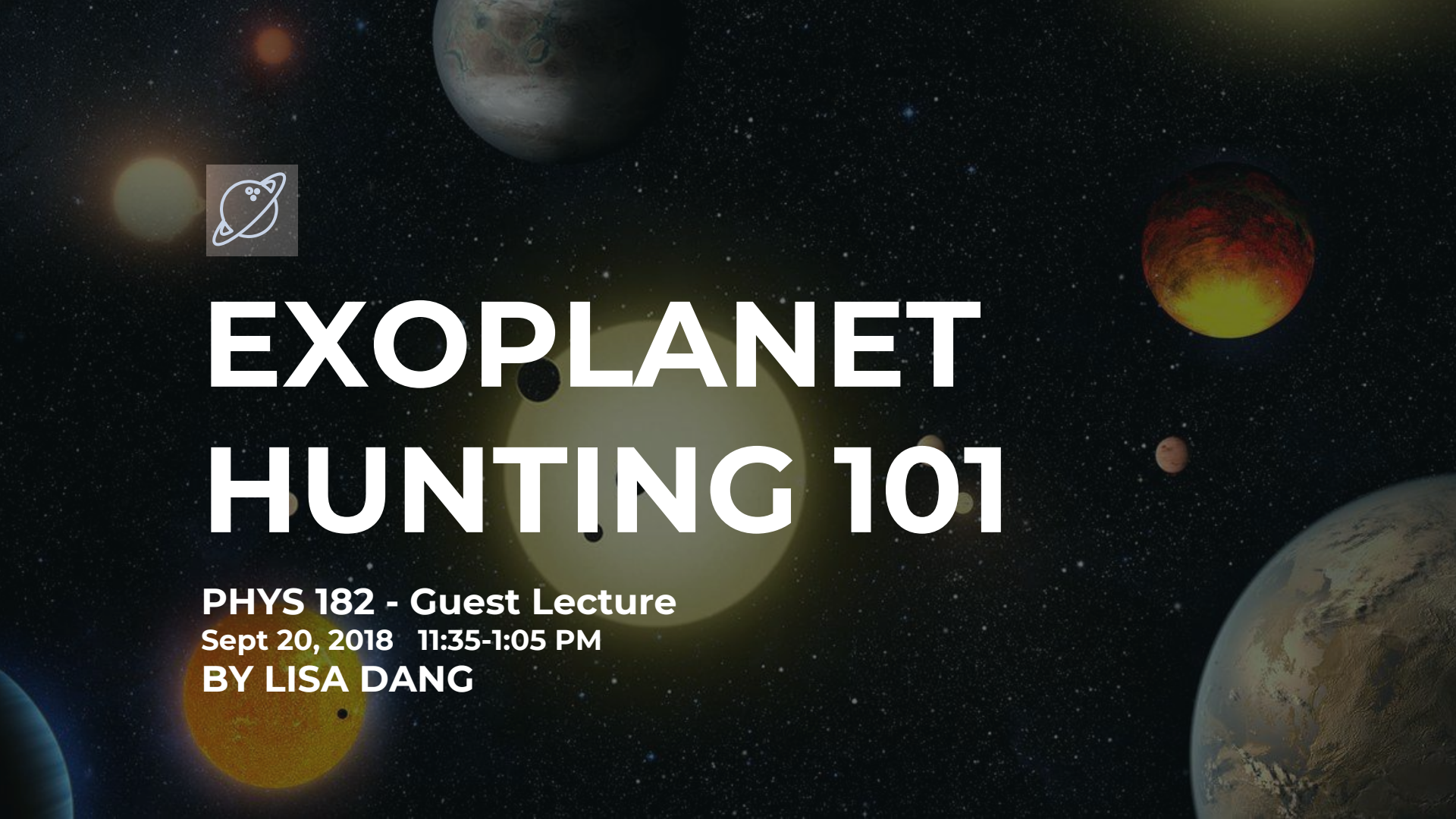

EXOPLANET HUNTING 101

PHYS 182 - Guest Lecture
Sept 20, 2018 11:35-1:05 PM
BY LISA DANG

WHAT IS A PLANET?

International Astronomical Union Definition

- In orbit around the Sun
- Massive enough to be round
- Cleared its orbit of debris

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International Astronomical Union Definition

- In orbit around the Sun
- Massive enough to be round
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PLUTO

WHAT IS AN EXOPLANET?

Also referred as exosolar planets or extrasolar planet

According to the IAU

- In orbit around a star
- Not massive enough for fusion of deuterium

WHAT IS AN EXOPLANET?

Also referred as exosolar planets or extrasolar planet

According to Lisa Dang (et al.)

- In orbit around a star
- Not massive enough for fusion of deuterium
- \+ Rogue (free-floating) planets

IS OUR SUN SPECIAL?

Not really, it's a pretty average star.

- 10 % of all stars are Sun-like stars
- 20 billions star in our Galaxy are just like our Sun

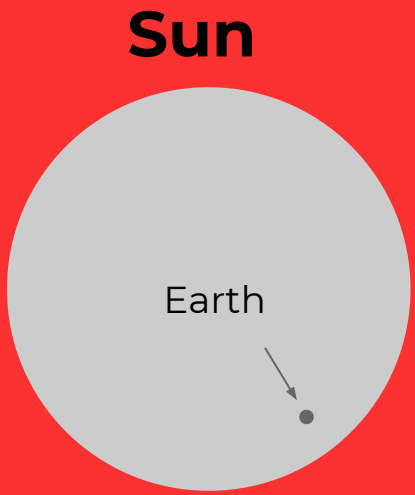
BUT YET, IT'S DIFFERENT

- Was the only known planetary system for centuries
- Still the only system hosting 9 ± 1 significantly diverse planets
- We think we understand how they formed

Finding is HARD.

(but we've gotten better at it!)

1. **They are** small **and far.**
2. **They are dim compared to their host star.**



1 IT ALL STARTED WITH *51 Peg b*

(aka Dimidium)

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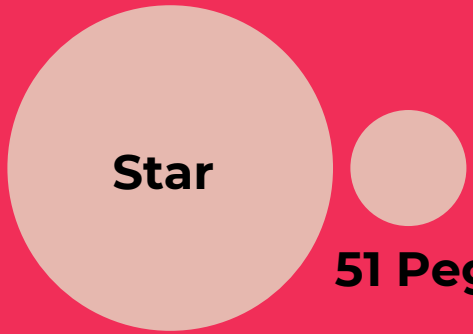
(aka Dimidium)

Hot Jupiter? What?

51 Pegasi b

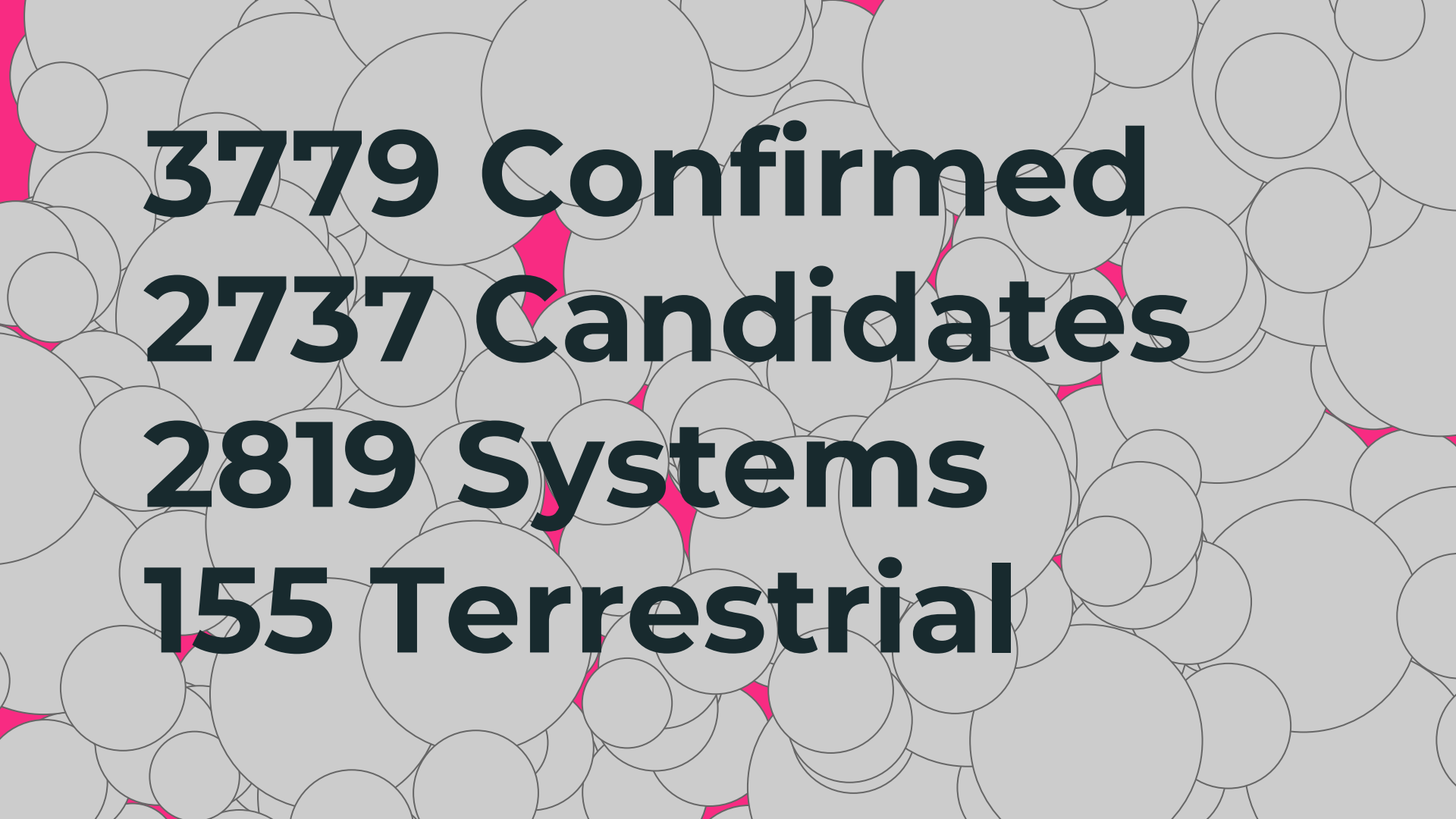
- Mass of **0.5** Jupiter mass
- Takes **4.23 days** to orbit around its star
- Temperature over **1300K** (Venus is about 700K)



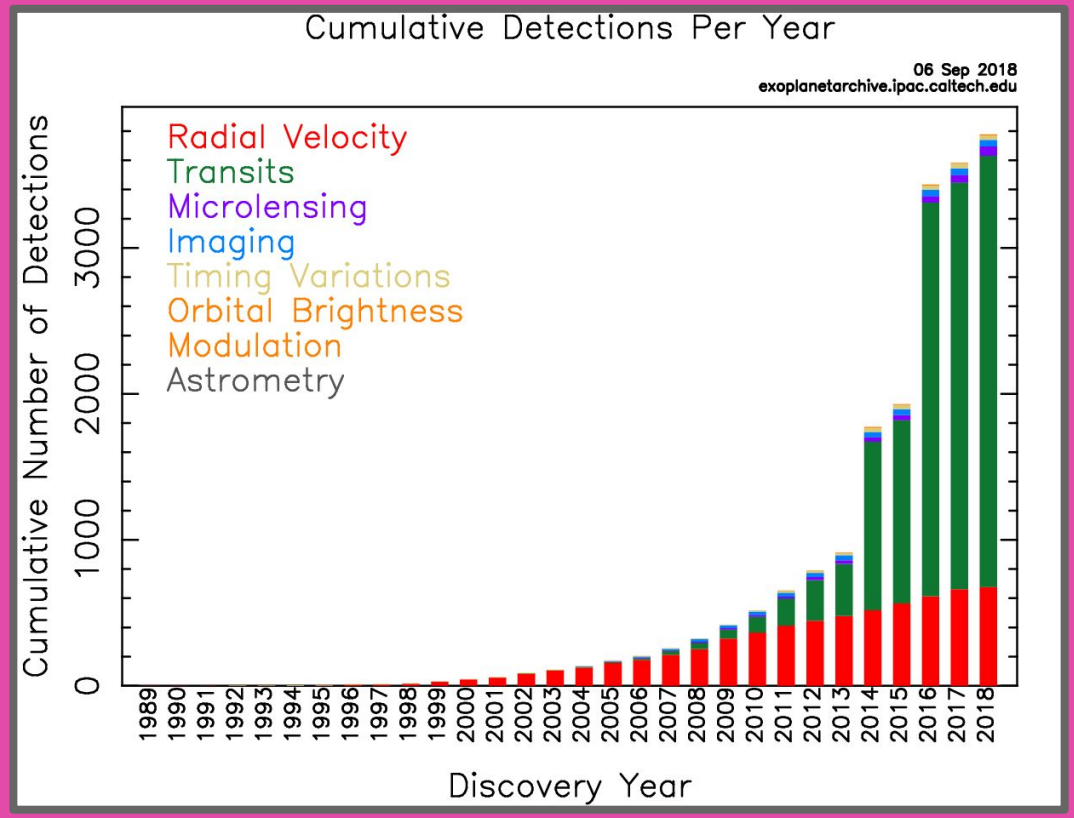
What’s next?

FIND.
MORE.
EXOPLANETS.


FIND.
MORE.
EXOPLANETS.

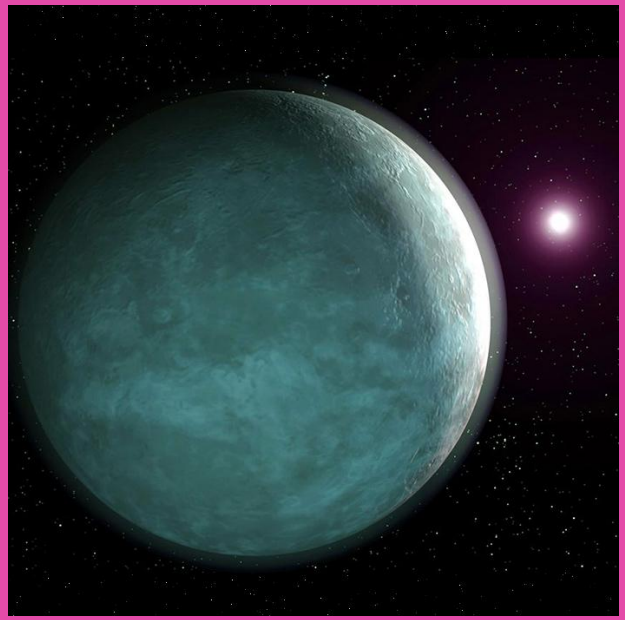

3779 Confirmed
2737 Candidates
2819 Systems
155 Terrestrial

Number of exoplanets found over the years.



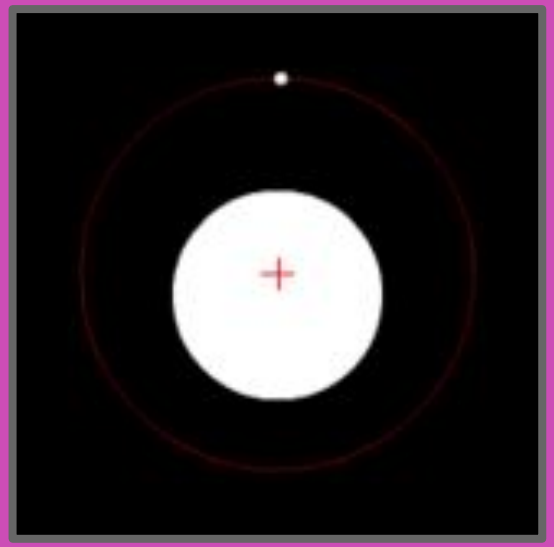
Most recent planet discovery: Wolf 503 b

A Neptune-like planet **discovered by student in Montreal!**

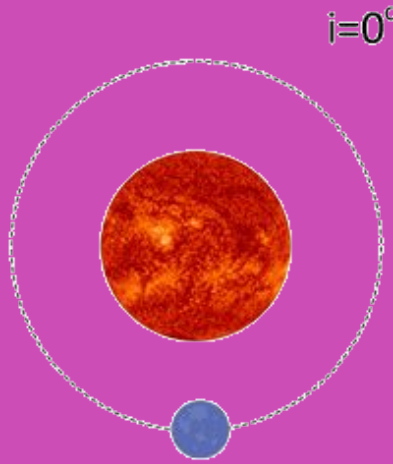


STARS' INVISIBLE DANCE PARTNER

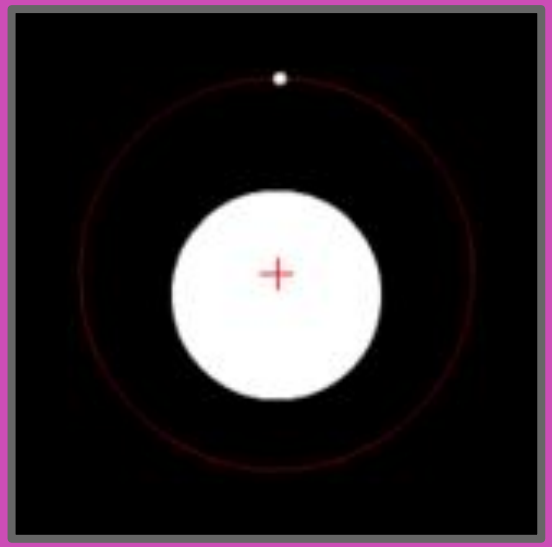
In the presence of **another body mass** orbiting a star, the star will also orbit about their **common centre of mass**



STARS' INVISIBLE DANCE PARTNER



Face on

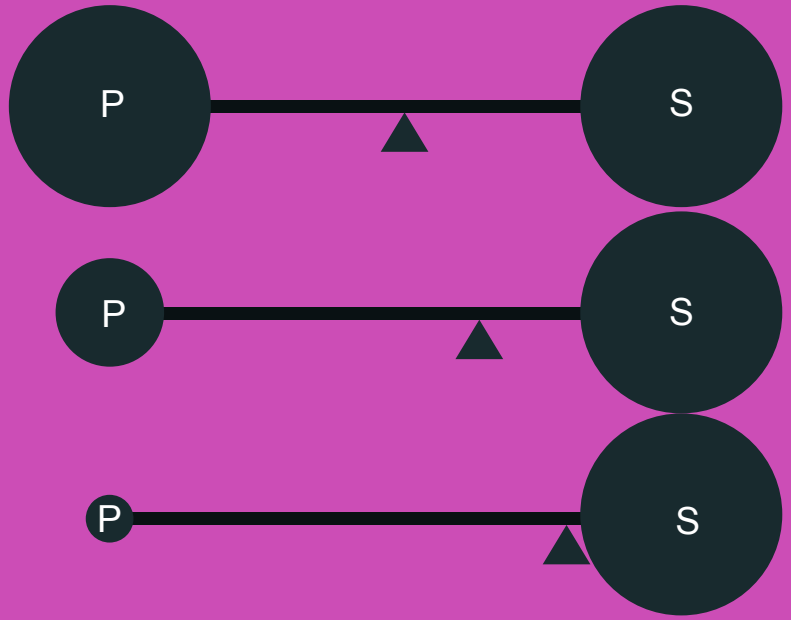


Centre of Mass

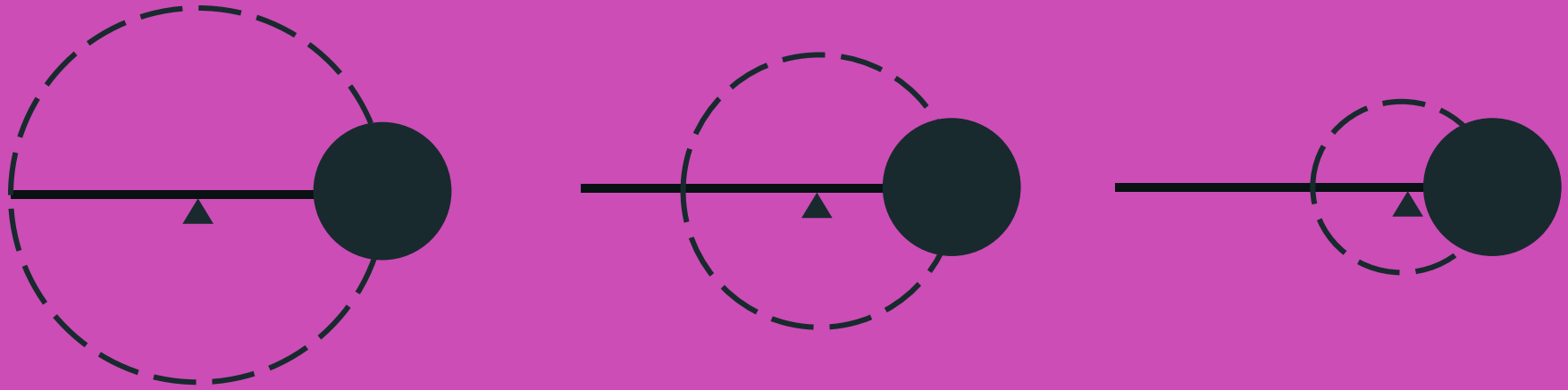
Definition:

Mean location of distribution of mass in space.

*The **heavier** the star is compared to the planet, the **closer** the centre the center of mass is to the star.*

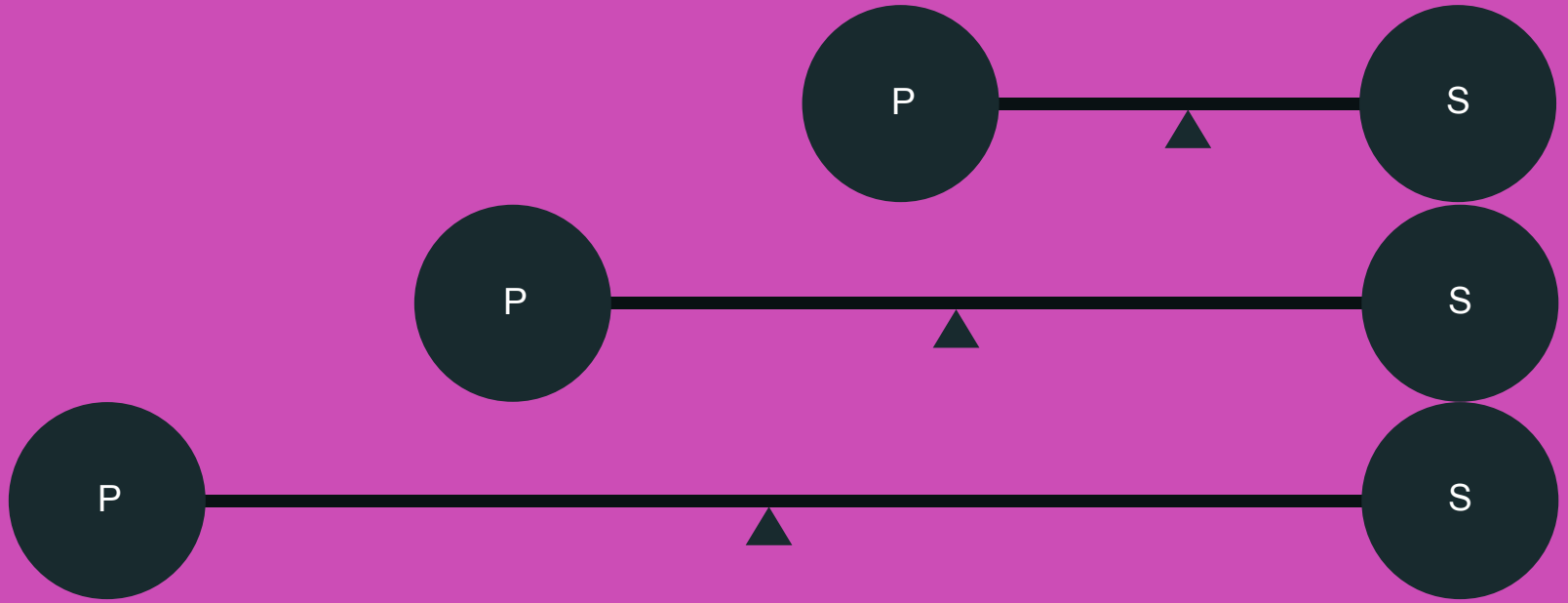


Centre of Mass



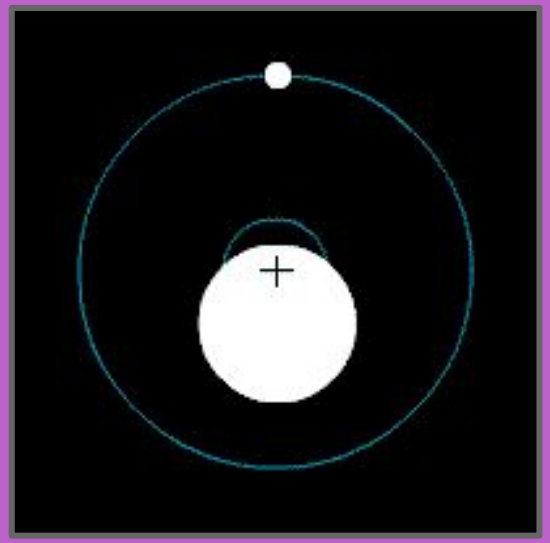
*The **closer** the center of mass is to the star, the smaller the orbit of the star*

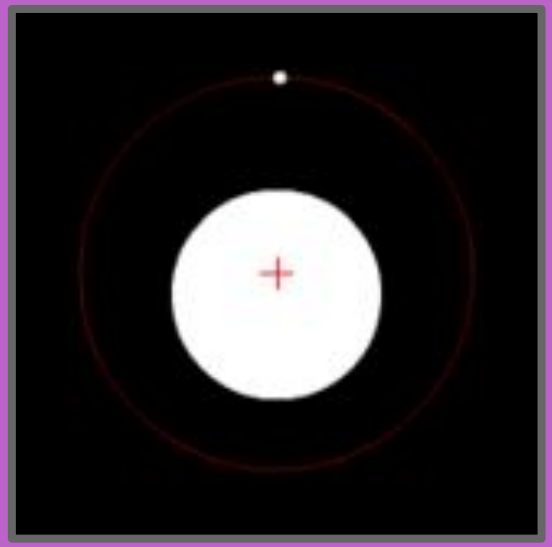
Centre of Mass



STARS DANCE

Even more when the planet is **HEAVY** and more rapidly if the planet is **CLOSE.**

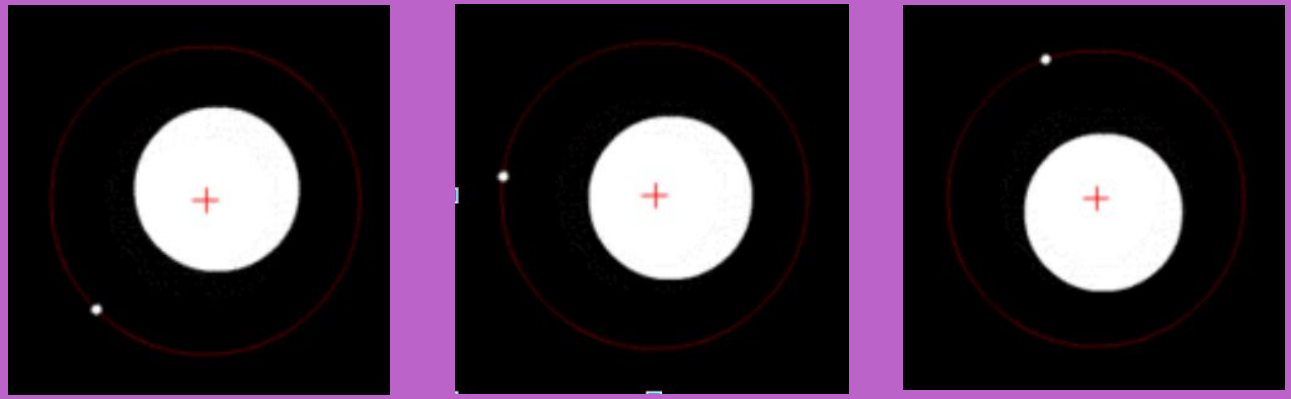




ASTROMETRY

Or the search for stars' invisible dance partners (part 1)

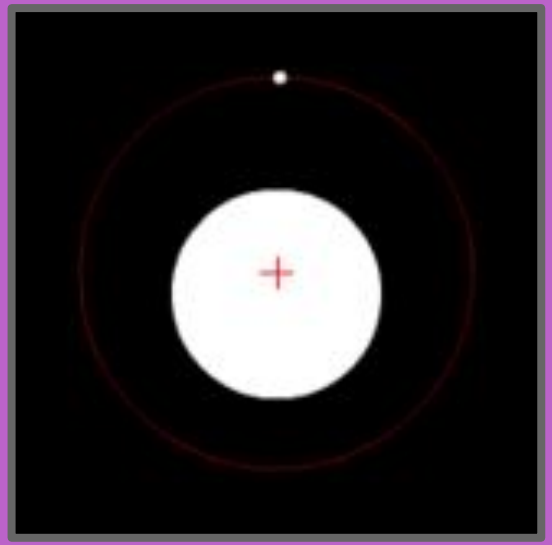
Definition: Precise measurement of location of objects in the sky.



ASTROMETRY

Or the search for stars' invisible dance partners (part 1)

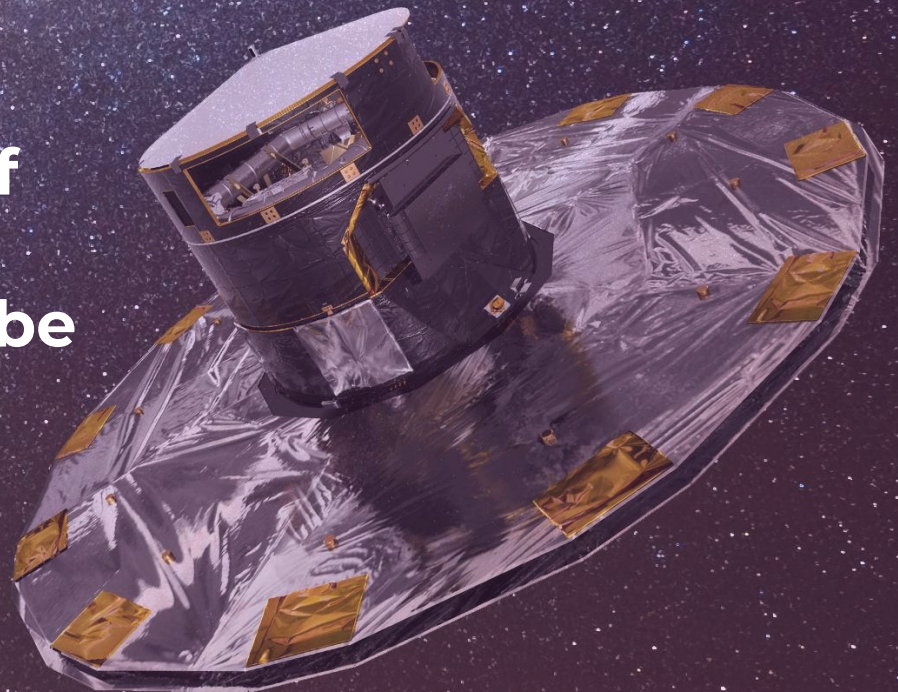
1 exoplanet found via astrometry....



GAIA Mission

Actively searching for stars' invisible dance partners

10 of 1000s of exoplanets expected to be discovered

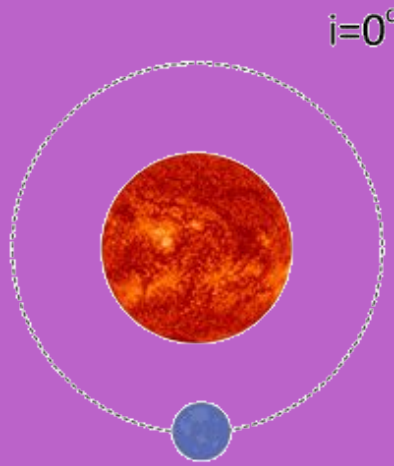


ASTROMETRY

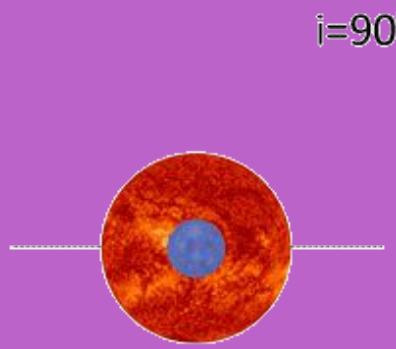
But these guys were found via astrometry!!!

Orbital Inclination

Face-On



Edge-On

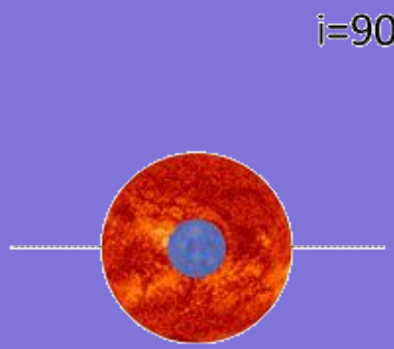


Radial Velocity

Or the search for stars' invisible dance partners (part 2)

Definition:

Precise measurement the velocity of an object towards and away from you

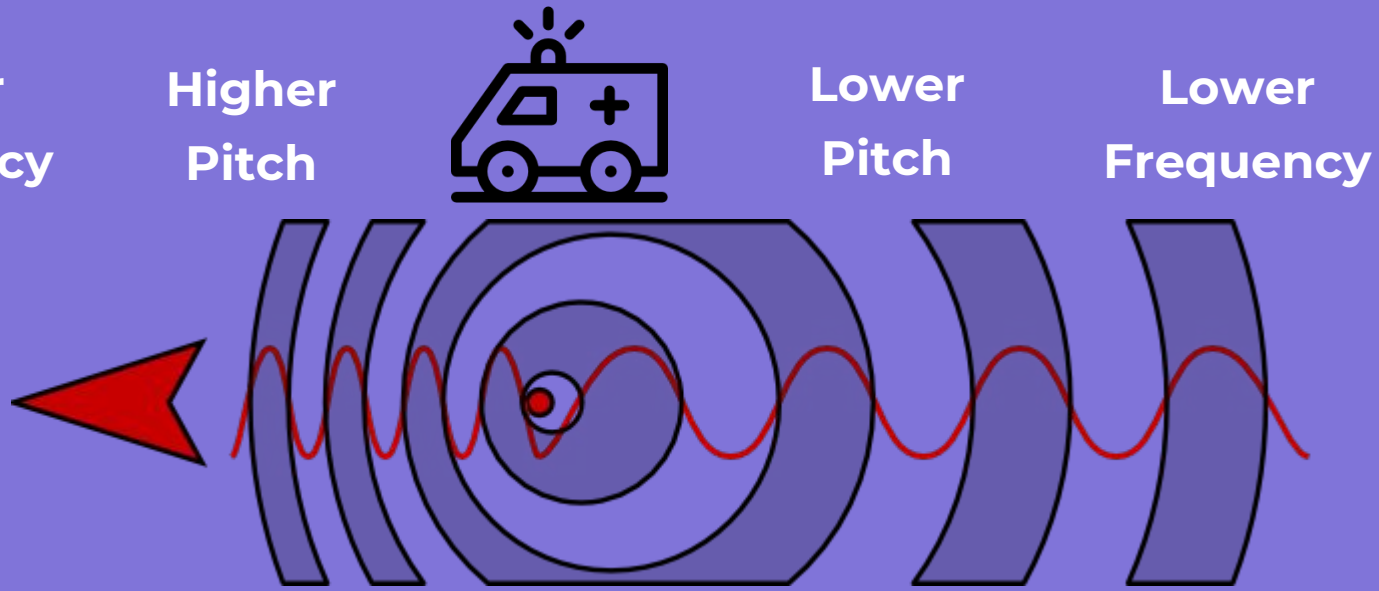


Doppler Effect

With SOUND

Higher Frequency

Higher Pitch



Lower Pitch

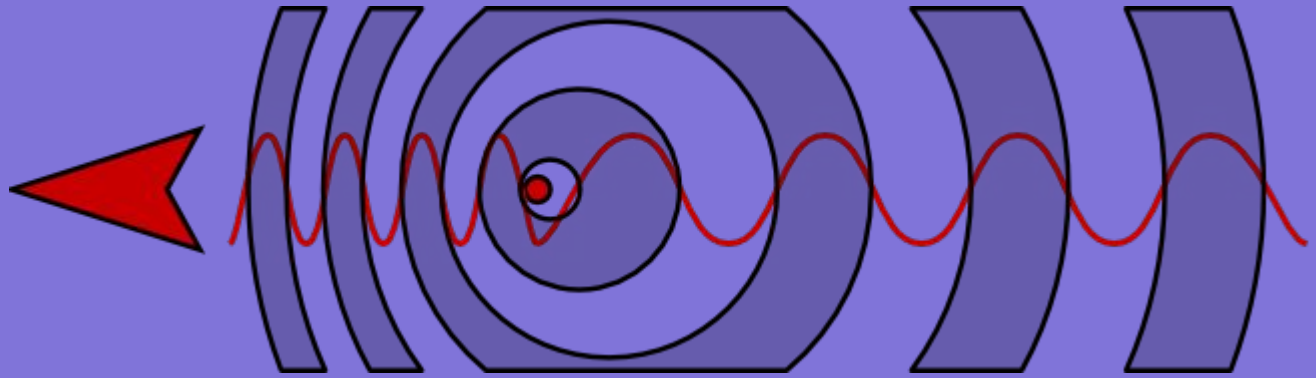
Lower Frequency

Doppler Effect

With Light

Higher Frequency

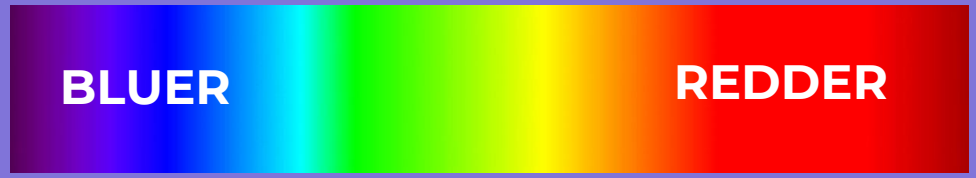
Lower Frequency



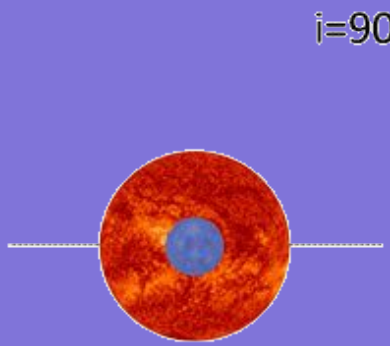
Doppler Effect

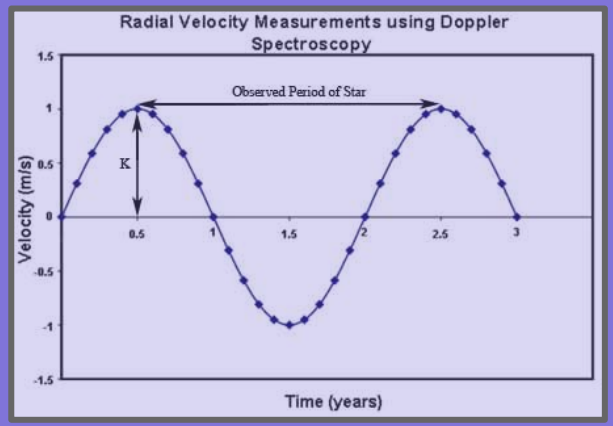
With Light

Higher Frequency



Lower Frequency



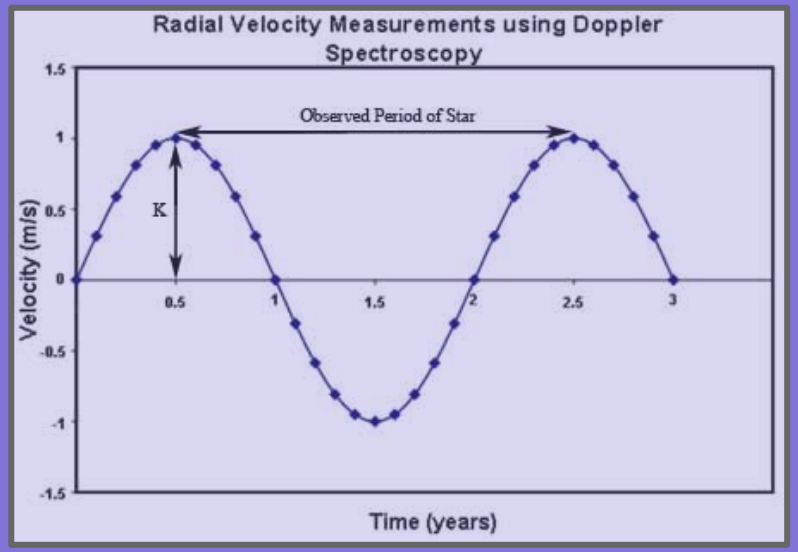


Radial Velocity

Or the search for stars' invisible dance partners (part 2)

ADDITIONAL INFO:

- Mass of the planet
- The size of its orbit
- eccentricity



Radial Velocity

Or the search for stars' invisible dance partners (part 2)

677 exoplanets found via radial velocity!

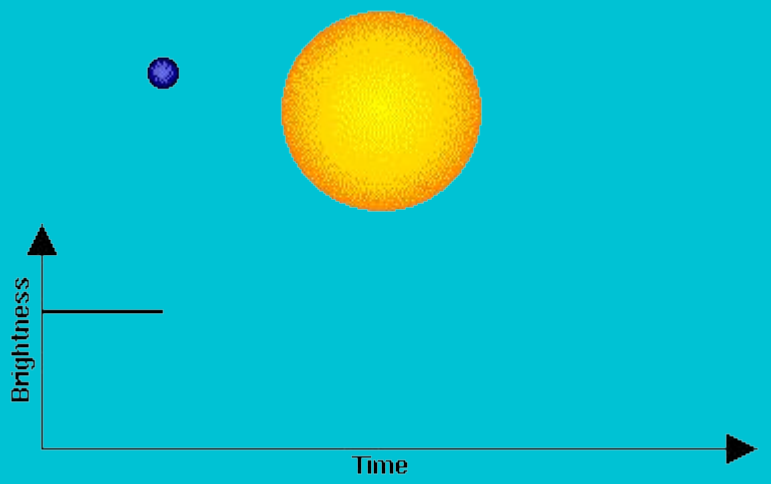

PLENTY
HOT JUPITER
WERE DISCOVERED!

TRANSIT

or the search for shadows

When the planet **passes in front** of the star, it ***blocks*** incoming flux from the star.

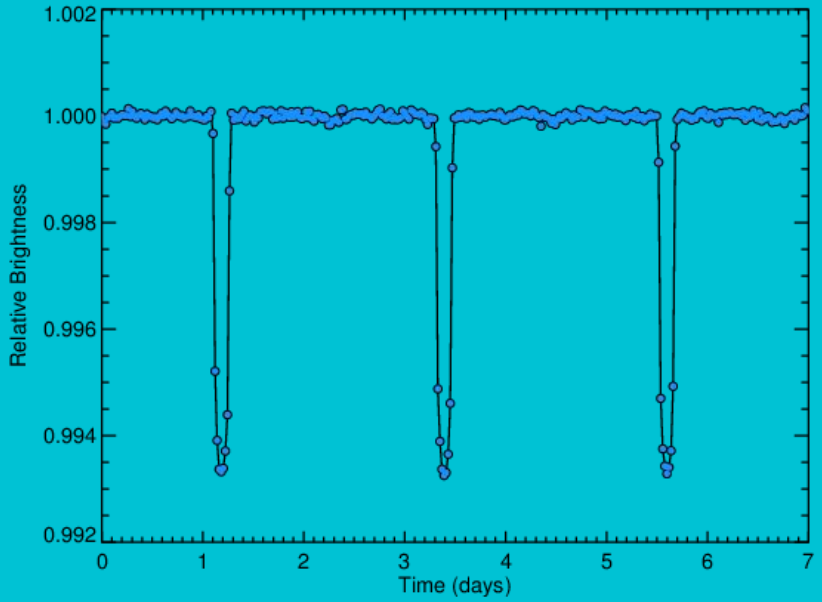
The star then appear ***dimmer*** for a distant observer



TRANSIT

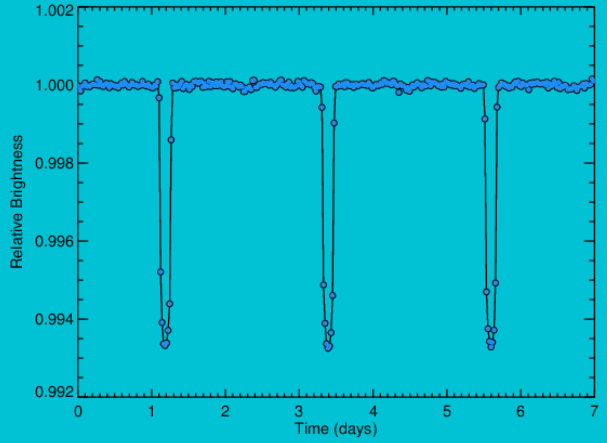
HOW DO YOU KNOW IT'S NOT JUST A **RANDOM OBJECT** PASSING IN FRONT?

If it's an object in orbit, it will pass in front **again**.



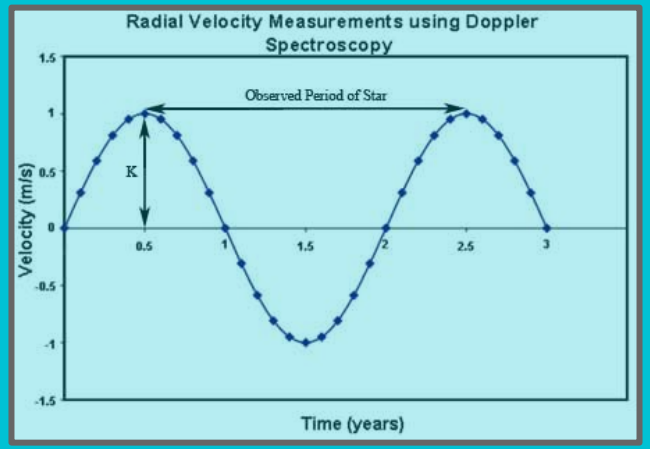
TRANSIT

BUT, IS IT A PLANET?



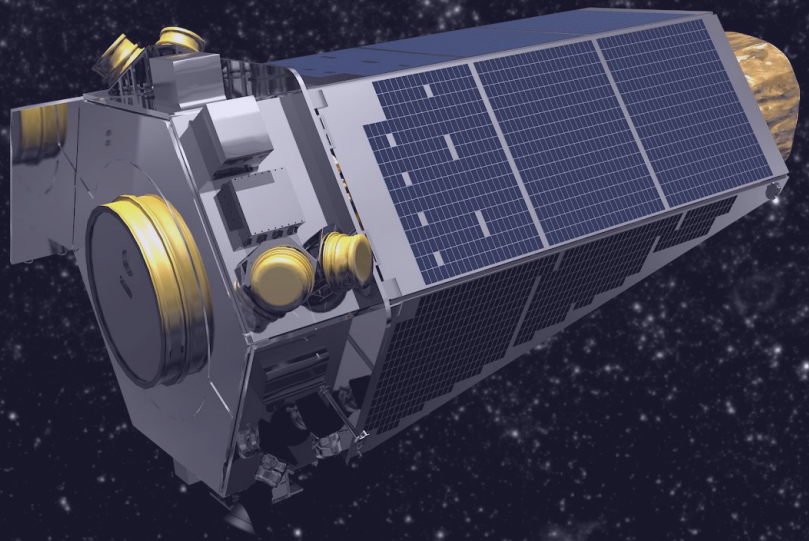
We can only confirm that is it a planet if we know its **mass**.

+



TRANSIT

Or the search for shadows



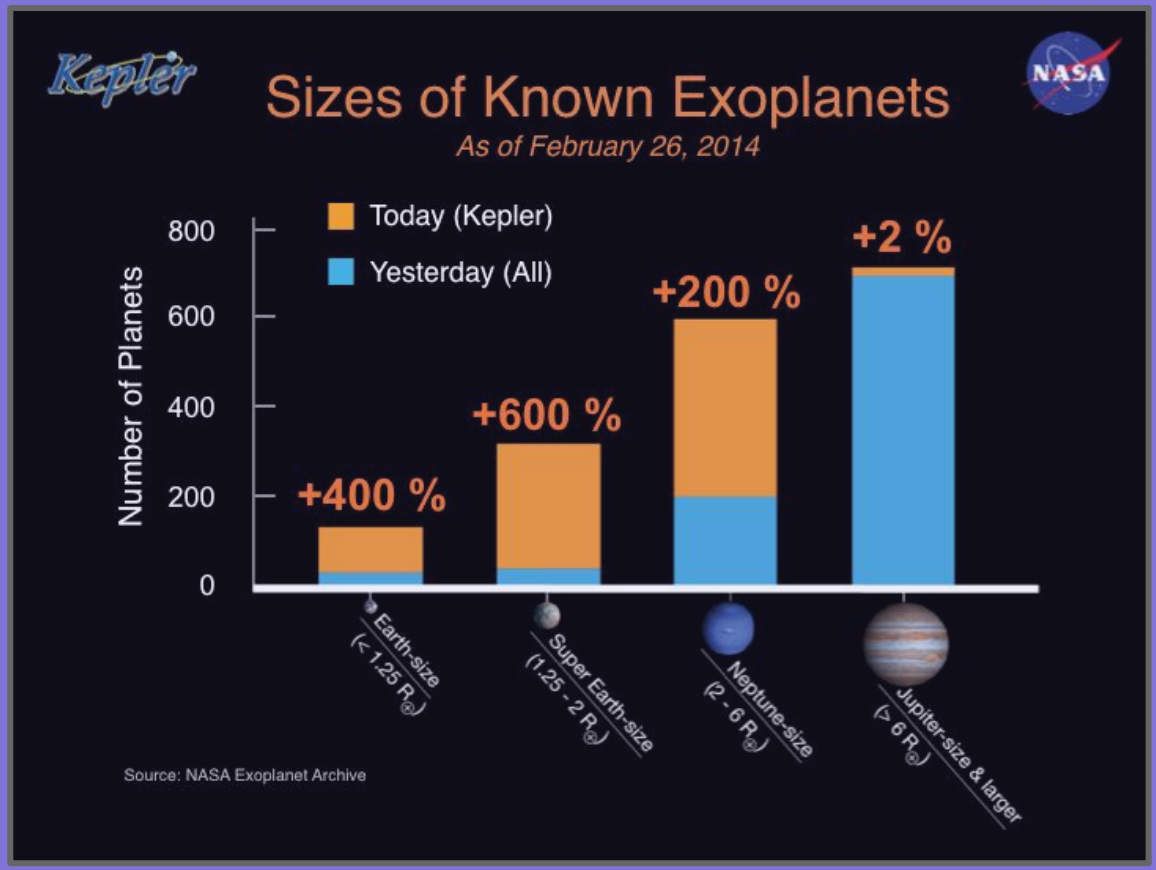
2955

exoplanets found via transit! (and +4000 of candidates!)

KEPLER SPACECRAFT

BEFORE KEPLER

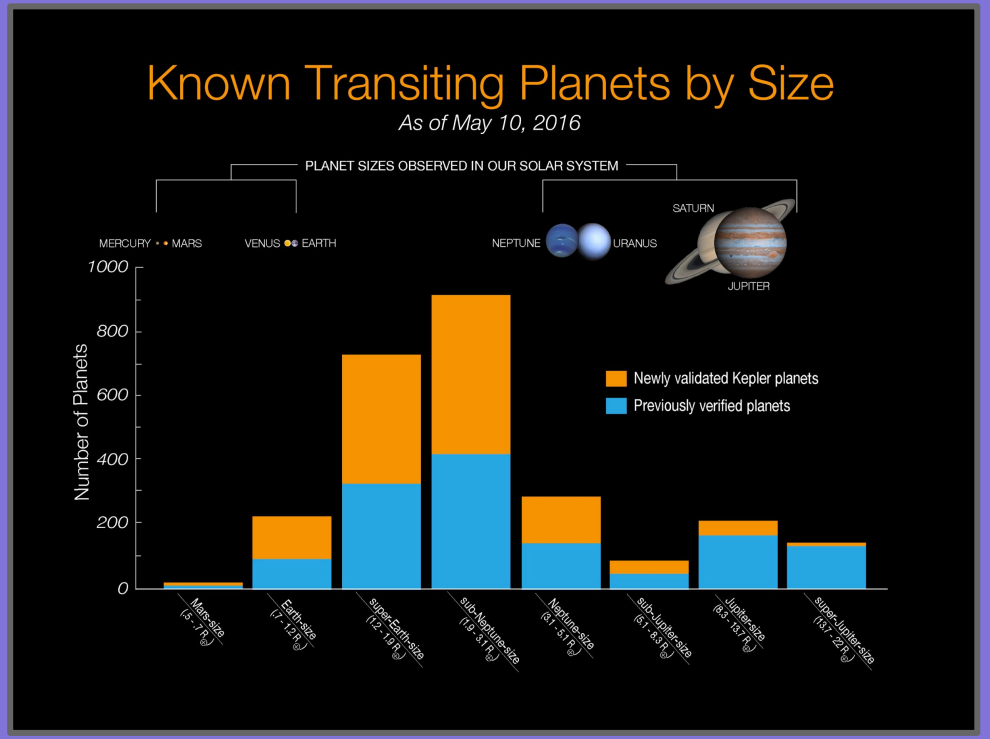
...



On May 10, 2016, the Kepler Team announced the discovery of

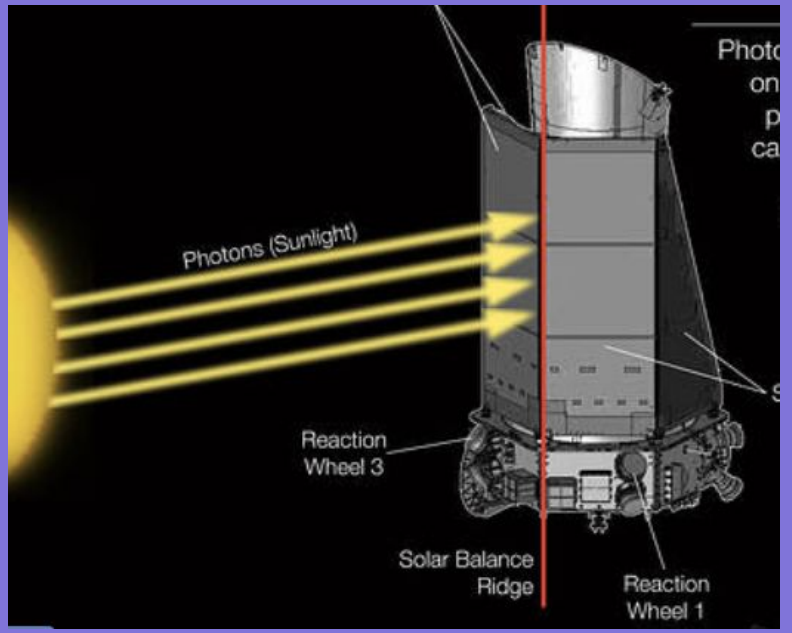
1284 EXOPLANETS

Sub-Neptune and Super Earth are the most common type of exoplanet



Kepler’s Second Life: K2

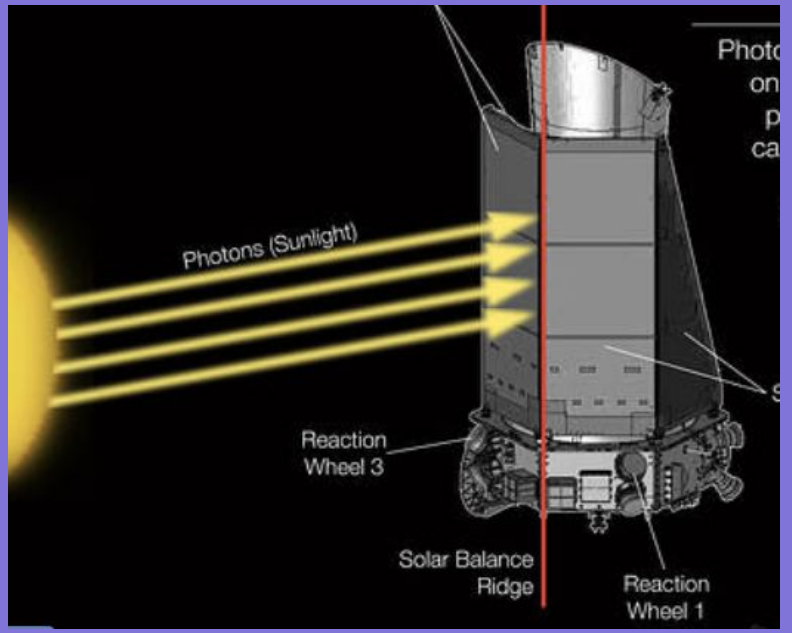
In May 2013, the reaction wheels of Kepler failed

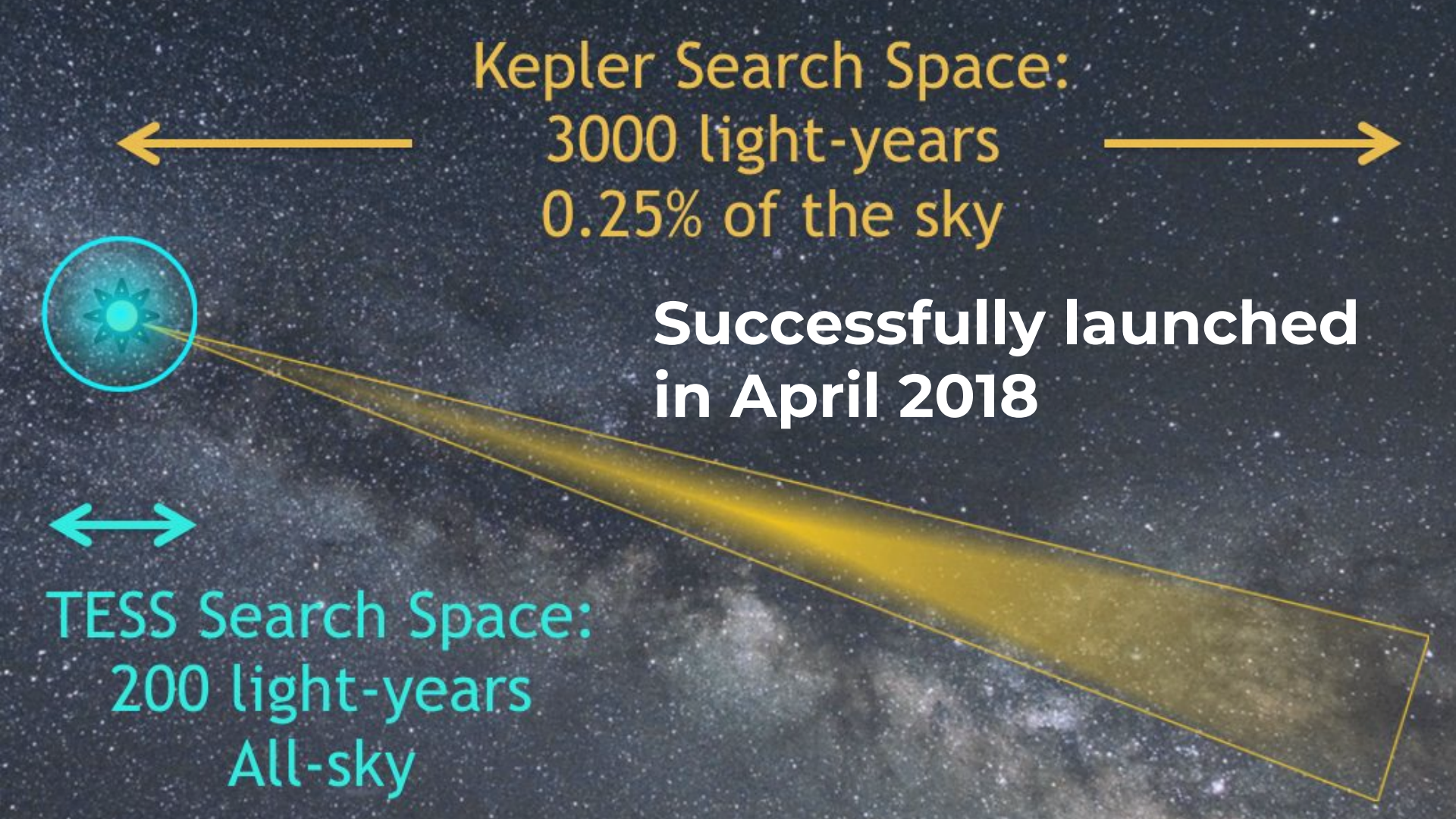


Kepler’s Second Life: K2

325

exoplanets found via transit! (and +500 candidates!)




Kepler Search Space:
3000 light-years
0.25% of the sky
Successfully launched
in April 2018
TESS Search Space:
200 light-years
All-sky


HONORABLE MENTION
SPITZER
FIRST 7 PLANETS
SYSTEM FOUND!!!
TRAPPIST-1 SYSTEM

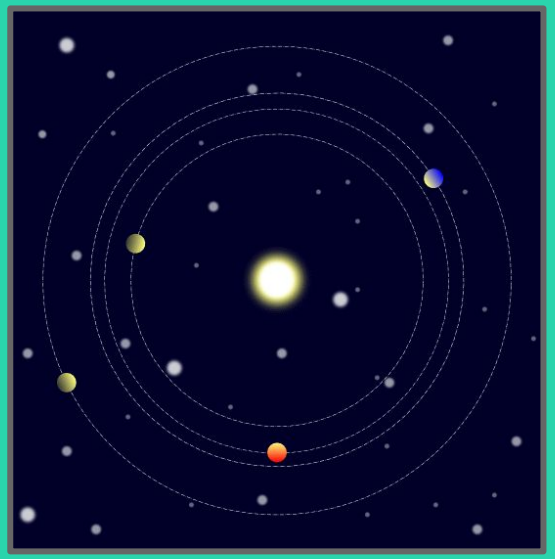
TESS FIRST IMAGES!!!

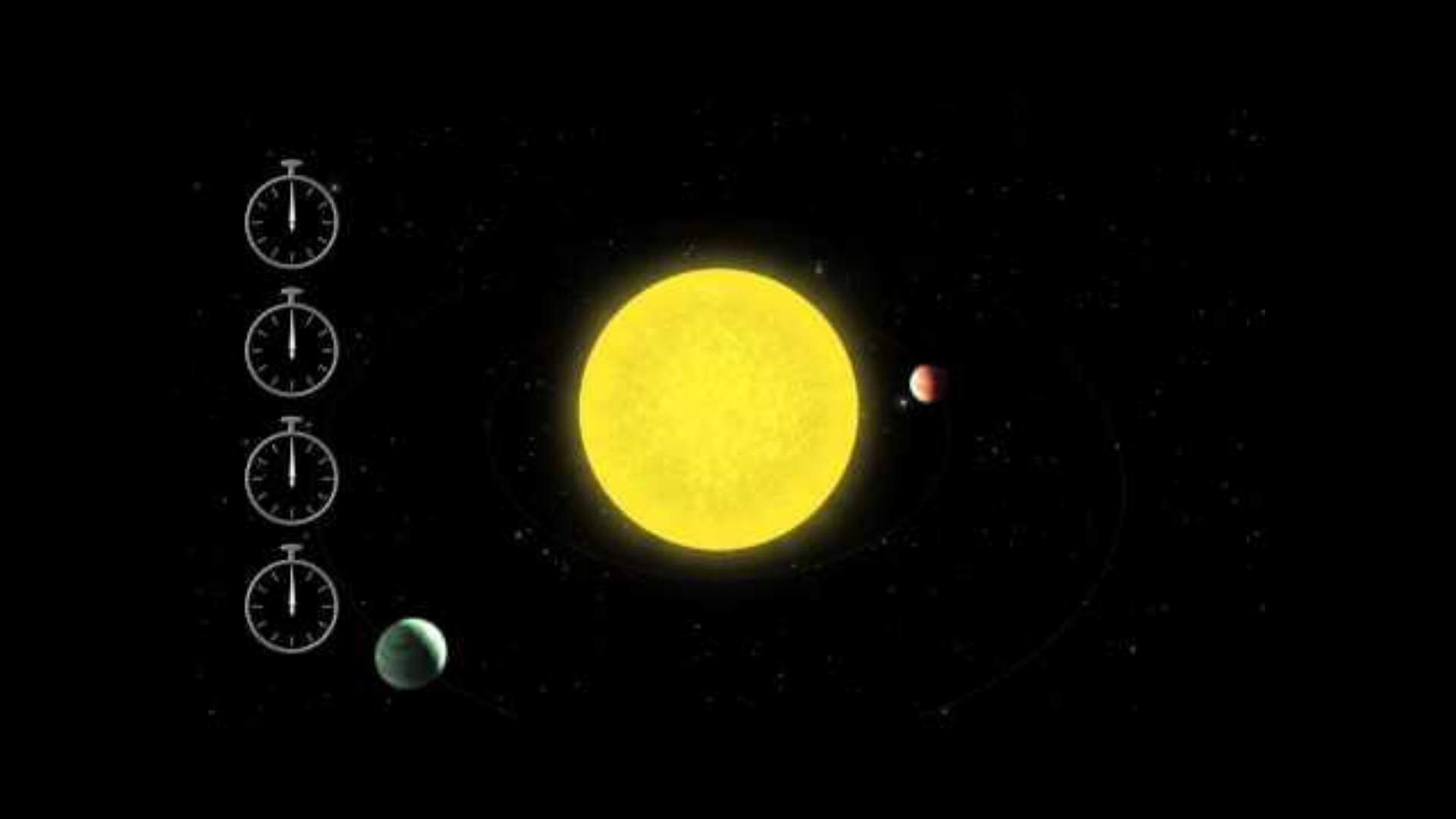
Transit Timing Variation

When 2 planets passes each other, they are **gravitationally attracted.**

They will **exchange energy**: one will speed up, the other will slow down.

The next transits will either occur slightly **before or after** expected.

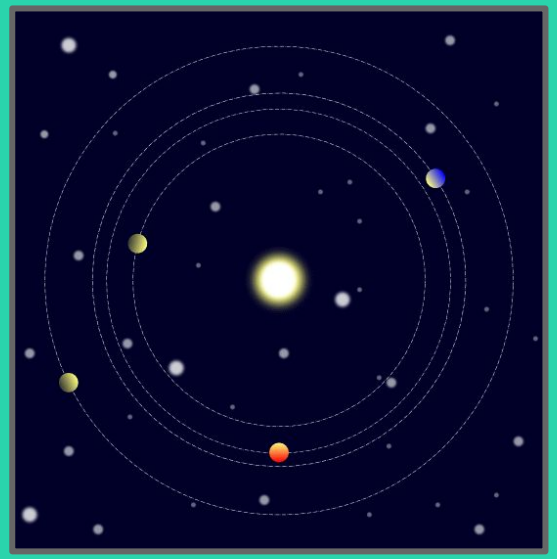




Transit Timing Variation

15 exoplanets found through TTV.

But more to come?



Microlensing

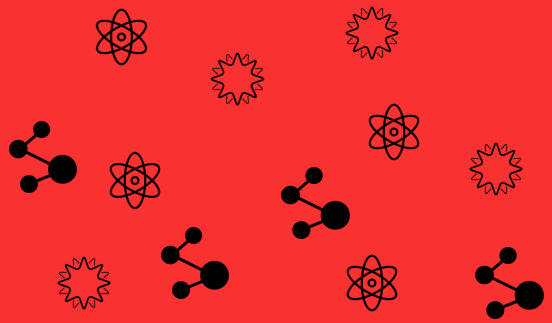
“Wait, so you are trying to find planets you can’t see around stars you can’t see?”

Dark Matter

5x more abundant than normal matter

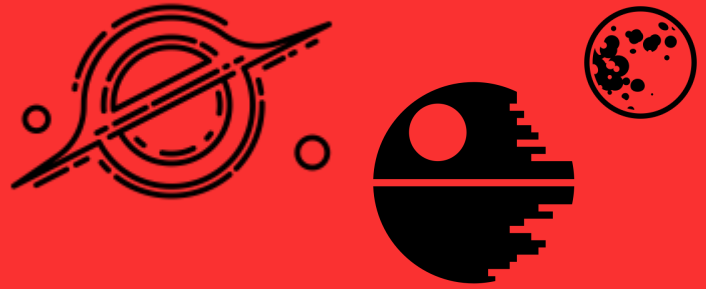
WIMPs

(Weakly Interacting Massive Particles)



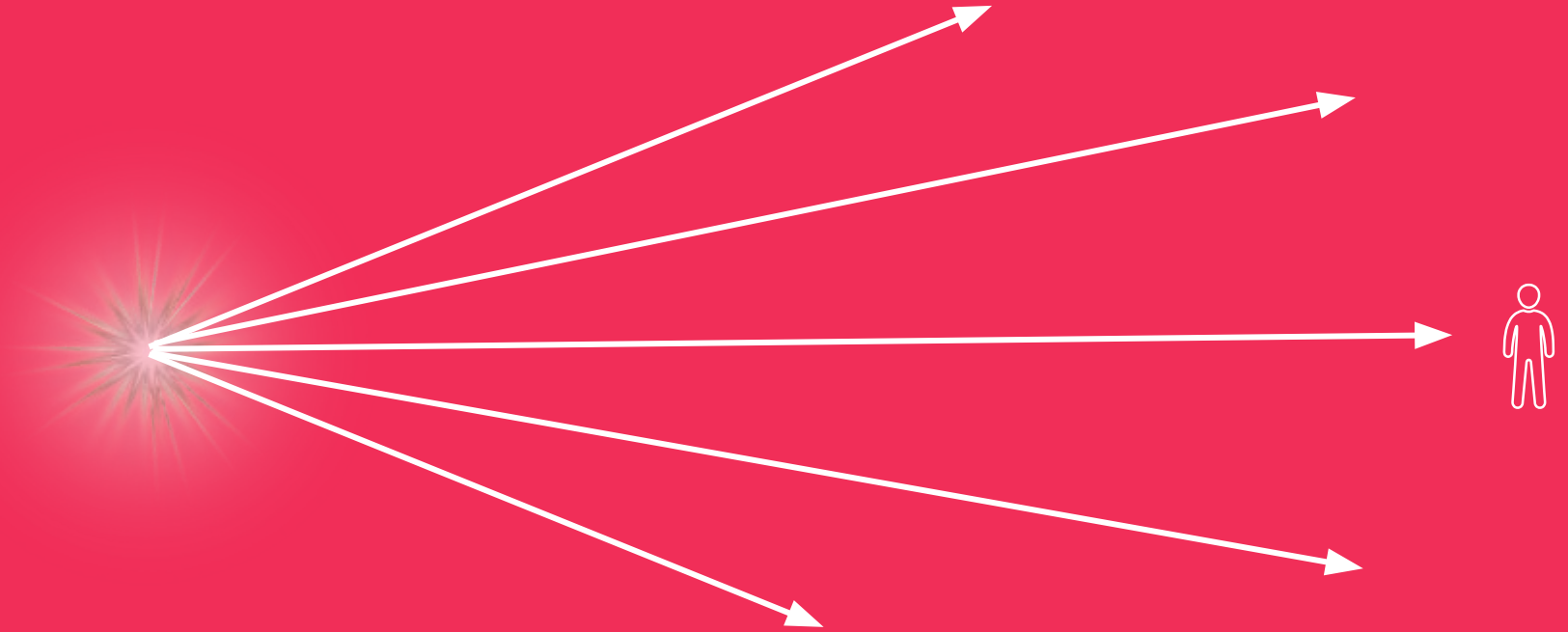
MACHOs

(MAssive Compact Halo Objects)



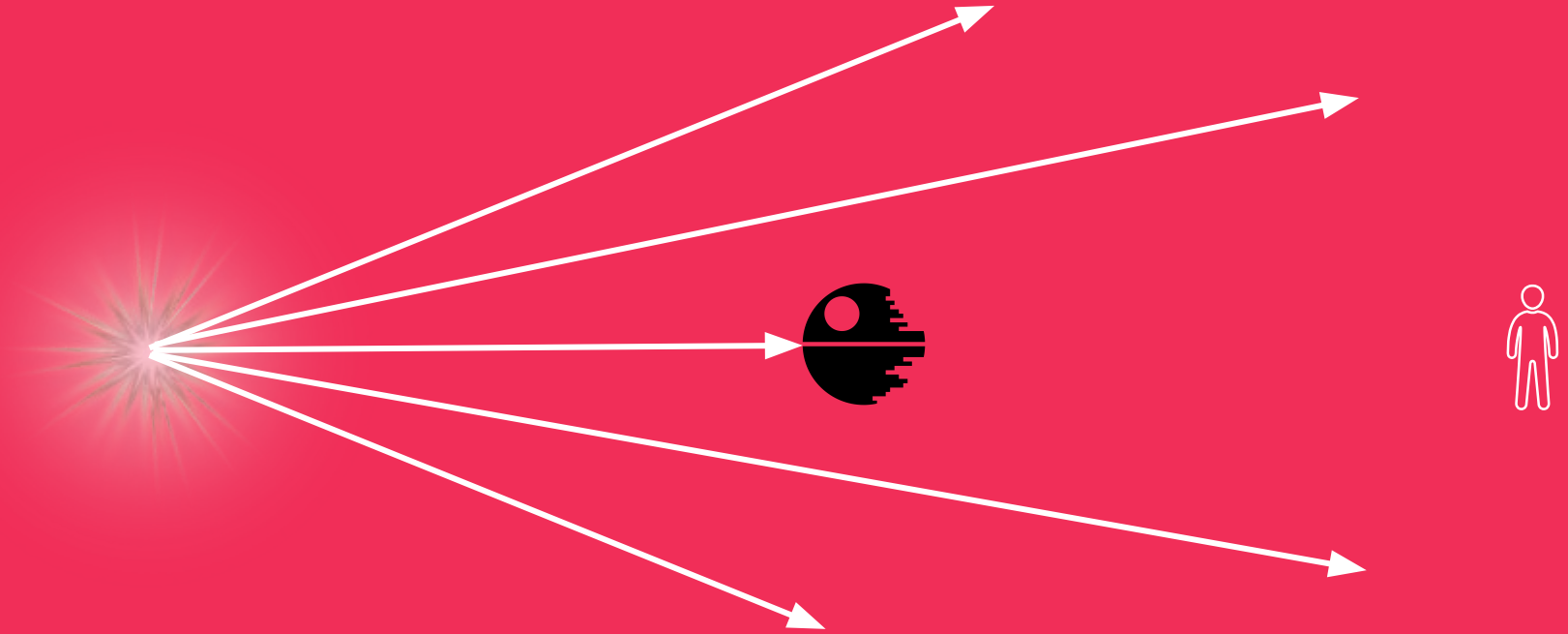
Trouver des MACHOs

Gravitational microlensing



Trouver des MACHOs

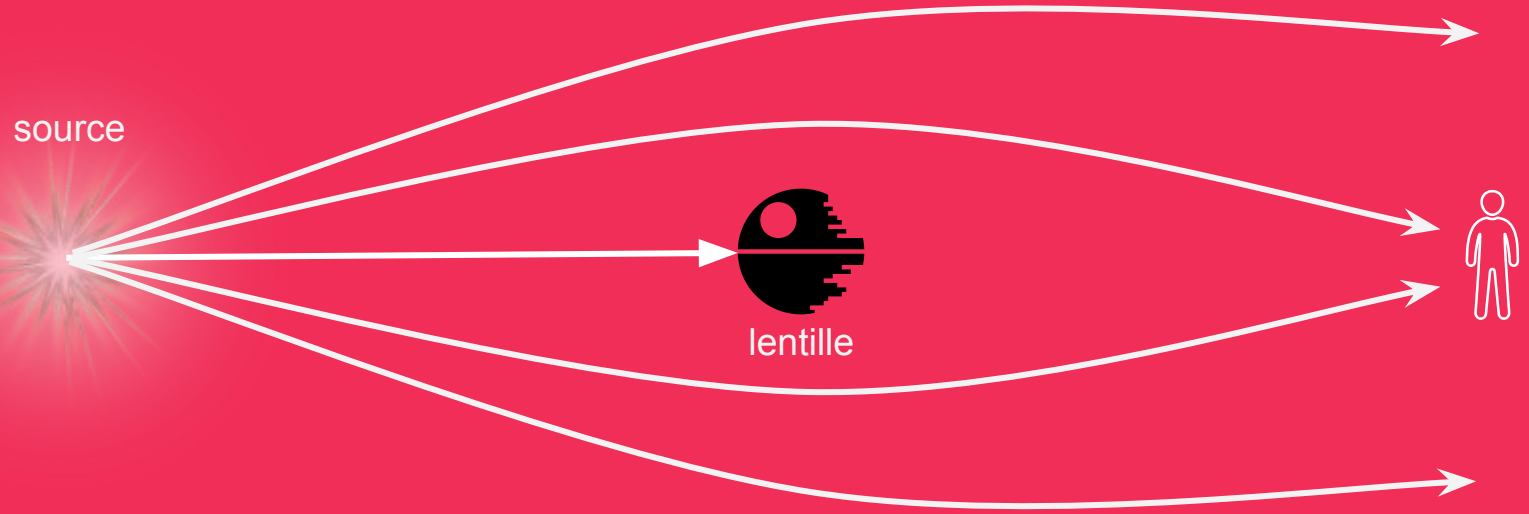
Microlentilles gravitationnelles



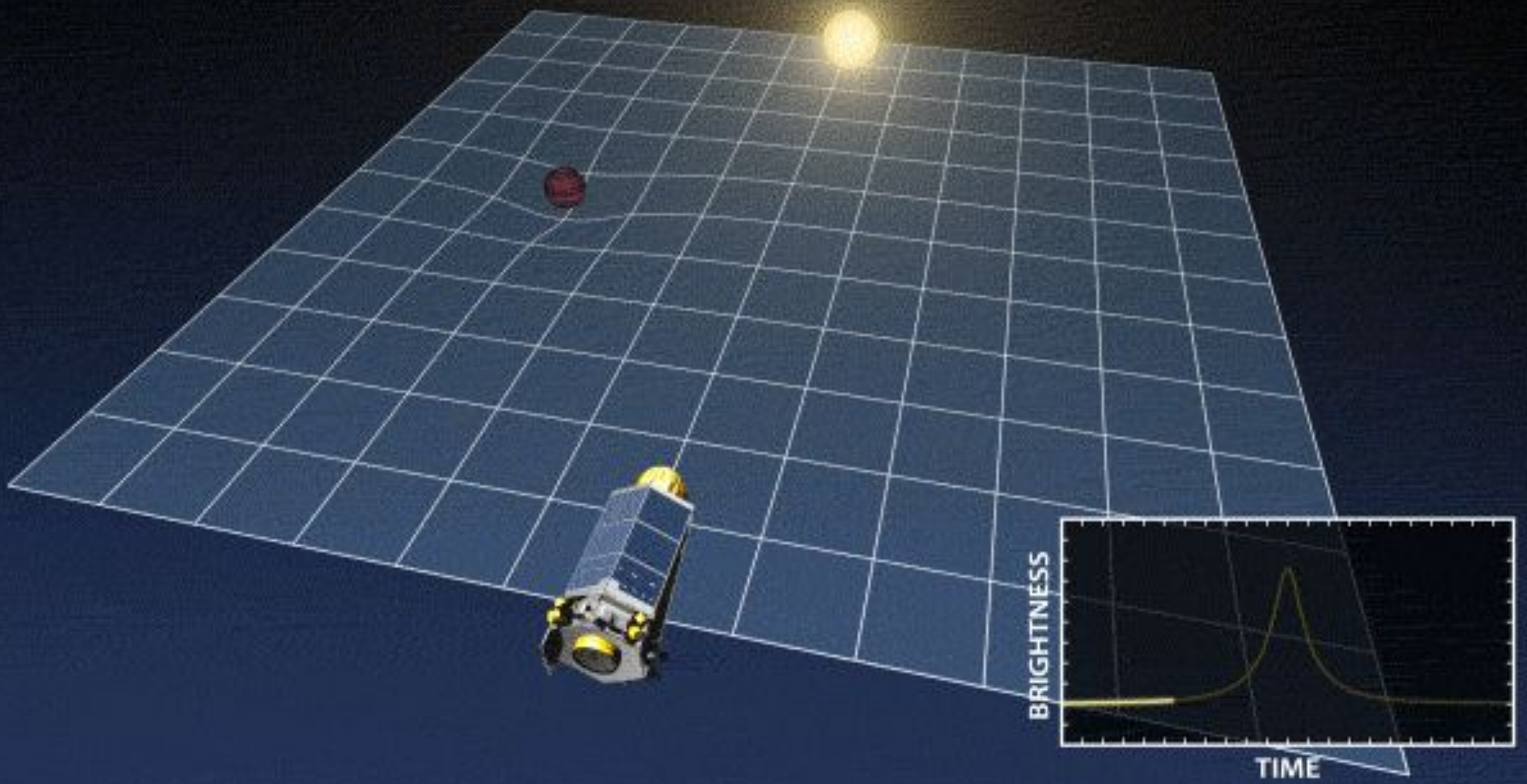
Finding MACHOs

Microlensing

But Einstein said that mass bends the path of light!

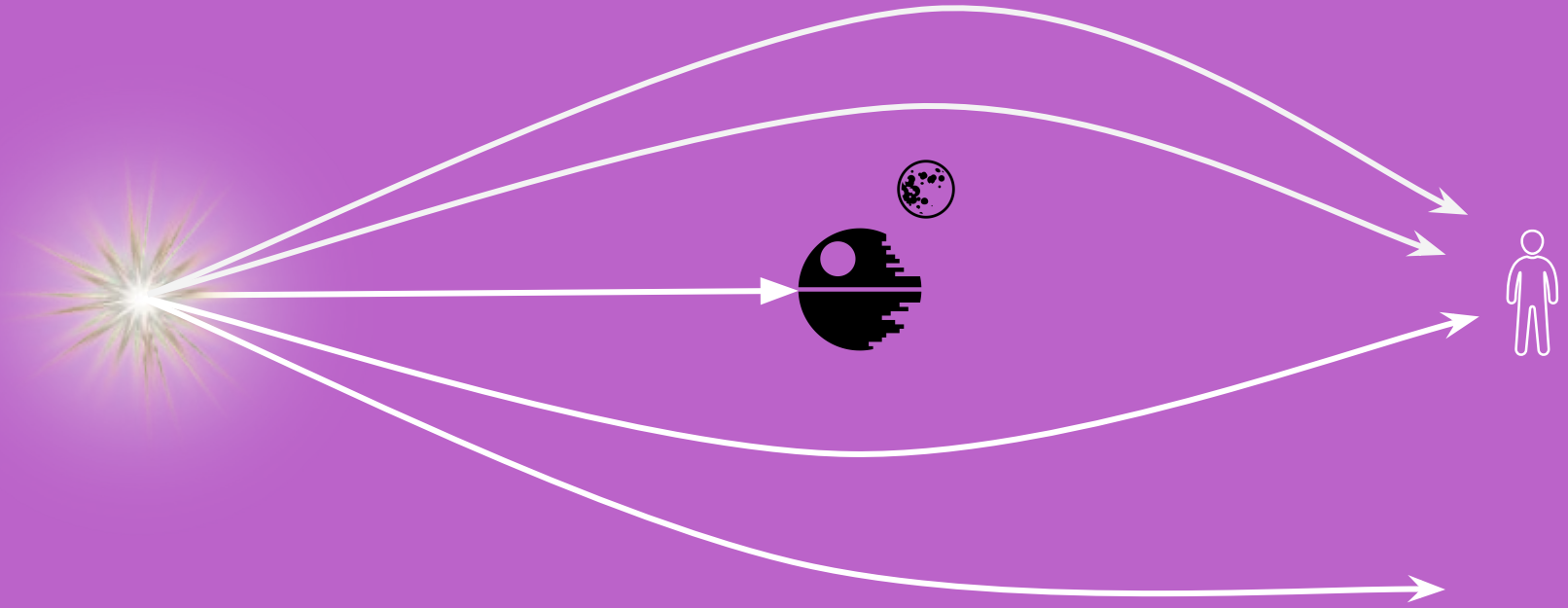


So the mass in between **acts like a magnifier**!


BRIGHTNESS
TIME

MACHOs

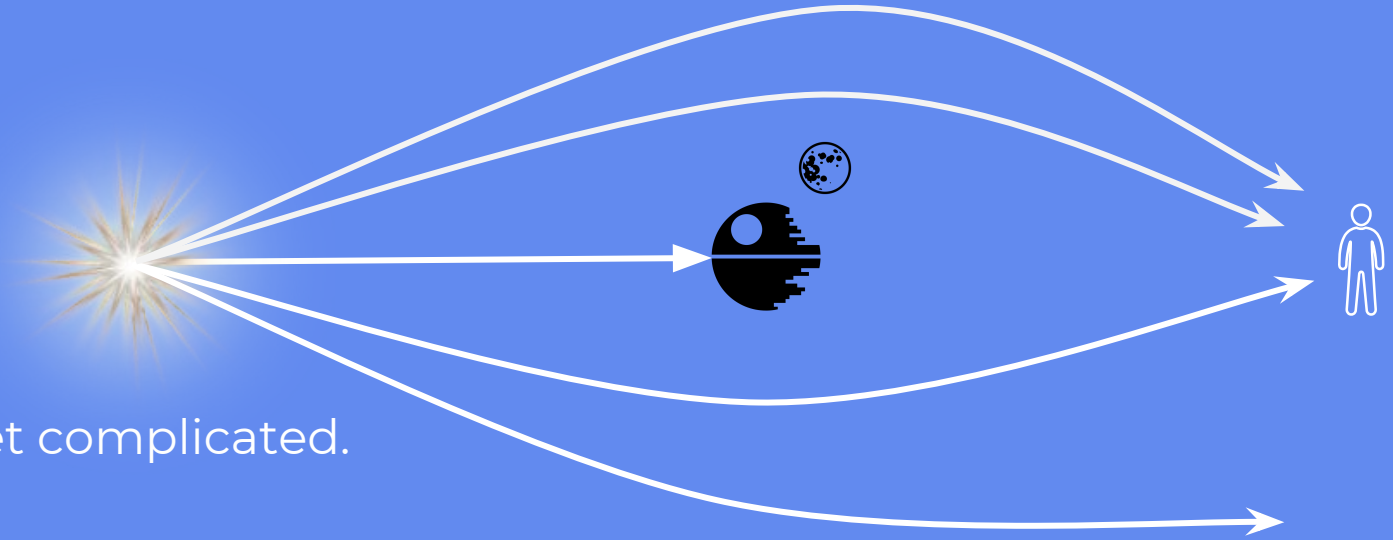
With a companion



Microlensing

Aka the study of the lens.

What happens when there is a companion to the lens?



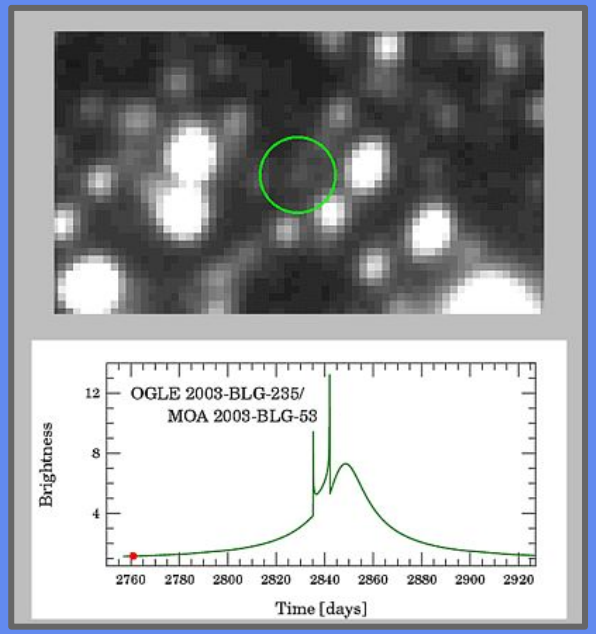
Things get complicated.

Microlensing

Aka the study of the lens.

The planet will cause the source to rapidly flash.

These flashes are unpredictable and last about a **couple of days**.



Microlensing

Aka the study of the lens.

Microlensing event are **unpredictable**.

If you stare at a star, this event will happen **once every million years**.

The strategy is to stare a 100 billions stars and hope for the best.

Microlensing

Procedure

1. Have a telescope looking at the bulge of the Milky way
2. Whenever a **star starts to get brighter**, put it on the public alert list.

***

If it gets **REALLY BRIGHT REAL QUICK**, make calls, tweet about it, alert everyone, stay up all night.

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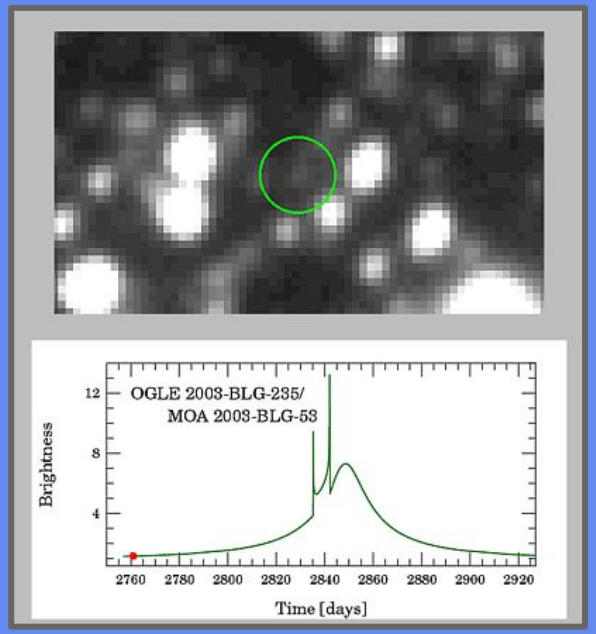
Microlensing

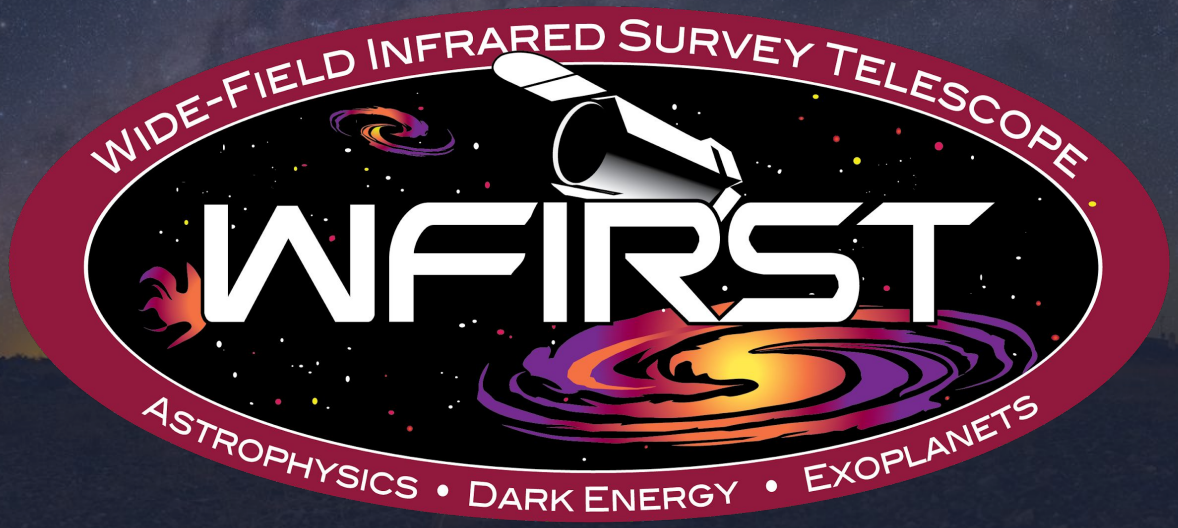
Aka the study of the lens.

64 exoplanets found through microlensing.

Advantage, finds planets on wide orbit!!!



WFIRST


WIDE-FIELD INFRARED SURVEY TELESCOPE
WFIRST
ASTROPHYSICS • DARK ENERGY • EXOPLANETS

Direct Imaging

Definition:

Taking a picture of the planet. Duh-uh

Direct Imaging

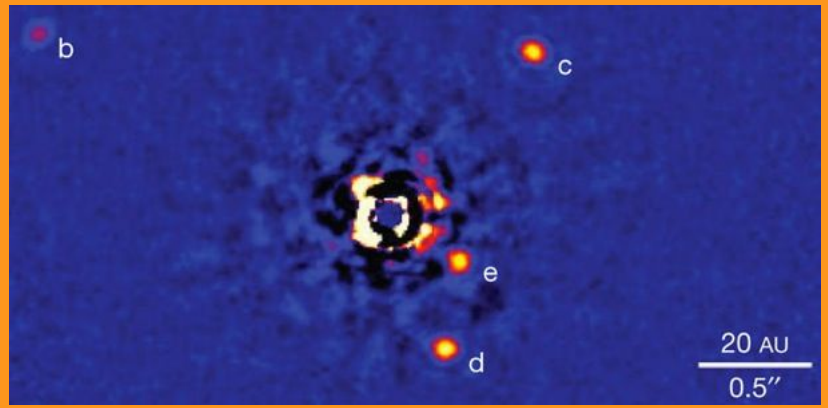
IS HARD.

In fact, it is as difficult as trying to photograph a fly next to a lighthouse beam while standing over 6 kilometers away....

CORONAGRAPH

Definition:

Technique to separate the light from the star and then block the light from the star.



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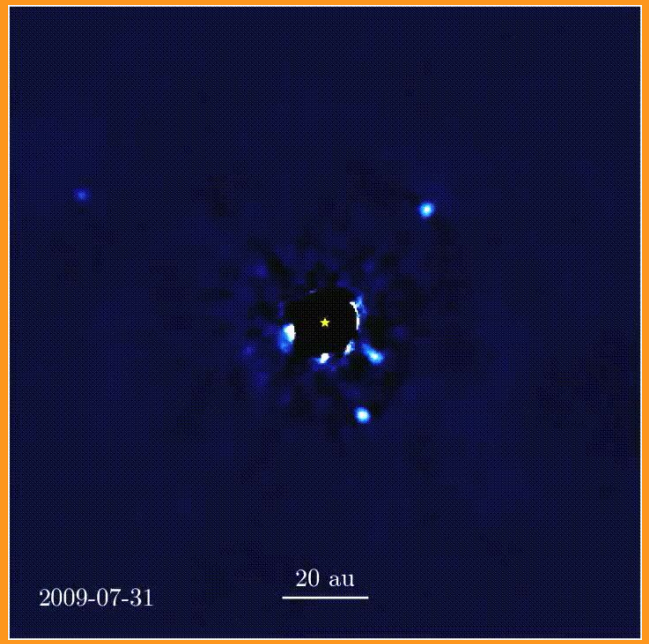


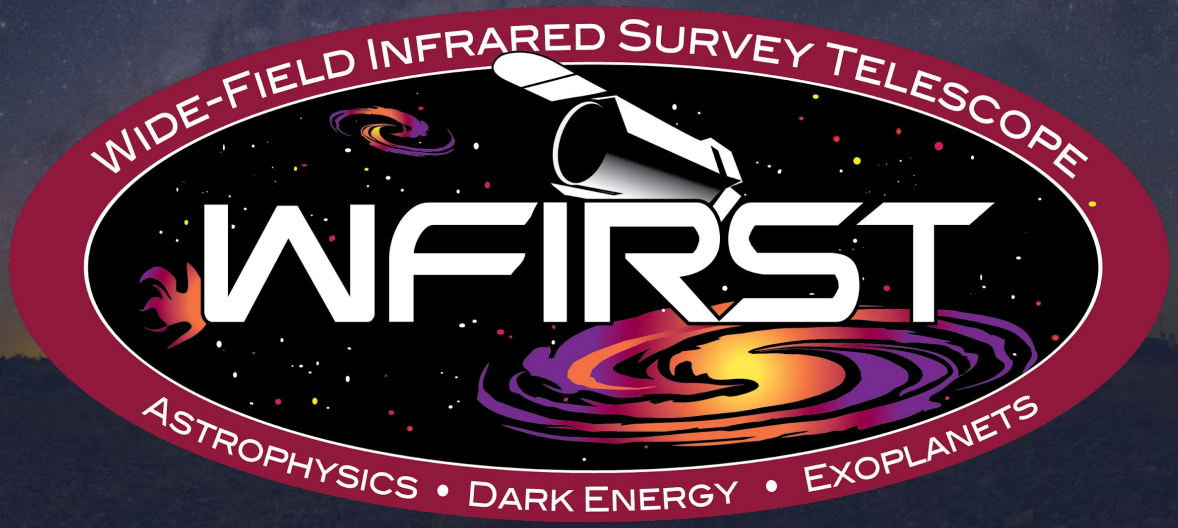
Direct Imaging

IS HARD, but not impossible

44 exoplanets found through direct imaging.

But more to come?

WFIRST


WIDE-FIELD INFRARED SURVEY TELESCOPE
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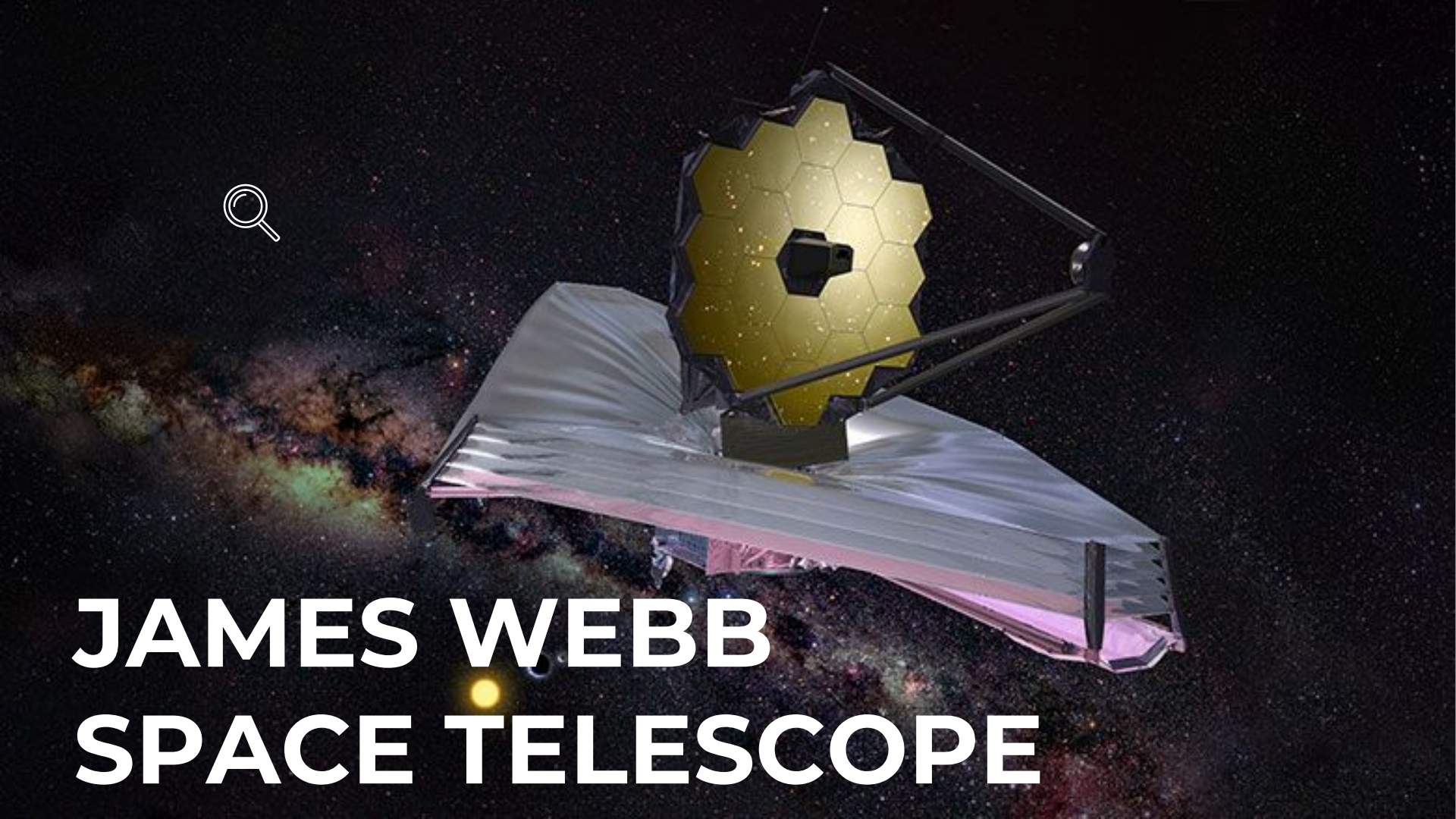
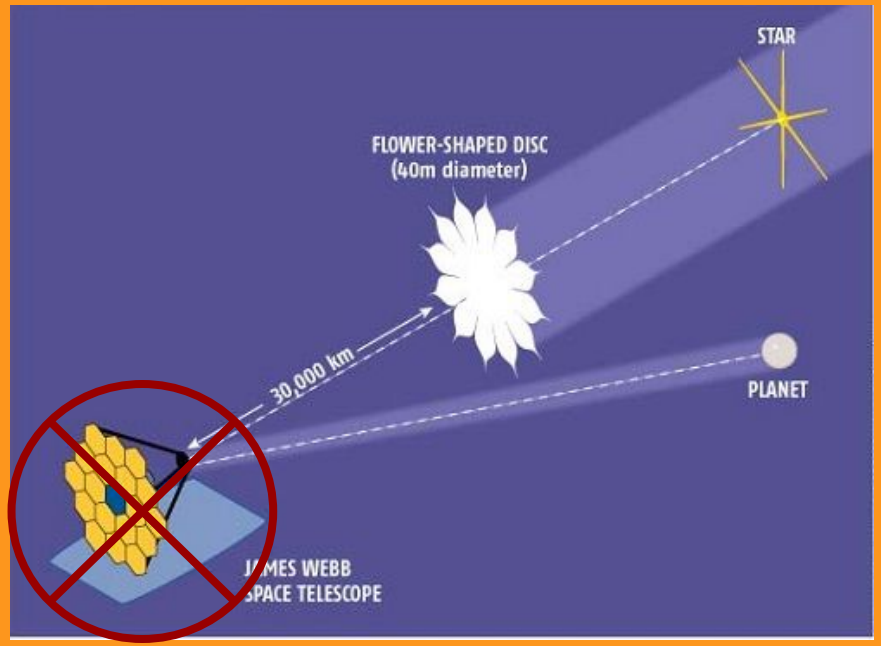
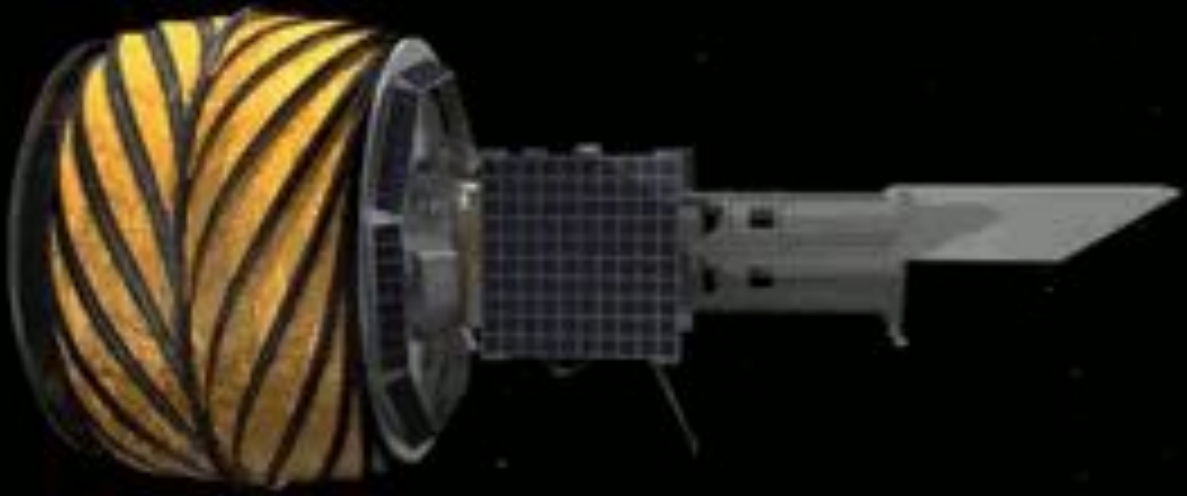

JAMES WEBB
SPACE TELESCOPE

STAR SHADE

SPACE ORIGAMI

Blocking the light from the star externally

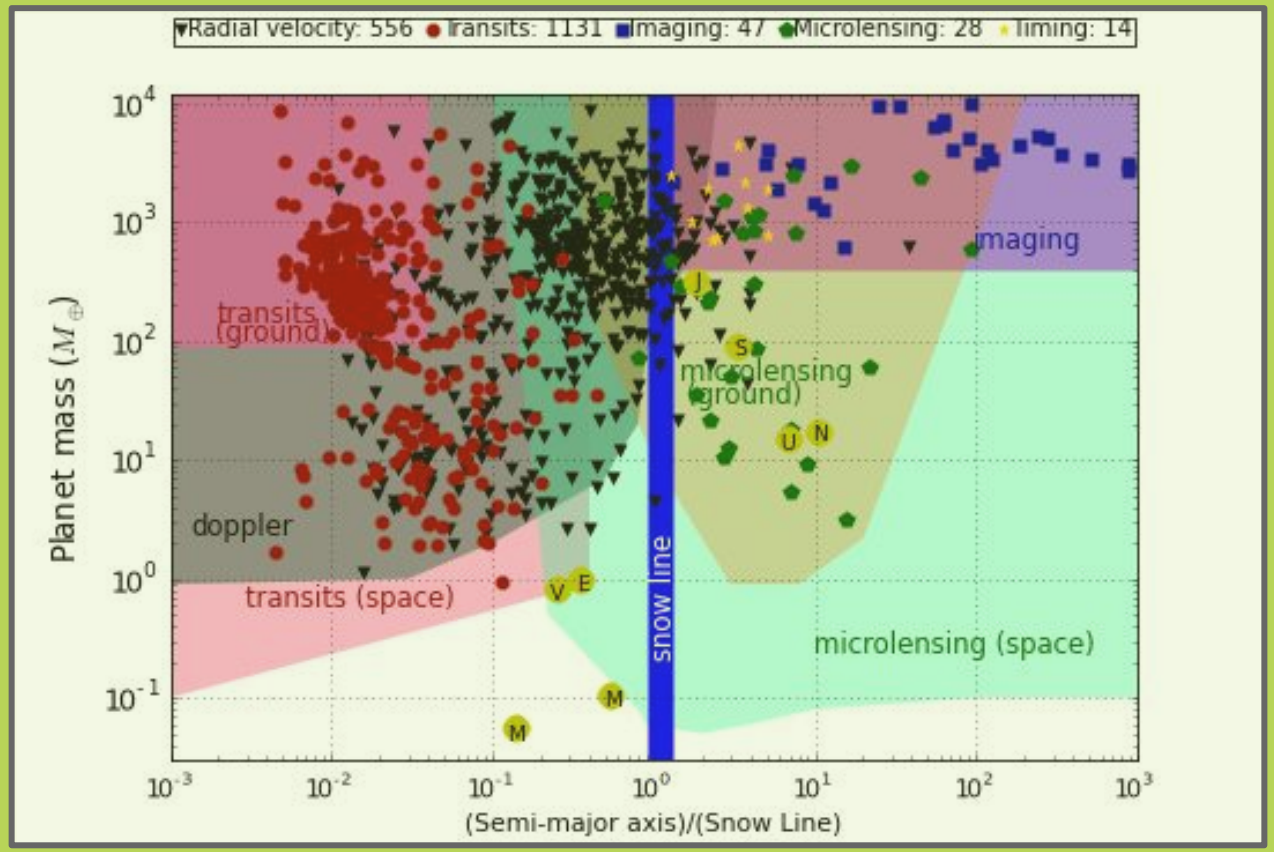




6 Methods to Detect Exoplanets

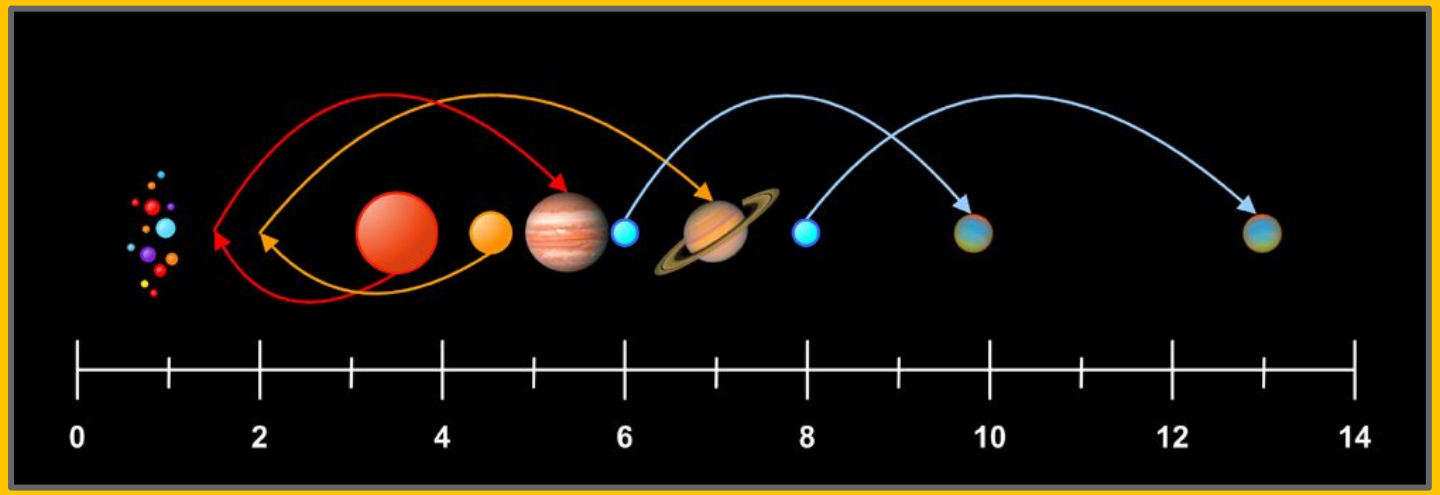
- ASTROMETRY (minuscule dance movements)
- RADIAL VELOCITY (periodically becomes bluer and redder)
- TRANSITS (blocking light from the star)
- TRANSIT TIMING VARIATION (non-equal period)
- MICROLENSING (taking advantage of general relativity)
- Direct Imaging (snapping photos)

WHY DO WE KEEP SEARCHING?



PLANET FORMATION?

OR THE PAST AND FATE OF THE SOLAR SYSTEM.

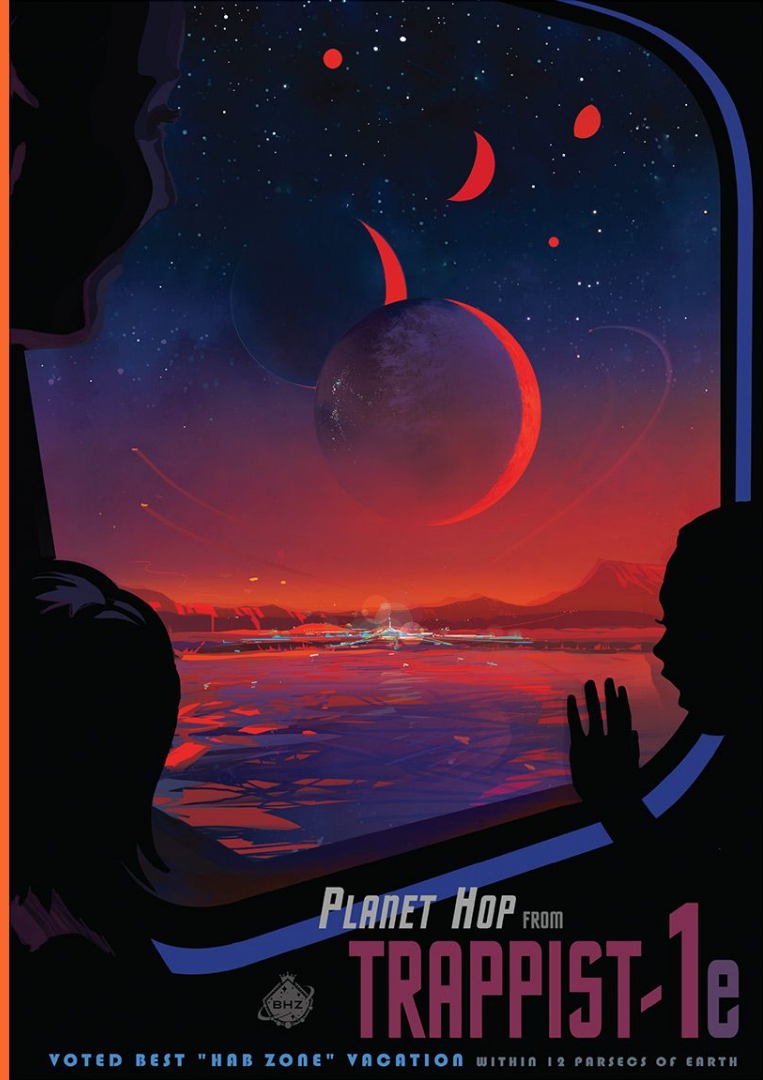


CLIMATE STUDIES

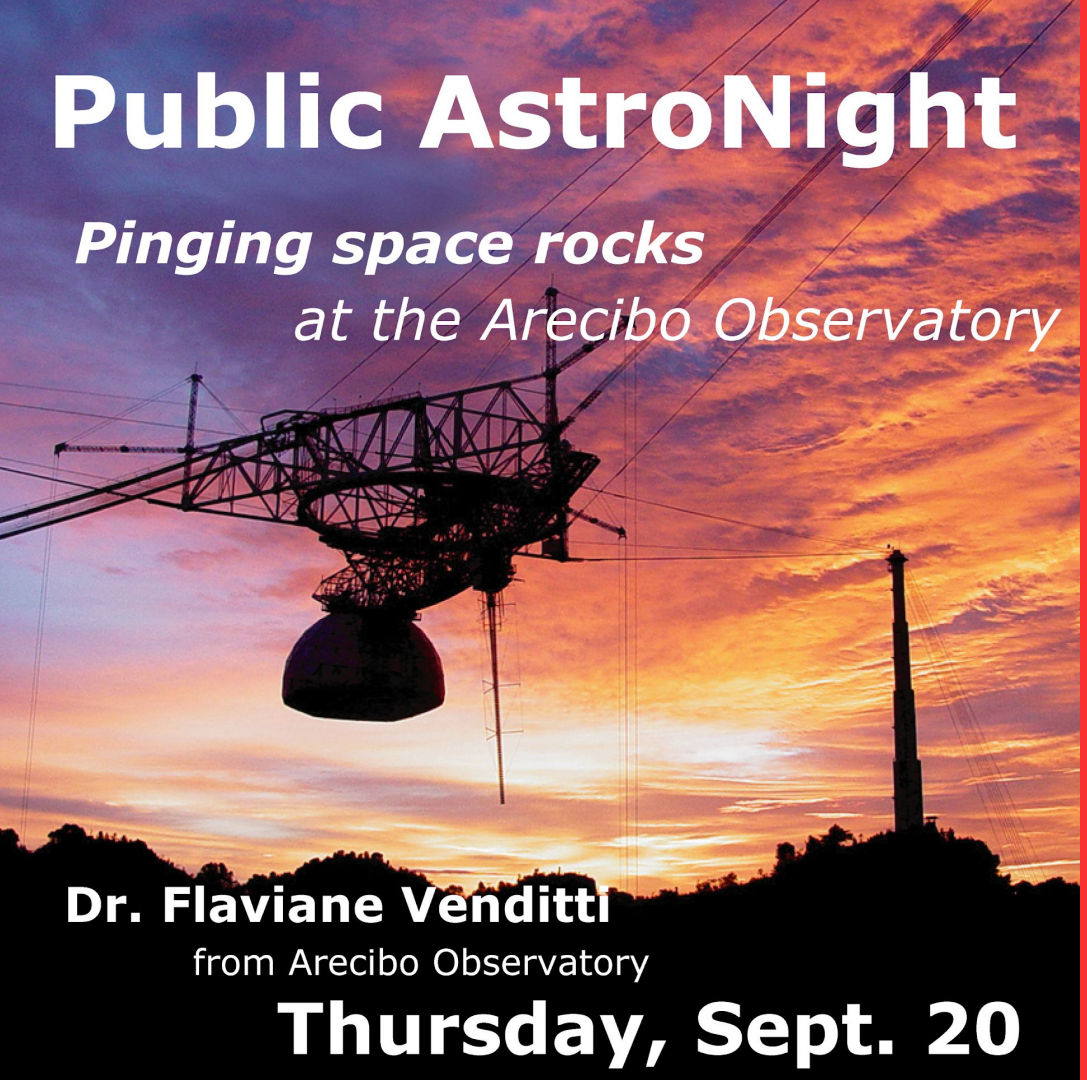
NOT TO BE CONFUSED WITH WEATHER...

ALIEN LIFE?

ARE WE ALONE IN THE UNIVERSE?

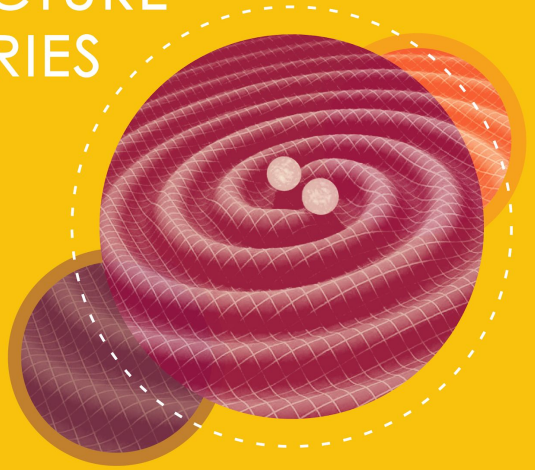


NOT A SEARCH FOR A SECOND HOME



Tonight
7 PM
McConnell
Room 204

PUBLIC
LECTURE
SERIES



UNPACKING GRAVITATIONAL WAVES: THE ROAD TO DISCOVERY

TALK BY BENJAMIN DRINGOLI
From McGill University

Location: Arts Building W-215
Metro McGill

Thursday, September 27, 7 PM
More info: physicsmatters.physics.mcgill.ca/lectures/

Ph Physics 18.67
Ma Matters 18.78

Next Thursday 7pm

Arts Build. Room W-215