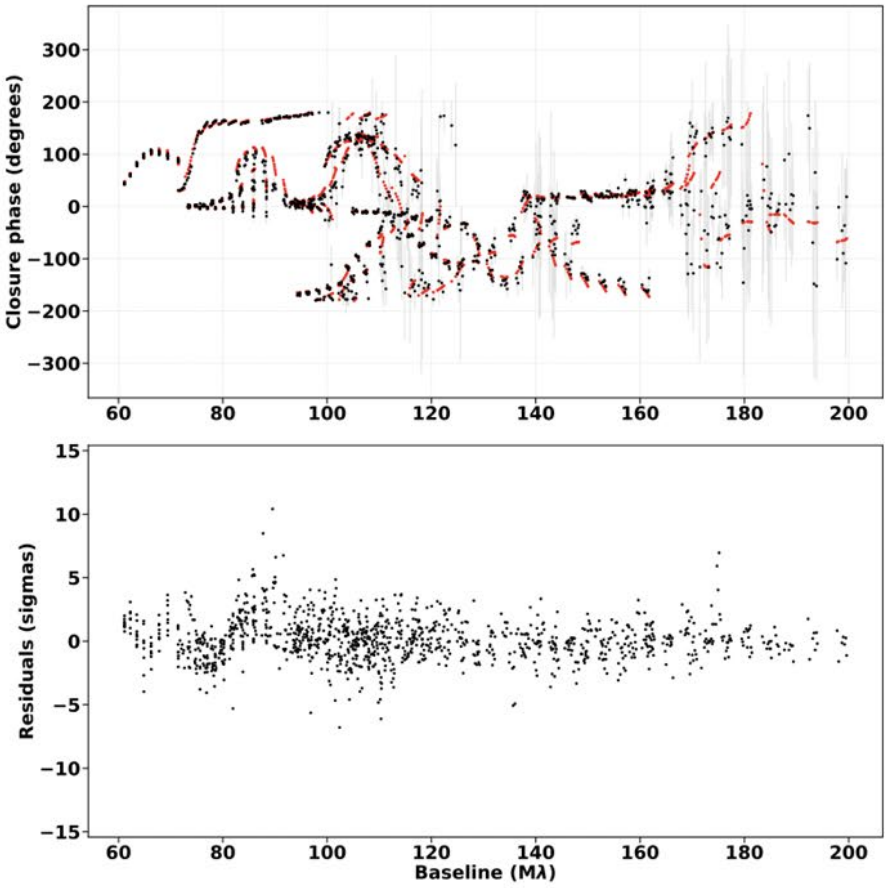
AZ Cyg



AZ Cyg (SQUEEZE) 2011



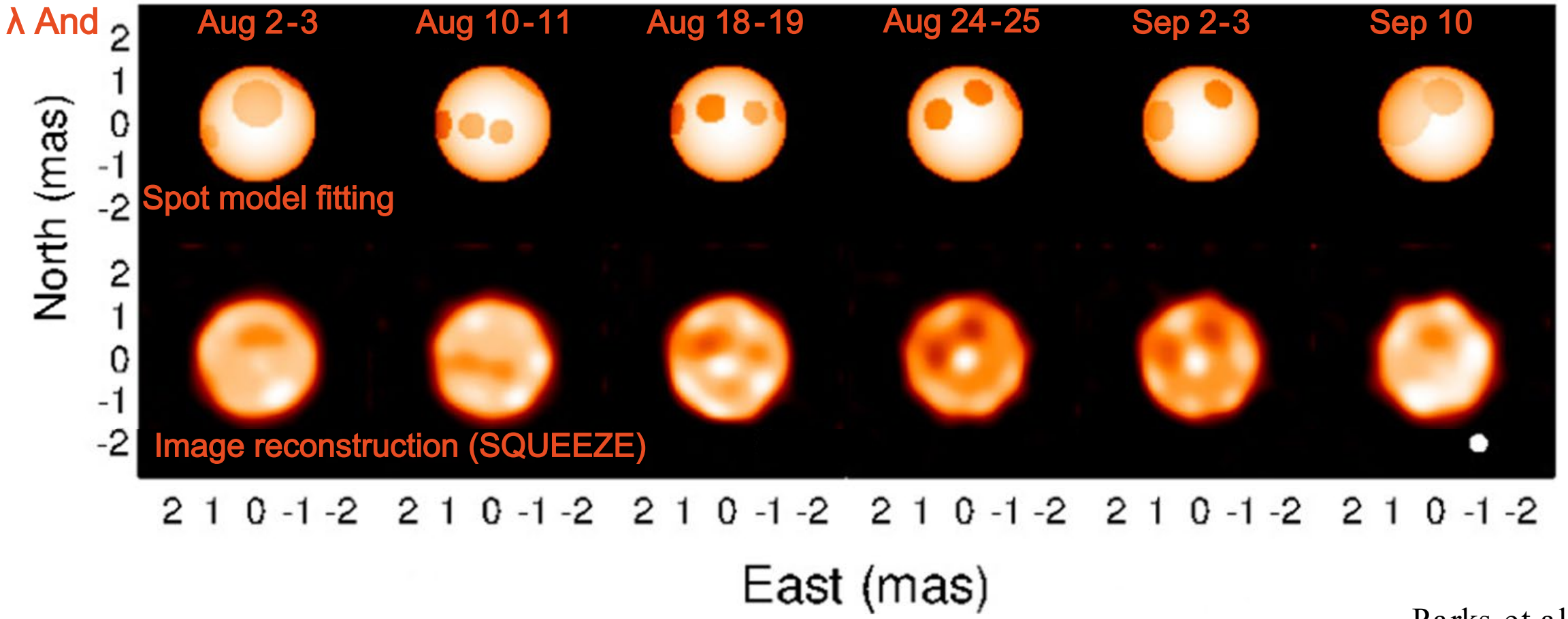
AZ Cyg 2011 Squared Visibilities



AZ Cyg 2011 Closure Phases

Norris et al. 2021

Starspots - Snapshot Imaging

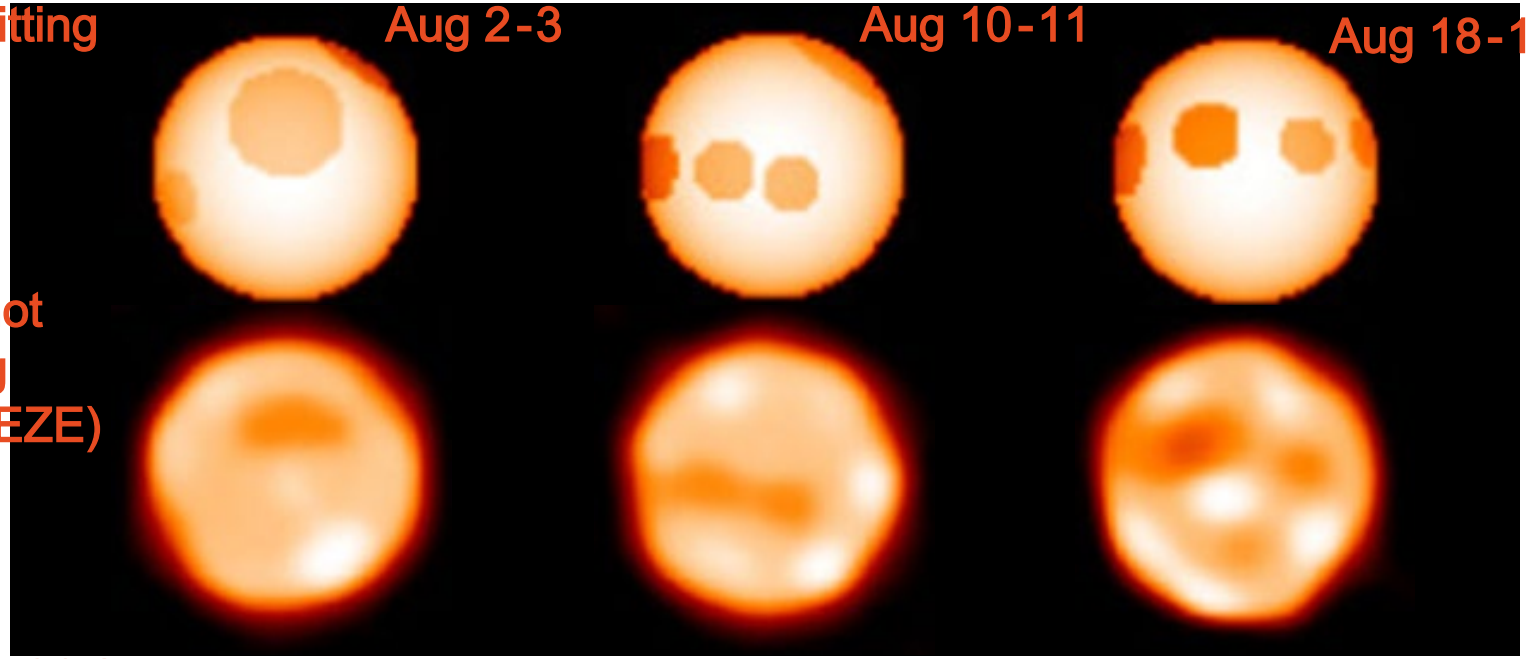


Parks et al. 2021

Starspots

λ And

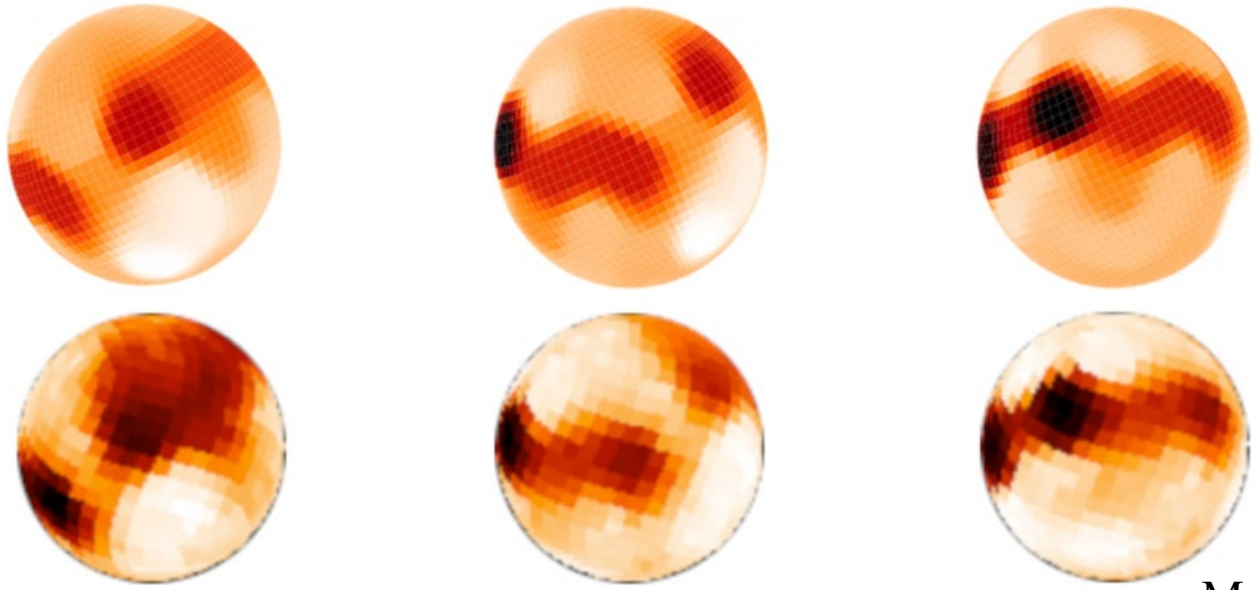
Model fitting



Snapshot imaging (SQUEEZE)

Imaging on a sphere (ROTIR)

Imaging on a sphere (SURFING)

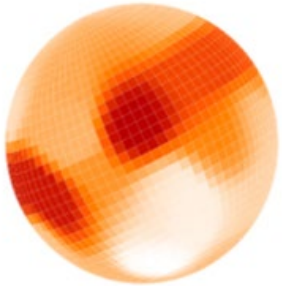


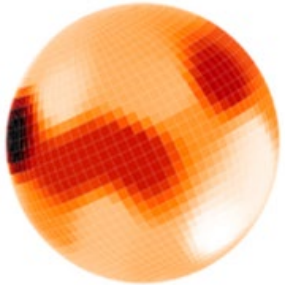
Parks et al. 2021

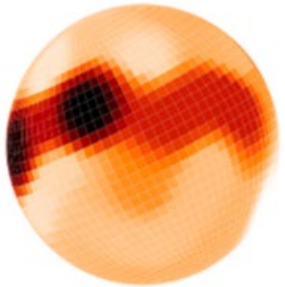
Martinez et al. 2021

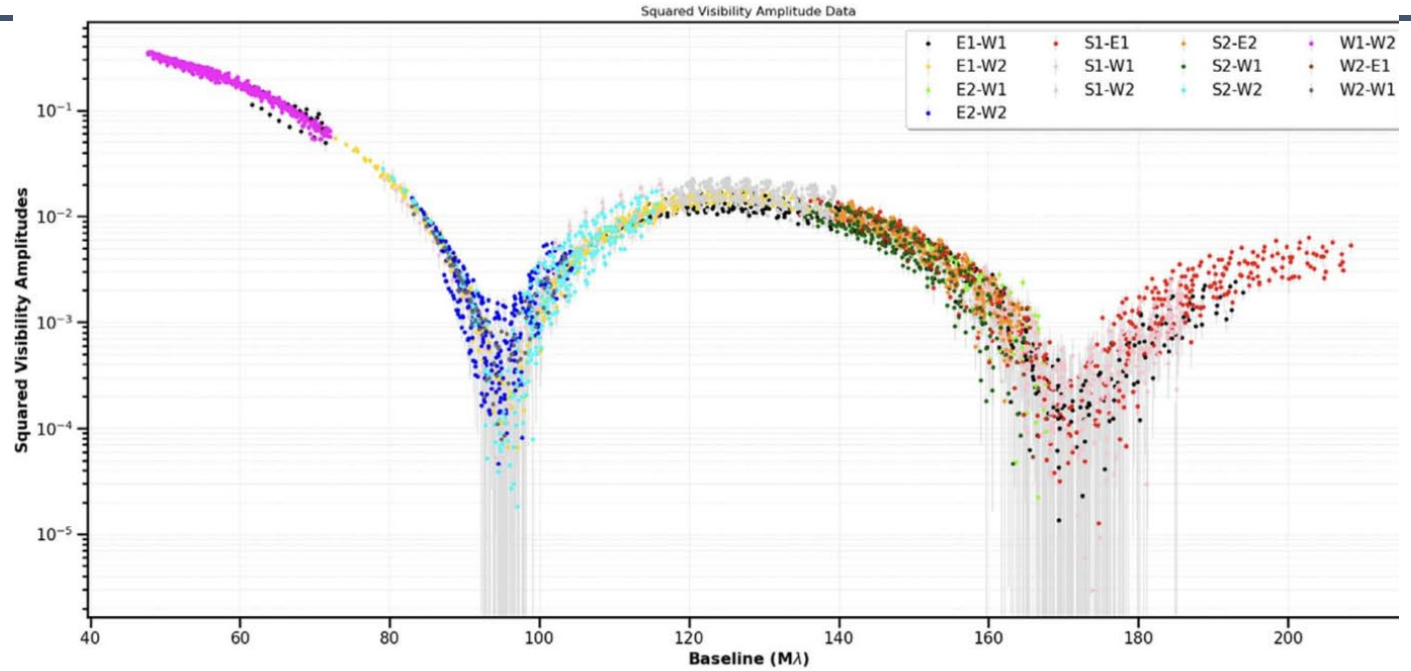
λ And

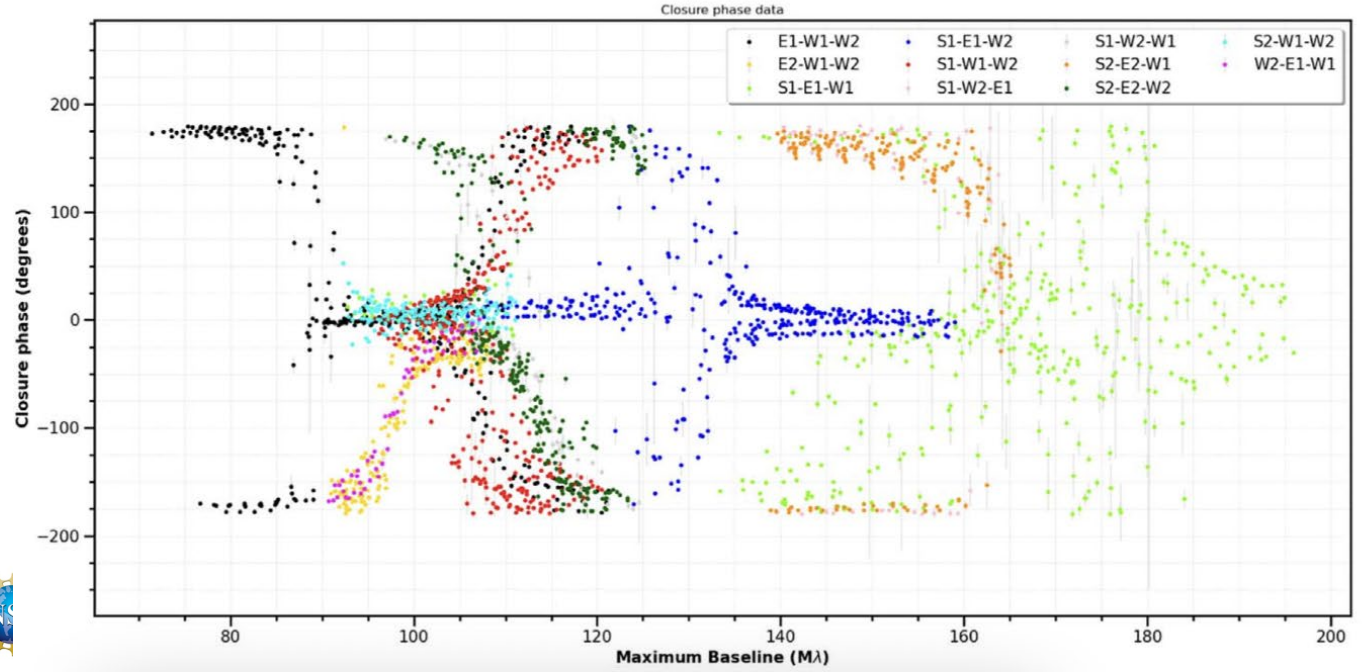
19 4T epochs







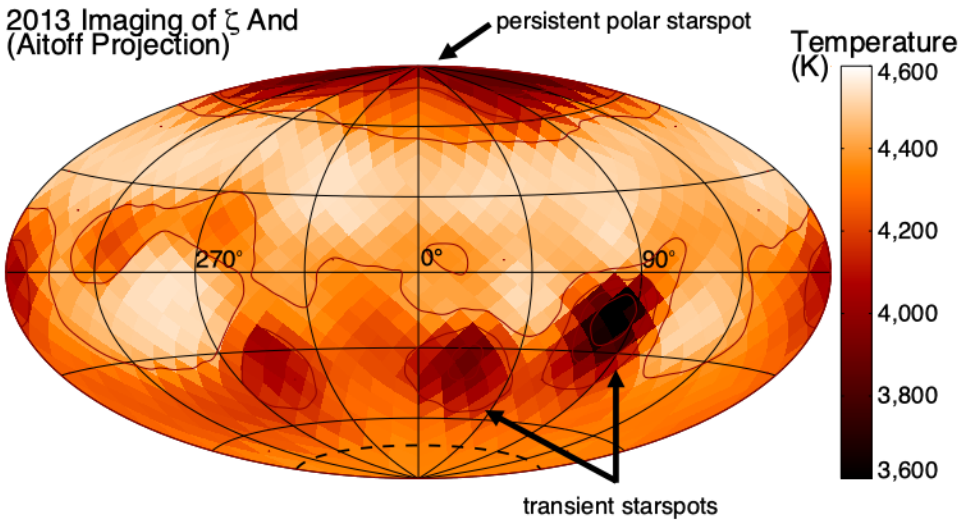


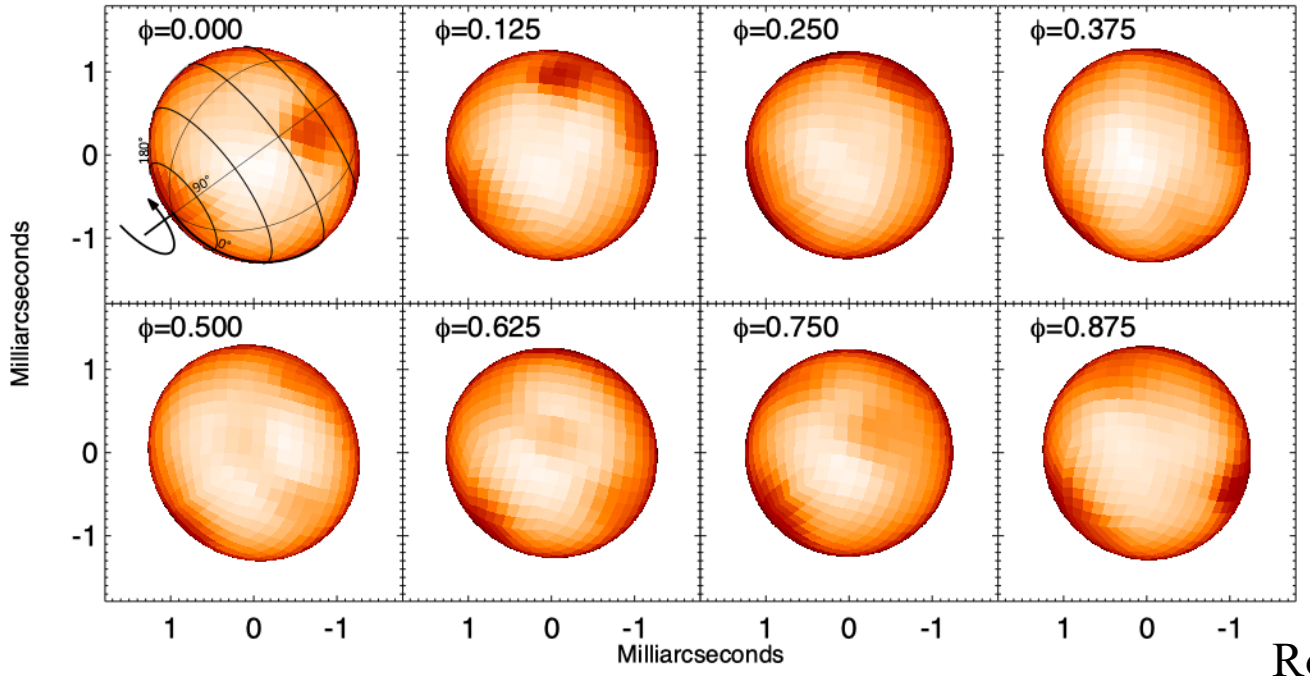


Martinez et al. 2021

Starspots

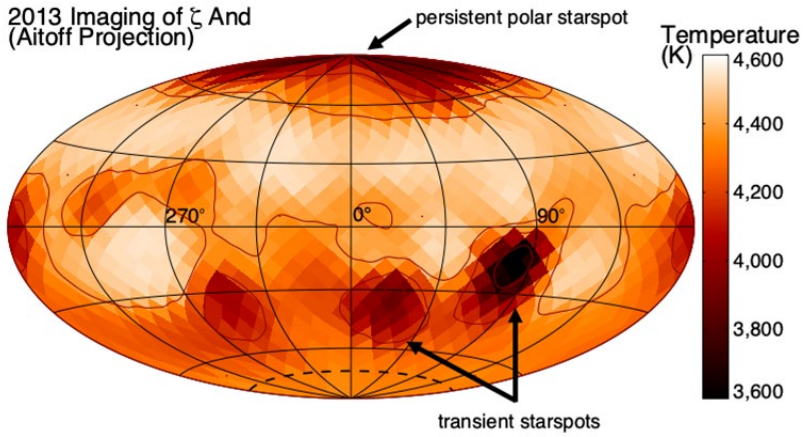
ζ And

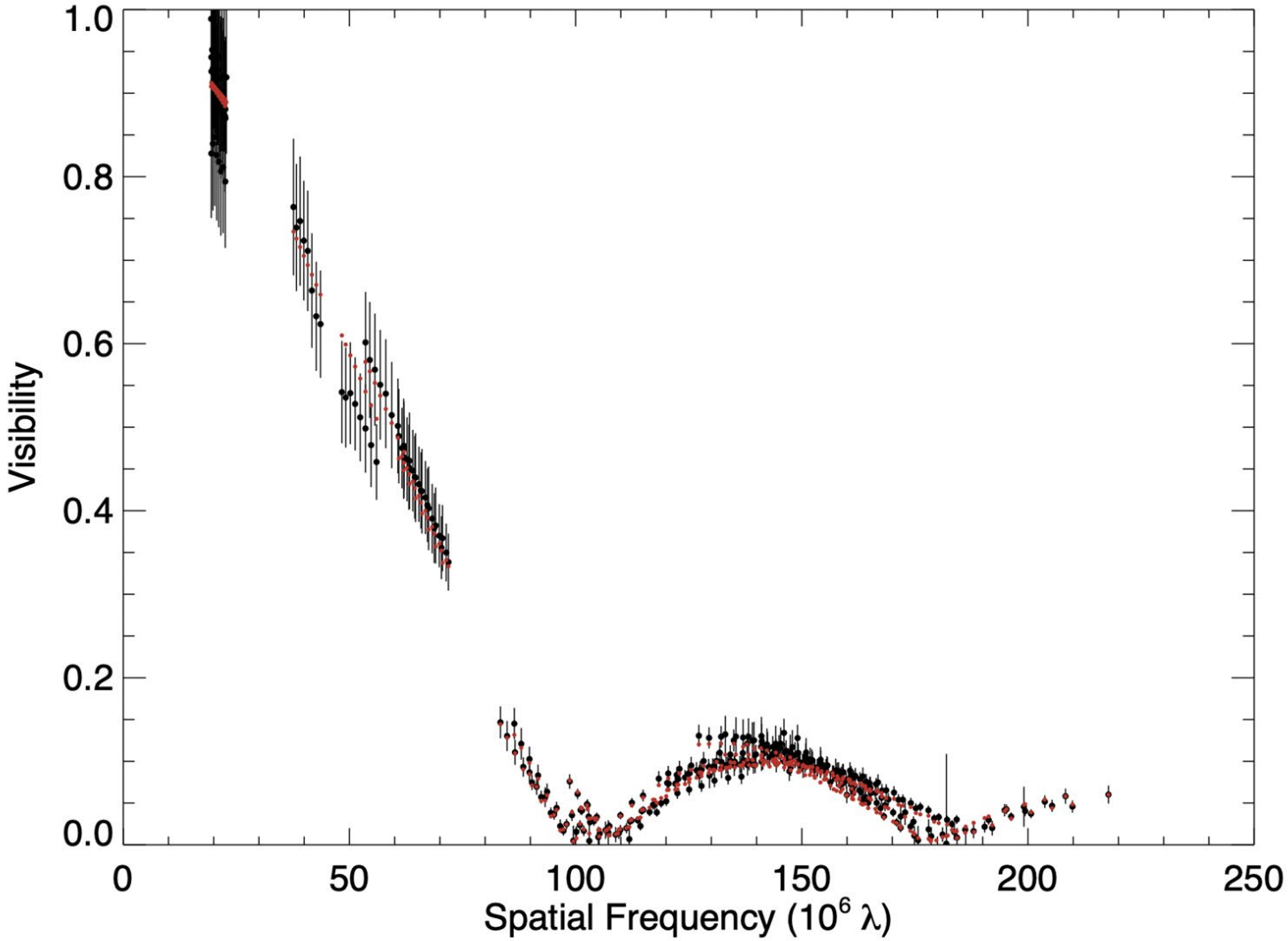




Roettenbacher et al. 2016

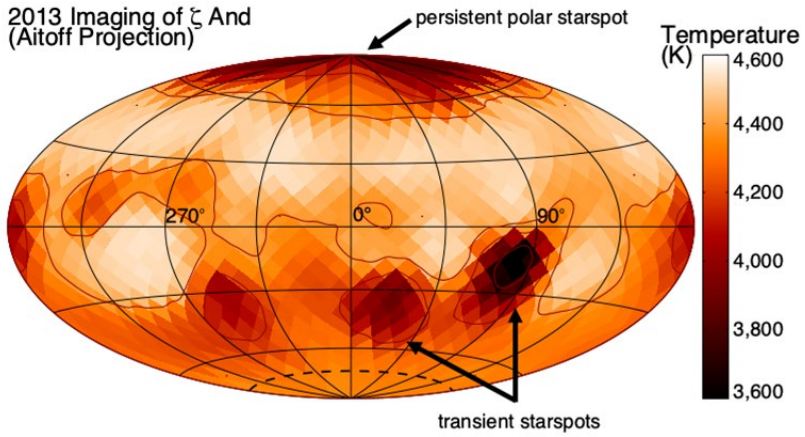
ζ And

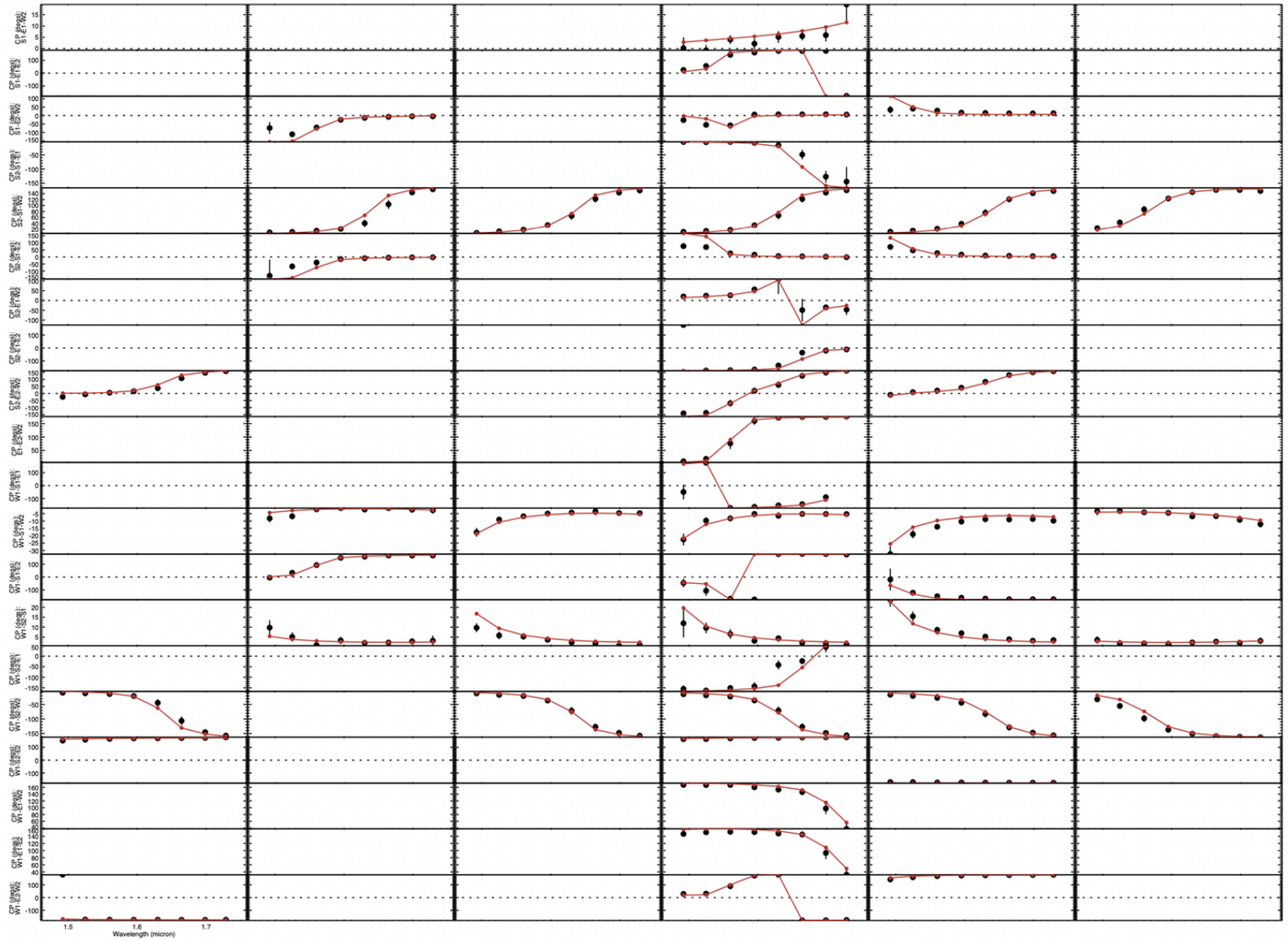




Roettenbacher et al. 2016

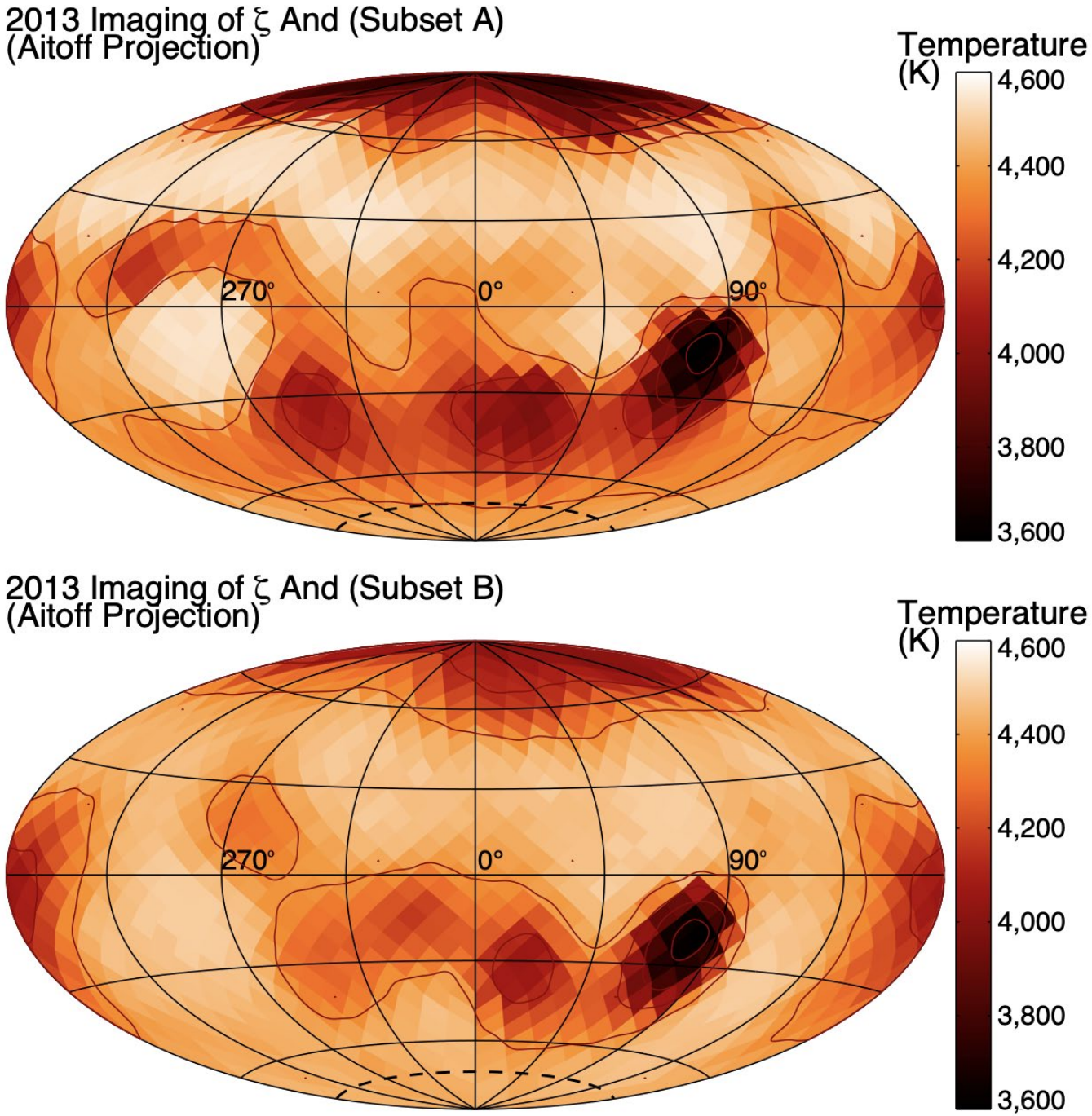
ζ And





Roettenbacher et al. 2016

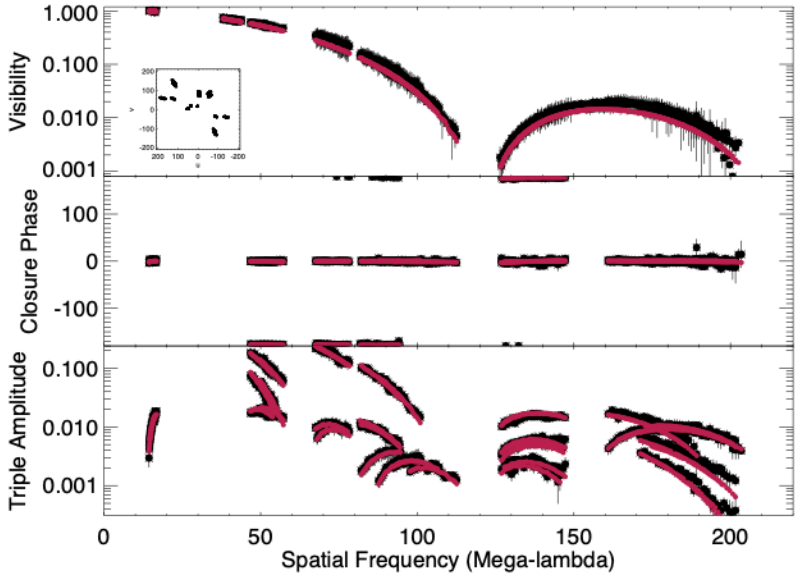
ζ And

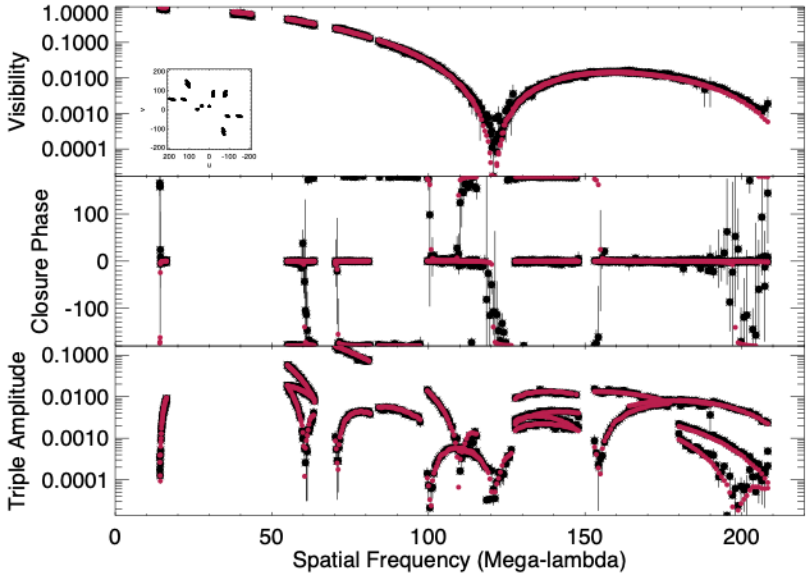


Roettenbacher et al. 2016

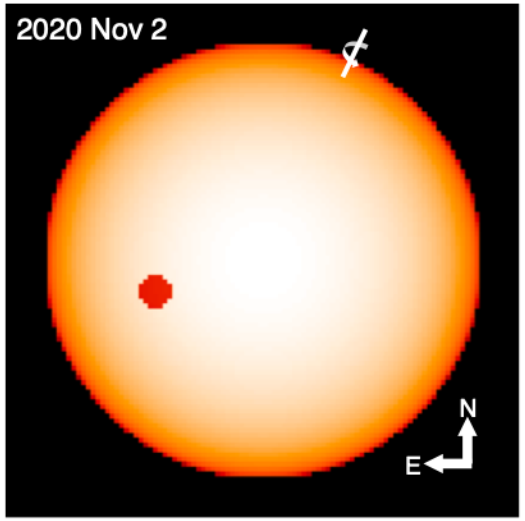
Data Available

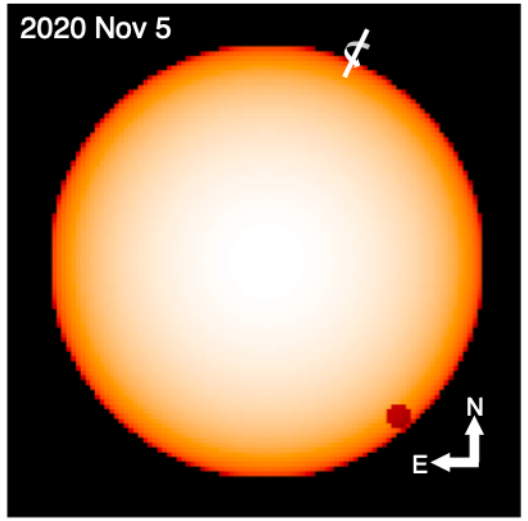
ε Eri (2020)





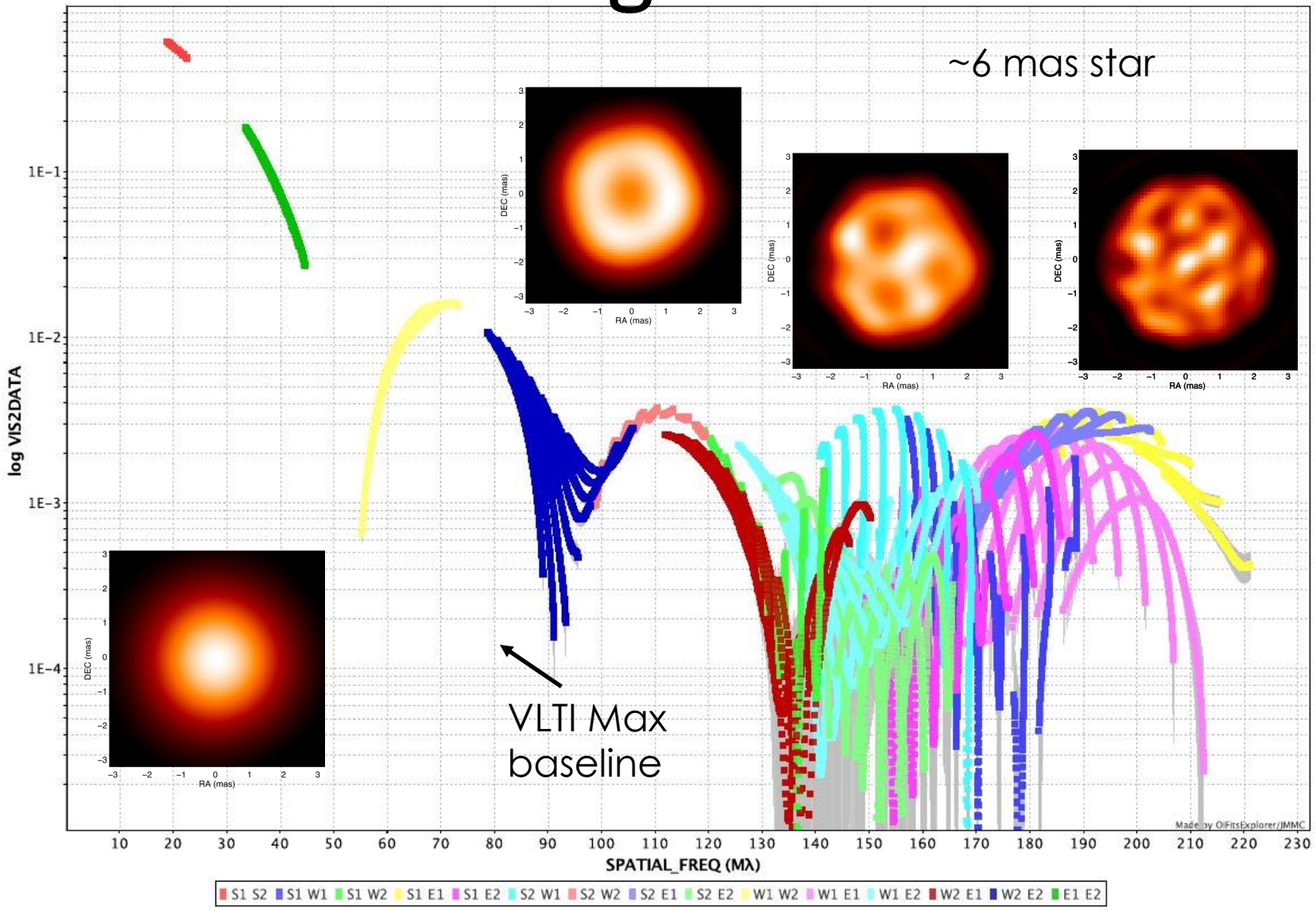
Notes:
- Assumed diameter from Baines & Armstrong (2011) 2.153 mas
- Used power-law limb-darkening ($\alpha = 0.27$)



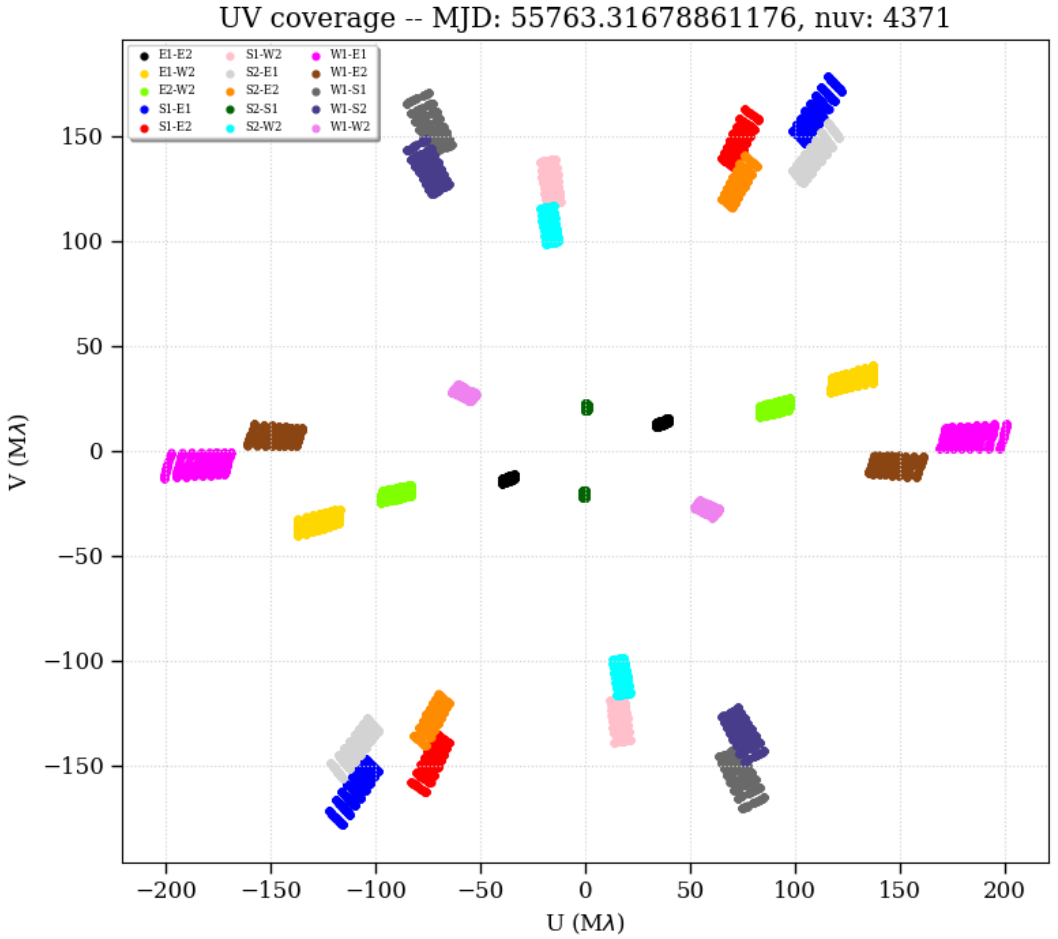


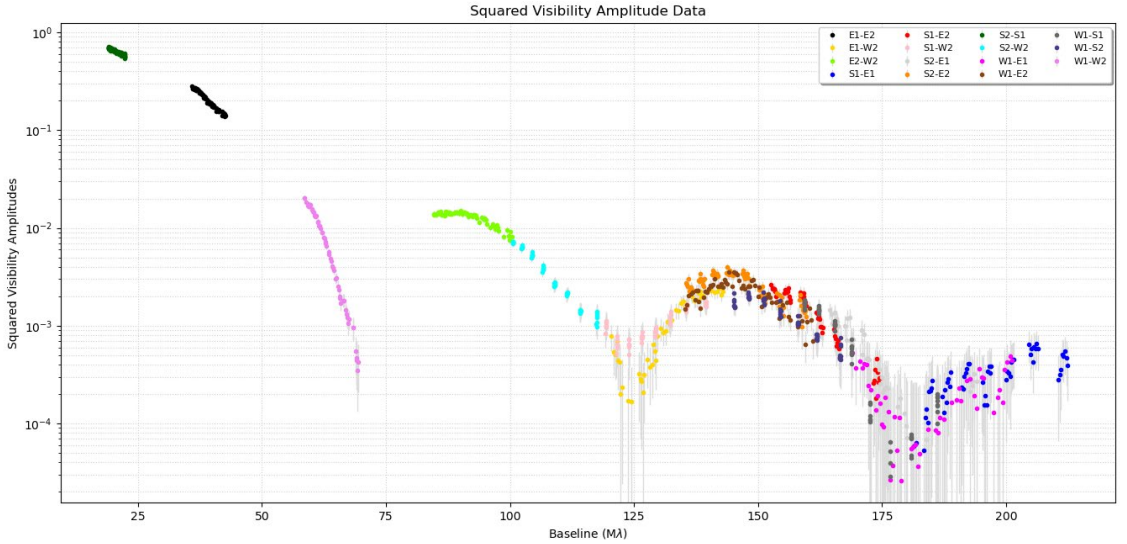
Roettenbacher et al. 2022

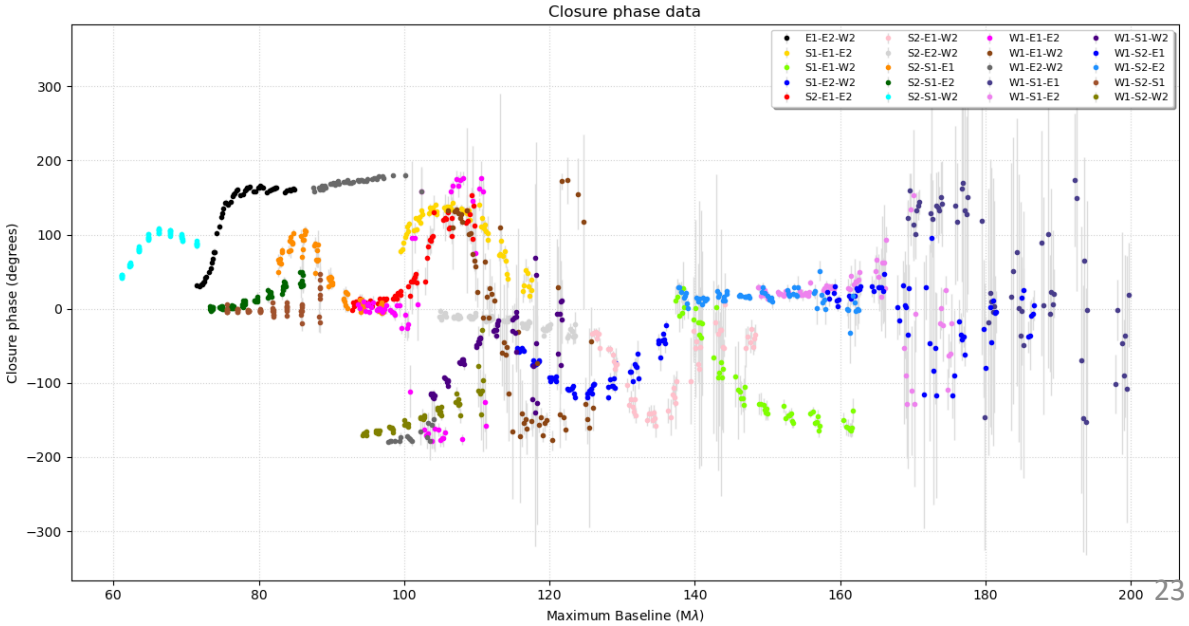
The benefit of long baselines



A Journey Through the Process

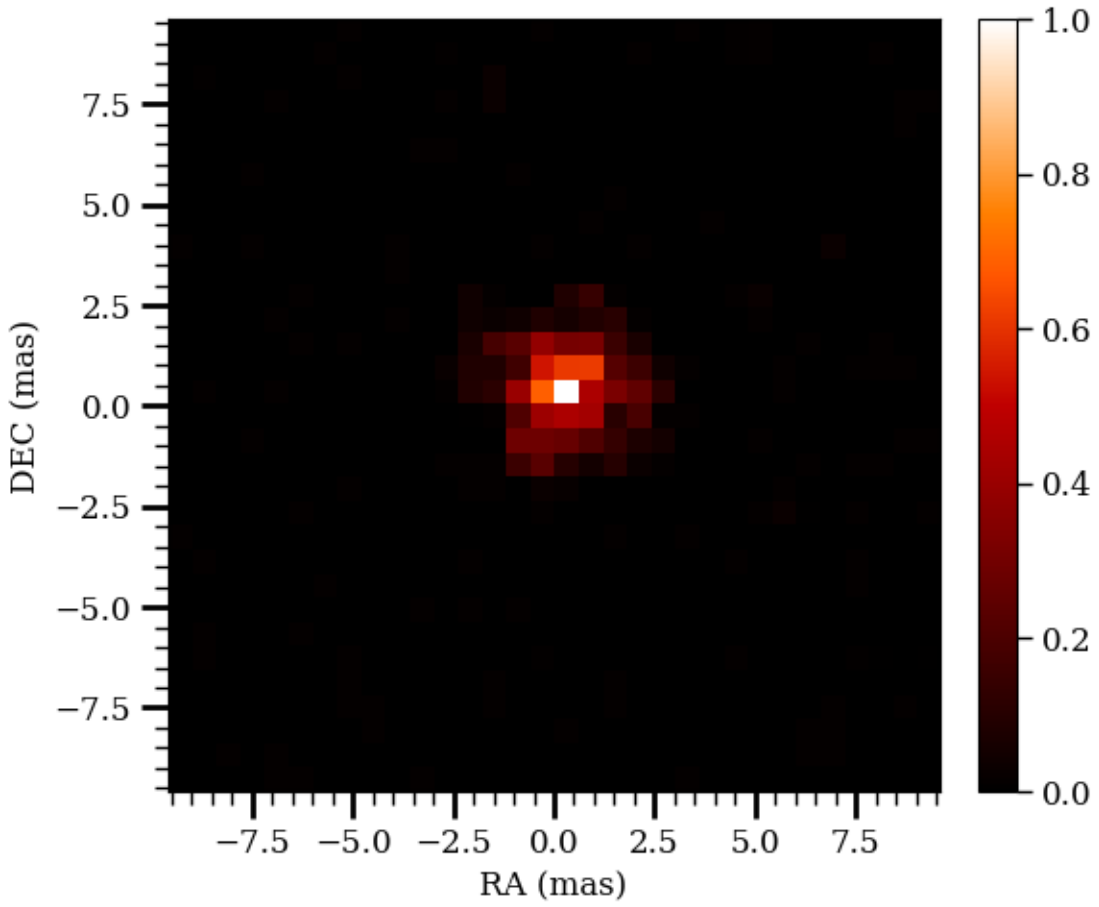






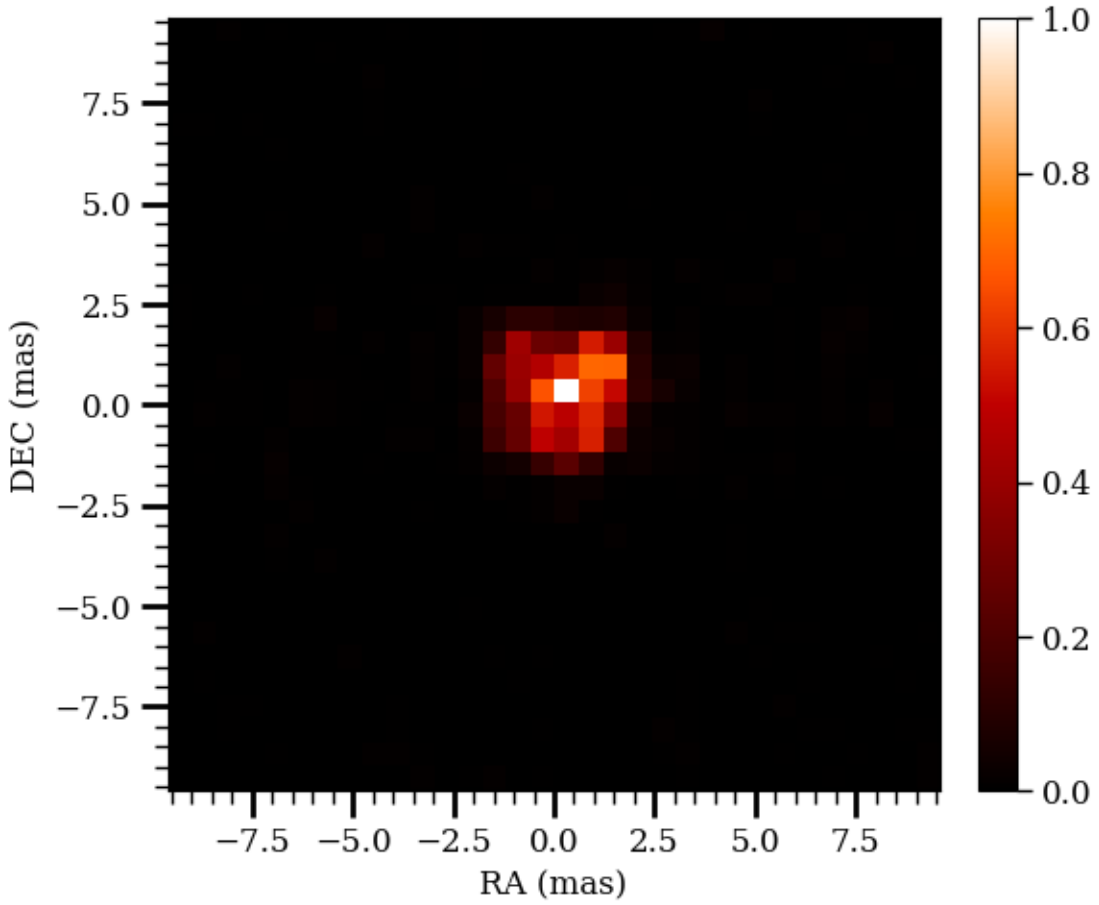
A Journey Through the Process

- Let's start by using SQUEEZE
- And let's try without a regularizer
- Using 32x32 at 0.6 mas/pixel
- 1000 elements



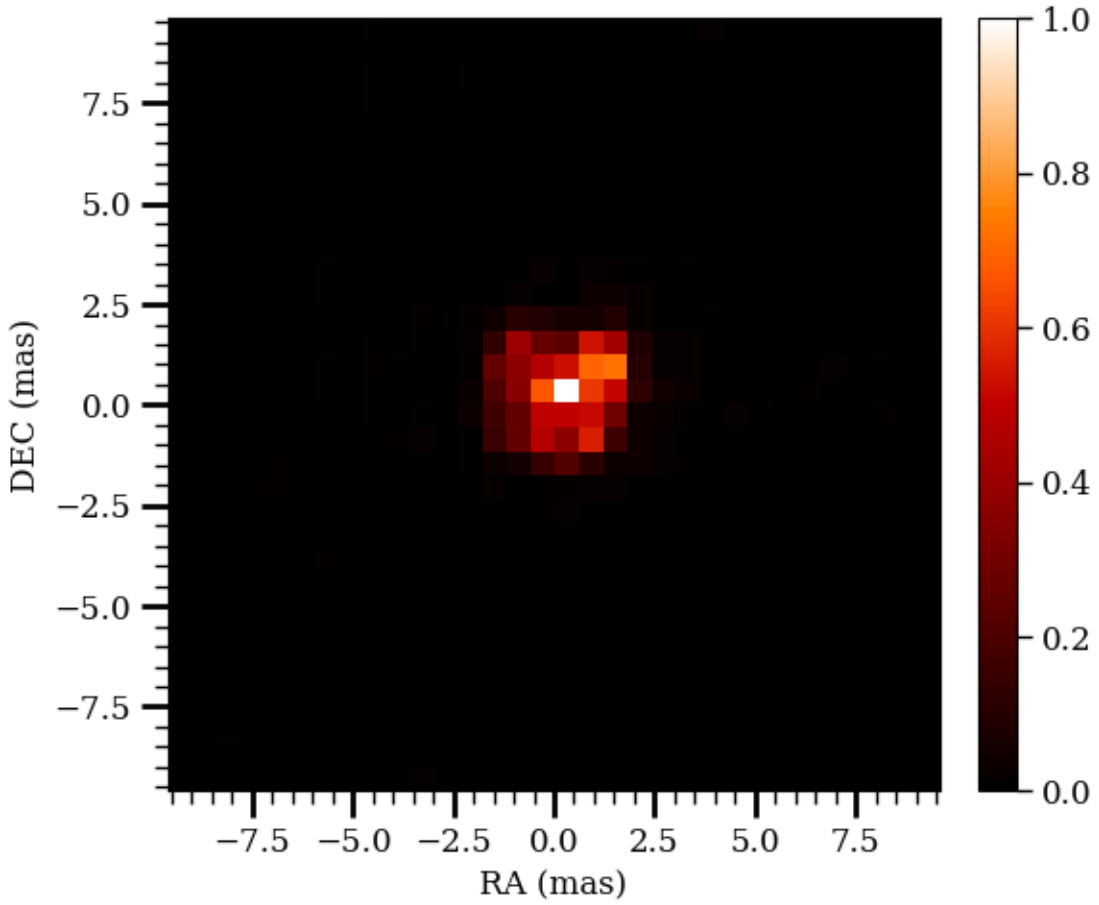
A Journey Through the Process

- Still no regularizers
- Using 32x32 at 0.6 mas/pixel
- 6000 elements



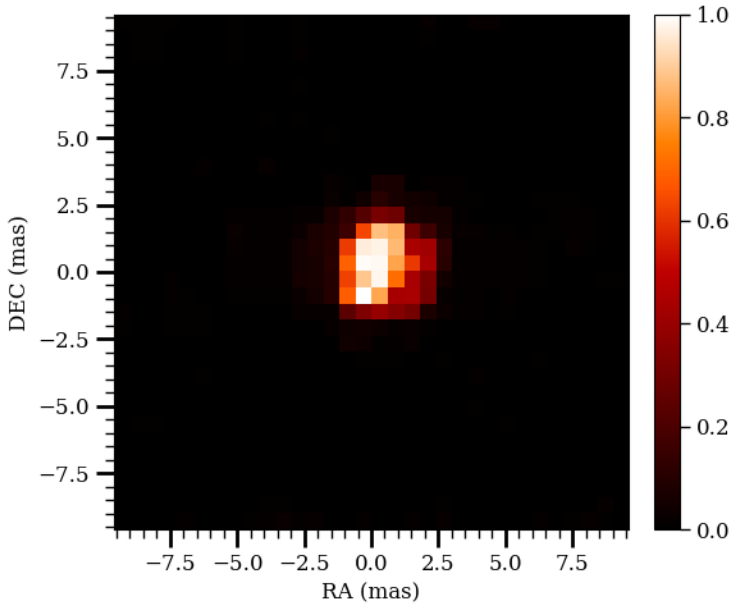
A Journey Through the Process

- Let's try Total Variation
- Hyperparameter 50

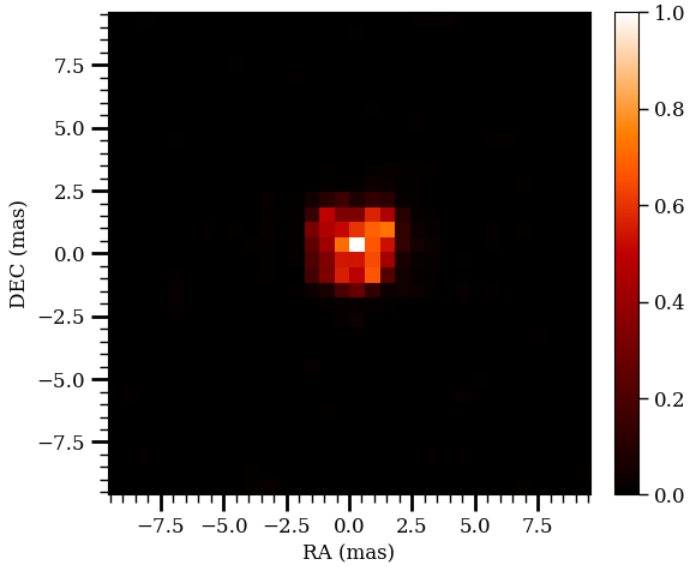


A Journey Through the Process

- Let's try Total Variation
  - Hyperparameter 15000

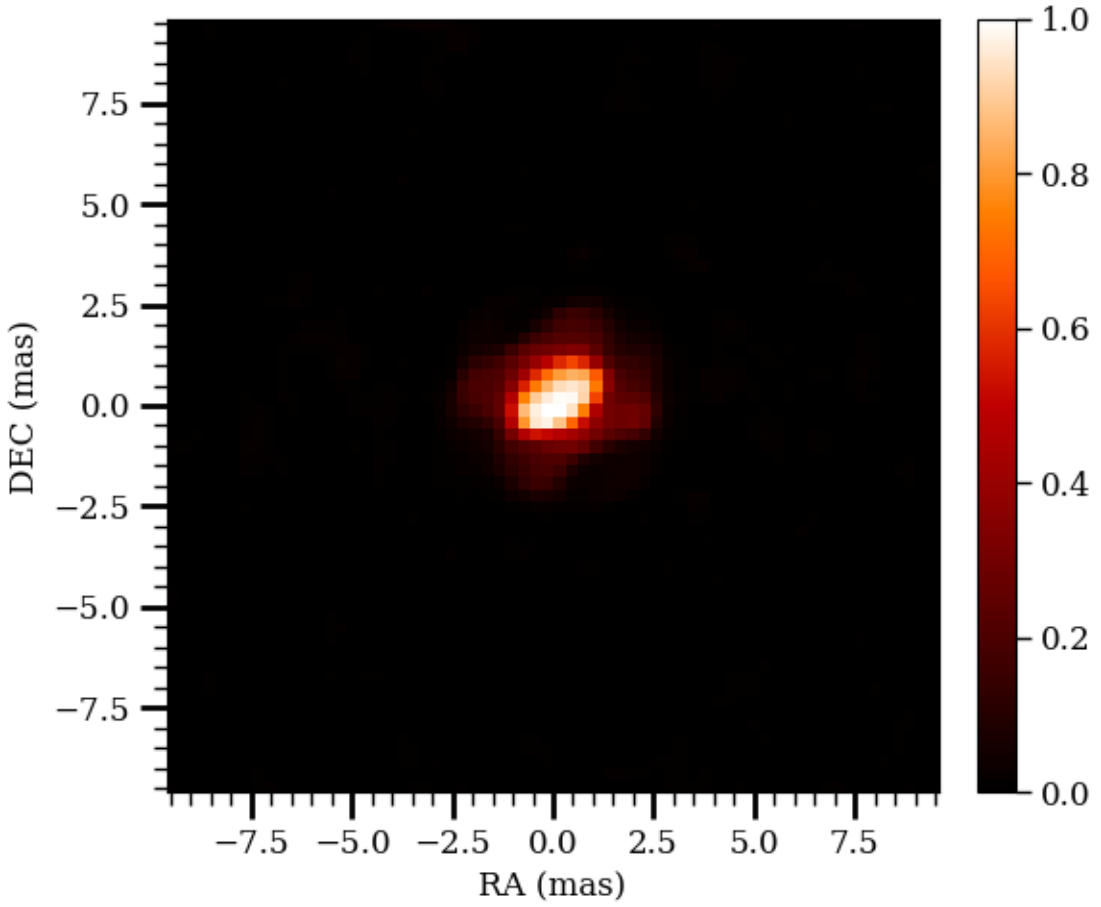


- Let's try the "uniform disk" regularizer
  - Hyperparameter 5



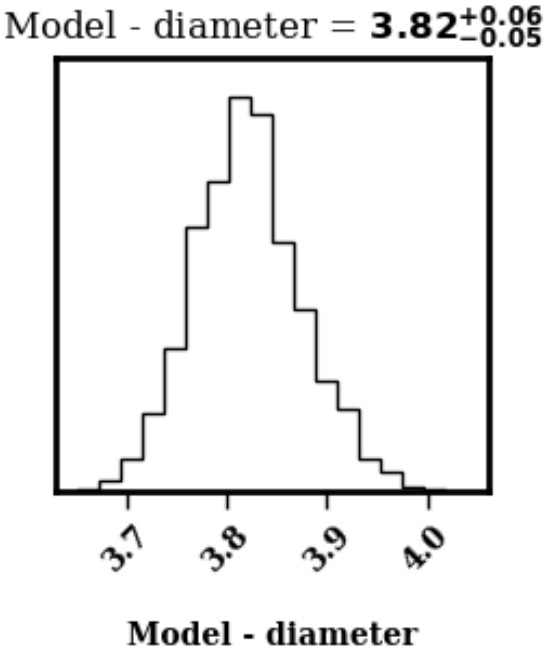
A Journey Through the Process

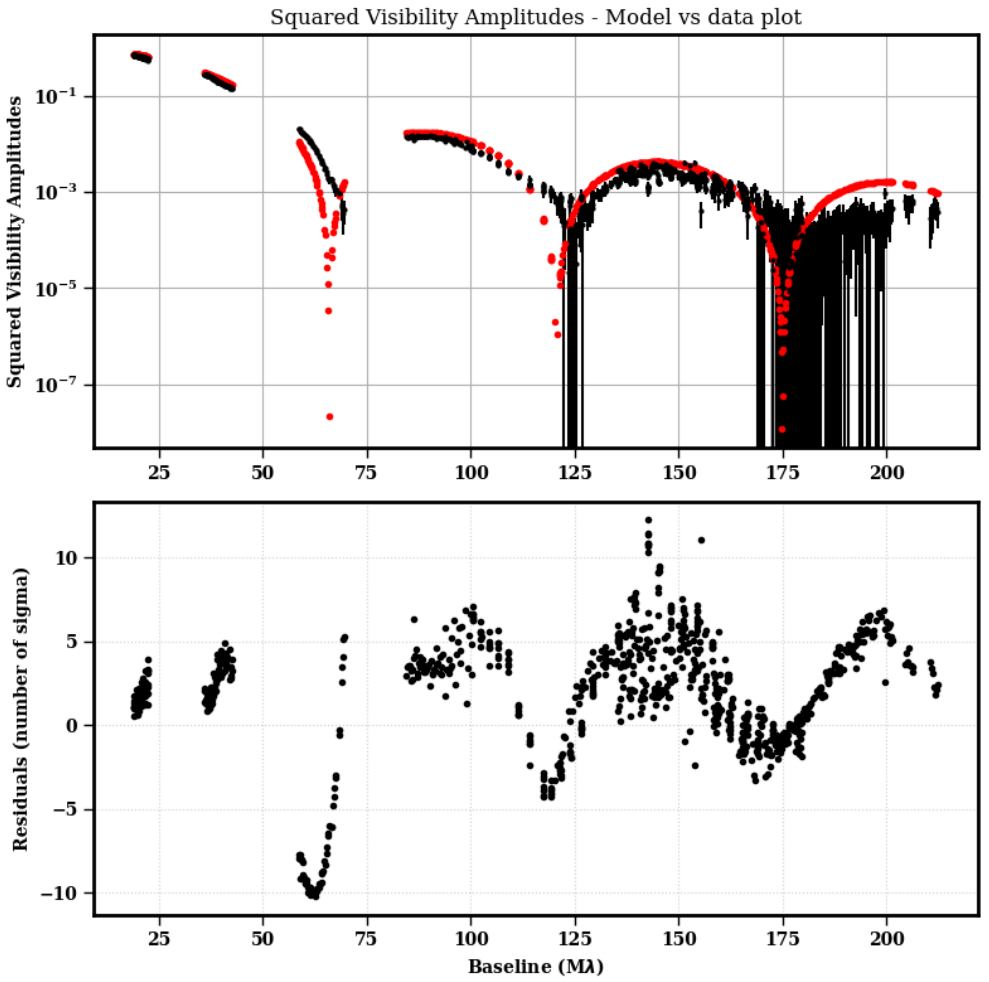
- Let's try in increasing resolution to 0.3 on 64x64 and 6000 elements
  - Hyperparameter 2500



A Journey Through the Process

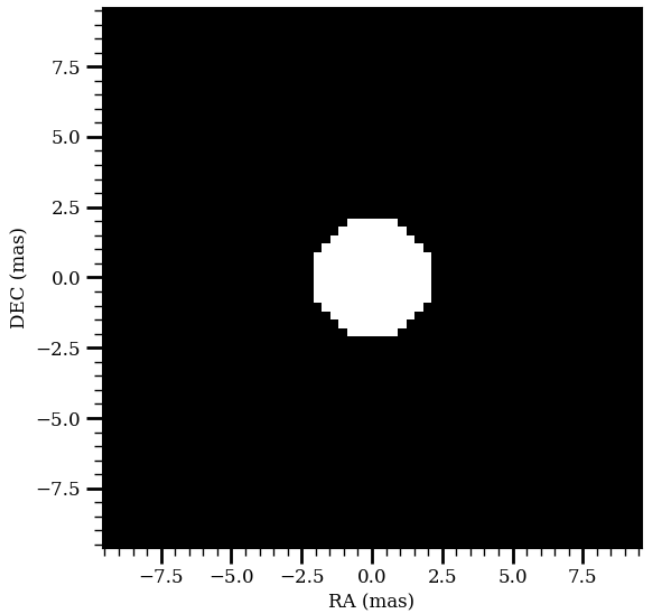
- Okay, let's get a model to start with

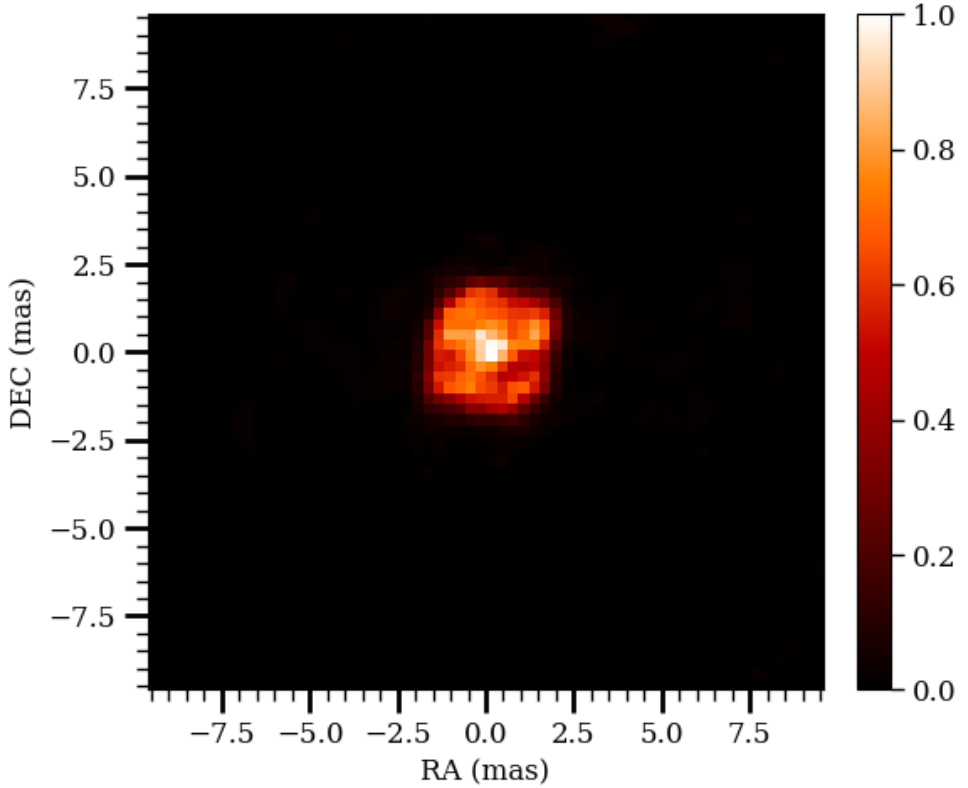




A Journey Through the Process

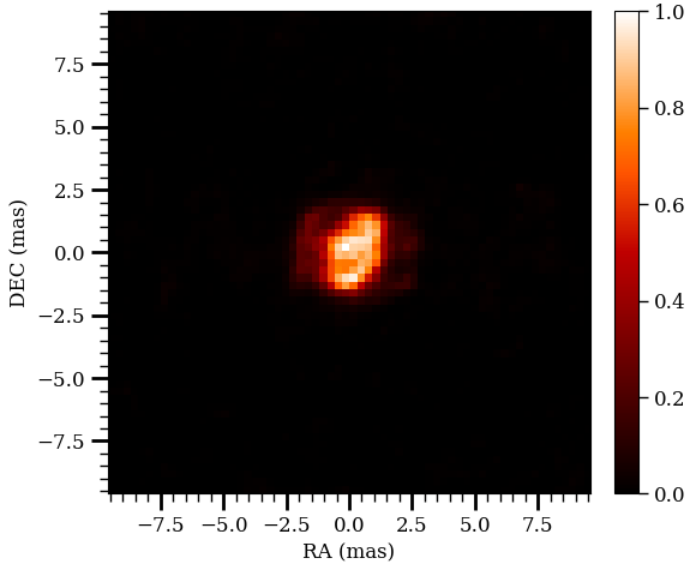
- 4.25 mas uniform disk
  - Starting image but not constrained to area



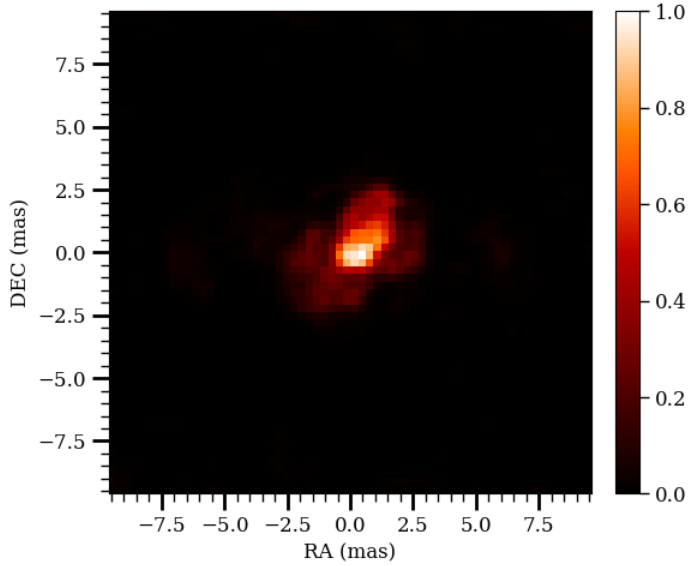


A Journey Through the Process

- Initial image matters
  - 3 mas disk

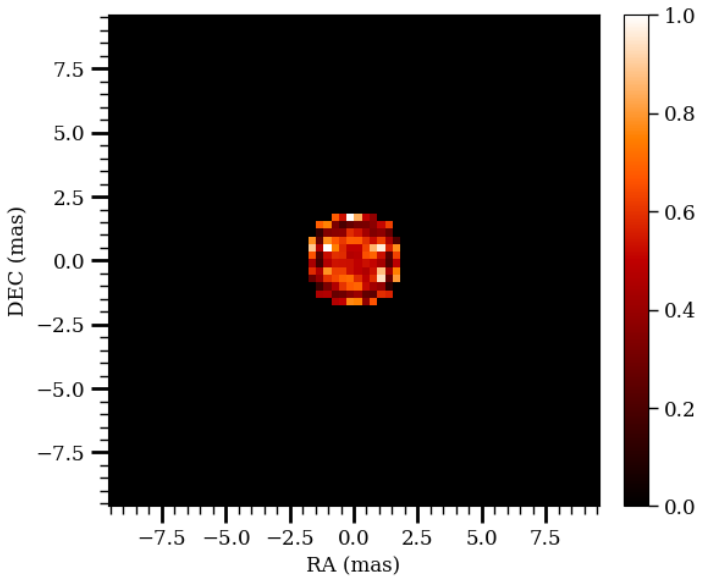


- 6 mas disk



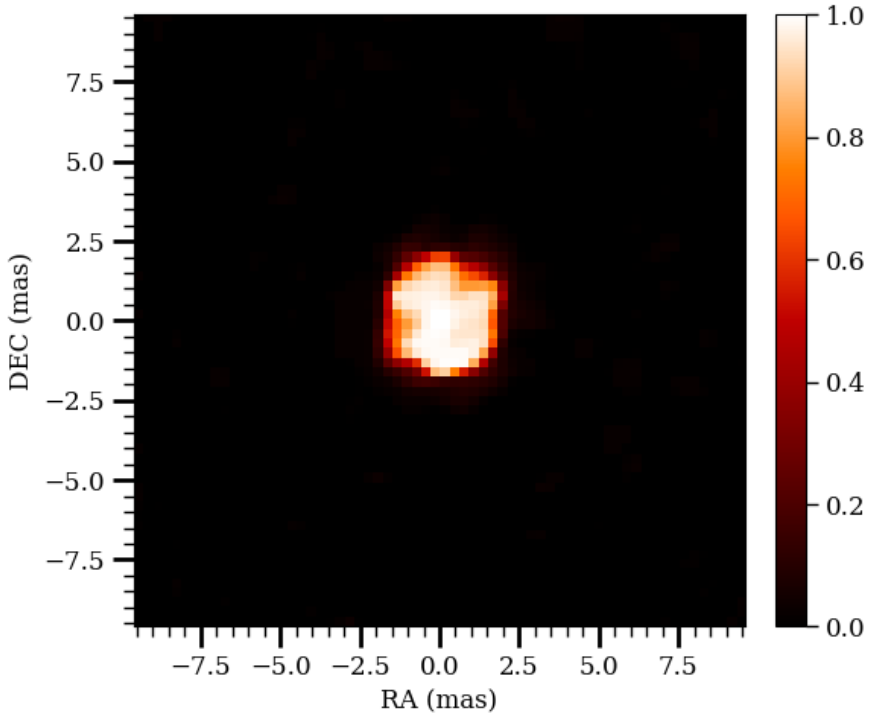
A Journey Through the Process

- Using just prior image (no starting, tries to match input)



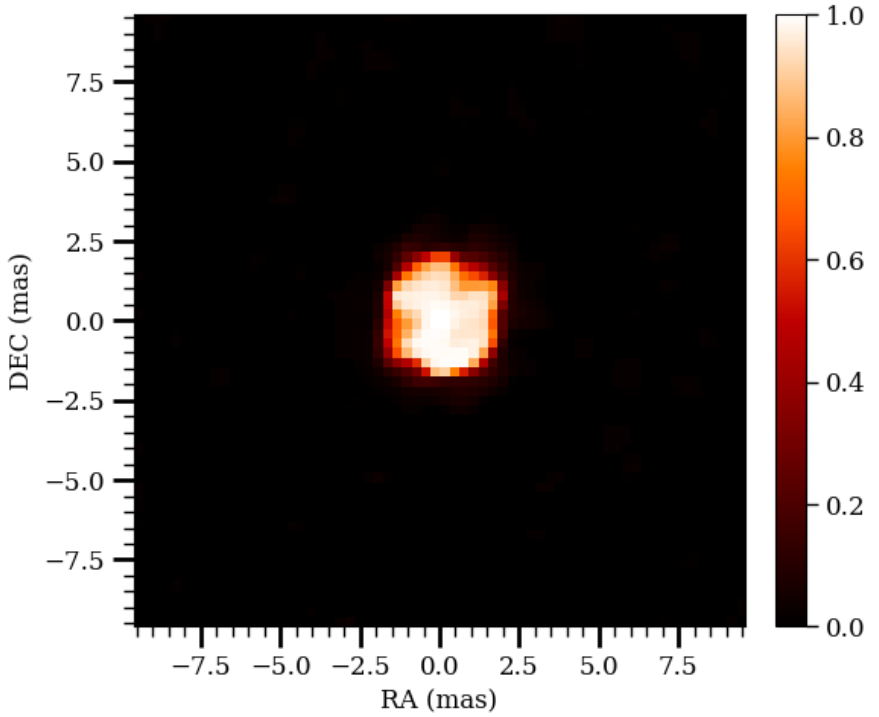
A Journey Through the Process

- Initial image and total variation (over regularized)
- So do we pick?!



A Journey Through the Process

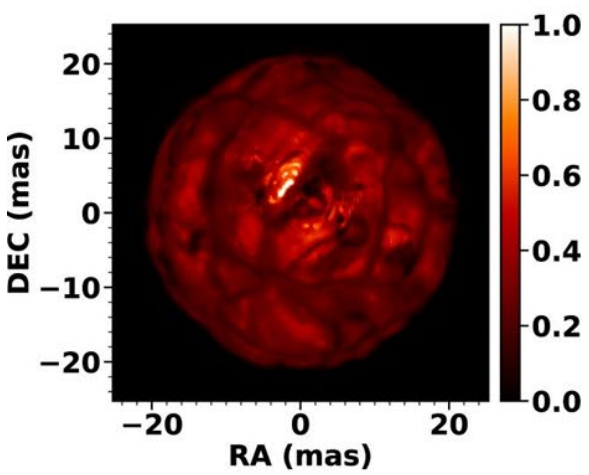
- Initial image and total variation (over regularized)
- So do we pick?!



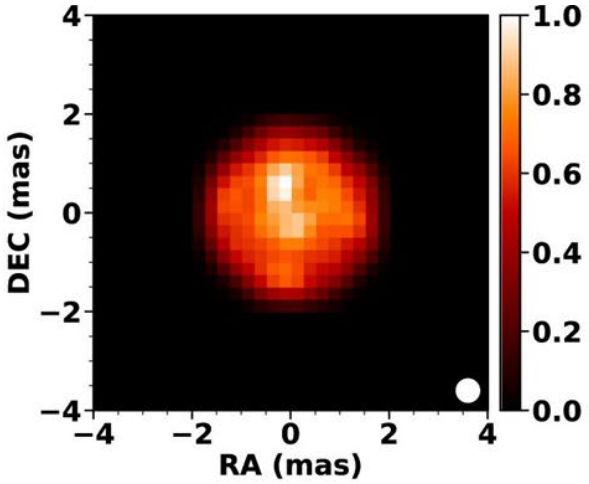
Choosing the Best Regularizer(s)

Make a simulated observation using existing data and a source image
(https://github.com/fabienbaron/OITOOLS.jl)

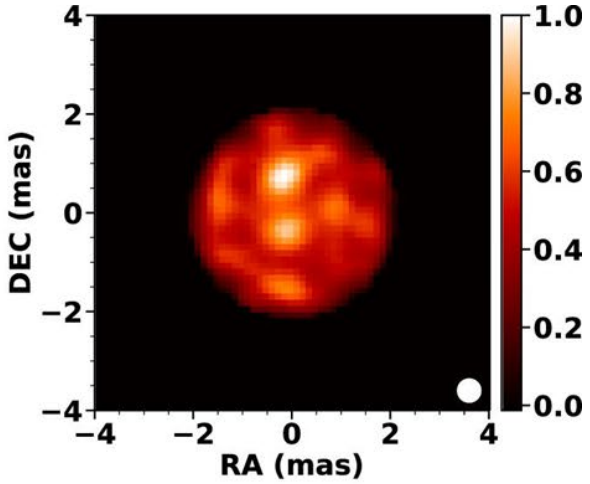
Reconstruct for a variety of combinations of regularizers and hyperparameters



Unconvolved Source Image

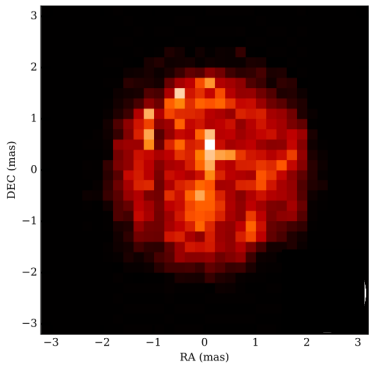


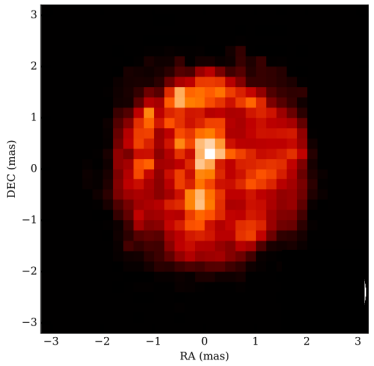
Scaled down, convolved Source Image

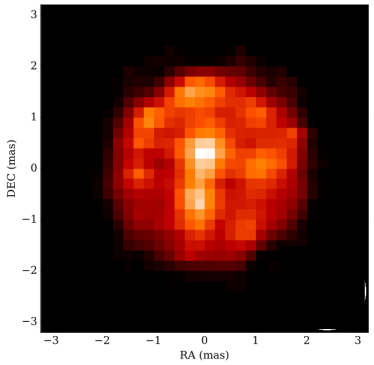


Best fitting reconstruction

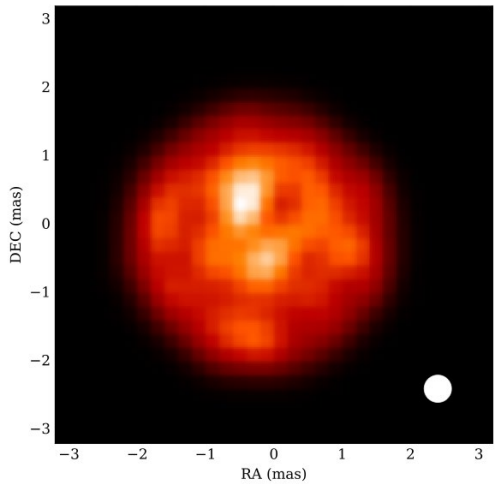
Choosing the Best Regularizer(s)





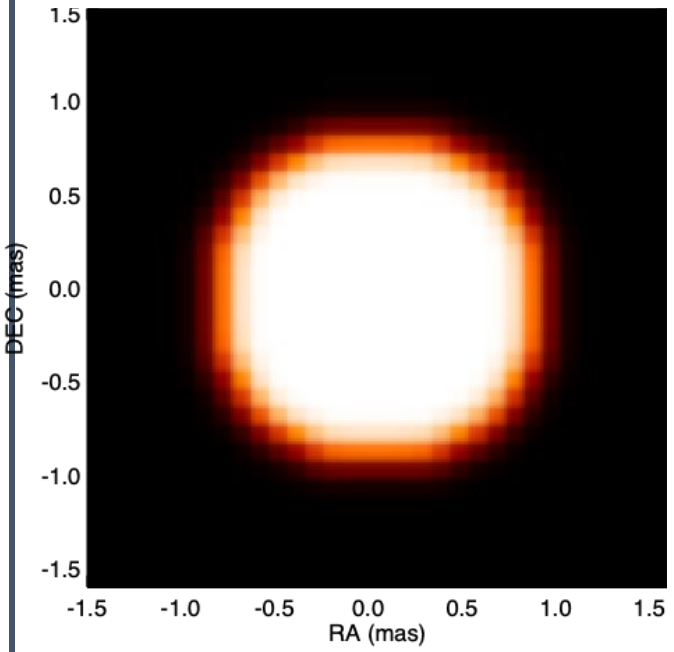


Gomes et al. 2017 found the l_1 -norm to be the best metric for assessing quality

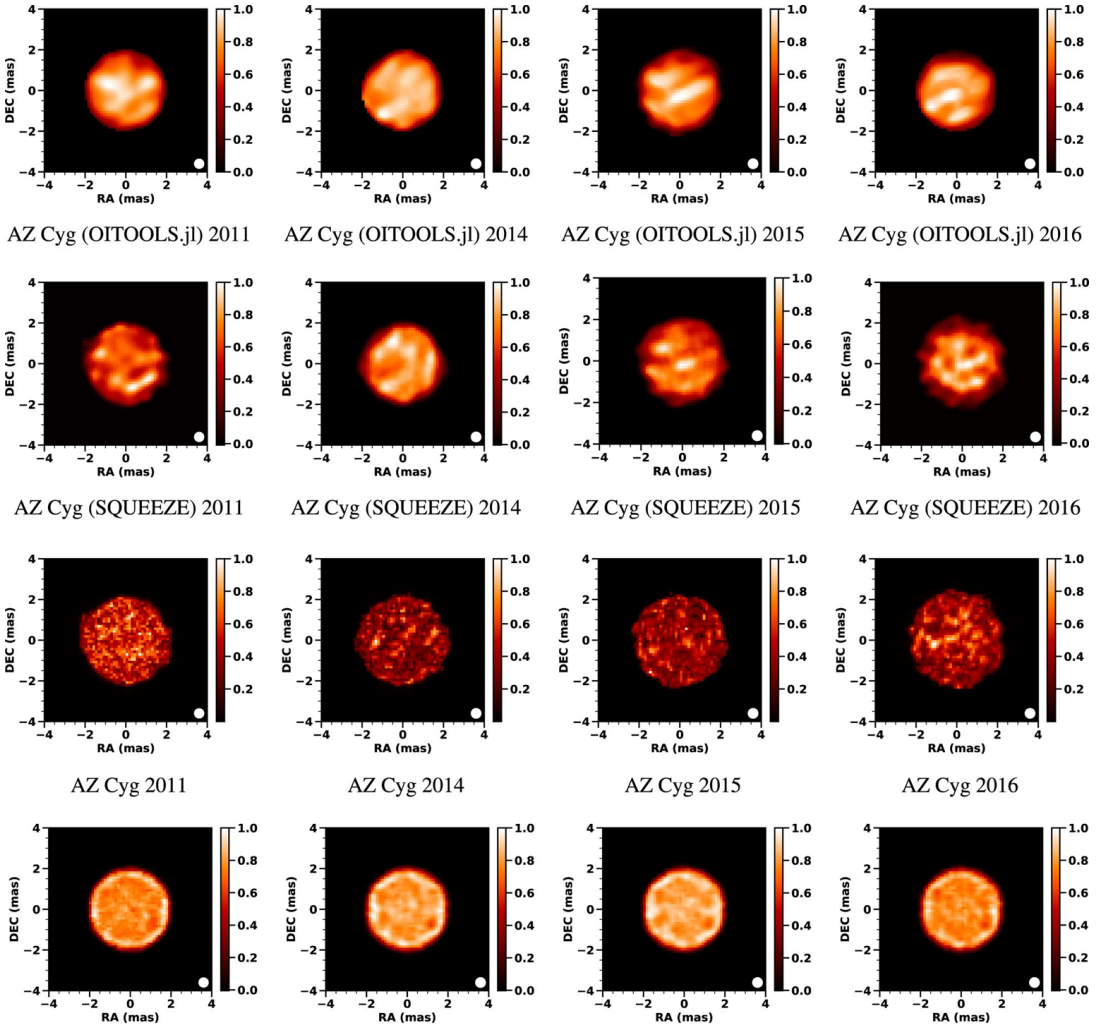


Compare the stack of reconstructions to the source image convolved to reconstruction resolution using some metric and find best fitting reconstruction

Verifying Features



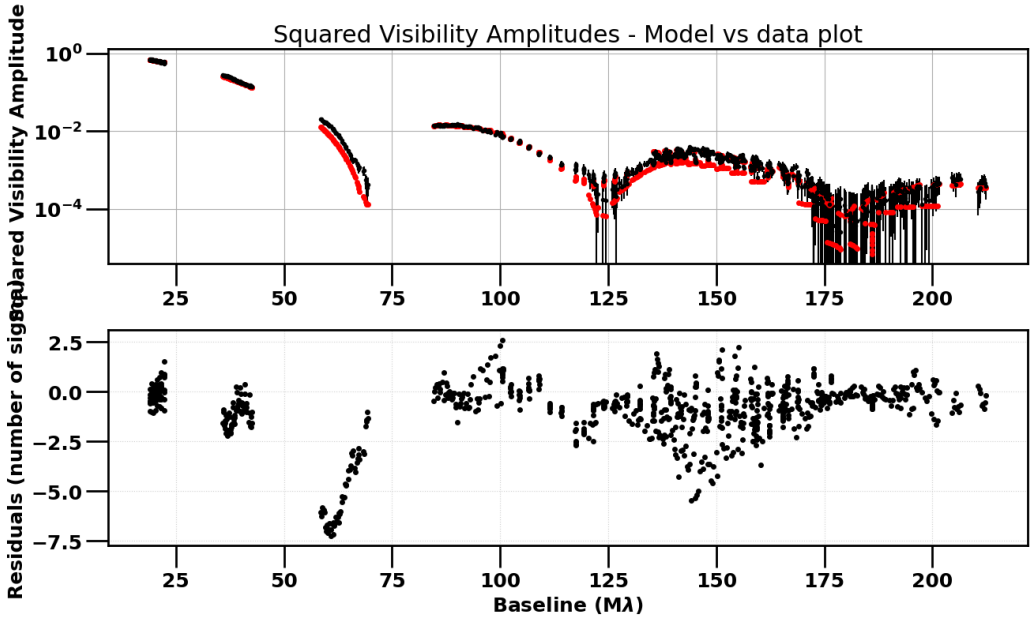
Make a simulated observation using existing data and a source image of a limb darkened disk

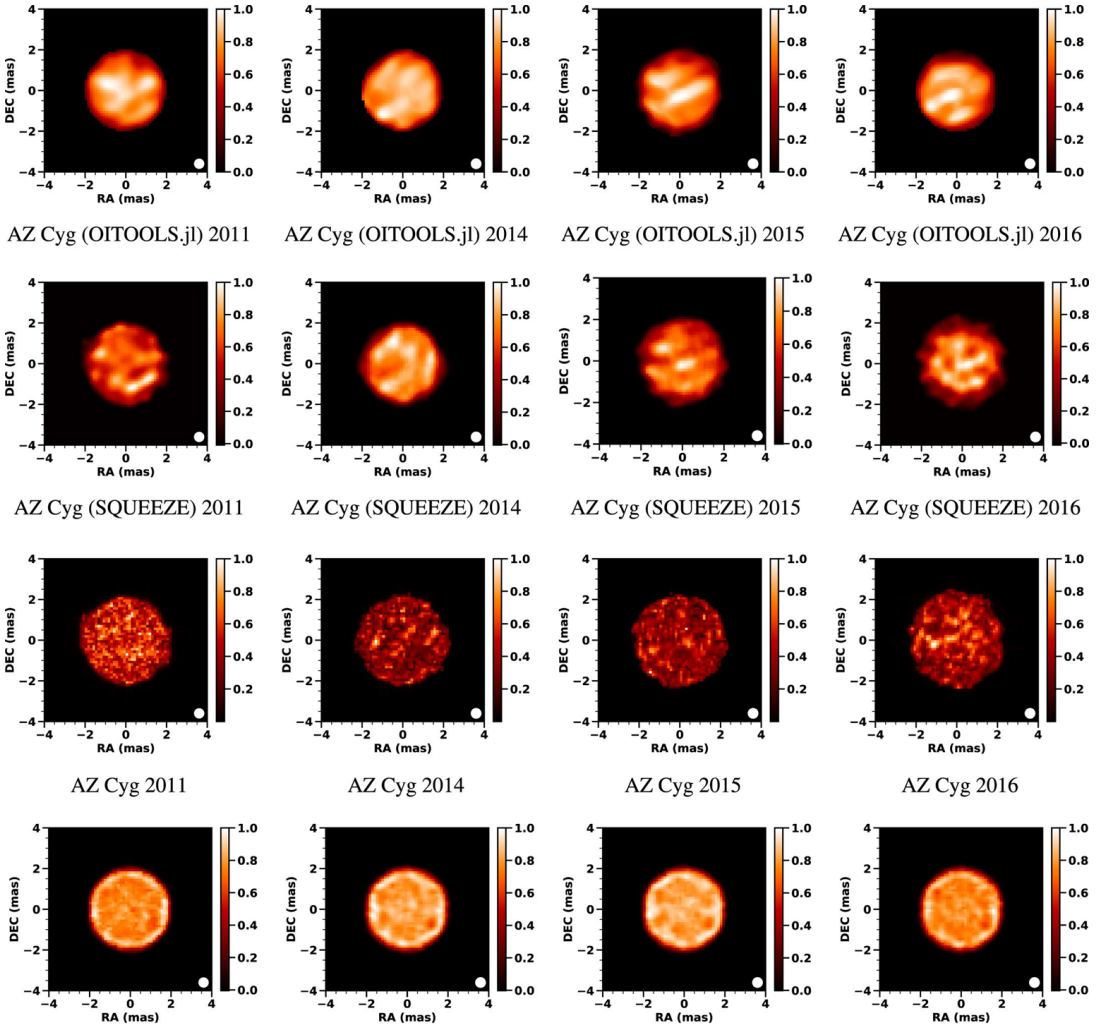


Reconstruct with the same parameters as your image and compare

Verifying Features

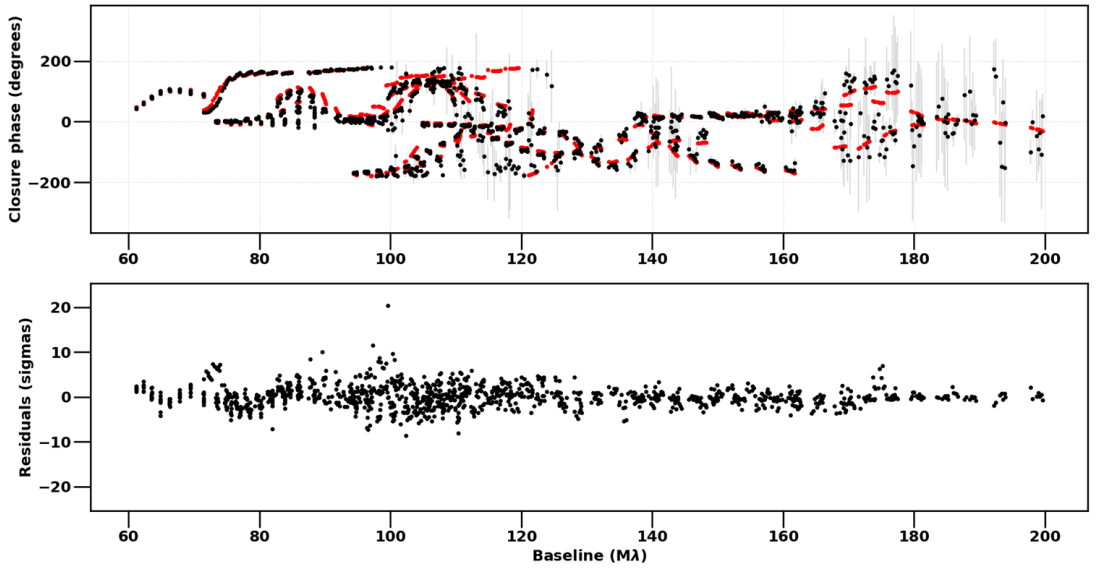
Use more than one type of image reconstruction method and/or tool!

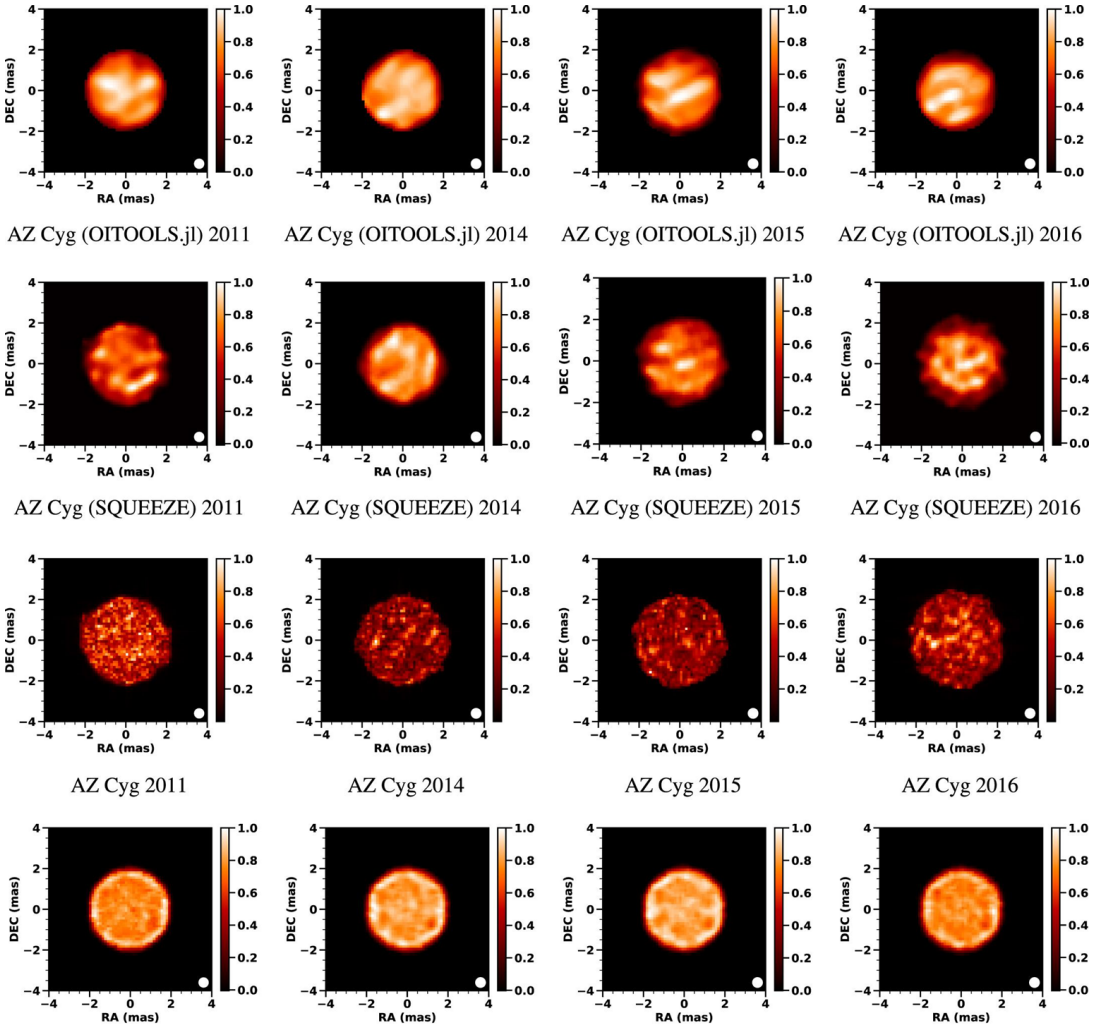




Verifying Features

Use more than one type of image reconstruction method and/or tool!





64x64 0.3 mas/pix 128x128 0.15 mas/pix