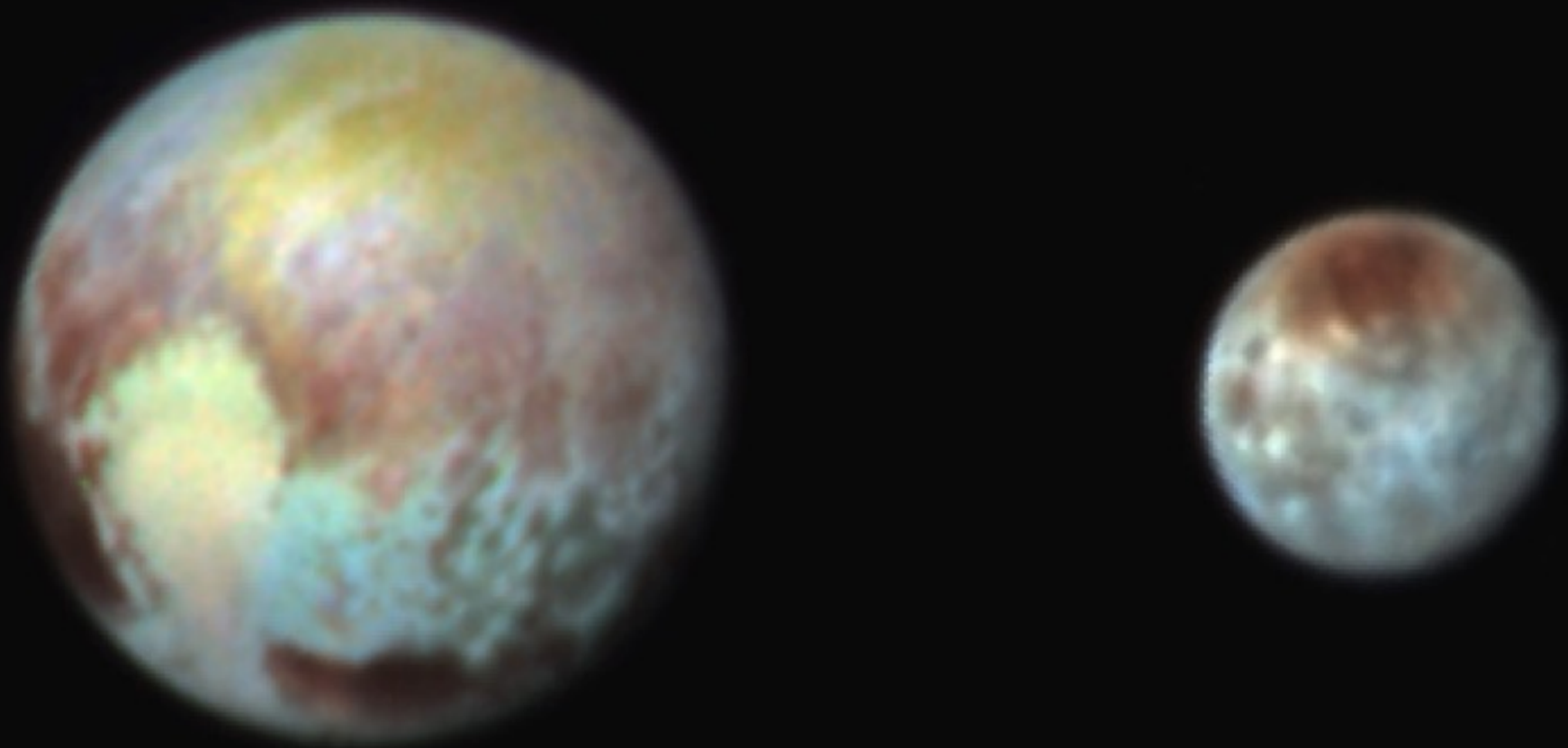
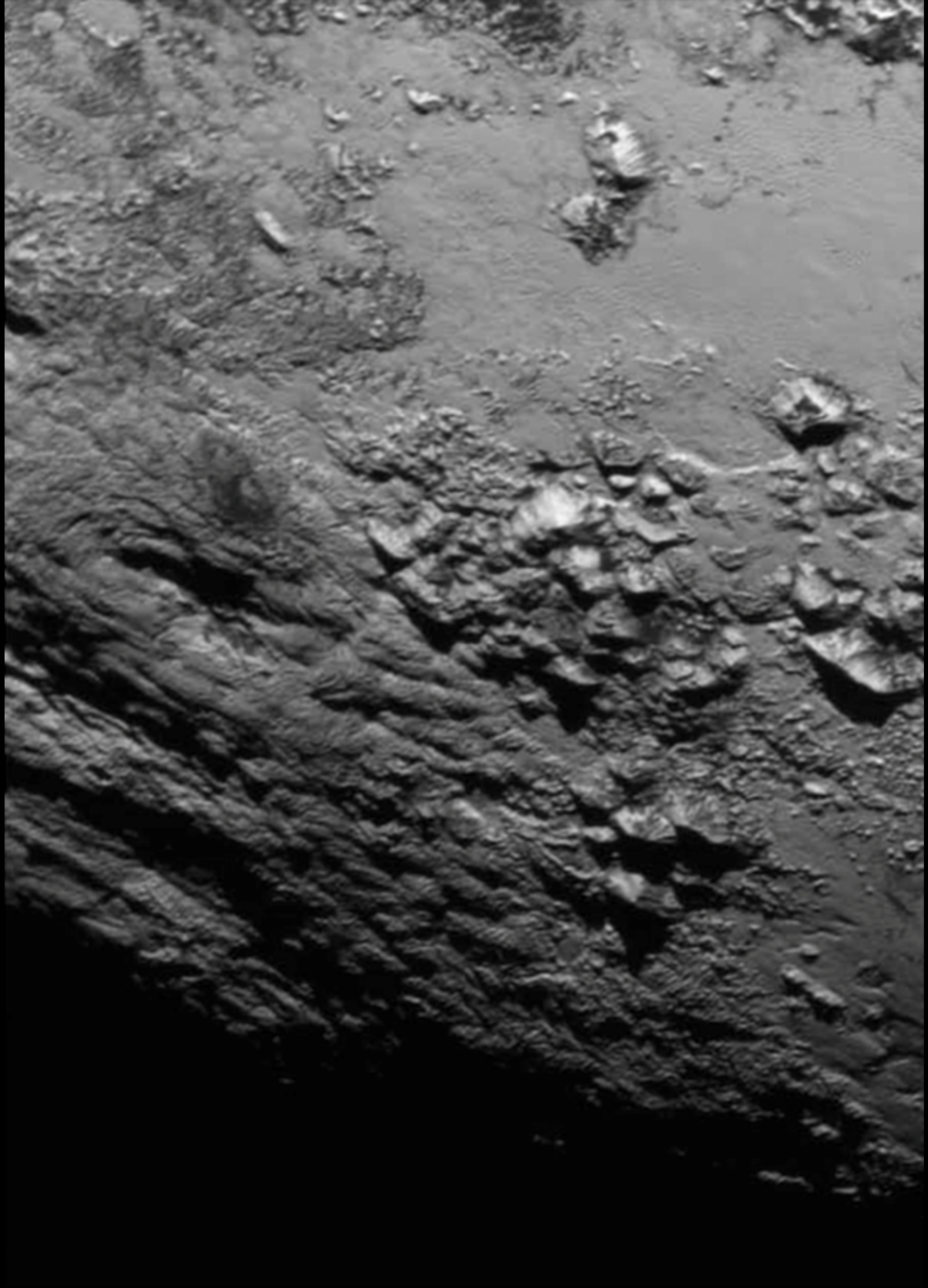
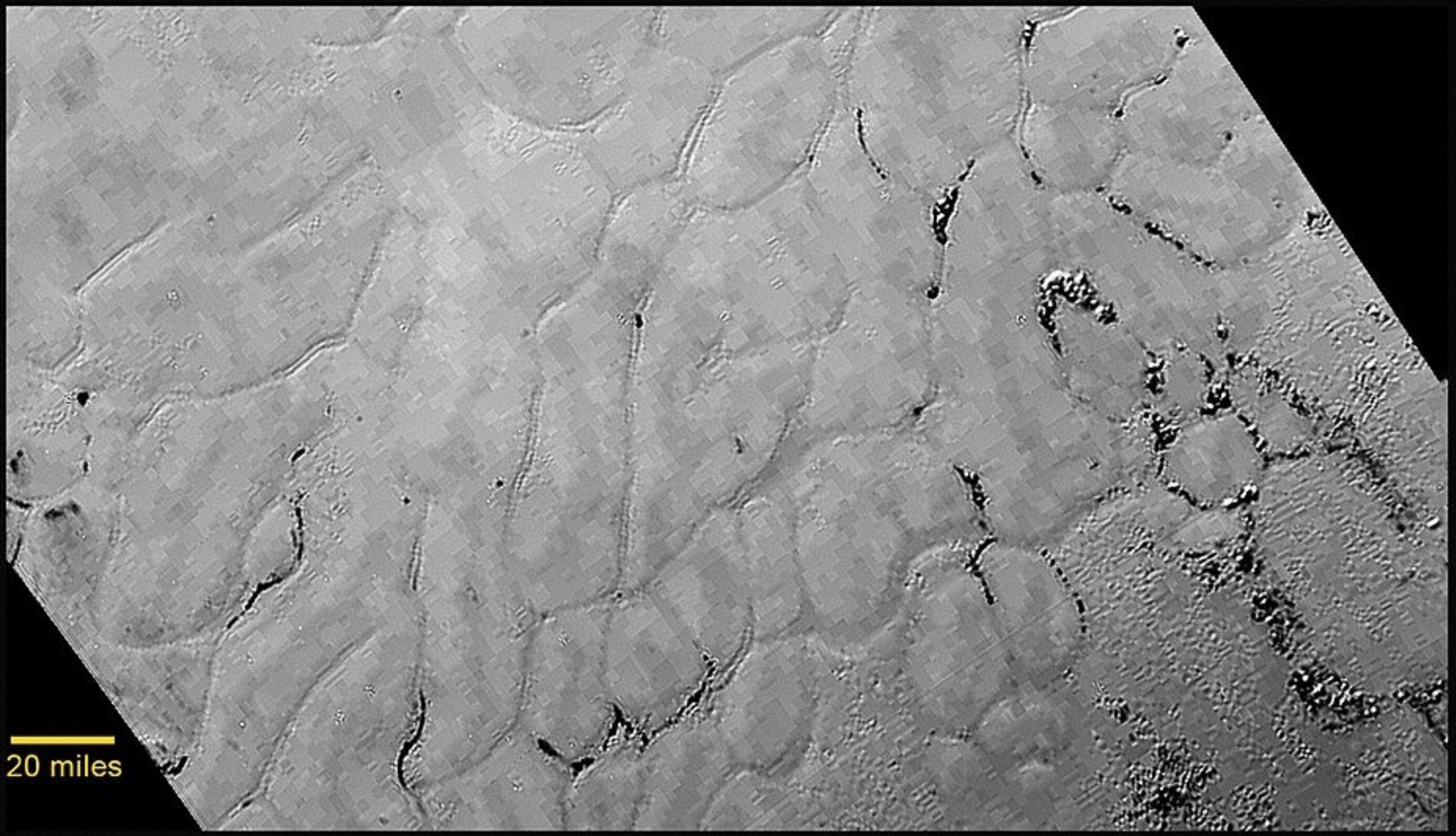
New Horizons

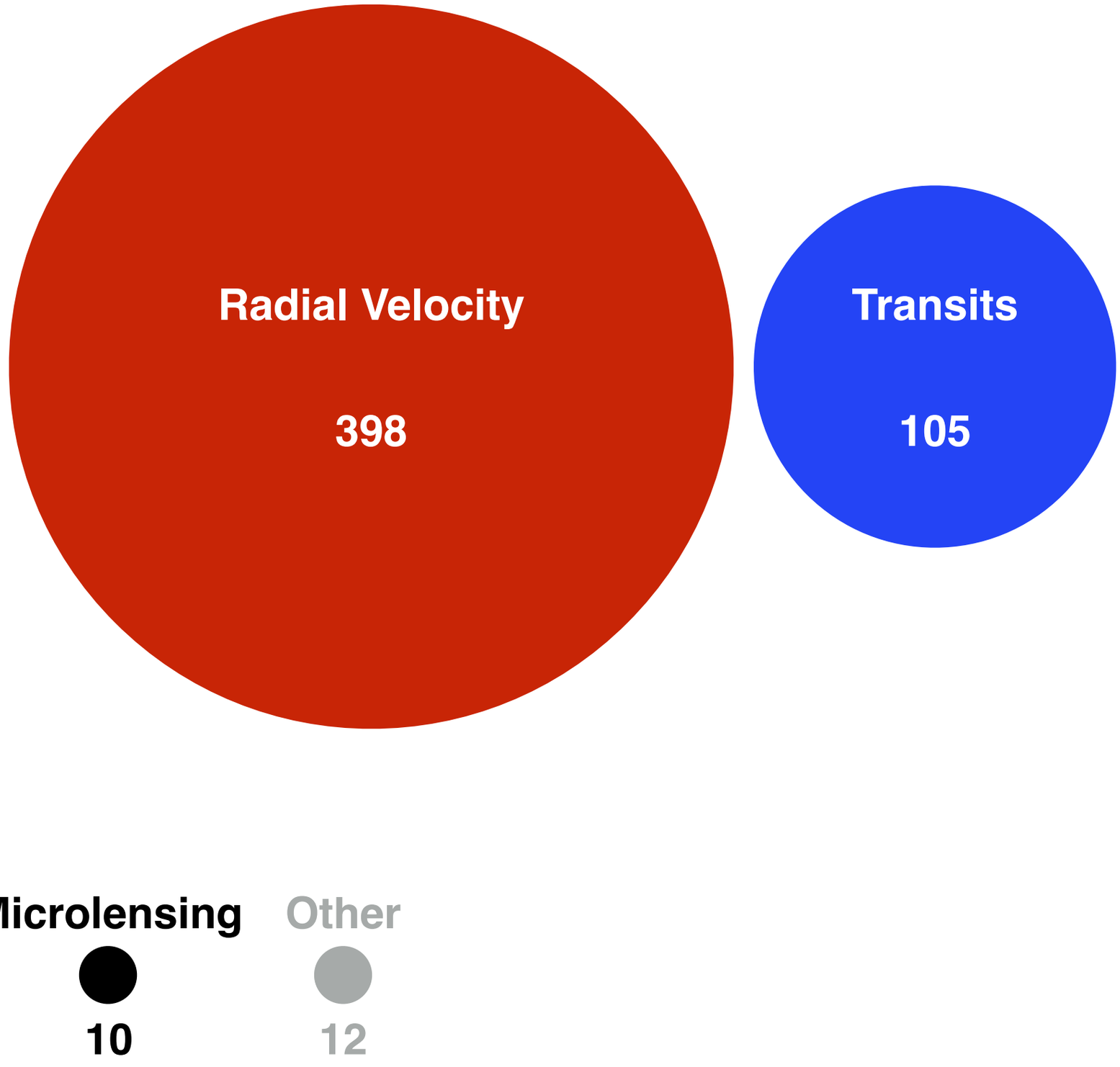


Pluto and Charon

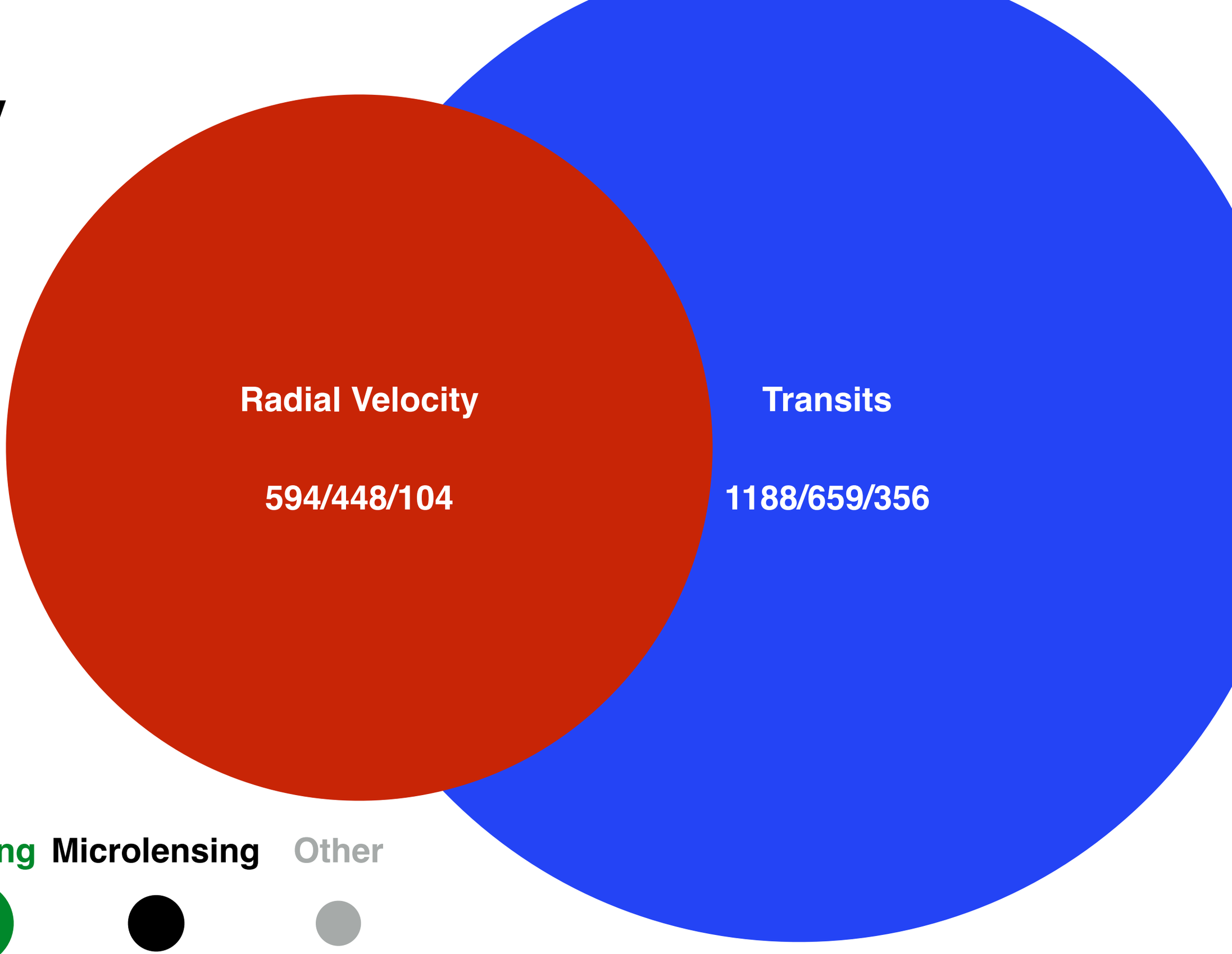



20 miles

EXOPLANETS KNOWN IN 2010



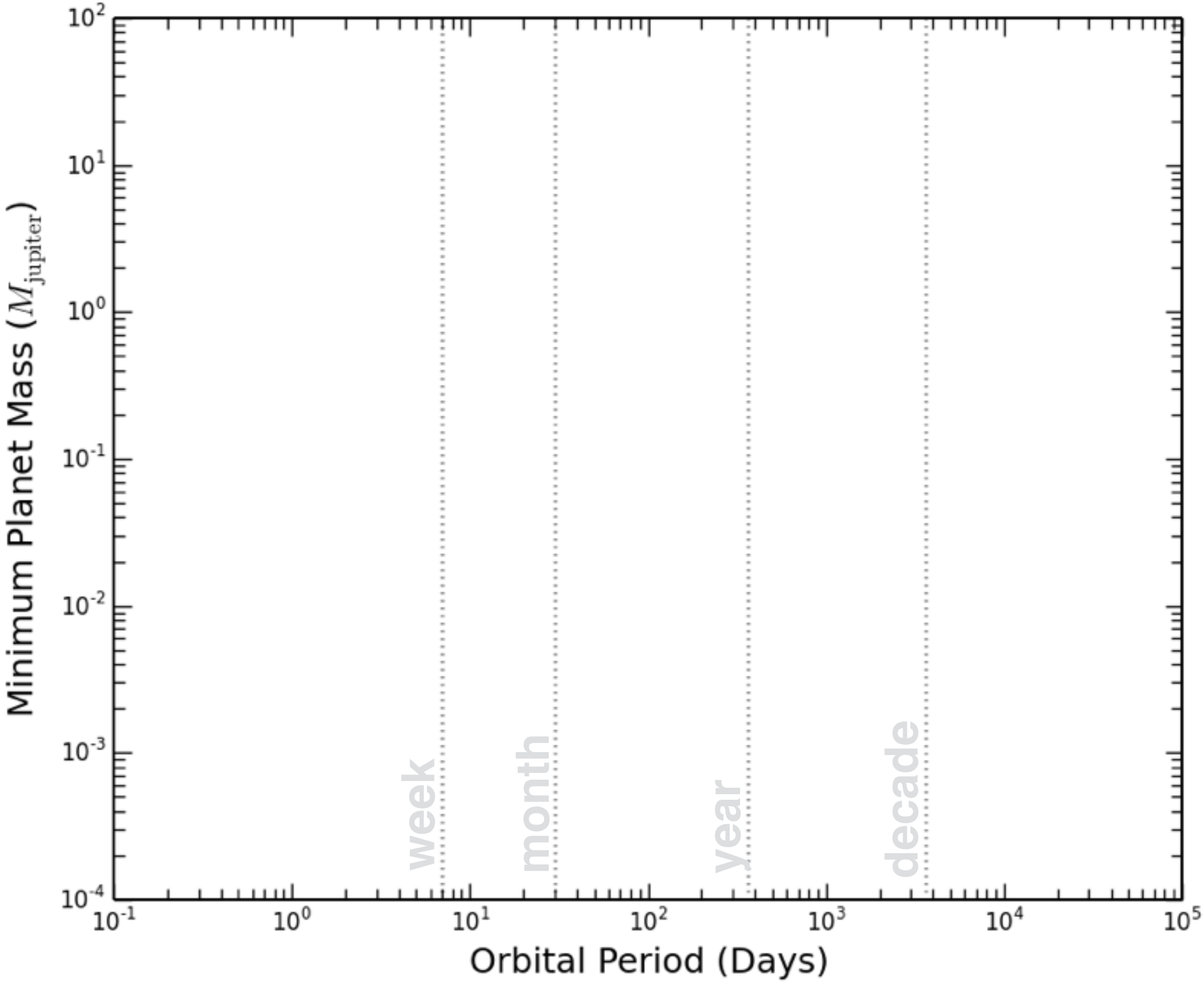
Today

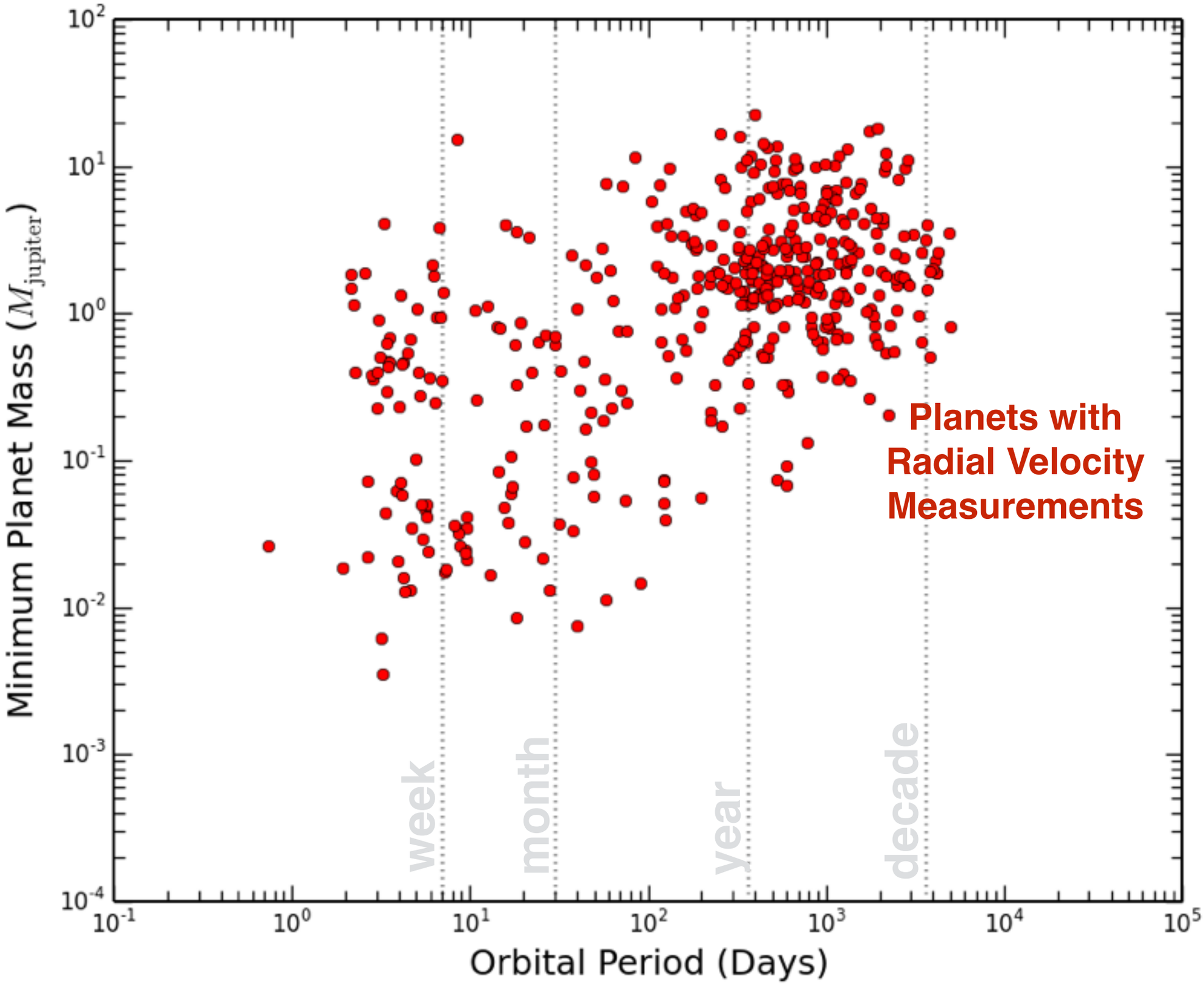


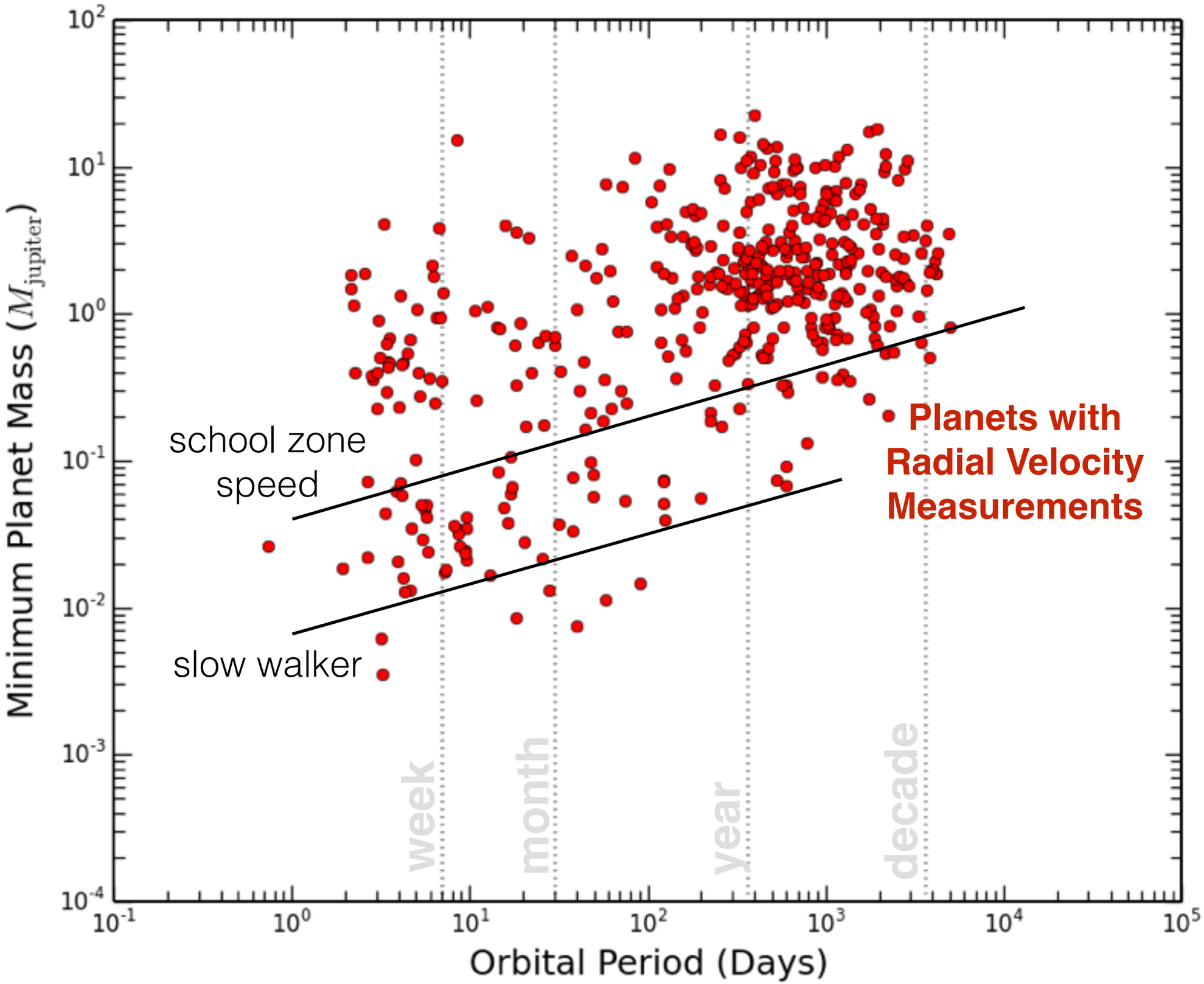
Imaging
51/47/2

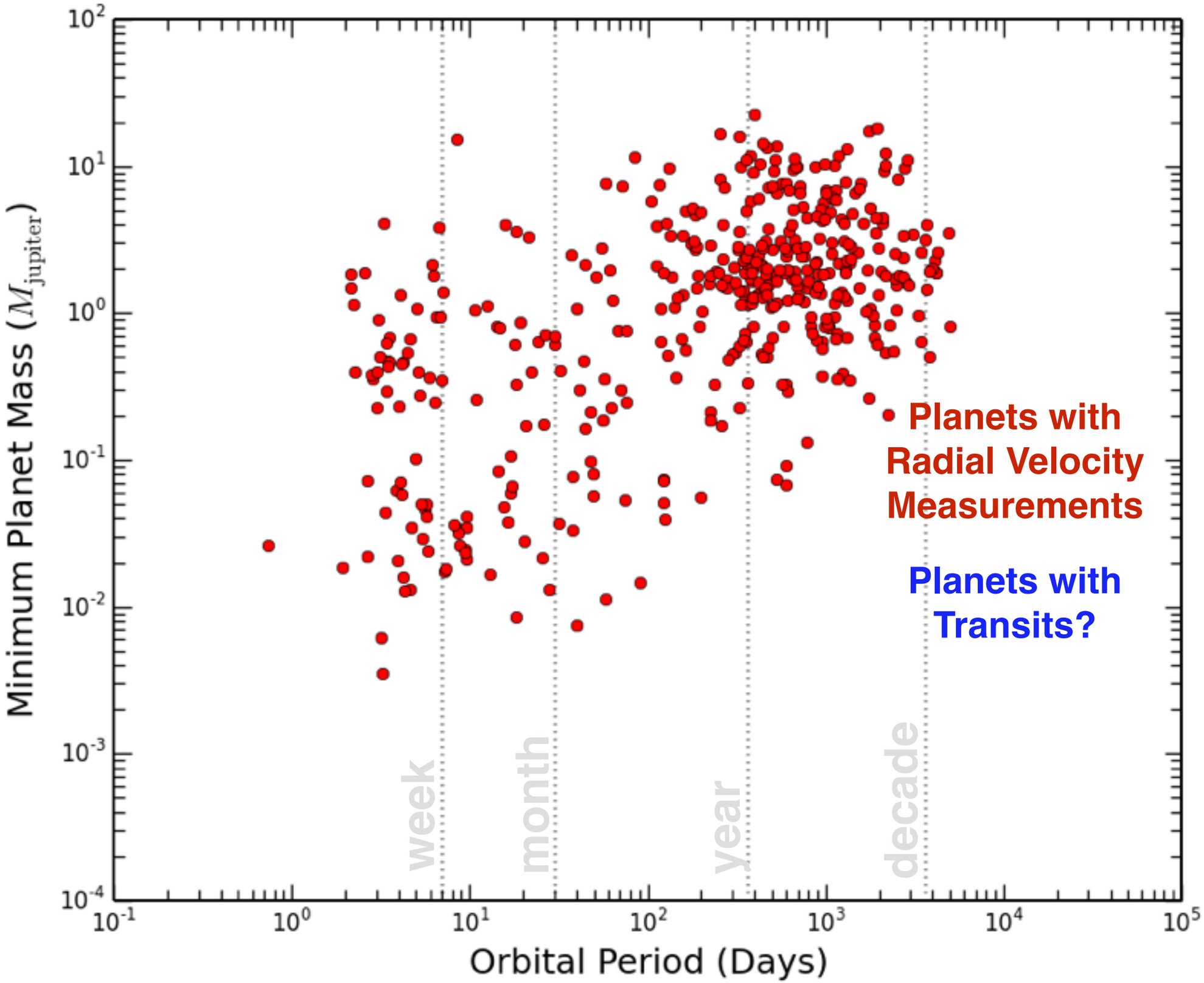
Microlensing
34/32/2

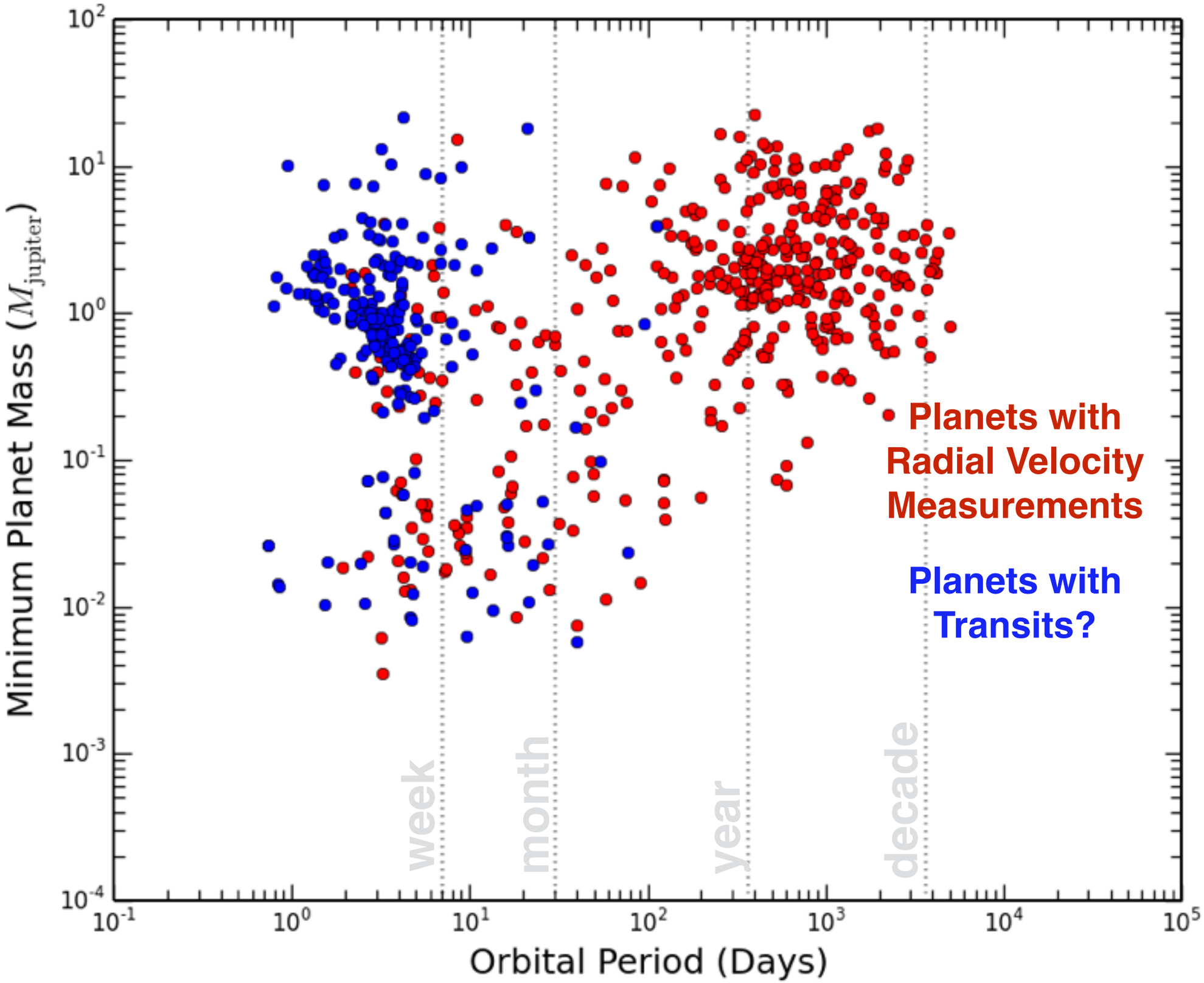
Other
21/16/4

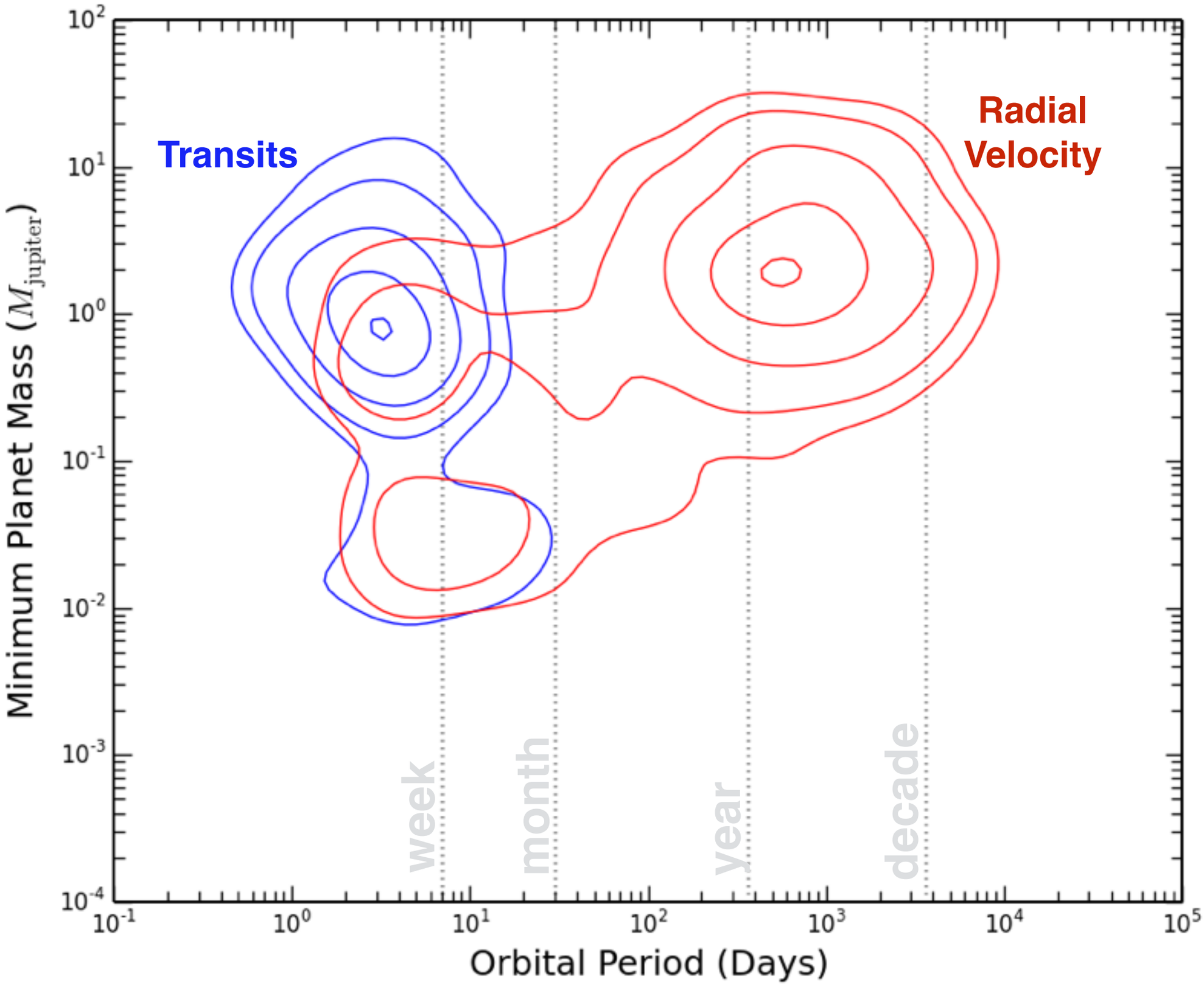

Minimum Planet Mass ($M_{\rm jupiter}$)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
week
month
year
decade
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
Orbital Period (Days)

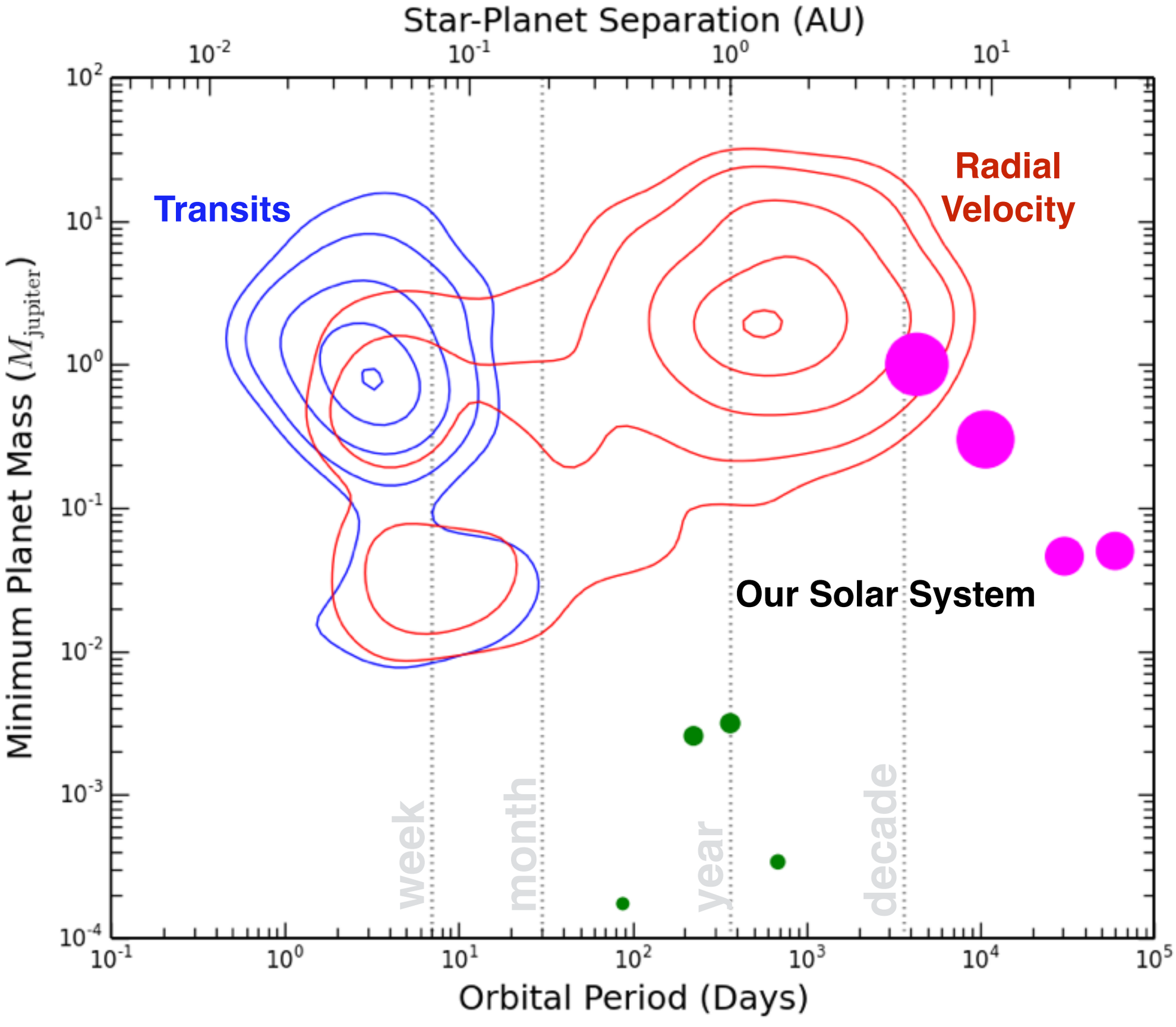

Minimum Planet Mass ($M_{\rm jupiter}$)
Orbital Period (Days)
week
month
year
decade
Planets with Radial Velocity Measurements

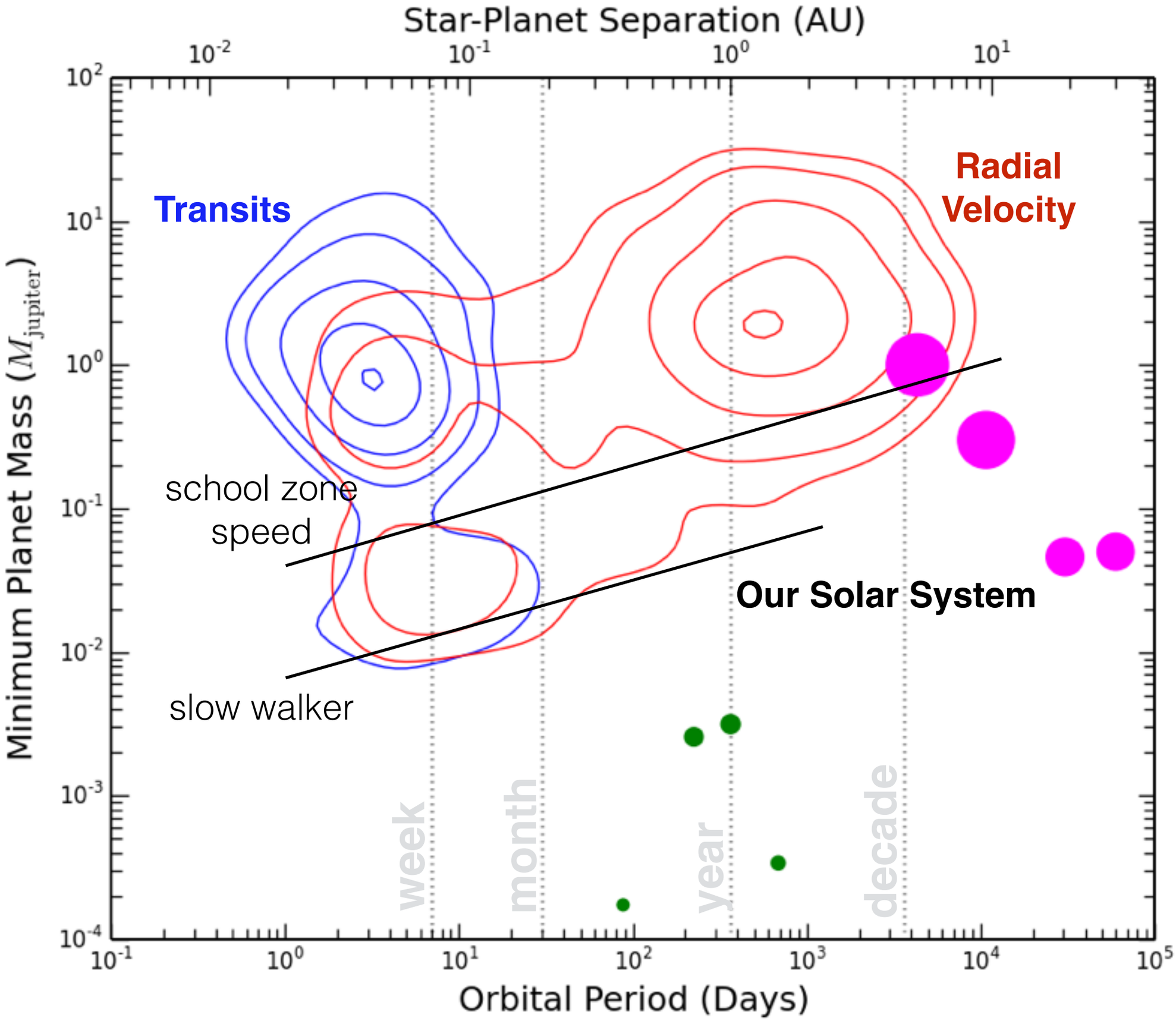

Minimum Planet Mass ($M_{\rm jupiter}$)
Orbital Period (Days)
school zone speed
slow walker
Planets with Radial Velocity Measurements
week
month
year
decade
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}

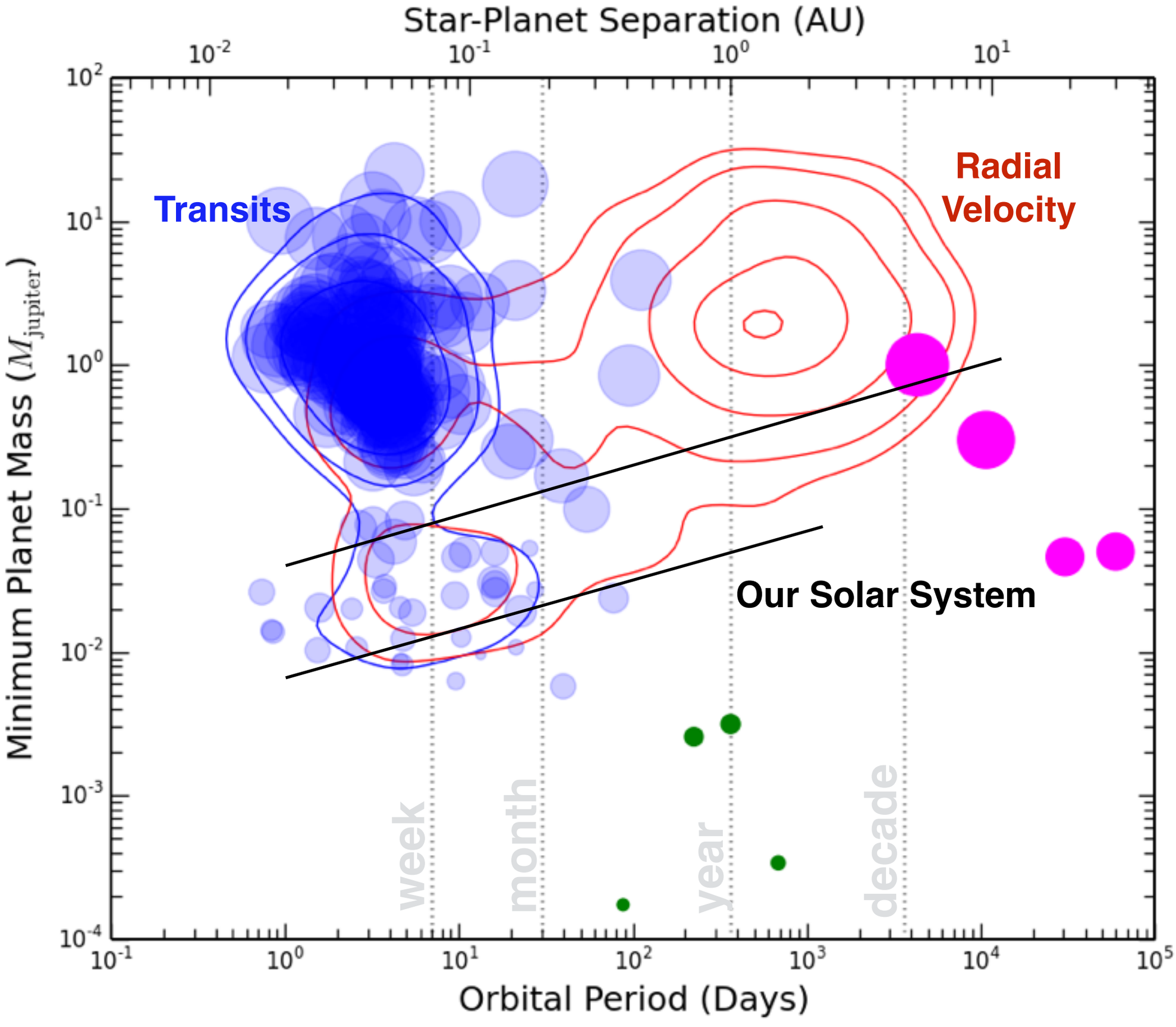

Minimum Planet Mass ($M_{\rm jupiter}$)
Orbital Period (Days)
week
month
year
decade
Planets with Radial Velocity Measurements
Planets with Transits?


Minimum Planet Mass ($M_{\rm jupiter}$)
Orbital Period (Days)
week
month
year
decade
Planets with Radial Velocity Measurements
Planets with Transits?

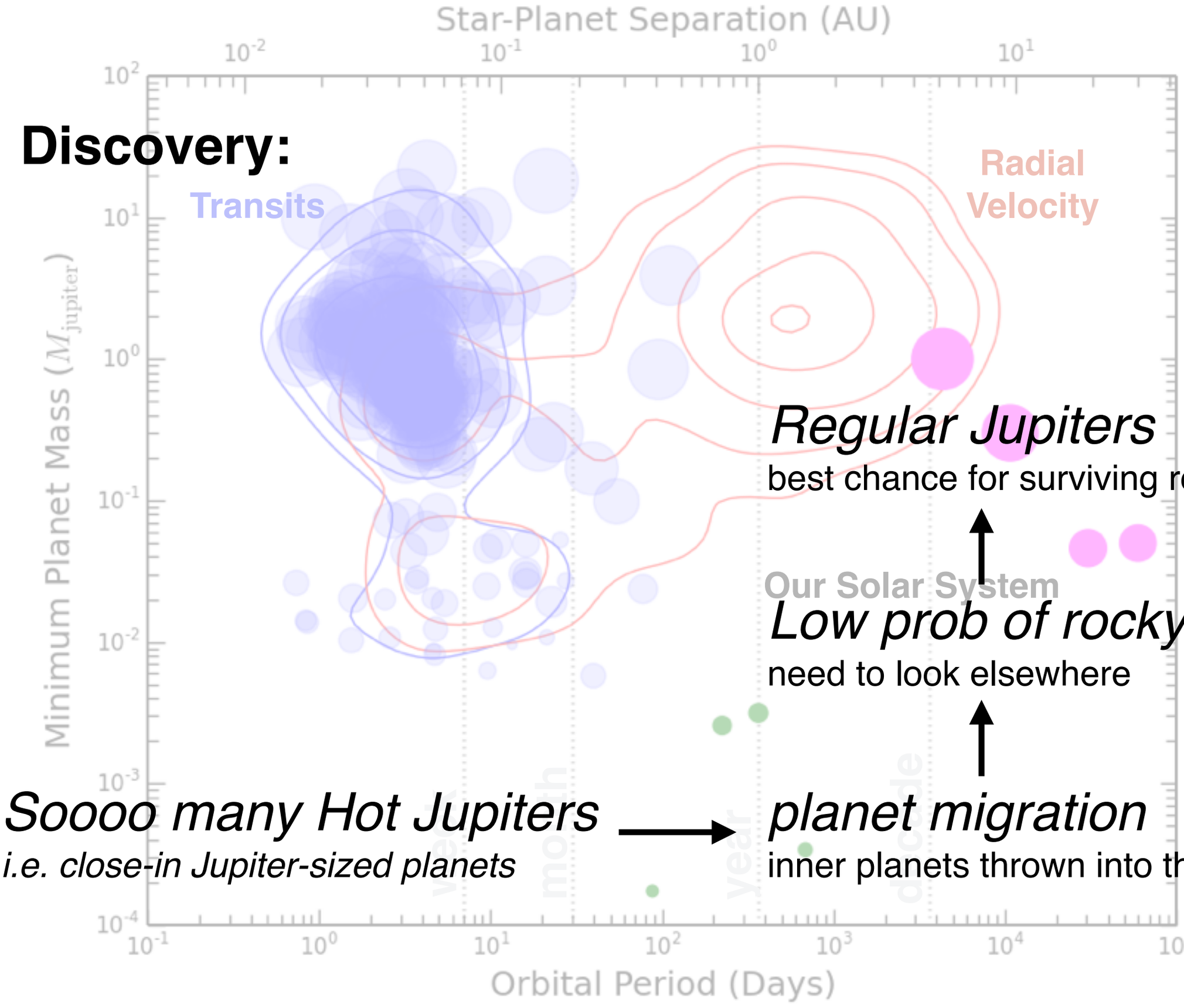

Transits
Radial Velocity
Minimum Planet Mass ($M_{\rm jupiter}$)
Orbital Period (Days)
week
month
year
decade
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}


Star-Planet Separation (AU)
Minimum Planet Mass ($M_{\rm jupiter}$)
Orbital Period (Days)
Transits
Radial Velocity
Our Solar System
week
month
year
decade


Star-Planet Separation (AU)
10^{-2}
10^{-1}
10^{0}
10^{1}
Transits
Radial Velocity
school zone speed
slow walker
Our Solar System
Minimum Planet Mass ($M_{\rm jupiter}$)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
week
month
year
decade
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
Orbital Period (Days)


Star-Planet Separation (AU)
10^{-2}
10^{-1}
10^{0}
10^{1}
Minimum Planet Mass ($M_{\rm jupiter}$)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
Transits
Radial Velocity
Our Solar System
week
month
year
decade
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
Orbital Period (Days)

Discovery:



Regular Jupiters

best chance for surviving rocky planets

↑

Our Solar System

Low prob of rocky planets

need to look elsewhere

↑

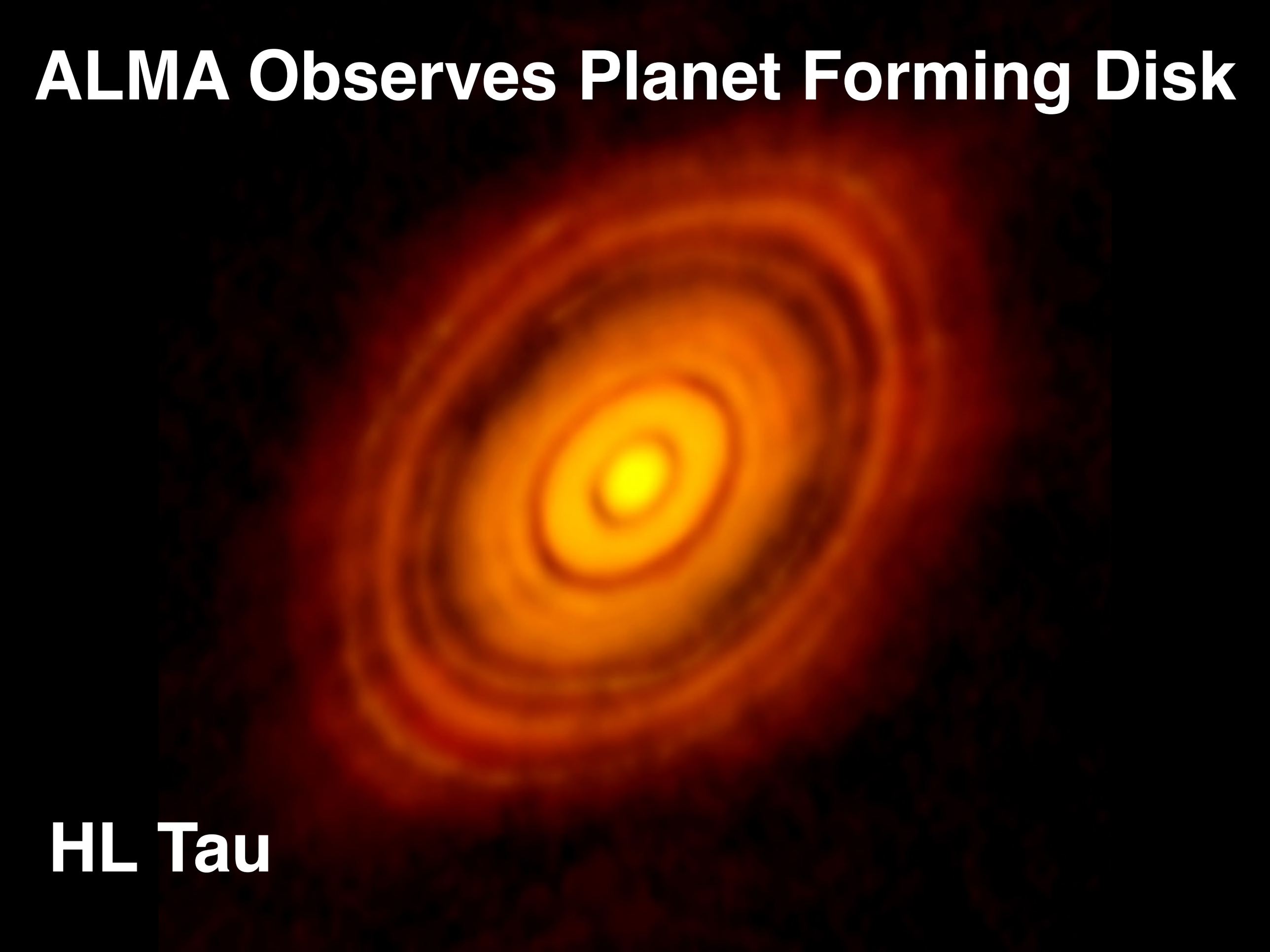
planet migration

inner planets thrown into the star

Soooo many Hot Jupiters →

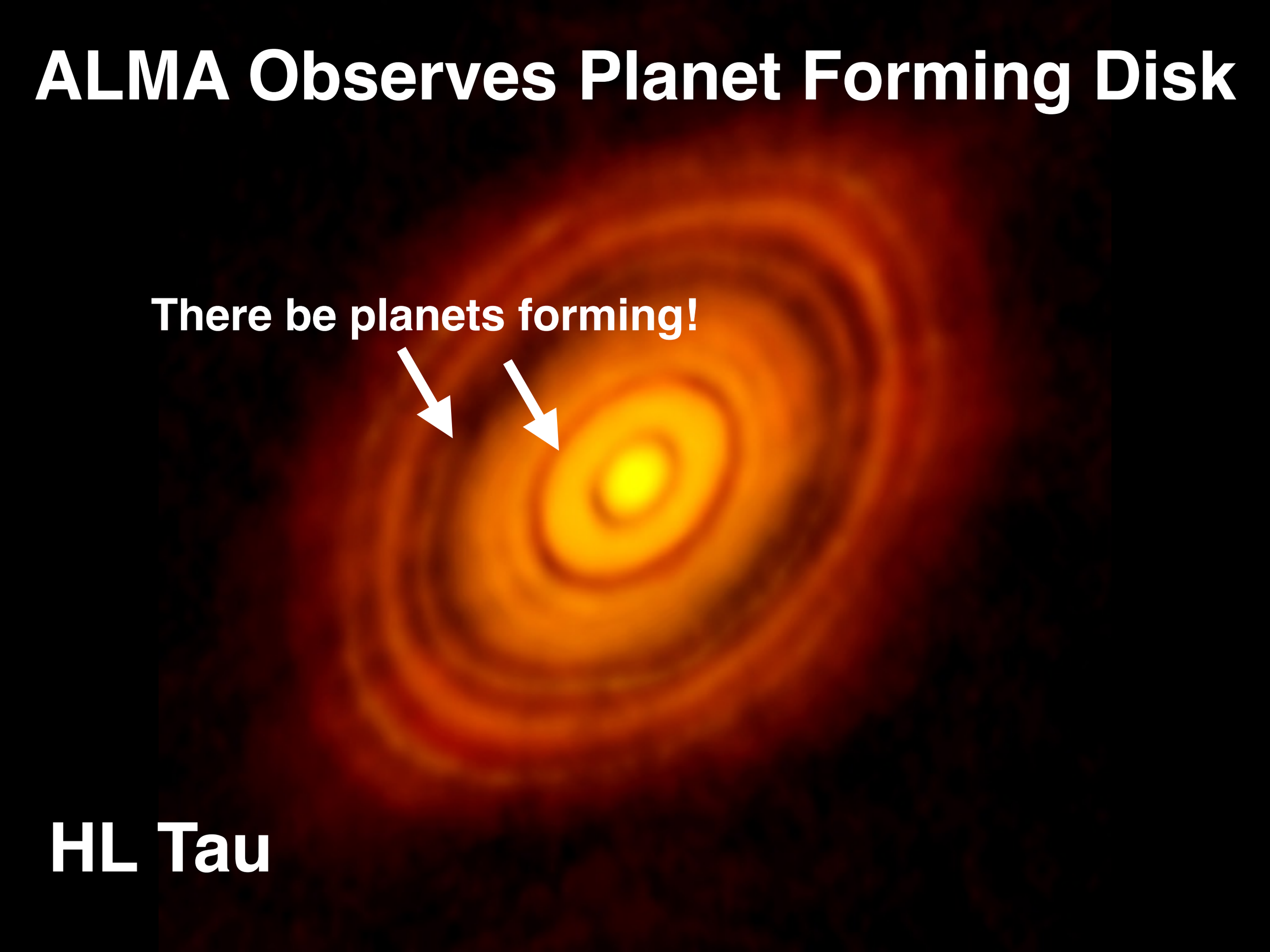
i.e. close-in Jupiter-sized planets

ALMA Observes Planet Forming Disk



HL Tau

ALMA Observes Planet Forming Disk



ALMA (Atacama Large mm Array)

Promised to solve all the problems…
revealing how much more there is to learn!

ALMA (Atacama Large mm Array)

A high-altitude desert in Chile

Interferometer (many telescopes acting as one)

Promised to solve all the problems…
revealing how much more there is to learn!

ALMA (Atacama Large mm Array)

Promised to solve all the problems…
revealing how much more there is to learn!

MY STUDIES ON STELLAR EVOLUTION (PRETTY PICTURES TIME)

RODOLFO MONTEZ JR.
BRIDGE POST-DOCTORAL FELLOW
VANDERBILT UNIVERSITY

HELIX NEBULA

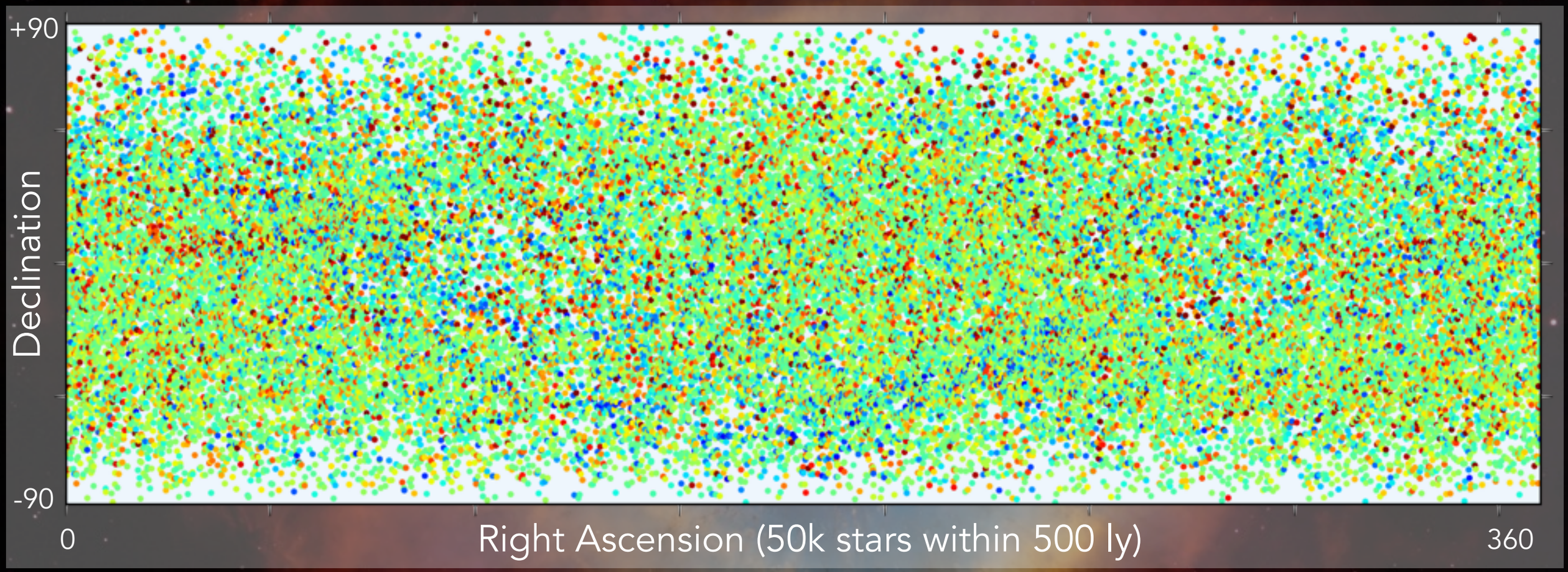
HUBBLE SPACE TELESCOPE

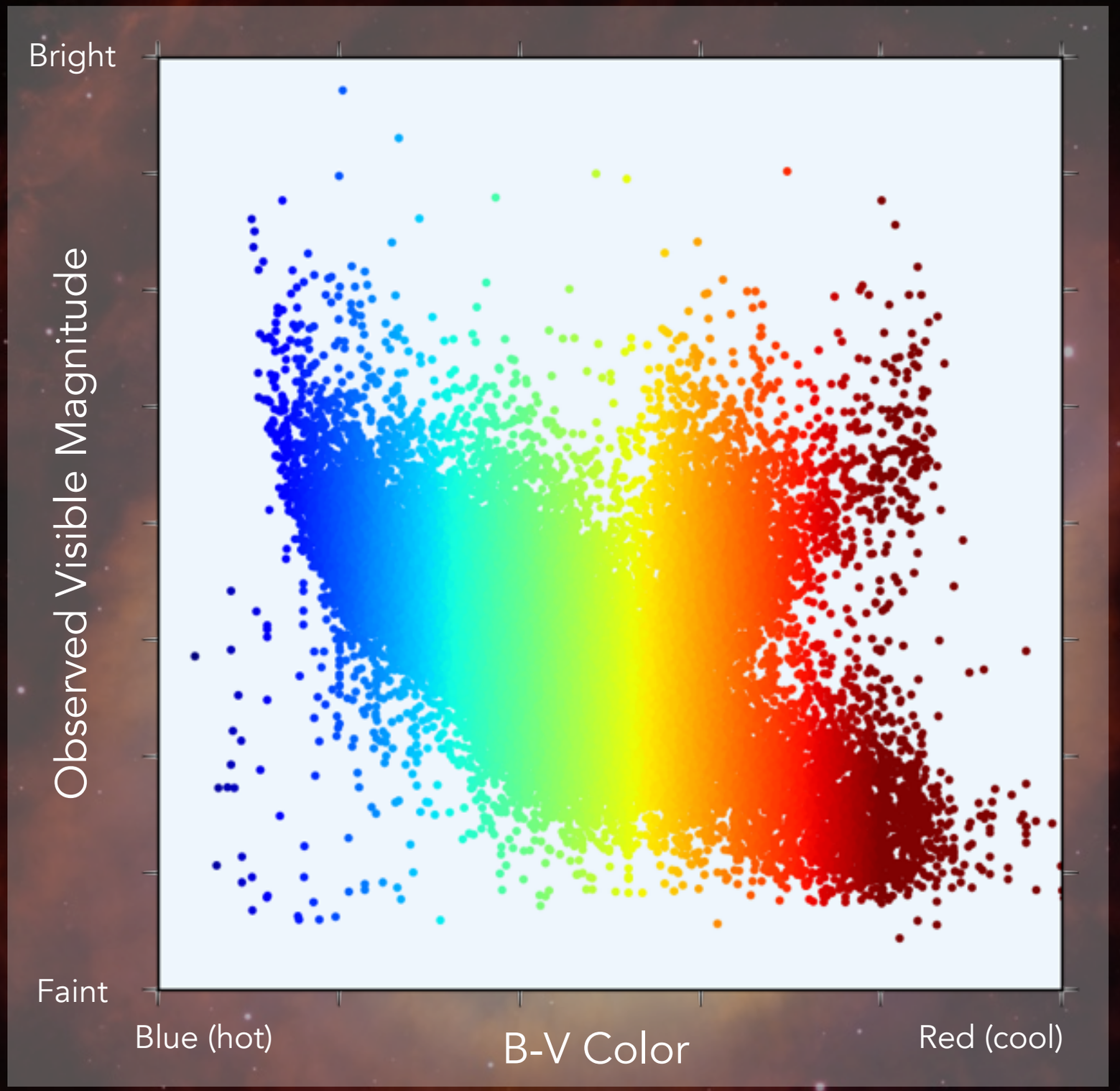
HELIX NEBULA

HUBBLE SPACE TELESCOPE

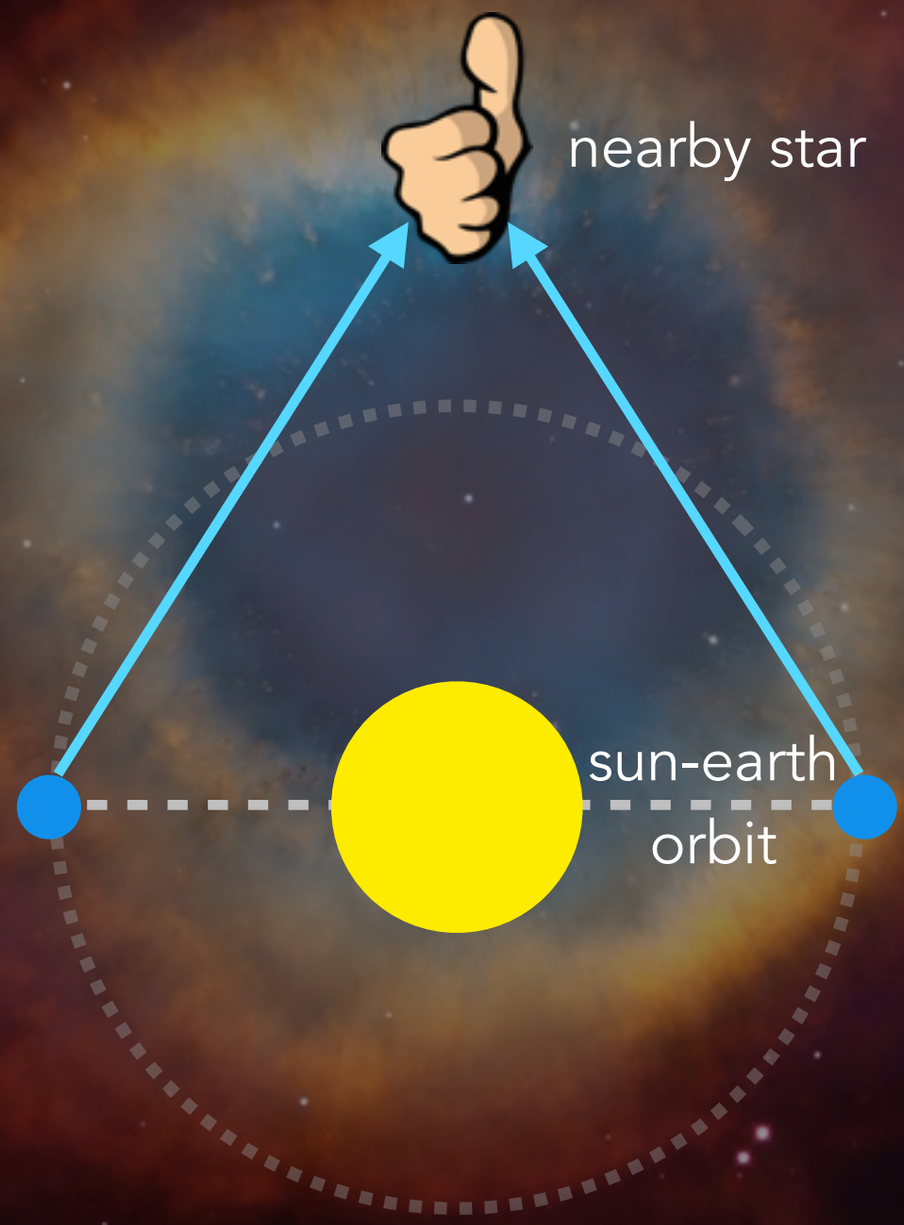
CLUES OF STELLAR EVOLUTION

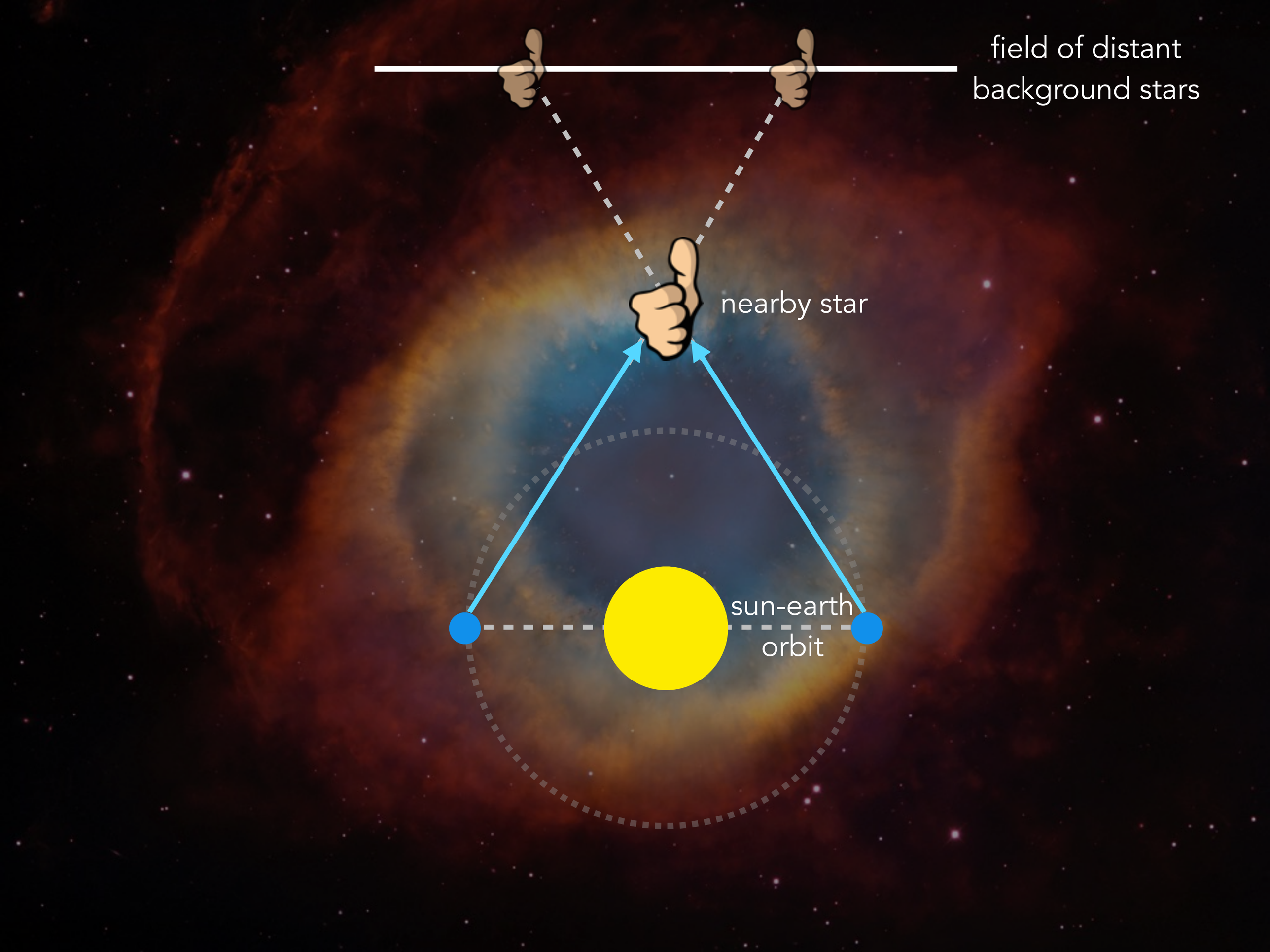
HOW TO MEASURE CHANGES THAT TAKE BILLIONS OF YEARS

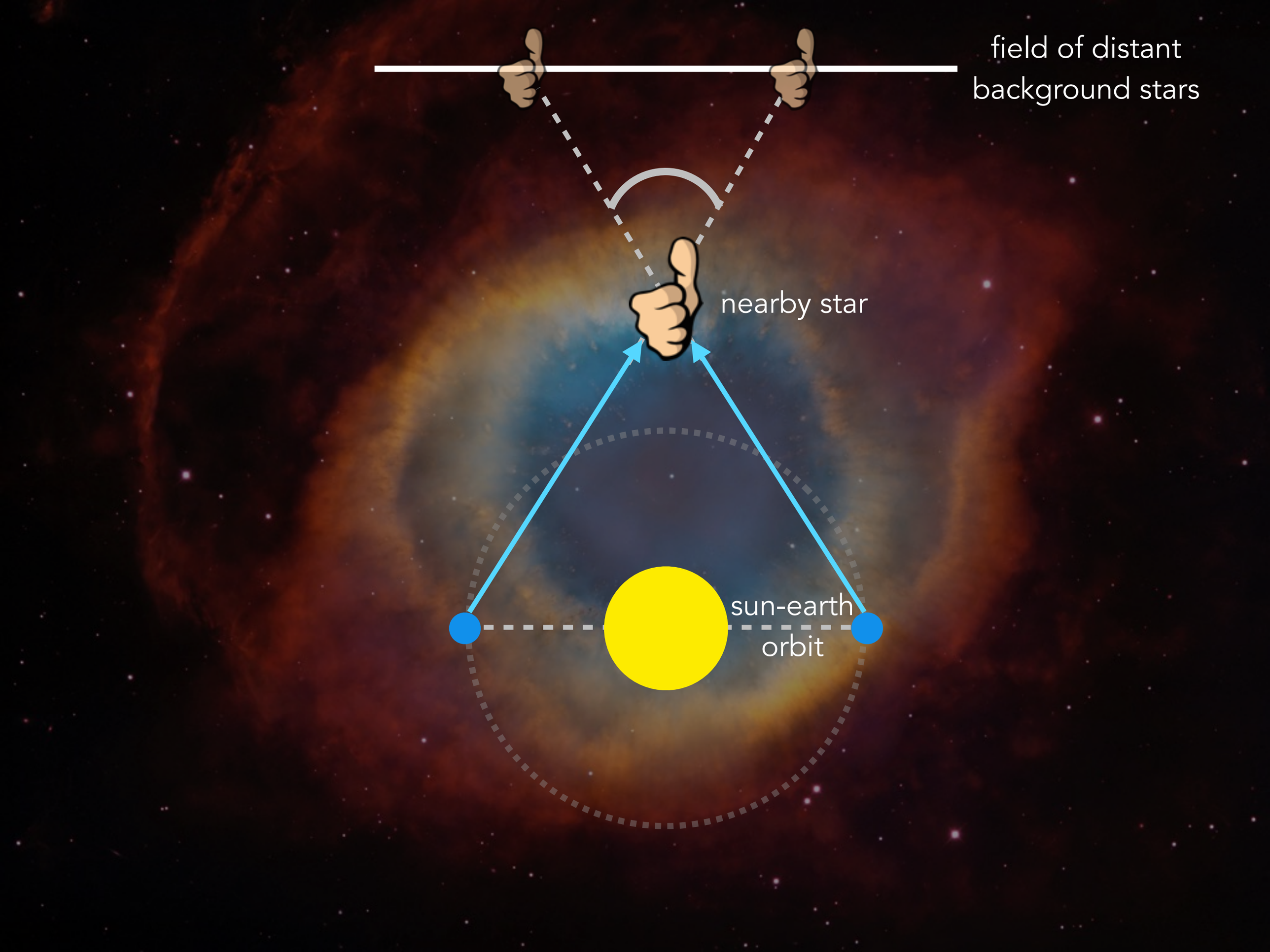



Bright
Observed Visible Magnitude
Faint
Blue (hot)
B-V Color
Red (cool)

field of distant
background stars




field of distant
background stars
nearby star
sun-earth
orbit


field of distant
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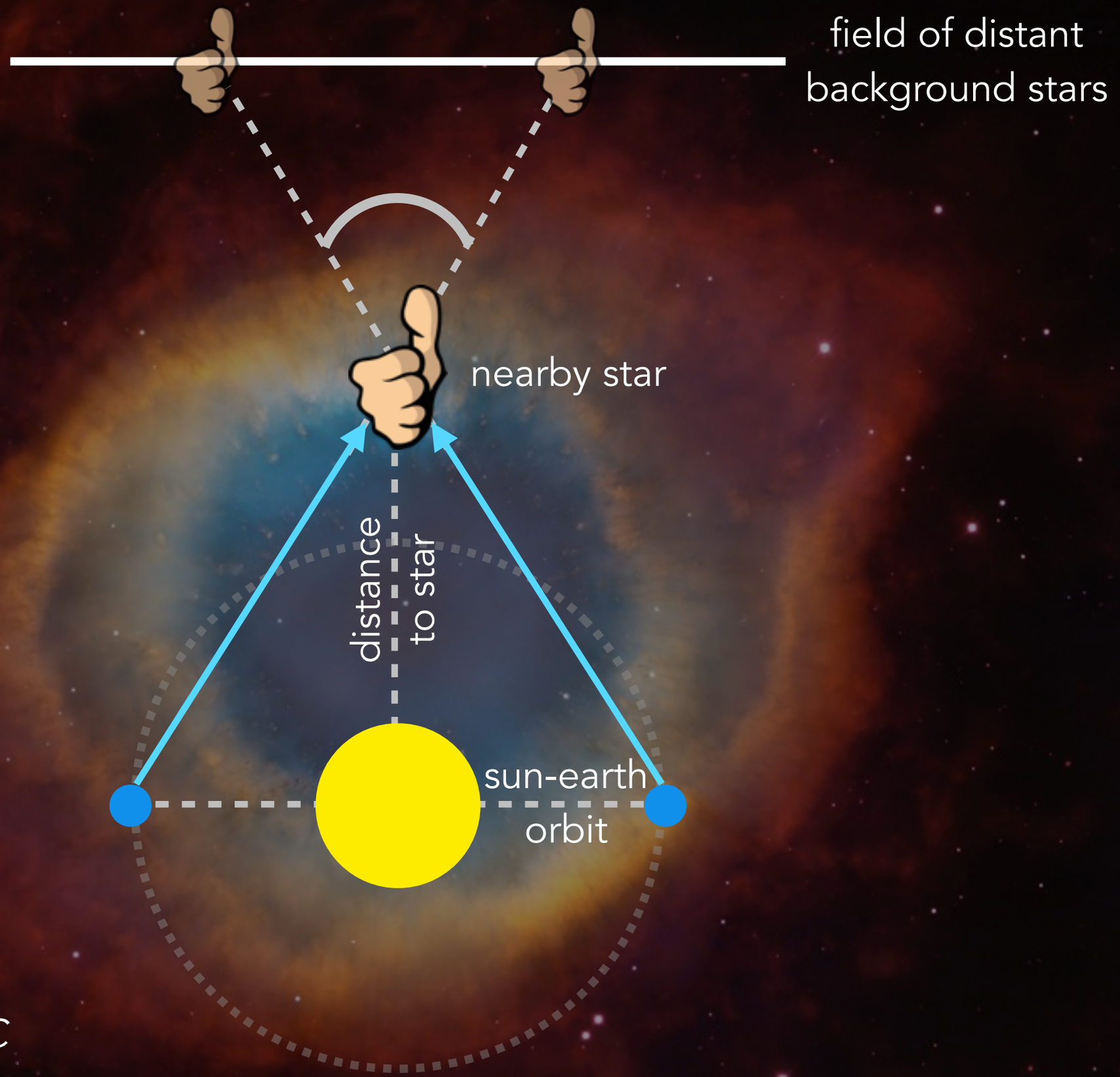
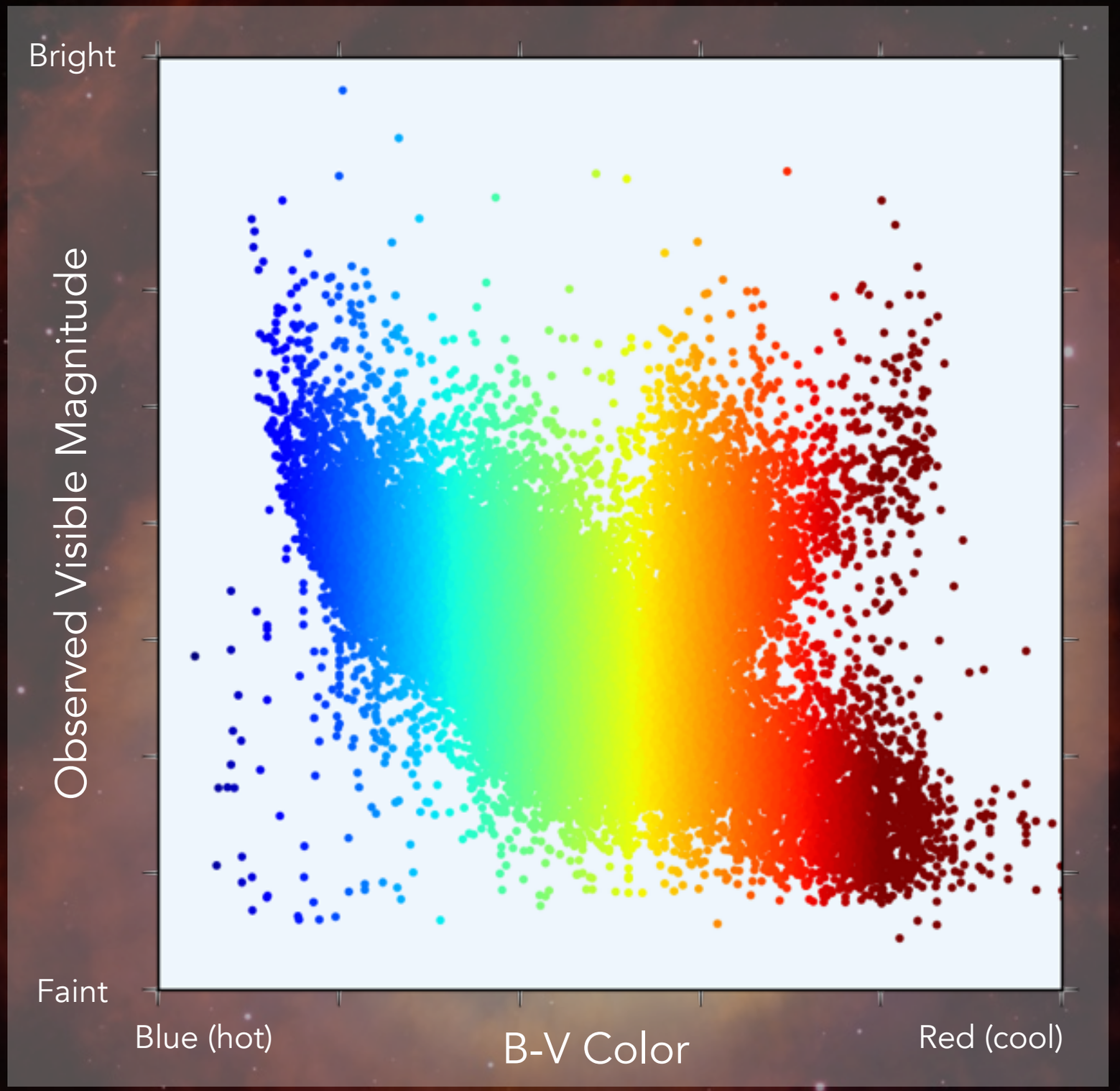
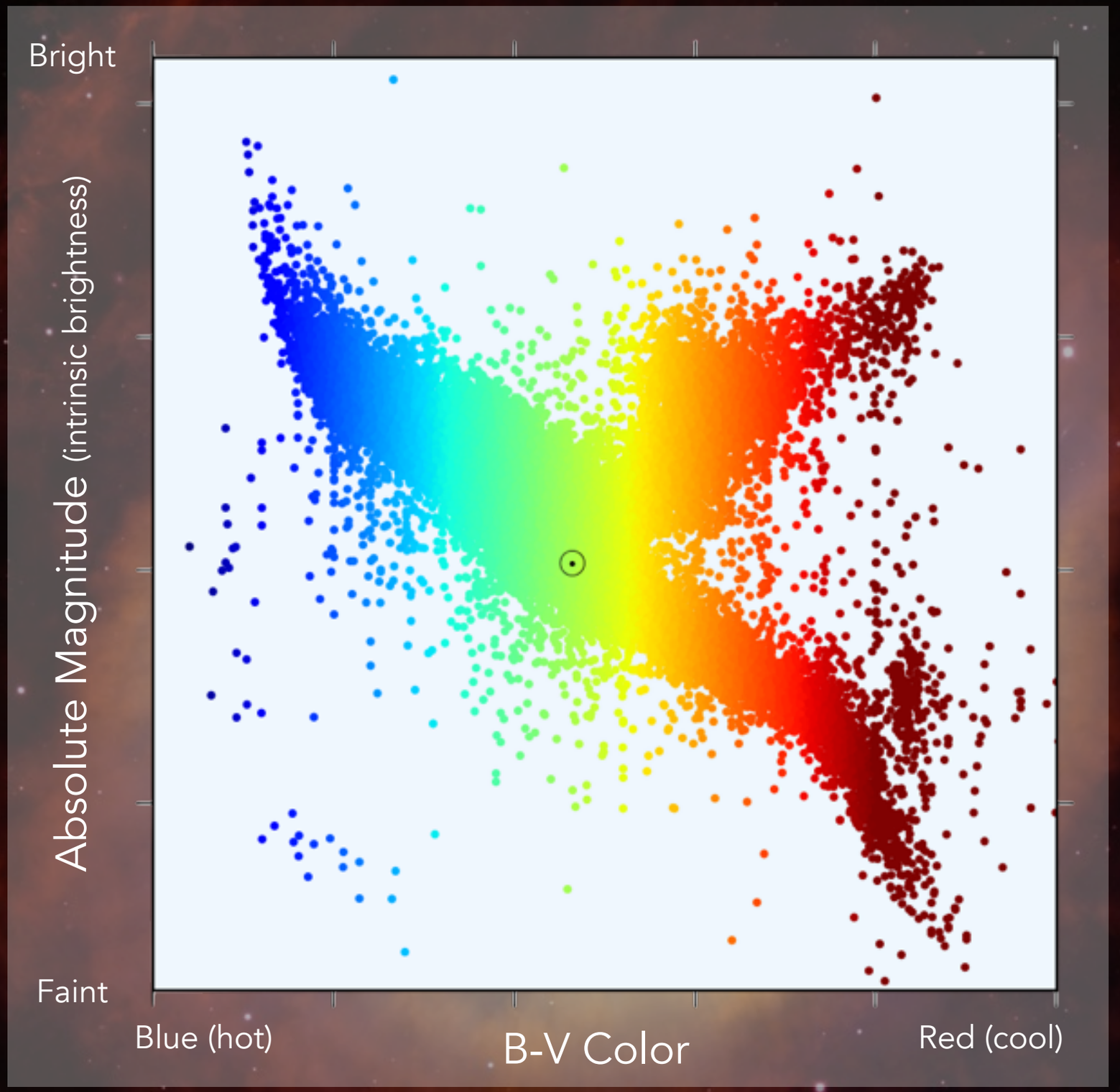
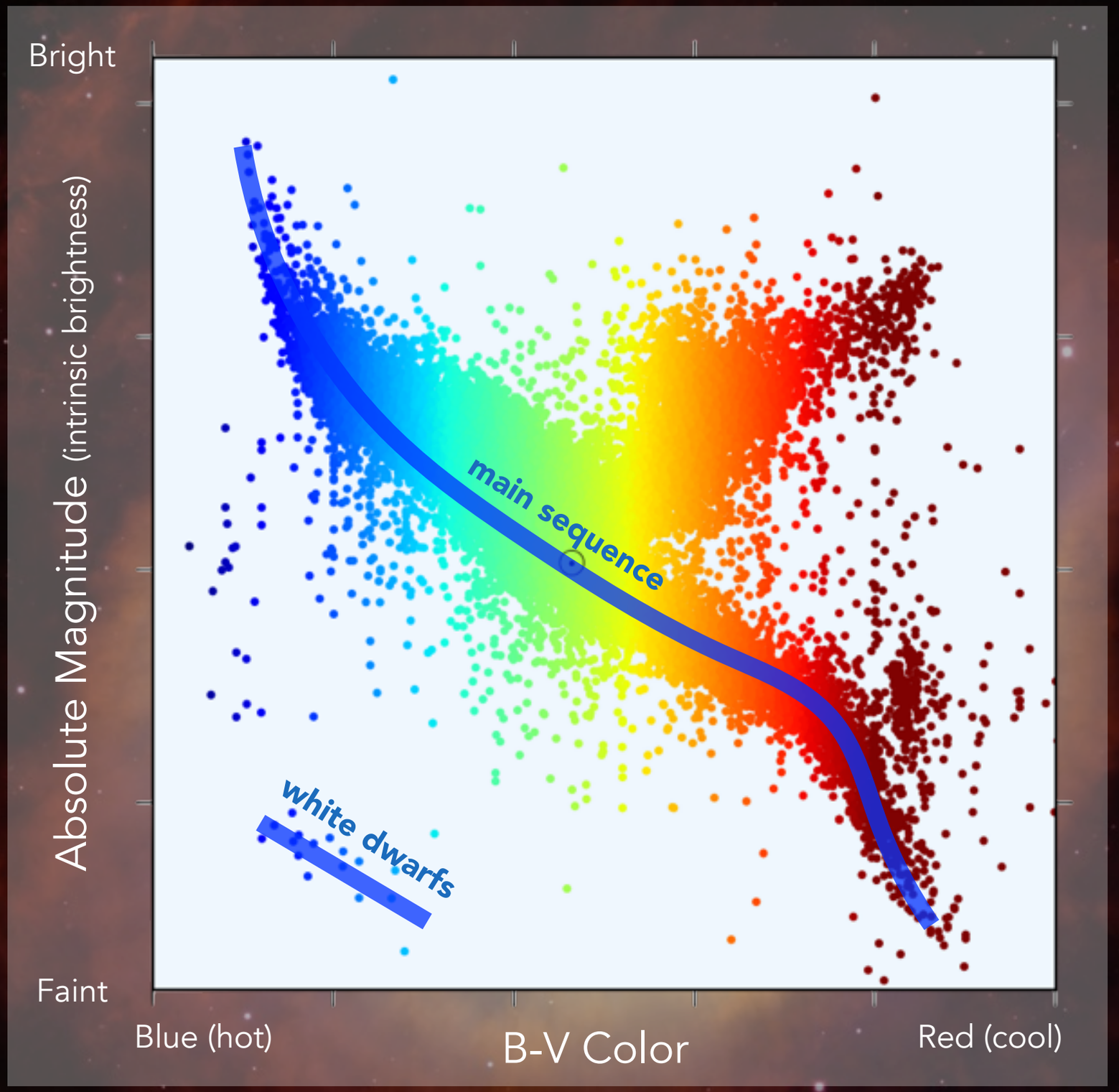
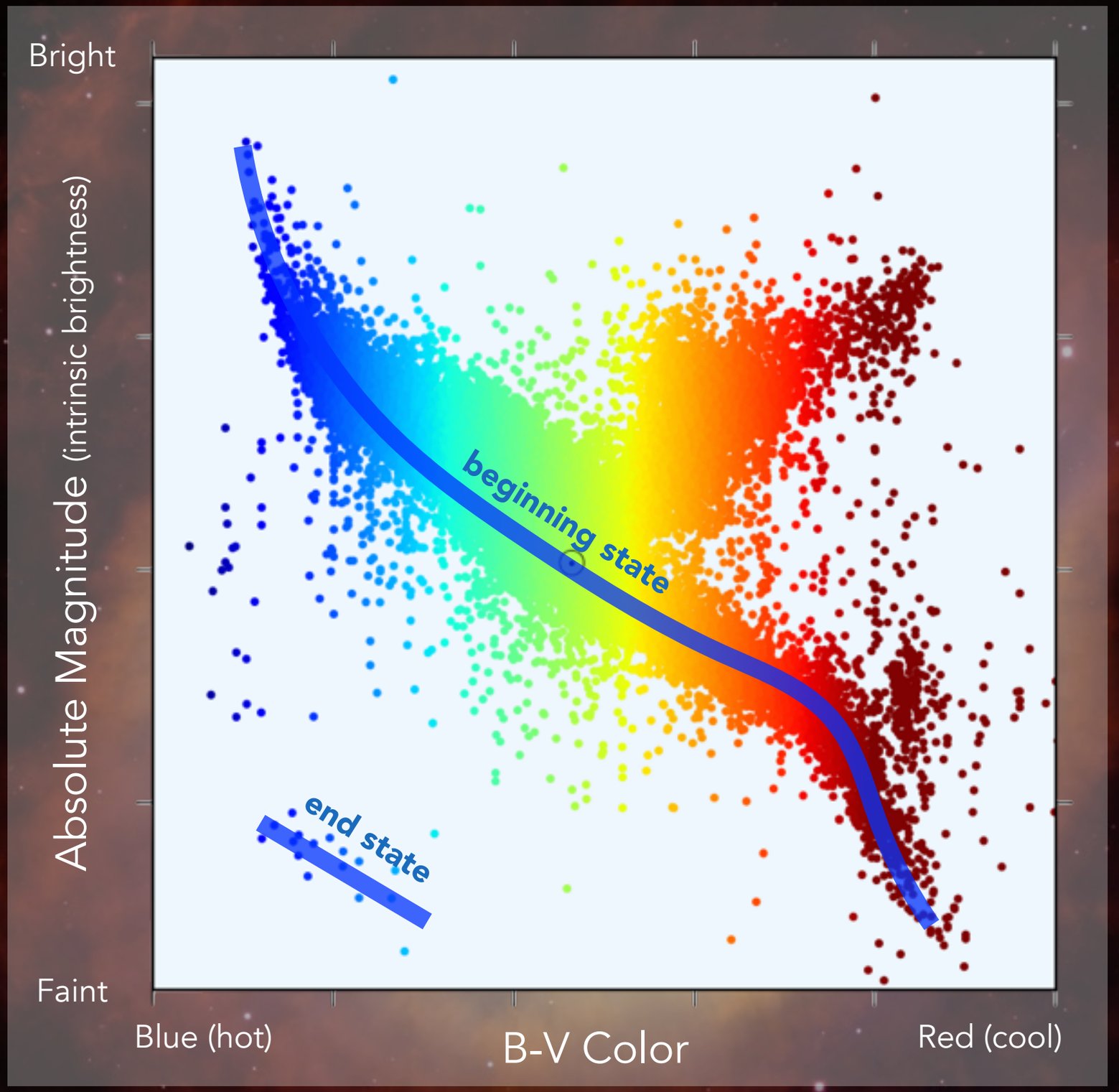


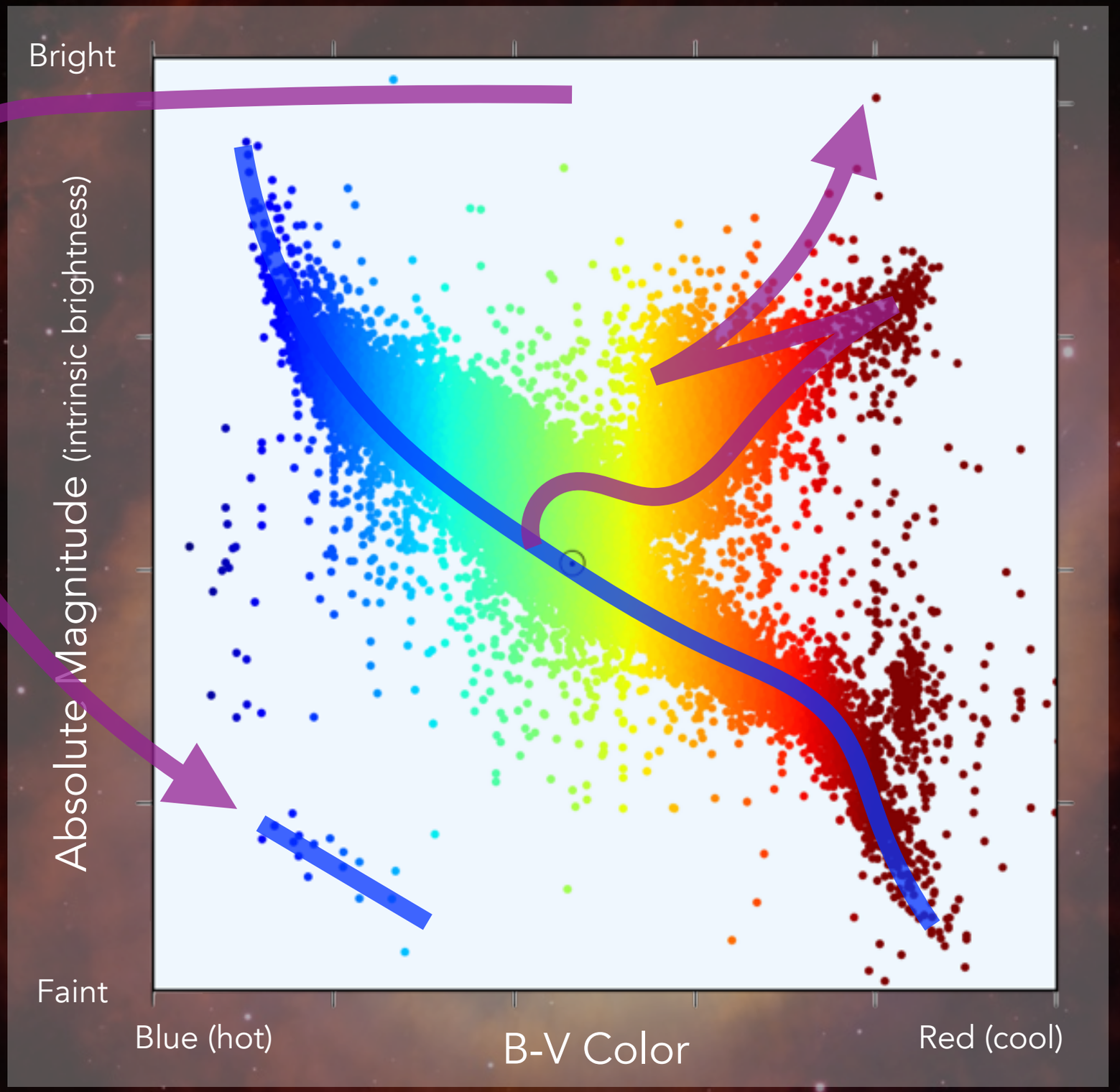
TRIGONOMETRIC PARALLAX

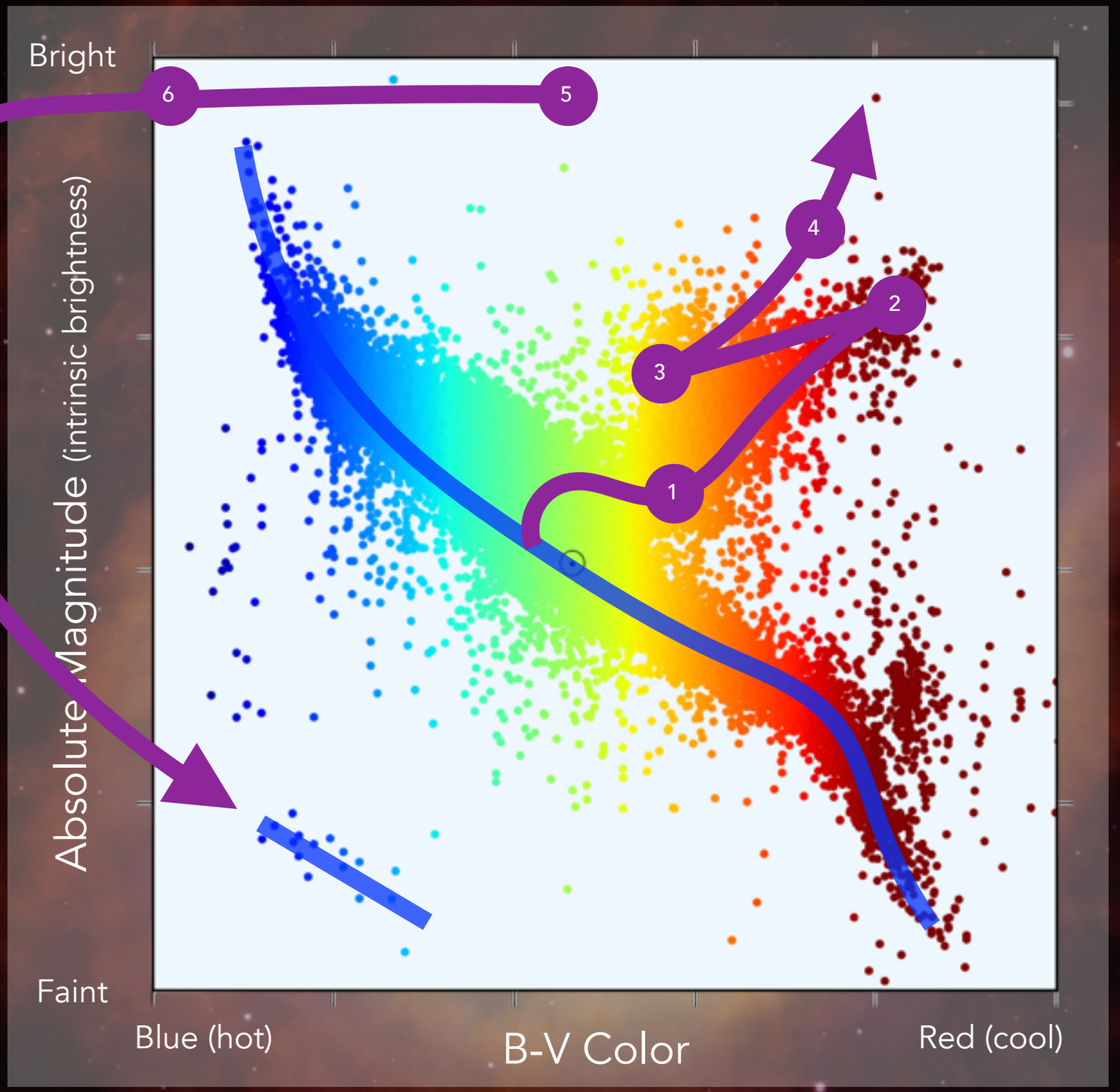

Bright
Observed Visible Magnitude
Faint
Blue (hot)
B-V Color
Red (cool)

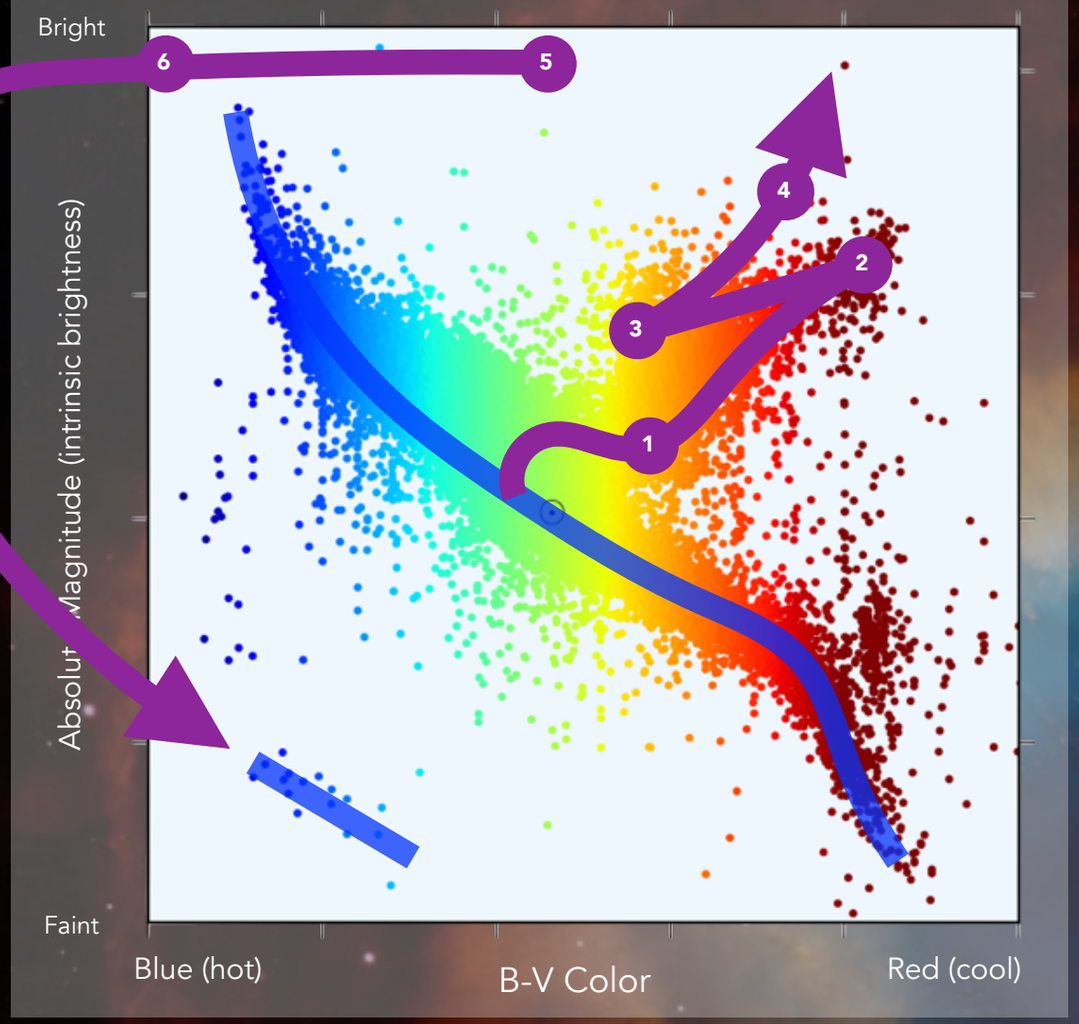

Bright
Absolute Magnitude (intrinsic brightness)
Faint
Blue (hot)
B-V Color
Red (cool)


Bright
Absolute Magnitude (intrinsic brightness)
main sequence
white dwarfs
Faint
Blue (hot)
B-V Color
Red (cool)


Bright
Absolute Magnitude (intrinsic brightness)
beginning state
end state
Faint
Blue (hot)
B-V Color
Red (cool)


Bright
Absolute Magnitude (intrinsic brightness)
Faint
Blue (hot)
B-V Color
Red (cool)


Bright
Faint
Absolute Magnitude (intrinsic brightness)
Blue (hot)
B-V Color
Red (cool)
1
2
3
4
5
6
7

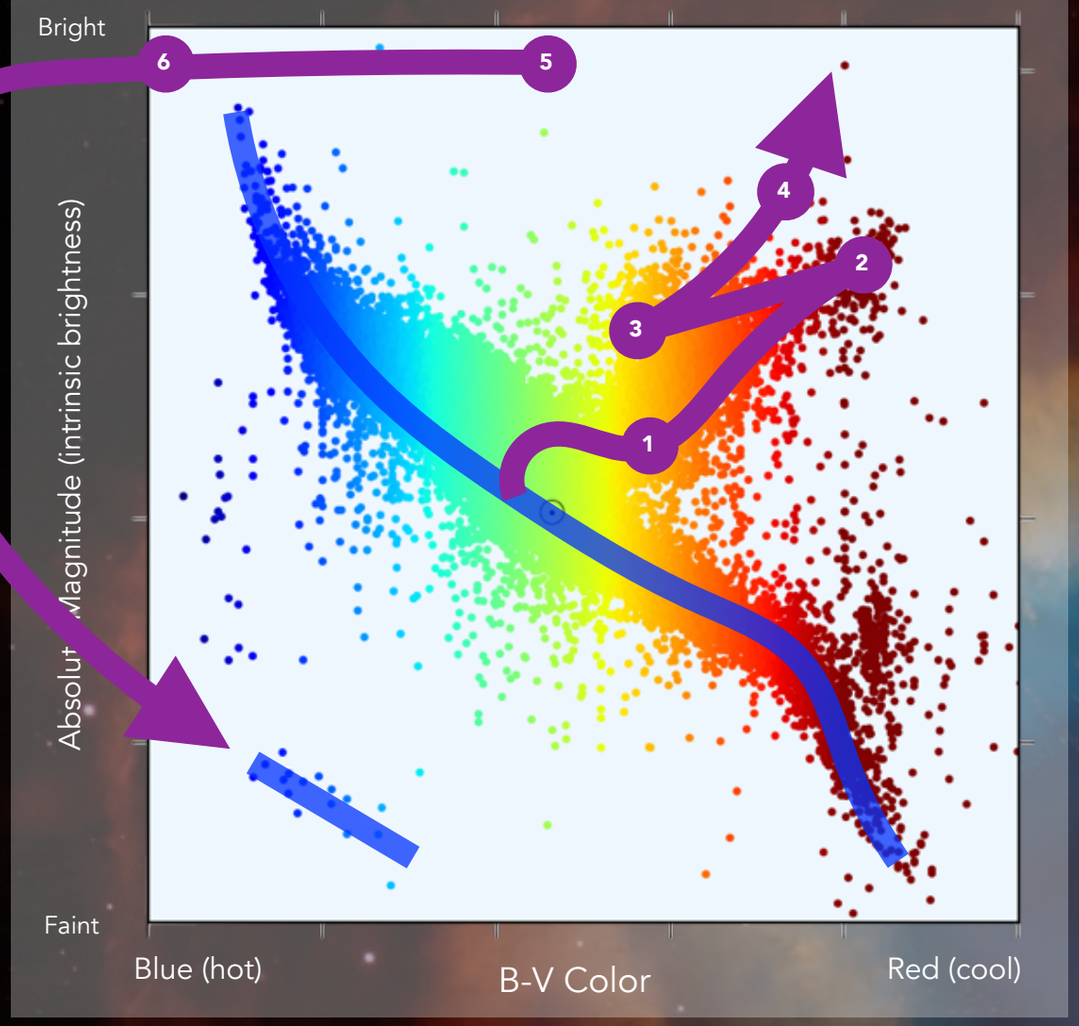


Post Main Sequence

1. Red Giant
2. Core Helium Ignition
3. Horizontal Branch (He Burning)
4. Asymptotic Giant Branch (AGB)

Post AGB

5. Nebula forms (fast wind?)
6. Nebula is ionized (hot core)
7. Fading Nebula and Core (pre-WD)



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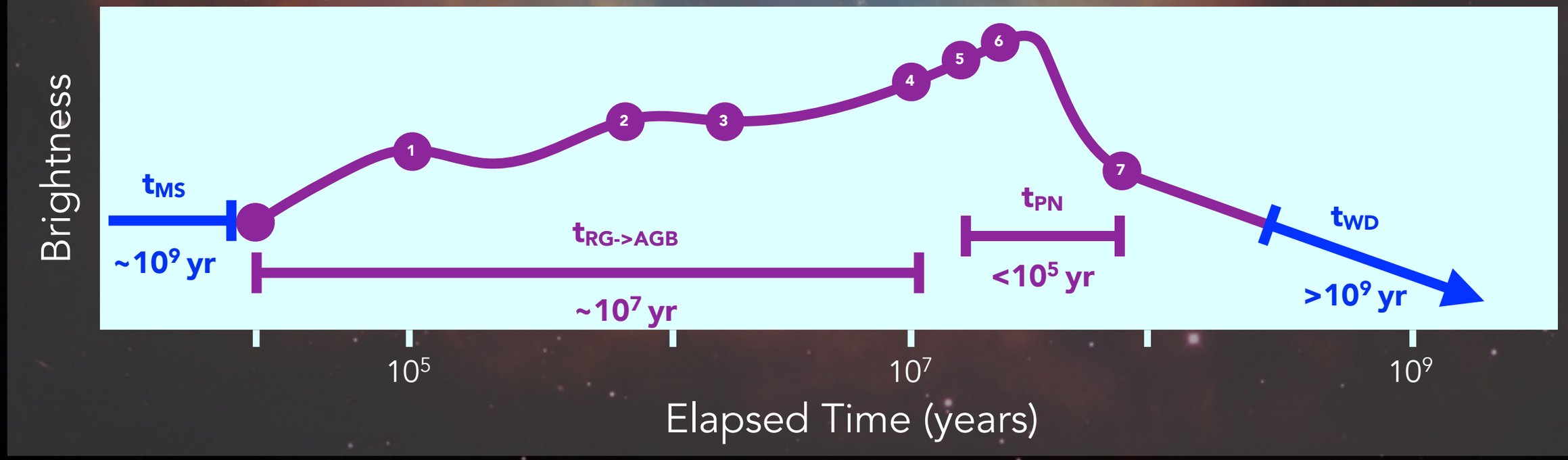

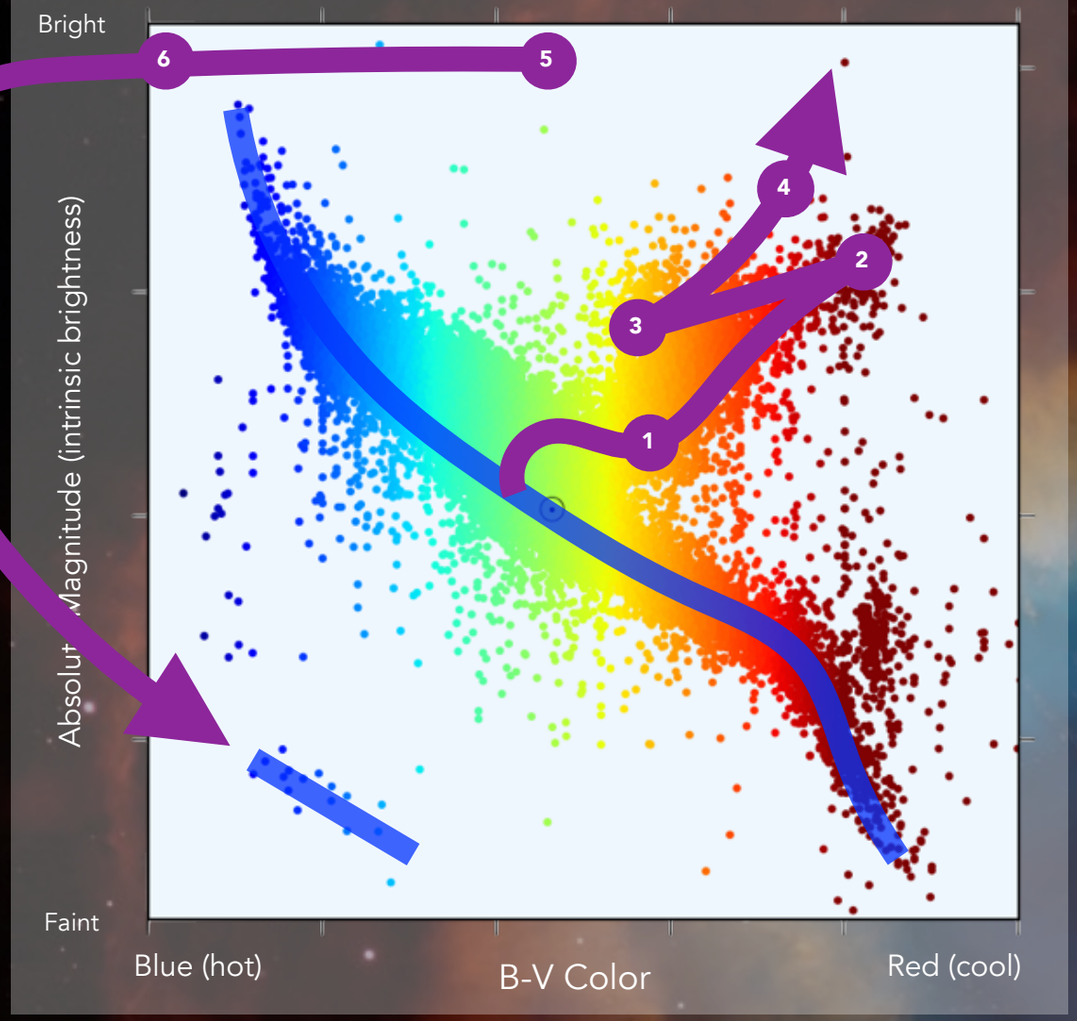

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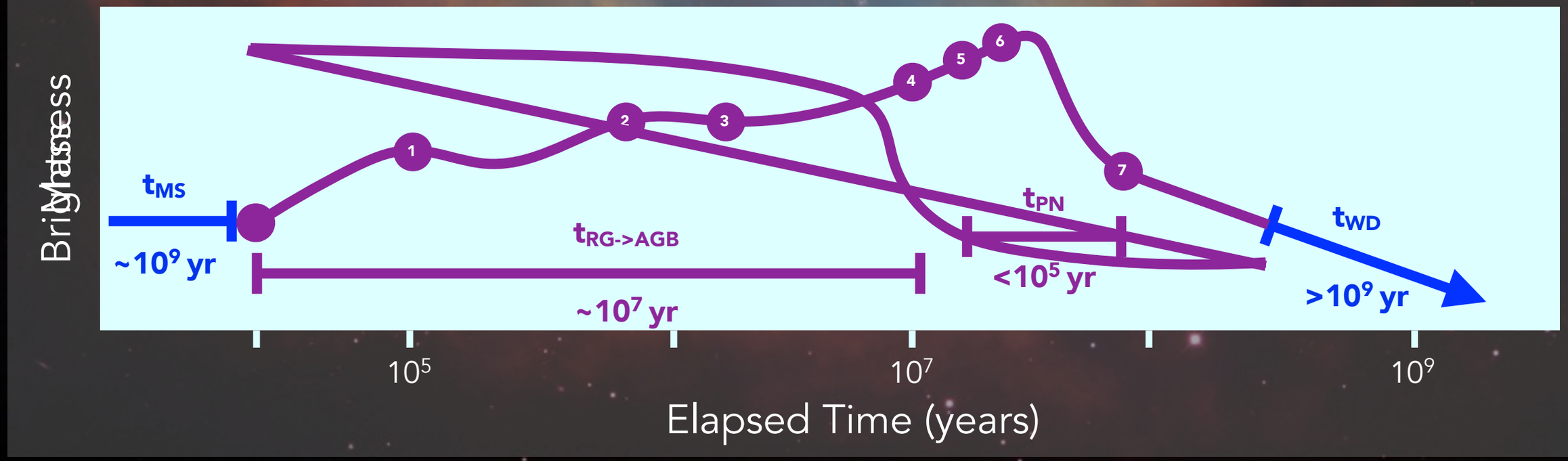

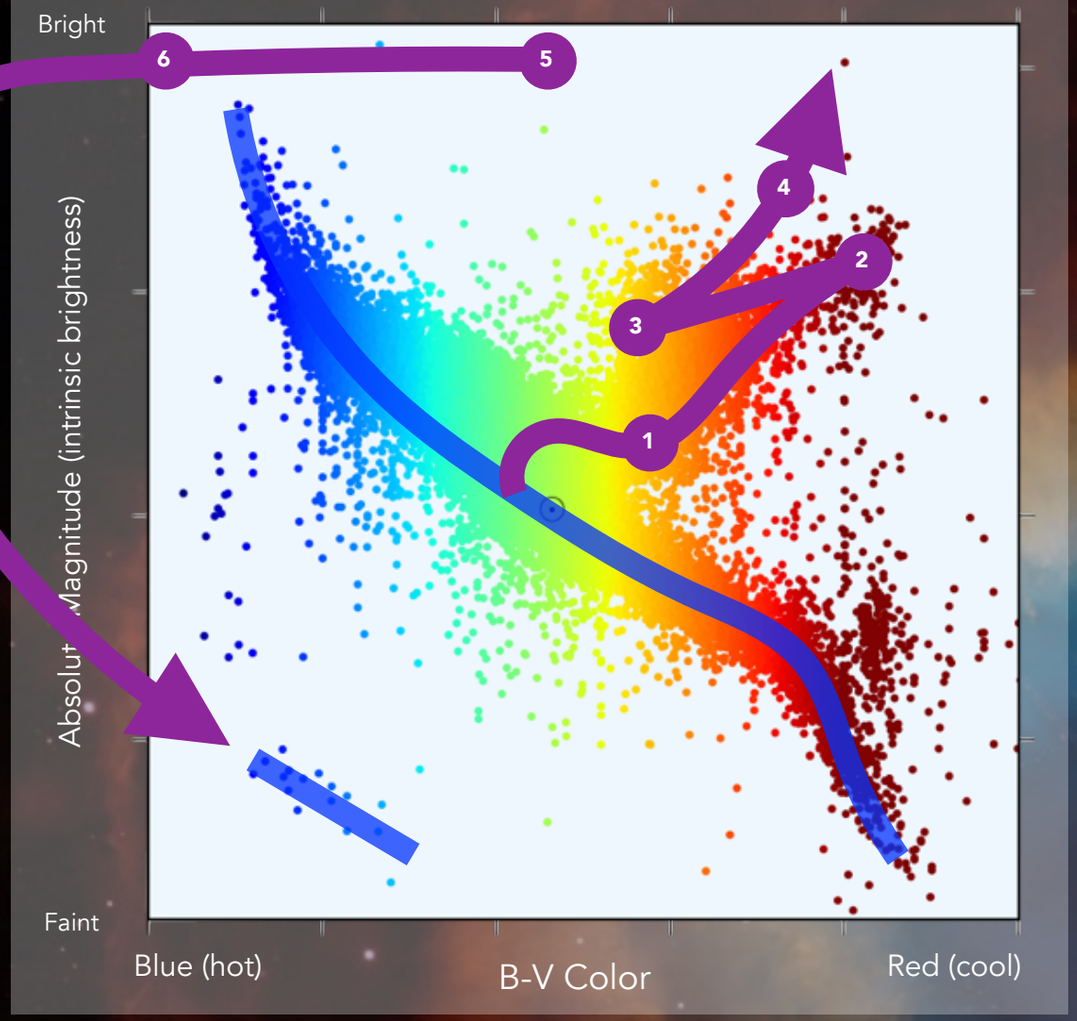

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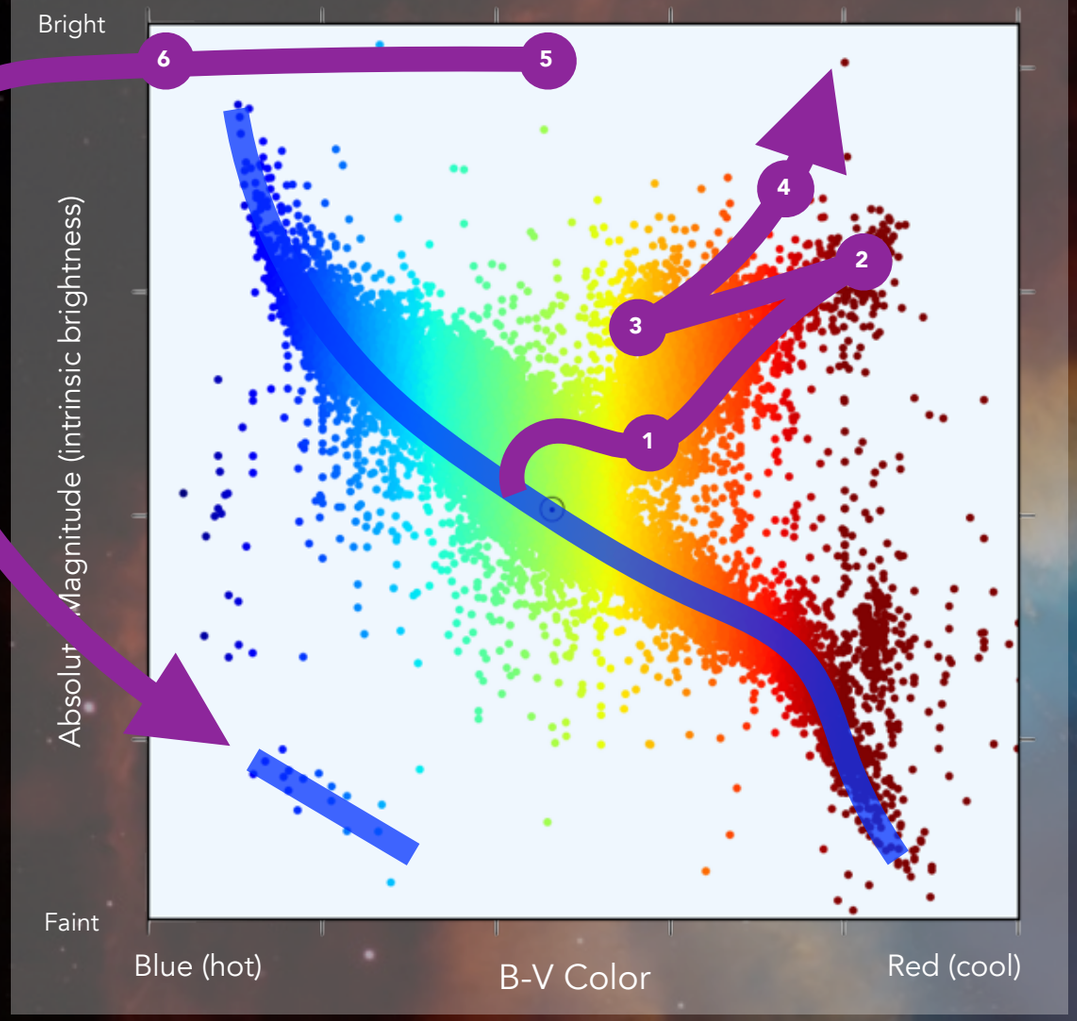

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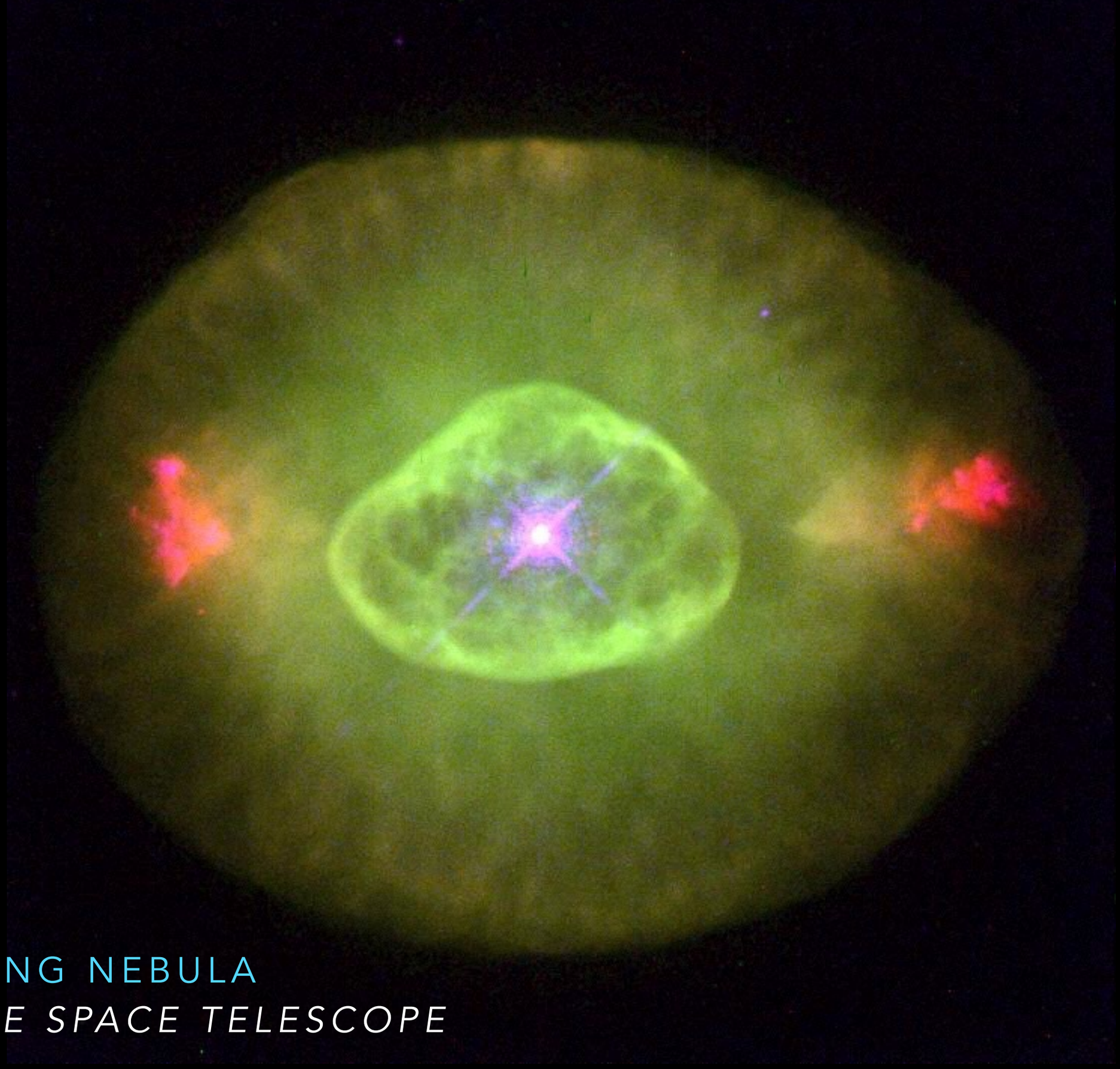
SPIROGRAPH NEBULA

HUBBLE SPACE TELESCOPE

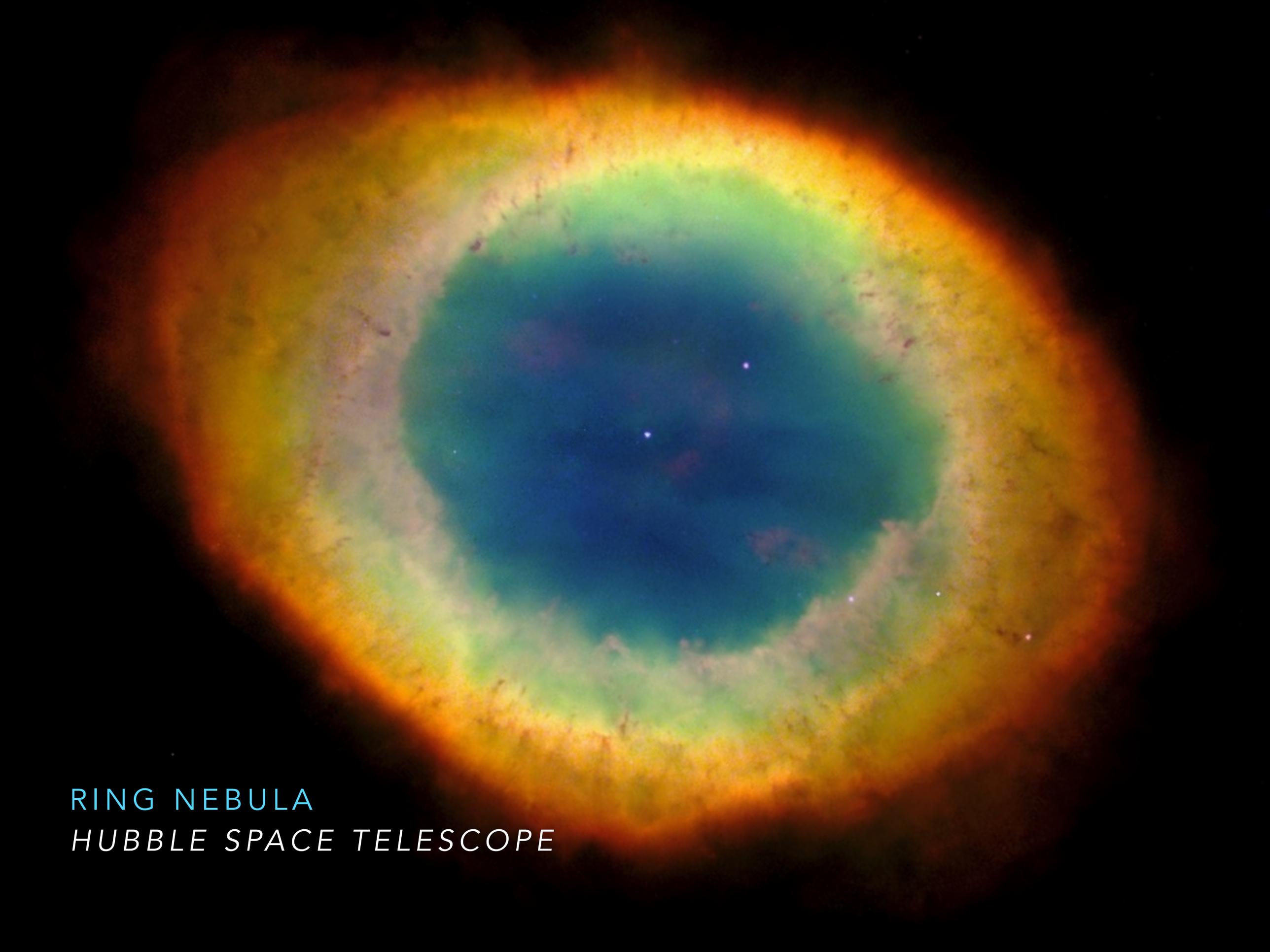


BLINKING NEBULA

HUBBLE SPACE TELESCOPE

ESKIMO NEBULA

HUBBLE SPACE TELESCOPE

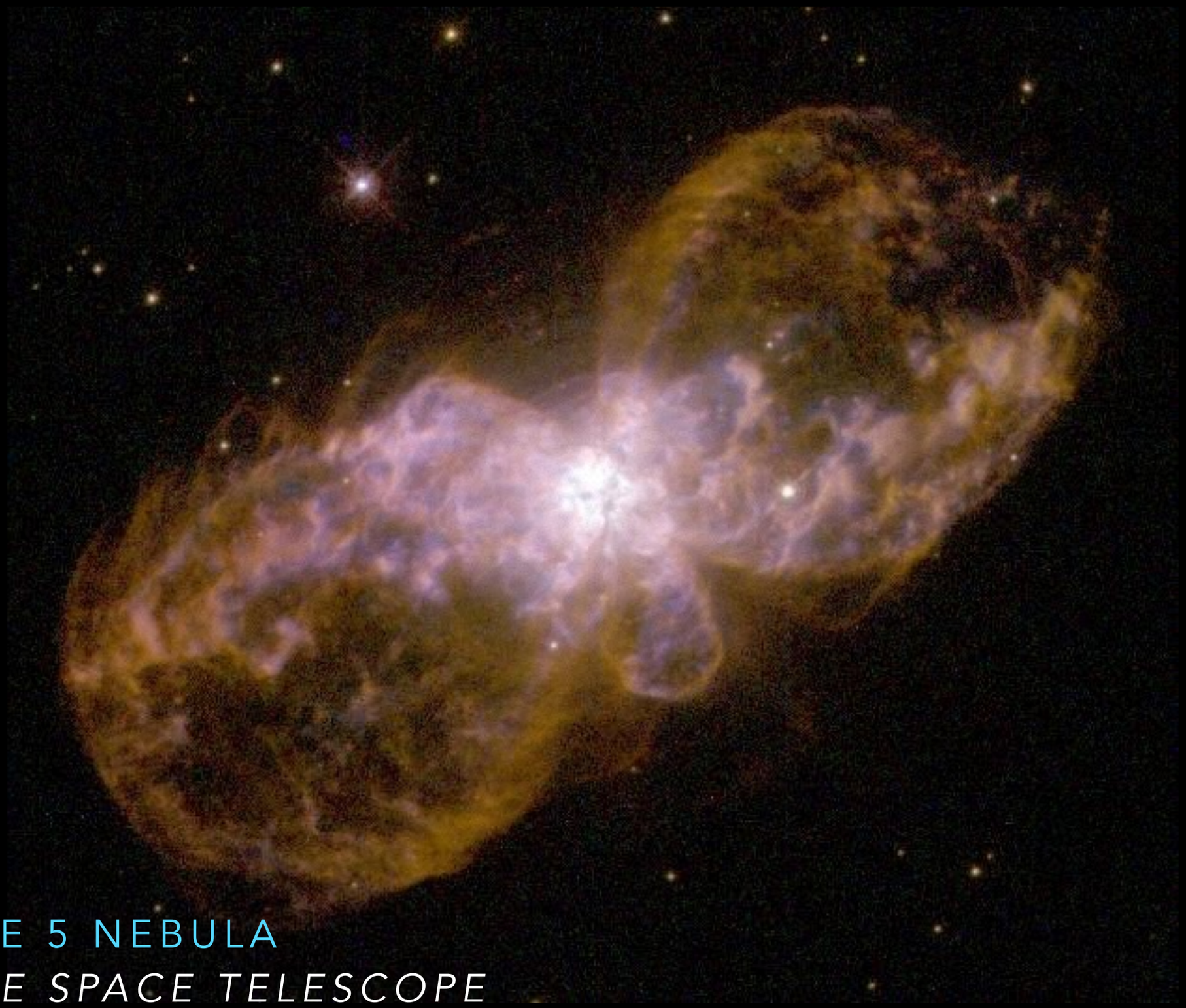


RING NEBULA

HUBBLE SPACE TELESCOPE

LITTLE GHOST NEBULA

HUBBLE SPACE TELESCOPE



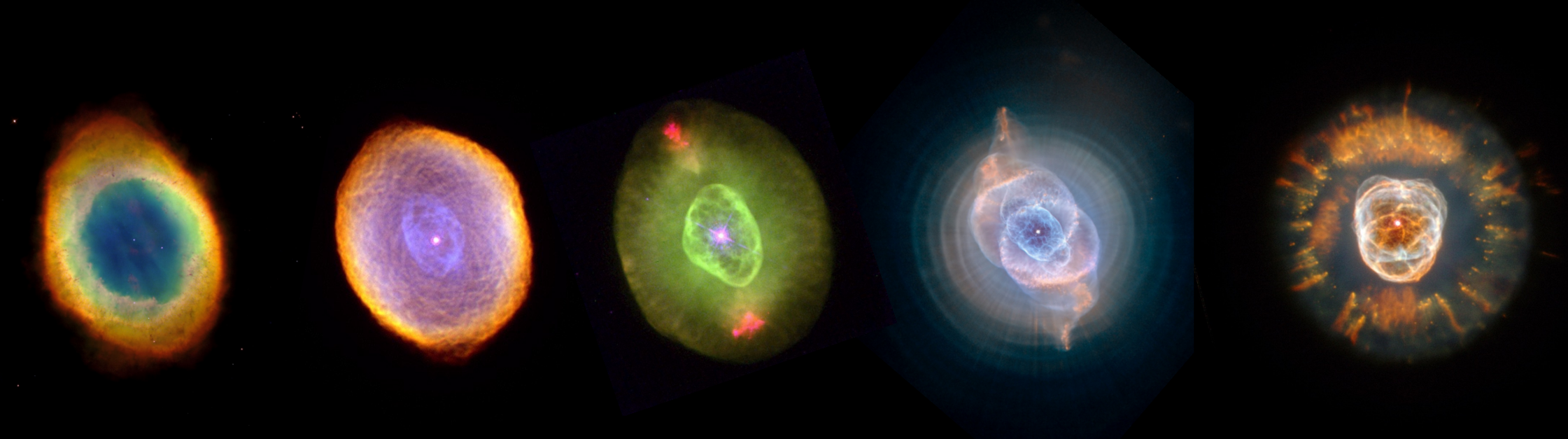
HUBBLE 5 NEBULA

HUBBLE SPACE TELESCOPE

CAT'S EYE NEBULA
HUBBLE SPACE TELESCOPE

ERA OF SPACE TELESCOPES

WHAT DOES HUBBLE SPY WITH ITS ORBITING EYE?



VARIETY OF MORPHOLOGICAL DETAILS

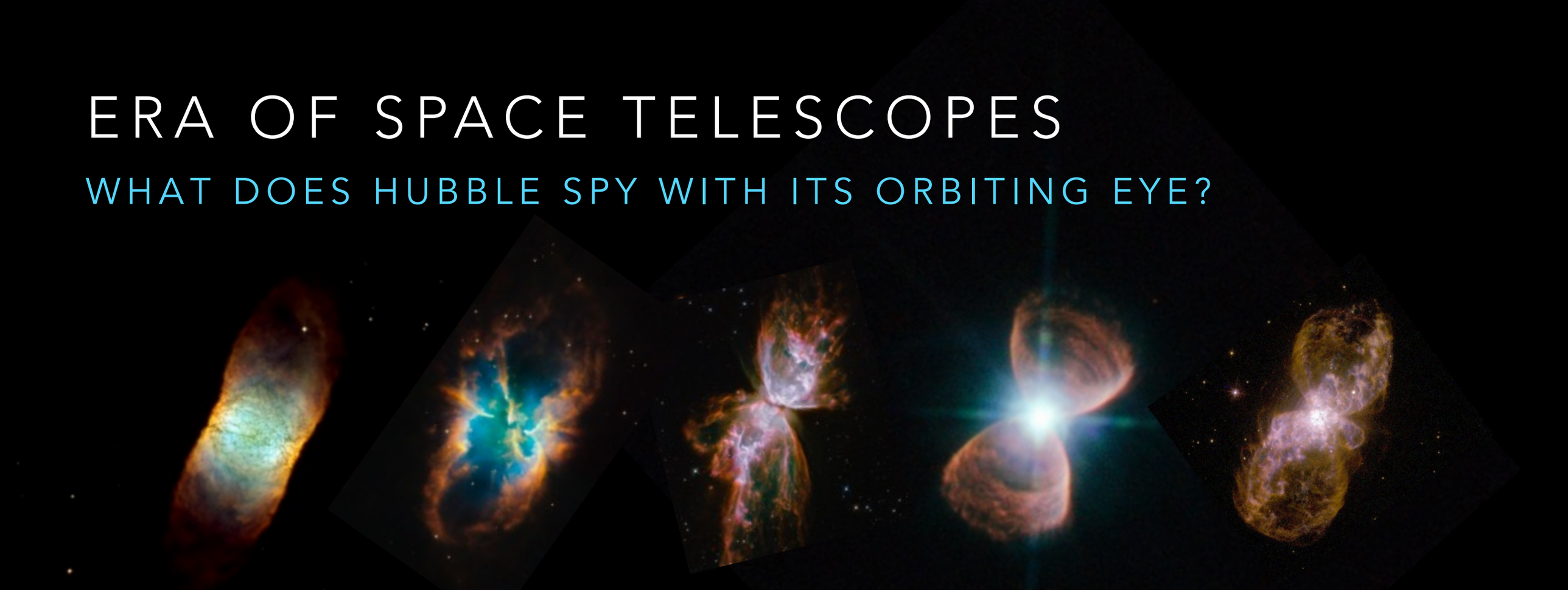
MOSTLY ELLIPTICAL OR ELONGATED

VERY FEW ROUND/SPHERICAL NEBULA

JET-LIKE AND BIPOLAR STRUCTURES

ERA OF SPACE TELESCOPES

WHAT DOES HUBBLE SPY WITH ITS ORBITING EYE?



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MOSTLY ELLIPTICAL OR ELONGATED

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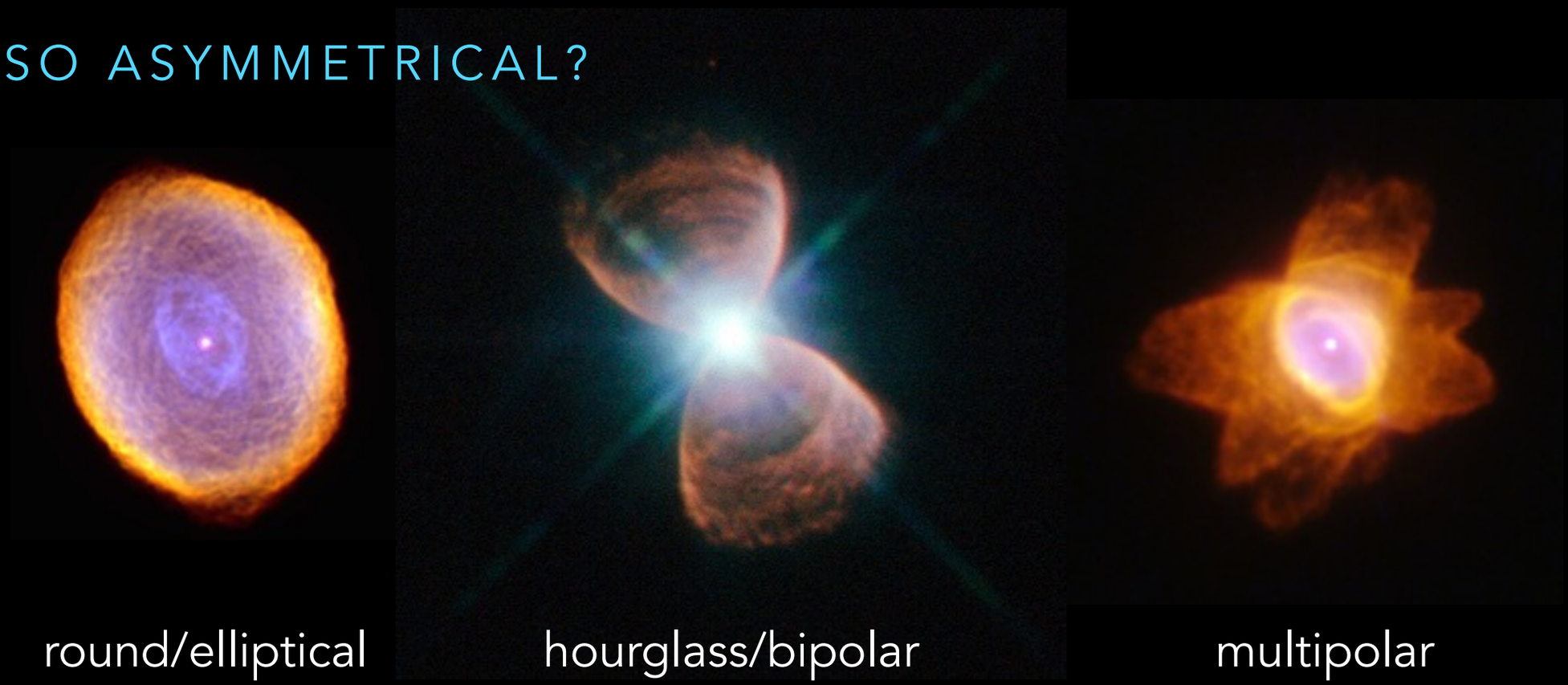
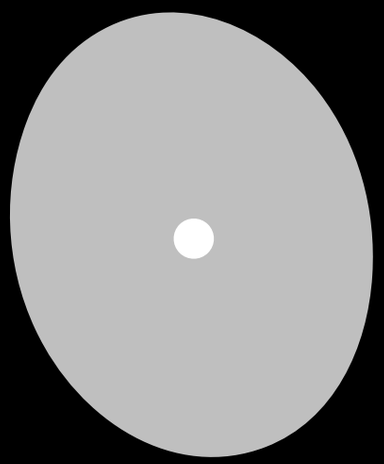
JET-LIKE AND BIPOLAR STRUCTURES

MORPHOLOGICAL CONFUSION

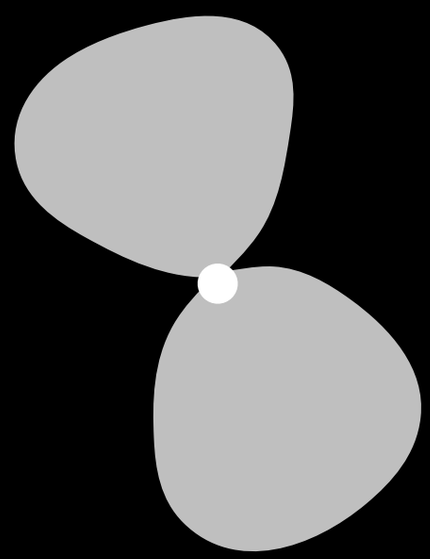
WHY SO ASYMMETRICAL?



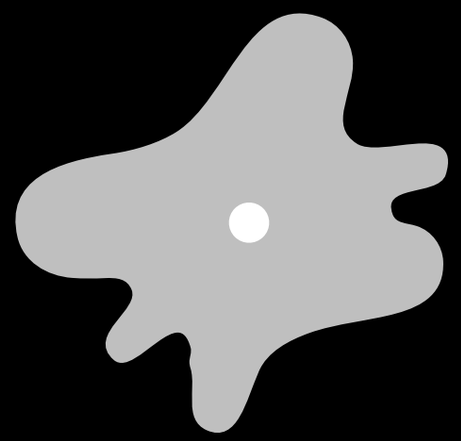
round/elliptical



hourglass/bipolar

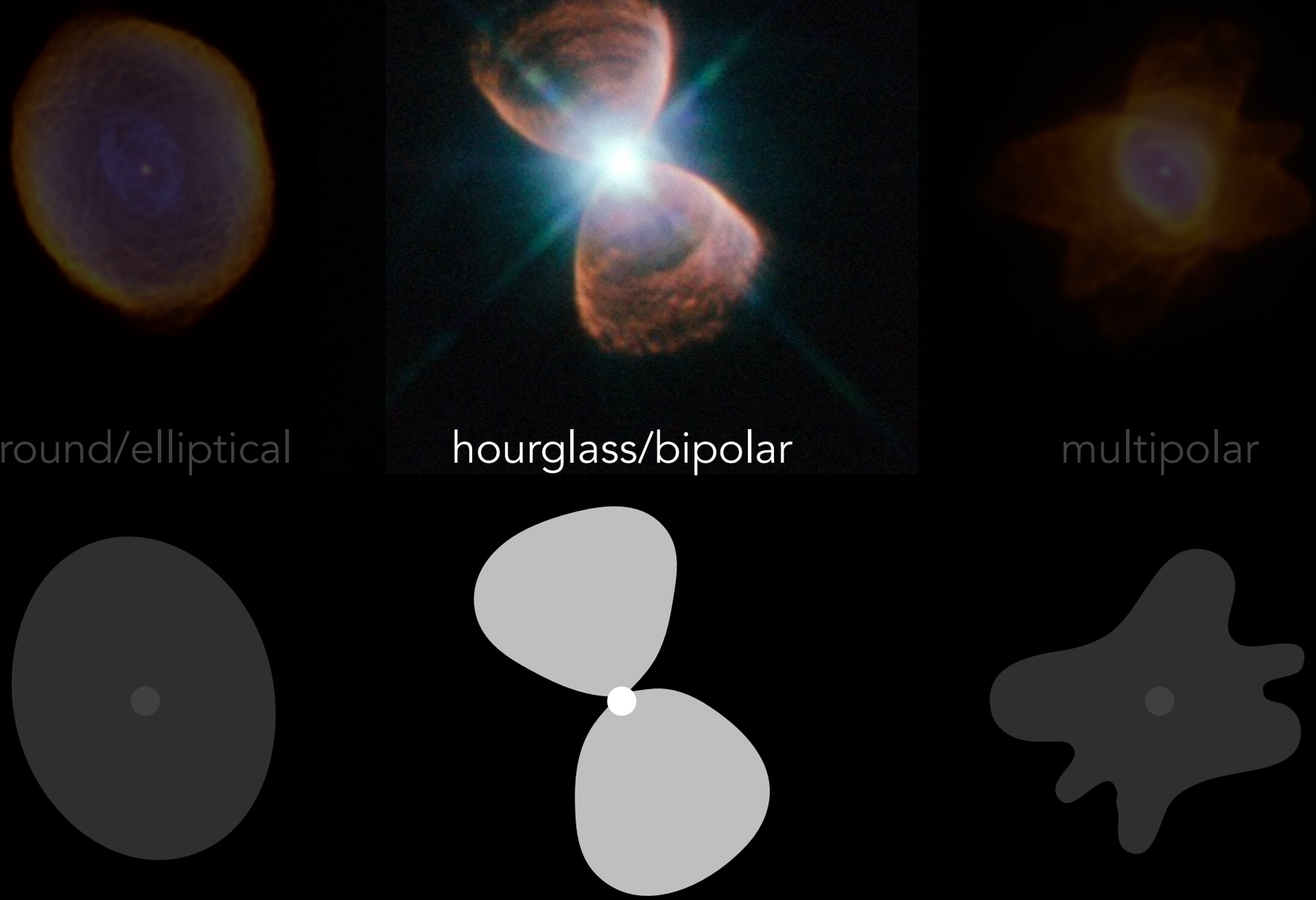


multipolar



MORPHOLOGICAL CONFUSION

WHY SO ASYMMETRICAL?



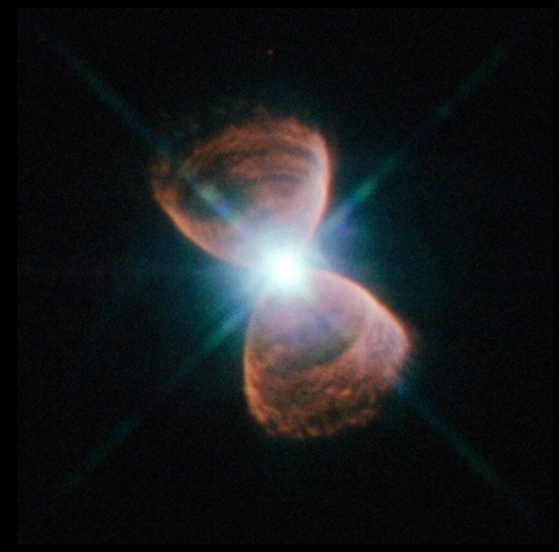
round/elliptical

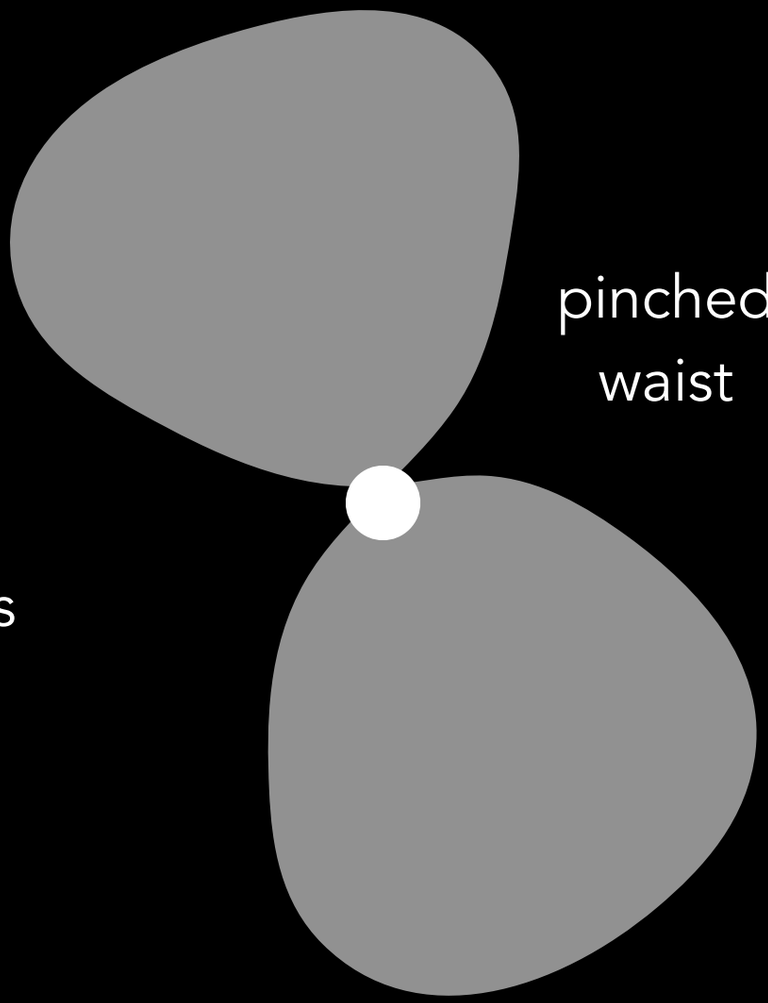
hourglass/bipolar

multipolar

MORPHOLOGICAL CONFUSION

WHY SO ASYMMETRICAL?





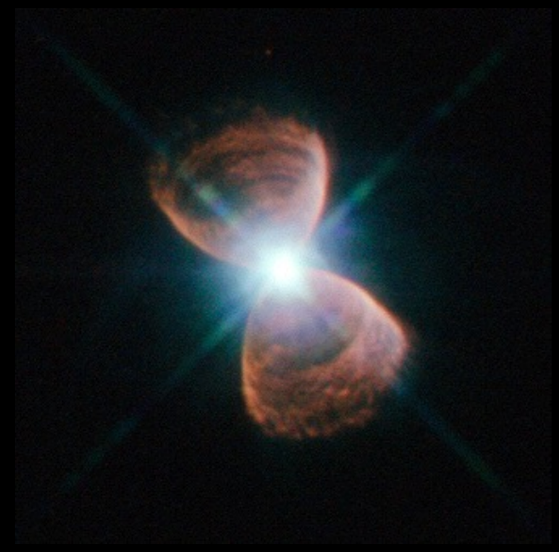
pinched
waist

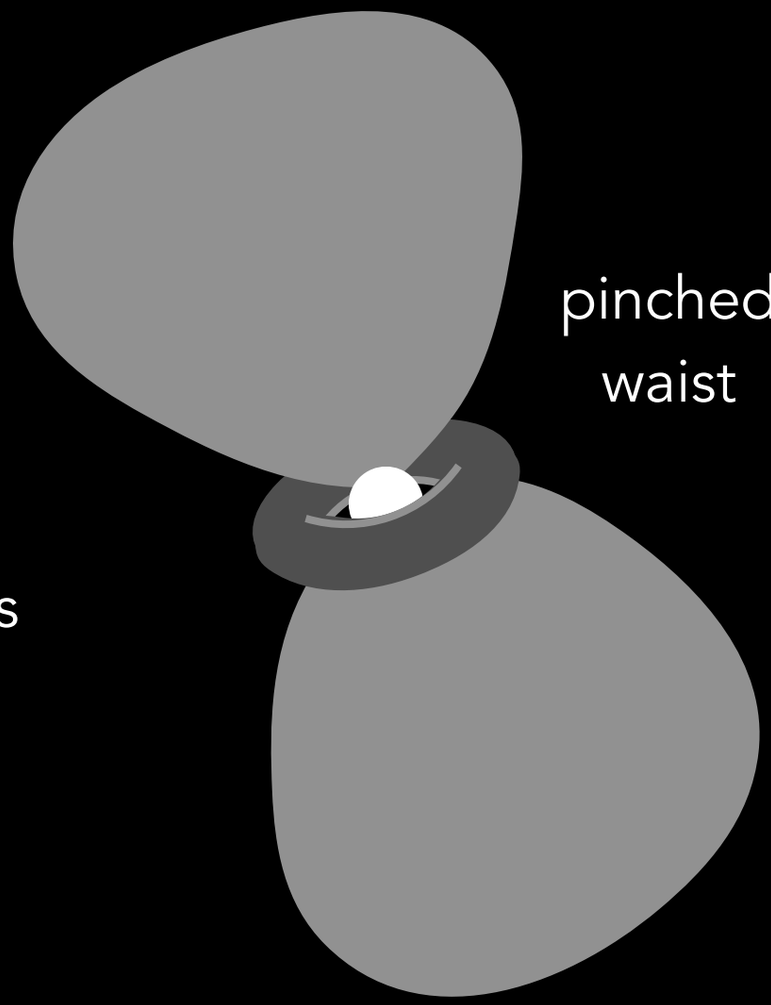
two lobes

hourglass/bipolar

MORPHOLOGICAL CONFUSION

WHY SO ASYMMETRICAL?

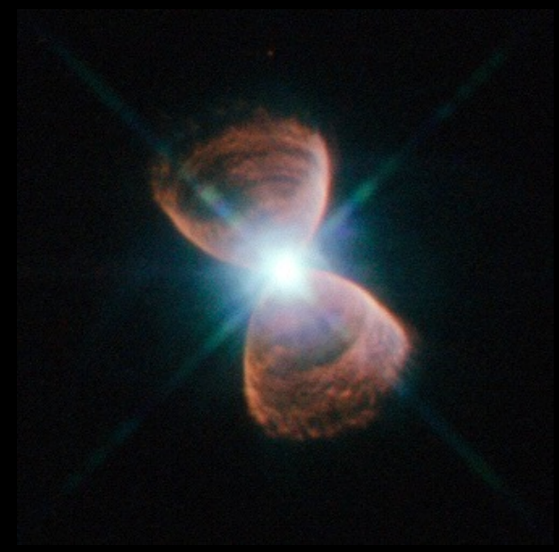


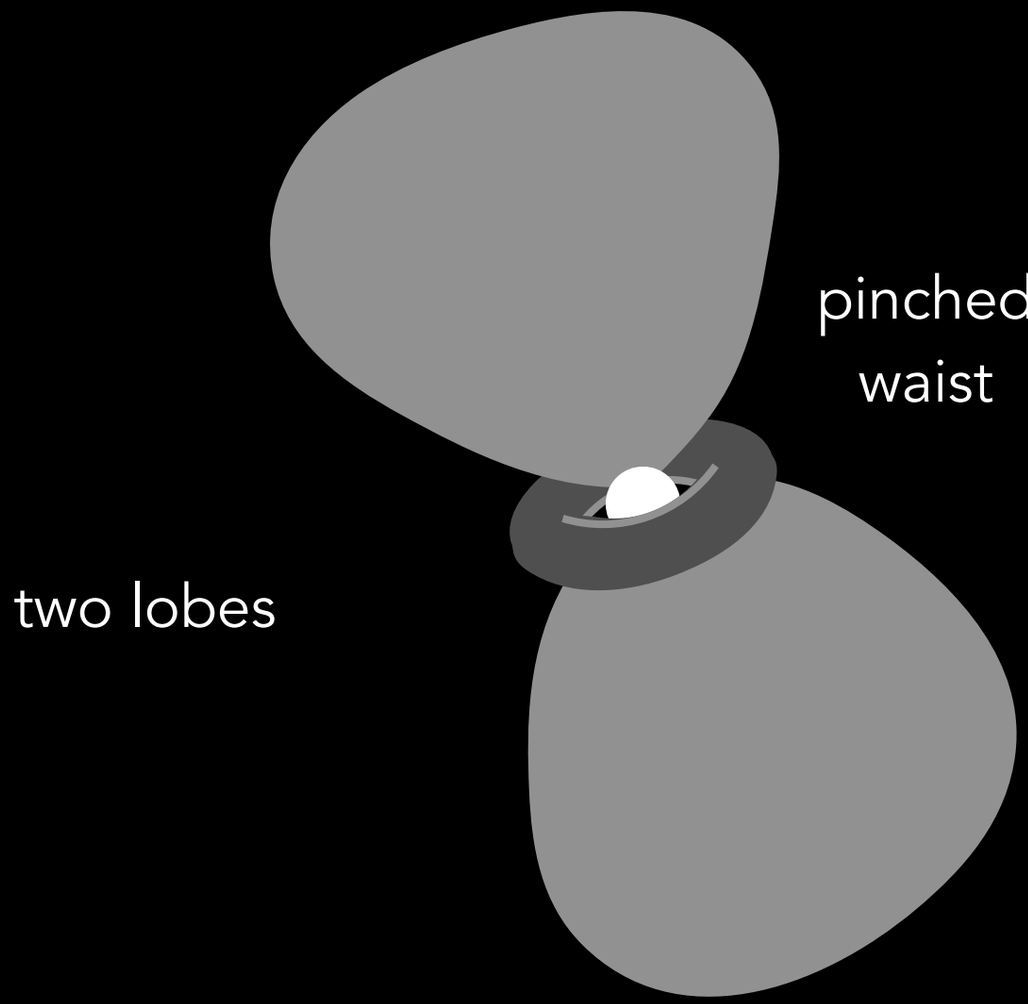


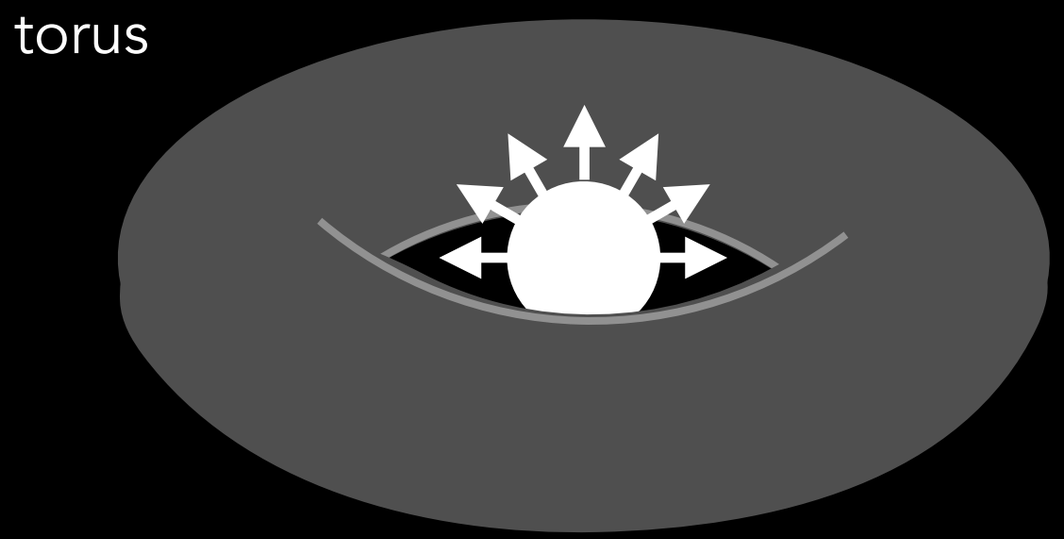
hourglass/bipolar

MORPHOLOGICAL CONFUSION

WHY SO ASYMMETRICAL?

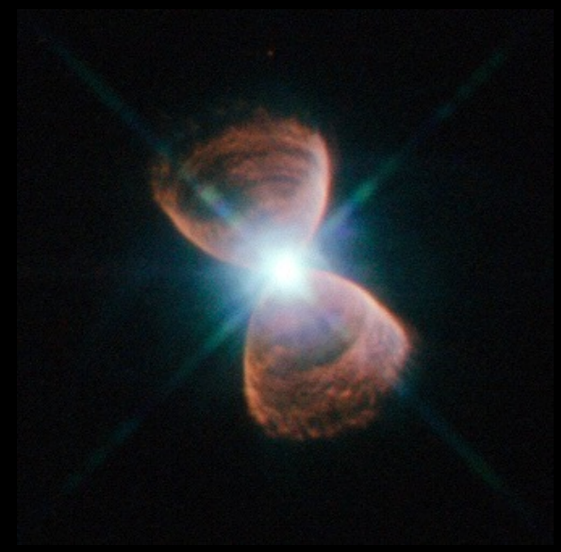


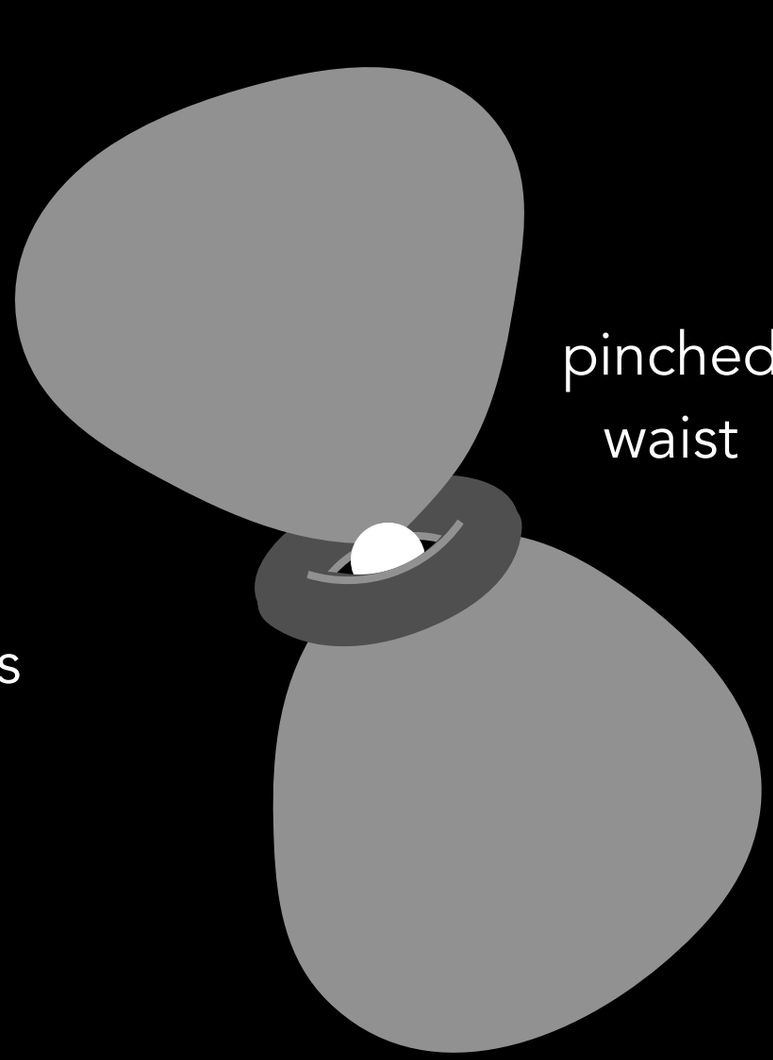




MORPHOLOGICAL CONFUSION

WHY SO ASYMMETRICAL?

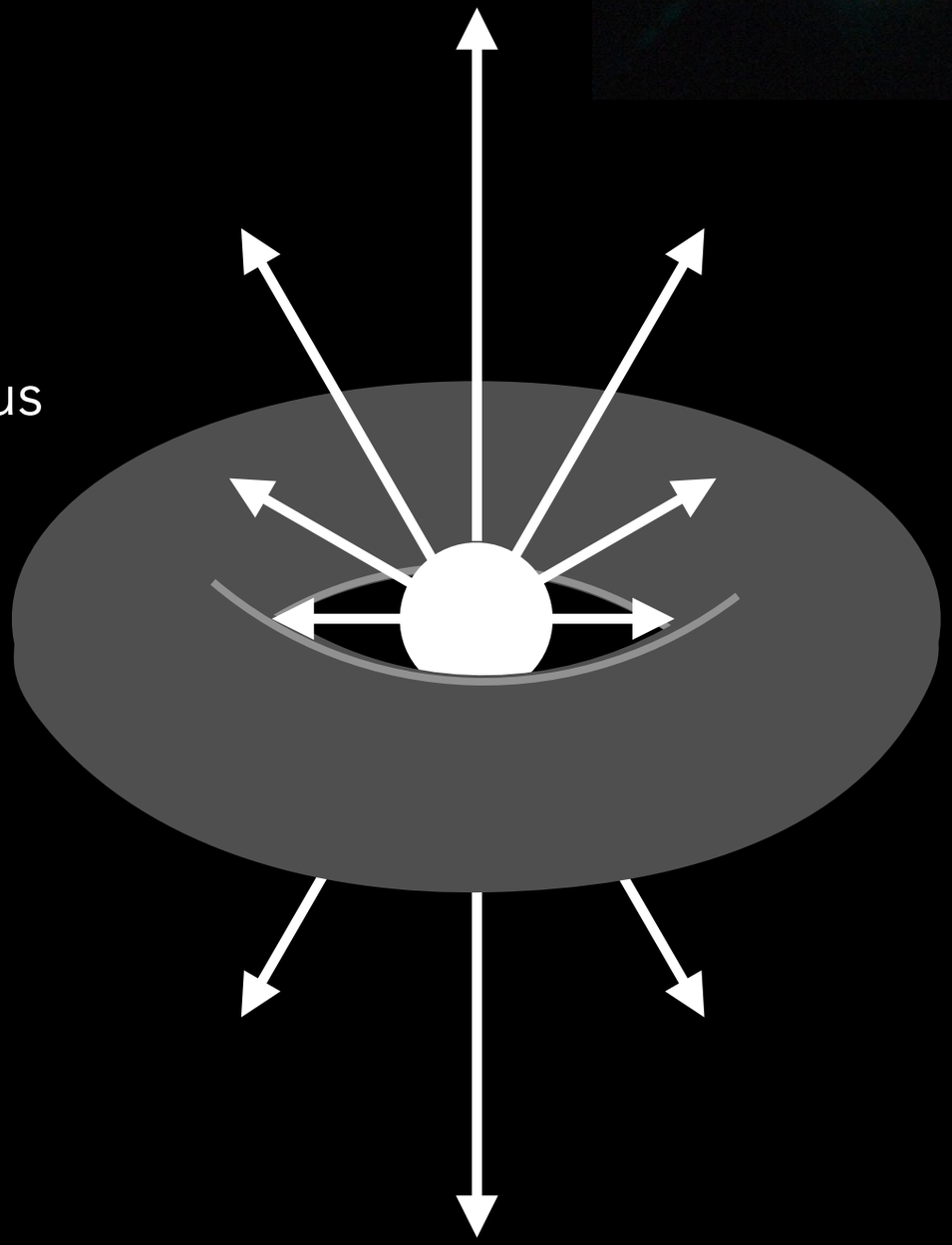




two lobes

pinched waist

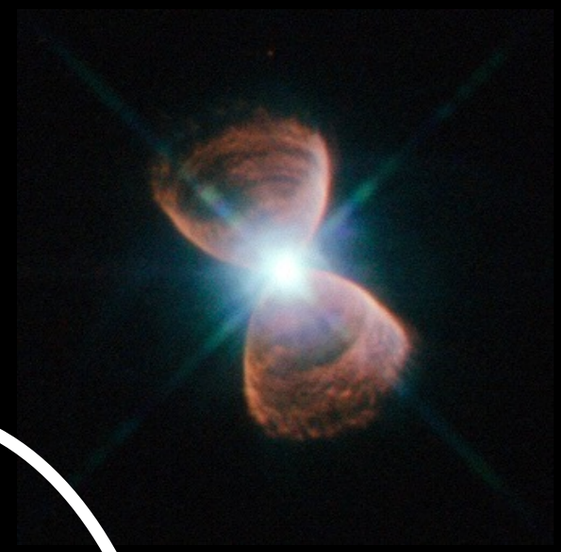
hourglass/bipolar

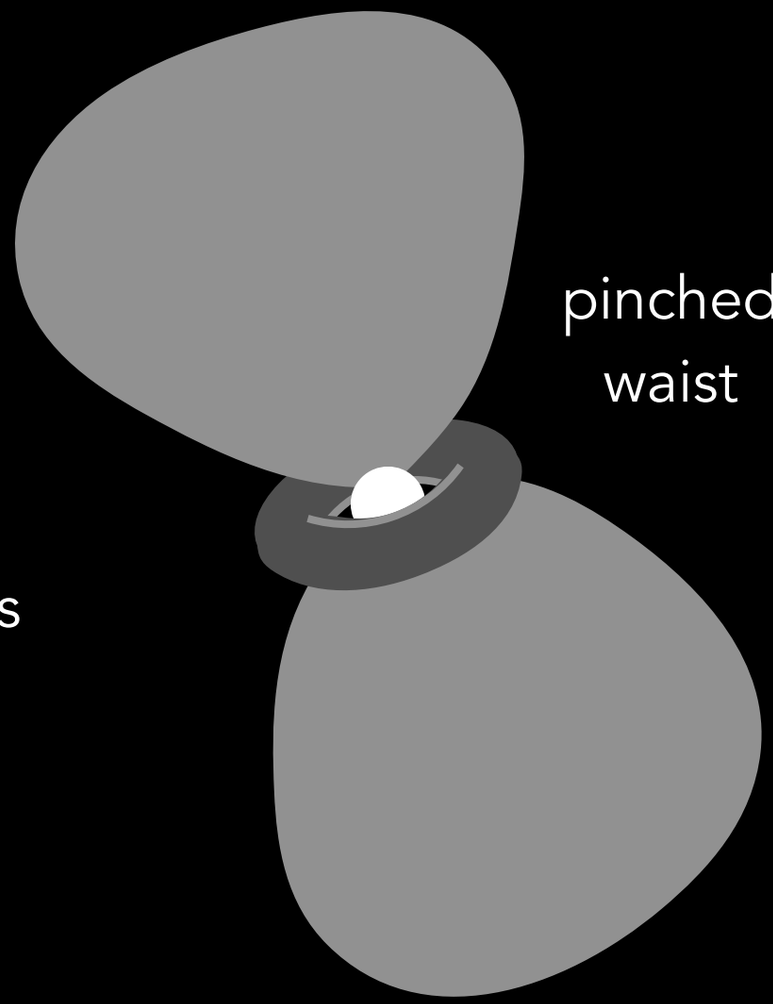


torus

MORPHOLOGICAL CONFUSION

WHY SO ASYMMETRICAL?

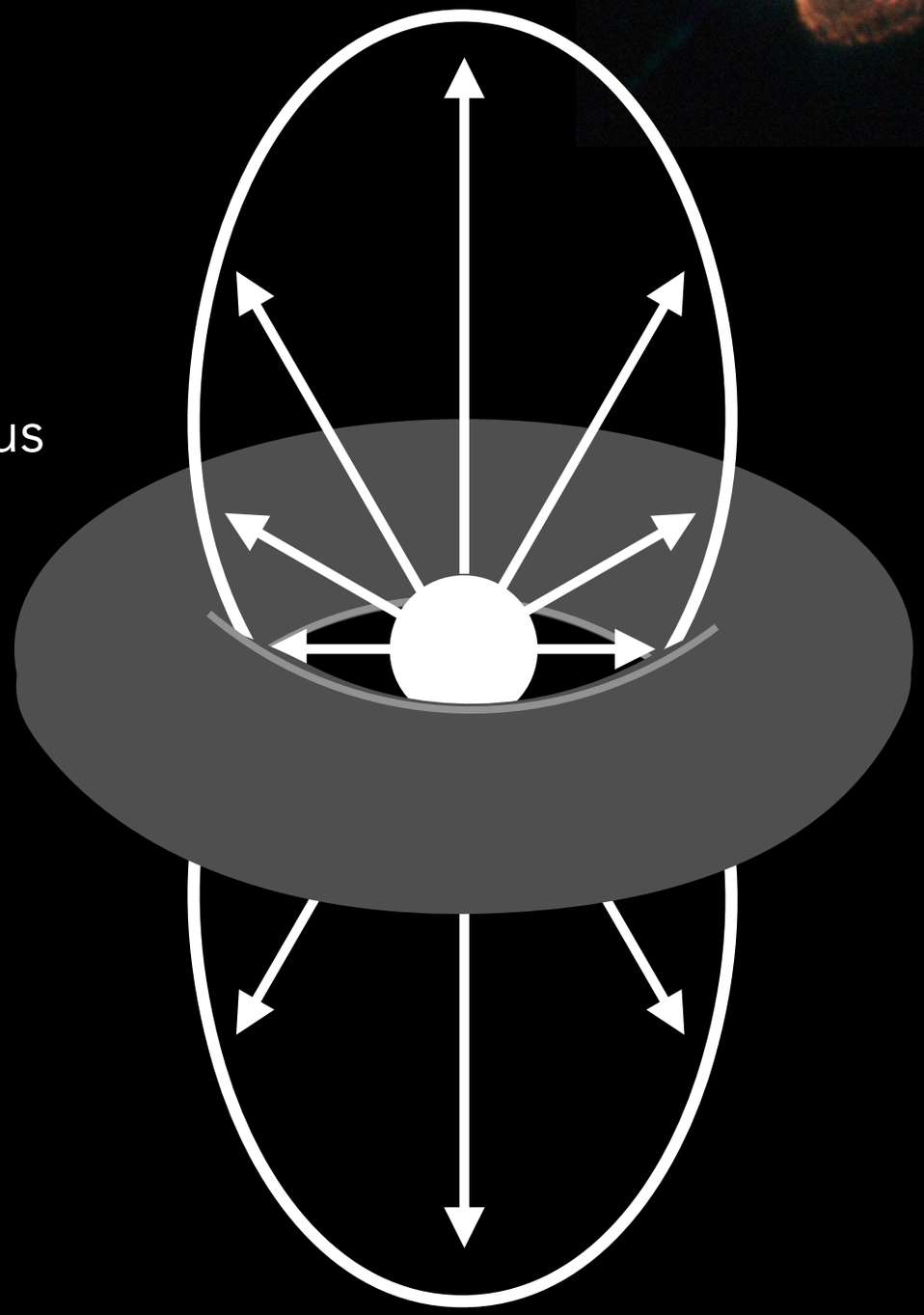




two lobes

pinched waist

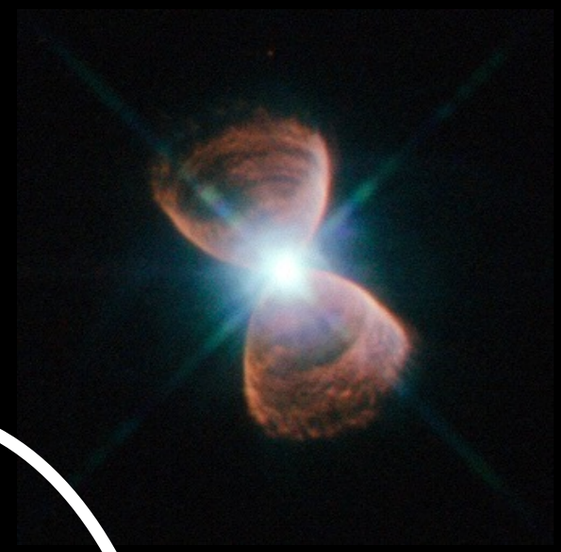
hourglass/bipolar

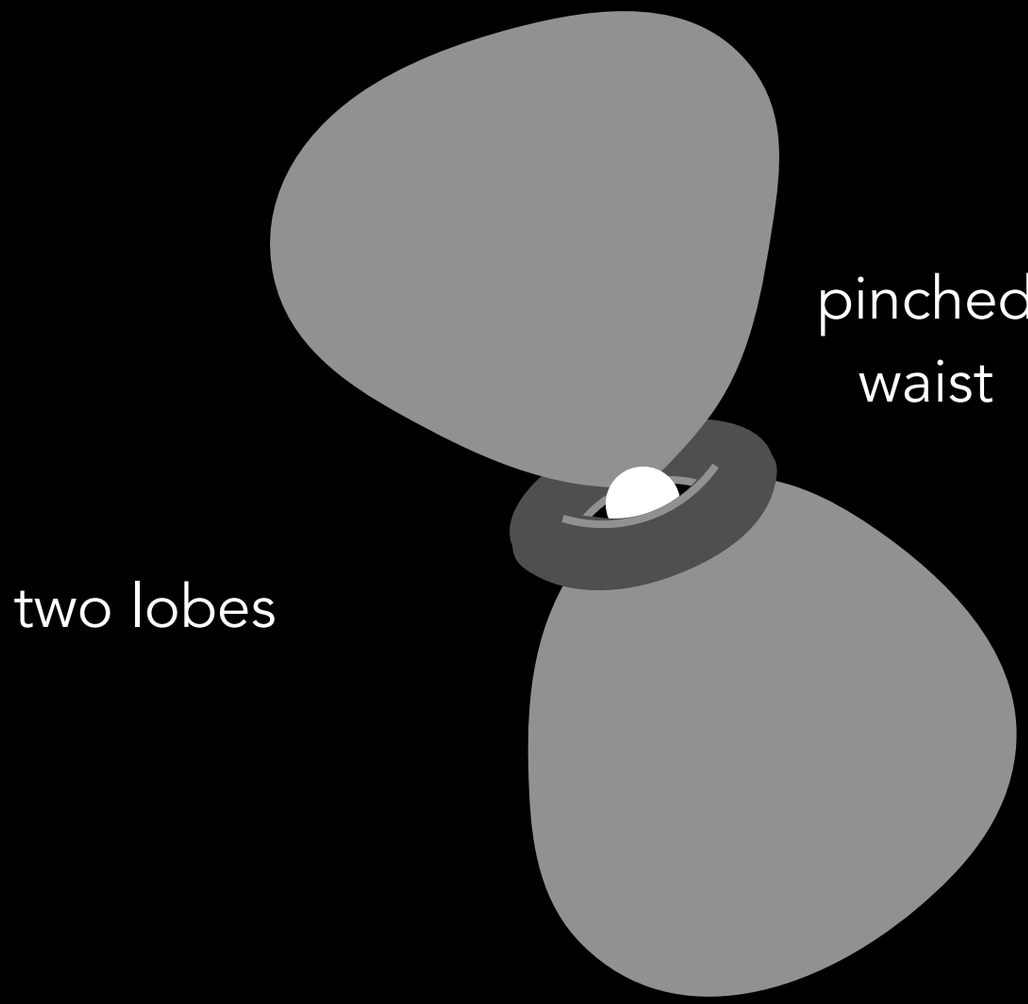


torus

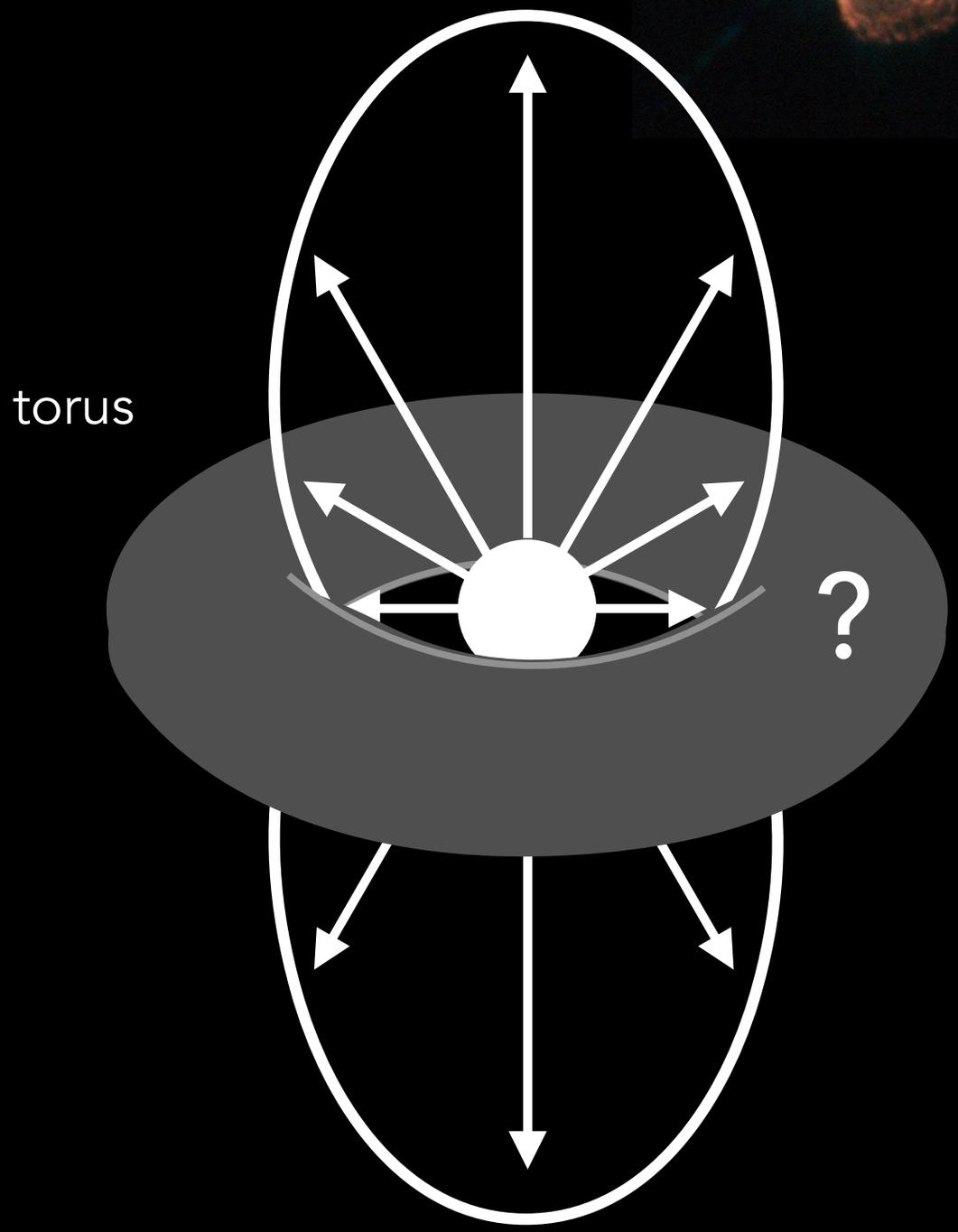
MORPHOLOGICAL CONFUSION

WHY SO ASYMMETRICAL?



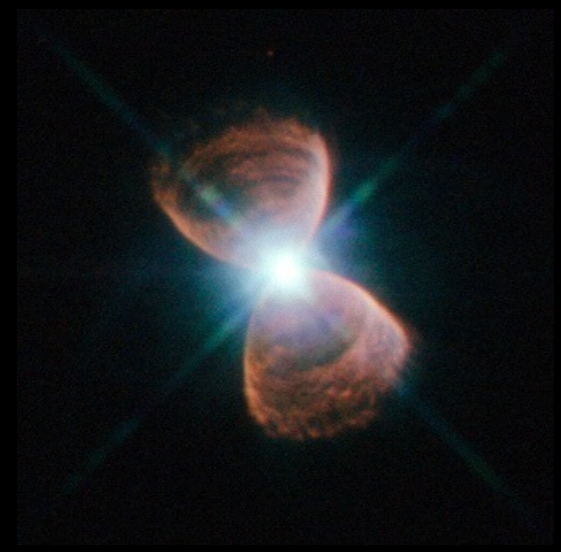


hourglass/bipolar



MORPHOLOGICAL CONFUSION

WHY SO ASYMMETRICAL?



two lobes

pinched waist

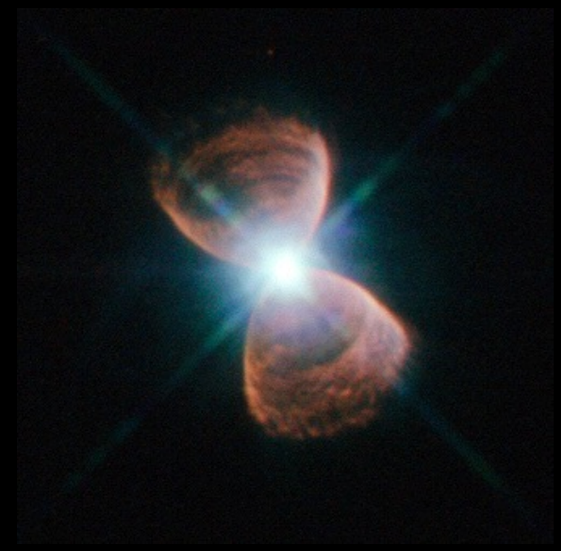
hourglass/bipolar

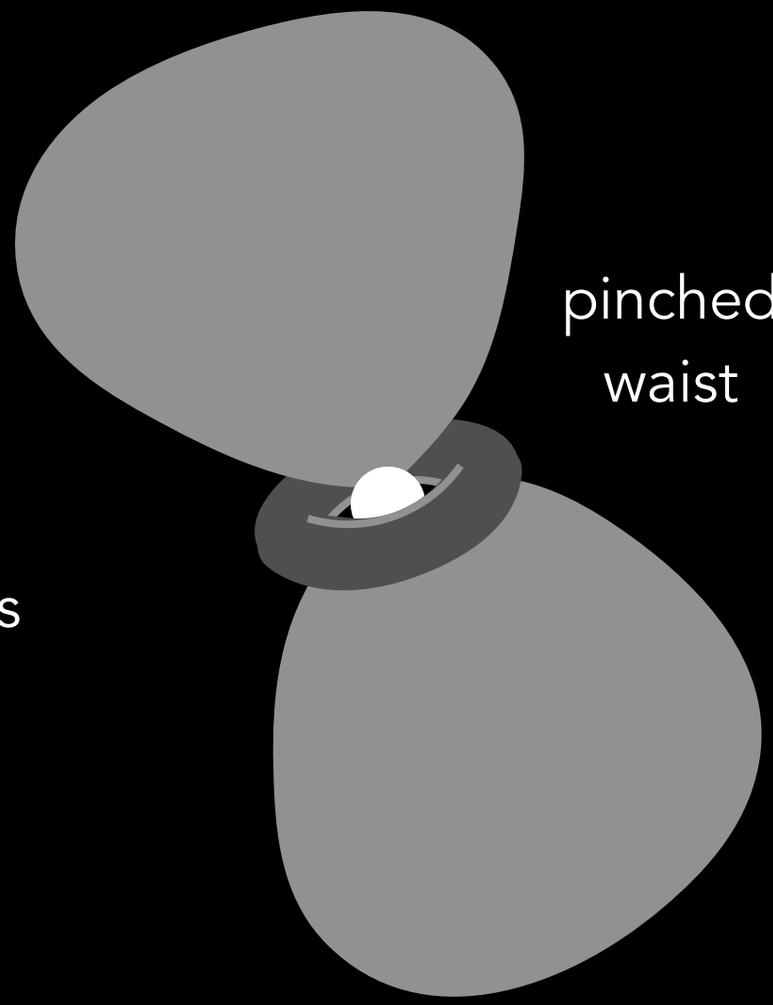
torus

?

MORPHOLOGICAL CONFUSION

WHY SO ASYMMETRICAL?



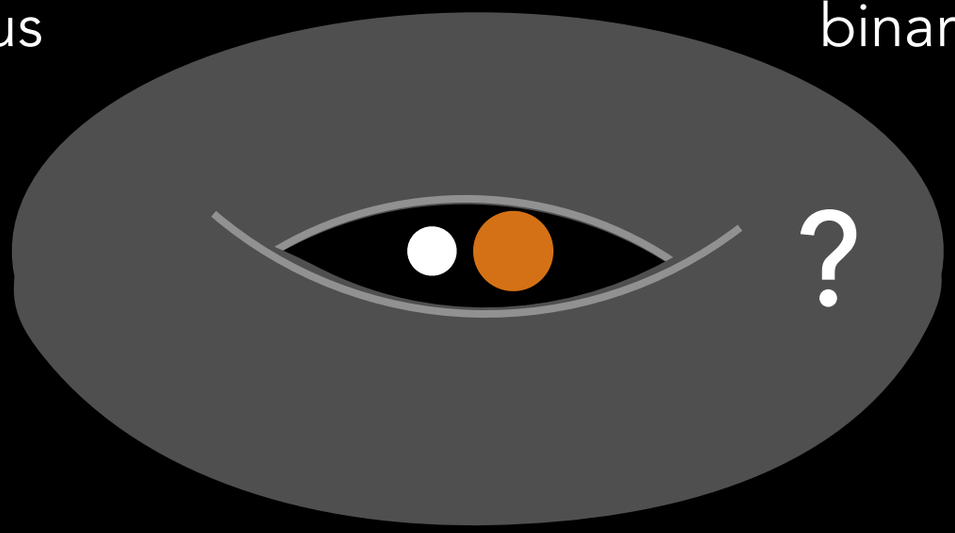


two lobes

pinched waist

hourglass/bipolar

torus

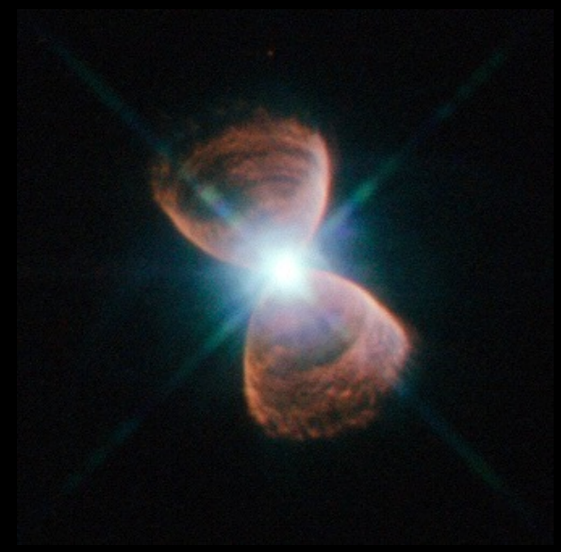


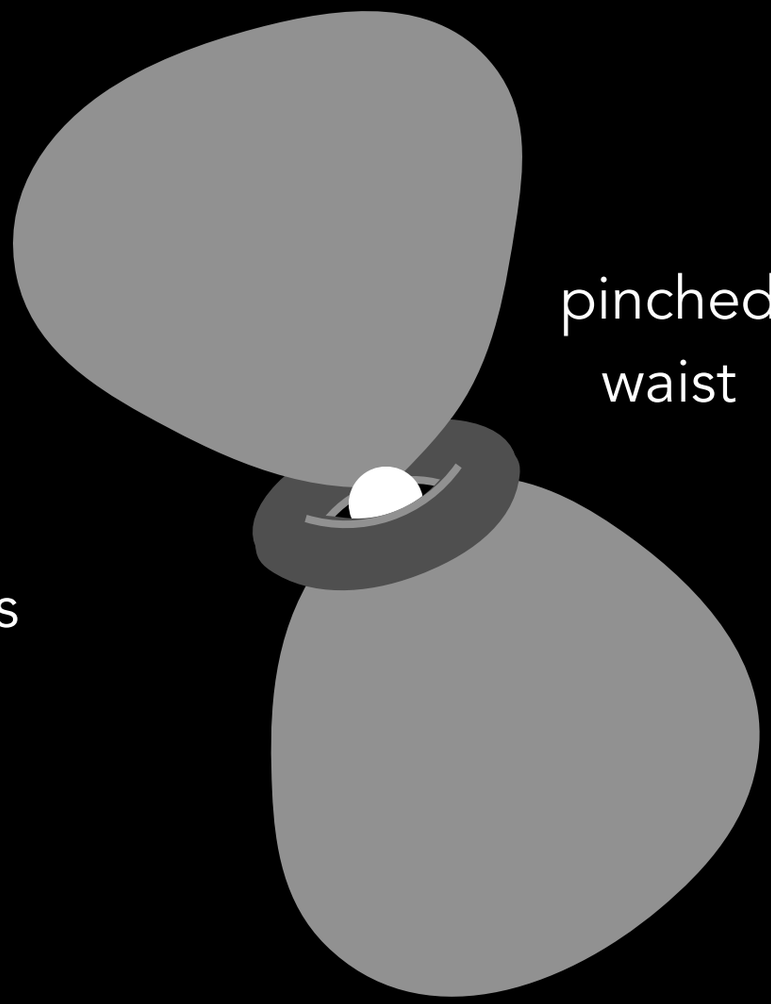
?

binary

BINARY HYPOTHESIS

RELATIONSHIPS ARE HARD

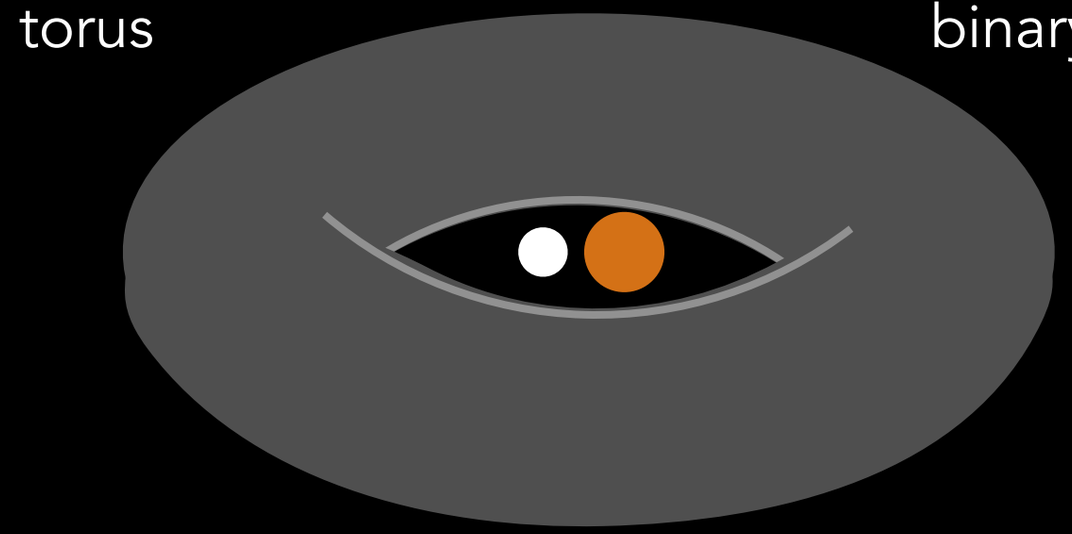




two lobes

pinched waist

hourglass/bipolar

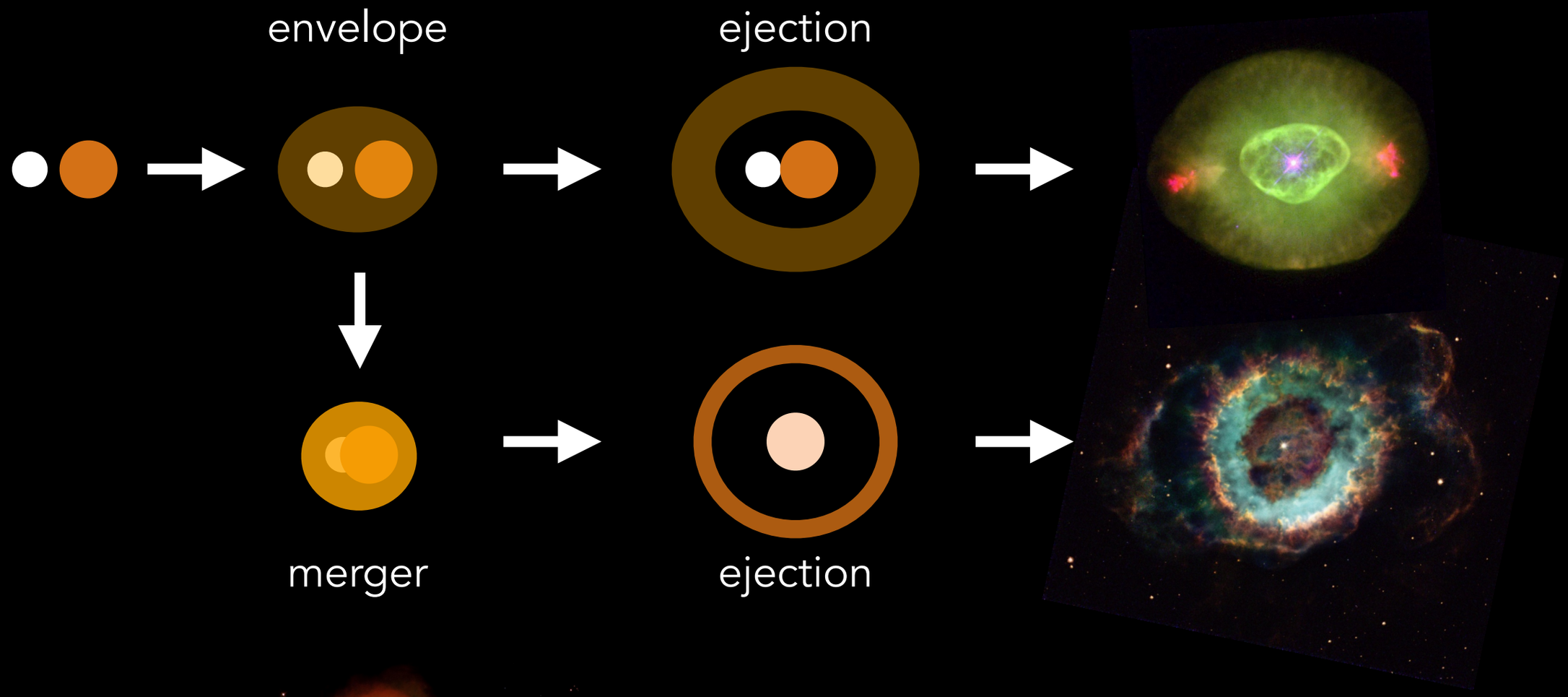


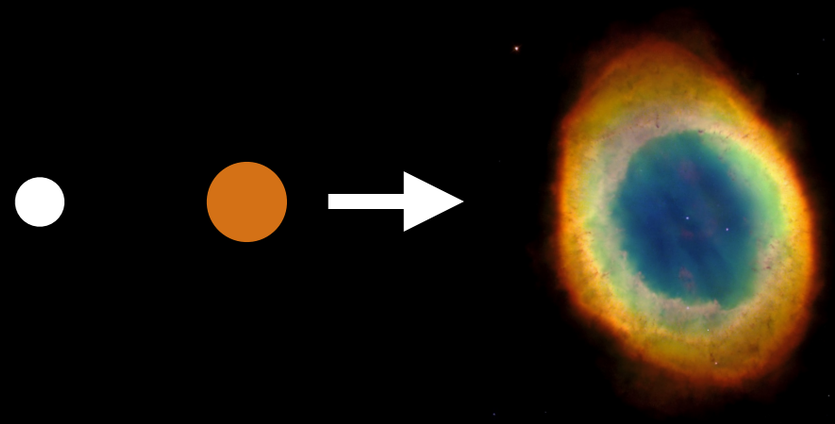
torus

binary

BINARY HYPOTHESIS

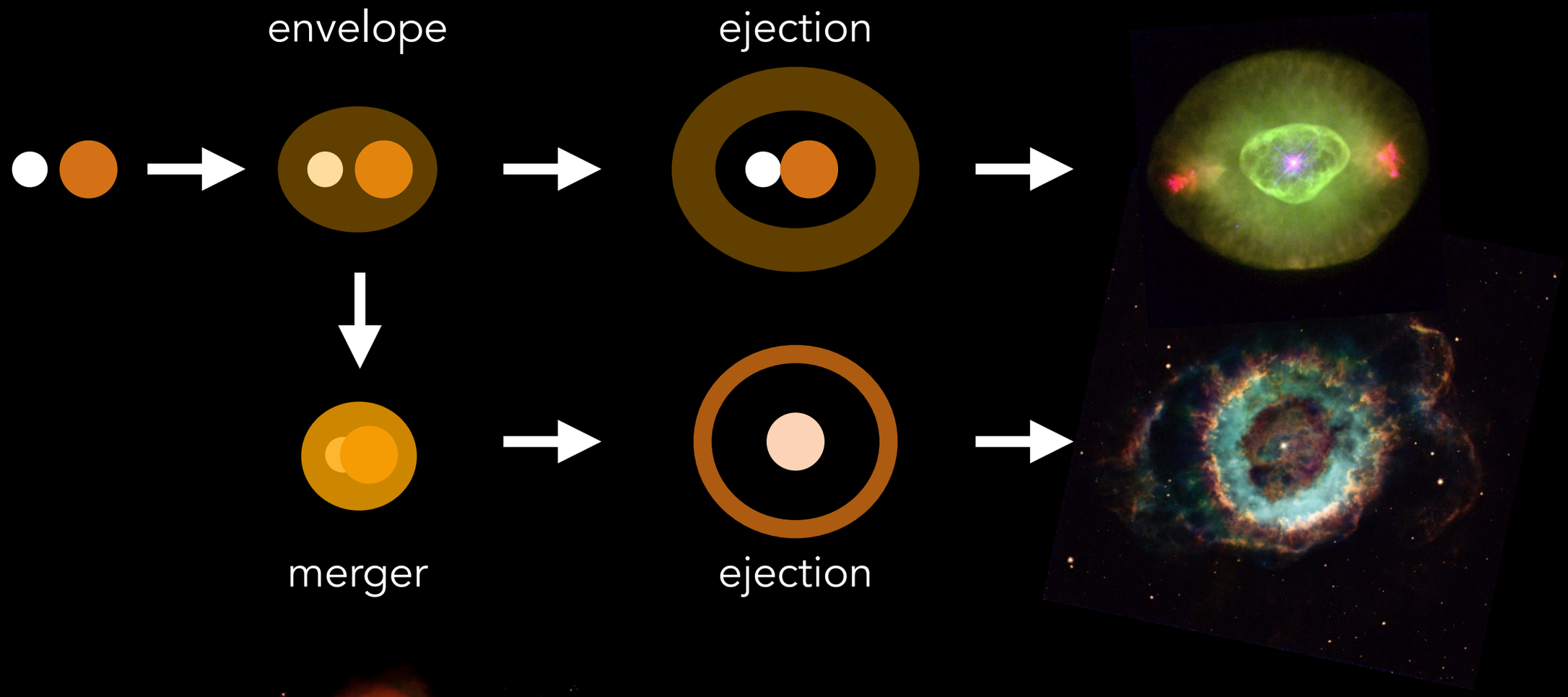
RELATIONSHIPS ARE HARD

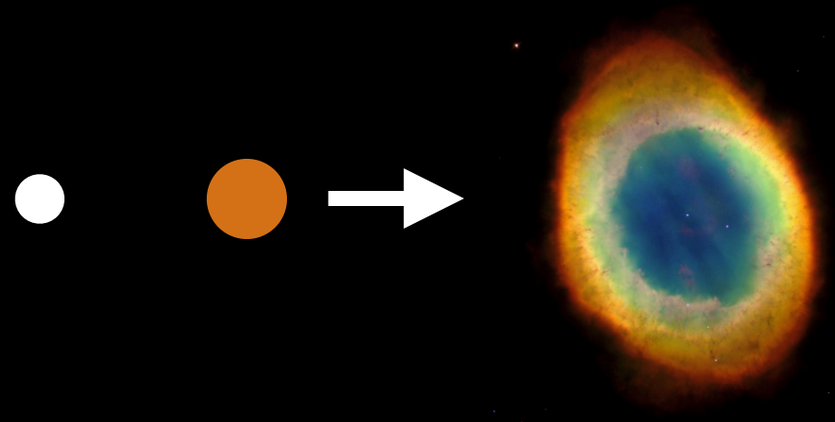




BINARY HYPOTHESIS

RELATIONSHIPS ARE HARD



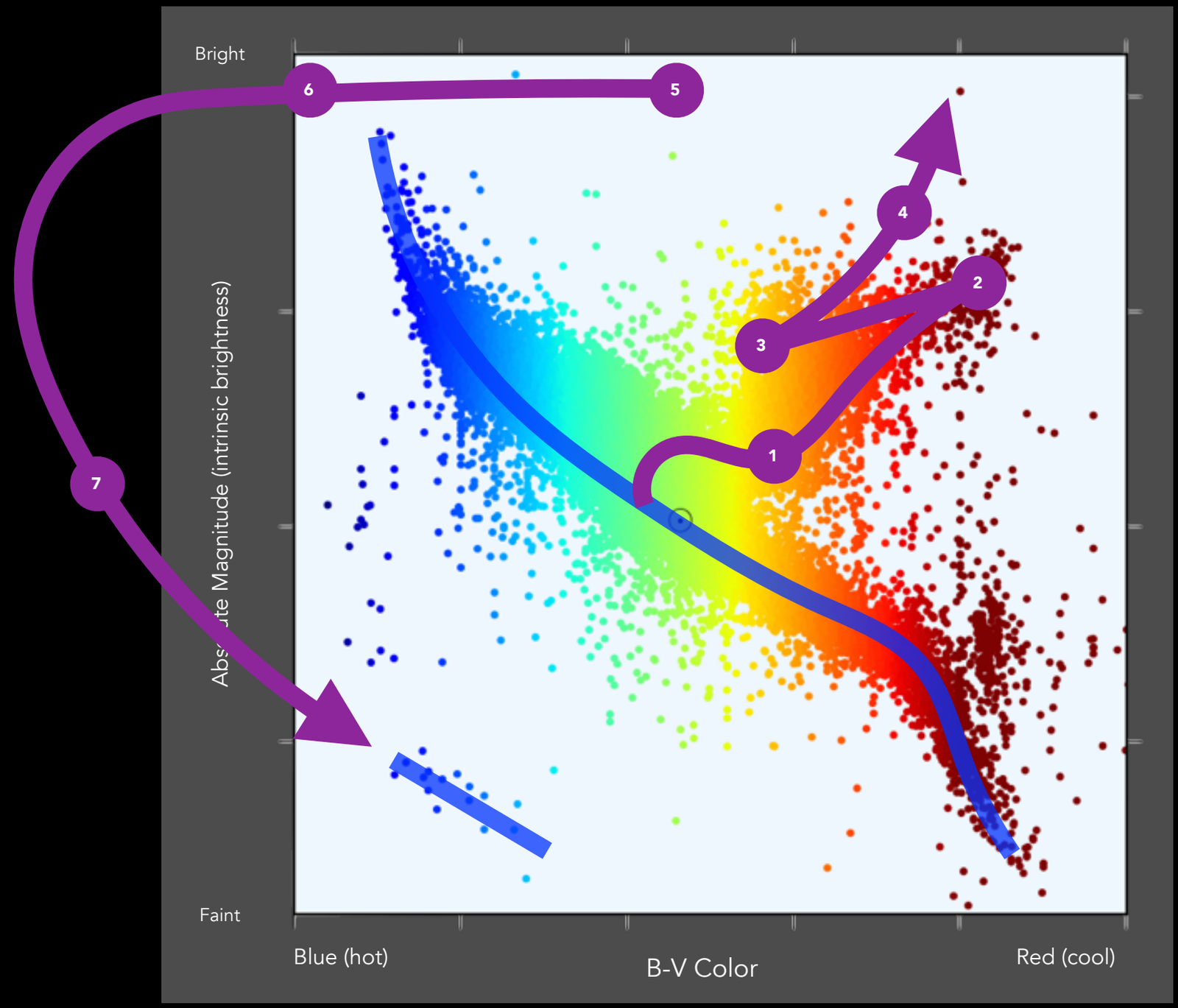


TESTING THE HYPOTHESIS

EVIDENCE FOR COMPANIONS

TESTING THE HYPOTHESIS

EVIDENCE FOR COMPANIONS (PAST AND PRESENT)

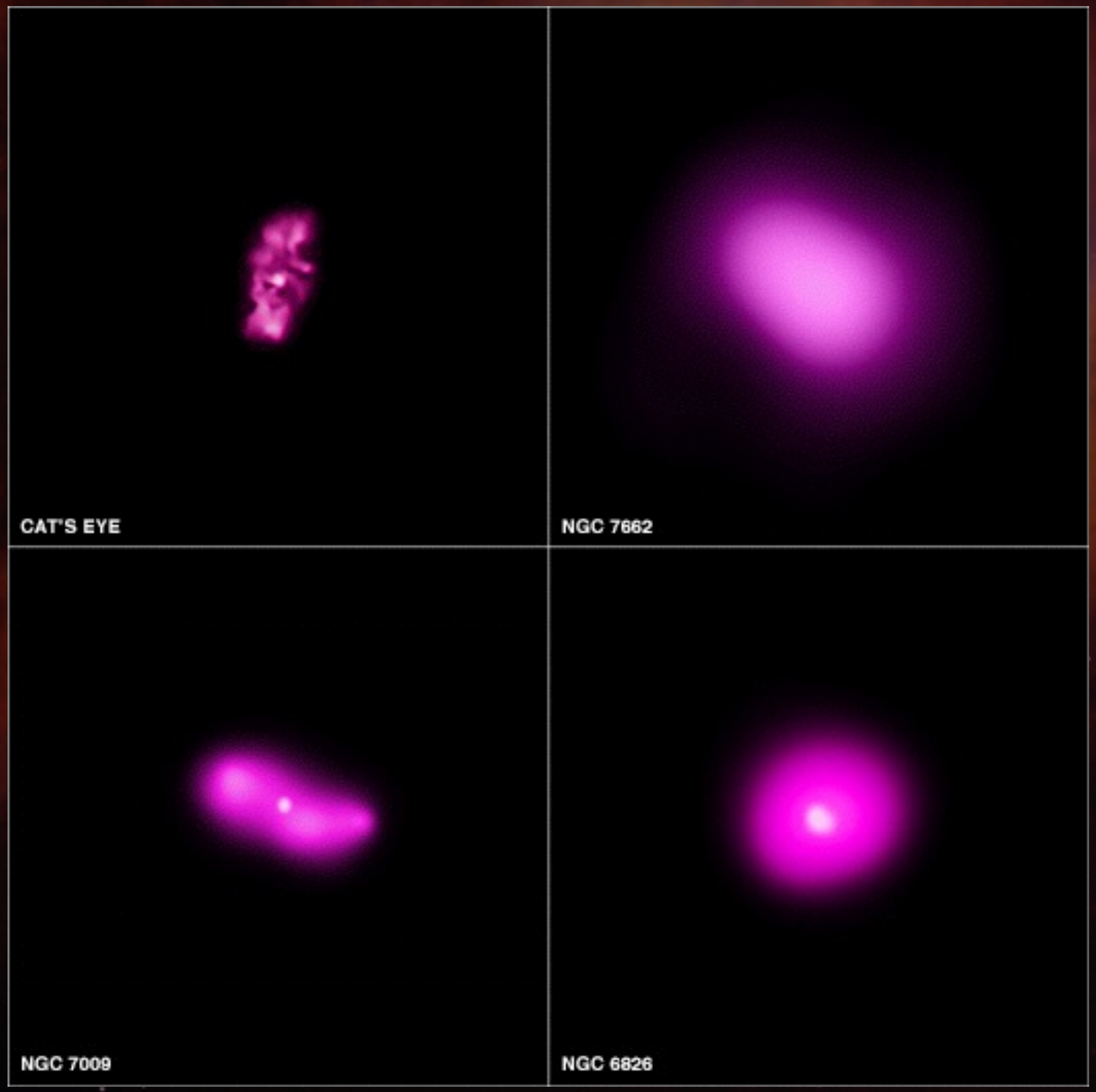


X-RAY SURVEY OF DYING STARS

HOT STARS AND HOT BUBBLES

X-RAY SURVEY OF DYING STARS

HOT STARS AND HOT BUBBLES



BUT THE SUN IS NOT A BINARY...

NO BEAUTIFUL SWAN SONG FOR THE SUN?