

# W SERPENTIS STARS



GEORGIA STATE UNIVERSITY

ADVISOR: DR. DOUGLAS GIES

KATHERINE SHEPARD

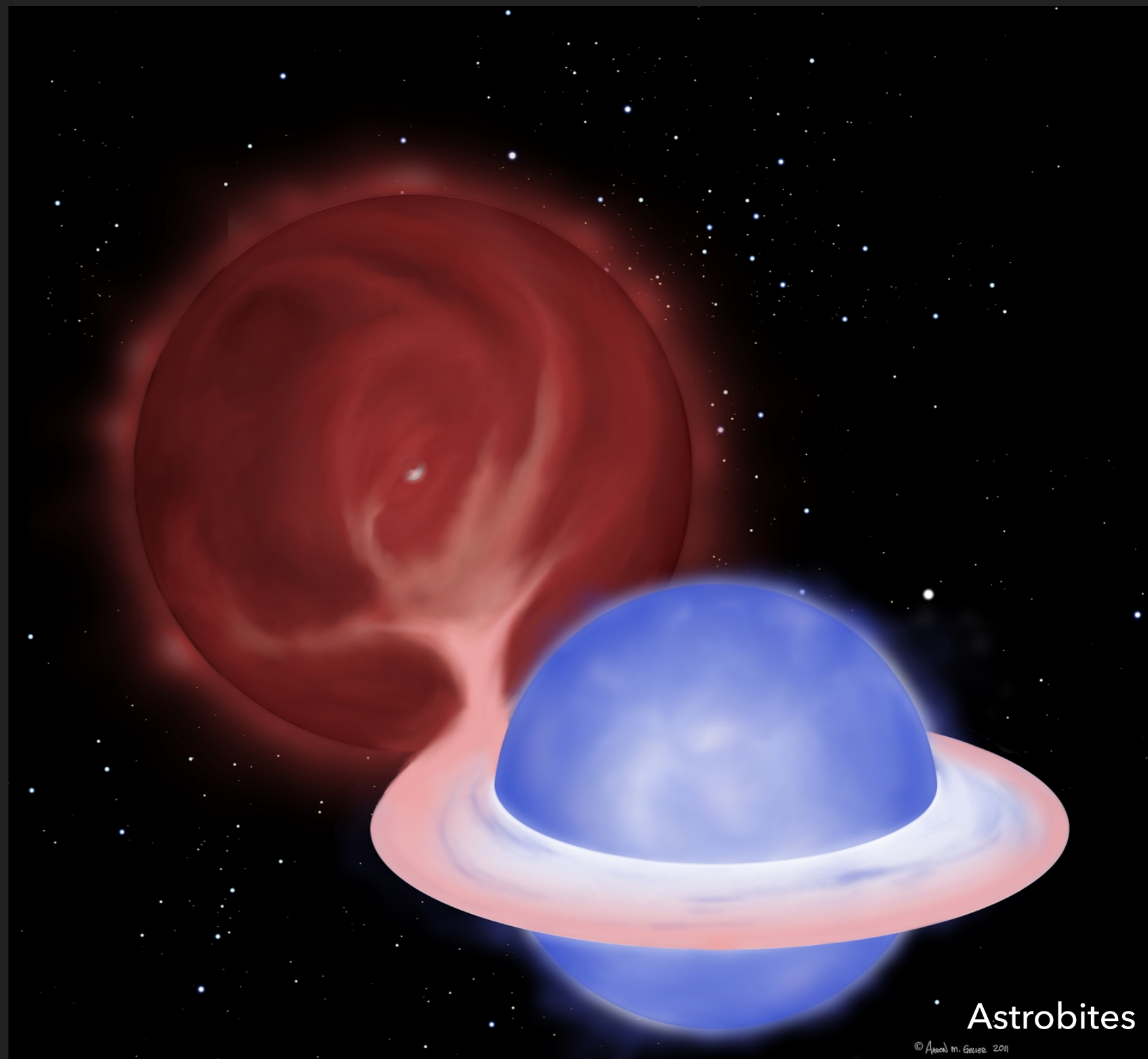


NASA/Casey Reed



# WHAT ARE THEY?

- ▶ Rare Binary Systems

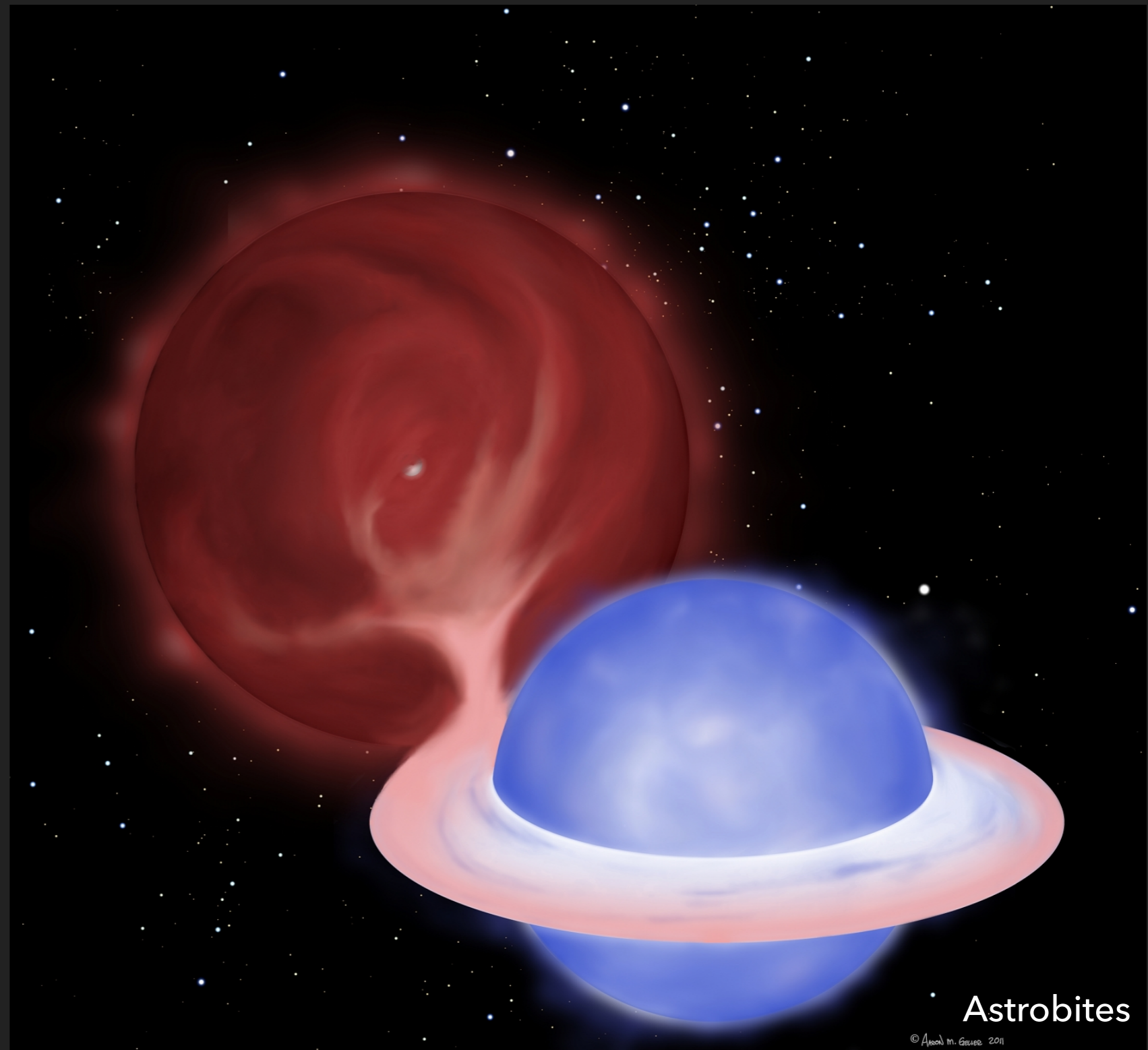


Astrobites

© Aaron M. Ghez 2011

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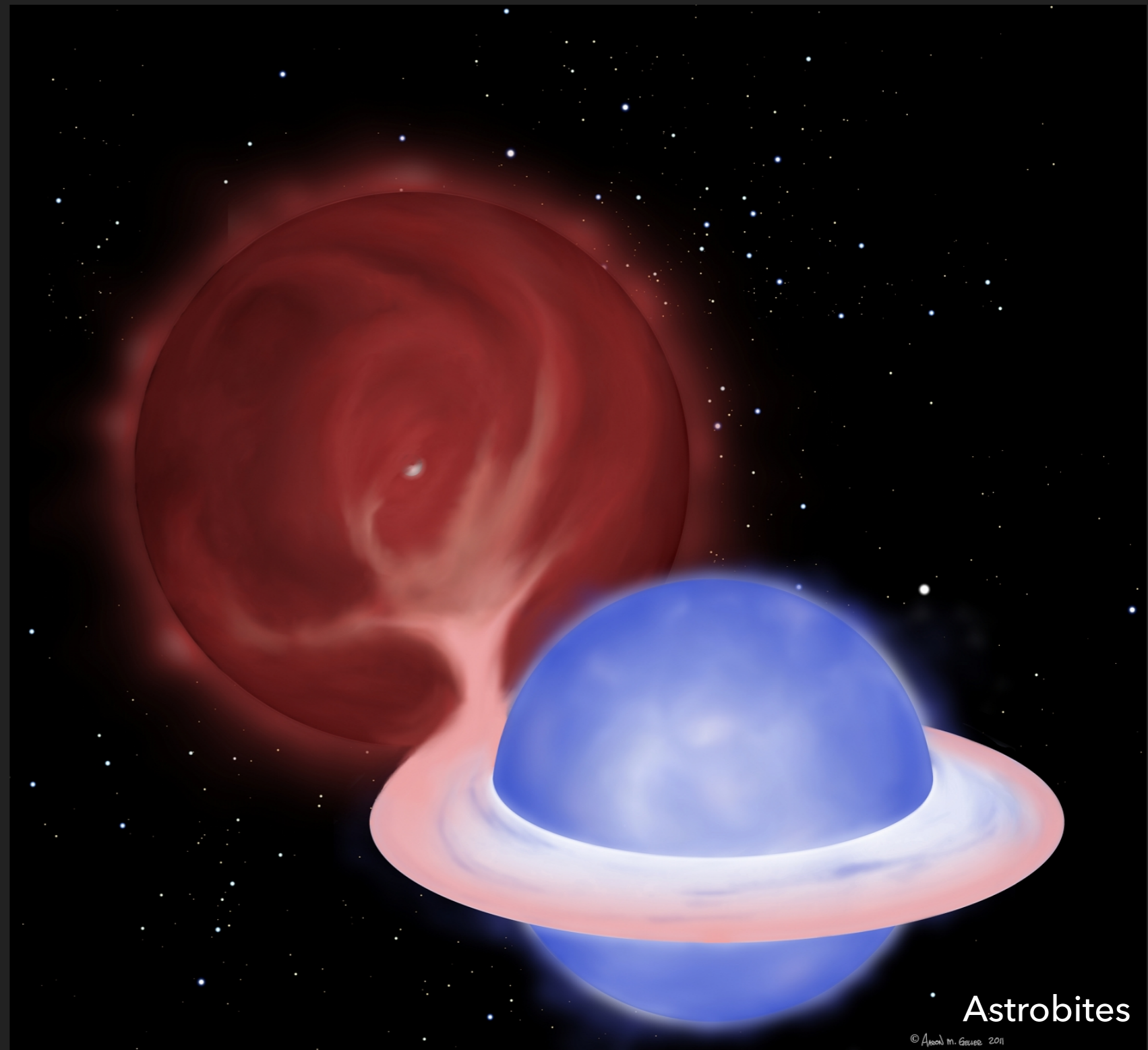
- ▶ Rare Binary Systems
- ▶ Massive Stars





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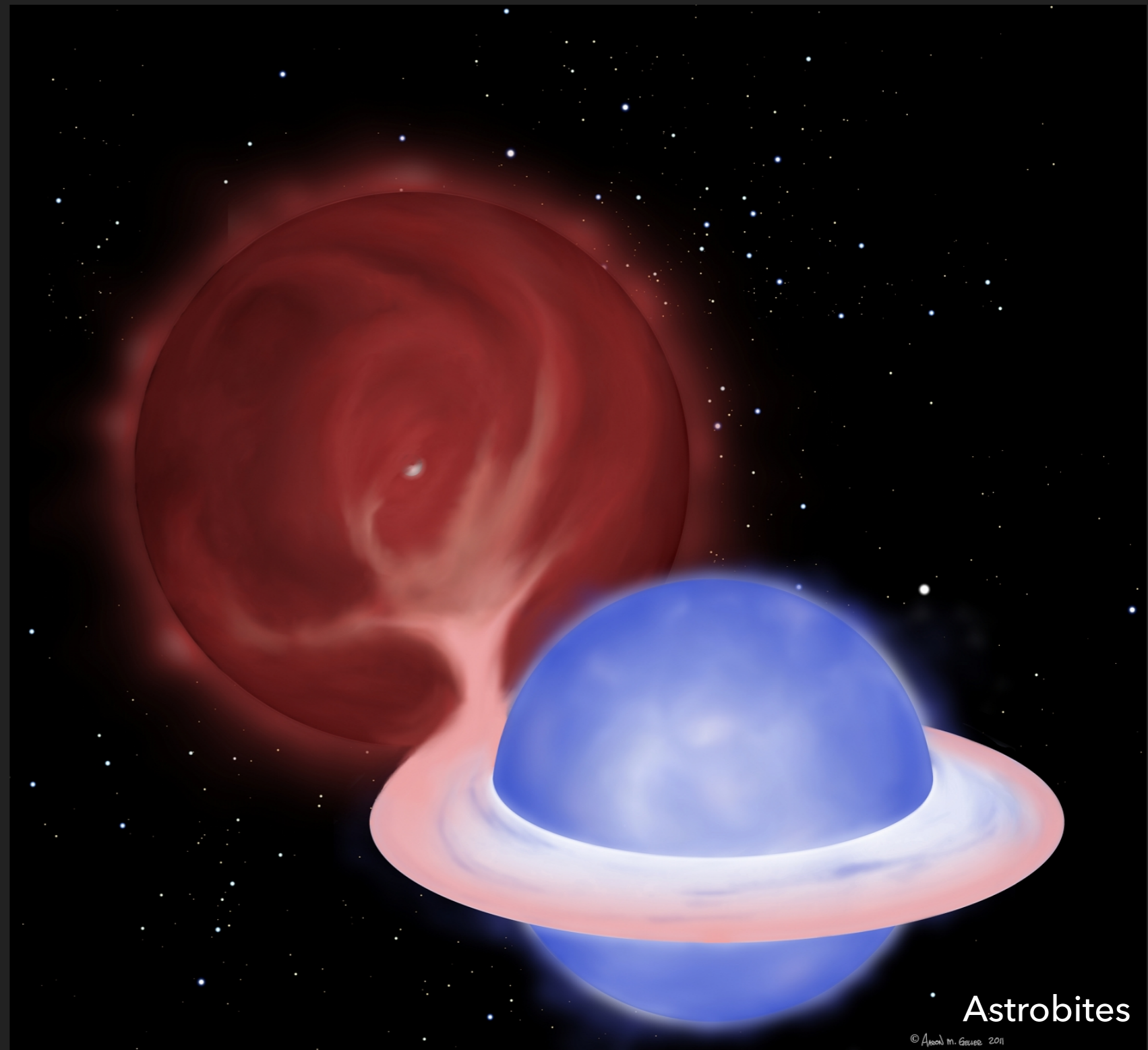
- ▶ Rare Binary Systems
- ▶ Massive Stars
- ▶ Nonconservative active mass transfer





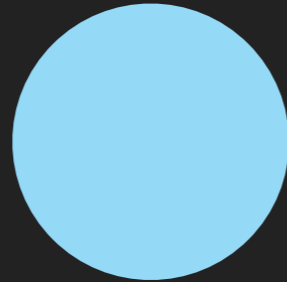
# WHAT ARE THEY?

- ▶ Rare Binary Systems
- ▶ Massive Stars
- ▶ Nonconservative active mass transfer
- ▶ Circumbinary disks



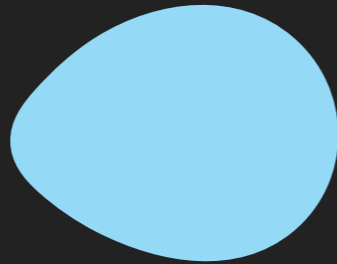
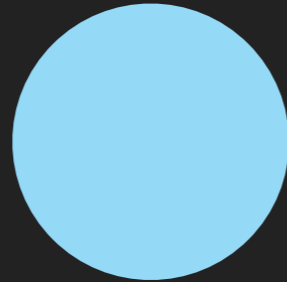


# MASS TRANSFER



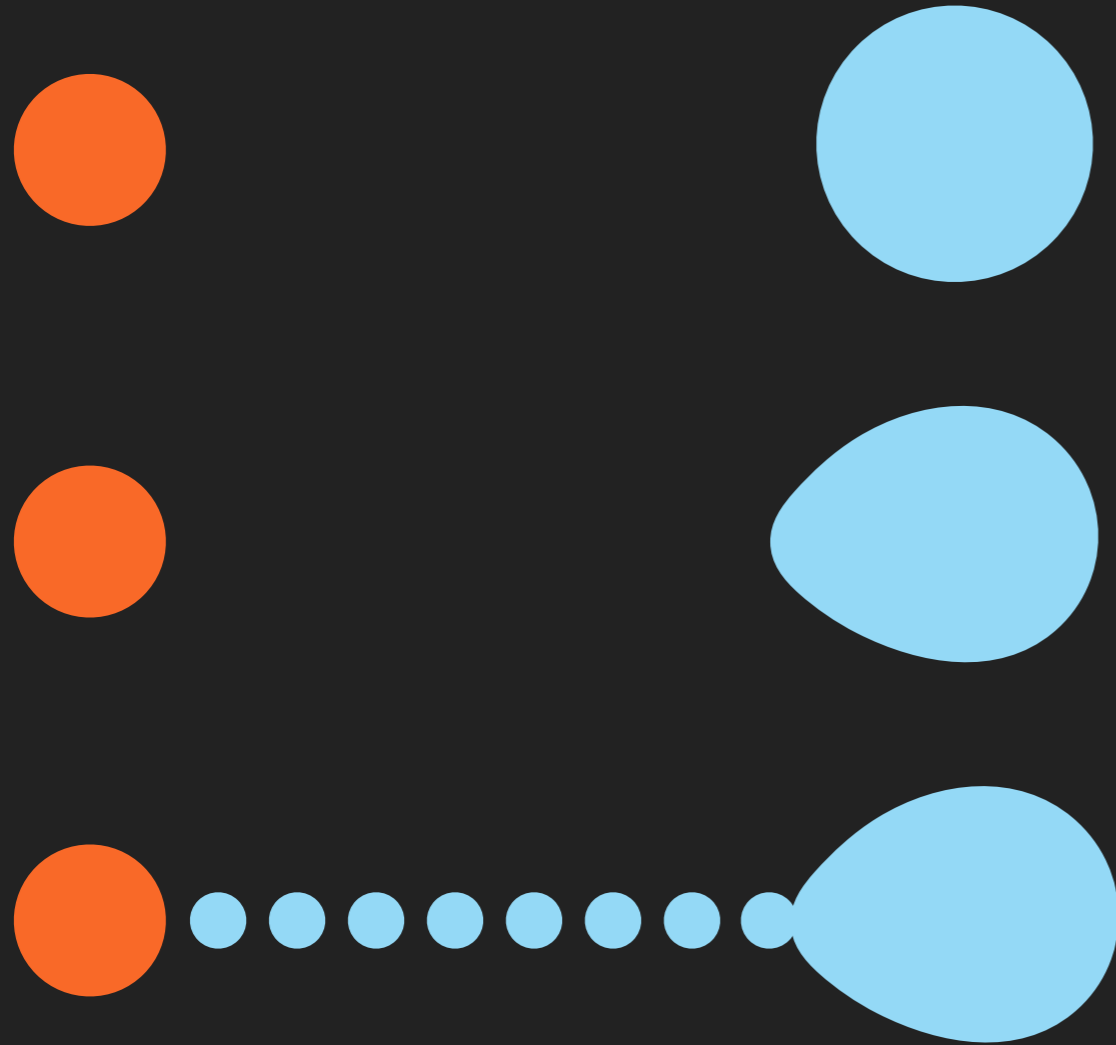


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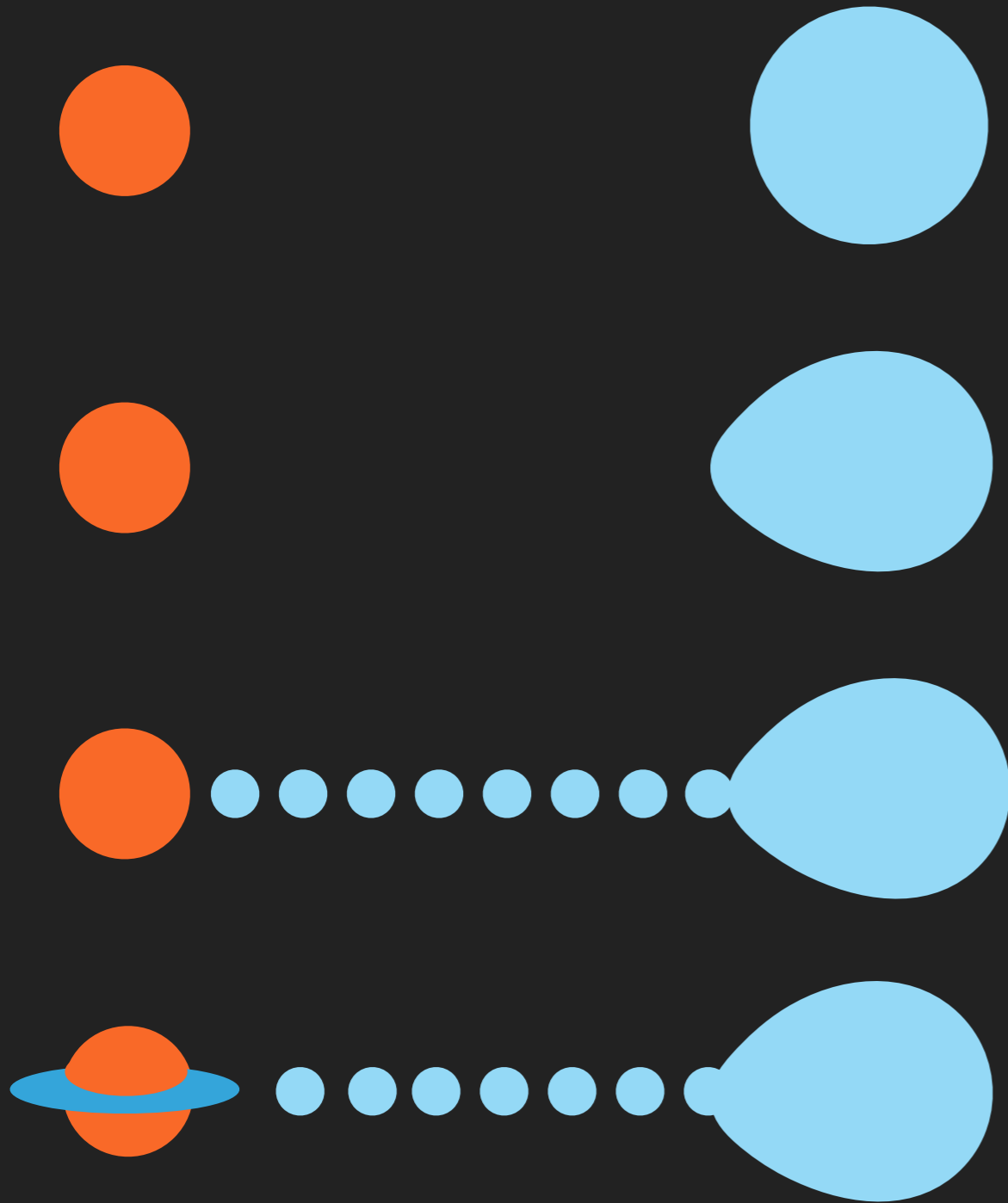




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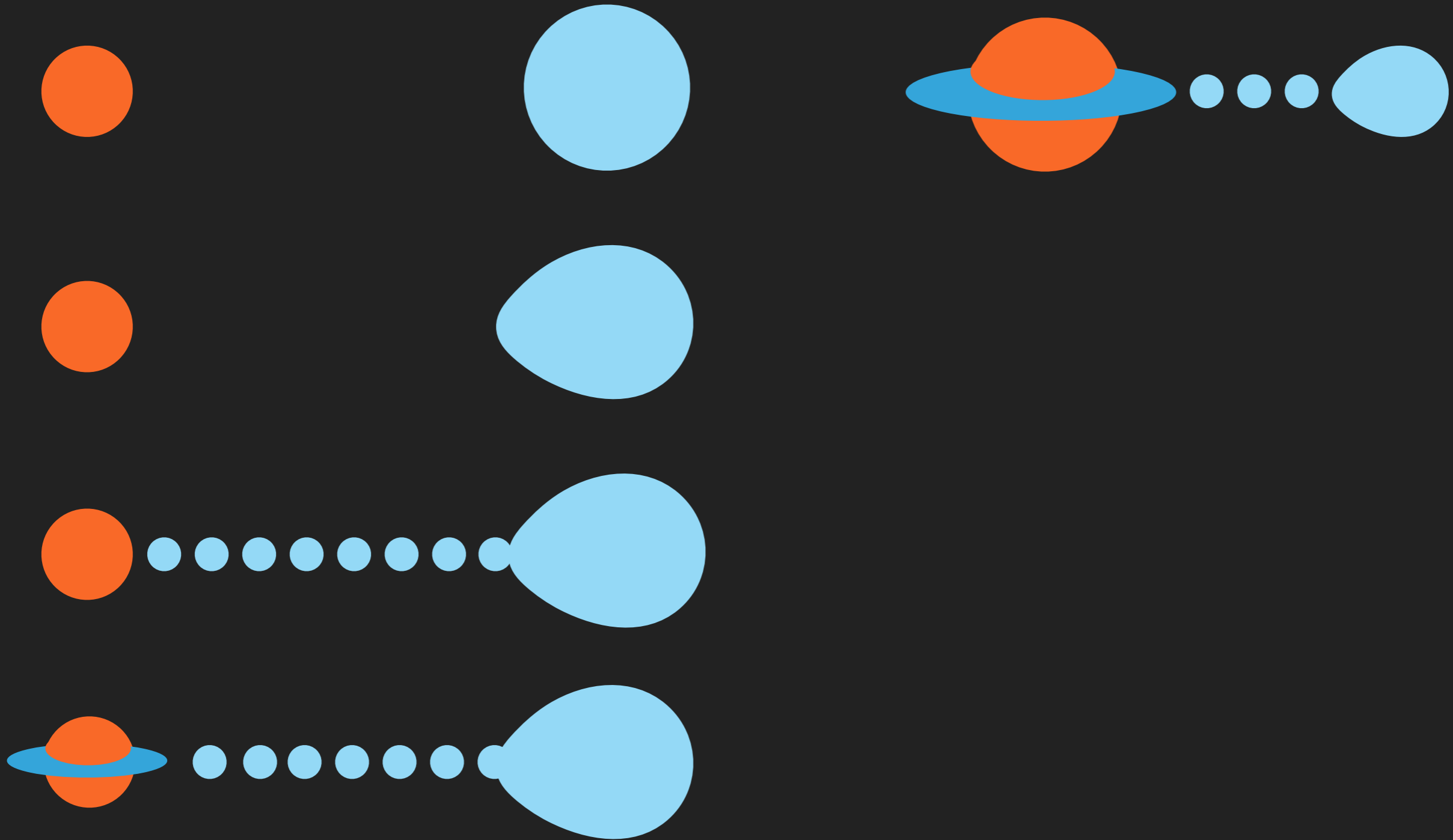


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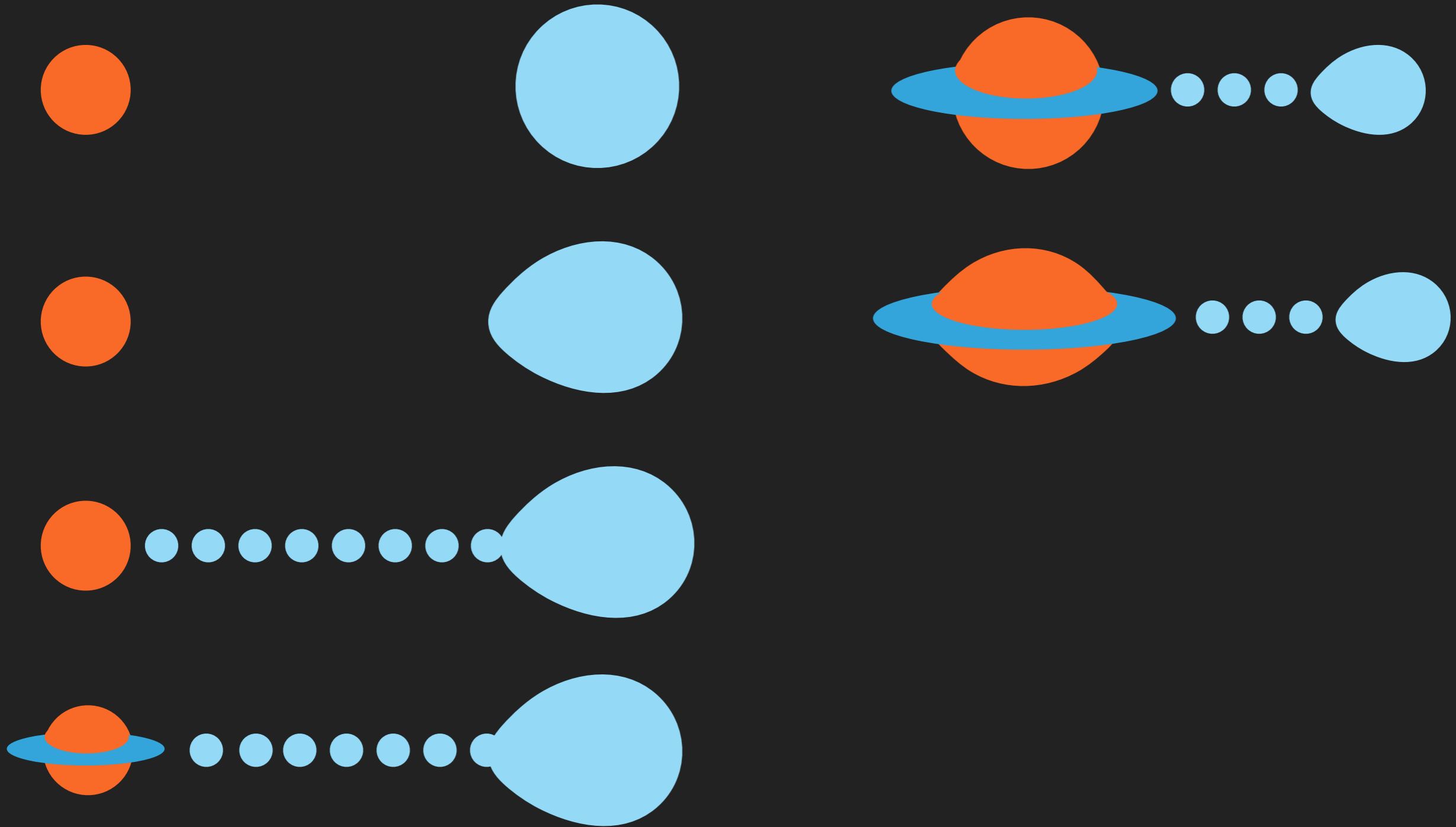




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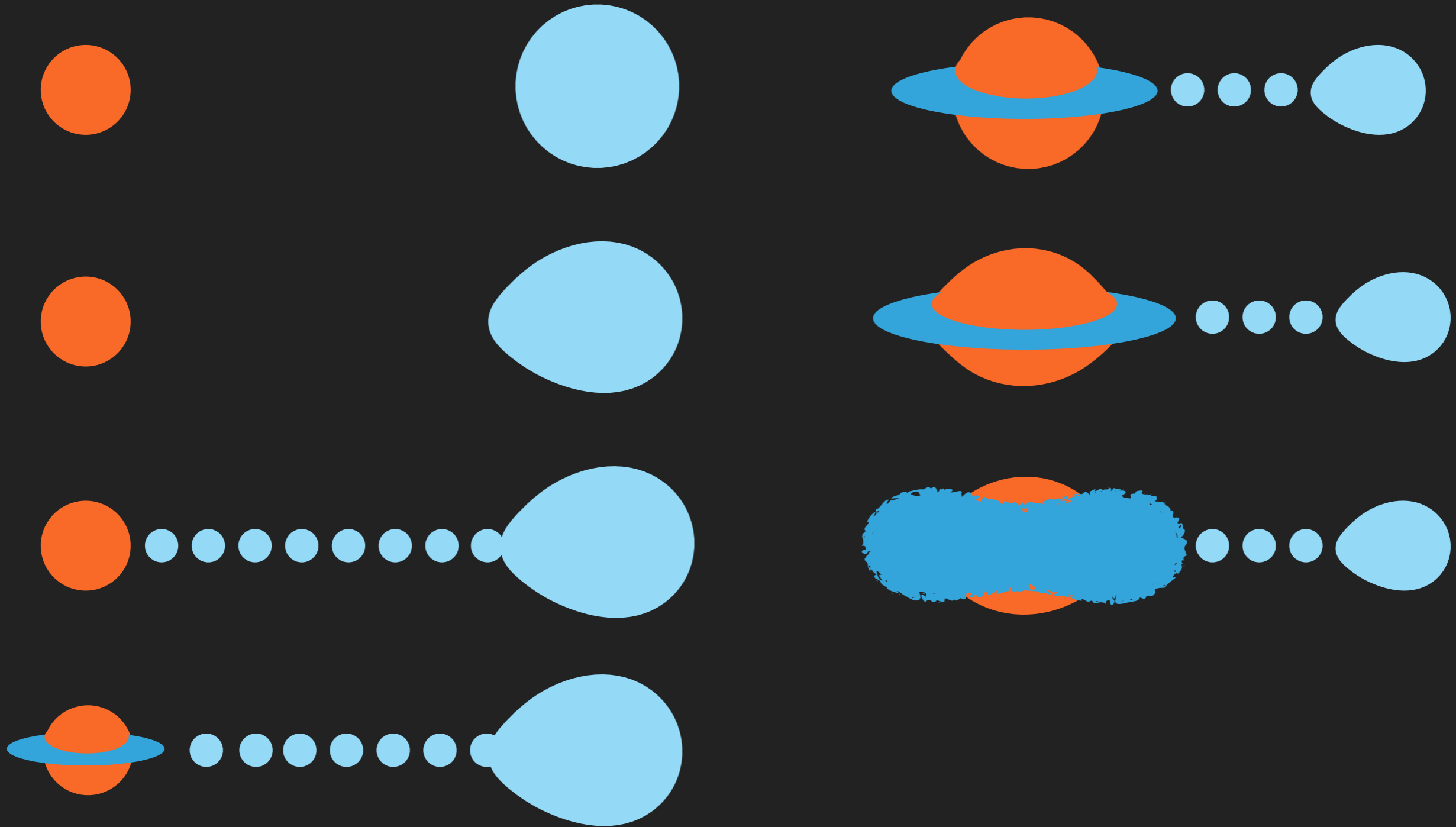


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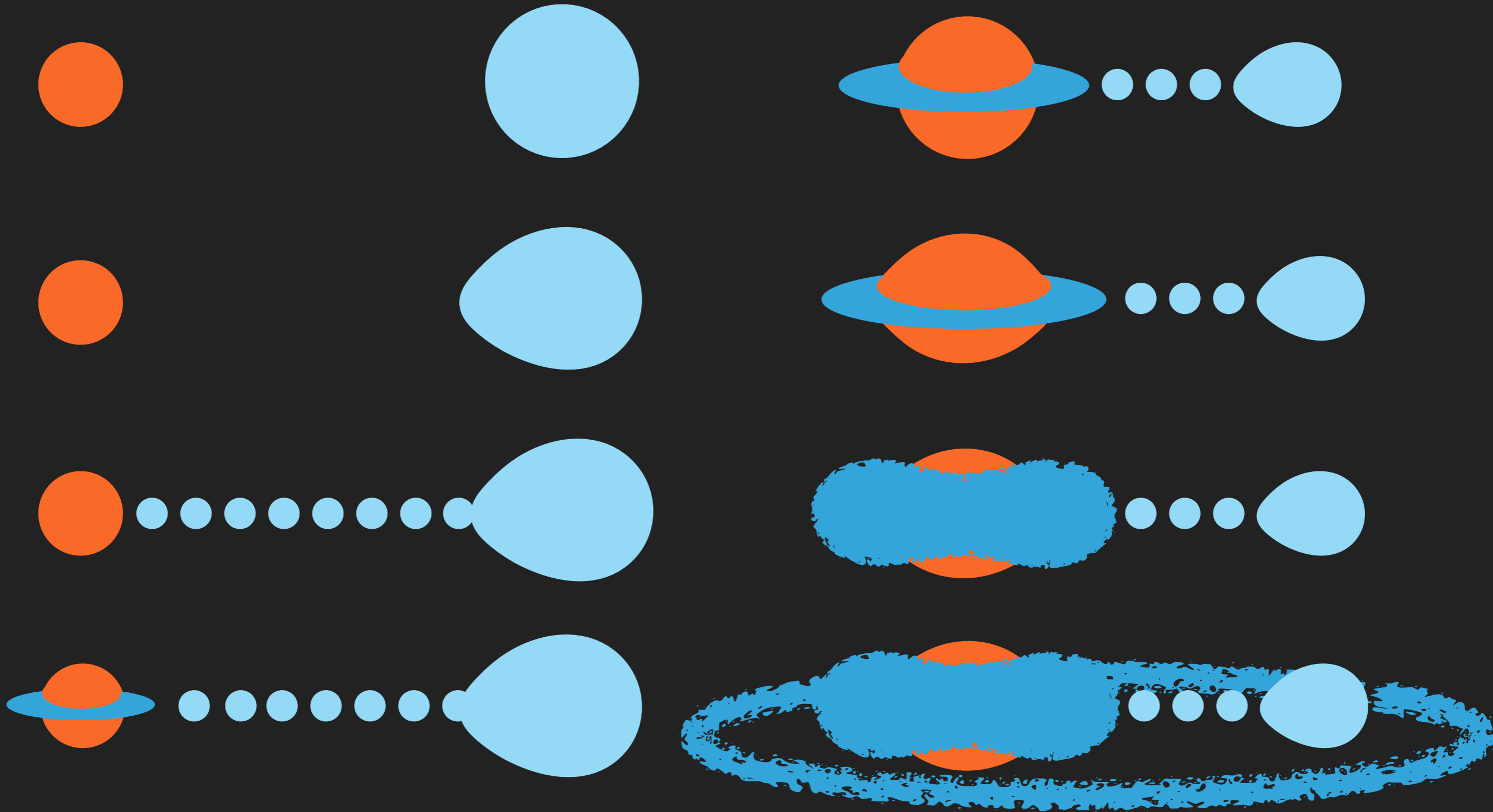




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- ▶ What do these systems evolve into?



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- ▶ What happens to the disk?
- ▶ How many of them exist?
- ▶ How do they influence their surroundings?





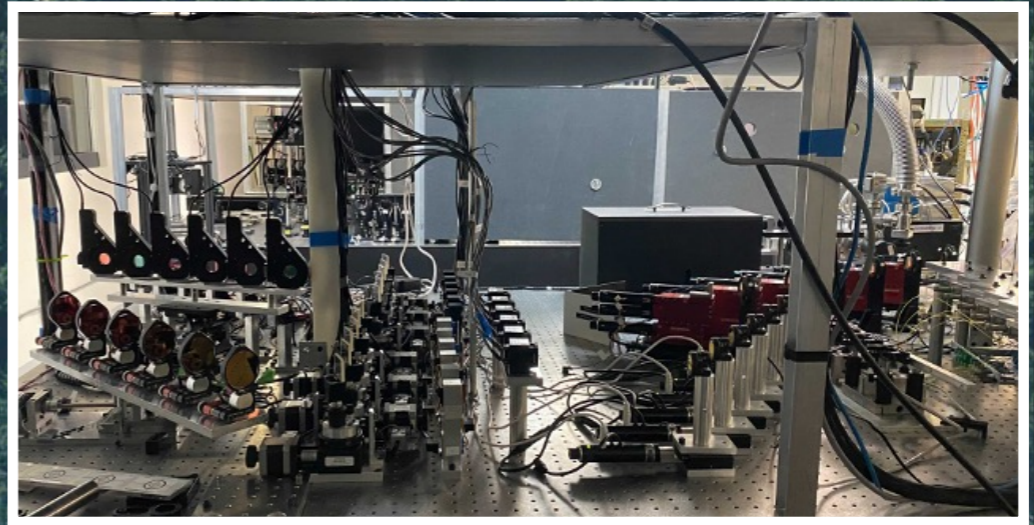
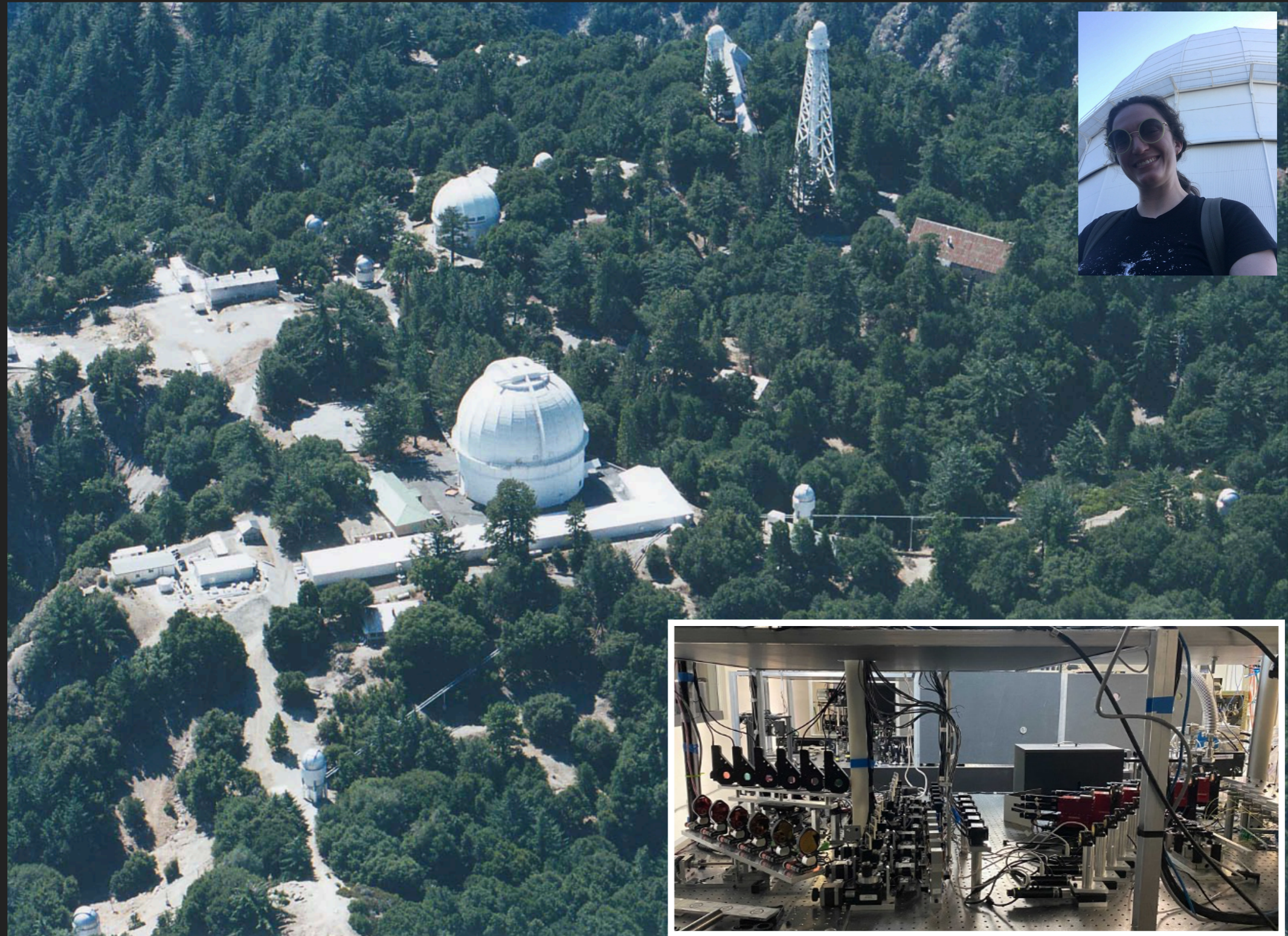
# WHY AM I STUDYING THESE?

- ▶ What do these systems evolve into?
- ▶ What happens to the disk?
- ▶ How many of them exist?
- ▶ How do they influence their surroundings?
- ▶ Further develop understanding of dynamics of mass transfer between stars





# HOW AM I GOING TO BE STUDYING THESE?





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## Interferometry

- ▶ Look at system as a whole
- ▶ Mass distribution of circumbinary disk
- ▶ Size of disk
- ▶ Separation of inner binary
- ▶ Orientation of system
- ▶ Binary motion signatures

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## Spectroscopy

- ▶ Look at energy levels
- ▶ Confirm orbital periods
- ▶ Maybe map orbits
- ▶ How does orbital phase influence circumbinary disk



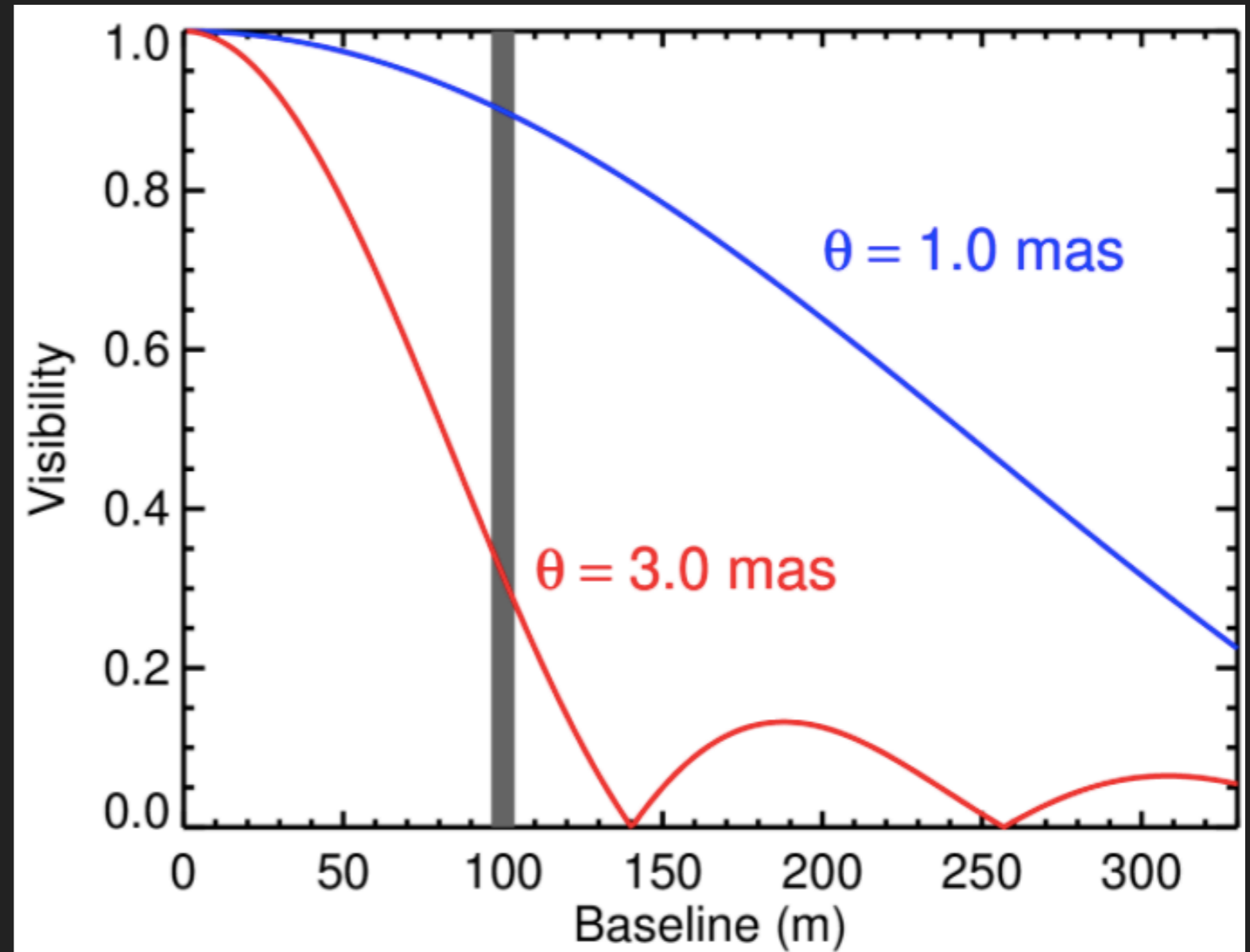
# NUMBER OF OBSERVATIONS SO FAR



Star Name	Spectral Type	# of MIRCX		# of Mystic		# of APO
		5T	6T	5T	6T	
▶ BD+14 3887	B3 Ibe	-	1	-	-	3
▶ HD 181615	B2 Vp sh	-	1	-	-	9
▶ V729 Cyg	O6.5 Iafe	-	4	-	2	3
▶ HD 198288	A3 Ibep	1	3	1	1	12
▶ HD 216200	B4+F9 III	-	4	1	2	20
▶ HD 218393	B3 pe+ K1 III	2	3	2	-	21
▶ HD 166126	F8/G2 Iaep	1	-	-	-	4
▶ HD 166937	B8 lab(e)	2	-	-	-	7
▶ HD 169515	O9.7 Ibep	3	-	2	-	8
▶ HD 45677	B2 IV/V[e]	-	-	-	-	4
▶ HD 45910	B2 IIIe	-	-	-	-	8
▶ HD 50138	A1 Ib/II	-	-	-	-	7
▶ HD 51480	Be sh	-	-	-	-	6

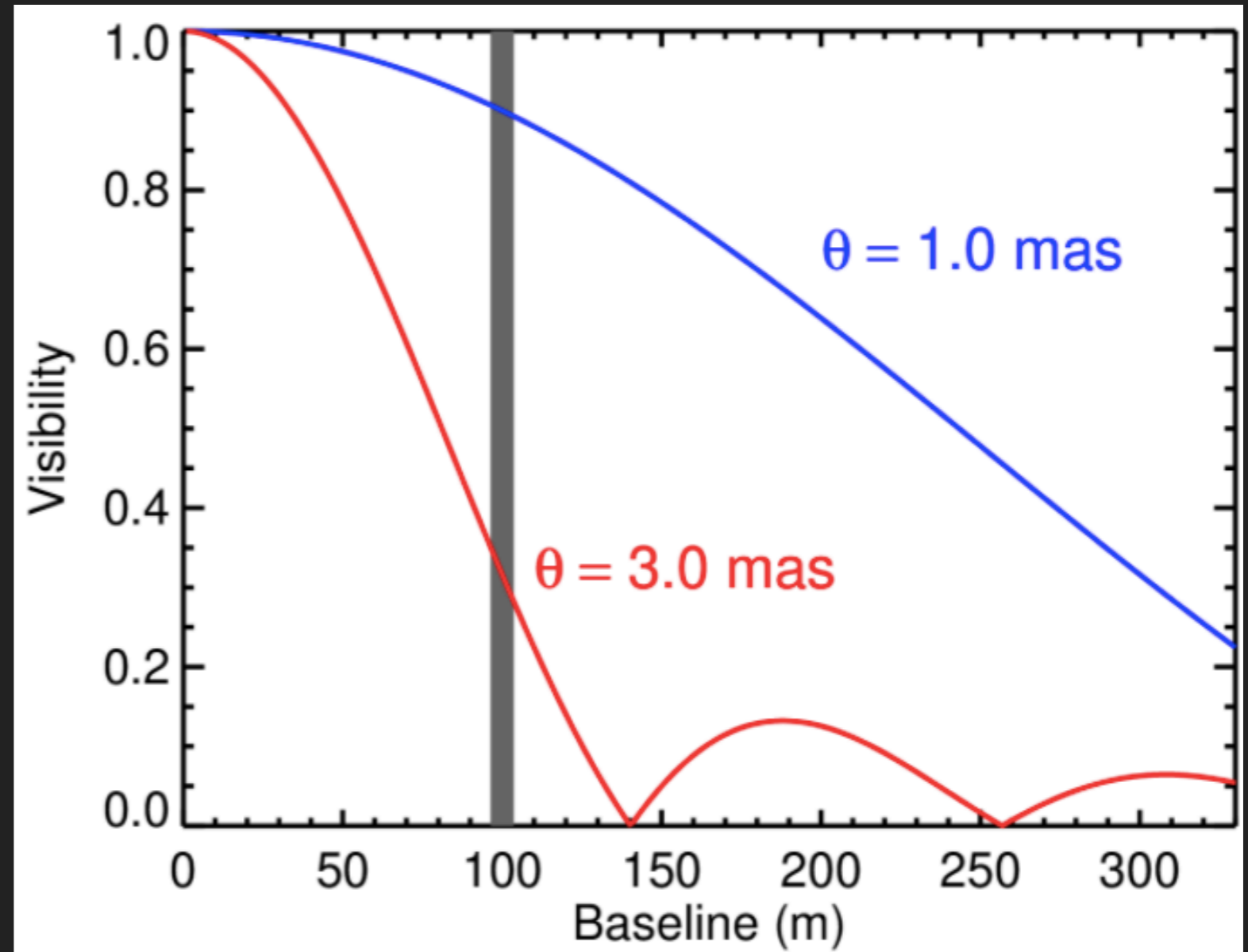
# REFRESHER ON VISIBILITIES

- ▶ Large objects produce smaller fringes (and vice versa)



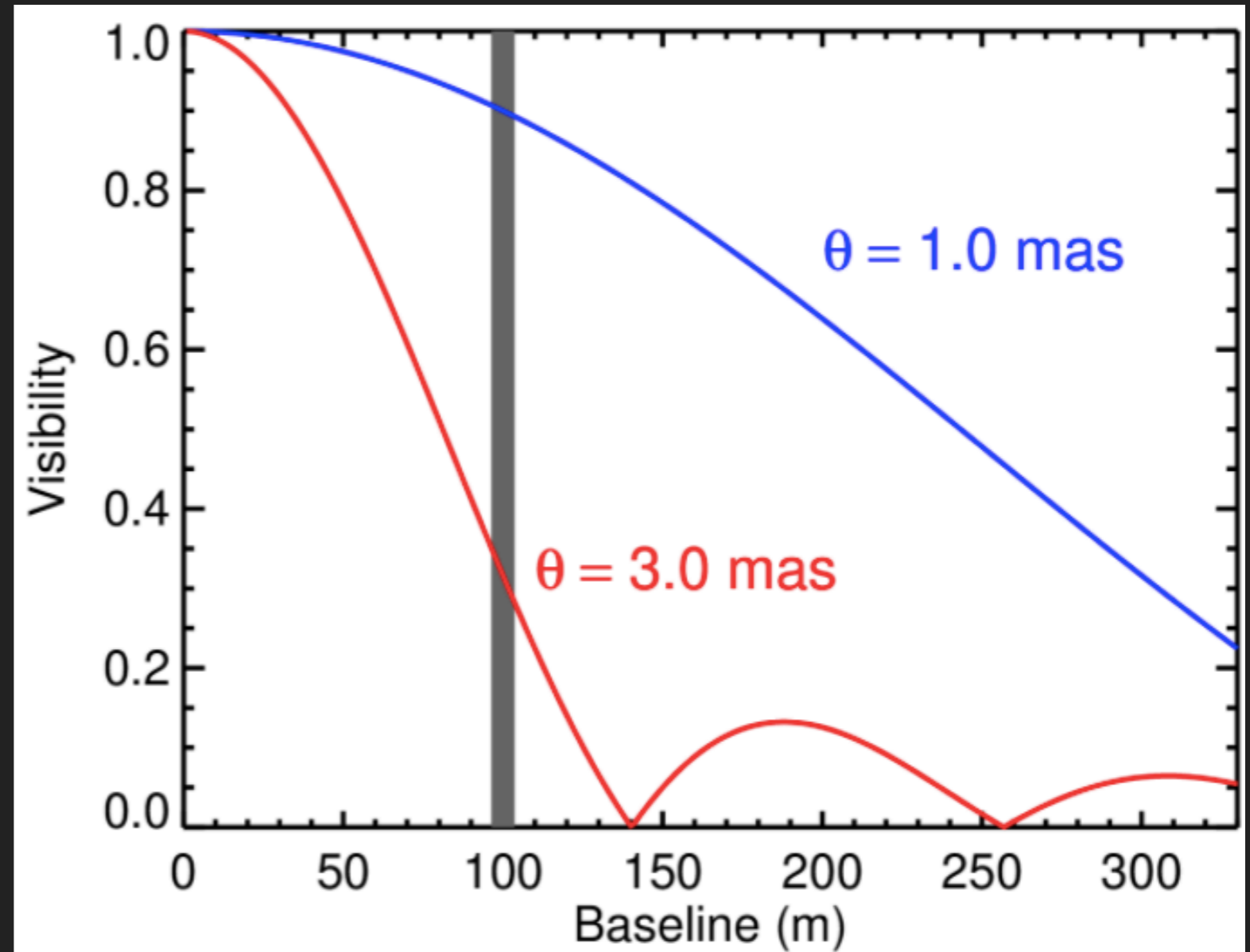
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- ▶ Visibilities measure the difference of the maximum and minimum amplitude of the fringe



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- ▶ Large objects produce smaller fringes (and vice versa)
- ▶ Visibilities measure the difference of the maximum and minimum amplitude of the fringe
- ▶ A large object will produce smaller visibilities

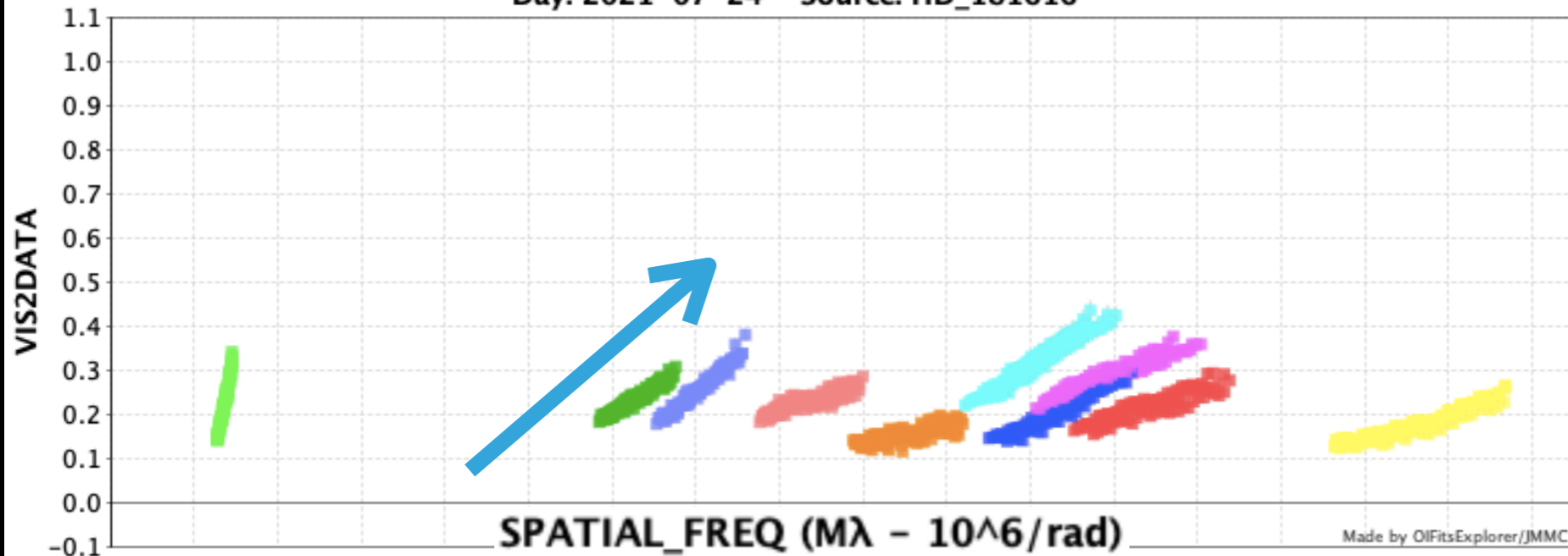




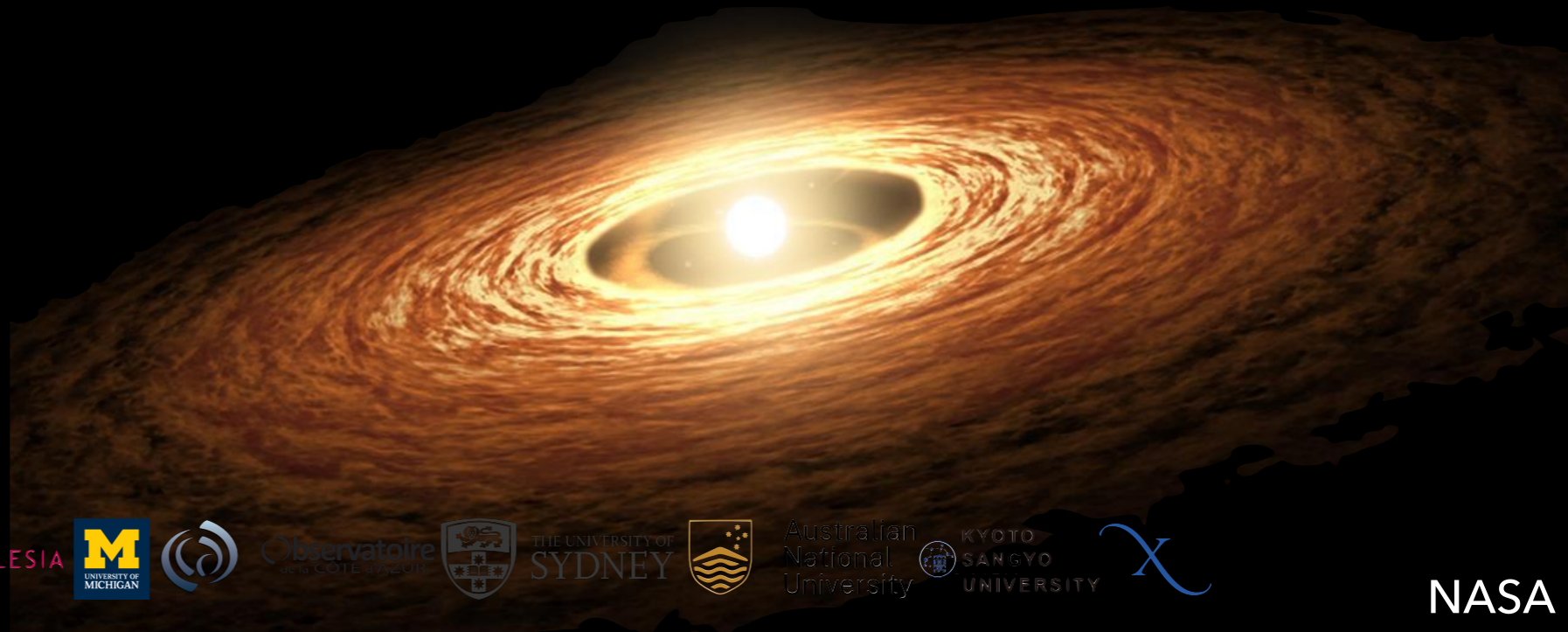
# INITIAL LOOK AT MIRCX DATA



CHARA - MIRCX [1.5003  $\mu\text{m}$  - 1.7352  $\mu\text{m}$ ] - S1-S2-E1-E2-W1-W2  
Day: 2021-07-24 - Source: HD\_181616



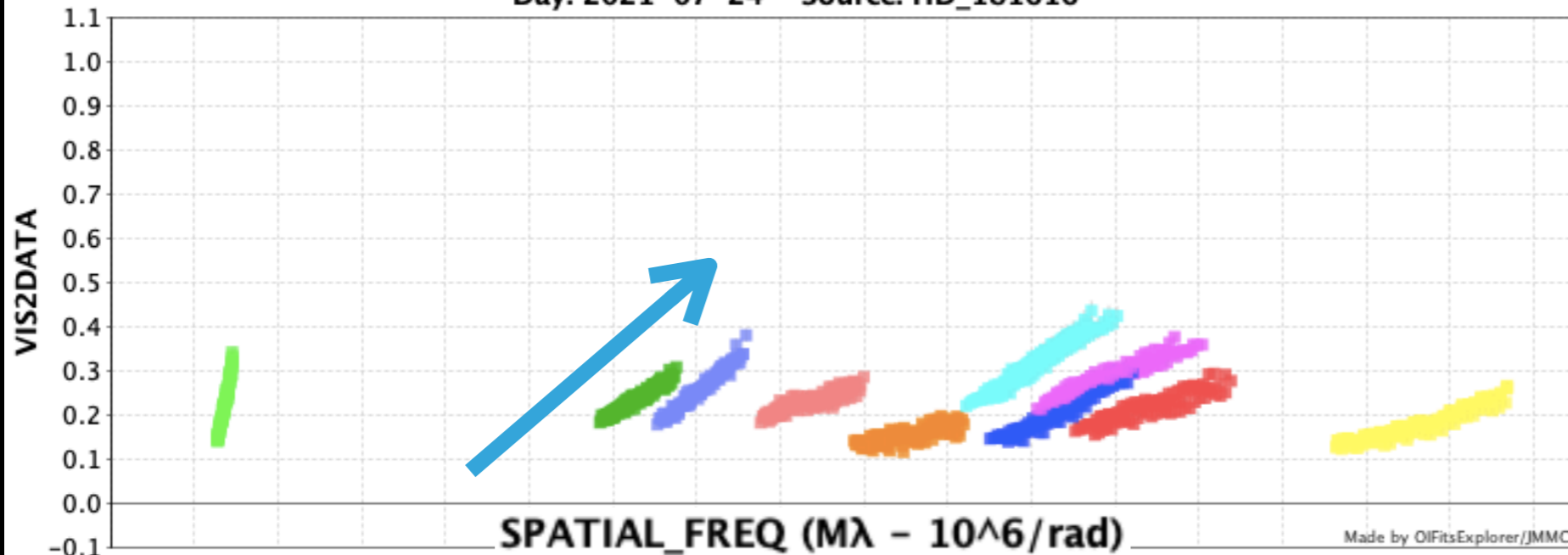
- ▶ Frequency is inversely related to wavelength



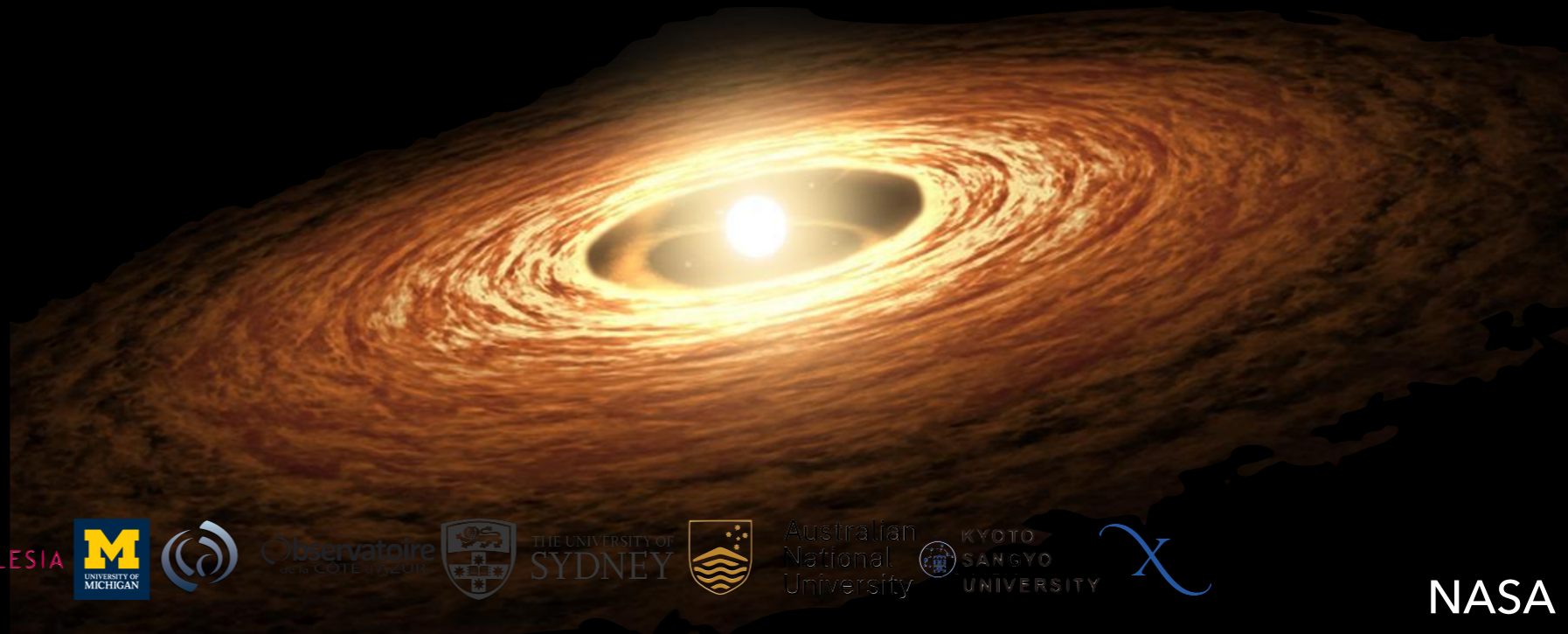
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- ▶ Frequency is inversely related to wavelength
- ▶ So smaller frequencies = longer wavelengths

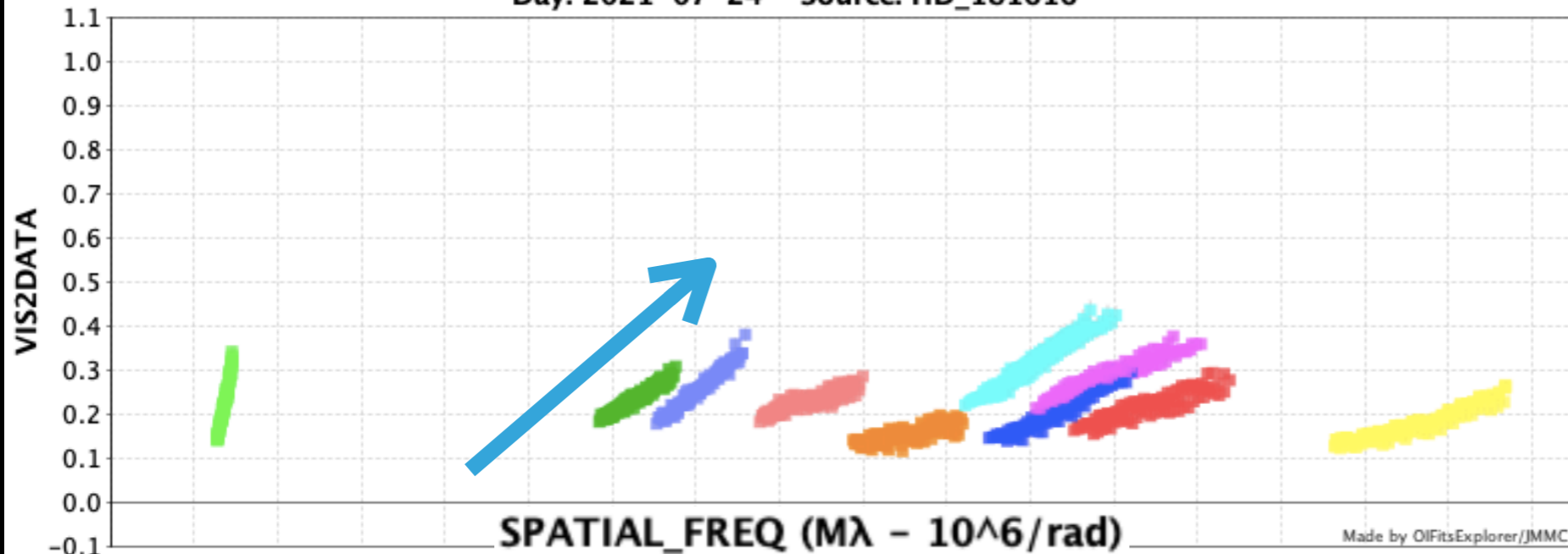




# INITIAL LOOK AT MIRCX DATA

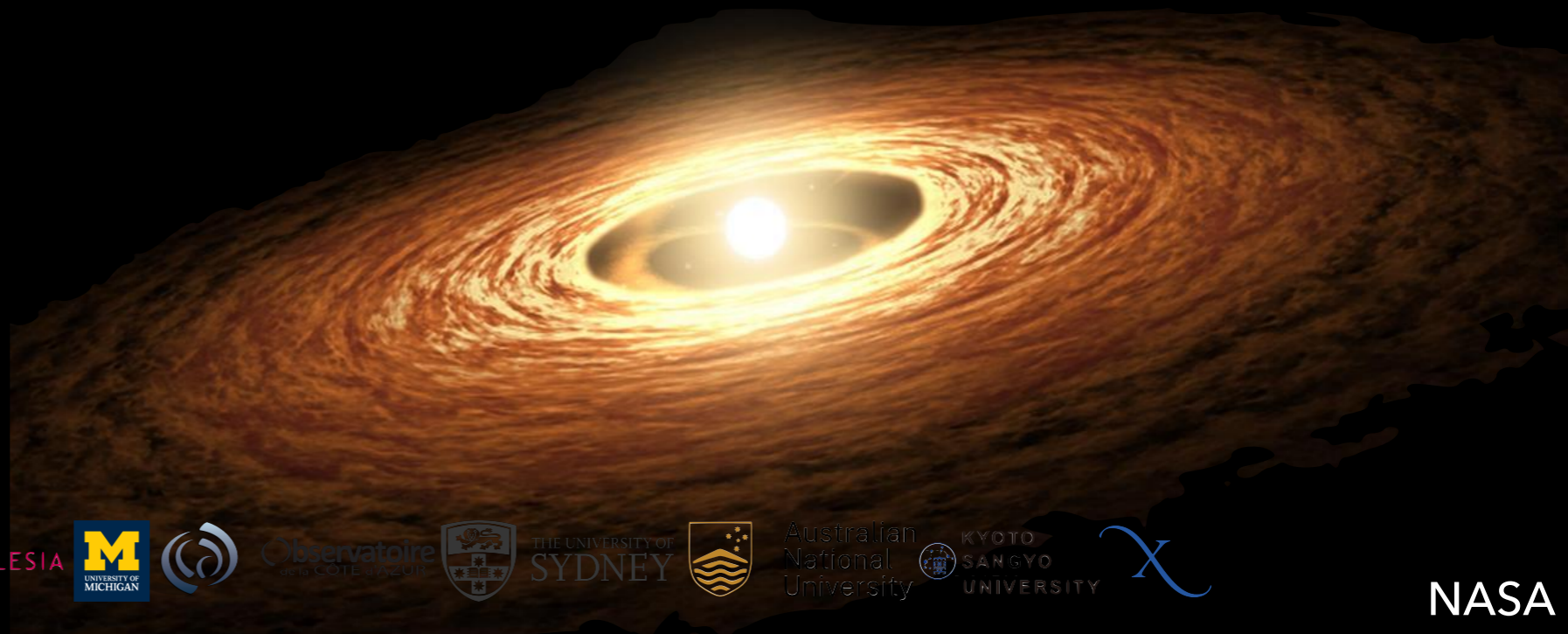


CHARA - MIRCX [1.5003  $\mu\text{m}$  - 1.7352  $\mu\text{m}$ ] - S1-S2-E1-E2-W1-W2  
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- ▶ Frequency is inversely related to wavelength
- ▶ So smaller frequencies = longer wavelengths

- ▶ Longer wavelengths correspond to cooler objects and vice versa

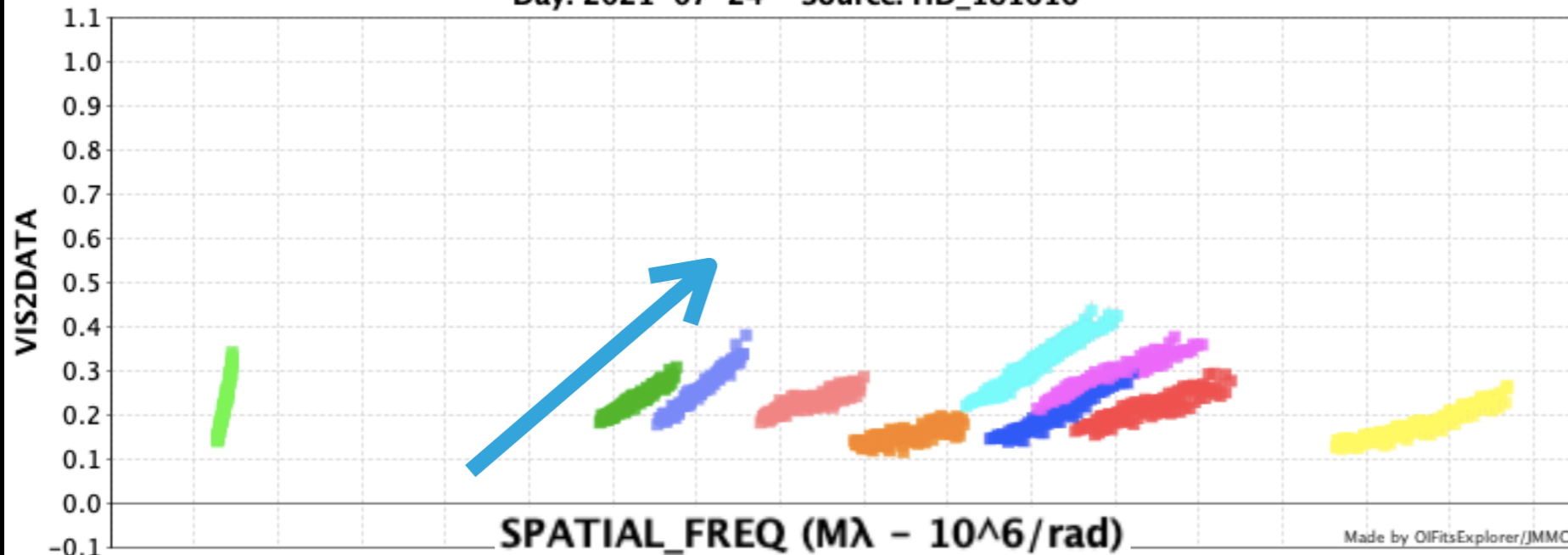




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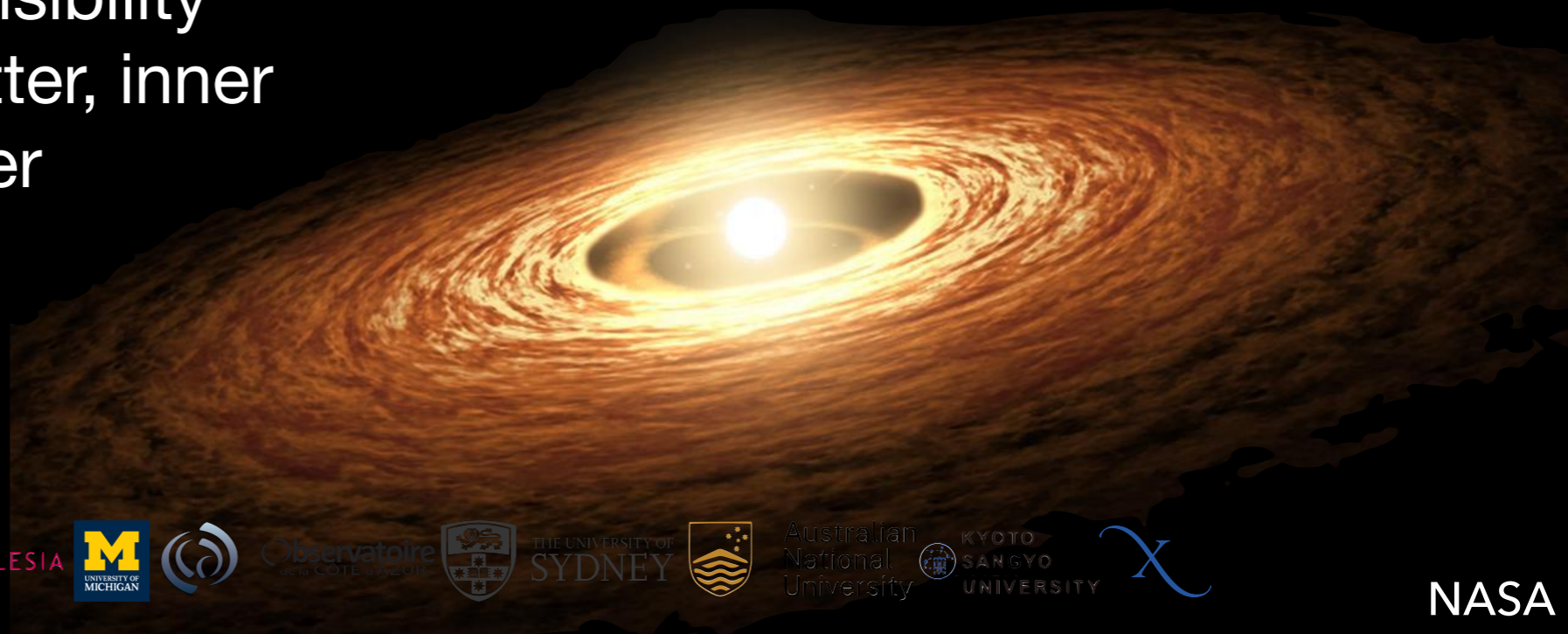


CHARA - MIRCX [1.5003  $\mu\text{m}$  - 1.7352  $\mu\text{m}$ ] - S1-S2-E1-E2-W1-W2  
Day: 2021-07-24 - Source: HD\_181616

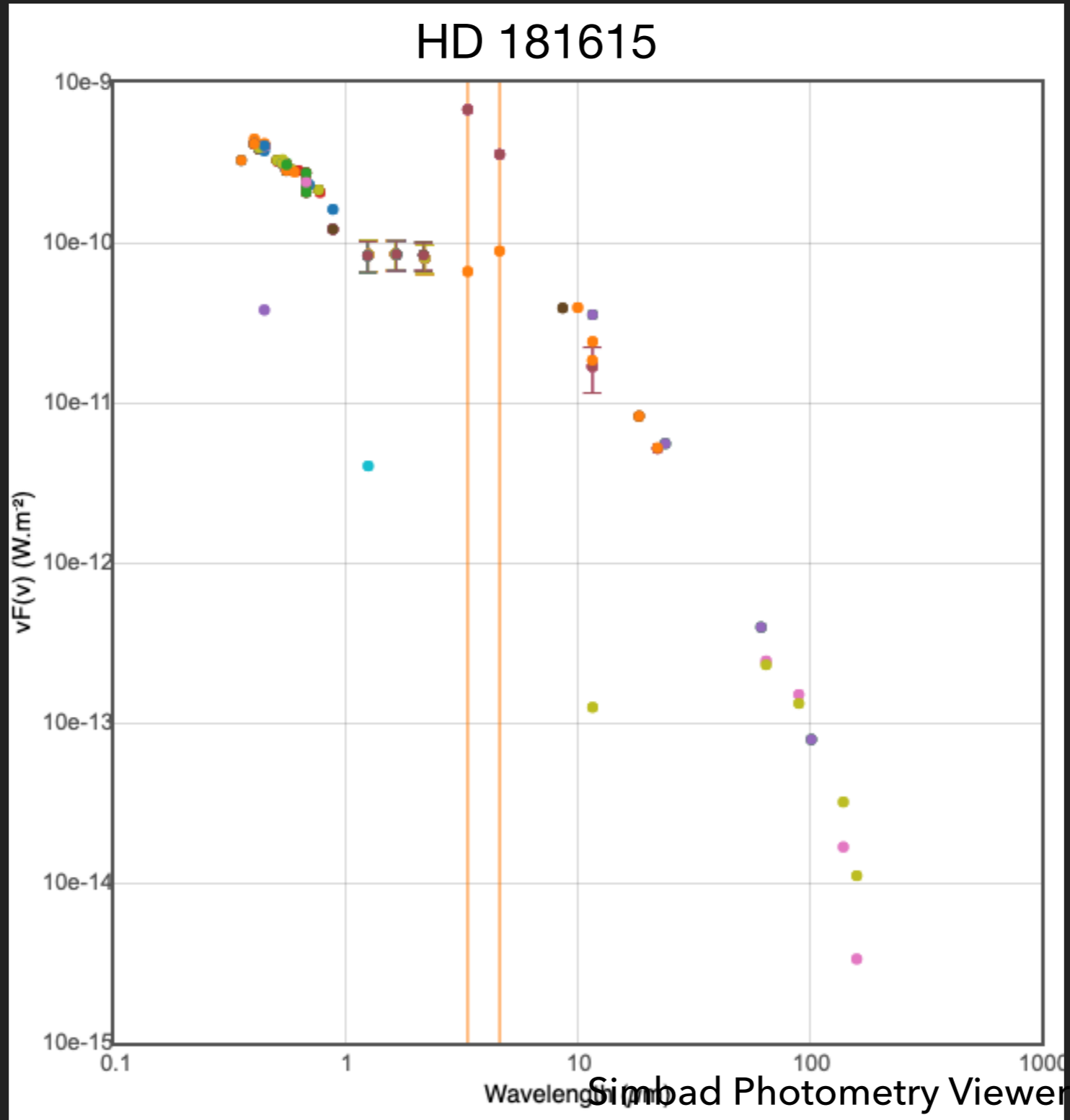


- ▶ Frequency is inversely related to wavelength
- ▶ So smaller frequencies = longer wavelengths

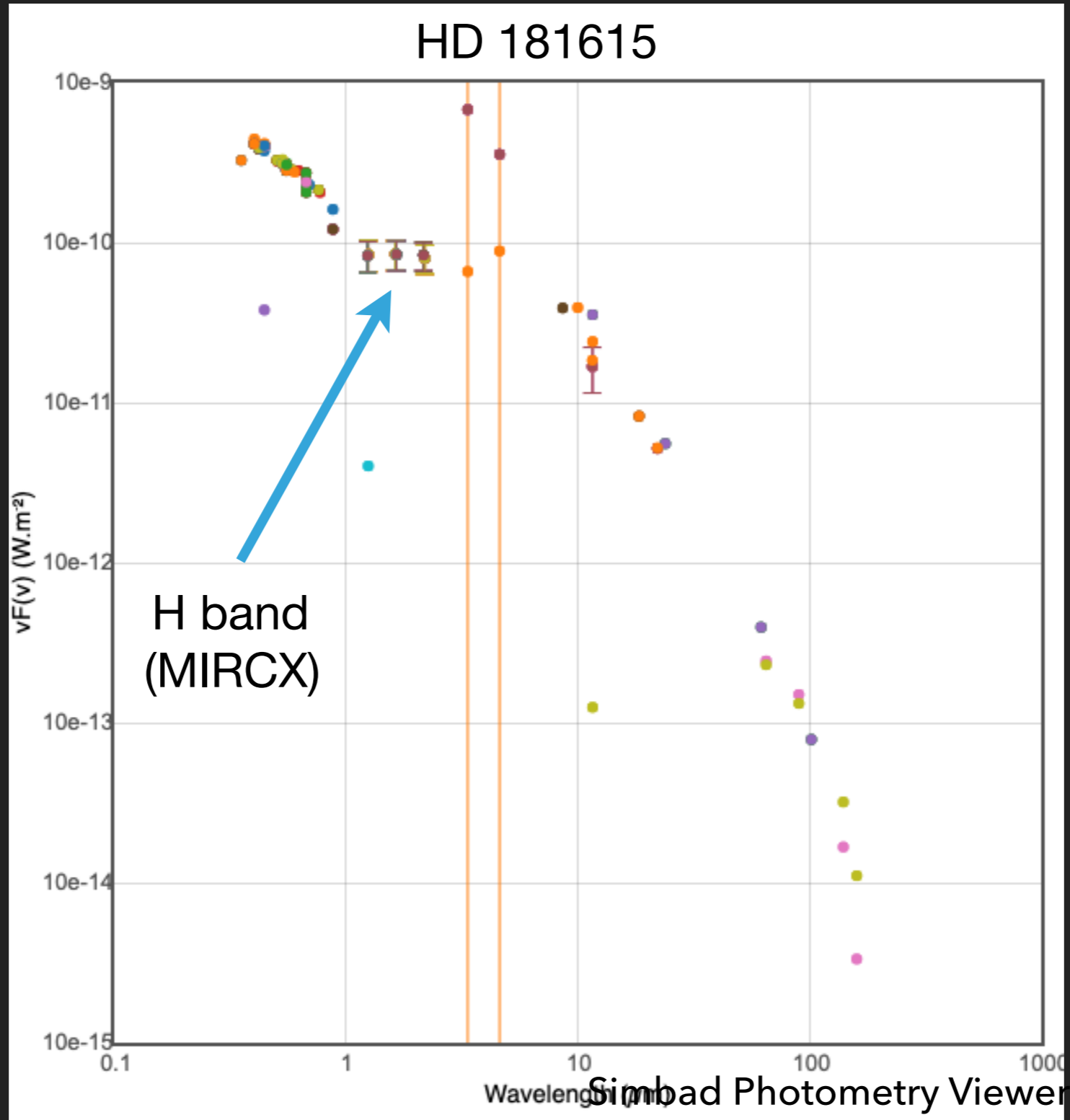
- ▶ Longer wavelengths correspond to cooler objects and vice versa
- ▶ The bigger, cooler, outer disk produces a smaller visibility while the smaller, hotter, inner disk produces a larger visibility



# INITIAL LOOK AT MIRCX DATA

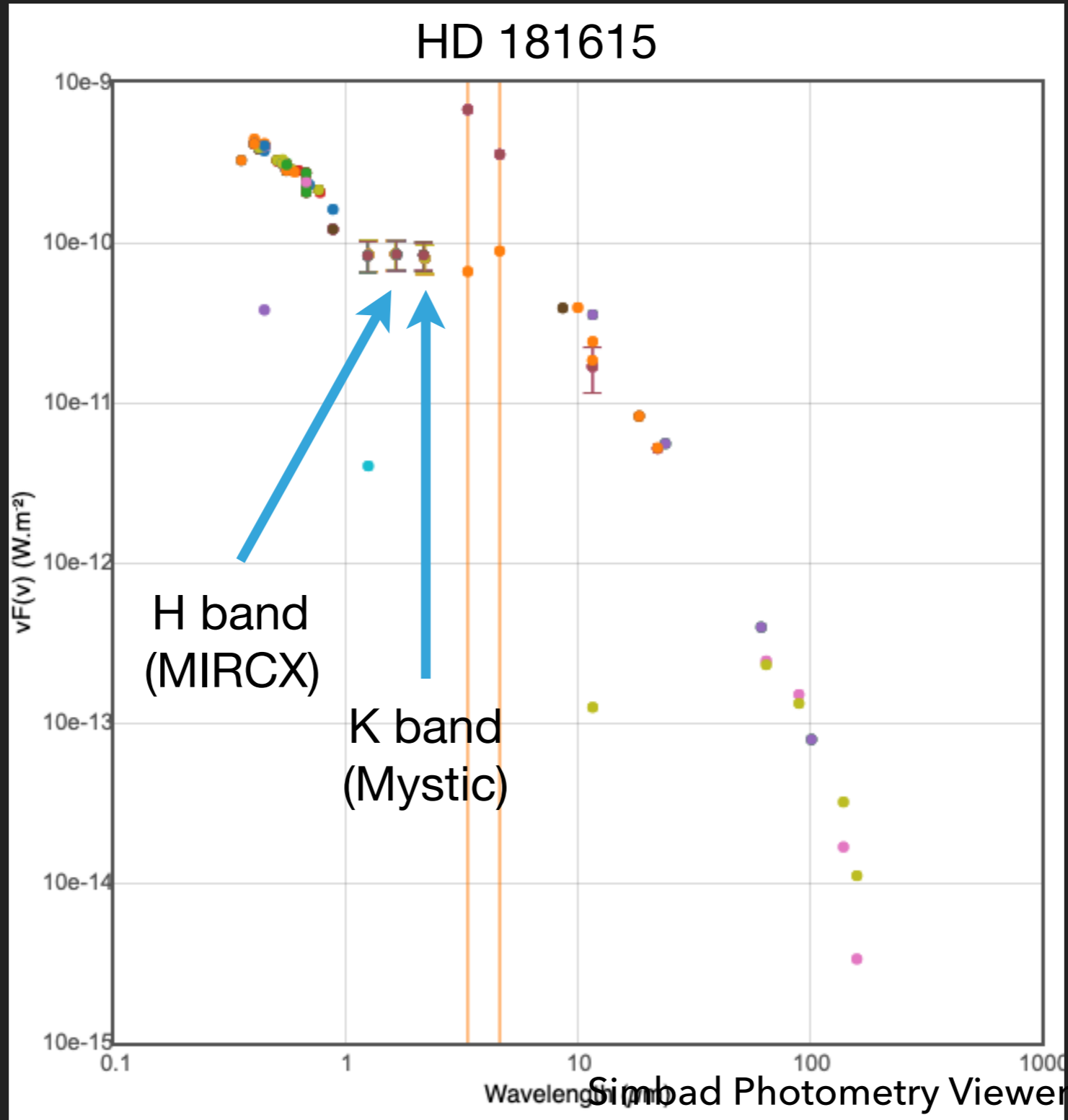


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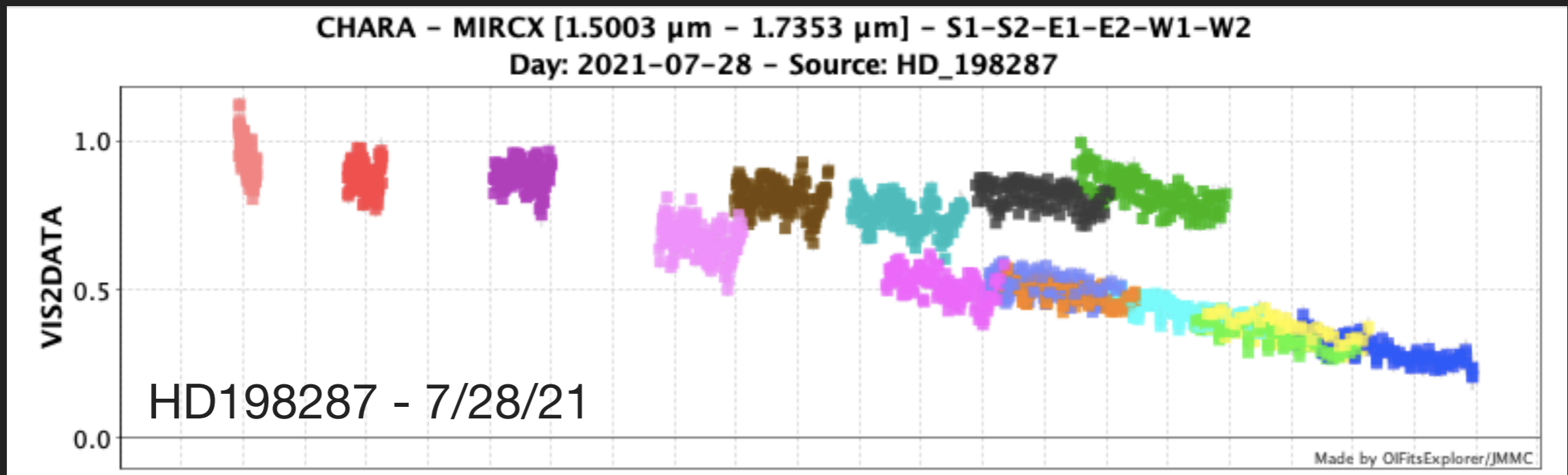
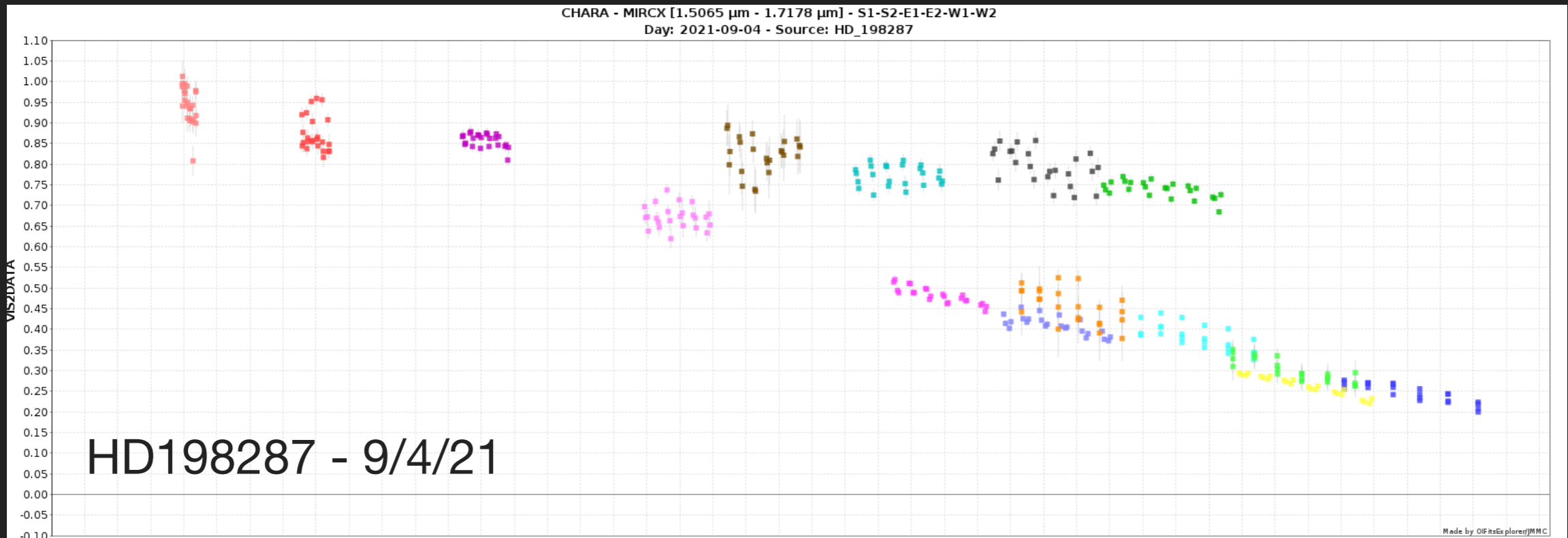




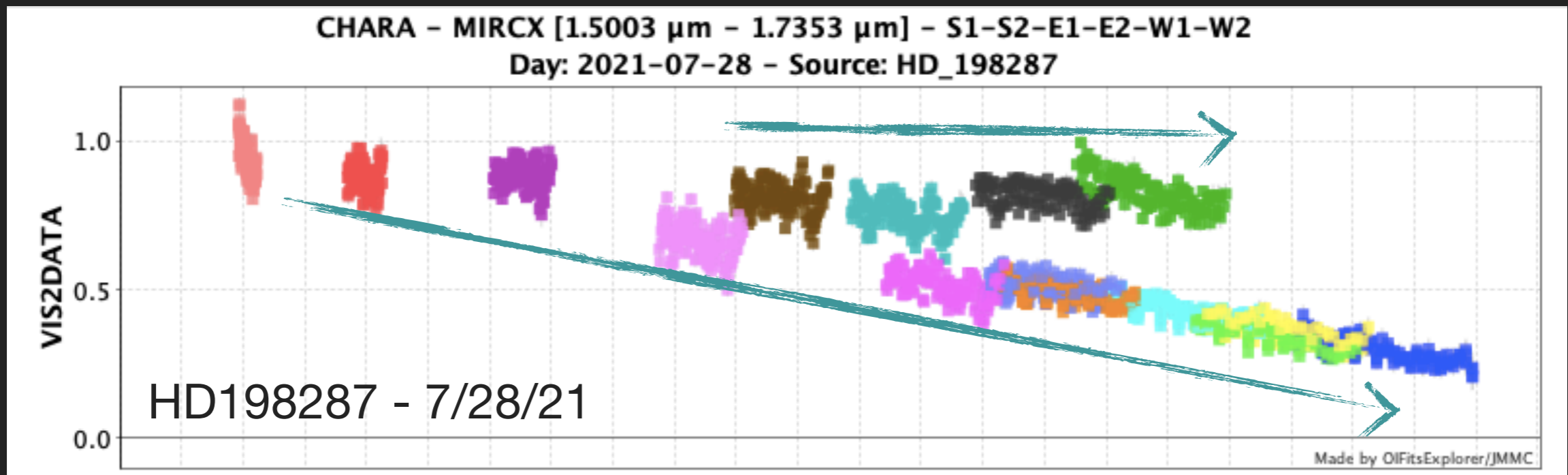
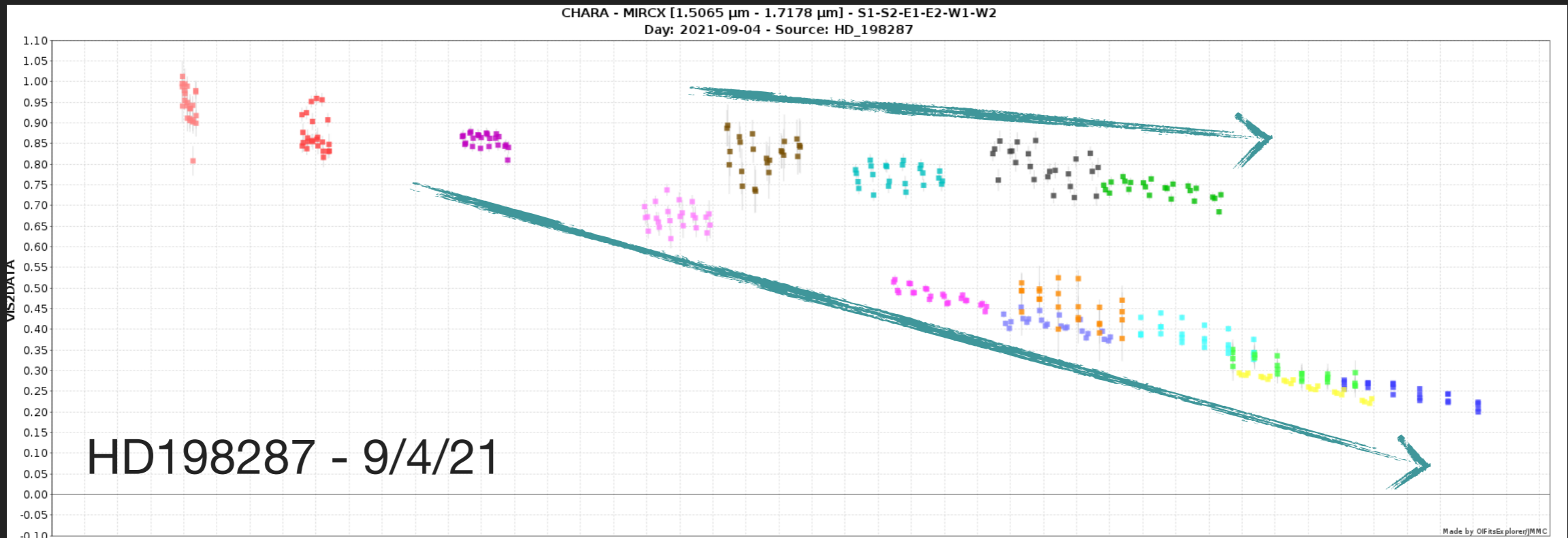
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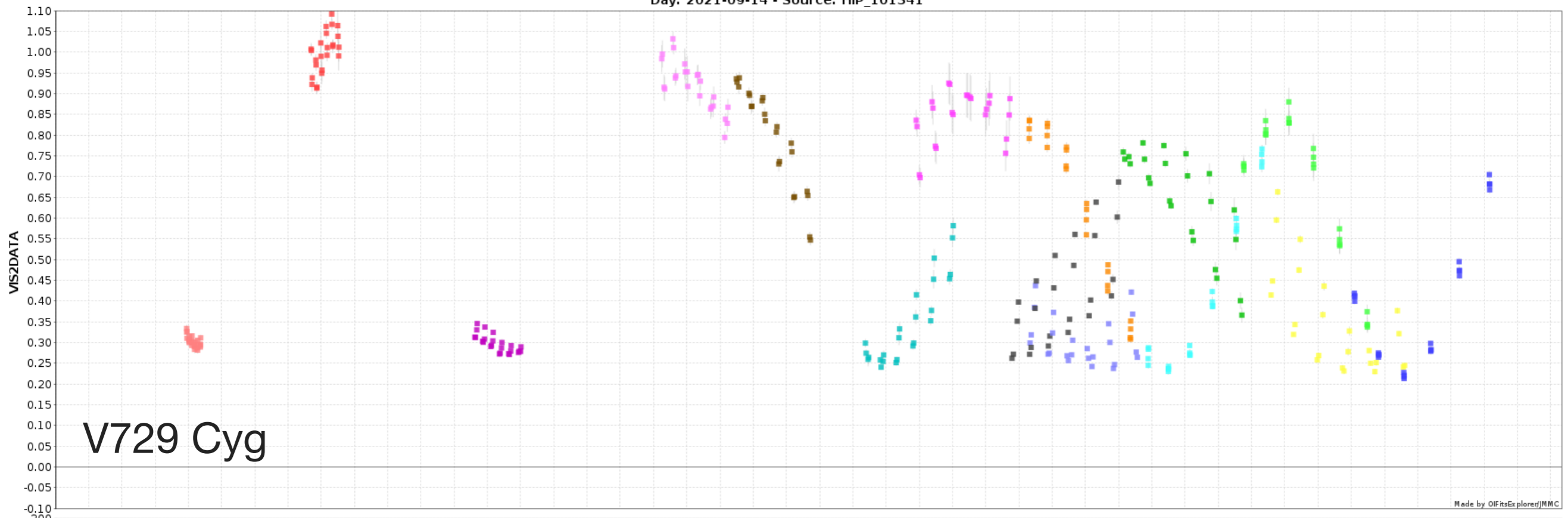




# INITIAL LOOK AT MIRCX DATA



CHARA - MIRCX [1.506  $\mu\text{m}$  - 1.7172  $\mu\text{m}$ ] - S1-S2-E1-E2-W1-W2  
Day: 2021-09-14 - Source: HIP\_101341

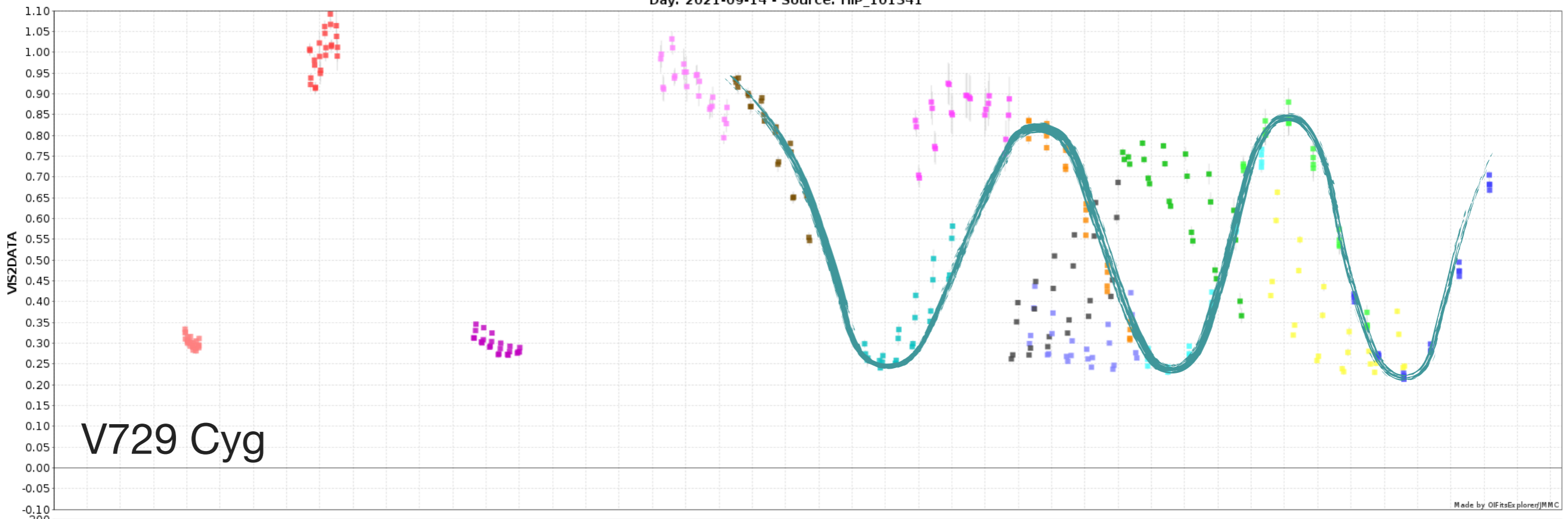


Made by OIFitsExplorer/JMMC

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Day: 2021-09-14 - Source: HIP\_101341



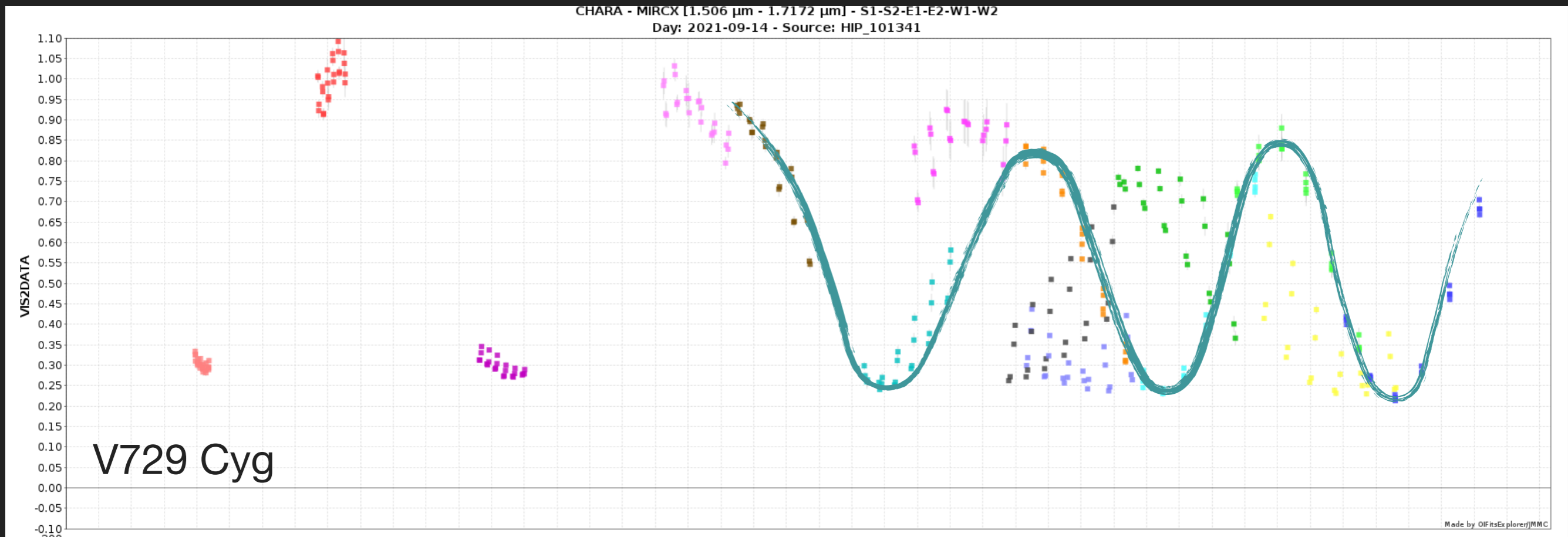
Made by OIFitsExplorer/JMMC



# INITIAL LOOK AT MIRCX DATA



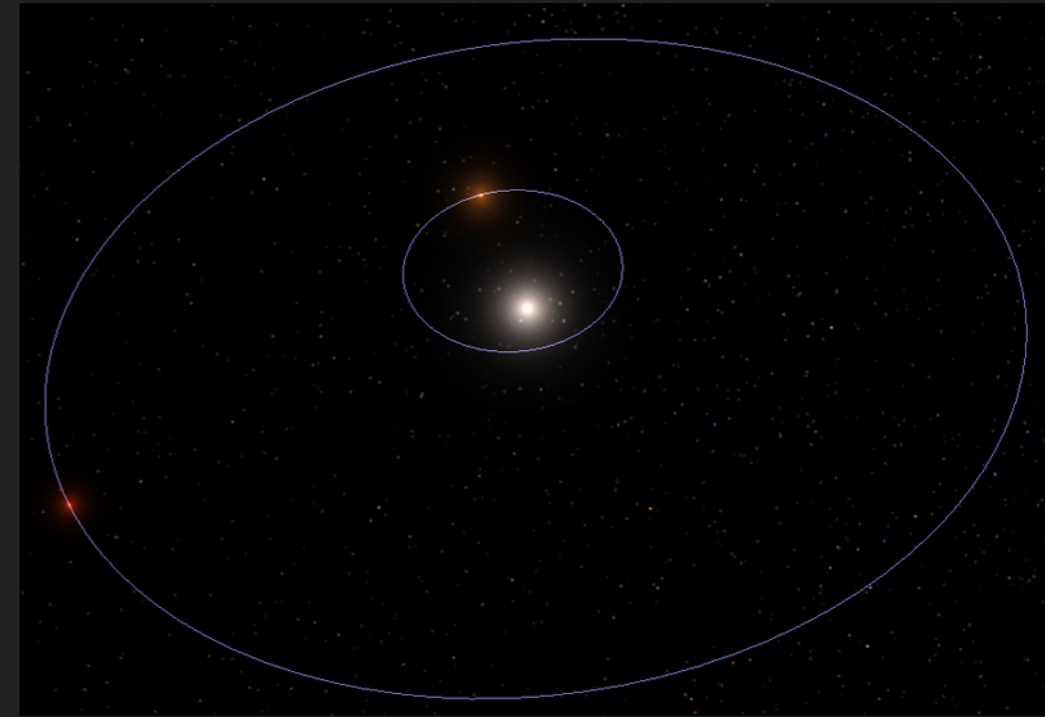
- ▶ Not binary motion



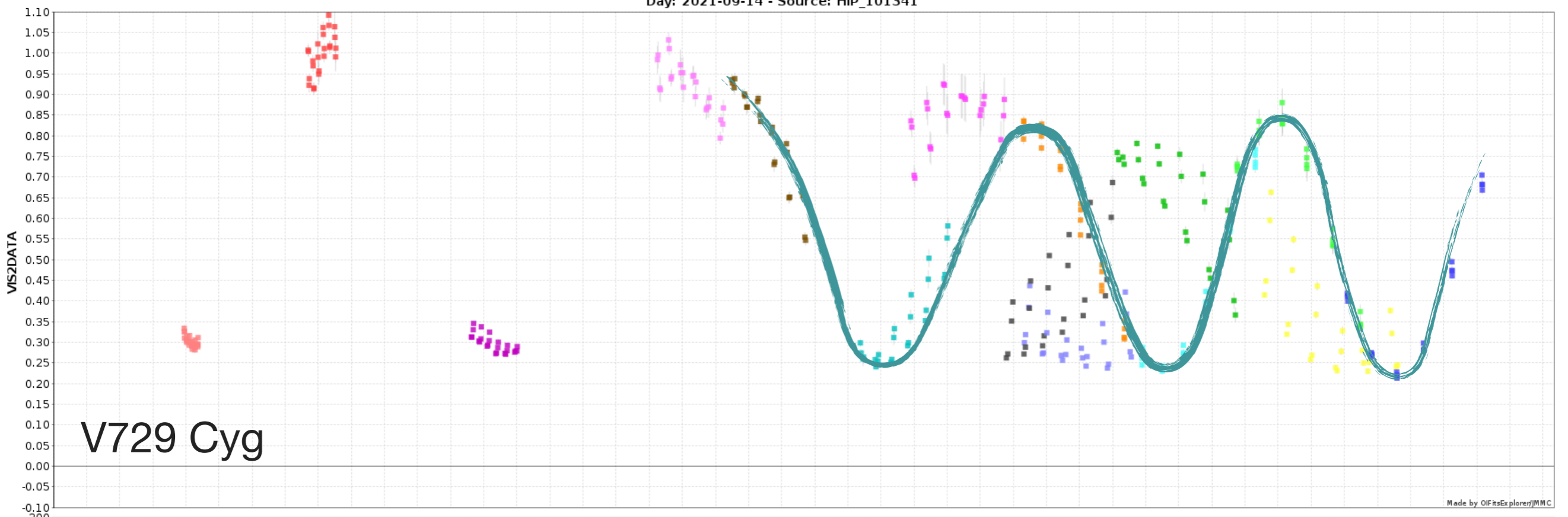
# INITIAL LOOK AT MIRCX DATA



- ▶ Not binary motion
- ▶ Actually tertiary motion! →



CHARA - MIRCX [1.506  $\mu\text{m}$  - 1.7172  $\mu\text{m}$ ] - S1-S2-E1-E2-W1-W2  
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# SIMPLE MODELS - 7/2421



## Adaptive Grid Search by Dr. Gail Schaefer

Grid Search Parameters

sepRA (mas):   Fix Companion is located at (sepRA, sepDEC) in mas.

sepDEC (mas):   Fix

f1:   Fix Flux contribution of star 1 (values from 0 to 1).  $f1 + f2 + f3 = 1.0$

f2:   Fix Flux contribution of star 2 (values from 0 to 1).

f3:   Fix Incoherent flux (values from 0 to 1). Fix to 0 if no incoherent flux.

Diam1 (mas):   Fix Diameters of star 1 and star 2 (in mas)

Diam2 (mas):   Fix For unresolved diameters, fix to 0 or fix to estimated size.

### Grid Search Parameters

RA range (mas):  RA step (mas):

DEC range (mas):  DEC step (mas):

For an adaptive grid search, leave sepRA and sepDEC as free parameters.

For a grid search at fixed intervals, check the boxes to fix sepRA and sepDEC.

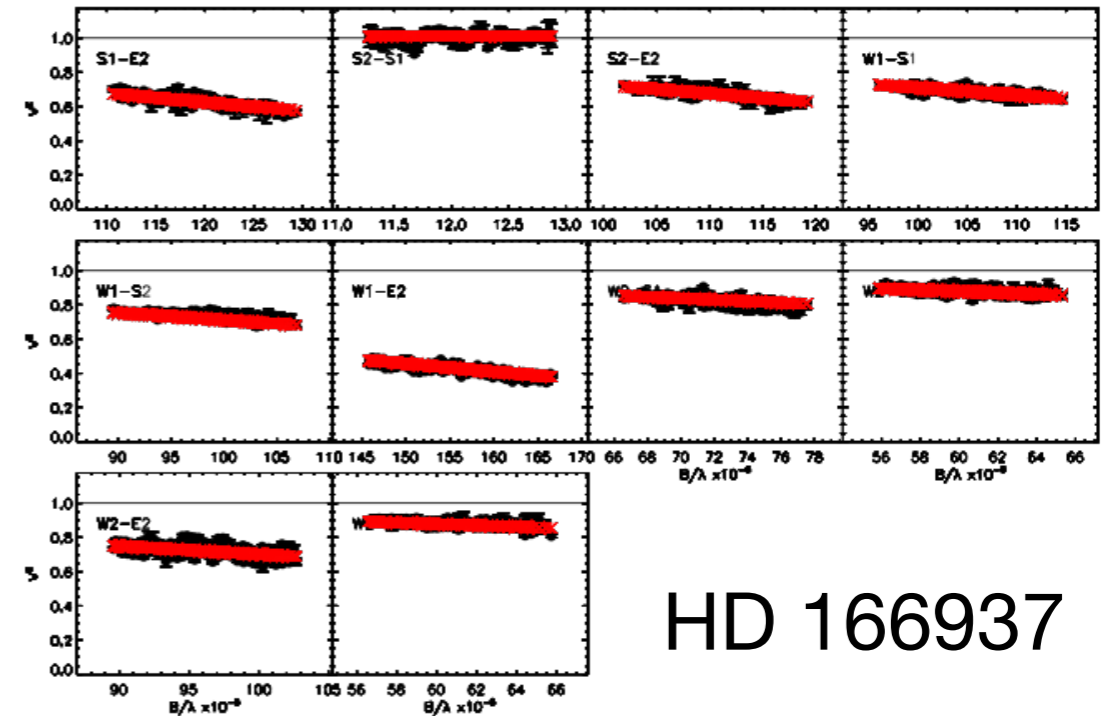
Pseudo-adaptive grid At each grid point, optimize position within a fixed box set by the step size.

Grid center at (0,0) Check to center grid search at (0,0) rather than (sepRA, sepDEC).

Include bandwidth smearing

Fit V2 only  Fit T3 only If unclicked then fit to both V2 and T3 data.

Save Param File



HD 166937

# SIMPLE MODELS - 7/2421



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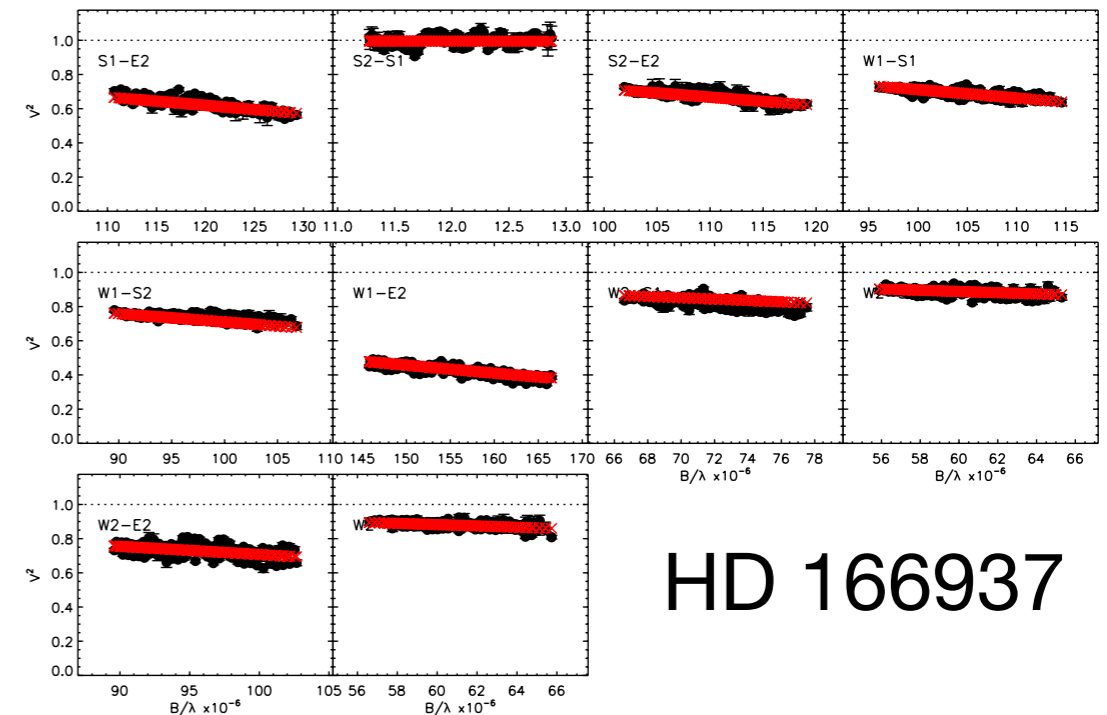
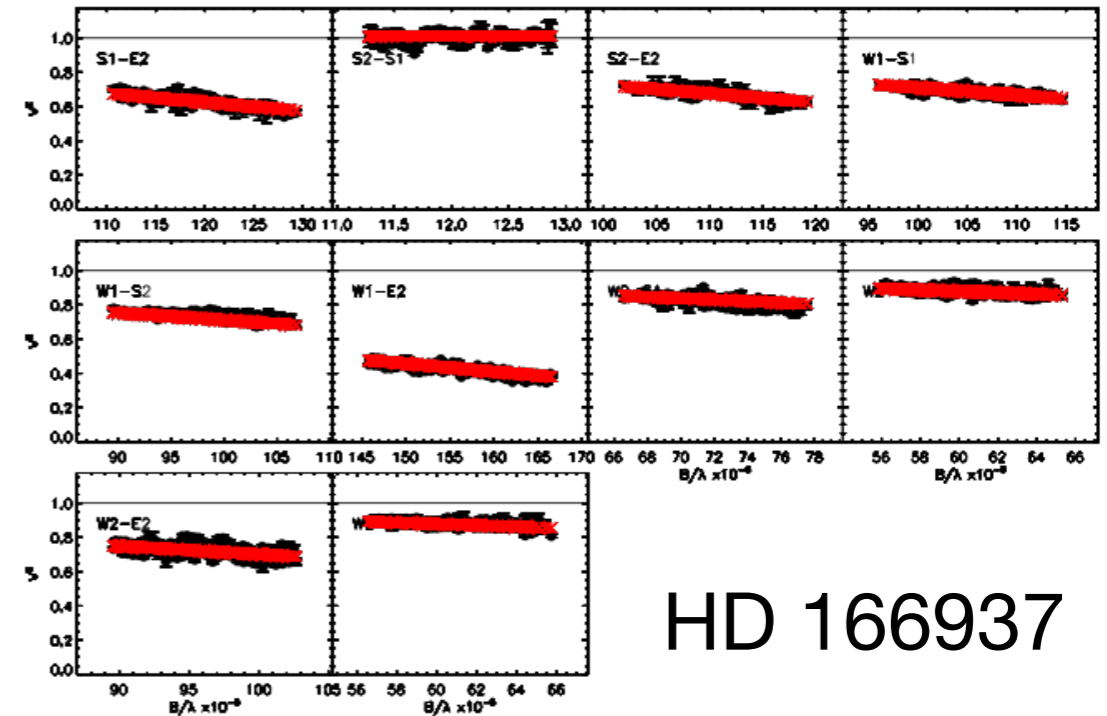
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## Elliptical Disk Fit with Gaussian Disk by Dr. Gail Schaefer



# SIMPLE MODELS - 7/24/21



Star	Separation	Disk?	F1	F2	F3
HD 166937					
HD 198288					
HD 181615					
HD 216200					
HD 218393					

- ▶ Separation: Binary separation in mas
- ▶ Disk?: Are there indications of a disk in this system?
- ▶ F1: Flux of the primary component
- ▶ F2: Flux of the secondary component
- ▶ F3: Flux of any additional component (disk, tertiary companion, etc.)



# SIMPLE MODELS - 7/24/21



Star	Separation	Disk?	F1	F2	F3
HD 166937	1.457	Y	0.999	0.008	<b>-0.008</b>
HD 198288	3.15	Y?	0.331	0.577	0.091
HD 181615	<b>1.2</b>	Y	<b>0.065</b>	<b>0.45</b>	<b>0.54</b>
HD 216200	1.248	Y	0.870	0.036	0.093
HD 218393	0.410	Y?	0.442	0.482	0.074

- ▶ Separation: Binary separation in mas
- ▶ Disk?: Are there indications of a disk in this system?
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QUESTIONS?

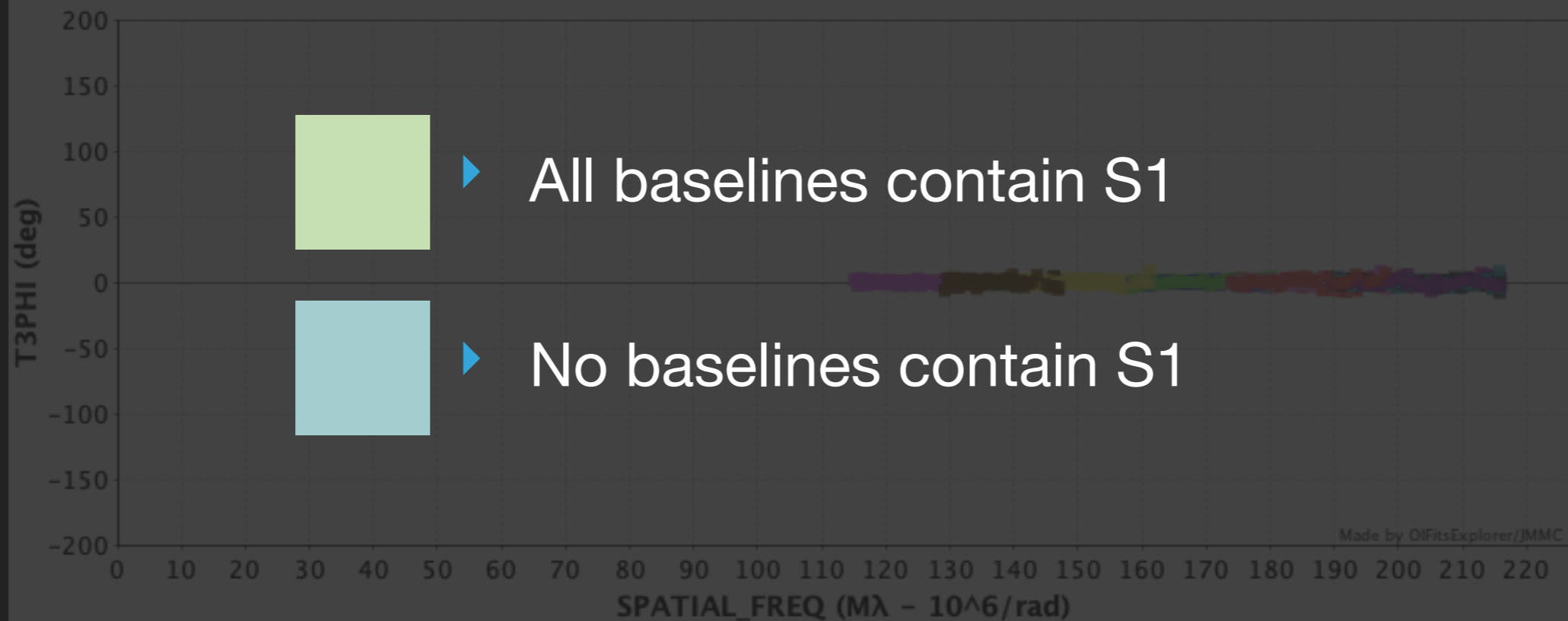
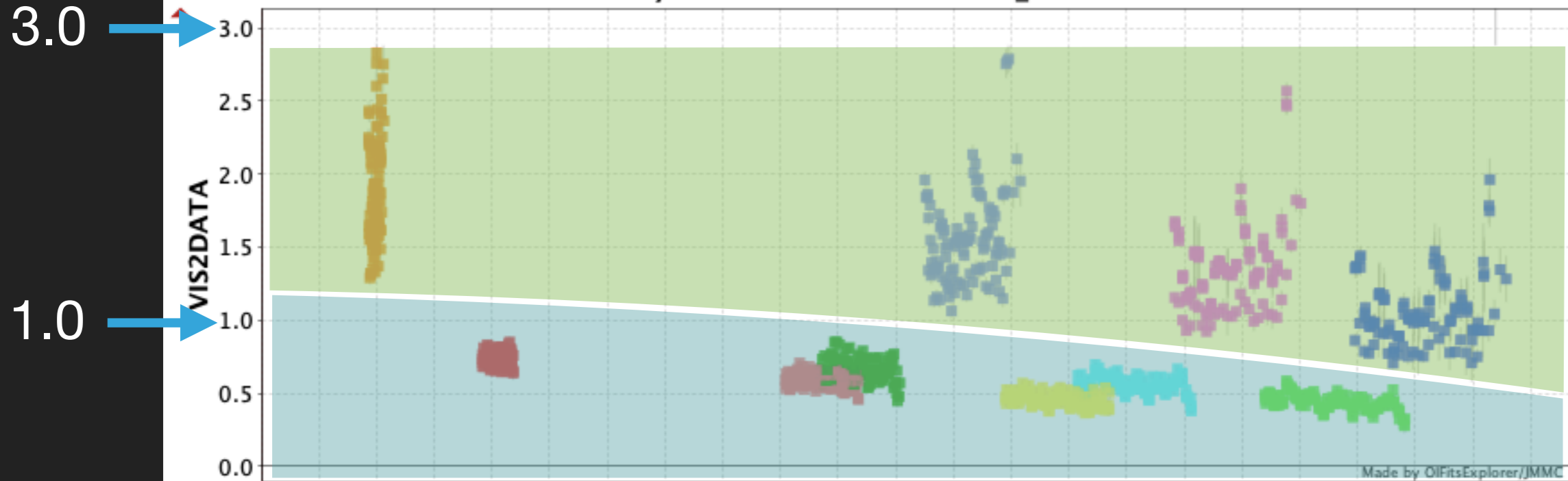
# BONUS SLIDES





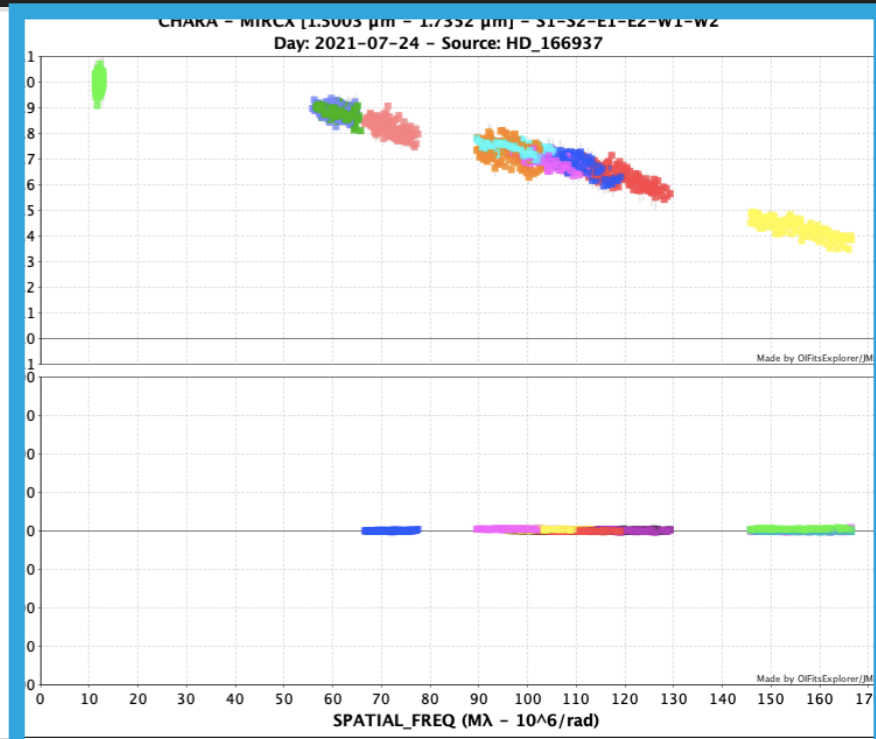
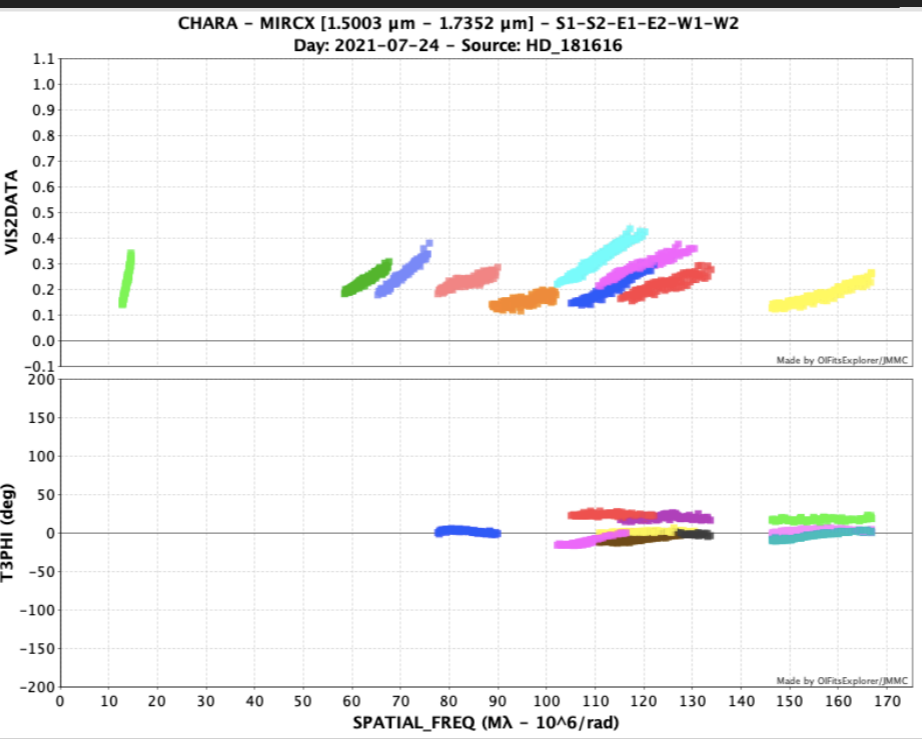
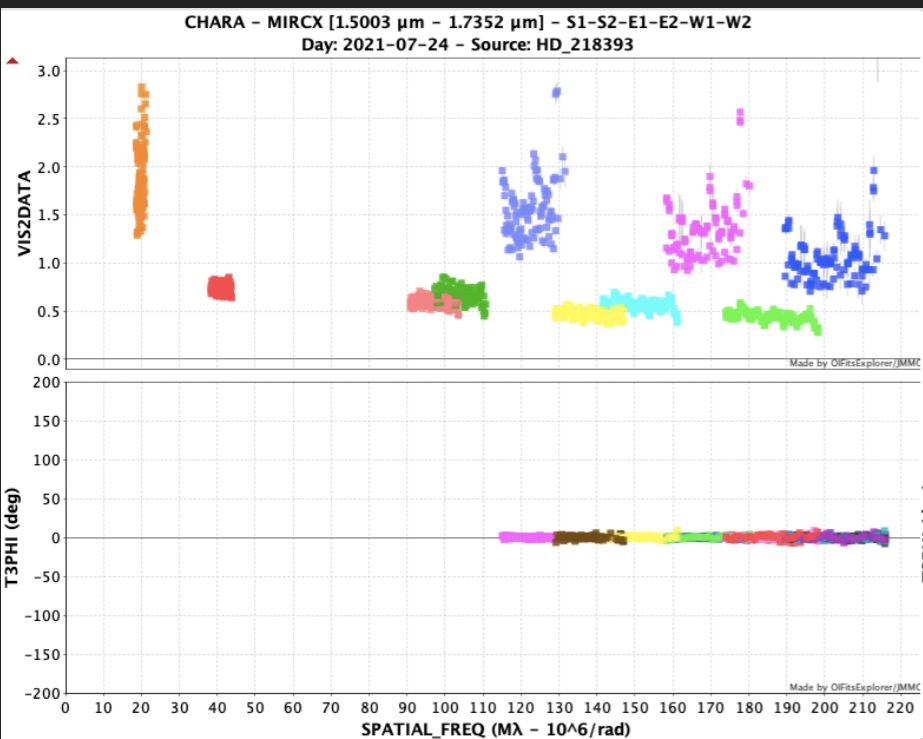
# INITIAL LOOK AT MIRCX DATA - 7/24/21

CHARA - MIRCX [1.5003  $\mu\text{m}$  - 1.7352  $\mu\text{m}$ ] - S1-S2-E1-E2-W1-W2  
 Day: 2021-07-24 - Source: HD\_218393



E1-E2 ■ E1-S1 ■ E1-S2 ■ E1-W2 ■ S1-E2 ■ S2-E2 ■ S2-S1 ■ W2-E2 ■ W2-S1 ■ W2-S2 ■ E1-S1-E2 ■ E1-S2-E2 ■ E1-S2-S1  
 E1-W2-E2 ■ E1-W2-S1 ■ E1-W2-S2 ■ S2-S1-E2 ■ W2-S1-E2 ■ W2-S2-E2 ■ W2-S2-S1

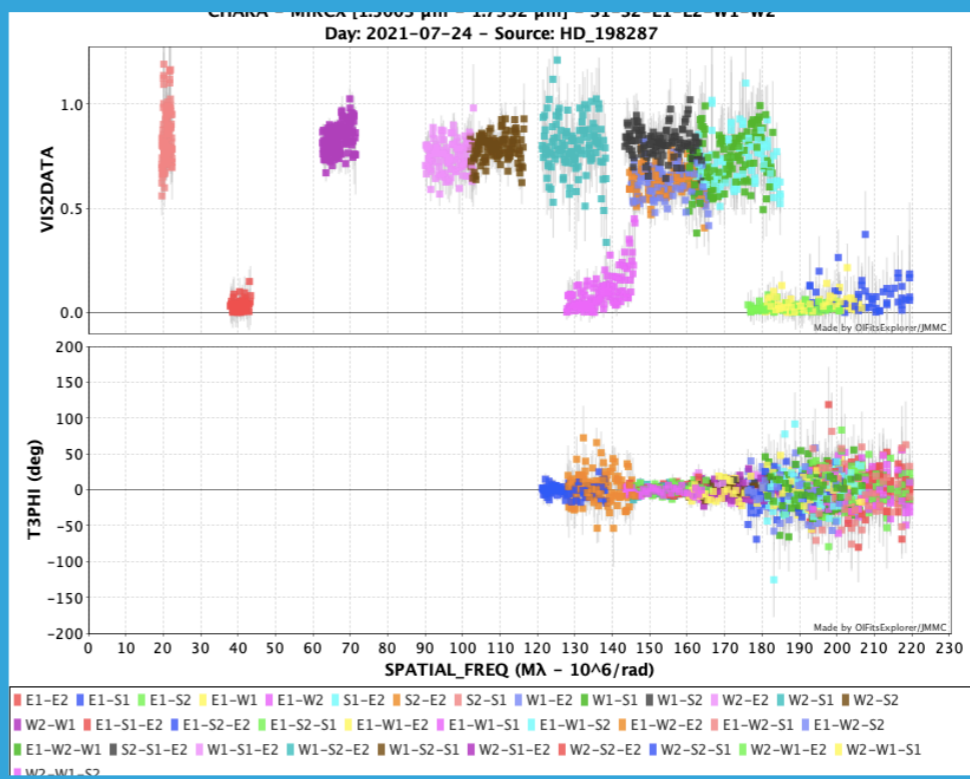
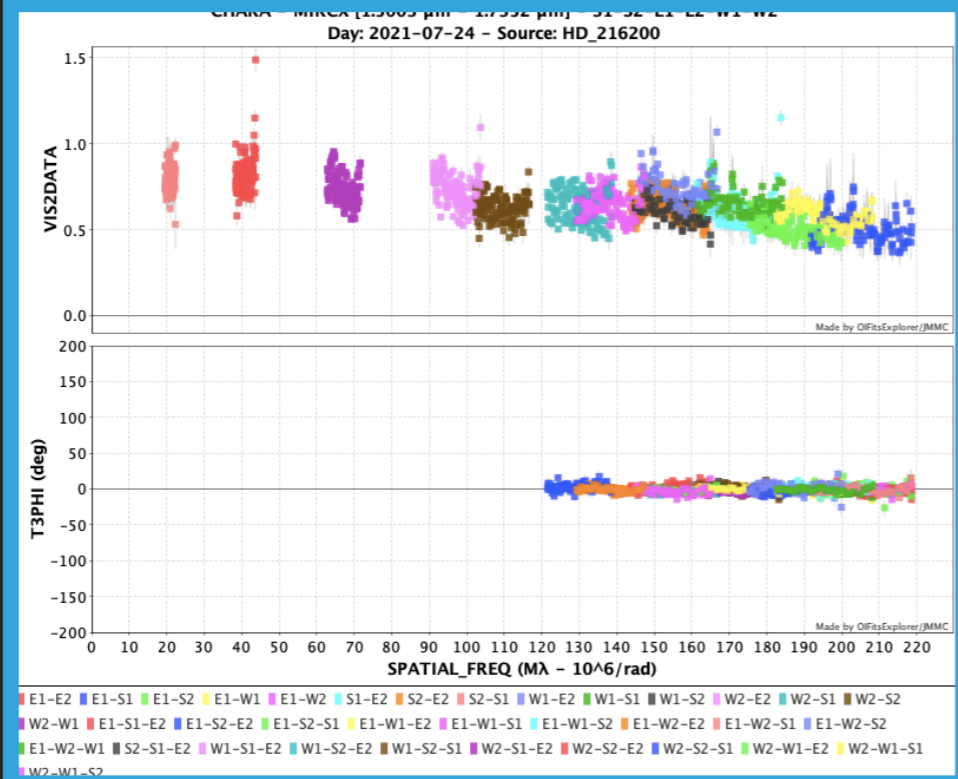
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E1-E2 E1-S1 E1-S2 E1-W2 S1-E2 S2-E2 S2-S1 W2-E2 W2-S1 W2-S2 E1-S1-E2 E1-S2-E2 E1-S2-S1  
E1-W2-E2 E1-W2-S1 E1-W2-S2 S2-S1-E2 W2-S1-E2 W2-S2-E2 W2-S2-S1

S1-E2 S2-E2 S2-S1 W1-E2 W1-S1 W1-S2 W2-E2 W2-S1 W2-S2 W2-W1 S2-S1-E2 W1-S1-E2 W1-S2-E2  
W1-S2-S1 W2-S1-E2 W2-S2-E2 W2-S2-S1 W2-W1-E2 W2-W1-S1 W2-W1-S2

S2-E2 S2-S1 W1-E2 W1-S1 W1-S2 W2-E2 W2-S1 W2-S2 W2-W1 S2-S1-E2 W1-S1-E2 W1-S2-E2  
S1 W2-S1-E2 W2-S2-E2 W2-S2-S1 W2-W1-E2 W2-W1-S1 W2-W1-S2



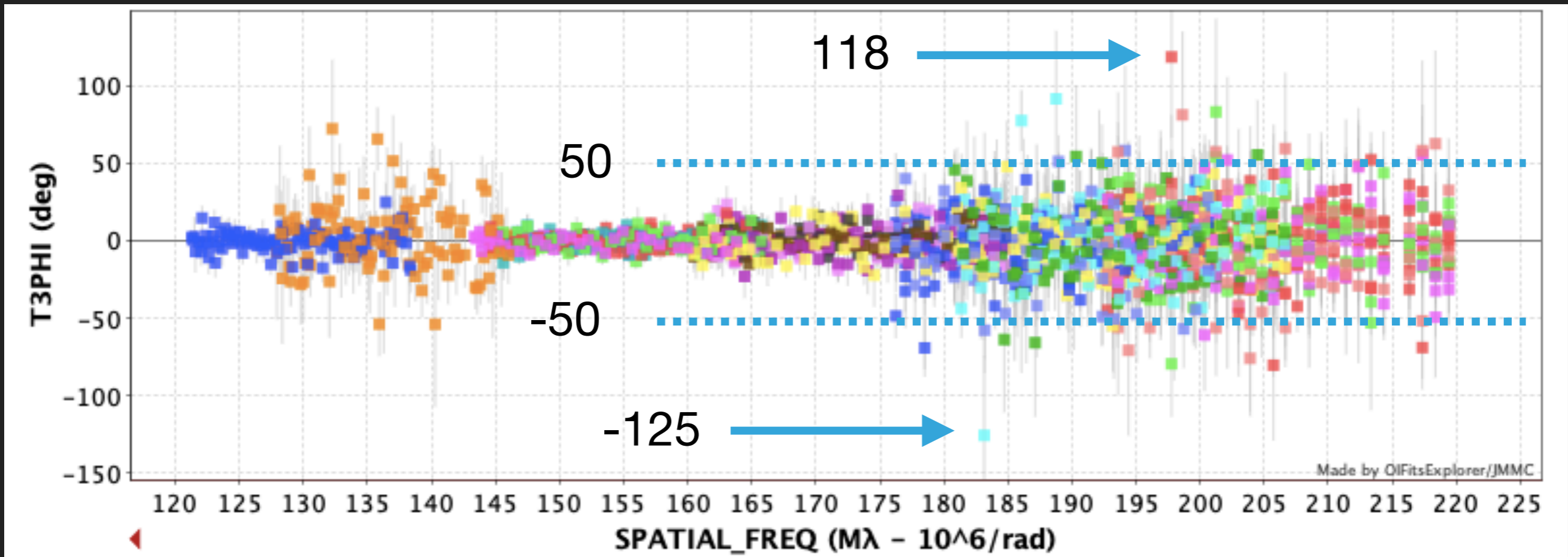
E1-E2 E1-S1 E1-S2 E1-W1 E1-W2 S1-E2 S2-E2 S2-S1 W1-E2 W1-S1 W1-S2 W2-E2 W2-S1 W2-S2  
W2-W1 E1-S1-E2 E1-S2-E2 E1-S2-S1 E1-W1-E2 E1-W1-S1 E1-W1-S2 E1-W2-E2 E1-W2-S1 E1-W2-S2  
E1-W2-W1 S2-S1-E2 W1-S1-E2 W1-S2-E2 W1-S2-S1 W2-S1-E2 W2-S2-E2 W2-S2-S1 W2-W1-E2 W2-W1-S1  
W2-W1-S2

E1-E2 E1-S1 E1-S2 E1-W1 E1-W2 S1-E2 S2-E2 S2-S1 W1-E2 W1-S1 W1-S2 W2-E2 W2-S1 W2-S2  
W2-W1 E1-S1-E2 E1-S2-E2 E1-S2-S1 E1-W1-E2 E1-W1-S1 E1-W1-S2 E1-W2-E2 E1-W2-S1 E1-W2-S2  
E1-W2-W1 S2-S1-E2 W1-S1-E2 W1-S2-E2 W1-S2-S1 W2-S1-E2 W2-S2-E2 W2-S2-S1 W2-W1-E2 W2-W1-S1  
W2-W1-S2





# INITIAL LOOK AT MIRCX DATA - 7/24/21



- ▶ Significant non-zero scatter in the closure phase
- ▶ There might be an asymmetry in the disk!

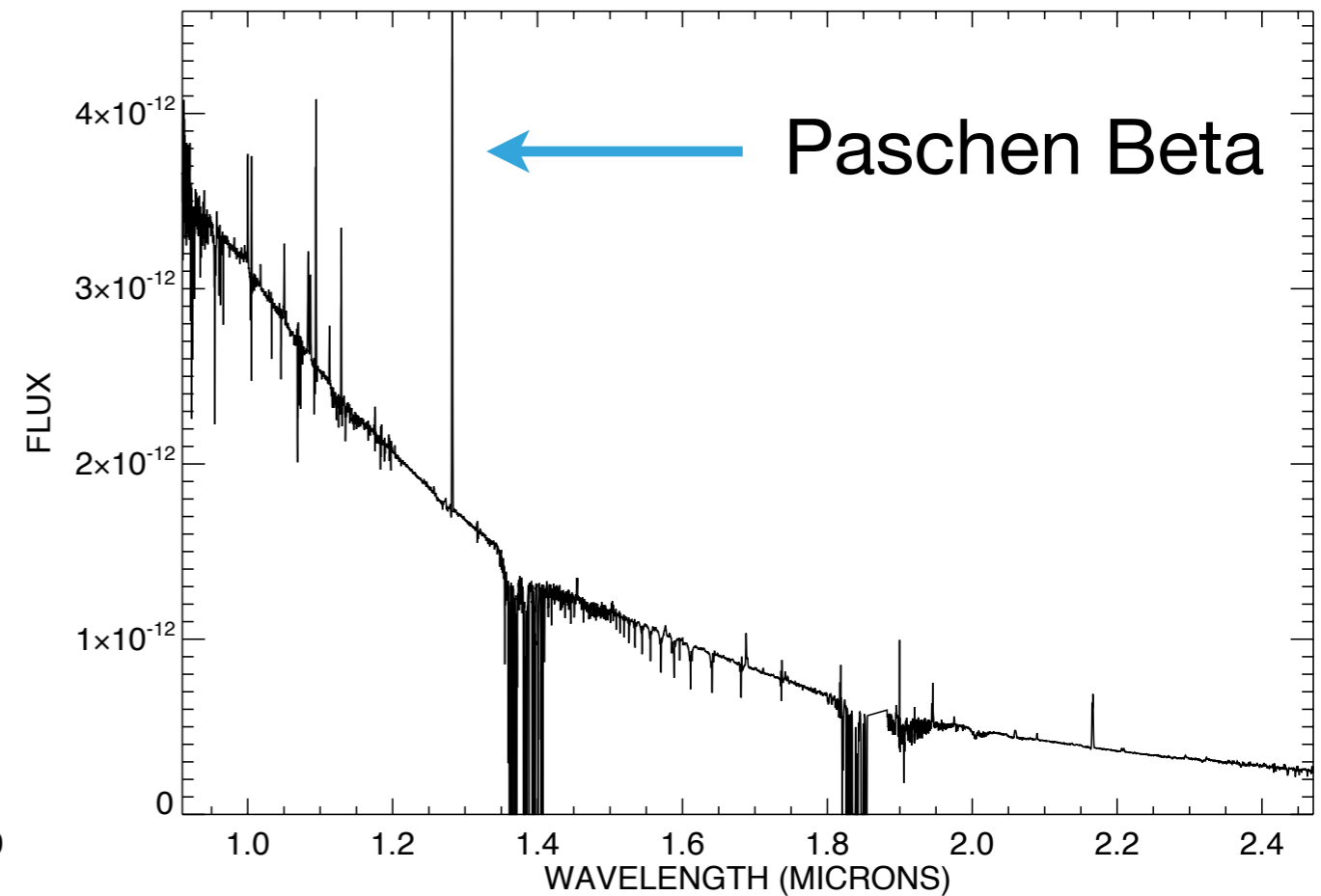
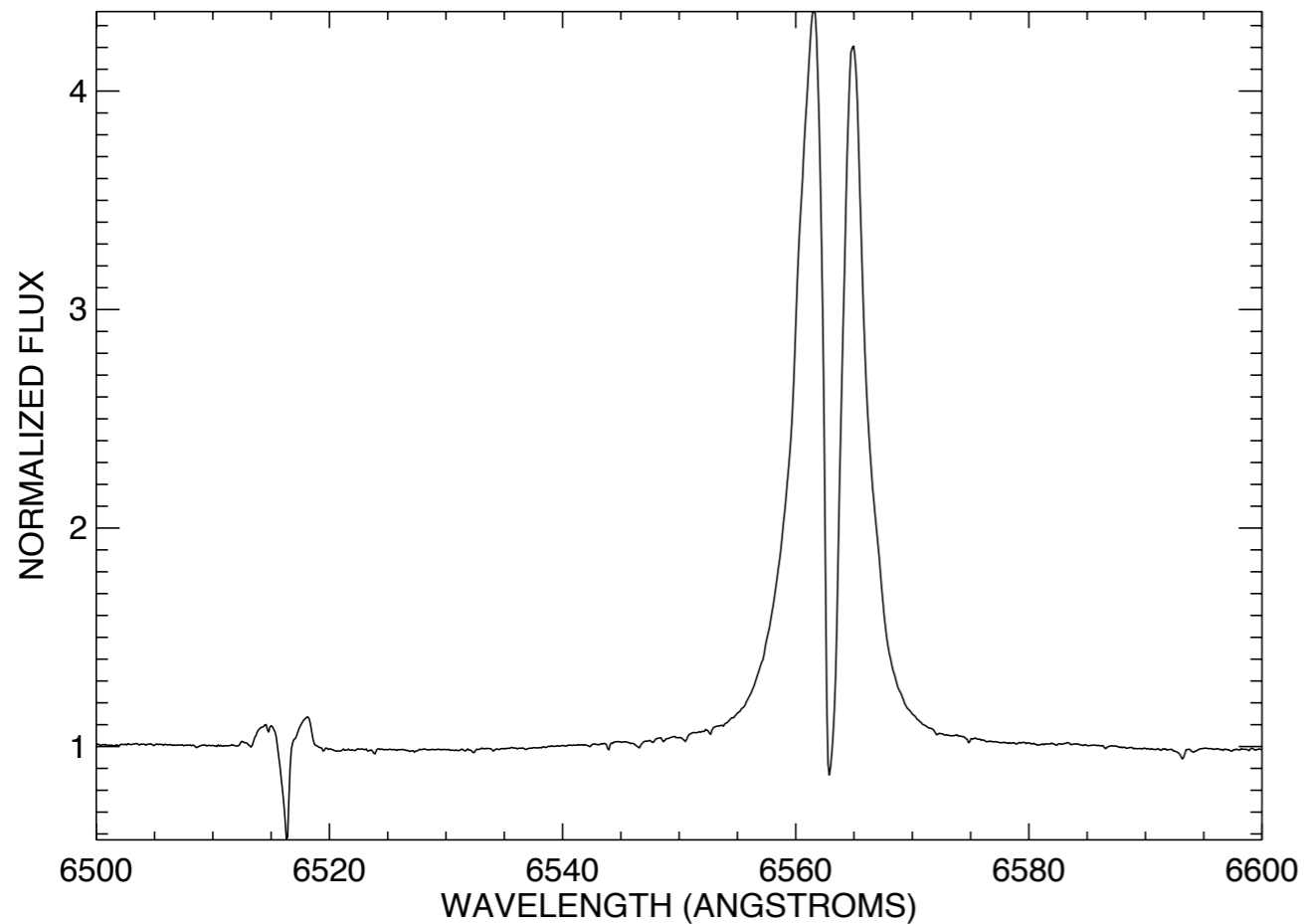
# INITIAL LOOK AT APO DATA



HD 198288

Echelle Spectrum (VIS)

TripleSpec Spectrum (NIR)





# SIMPLE MODELS - 7/24/21

Star	Separation	Disk?	F1	F2	F3
HD 166937	1.457 +/-0.018	Y	0.999 +/- 0.0006	0.008 +/- 0.0002	-0.008 +/- 0
HD 198288					
HD 181615					
HD 216200					
HD 218393					

- ▶ Separation: Binary separation in mas
- ▶ Disk?: Are there indications of a disk in this system?
- ▶ F1: Flux of the primary component
- ▶ F2: Flux of the secondary component
- ▶ F3: Flux of any additional component (disk, tertiary companion, etc.)