

Esopianeti e Vita nell'Universo



F. Berrilli – Dip. Di Fisica – UTOV

Mestre, 7 Maggio 2012

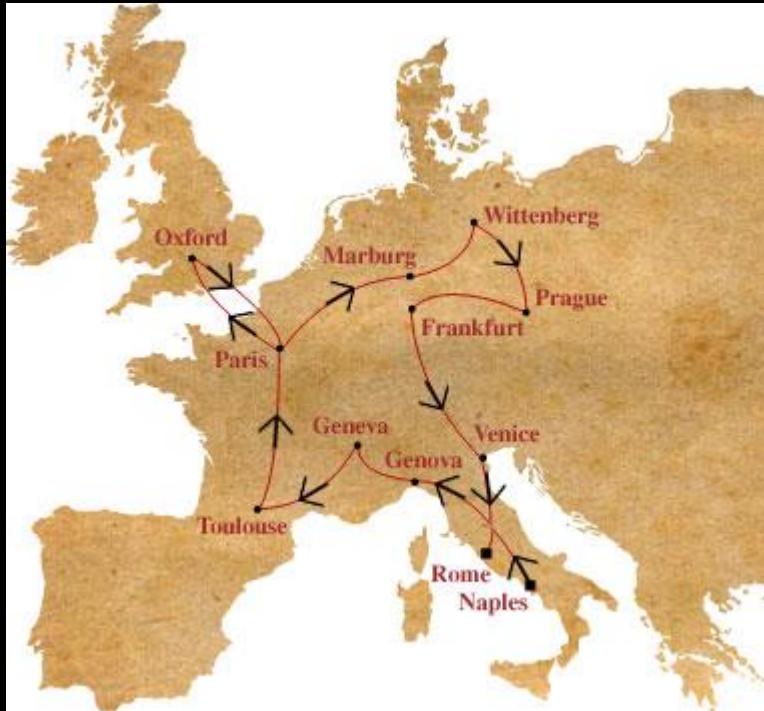
*“Esistono innumerevoli soli;
innumerevoli terre ruotano attorno a
questi similmente a come i sette pianeti
ruotano attorno al nostro sole. Questi
mondi sono abitati da esseri viventi”*

Campo de' Fiori





*Di maniera che non è un sol
mondo, una sola terra, un solo
sole; ma tanti son mondi quante
veggiamo circa di noi lampade
luminose, le quali non sono più né
meno in un cielo ed un loco ed un
comprendente, che questo mondo,
in cui siamo noi, è in un
comprendente, luogo e cielo.*



*Ma se infiniti sono i Mondi e le
galassie, l'uomo non può essere il
privilegiato del creato. Tantomeno
lo è un unico popolo, appartenente
alle molteplici e poliedriche razze
umane.*

De Infinito, Giordano

Nel "De l'infinito universo et mondi" il copernicano Giordano Bruno sostiene, come già Epicuro da Samo e Lucrezio, che le stelle sono soli lontanissimi attorno ai quali girano pianeti e alcuni di questi mondi sono abitati da esseri intelligenti.

Quattro secoli prima della scoperta (1995) dell'esistenza dei pianeti extrasolari e 350 anni prima dell'inizio (1960) della ricerca radiotelescopica di segnali provenienti da eventuali civiltà extraterrestri (SETI, Search for Extra Terrestrial Intelligence).

Subito dopo il rogo di Giordano Bruno, le scoperte di Galileo abbattono l'architettura filosofica aristotelica e tolemaica delle "sfere di cristallo".

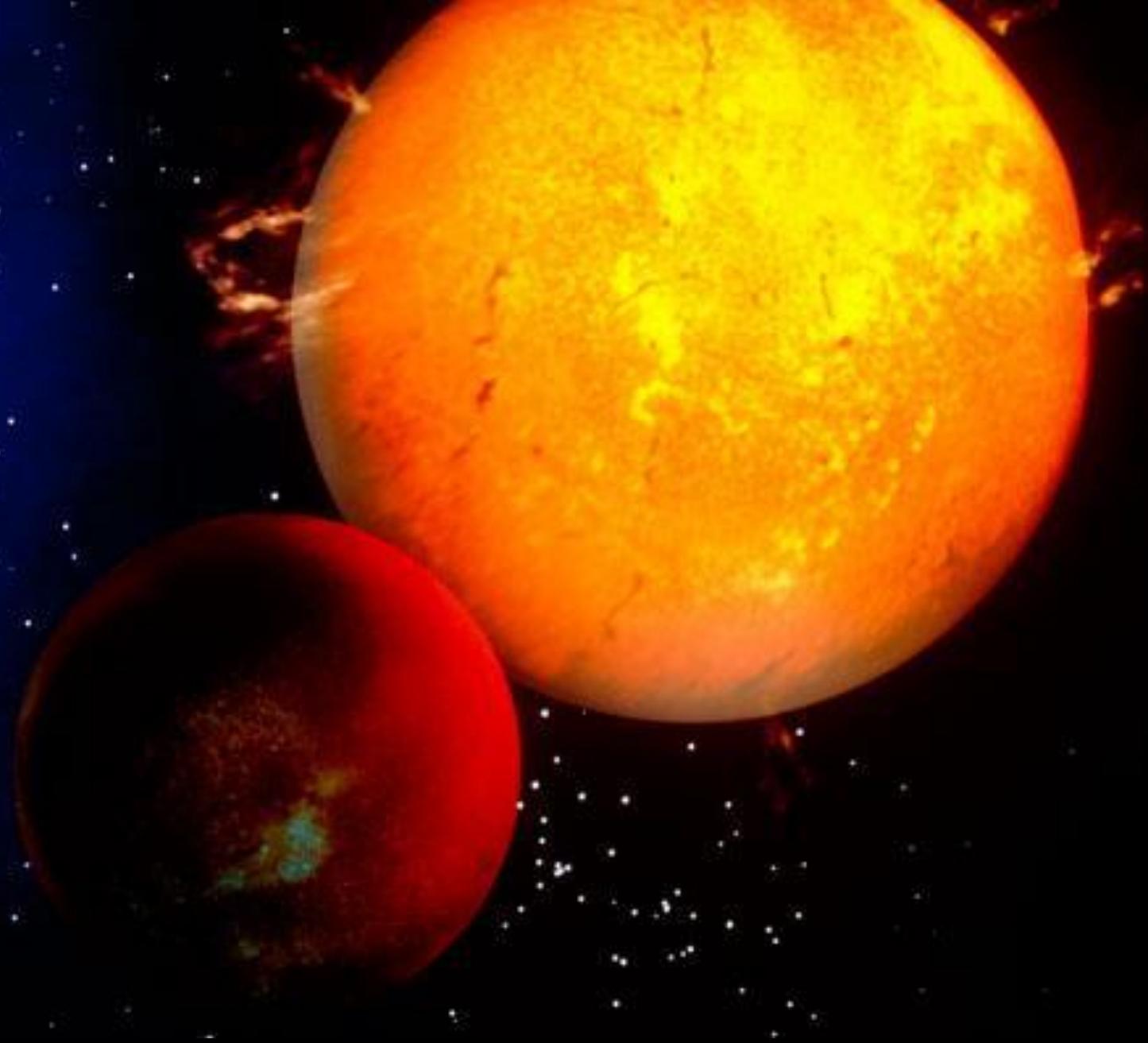


Image: An artist's impression of the planet 51 Pegasi B (credit: Dr Seth Shostak/SPL)

51 Pegasi

In 1995 astronomers announced that they had discovered a planet, 51 Pegasi B, in orbit around its star, 51 Pegasi - the first exoplanet found orbiting a star similar to the Sun.

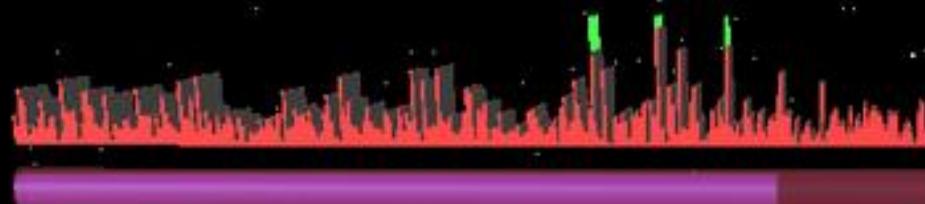
Measurements of the tiny wobbles the planet's gravitational interaction caused in 51 Pegasi's orbit confirmed its existence. It takes 51 Pegasi B only four days to orbit its star, and surface temperatures are thought to exceed 1,000C.

The first exoplanet was discovered orbiting a pulsar in 1992. Hundreds of exoplanets have been discovered since.

Ratio Sun/Earth masses 333000

SETI@Home Enhanced

Computing Fast Fourier Transform
Doppler drift rate 18.1931 Hz/sec Resolution 0.075 Hz
Best Triplet power 7.88, period 0.0893



Overall 83.364% done

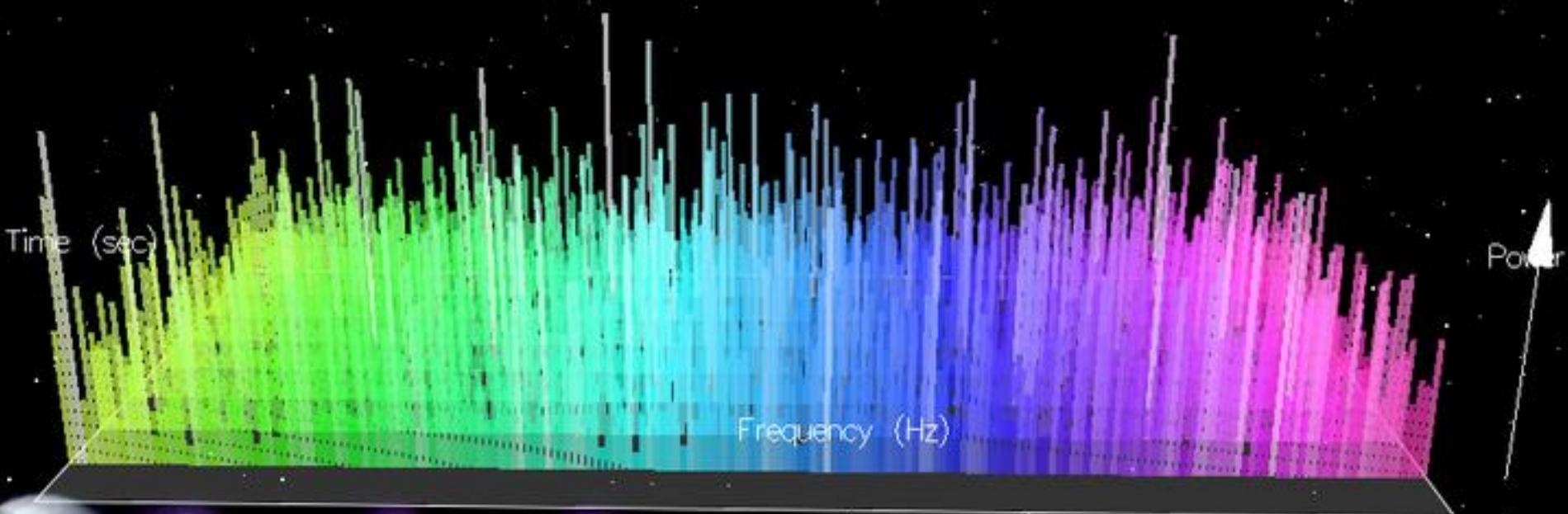
CPU time: 47 min 39.28 sec

Data info

From: 22 hr 49' 40" RA, +23 deg 41' 47" Dec
Recorded on: Sat May 07 11:37:35 2005
Recorded at: Arecibo 1.42GHz Flat Feed
Base frequency: 1.420976563 GHz

User info

Name: wrightbus
Team: The Chinese University of Hong Kong
Total credit: 3034.15



SETI@home

The Search for Extraterrestrial Intelligence

Data Analysis

Searching for Pulses / Triplets

21% 

Doppler drift rate: 0.0000 Hz/sec Resolution: 76.294 Hz

Pulse: power 1.22, period 0.7274, score 0.54



Overall: 0.198% done

CPU time: 0 hr 01 min 33.2 sec

Data Info

From: 12 hr 1' 1" RA, + 25 deg 51' 36" Dec

Recorded on: Fri Oct 03 16:10:19 2003 GMT

Source: Arecibo Radio Observatory

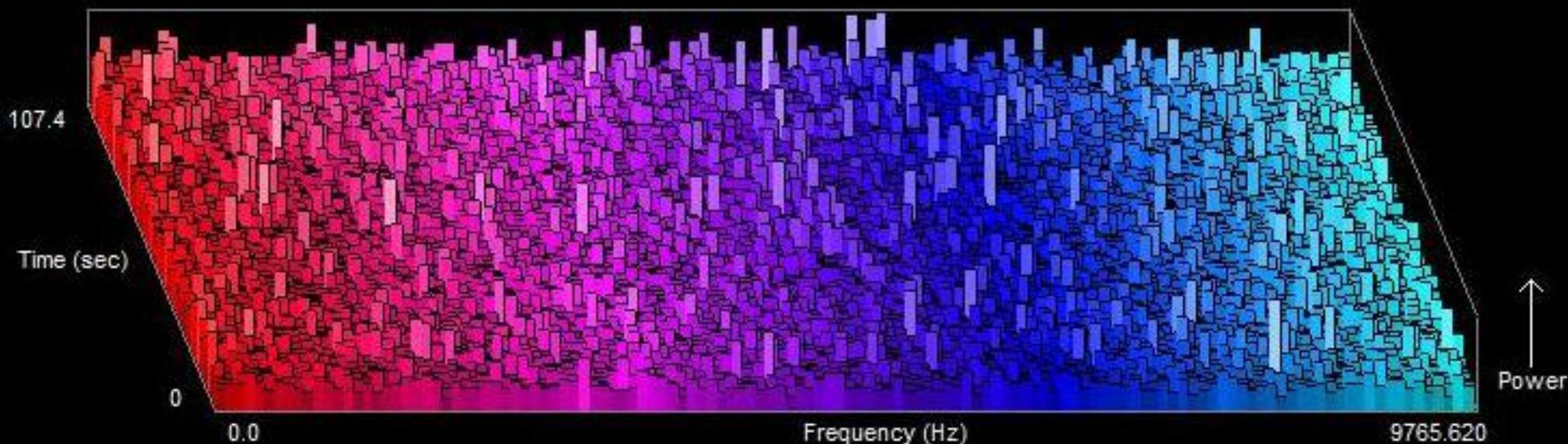
Base Frequency: 1.420019531 GHz

User Info

Name: nnn

Data units completed: 2216

Total computer time: 20330 hr 06 min 07.0 sec

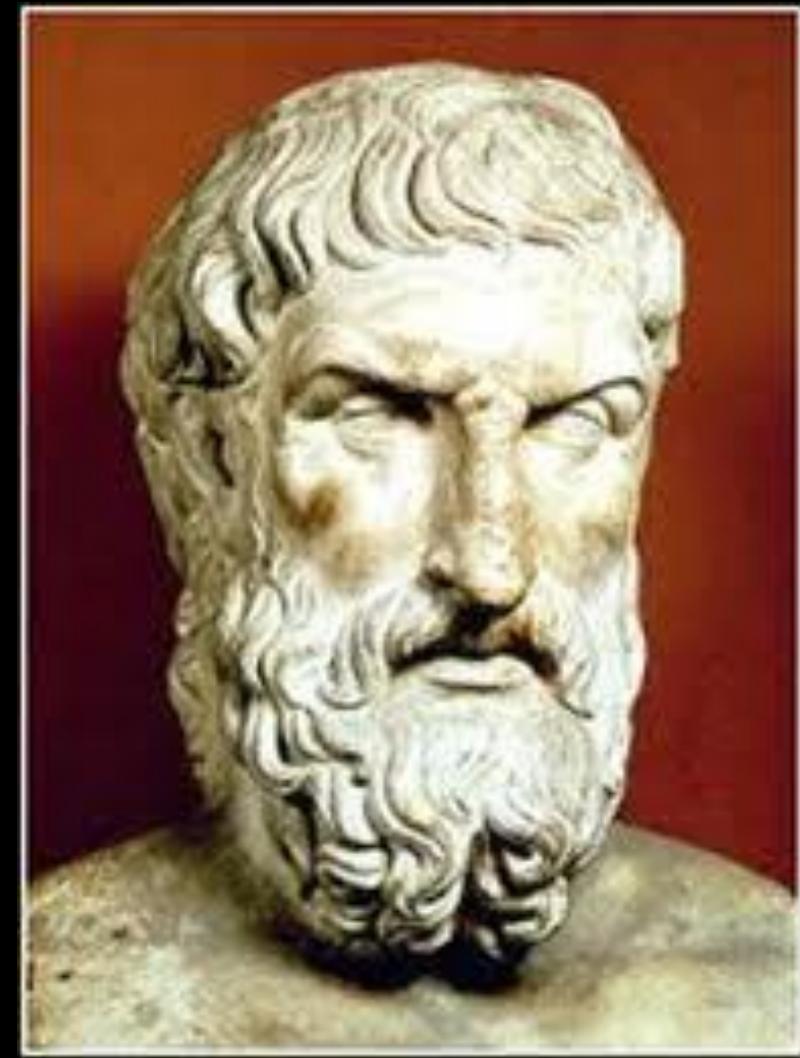


Epicuro da Samo

Il numero degli atomi è infinito, così come infinito è lo spazio vuoto. E, poiché infinite sono pure le possibilità di aggregazione, infiniti sono i mondi possibili, ciascuno in sé destinato a perire: anche la Terra, perciò, non è che uno degli infiniti mondi possibili ed è destinata a morire, prima o poi.

Epicuro afferma che l'uomo non è che uno degli infiniti aggregati di atomi possibili, così come lo è la Terra, e non esiste alcun progetto divino che lo voglia re del creato e lo autorizzi a ritenersi superiore alle altre forme viventi.

Epicuro rifiuta ogni teleologismo (o finalismo): ciò che accade non accade per uno scopo prestabilito (da chi?), per cui non esiste il Destino ed è completamente irrazionale l'interpretazione che l'uomo dà di alcuni fenomeni naturali, come le malattie, il fulmine o il terremoto, quasi che essi accadessero allo scopo di punire l'uomo. Essi dipendono dall'incontro casuale e non necessario degli atomi, e non "significano" nulla.



PLANETENSYSTEM

Wichtige Größen der Planeten im Verhältnis zur Erde:



Innerer Planetengürtel

Outerer Planetengürtel

COME NASCE UN SISTEMA PLANETARIO

Die ersten Aufnahmen der Rosetta von der Sonne und den Asteroiden ist für heute sehr neue Information.



Stars, like our Sun, can be thought of as “basic particles” of the Universe, just as atoms are “basic particles” of matter.

A hundred years ago, scientists did not know that stars are powered by nuclear fusion, and 50 years ago they did not know that stars are continually forming in the Universe.

Researchers still do not know the details of how clouds of gas and dust collapse to form stars, or why most stars form in groups, or exactly how planetary systems form. Young stars within a star-forming region interact with each other in complex ways. The details of how they evolve and release the heavy elements they produce back into space for recycling into new generations of stars and planets remains to be determined through a combination of observation and theory.





The picture captures the chaotic activity atop a three-light-year-tall pillar of gas and dust that is being eaten away by the brilliant light from nearby bright stars.



Visible



Infrared

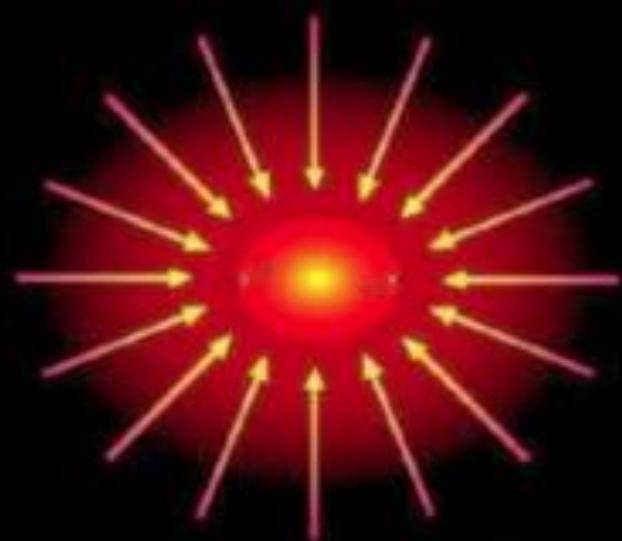
These two images of Carina Nebula show observations taken in visible and in infrared light by Hubble reveal dramatically different views. The one on the right reveals the stars behind the nebula's wall of hydrogen laced with dust

The pillar is also being assaulted from within, as infant stars buried inside it fire off jets of gas that can be seen streaming from towering peaks.

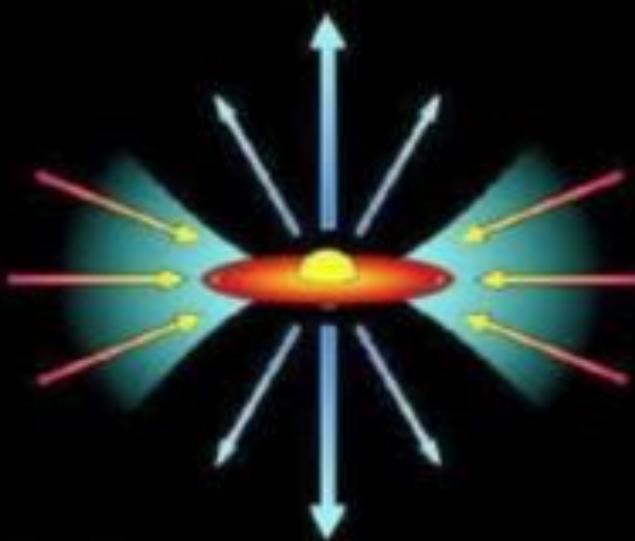
This turbulent cosmic pinnacle lies within a tempestuous stellar nursery called the Carina Nebula, located 7,500 light years away in the southern constellation Carina.

Visible

Infrared



10^4 yrs; 10– 10^4 AU; 10–300K



10^{5-6} yrs; 1–1000AU; 100–3000K



10^{6-7} yrs; 1–100AU; 100–3000K



10^{7-9} yrs; 1–100AU; 200–3000K

The stages of solar system formation, starting with a protostar embedded in a gas cloud (upper left), to an early star with a circumstellar disk (upper right), to a star surrounded by small "planetesimals" which are starting to clump together (lower left) to a solar system like ours today. Credit: Shu et al. 1987



Edge-On Protoplanetary Disk Orion Nebula

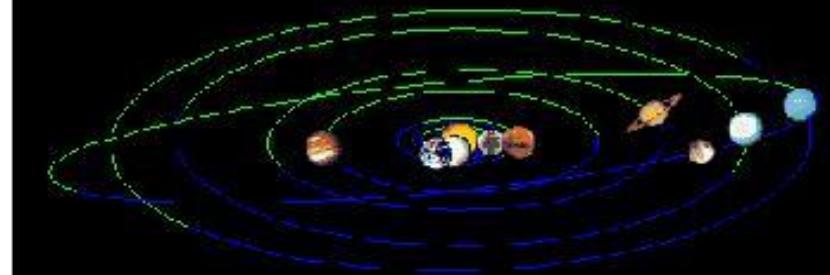
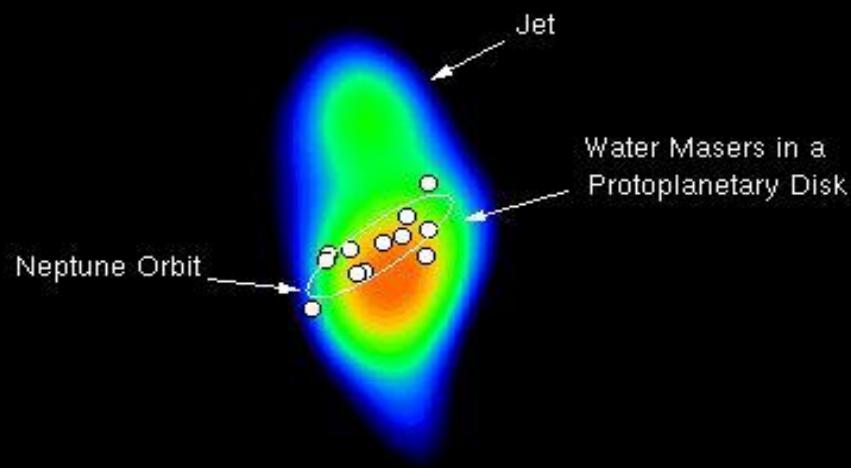
PRC95-45c - ST Scl OPO - November 20, 1995

M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA



HST - WFPC2

NGC 2071-IRS3



Our Solar System

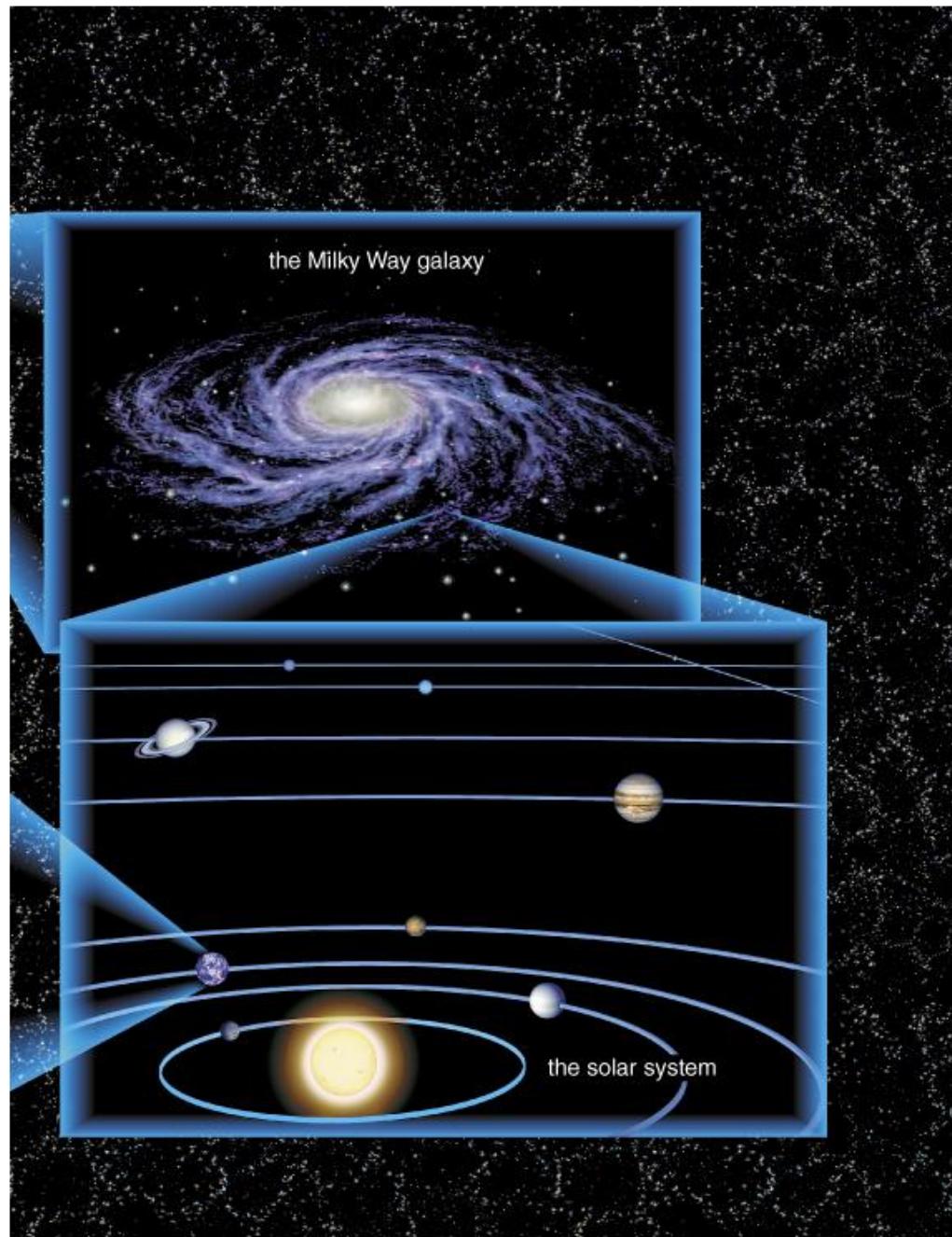
One way to study protoplanetary disks is to use water masers, clumps of water molecules in an odd state which makes them amplify radio emission. Here, the VLA (Very Large Array), has glimpsed some water masers in a protoplanetary disc. The left figure shows the size Neptune's orbit would be if it were around this star, and the right figure shows the orbits of all of our Solar System's planets for scale comparison. Over time, the water masers may move with the disk, allowing us to study its motion very precisely.



Esopianeti



“Esistono innumerevoli soli; innumerevoli terre ruotano attorno a questi similmente a come i sette pianeti ruotano attorno al nostro sole. Questi mondi sono abitati da esseri viventi”



©Addison Wesley Longman, Inc.

To date, we think that about 1 in 2 stars has planets

Presently 100 billion stars in our Galaxy, and 1-10 planets per star...

50 billion to 5 trillion planets in our Galaxy (alone).

There are about 10 new stars forming each year in our Galaxy...

~5 new planetary systems/year...

~5-50 new planets/year

METHODS AND PRINCIPLES

-
- | | |
|--------------------|---|
| 1) RADIAL VELOCITY | Gravitational Tug of War causes star to “wobble”

<u>Radial Velocity</u> : Motion toward and away detected by Doppler shifts in stellar spectra |
| 1) ASTROMETRY |
<u>Astrometry</u> : Motion Side to Side (in plane of sky) detected in images of stars compared to background |
| 1) TRANSIT |
Eclipses by planets dim the star’s light (very slightly)

Detected by temporary brightness decrease in light curve |
| 1) MICROLENSING |
Stars sometimes gravitationally lens background stars and the planet can contribute (very slightly)

Detection of planet is small blip in lens light curve |
| 1) IMAGING |
Planets reflect the starlight and this can be imaged

Very Difficult: Requires nulling the star- two ways |
-

EXOPLANET HYPERSPACE

exoplanets.org

Main page of the California/Carnegie Planet Hunters

exoplanets.org/linkframe.html

Links to tutorials and to explanations of different future plans

www.jtwinc.com/Extrasolar

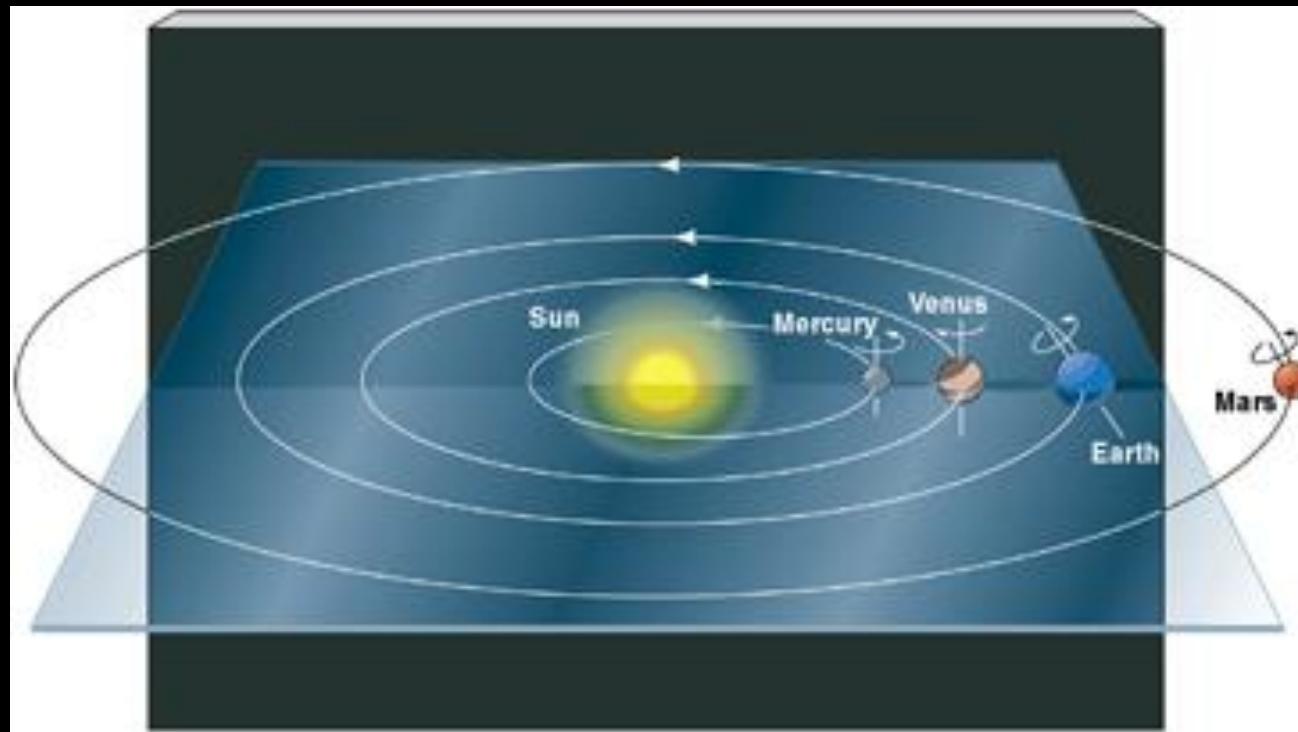
Visualizations of Exoplanets

origins.jpl.nasa.gov/library/exnps/ExNPS.html

Everything you ever wanted to know about Exoplanets- and even things you didn't know you wanted to know!

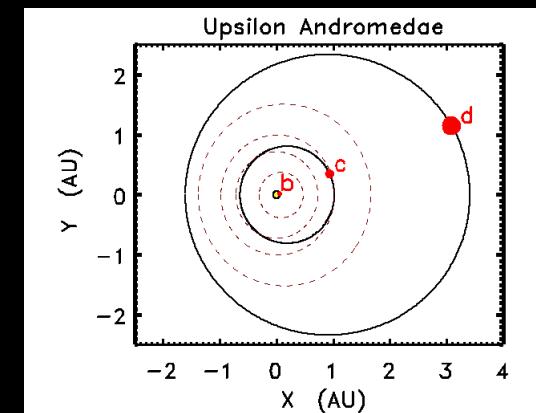
PLANETARY SYSTEMS ALIGN IN A PLANE

The orientation (inclination) of any given planetary system can range from “edge on” to “face on”



edge-on - high inclination (like in the above picture)

face-on - low inclination (like in the picture to the right)



STELLAR WOBBLE- SUN STYLE

1960: Planet hunters born

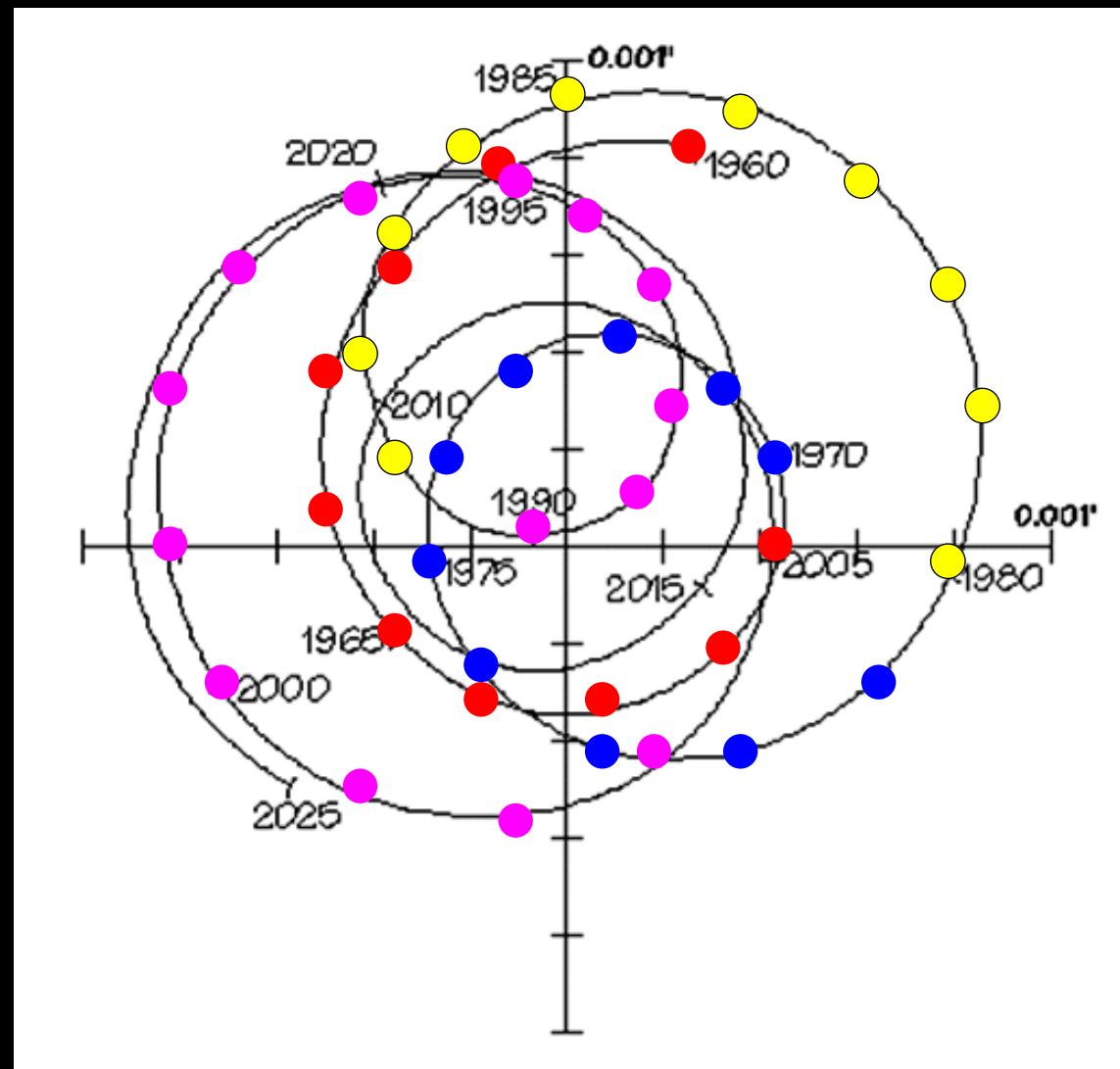
1969: First moon walk

1980: First space shuttle; many of you born

1990: Desert Storm

1995: Planet hunting begins in earnest

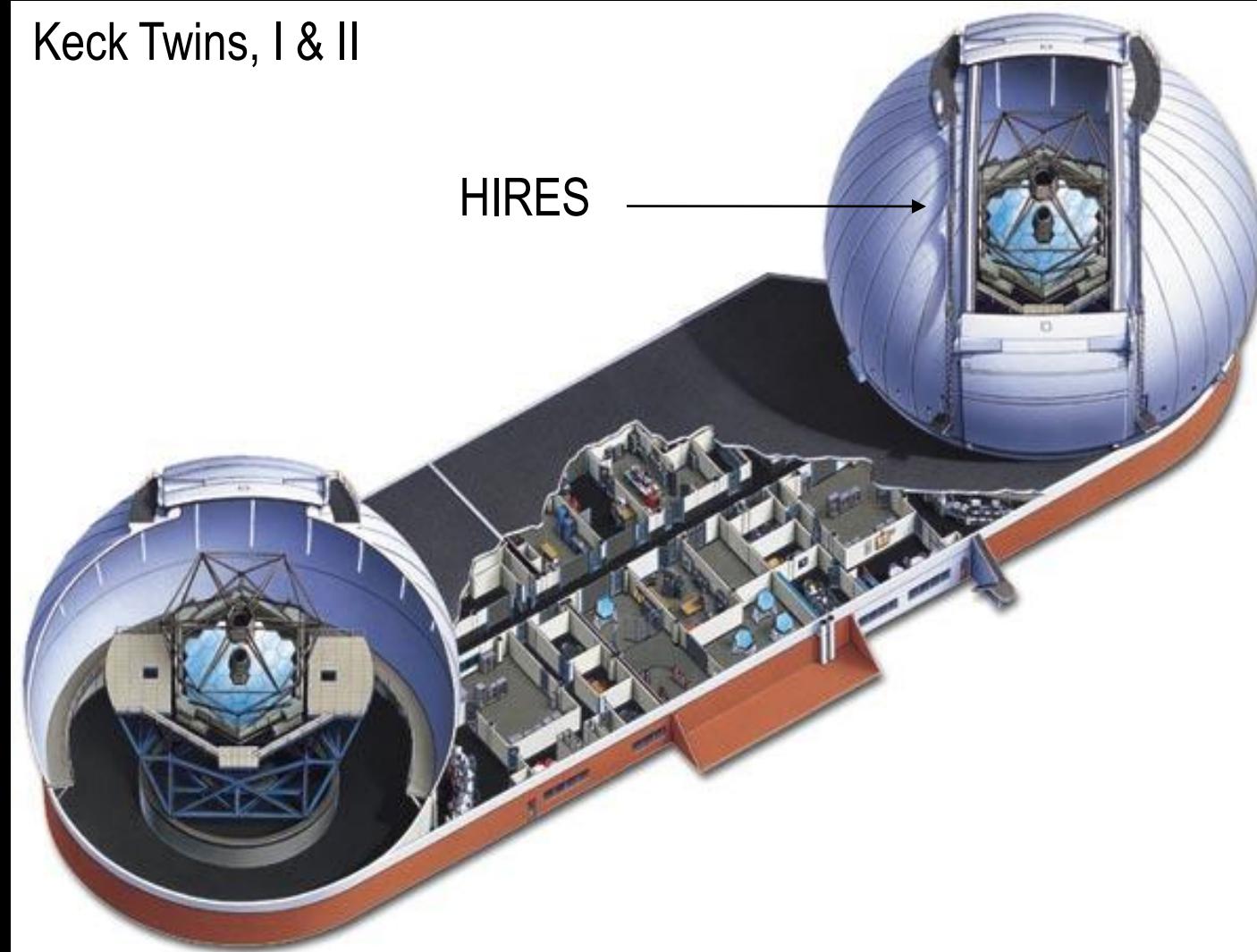
2000: Many of you enter college



We would not have detected Jupiter around our star using Radial Velocity
We could detect Jupiter if we had been watching using Astrometry

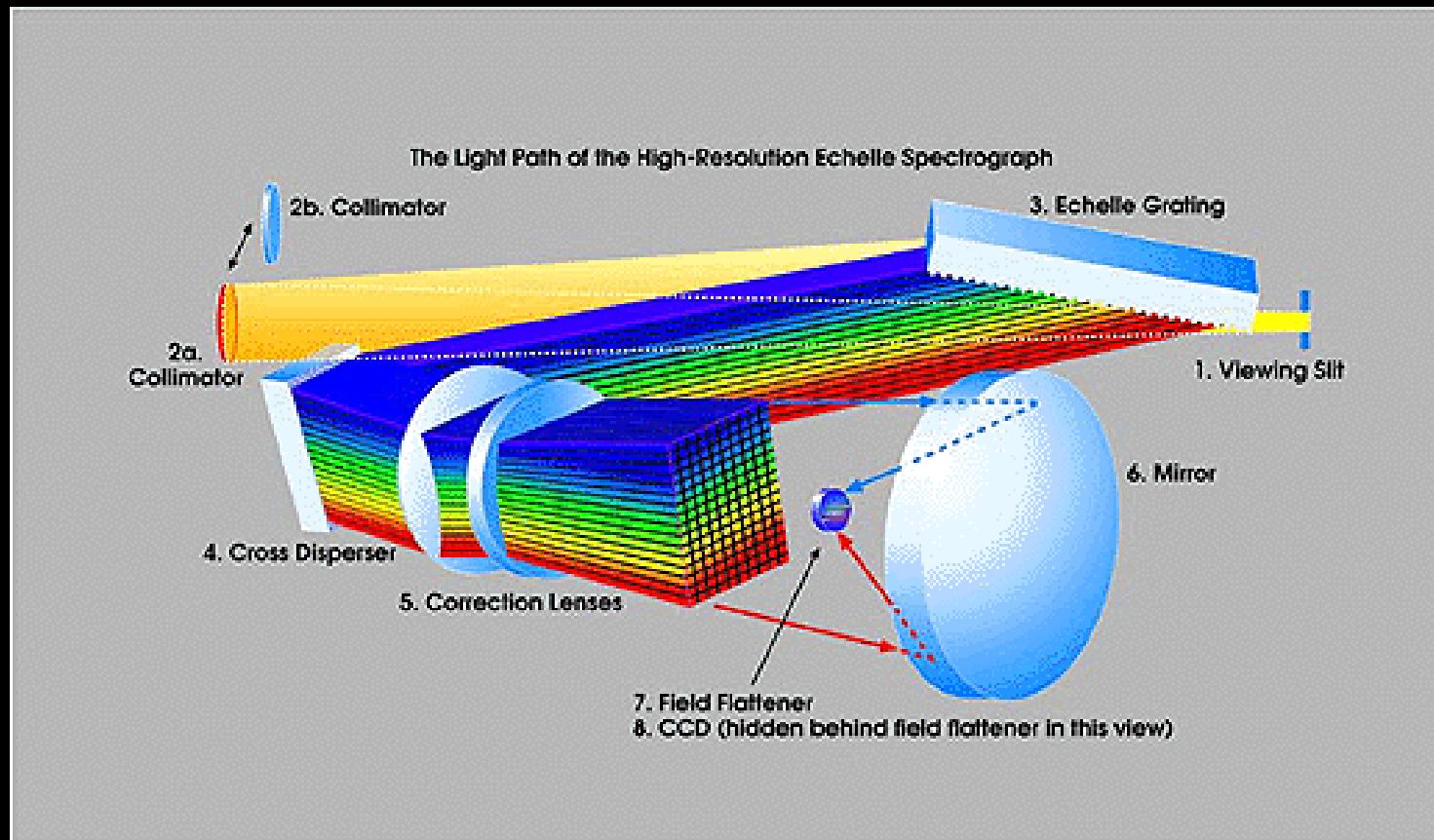
RADIAL VELOCITY METHOD

Keck Twins, I & II



RADIAL VELOCITY METHOD

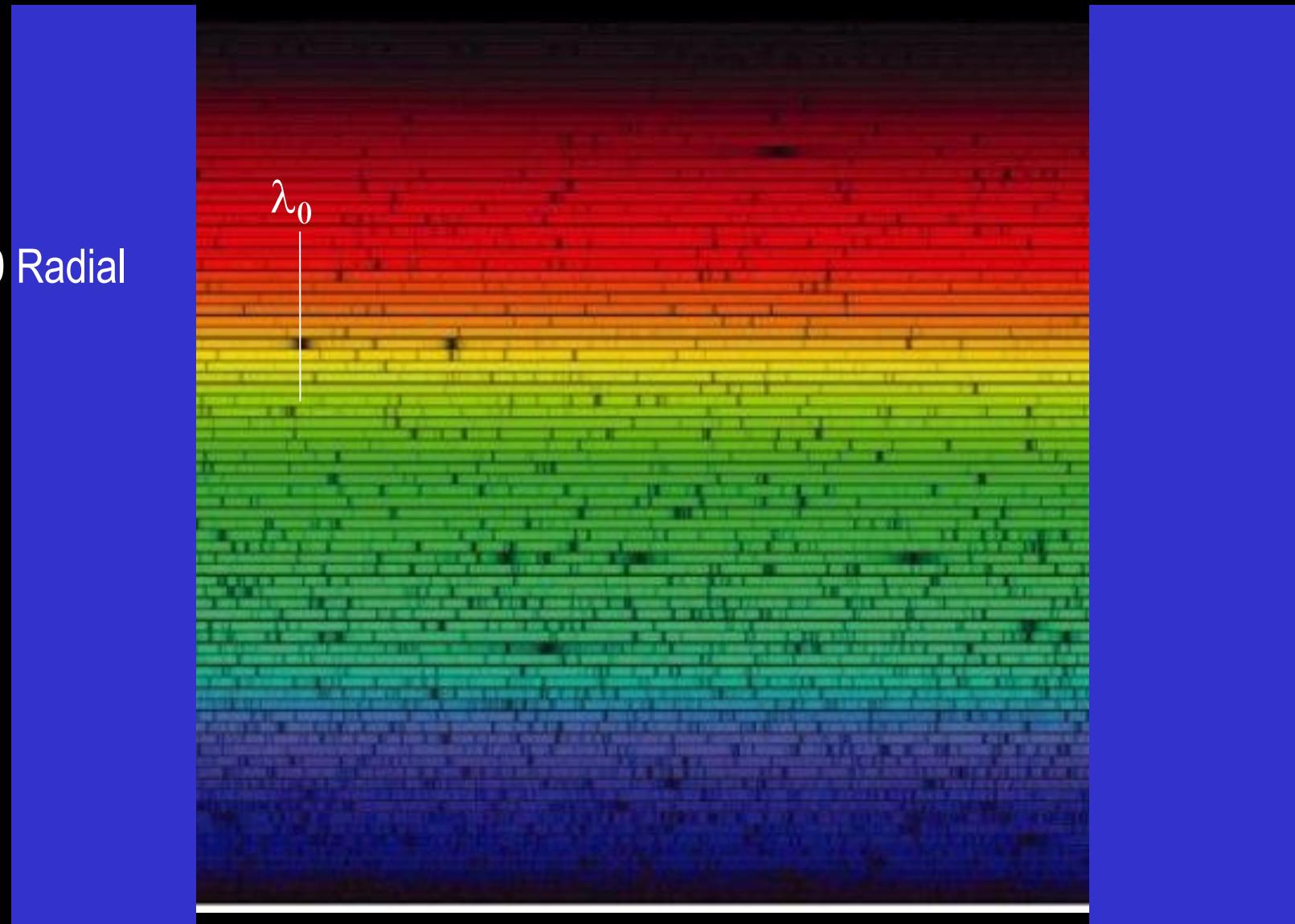
(Doppler Shifts Of Star Light)



Follow the numbers... 1-6 : The starlight is highly dispersed into a spectrum

RADIAL VELOCITY METHOD

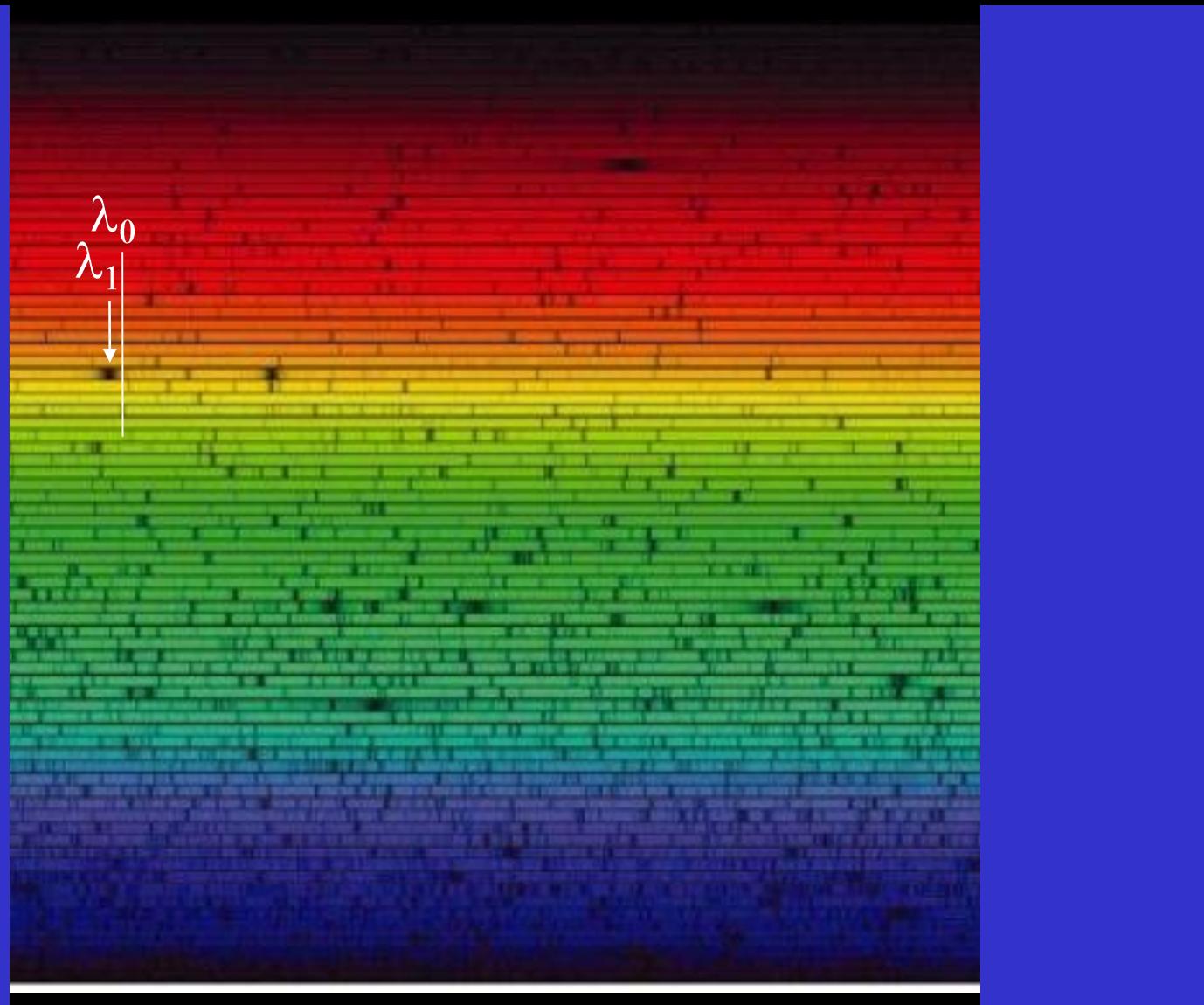
$V = 0$ Radial



RADIAL VELOCITY METHOD

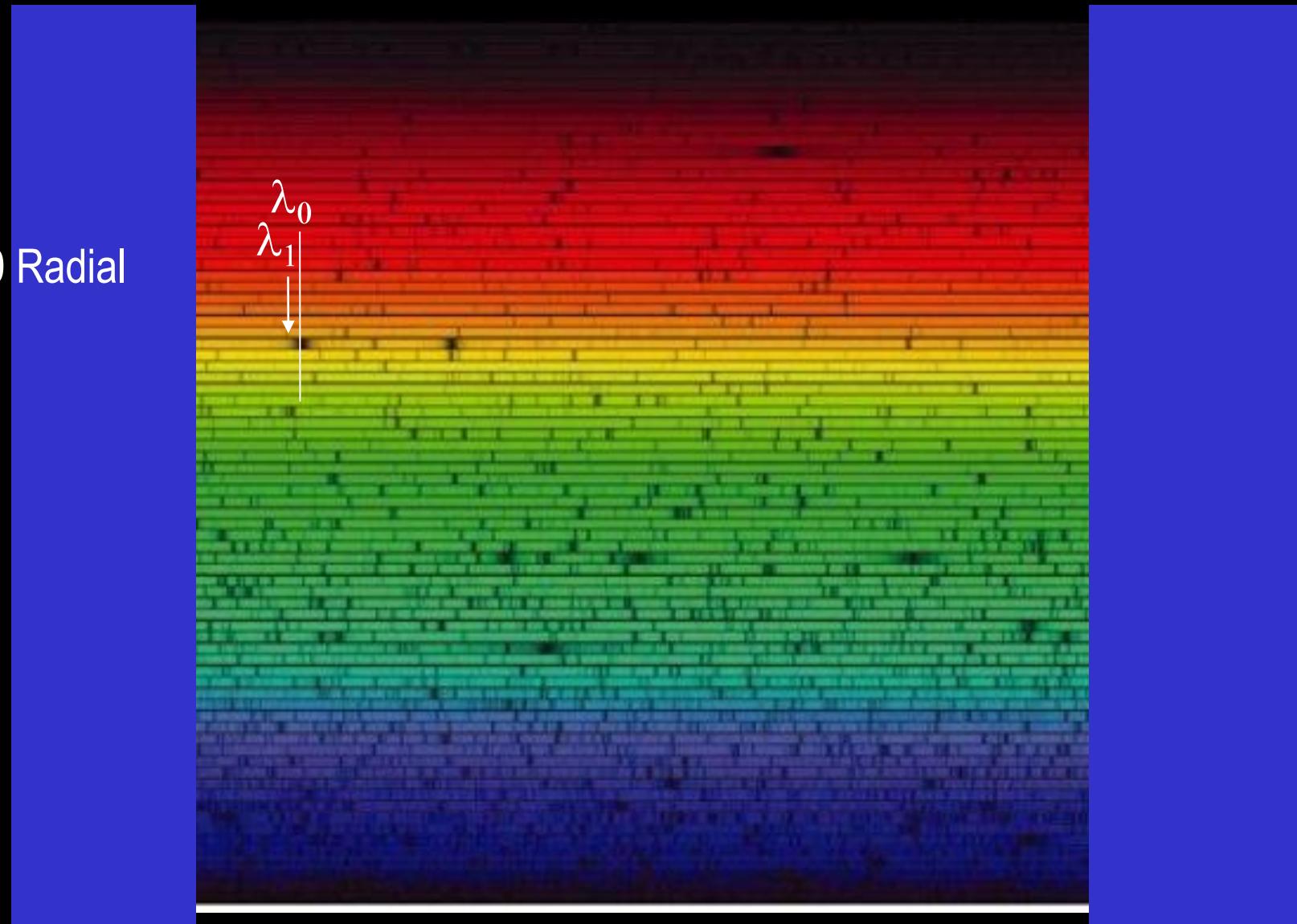
$V = \text{Toward}$

$$\lambda_0 \\ \lambda_1 \\ \downarrow$$



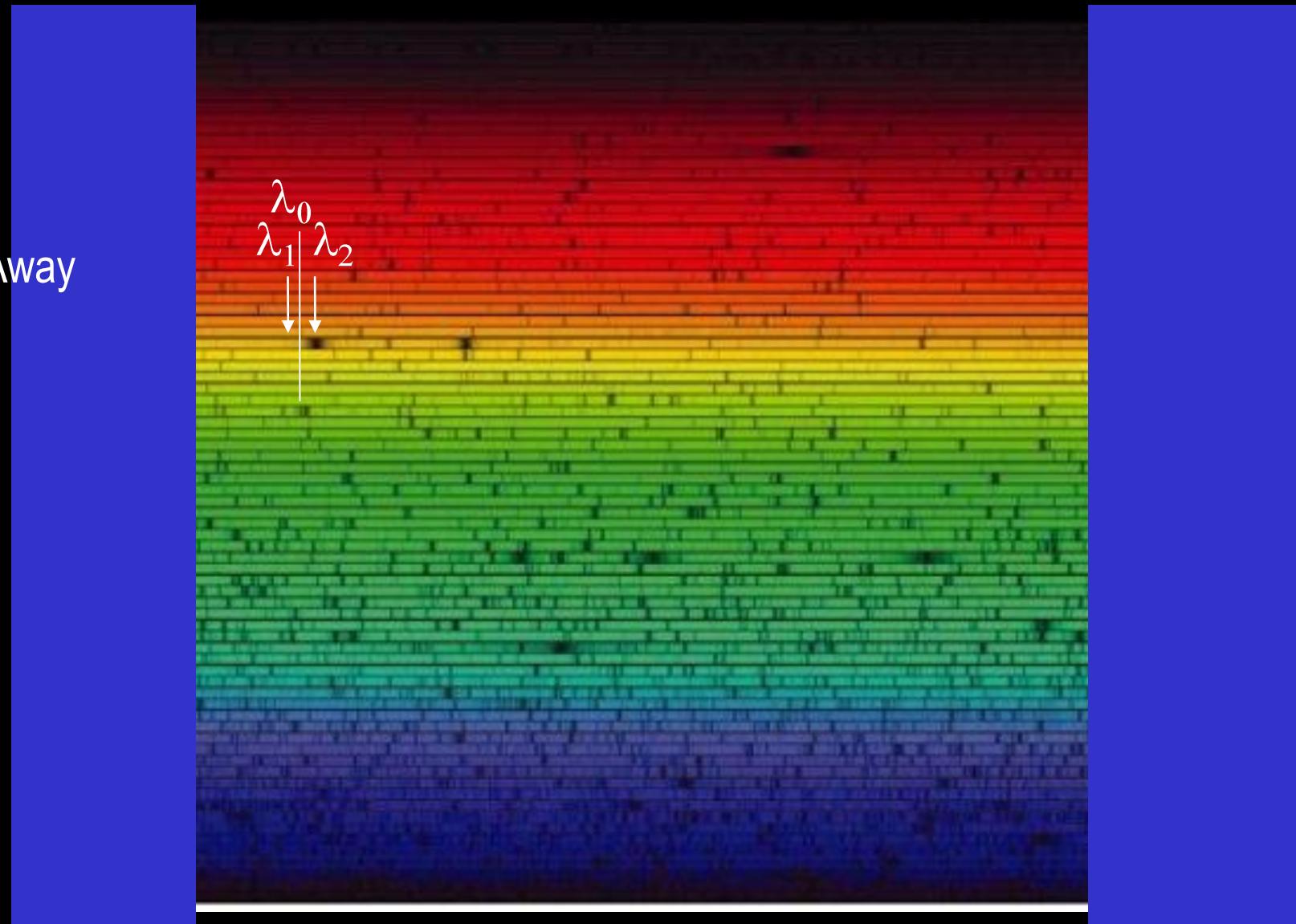
RADIAL VELOCITY METHOD

$V = 0$ Radial



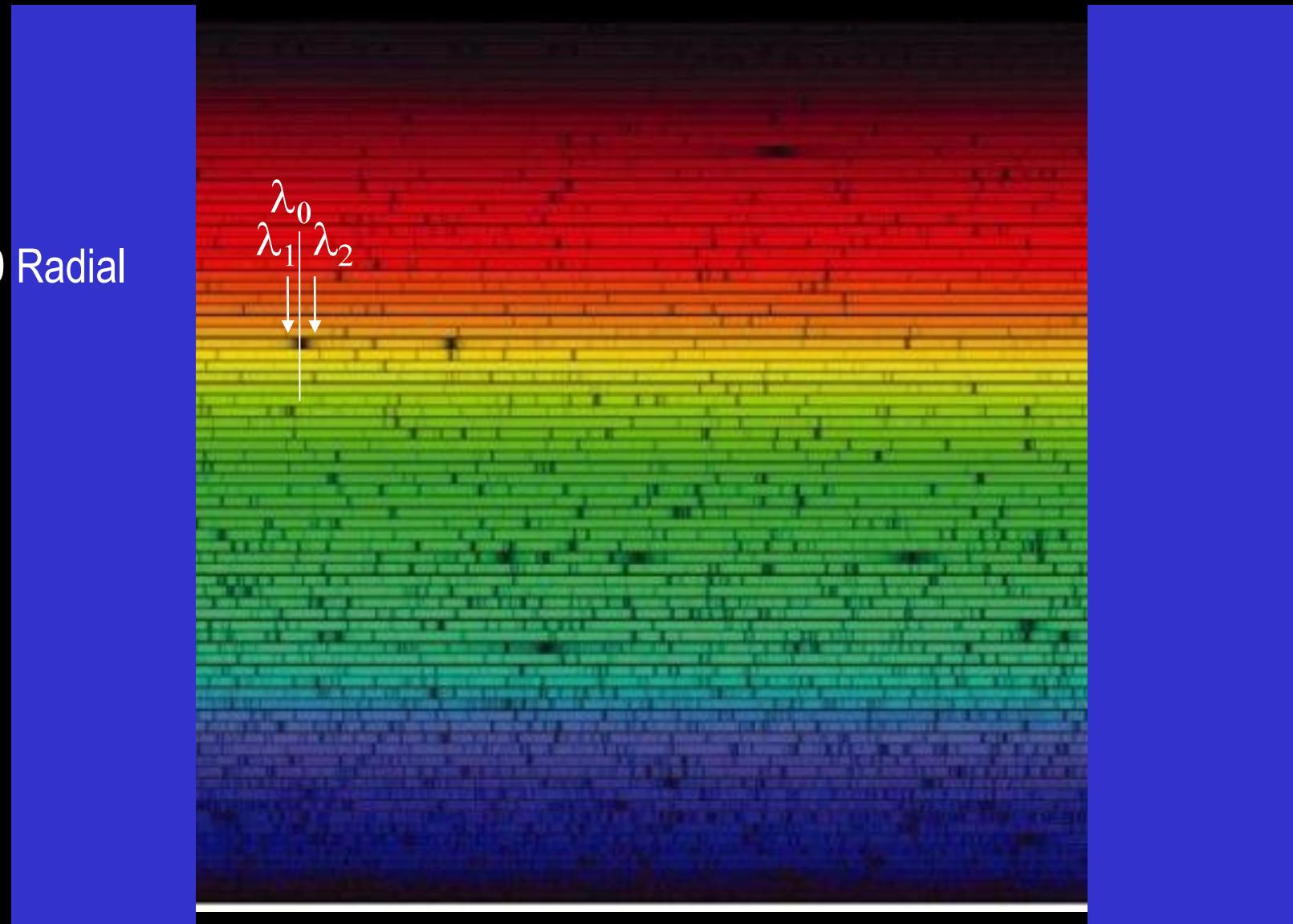
RADIAL VELOCITY METHOD

$V = \text{Away}$



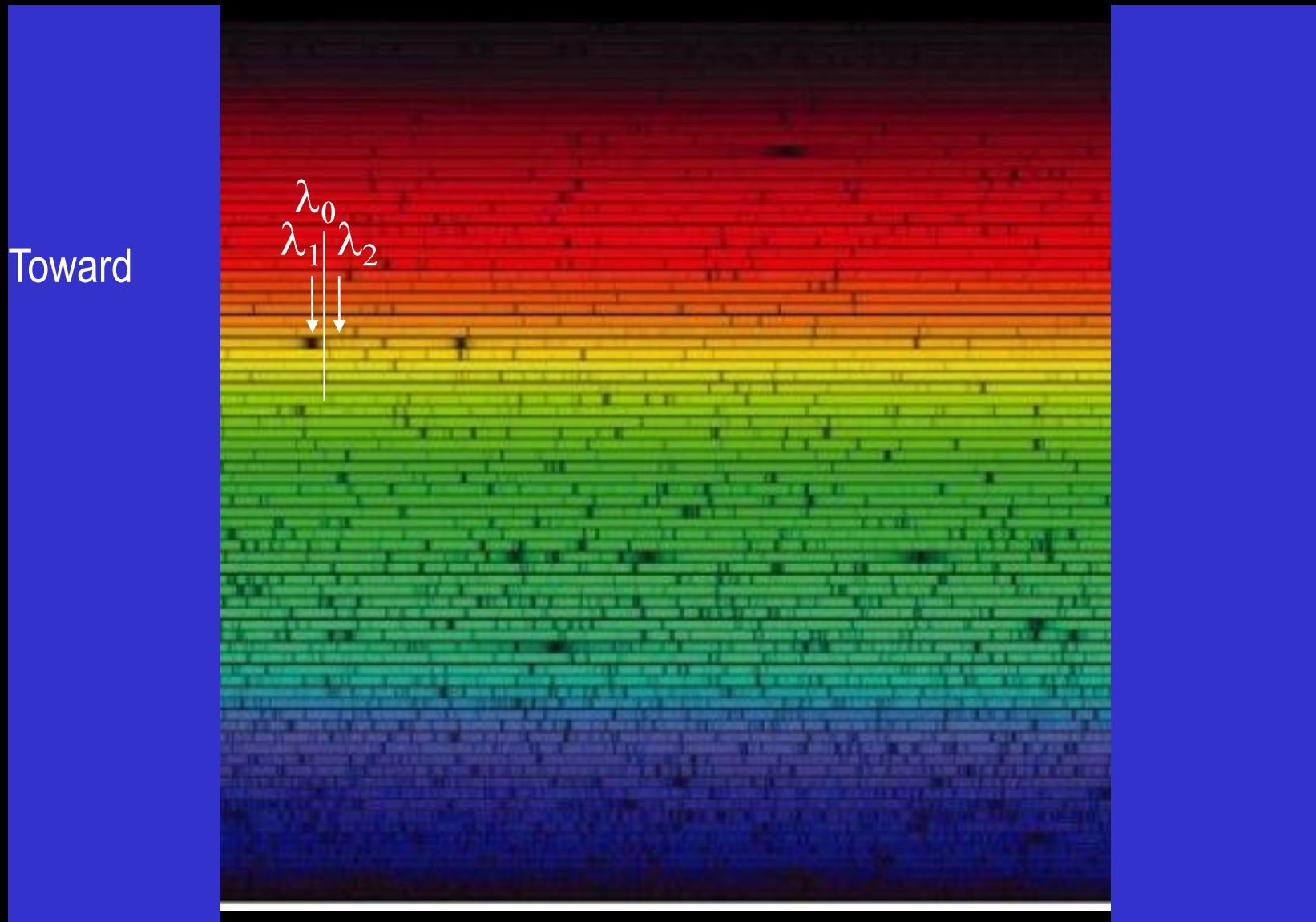
RADIAL VELOCITY METHOD

$V = 0$ Radial

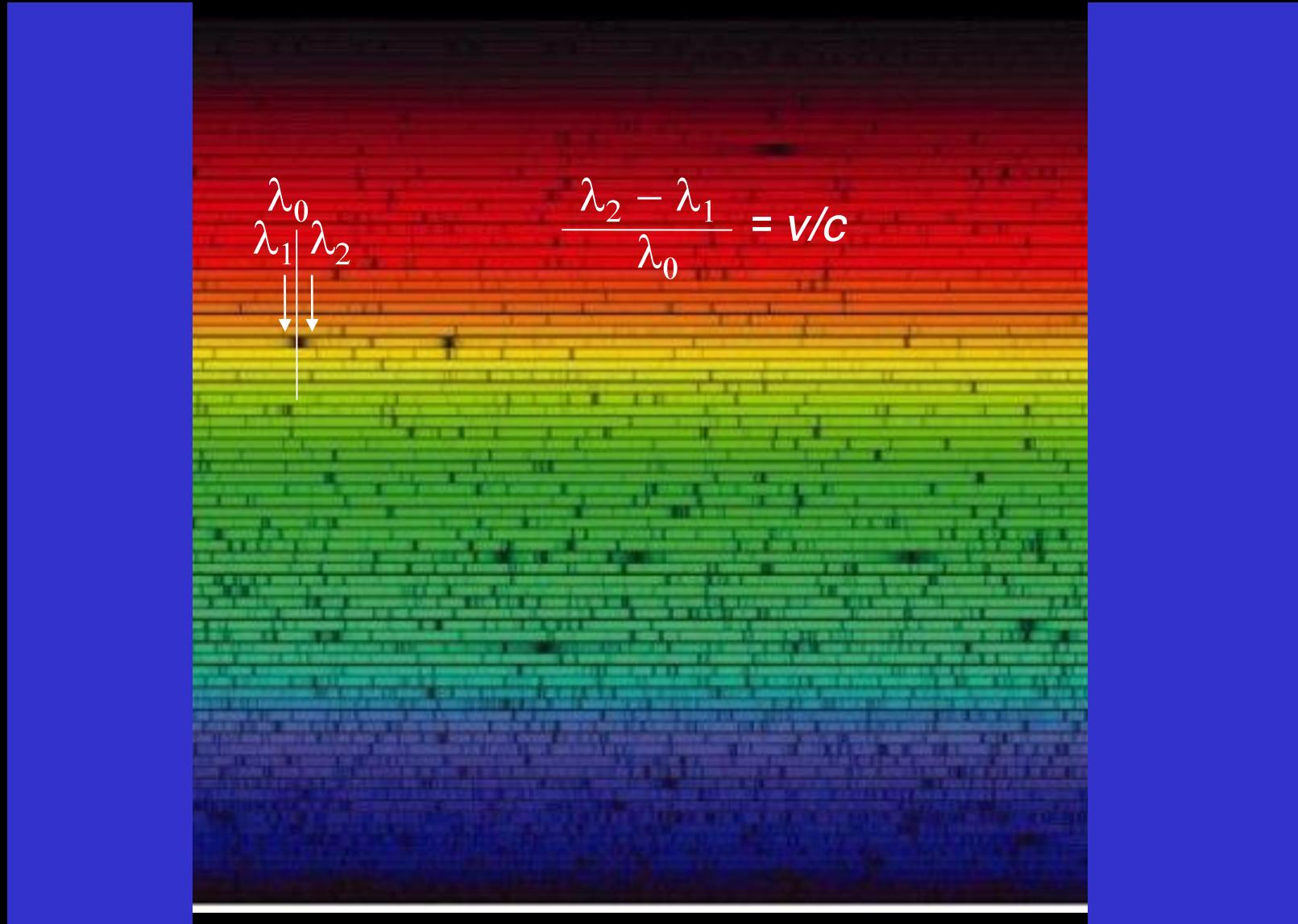


RADIAL VELOCITY METHOD

$V = \text{Toward}$



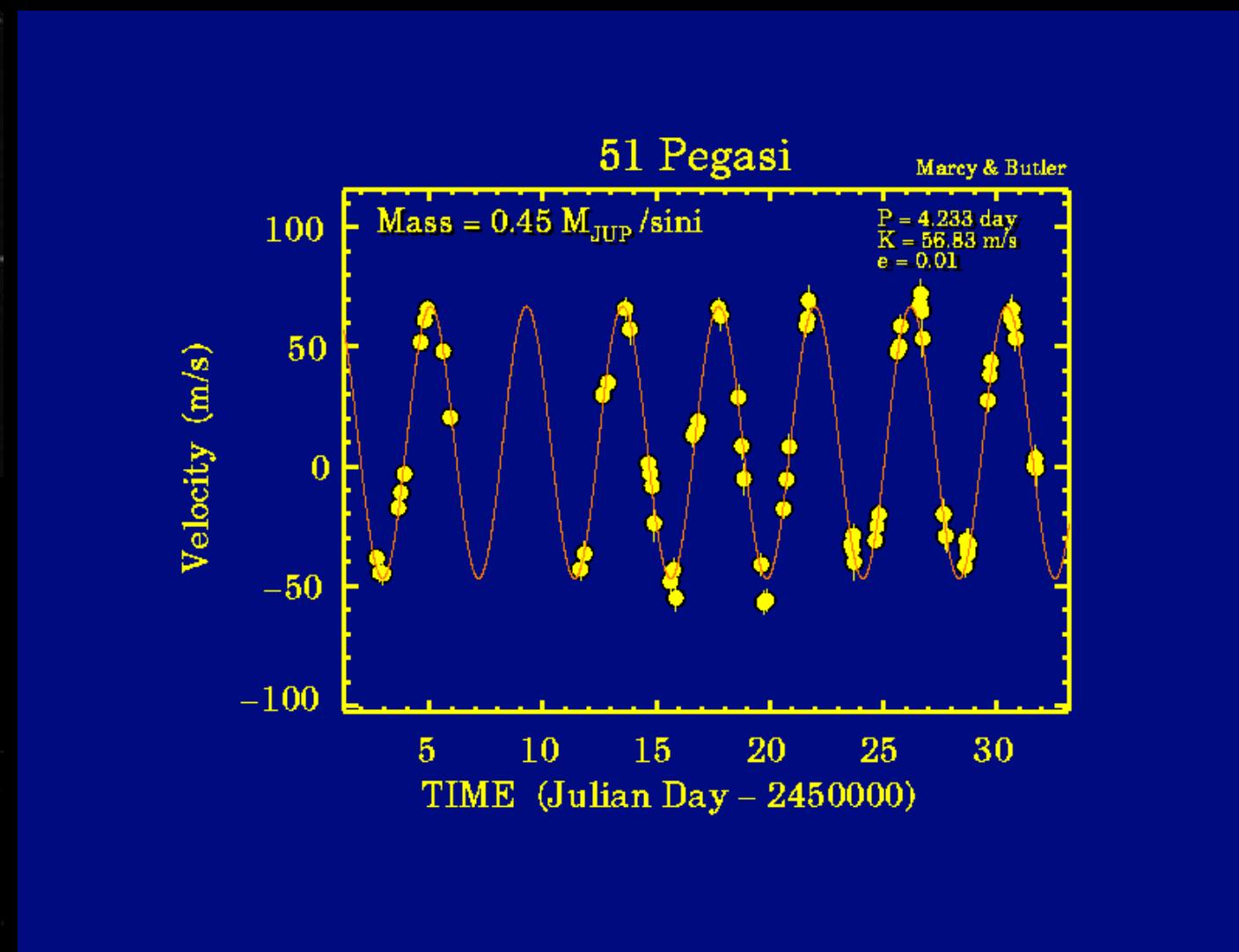
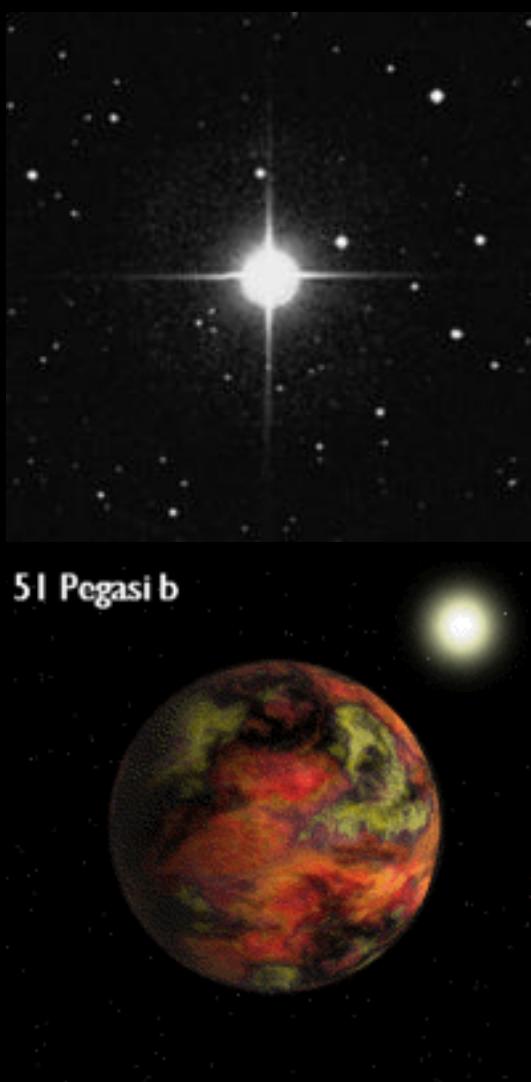
RADIAL VELOCITY METHOD



This actually has calculated only the peak-to-peak velocity difference!

RADIAL VELOCITY METHOD

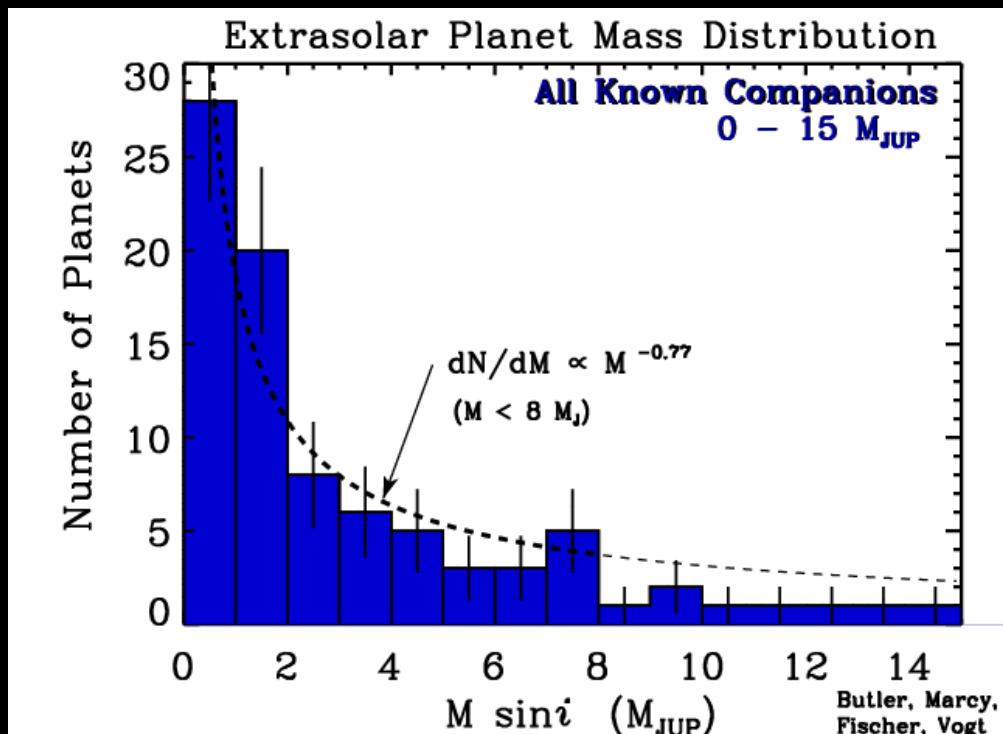
(Doppler Shifts Of Star Light)



RADIAL VELOCITY METHOD

(Doppler Shifts Of Star Light)

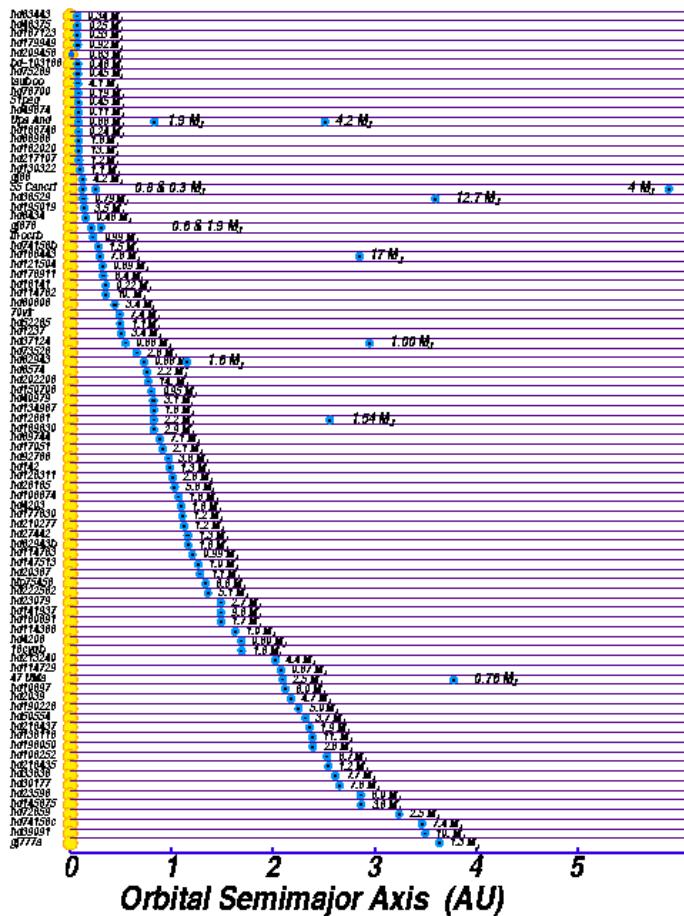
The number of planets with a given “mass”.



- 1) One cannot get the mass directly, if the inclination of the system is unknown
- 1) One determines combined quantity of planet mass and the inclination angle
- 1) Most planets are of smaller “mass” (these are hardest to find) - thus low “mass” planets are very numerous indeed

RADIAL VELOCITY METHOD

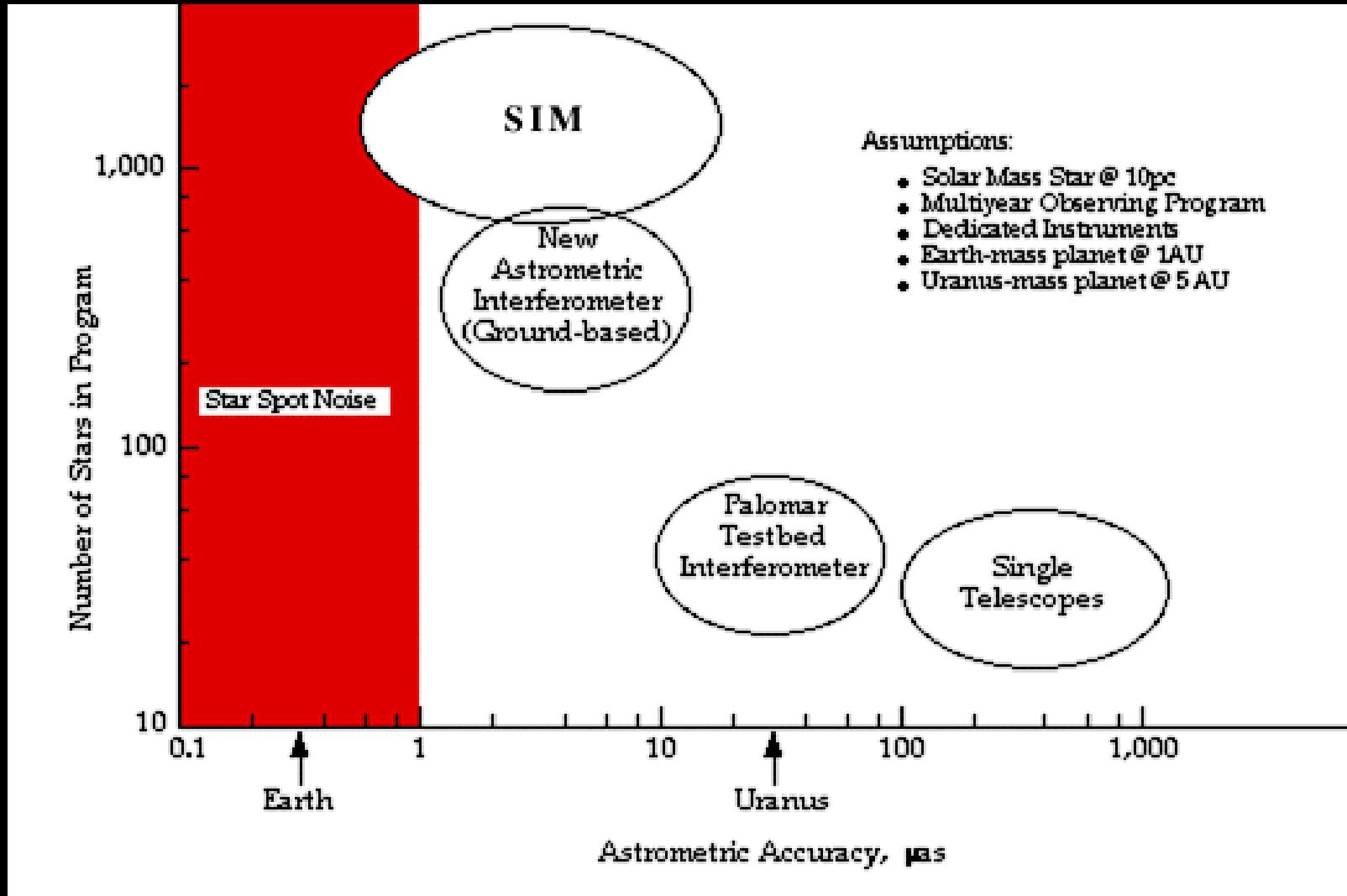
(Doppler Shifts Of Star Light)



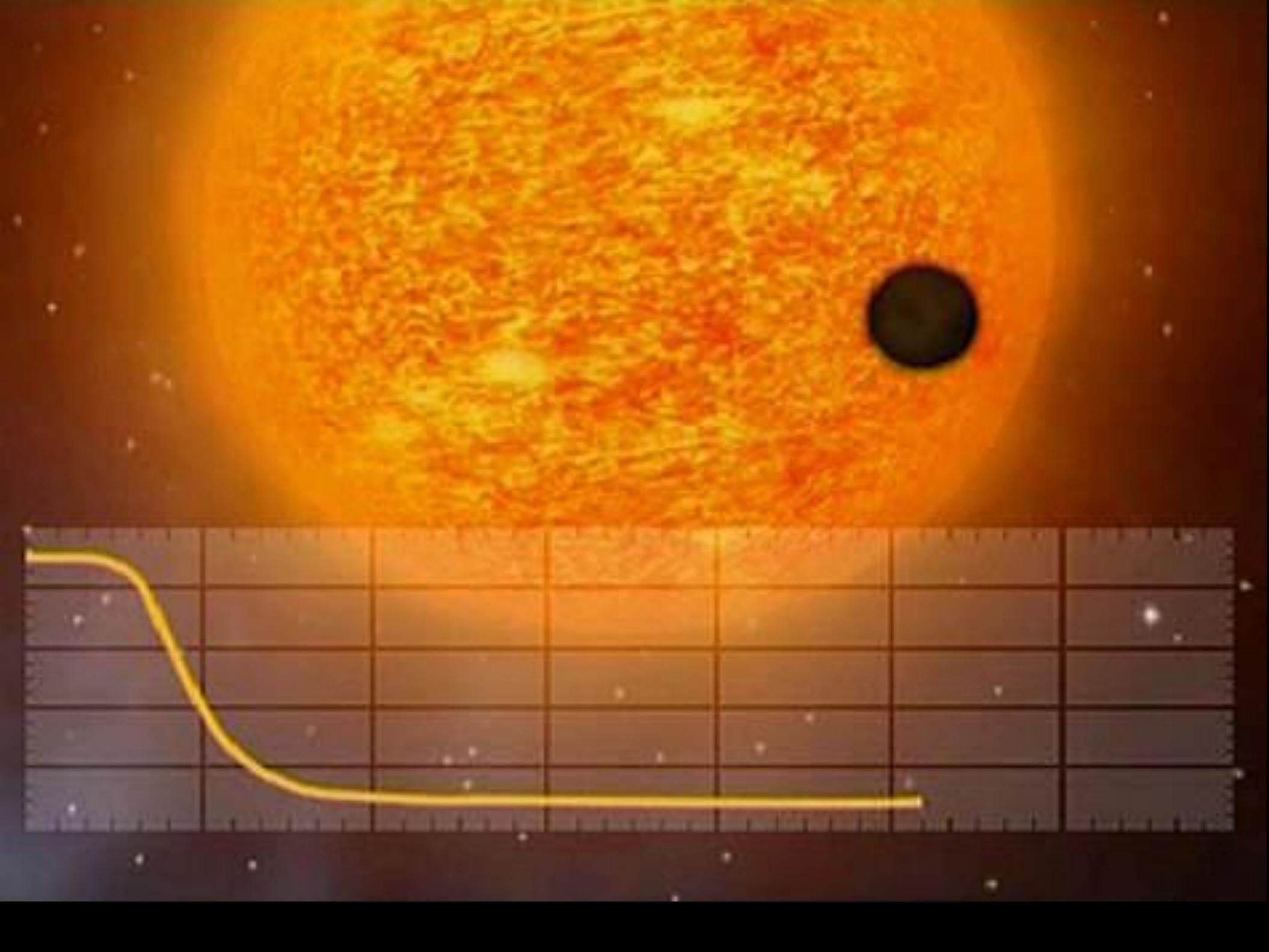
- 1) Over 100 planets discovered since 1995 (8 hunting years)
- 1) Methods selects high mass planets with small orbits
- 1) Some stars have multiple planets

ASTROMETRY METHOD

(Movement With Respect to Background Stars)

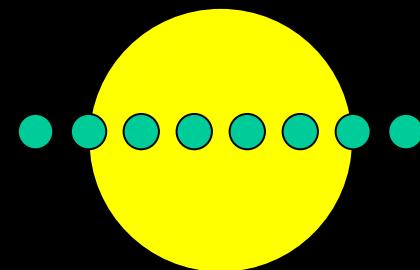
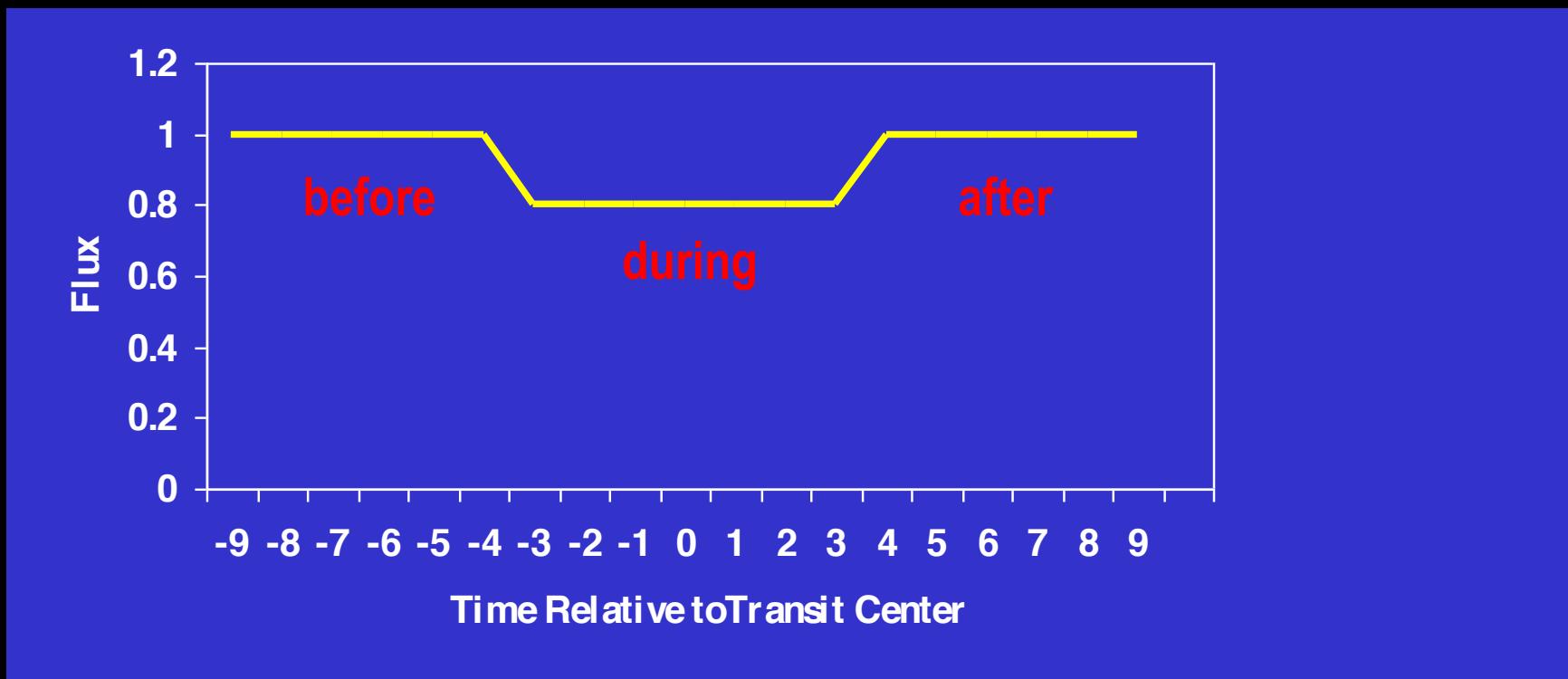


Assumes Our Solar System at 10pc (32 lys) distance.



TRANSIT METHOD

(Brightness Variations Due to Planet Eclipses)



TRANSIT METHOD

(Brightness Variations Due to Planet Eclipses)

Well.... In principle this can be done.

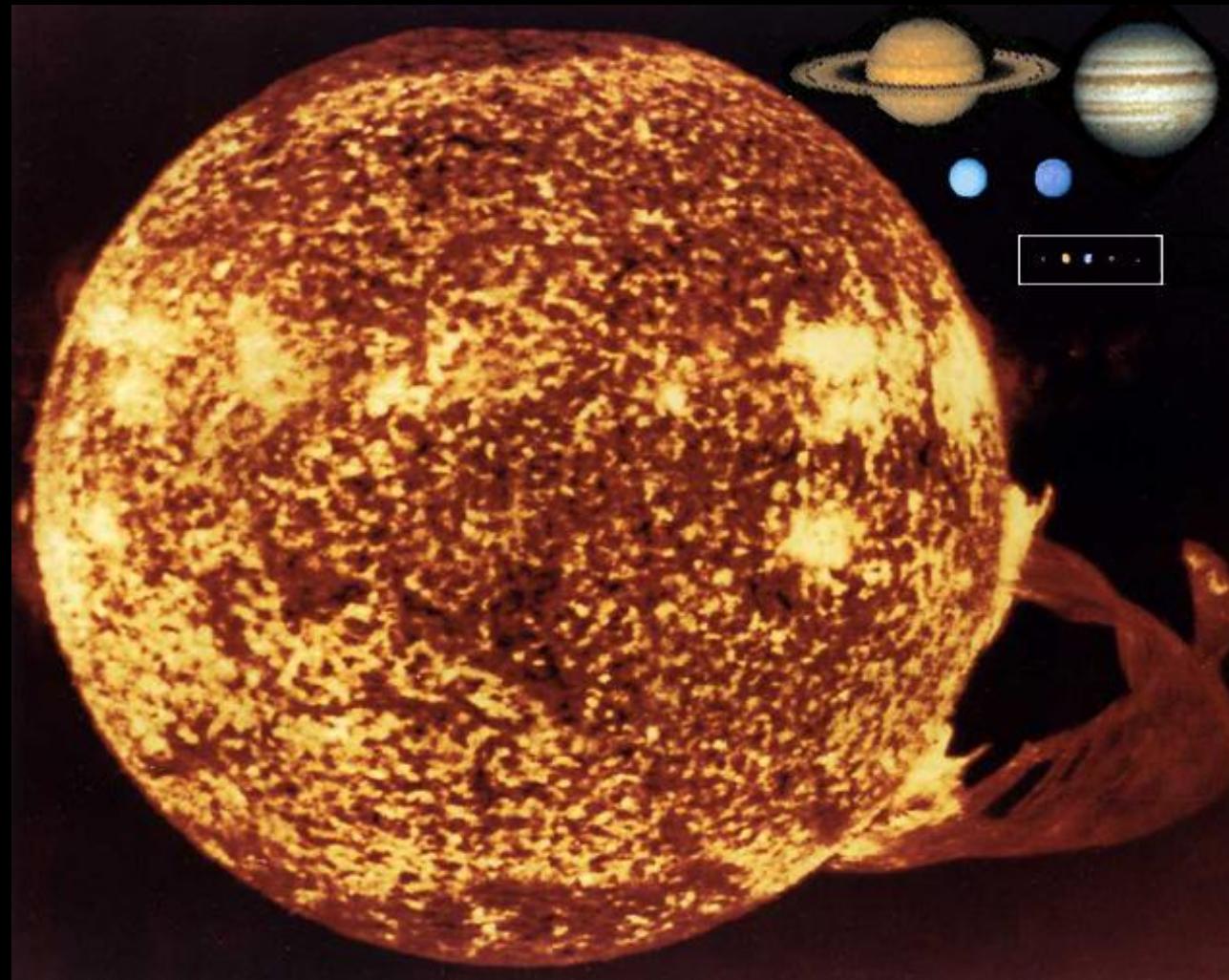
Like other methods... it is a technical challenge.

And, well. If you can find an edge-on (highly inclined planetary system) and it had a Jupiter, you would have to wait about 10 years between events and the event lasts only days.

I would not invest time and resources in the TRANSIT METHOD

TRANSIT METHOD

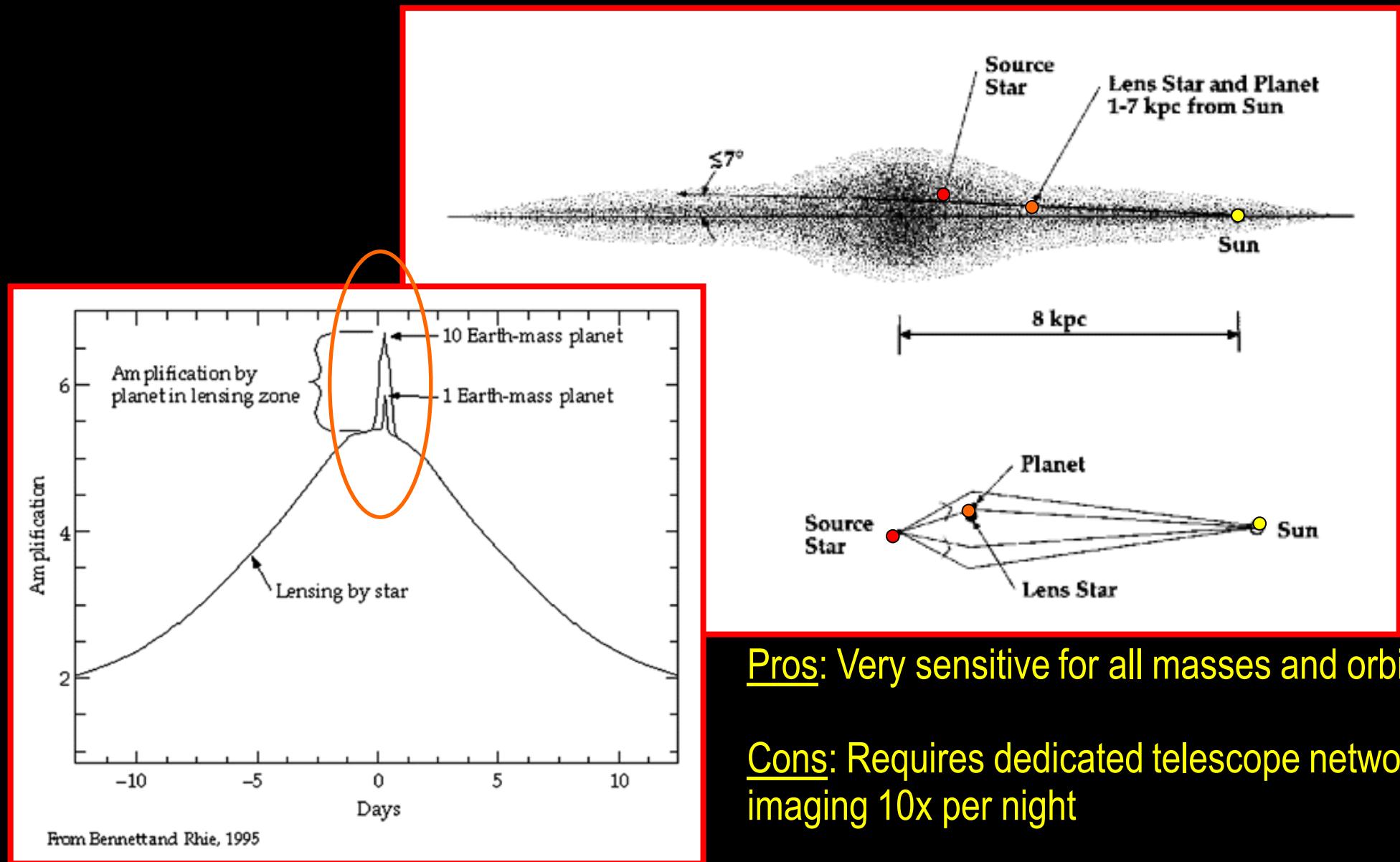
(Brightness Variations Due to Planet Eclipses)



.... Here are the relative sizes of planets in our Solar System.

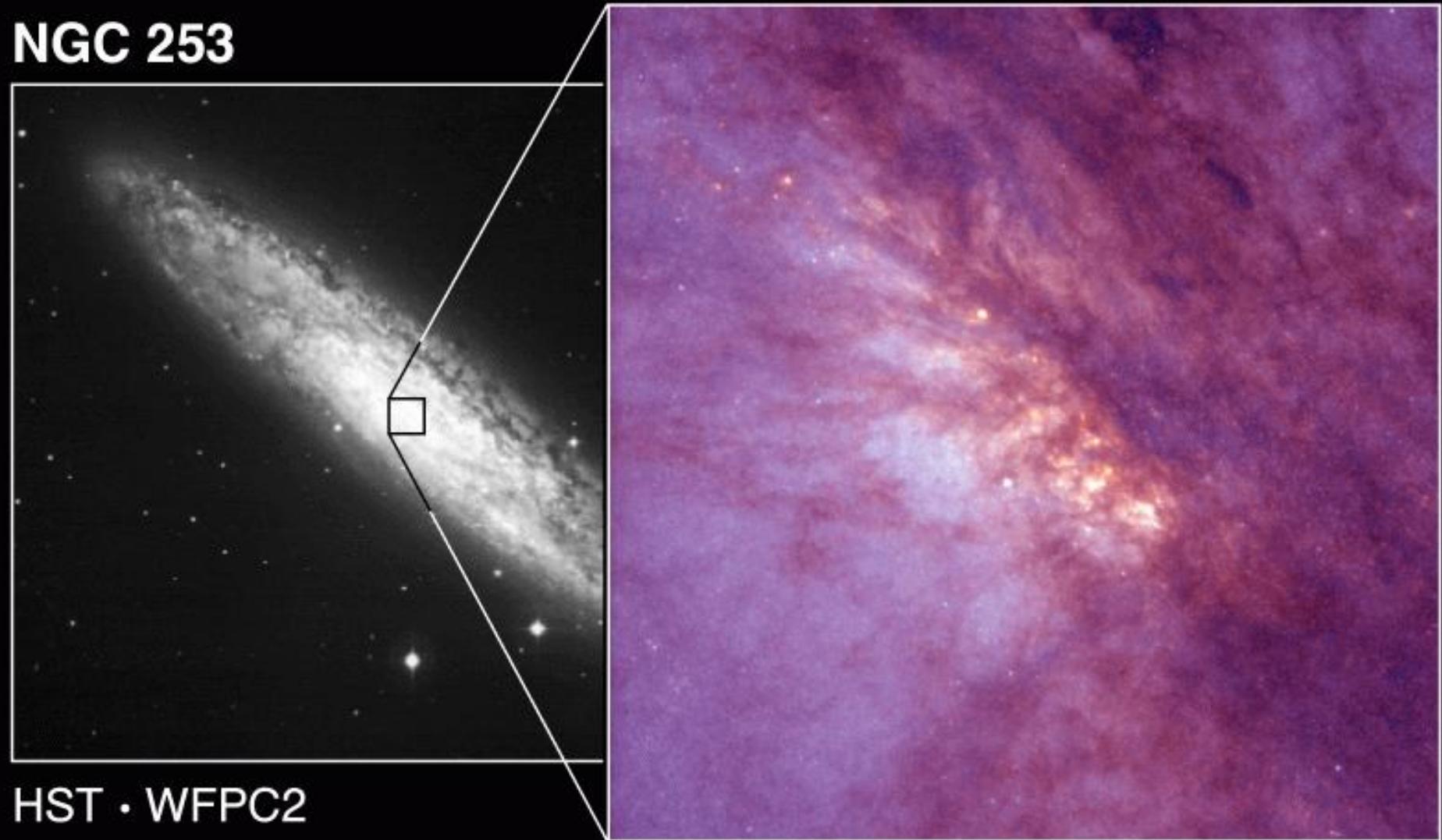
MICROLENSING METHOD

(Quick Brightness Spikes Due to Gravitational Lensing of Background Stars)



MICROLENSING METHOD

NGC 253



HST • WFPC2

PRC 95-10 • ST Scl OPO • February 1995 • J. Gallagher (U.WI), NASA

2/14/94 zgl

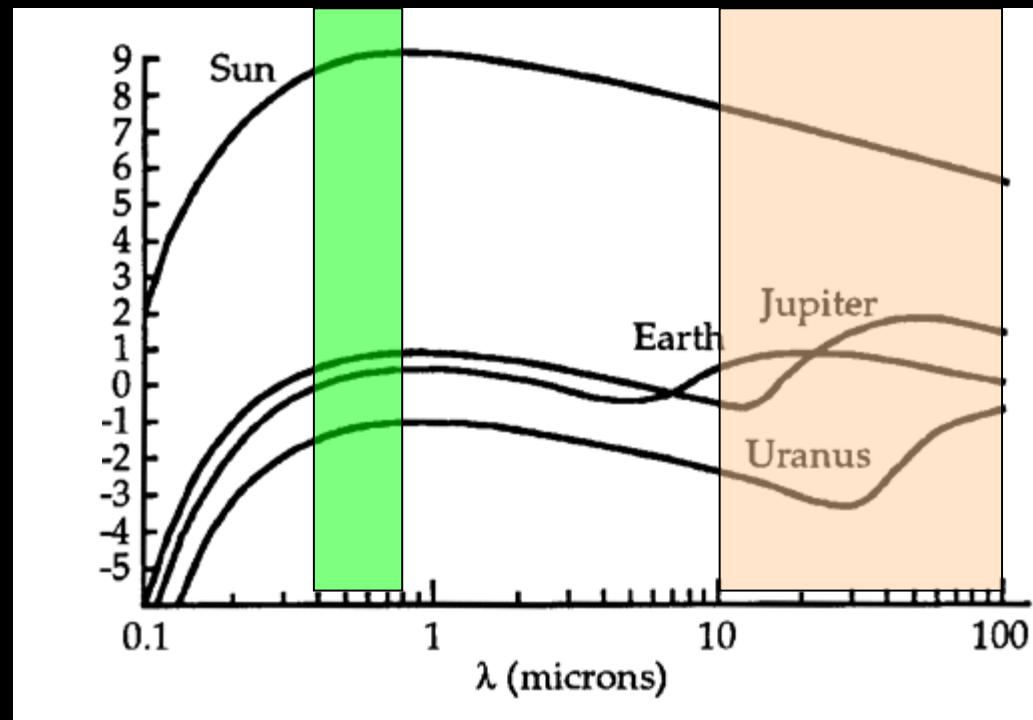
In the future, one can do this in external galaxies!

IMAGING METHOD

(Imaging of Reflected/Reprocessed Starlight)

Optical: star/planet = 1 billion = 10^9

Infrared: star/planet = 1 million = 10^6



We need to search in the infrared and we need some extra help! Block out the star!

IMAGING METHOD

(Imaging of Reflected/Reprocessed Starlight)

Visible (optical) band

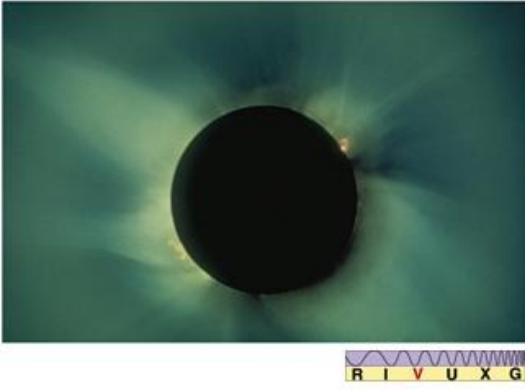


Planet lost in glare of star that
is very bright in the visible band.

Infrared band



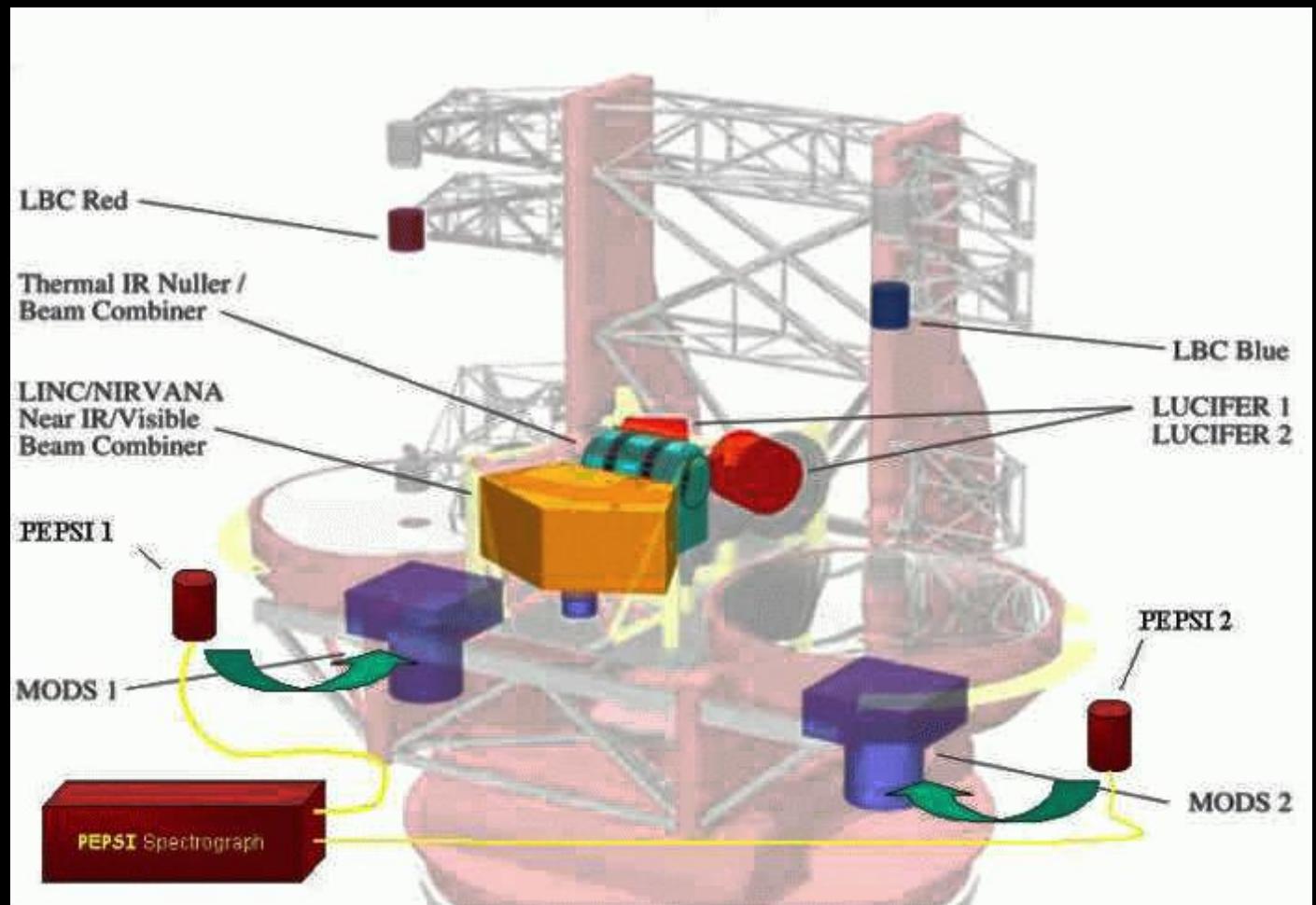
Planet more luminous in the infrared
band and star not so bright.



IMAGING METHOD

Interferometry and Adaptive Optics (AO)
nulling the star light

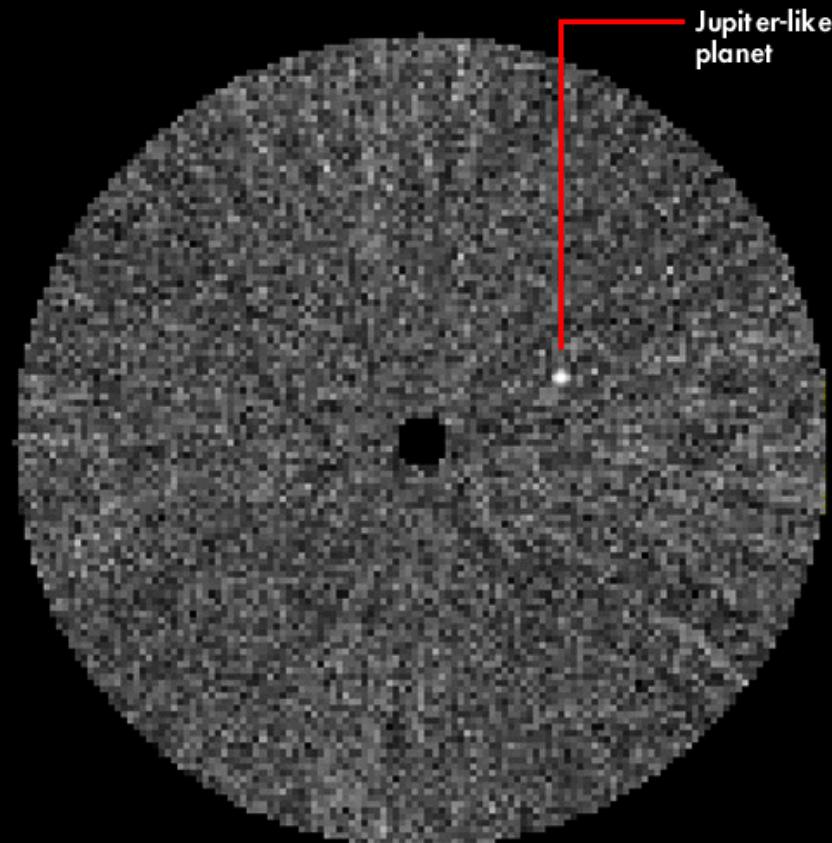
This old fashioned way of blocking out the star is called a coronagraph, which is being replaced by interferometry



Requires large telescopes and specialized instrumentations...

IMAGING METHOD

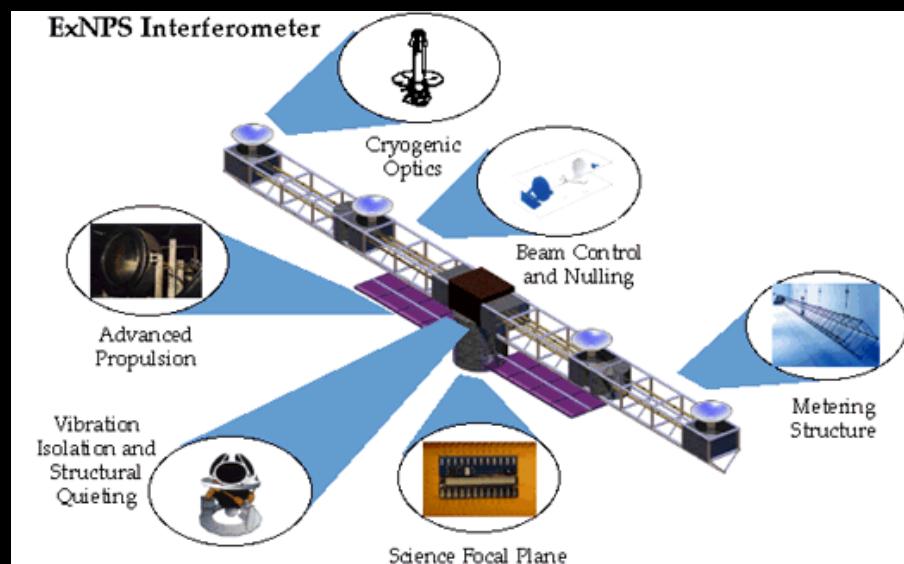
(Simulated Image of Jupiter in “solar system” 10pc distant)



Using interferometry in the infrared from the ground.
Success does not depend upon inclination of system, but brightness of planet.

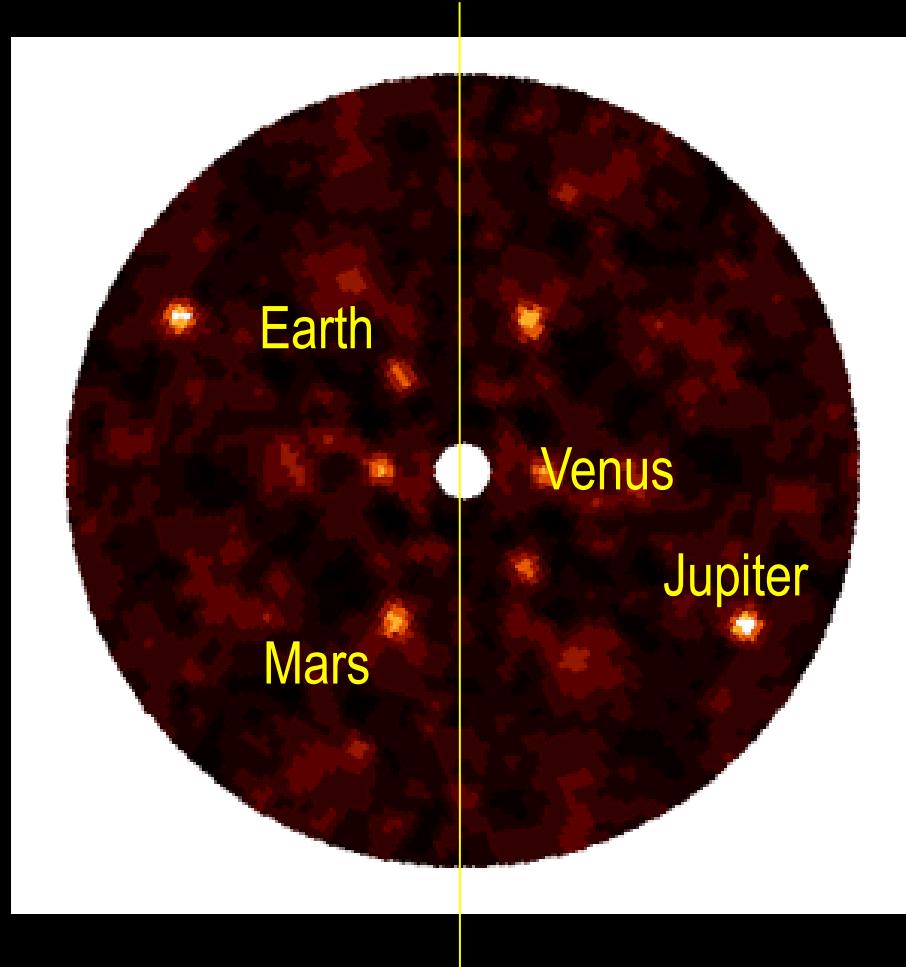
IMAGING METHOD

(taking it to the next level- the future)



IMAGING METHOD

(Family Portrait- Venus, Earth, Mars, and Jupiter)



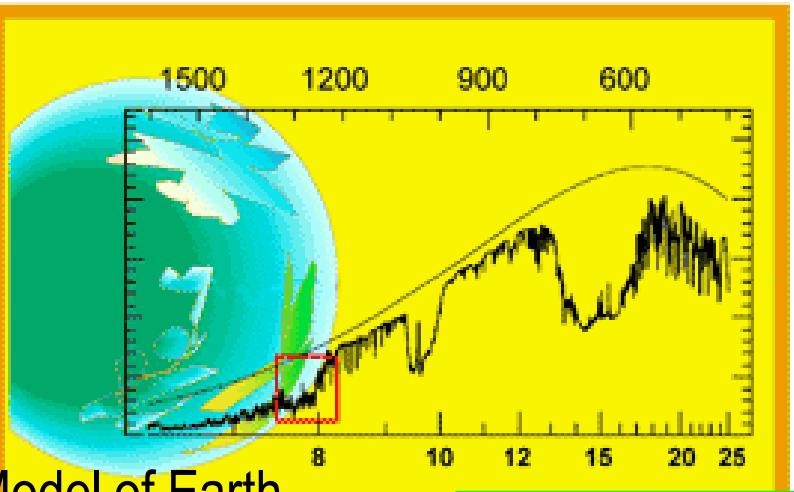
The images are reflected about the origin- artifact of interferometry method

Space based interferometry can probe deeper... mostly because of the bigger collecting area of the telescope.

LIFE: THE HOLY GRAIL

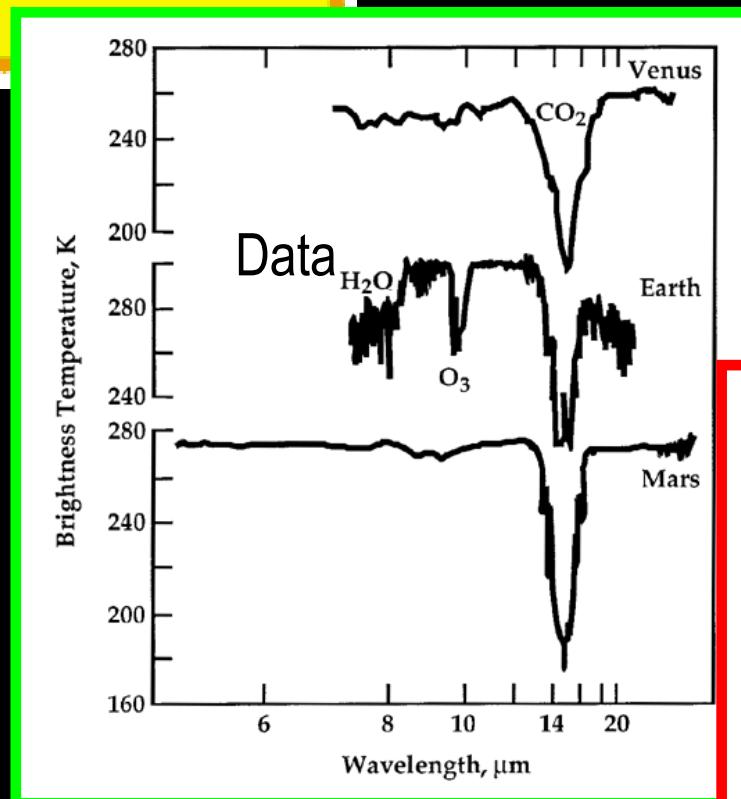
(look for water and ozone)

Model of Earth



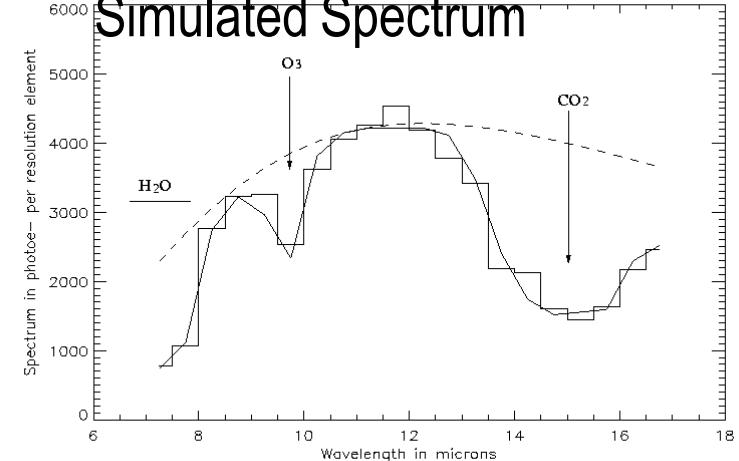
Venus, Earth, & Mars all have CO₂

Earth has H₂O and O₃



These features are in the infrared (again!)

Simulated Spectrum

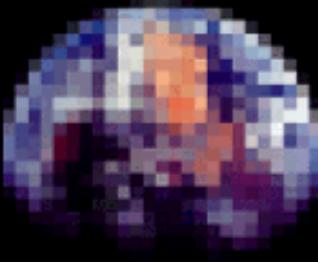
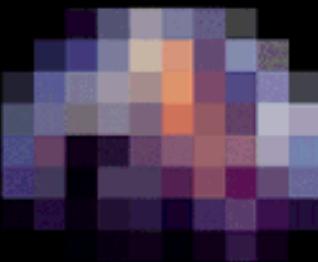


Pixels

finer

Telescope

bigger

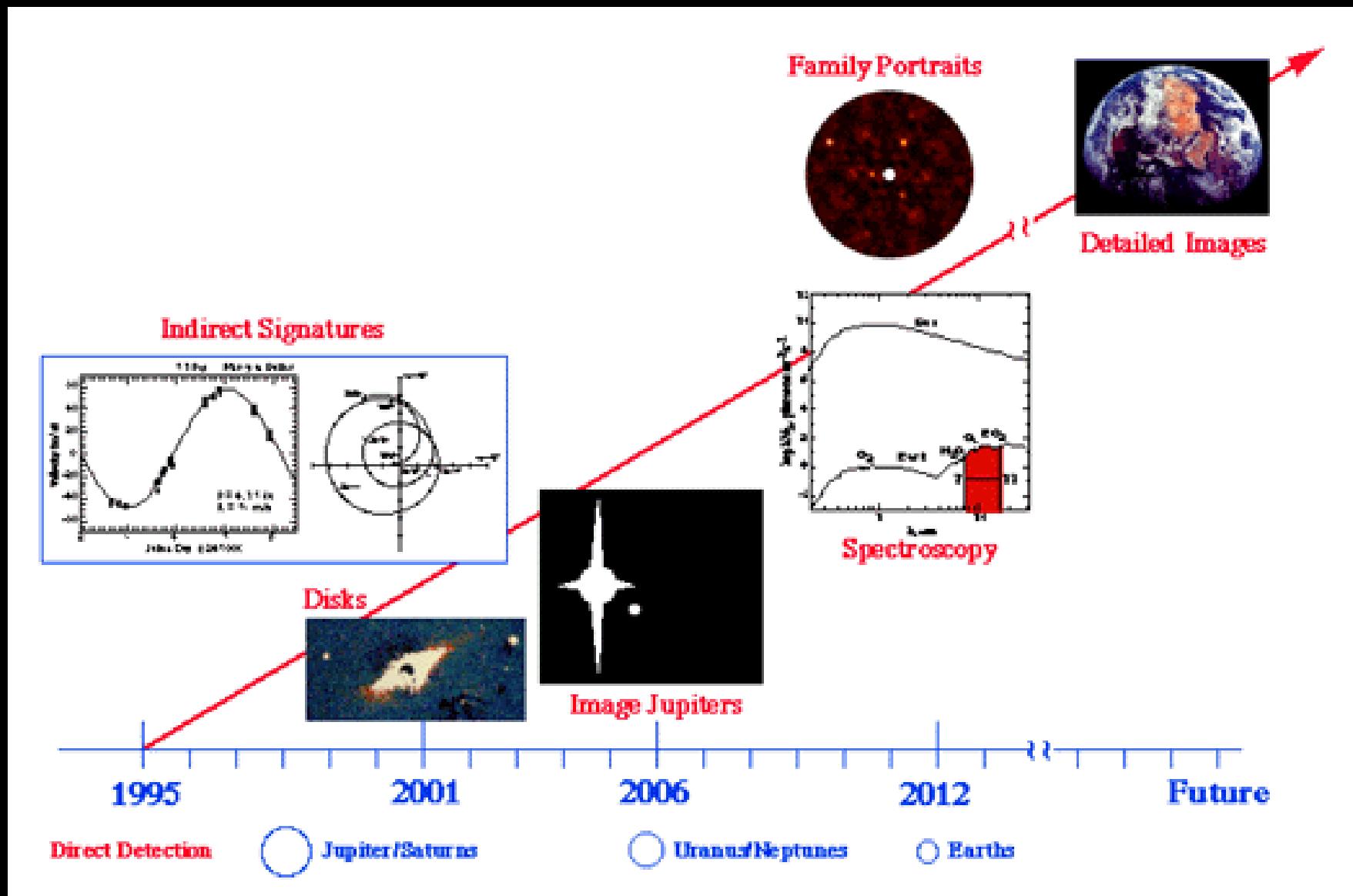
Pixel / Diameter	Pixel size @ planet (km)	Image	Interferometer Requirements		
			Collecting Area	Baseline	
400	32		IR Visible	144 km ² 1,296 km ²	100,000 km 5,000 km
100	128		IR Visible	0.64 km ² 5.76 km ²	24,000 km 1,200 km
Pixel / Diameter	Pixel size @ planet (km)	Image	Interferometer Requirements		
			Collecting Area	Baseline	
25	510		IR Visible	1,024 m ² 9,216 m ²	6,000 km 303 km
10	1276		IR Visible	64 m ² 576 m ²	2.4 km 120 km

coarser

smaller

In our life times?

NASA's PLANET HUNTING ROADMAP



COMPARING METHODS

MASS SELECTION

Doppler Velocity



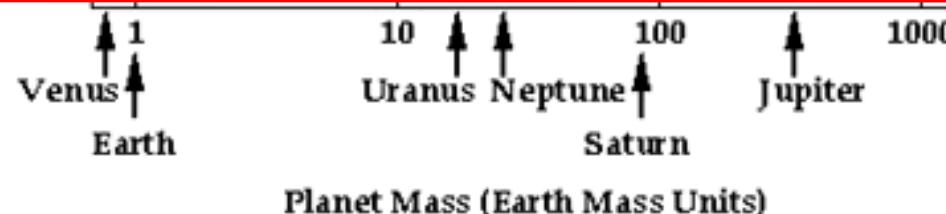
Astrometry



Lensing



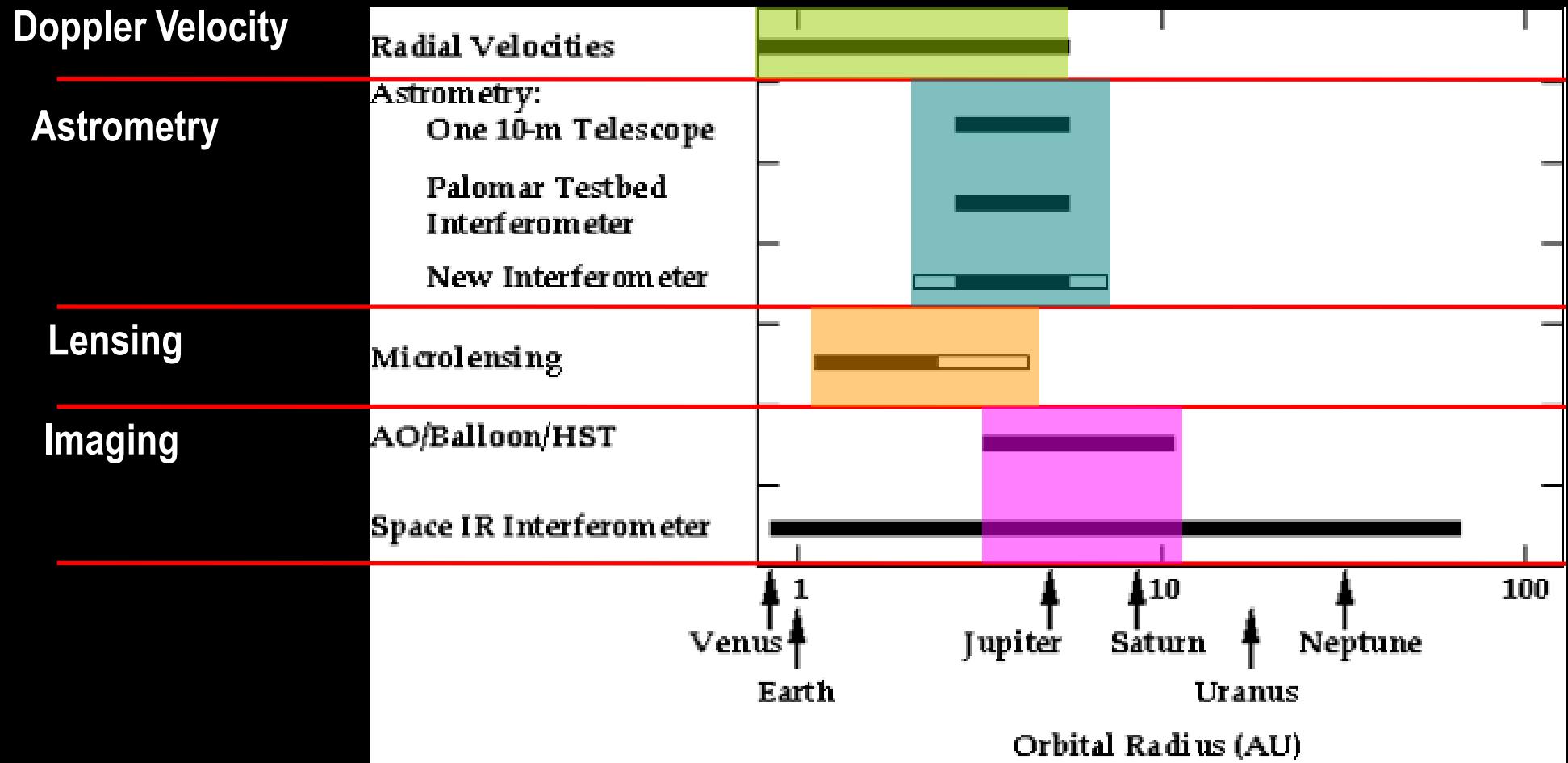
Imaging



^a The direct imaging methods are sensitive to planet size, albedo and temperature, rather than mass.

COMPARING METHODS

ORBIT SELECTION



Sistema Planetário Gliese 581

Gliese 581b

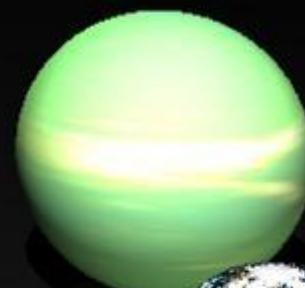


Gliese 581 é uma estrela anã vermelha, localizada a 20,3 anos luz da Terra, na constelação Libra (Balança). Com um terço da massa do Sol, possui pelo menos ~~seis~~ planetas. O quarto planeta mais perto da estrela, Gliese 581g, foi o primeiro planeta “tipo-Terra” detectado a orbitar uma estrela.

Gliese 581f



Gliese 581c



Gliese 581d



Gliese 581g



Gliese 581e



Terra

Buckminster Fuller quote:

A volte penso che siamo soli nell'universo.
A volte penso che non lo siamo. In
entrambi i casi, è piuttosto sconcertante

Fermi Paradox:



The Quest for Life's Origins

We could wait till They contact us or arrive, or we can explore

Understanding the origins of life on earth may provide an important understanding to life elsewhere. We can then compare conditions on Earth to conditions elsewhere and estimate the probability of life existing beyond the Earth.

The Universe is OLD

14.2 billion years ago

4.5 billion years ago

Jan. 1
The Big Bang

Feb.
The Milky Way forms.

JANUARY							FEBRUARY							MARCH							APRIL									
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S			
1	2	3	4	5	6		1	2	3		4	5		1	2	3	4	5	6		1	2	3	4	5	6				
7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20				
14	15	16	17	18	19	20	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30			
21	22	23	24	25	26	27	18	19	20	21	22	23	24	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31		
28	29	30	31				25	26	27	28	29			26	27	28	29	30				28	29	30						
MAY							JUNE							JULY							AUGUST									
1	2	3	4				1	2	3	4	5	6		1	2	3	4	5	6		1	2	3							
5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
12	13	14	15	16	17	18	9	10	11	12	13	14	15	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28		
19	20	21	22	23	24	25	16	17	18	19	20	21	22	21	22	23	24	25	26	27	28	29	30	31	2	3	4	5		
26	27	28	29	30			26	27	28	29	30			29	30	31					25	26	27	28	29	30	31			
SEPTEMBER							OCTOBER							NOVEMBER							DECEMBER									
1	2	3	4	5	6	7	1	2	3	4	5	6		1	2	3	4	5	6		1	2	3	4	5	6	7			
8	9	10	11	12	13	14	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
15	16	17	18	19	20	21	13	14	15	16	17	18	19	18	19	20	21	22	23	24	25	26	27	28	29	30	31			
22	23	24	25	26	27	28	29	30	31					29	30	31														

Sept. 3
Earth forms.

Sept. 22
Earliest evidence of life on Earth

59 seconds:
Kepler and Galileo prove Earth orbits the Sun.



49 seconds:
Pyramids are built.



35 seconds:
Agriculture arises.



DECEMBER						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

DECEMBER 31

Morning—
12:00 pm _____
1:00 pm _____
2:00 pm _____
3:00 pm _____
4:00 pm _____
5:00 pm _____
6:00 pm _____
7:00 pm _____
8:00 pm _____
9:00 pm Early hominids
10:00 pm _____
11:00 pm _____
11:58 pm Modern humans evolve.
11:59 pm _____
12:00 am _____



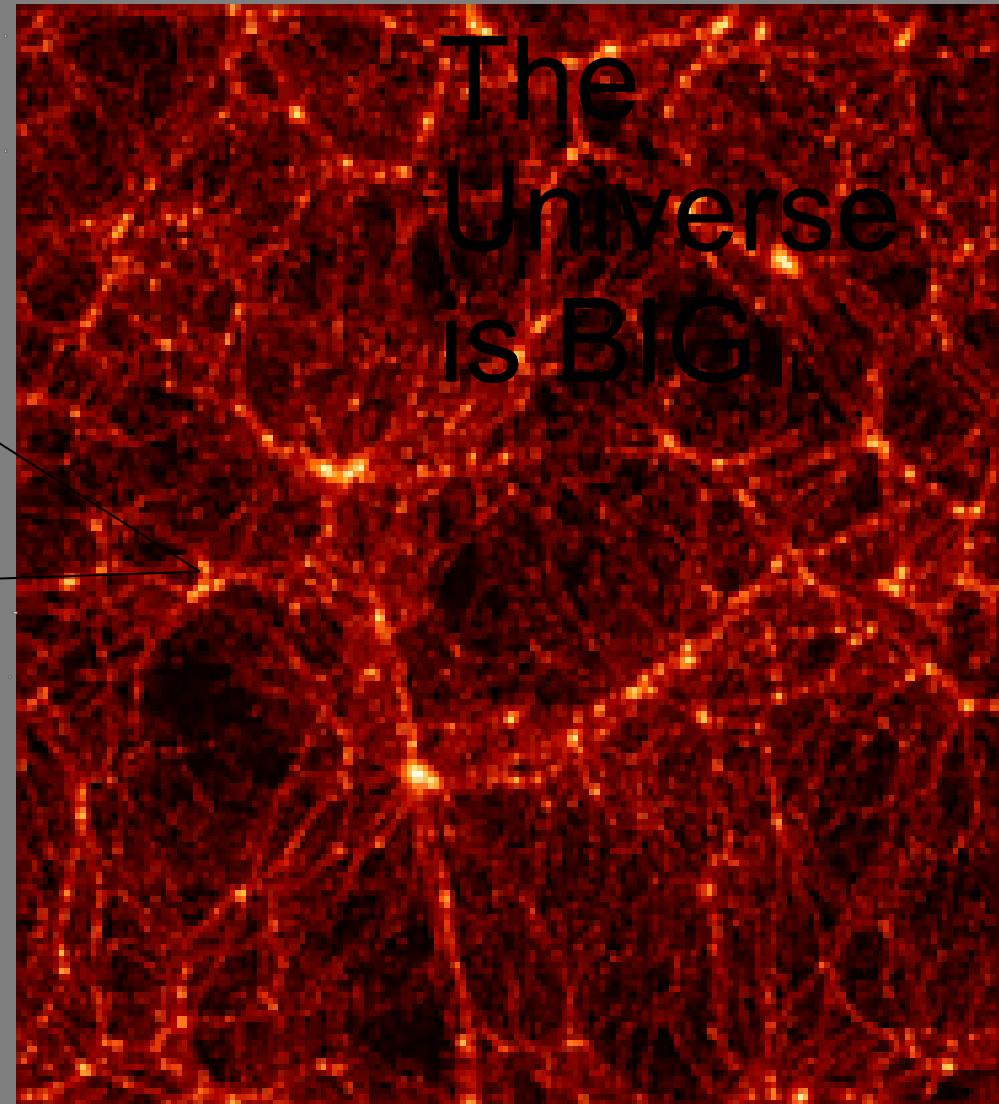
Side View

Top View

Our Sun is one of 100,000,000 stars in our Galaxy (The 'Milky Way')

The observable universe contains 100,000,000 Galaxies... so the sun is one in 1000,000,000,000 stars...

You
Are
Here

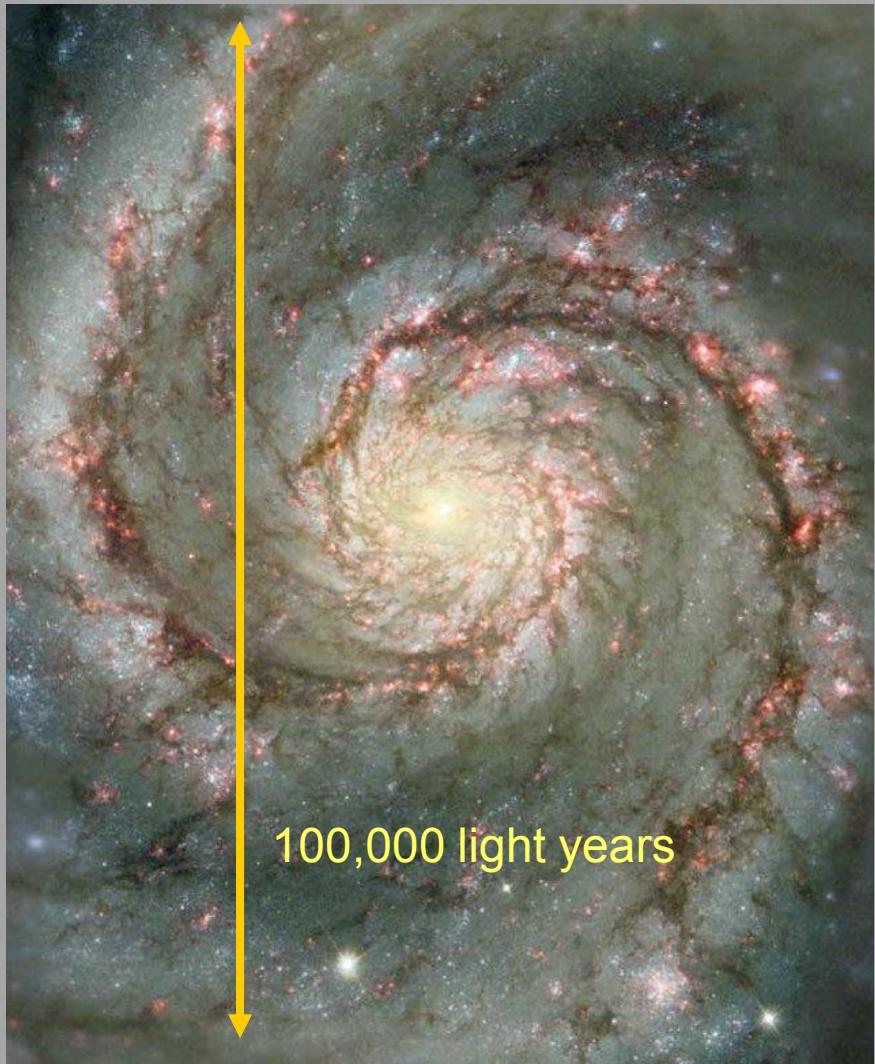


Feeling small ?
Surely there must be other 'people' out there ... ?

That's approximately one star for every grain of sand,
on every beach on Earth...



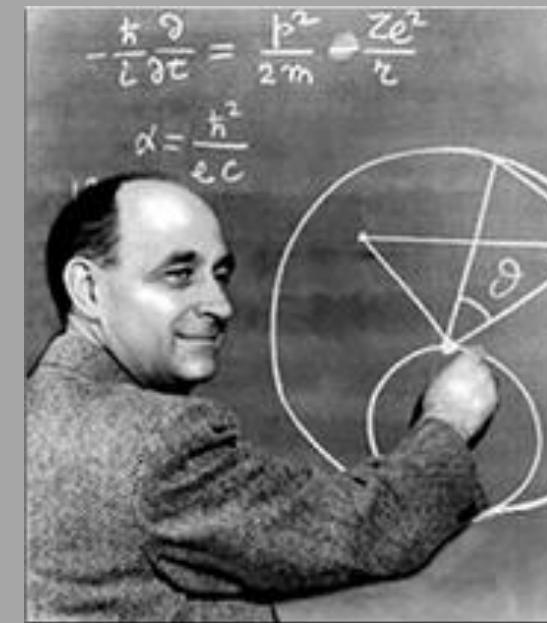
The Fermi Paradox



100,000 light years

Age of galaxy:
14,000 M yr

Time to colonize
galaxy, moving at
attainable speeds:
10 M yr



So there has been enough time for the
galaxy to be colonised 1400 times...
[probably more like few 100]

Plus the oldest civilisations should be
at least 5,000 M yr ahead of us !

(i.e. Our galaxy is much older than it is big)

So where is everybody ? ? ? (does this mean we are alone ?)

zona Goldilocks o Cintura Verde

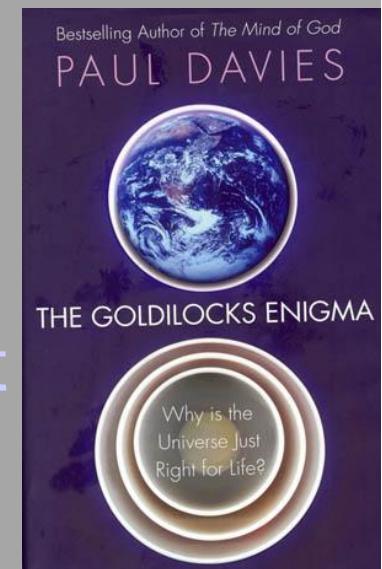
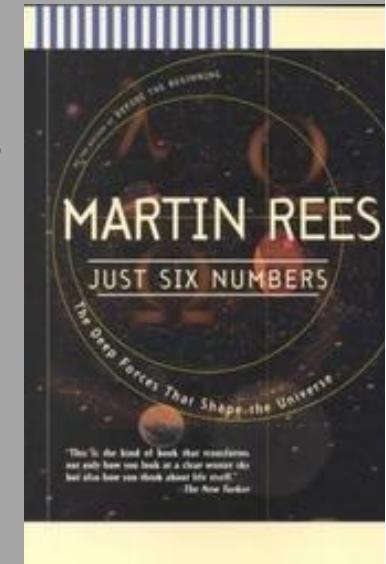
*In astronomia, una **zona abitabile** (detta anche **zona Goldilocks** o **Cintura Verde**) è una regione dello spazio le cui condizioni favoriscono la presenza della vita. Anzitutto, affinché una zona del cosmo sia abitabile, deve rispettare delle importanti condizioni spaziali: deve infatti avere una certa posizione nella galassia (**zona galattica abitabile**), e un'altra determinata posizione all'interno di un sistema solare (**zona circumstellare abitabile**). I pianeti e le lune che rispettano queste prime condizioni sono i migliori candidati al sostentamento della vita. Nello specifico, il termine "zona abitabile" può anche riferirsi alla fascia del nostro Sistema Solare, che comprende, ovviamente, anche la Terra, estendendosi da una distanza dal Sole di 0,95 UA a una di 1,37 UA.*

The Goldilocks Universe

All the laws of Nature have constants associated with them. We do not know what selects the values of these constants, however, they seem to be fine-tuned for life ! E.g.

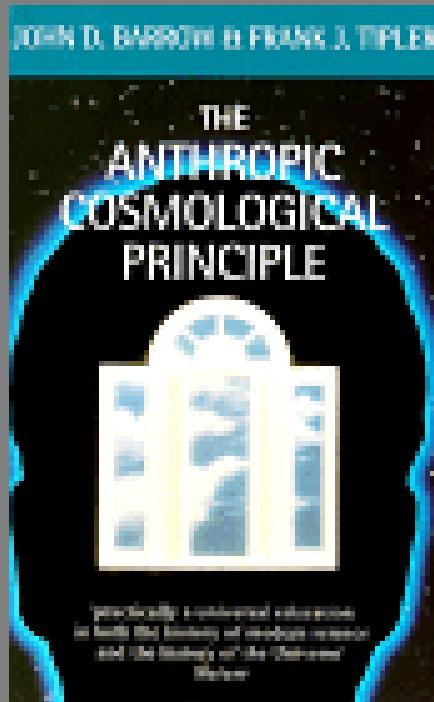
- If the gravitational constant were smaller fusion would not start in stars. If larger stars would burn too quickly for intelligent life to develop
- The *strong force constant*: if different we would have a universe of only hydrogen (weaker) or iron (stronger)
- The *electromagnetic coupling constant*: if different then no molecules could form

Deviations of more than ~5% in any of these constants would have prevented us developing...



So why does the universe appear to be just right for life ?

The **Anthropic Principle** states that *of course the universe is right for us, otherwise we wouldn't be here to be commenting on the fact...*



(many consider this to be a cop-out)

More ‘physical’ proposals include

- There is a requirement for life ‘hard-wired’ into the Universe somehow
- This is but one Universe in a vast multiverse
- ‘M-theory’ will derive values

and of course there is the ‘designed’ (theological) explanation

The Multiverse

One version has a new universe created every time a quantum wave function collapses... which implies the creation of

10000000.00000000.000000
00.00000000.00000000.0000
00000.00000000.00000000.0
00000000.00000000

..new universes every second

E.T.

THE EXTRA-TERRESTRIAL
THE 20th ANNIVERSARY



