

Fundamentos de Astronomía y Astrofísica

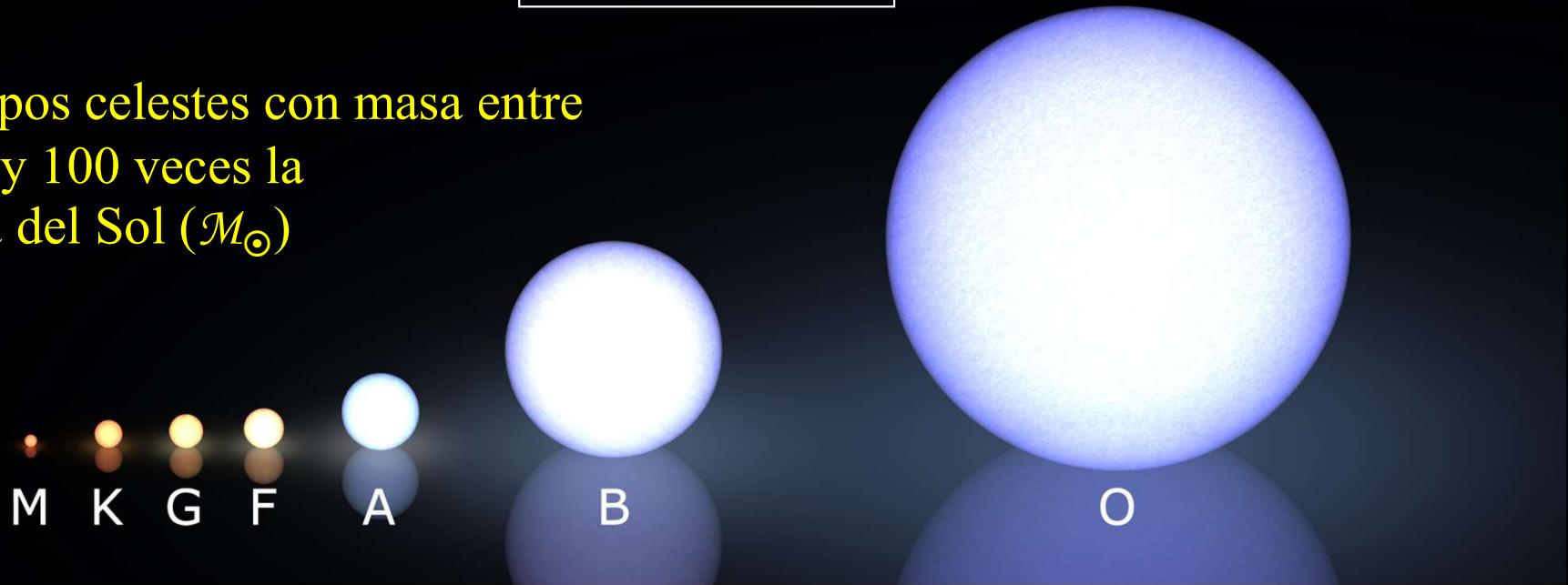
*Tema: sistemas planetarios
y misiones espaciales*

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Dep. de Astronomía – Universidad de Guanajuato
2022

Estrellas

Cuerpos celestes con masa entre
0.08 y 100 veces la
masa del Sol (M_{\odot})



SPECTRAL CLASSIFICATION

Table 11.1 The full range of spectral classes in current use.

O4	B0	A0	F0	G0	K0	M0
O5	B0.5	A2	F2	G2	K2	M1
O6	B1	A3	F3	G5	K3	M2
O7	B2	A5	F5	G8	K4	M3
O8	B3	A7	F7		K5	M4
O9	B5		F8			M7
O9.5	B7		F9			M8
	B8					M9
	B9.5					

Sistemas Planetarios

Criterios de clasificación (UAI, 24/08/2006): masa menor a $\sim 25 M_J$

- ¿Gira alrededor de la Estrella?

No



Satélite



Sí



- ¿Tiene suficiente masa para alcanzar equilibrio hidrostático (esférico)?
(su gravedad supera las fuerzas del cuerpo rígido)

No



Pequeño cuerpo
(asteroide o cometa)



Sí

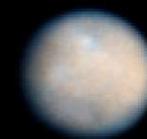


- ¿Fue capaz de despejar la región de su órbita?
(no se encuentra en un Cinturón de Asteroides)

No



Planeta Enano



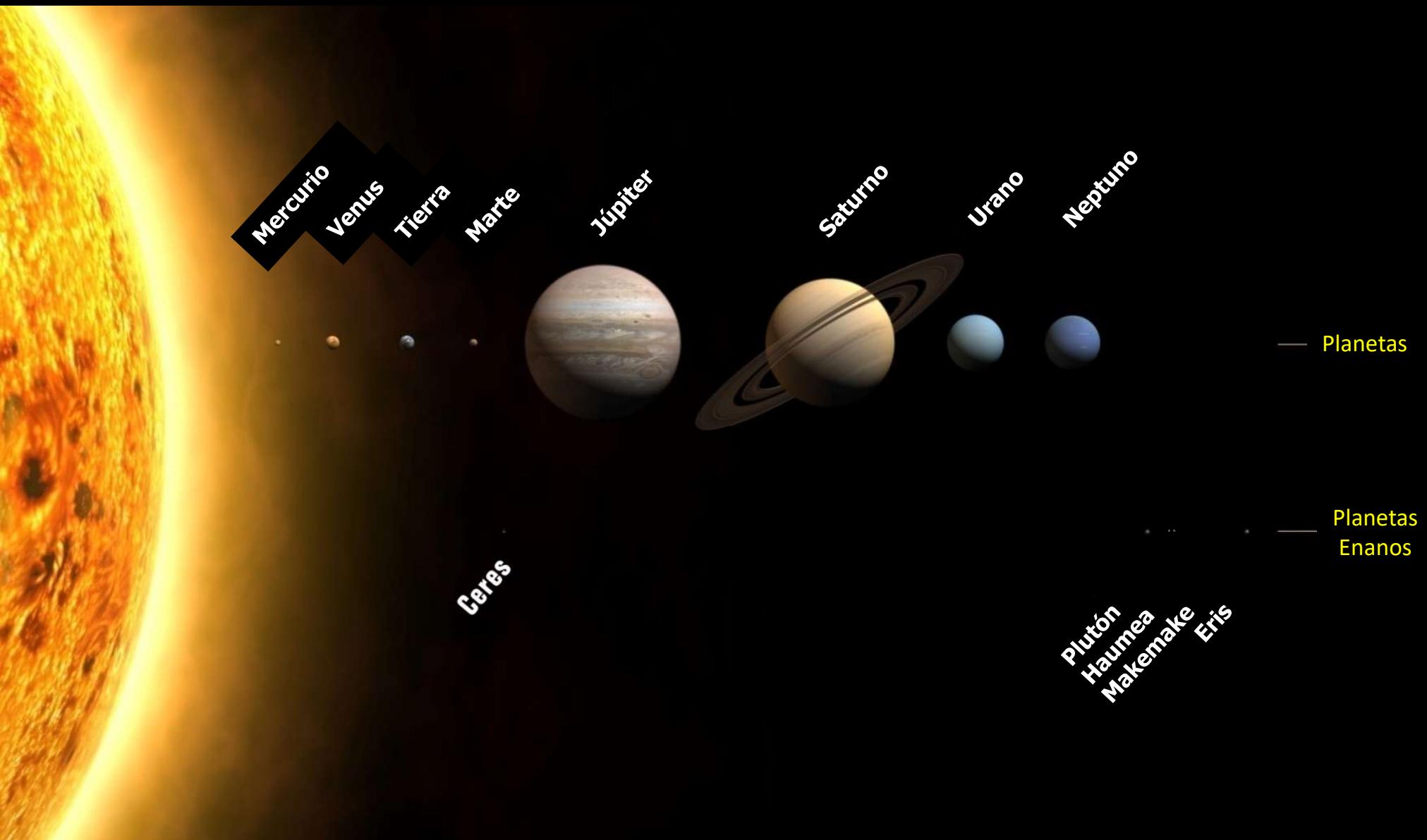
Sí



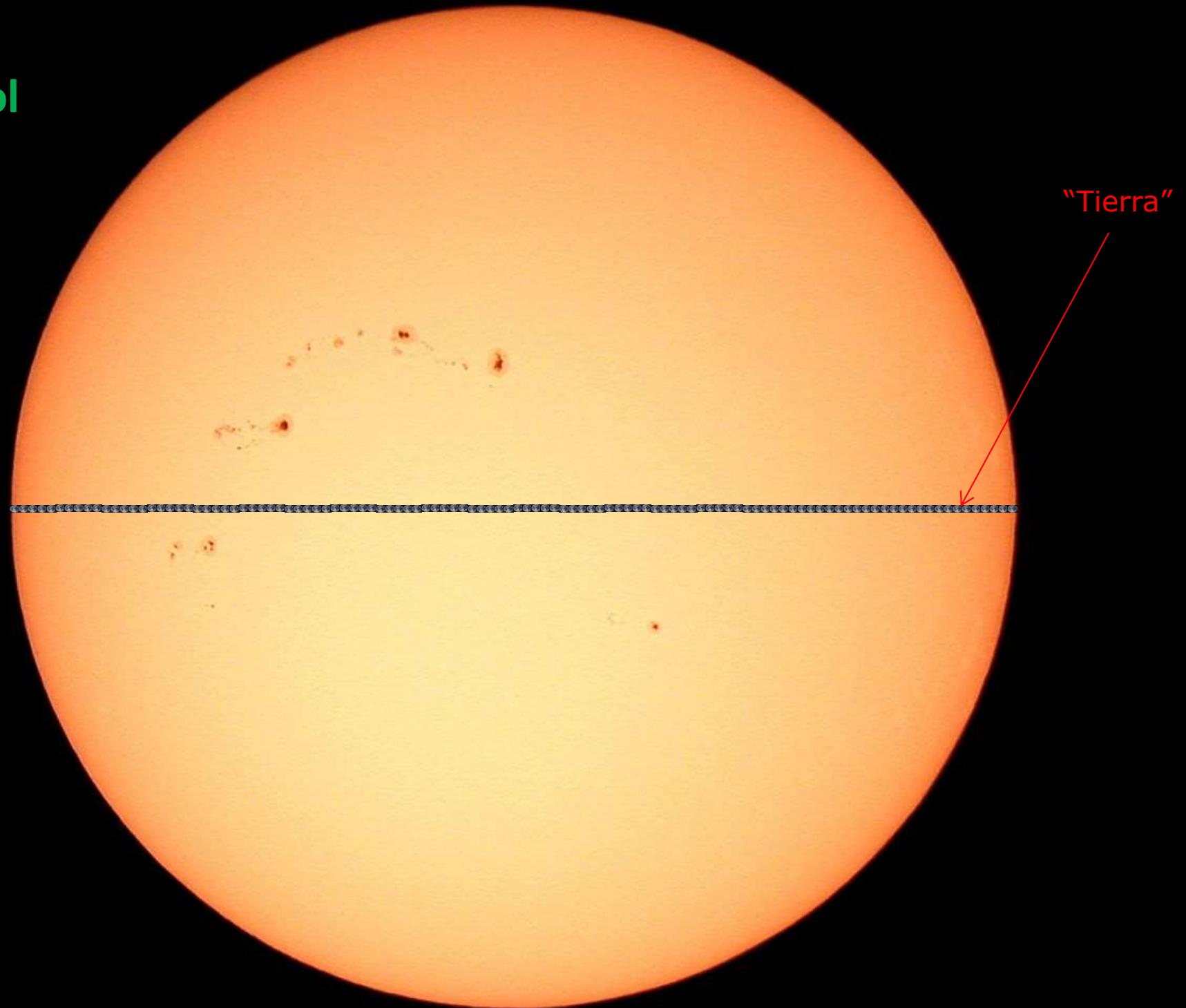
Planeta



A) Nuestro sistema planetario

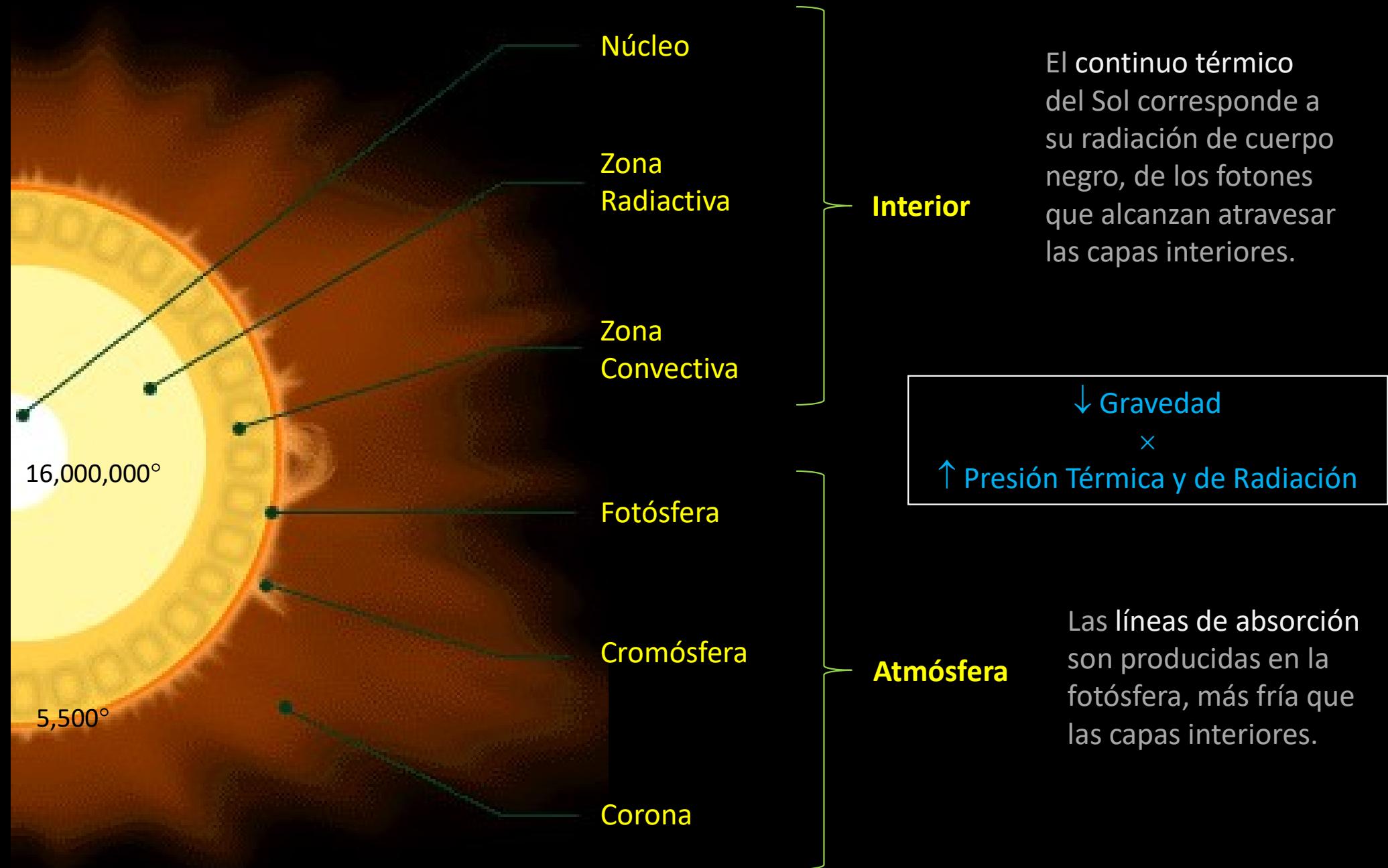


1. El Sol



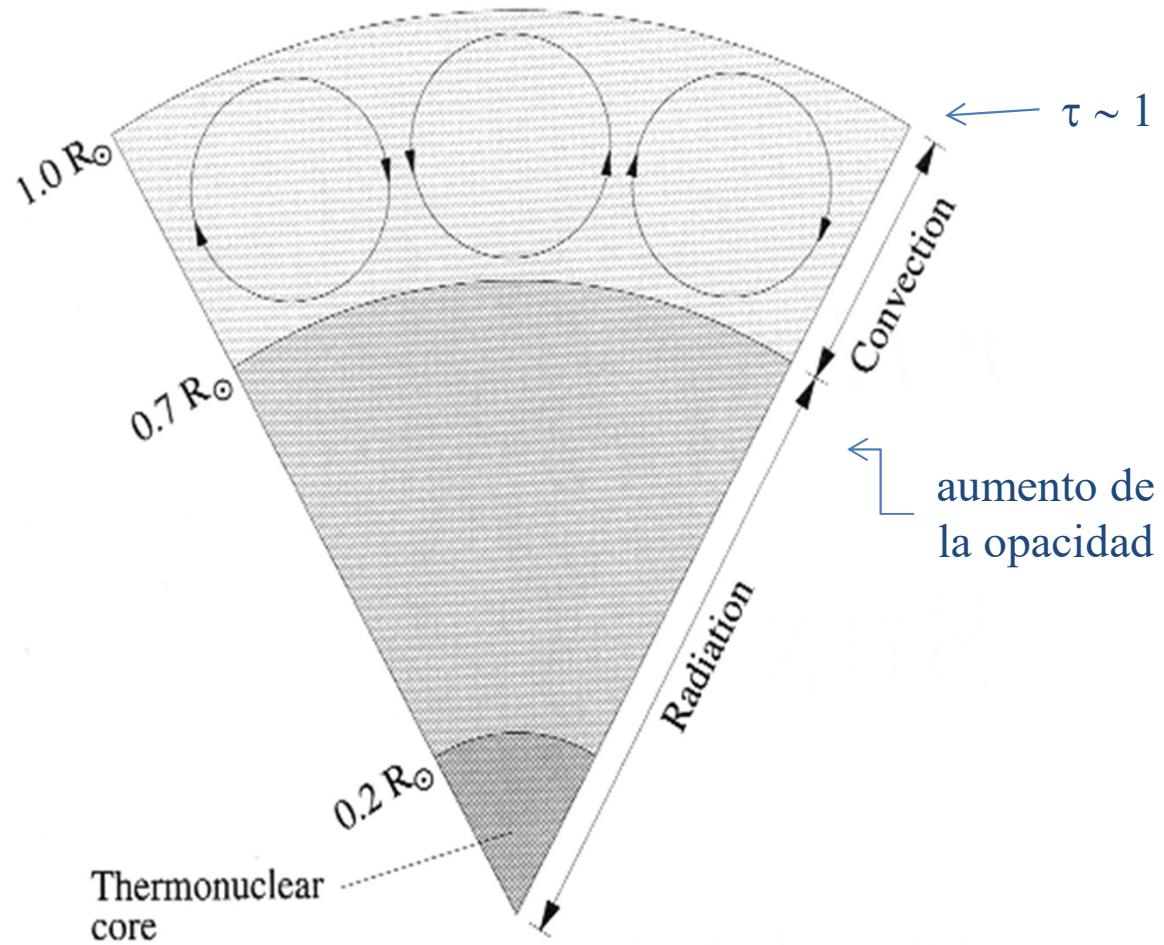
radio = $109 \times$ el radio de la Tierra

masa = $333\,000 \times$ la masa de la Tierra



gravedad → presión → calentamiento → fusión del H en He → energía → transmisión → radiación

Estructura del Interior del Sol



Tipo: G2-V

$$T_e = 5770 \text{ K}$$

$$X = 0.74$$

$$Y = 0.24$$

$$Z = 0.02$$

$$\langle \rho \rangle = 1.41 \text{ g cm}^{-3}$$

$$M_{\odot} = 1.989 \times 10^{30} \text{ kg}$$

$$R_{\odot} = 6.960 \times 10^8 \text{ m}$$

$$L_{\odot} = 3.826 \times 10^{33} \text{ erg s}^{-1}$$

$$T_c = 1.57 \times 10^7 \text{ K}$$

$$X = 0.34$$

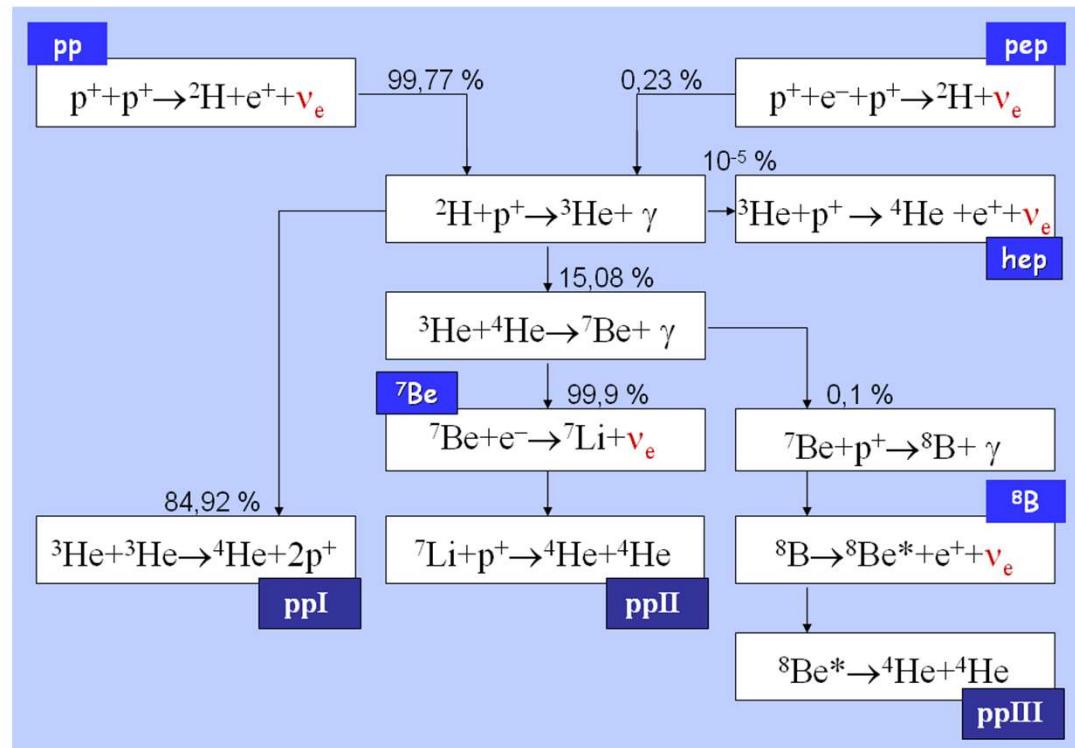
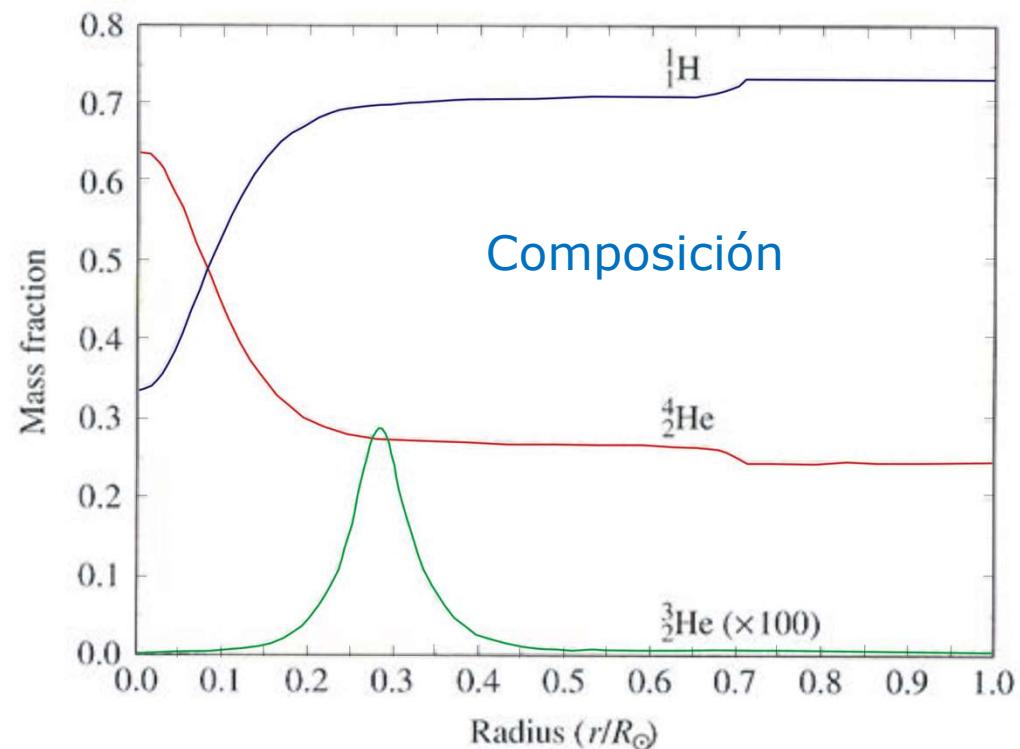
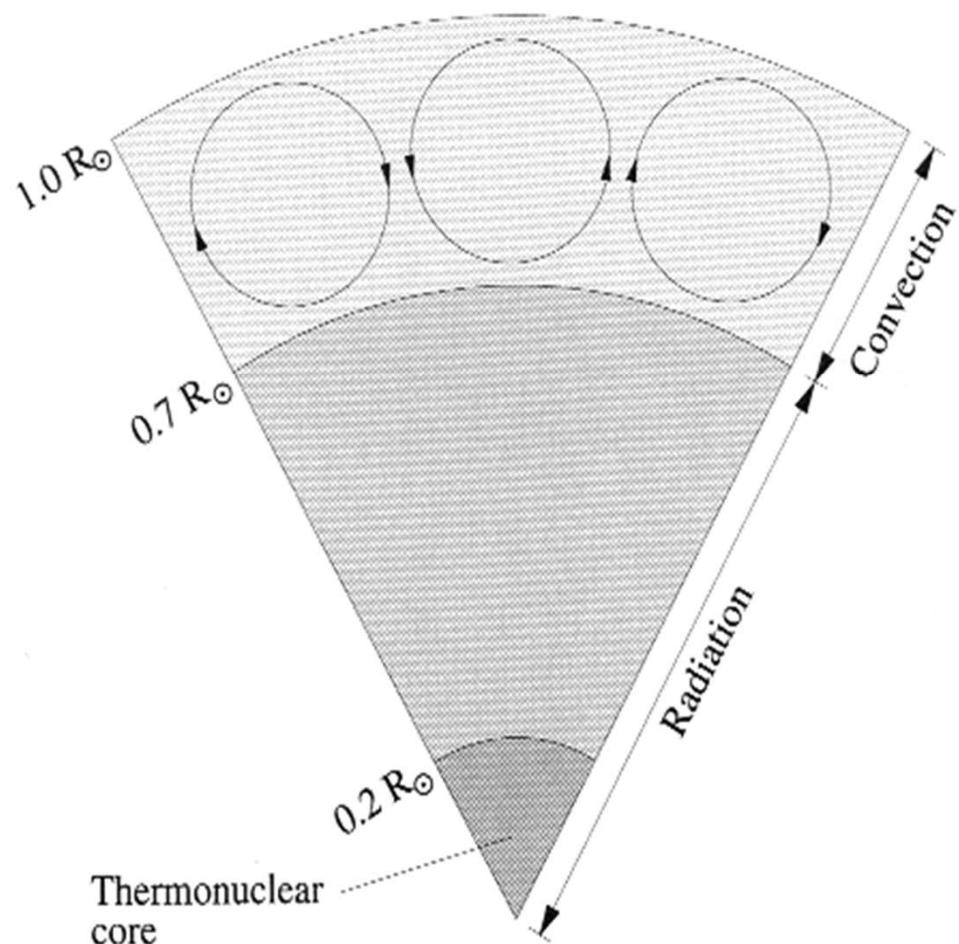
$$Y = 0.64$$

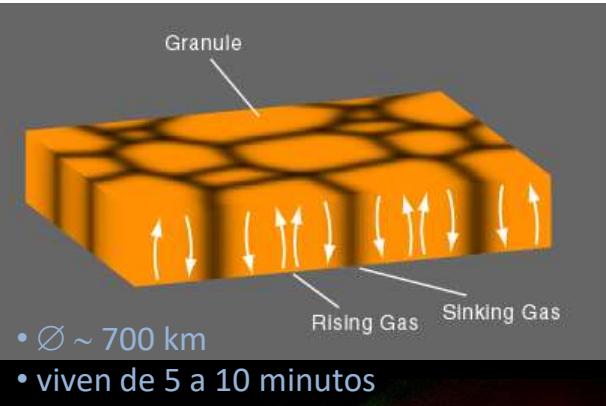
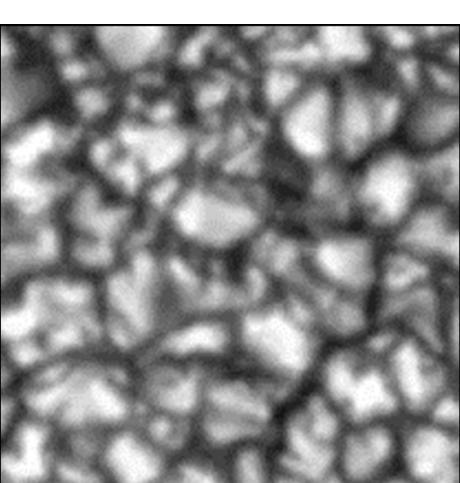
$$Z = 0.02$$

$$\rho_c = 162 \text{ g cm}^{-3}$$

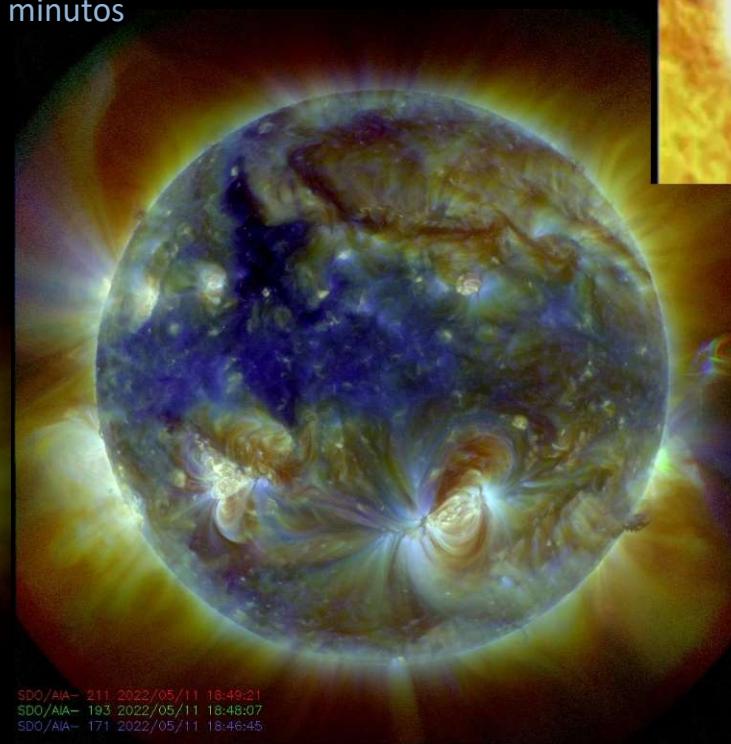
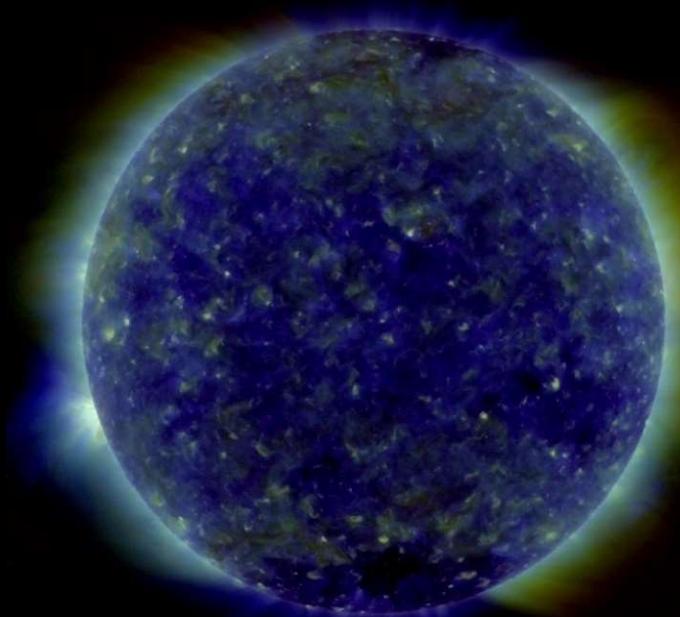
$$P_c = 2.34 \times 10^{16} \text{ N m}^{-2}$$

Estructura del Interior del Sol





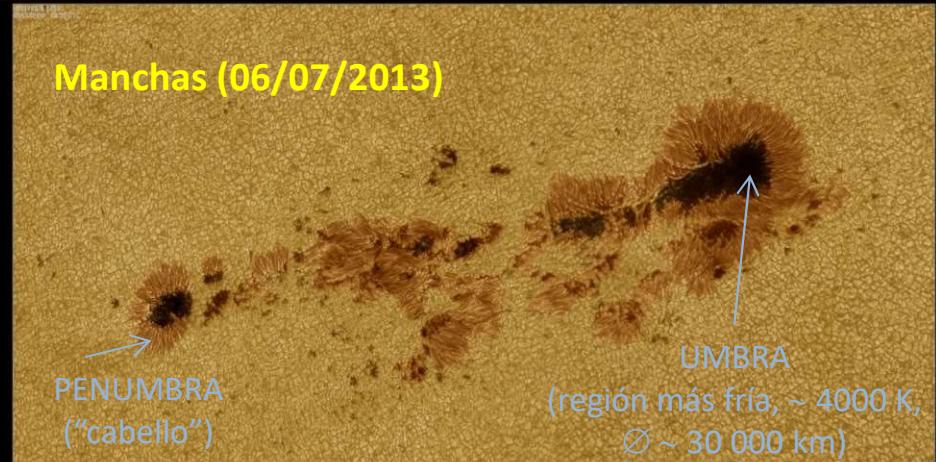
Campos magnéticos

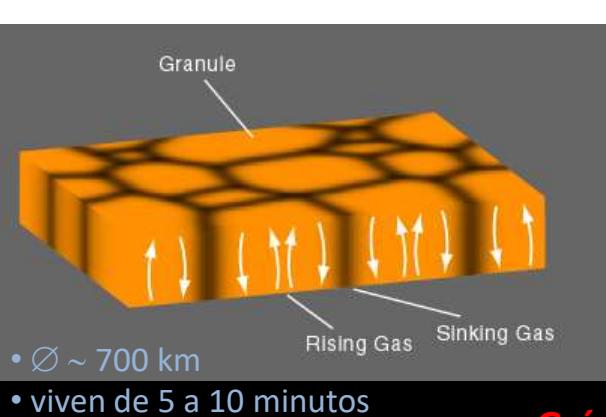
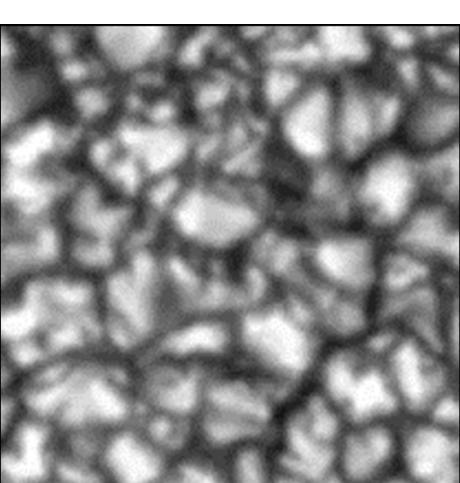


El Sol algunos años atrás
(*Solar Dynamics Observatory: SDO*)

El Sol esta semana (*SDO*)

Manchas solares

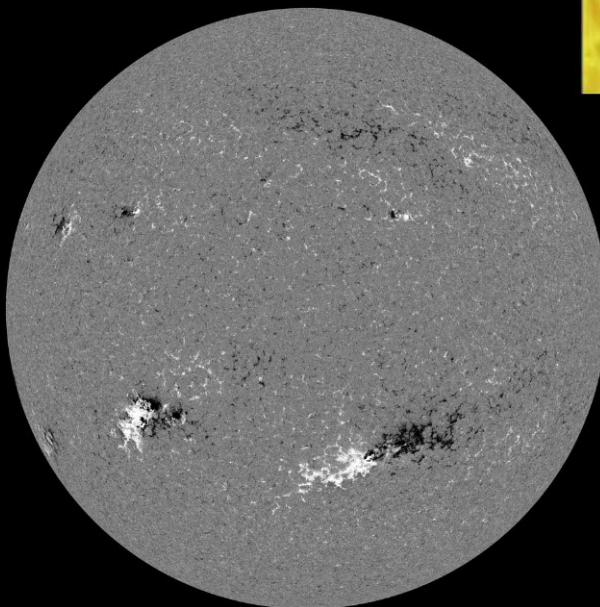
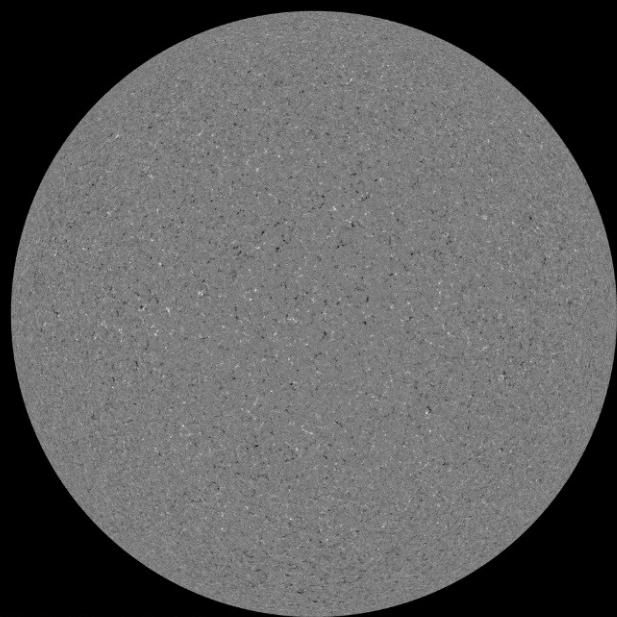




Campos magnéticos



Gránulos

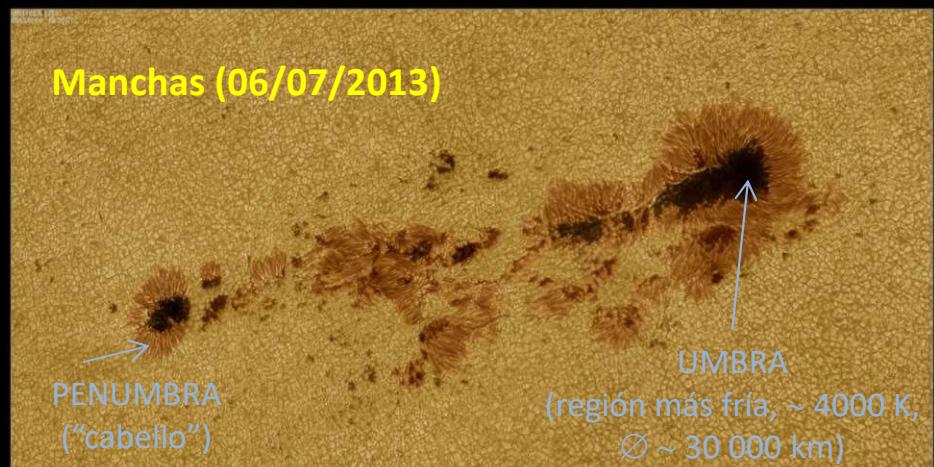


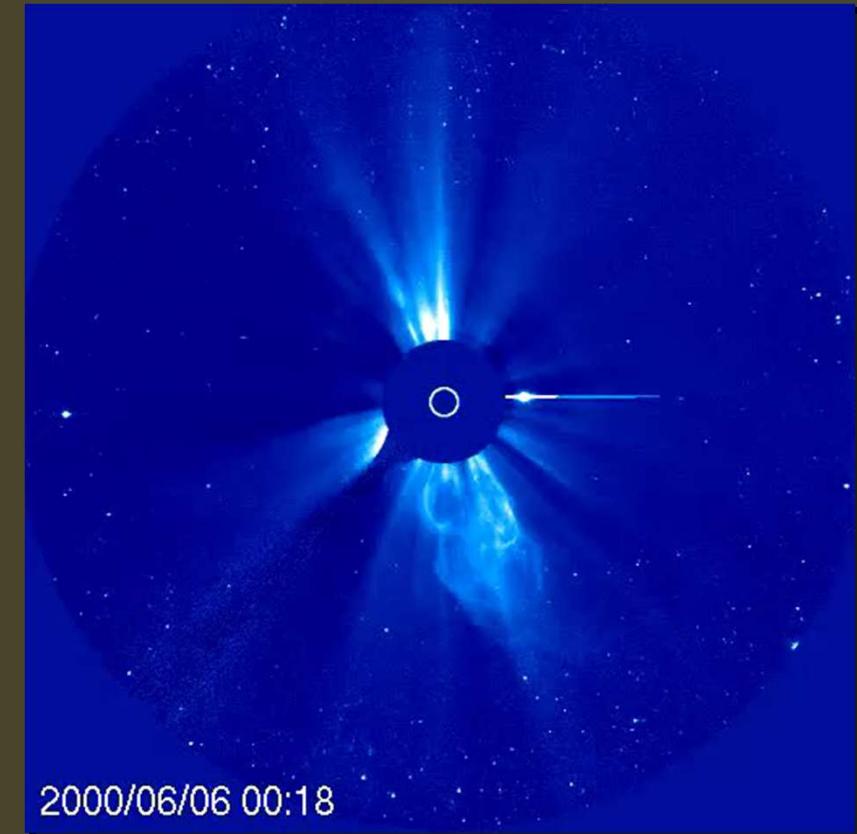
El Sol esta semana
(*SDO*)



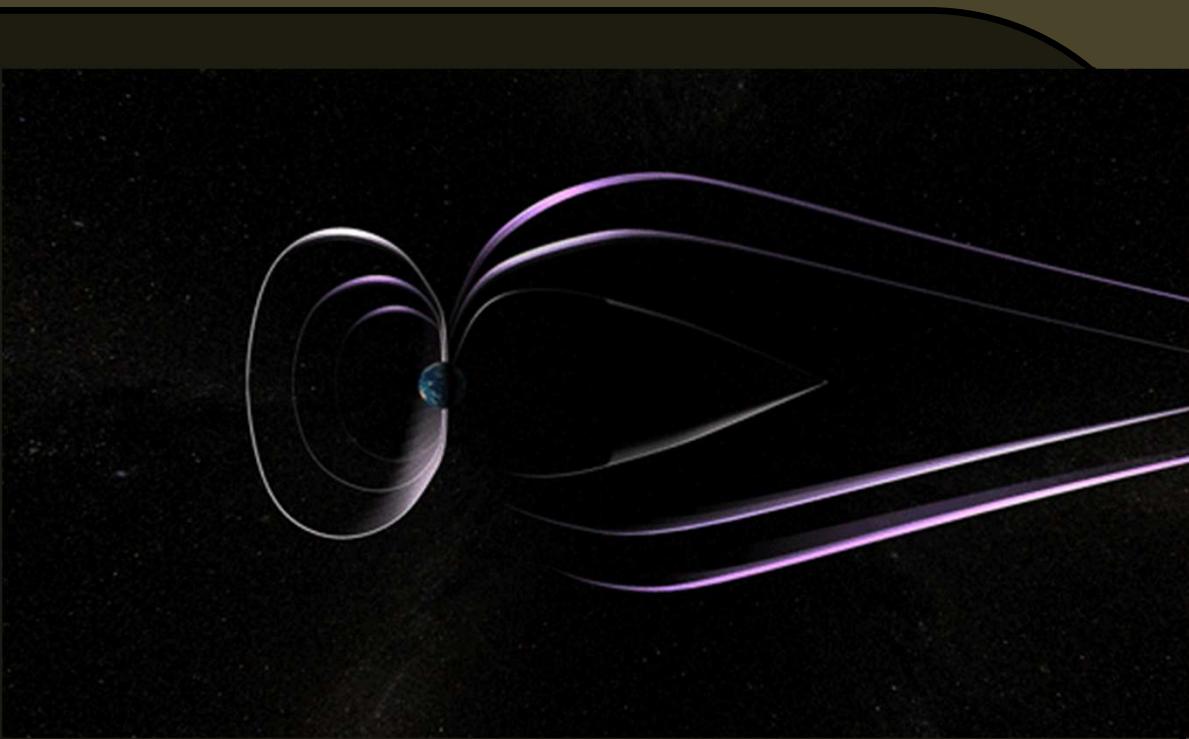
El Sol algunos años atrás
(*Solar Dynamics Observatory: SDO*)

Manchas solares

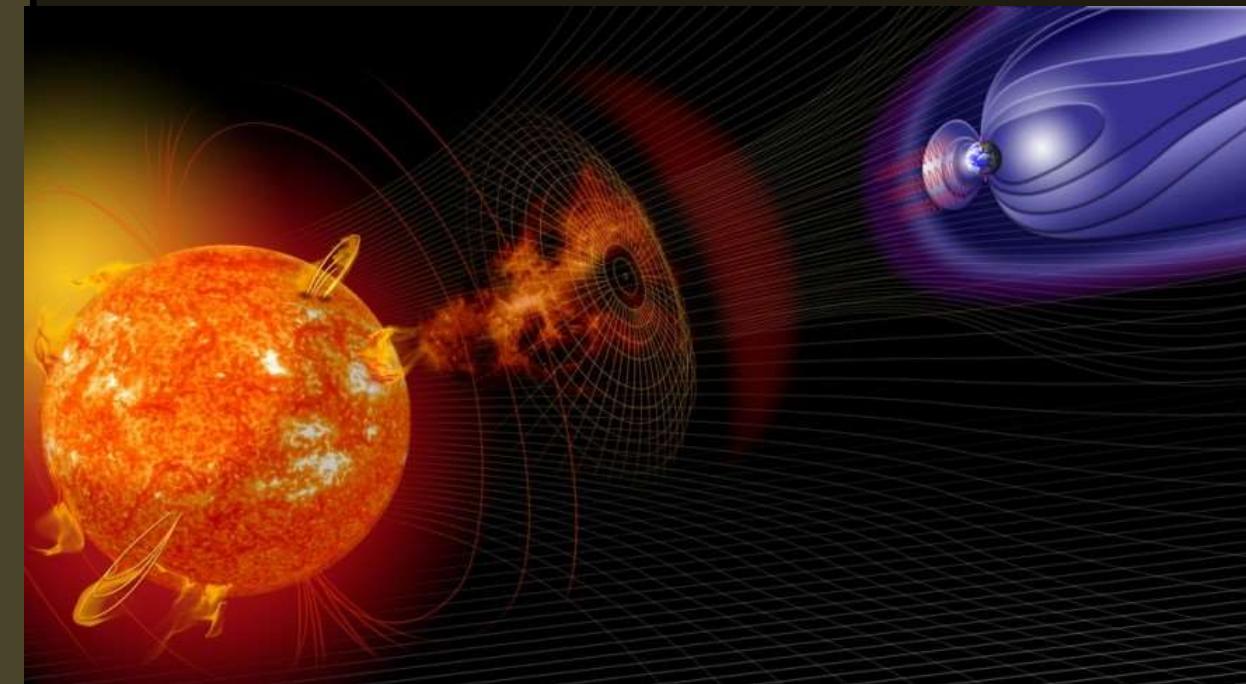




2000/06/06 00:18



viento solar,
eyecciones
coronales
y el clima
espacial



SPACE WEATHER IMPACTS



WEATHER.GOV/SPACE

AURORA
(NORTHERN LIGHTS)



SATELLITES



HUMAN SPACE
EXPLORATION



GPS



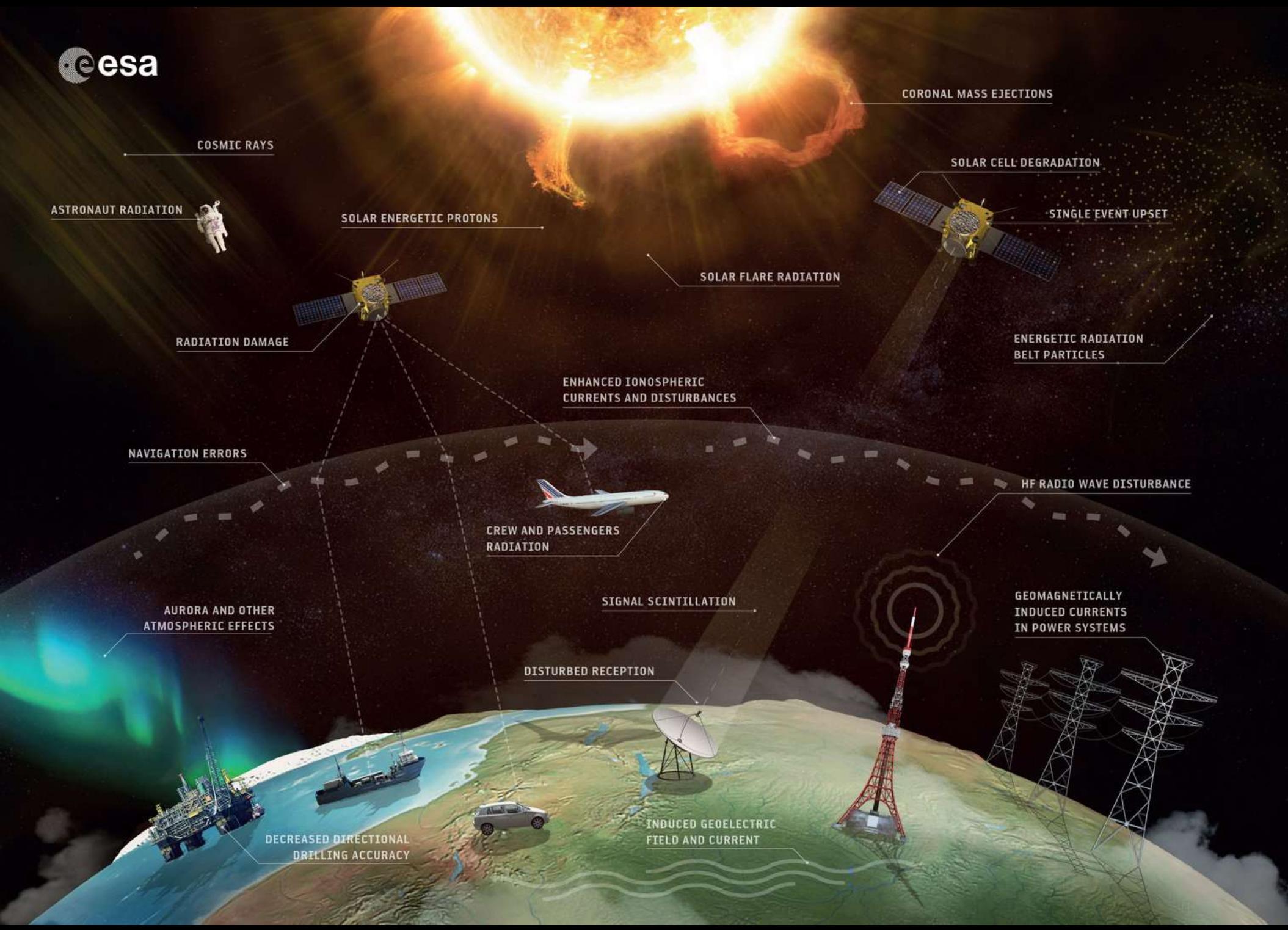
COMMUNICATIONS

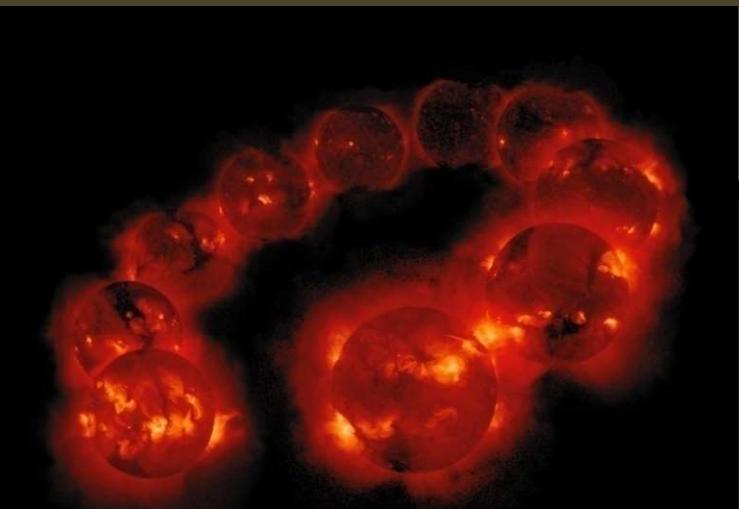
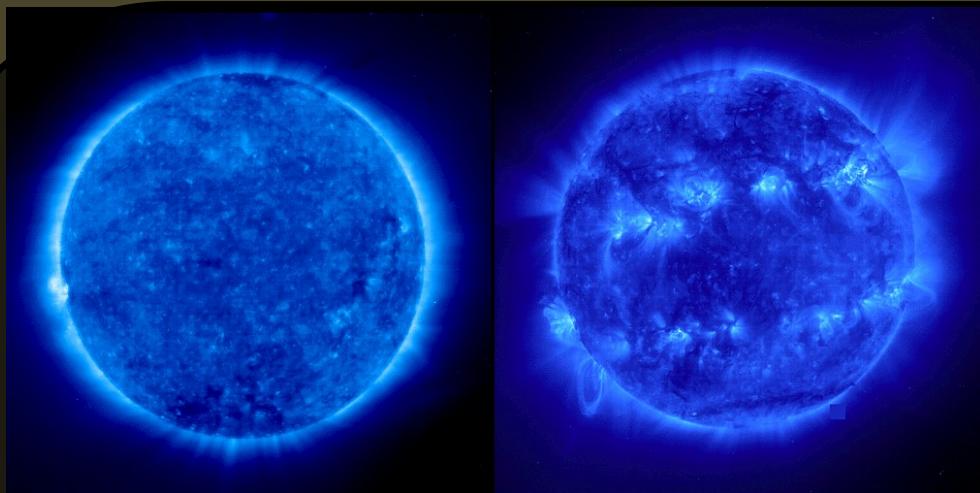


AVIATION

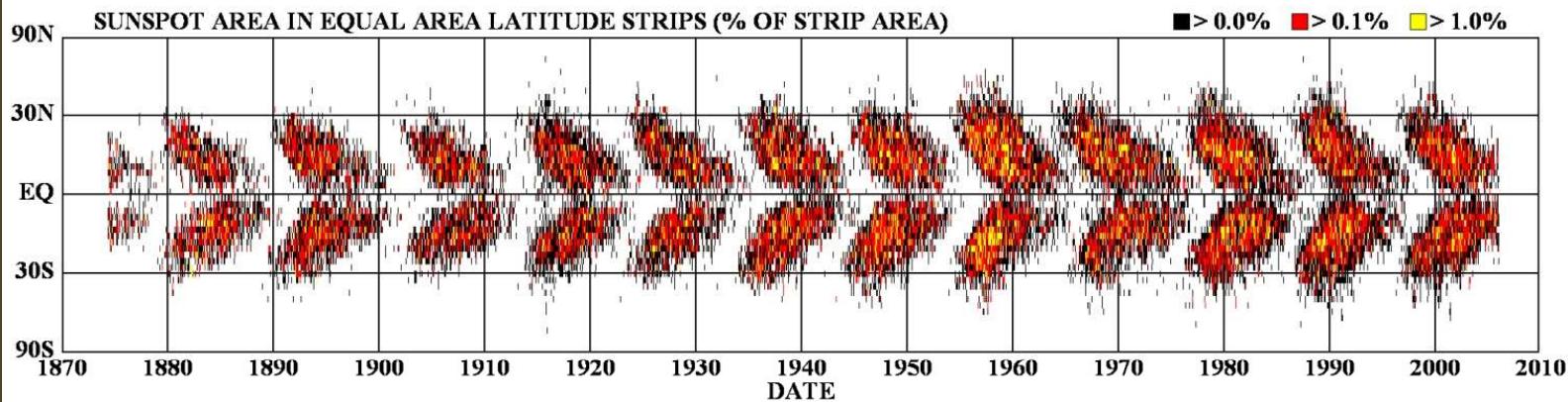


ELECTRIC POWER

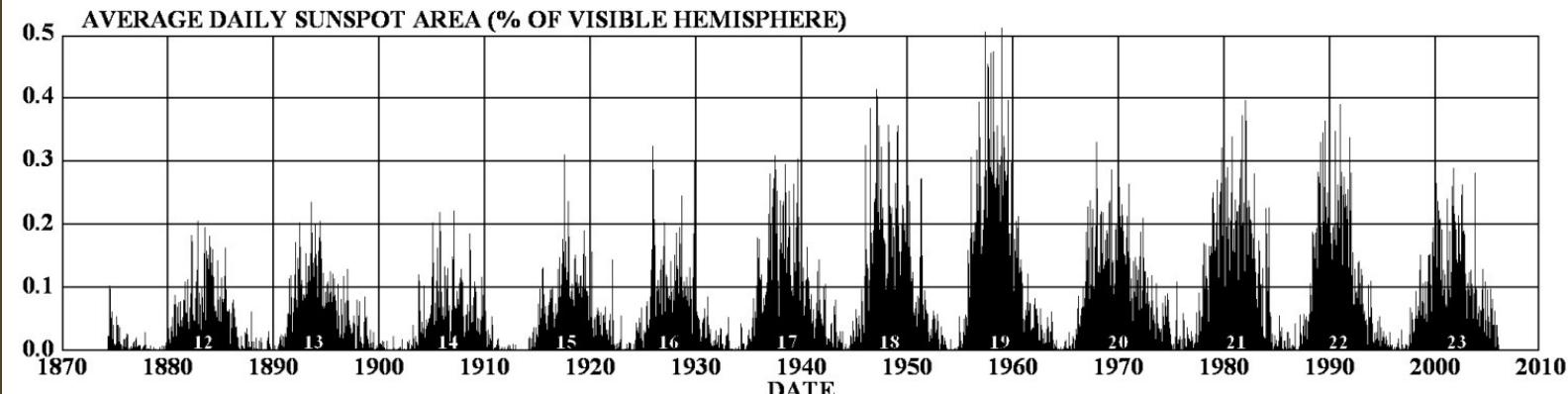




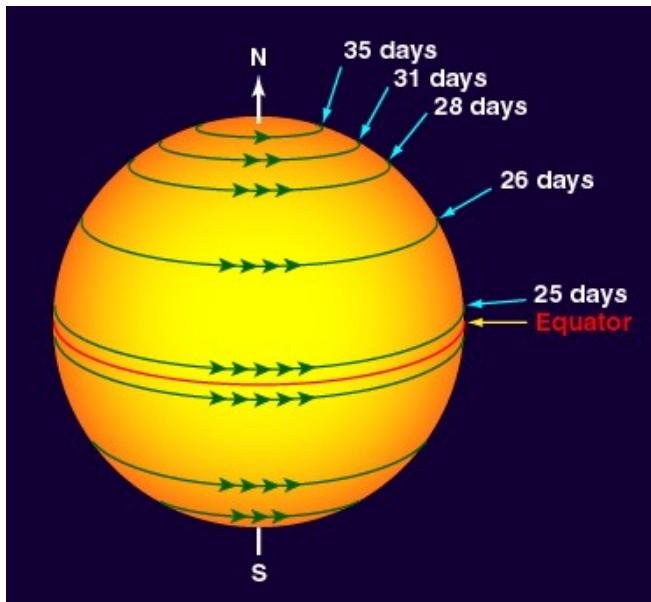
DAILY SUNSPOT AREA AVERAGED OVER INDIVIDUAL SOLAR ROTATIONS



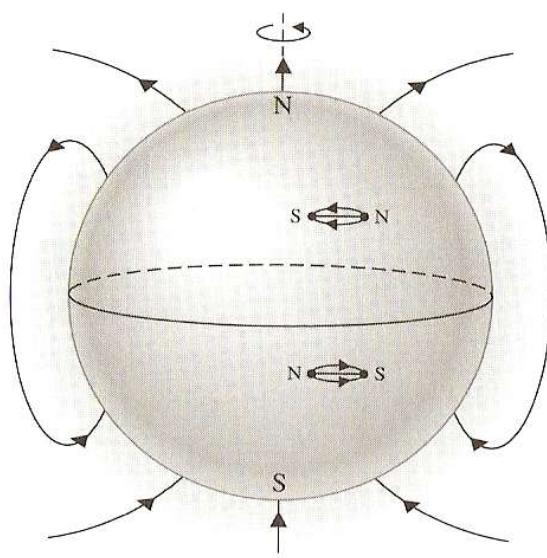
el ciclo
solar



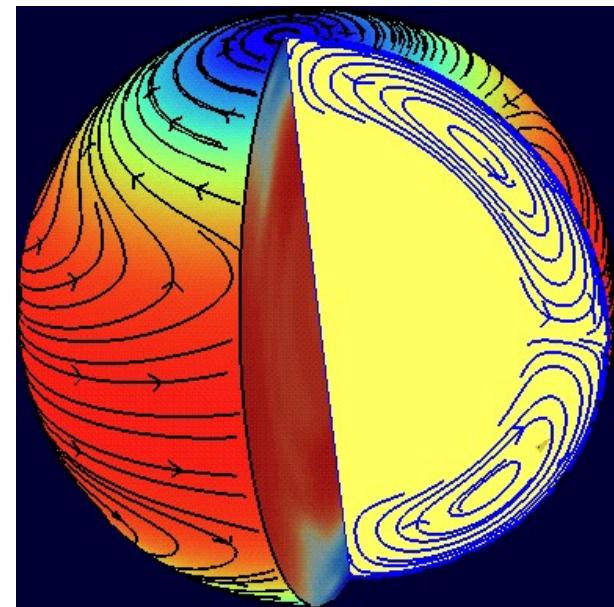
¿Qué produce el ciclo solar?



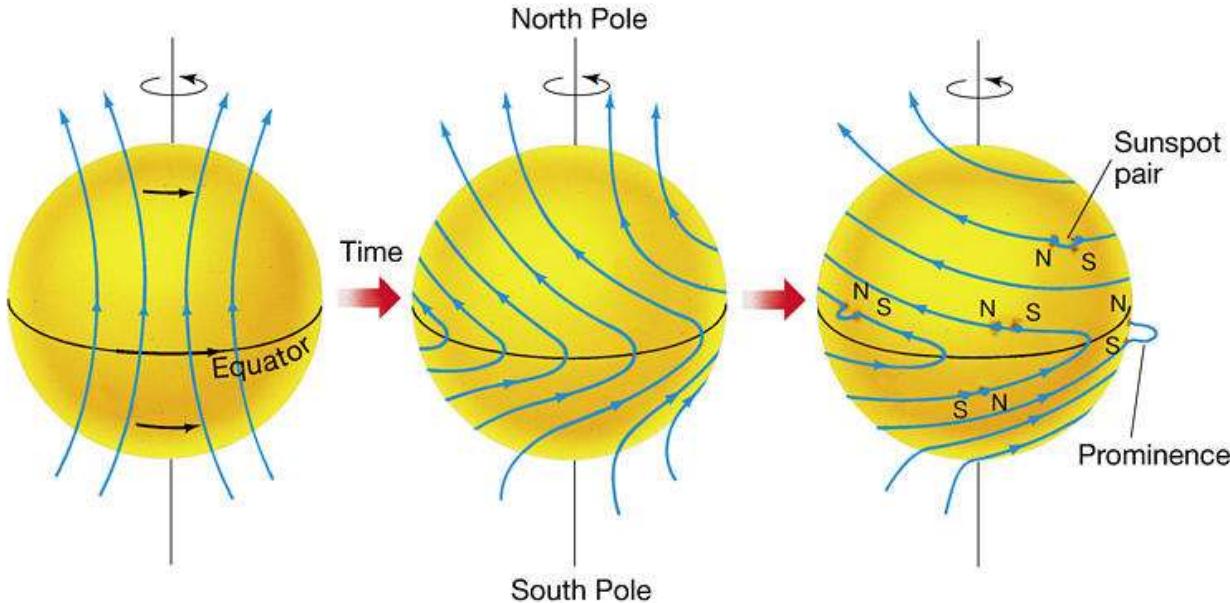
Rotación diferencial



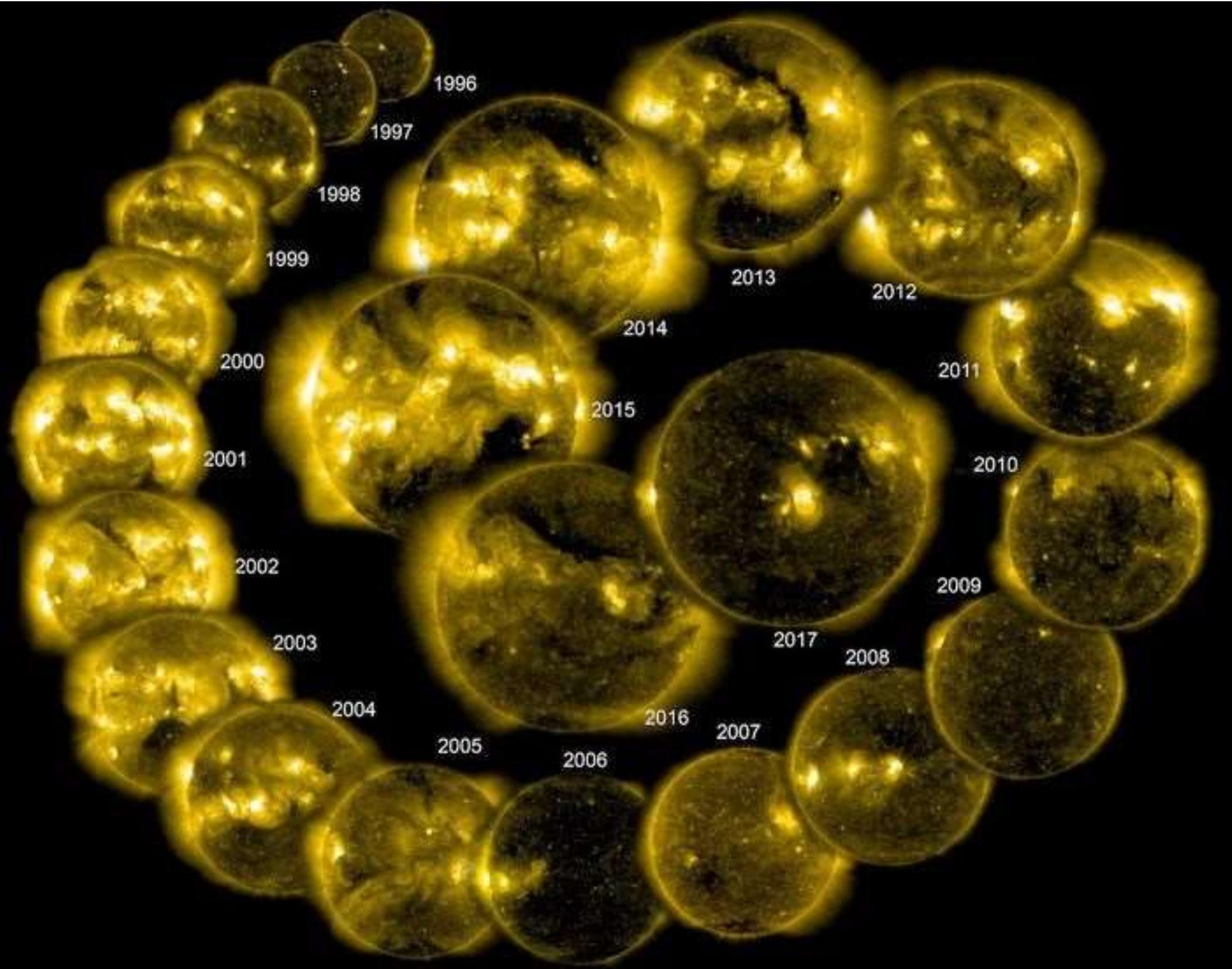
Campos magnéticos

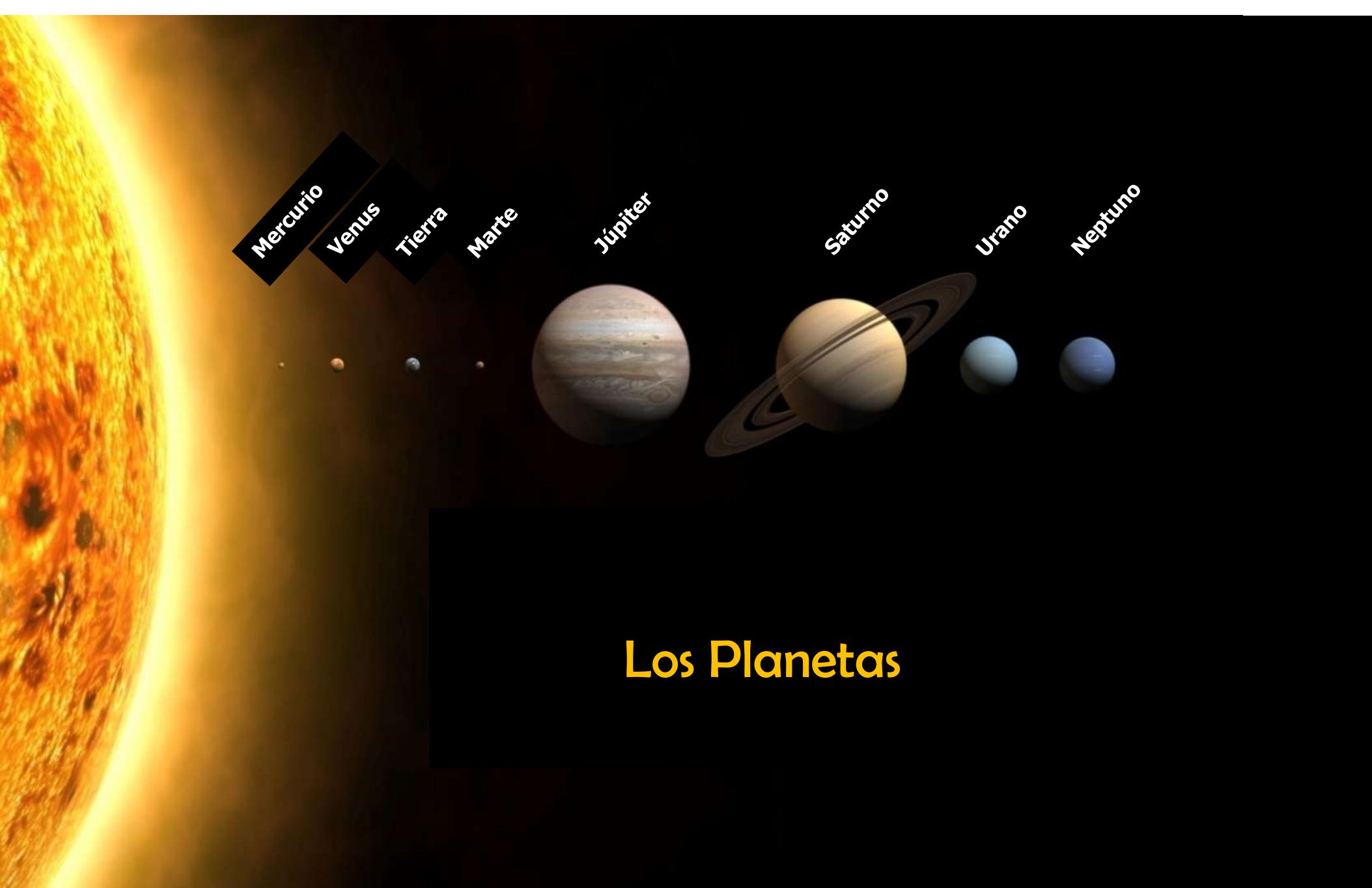


Zona convectiva



Dínamo





Sol
 $\varnothing = 1,400,000 \text{ km}$

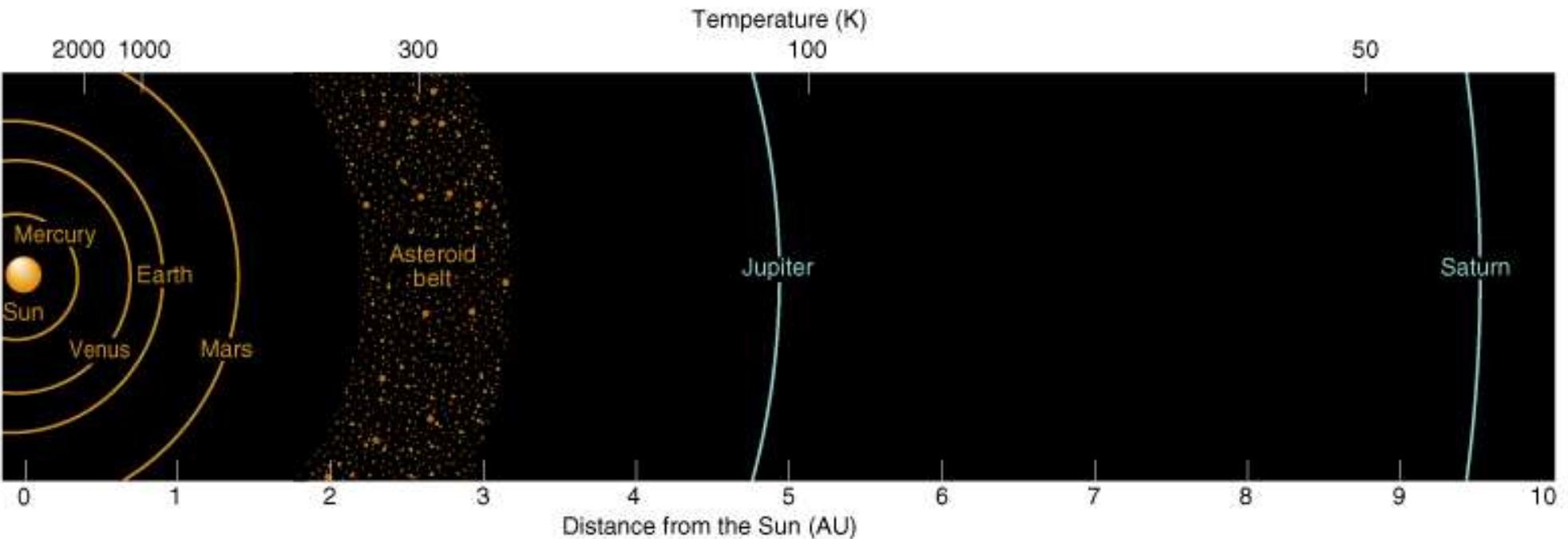
Mercurio
 $\varnothing = 4,879 \text{ km}$

Tierra
 $\varnothing = 12,756 \text{ km}$

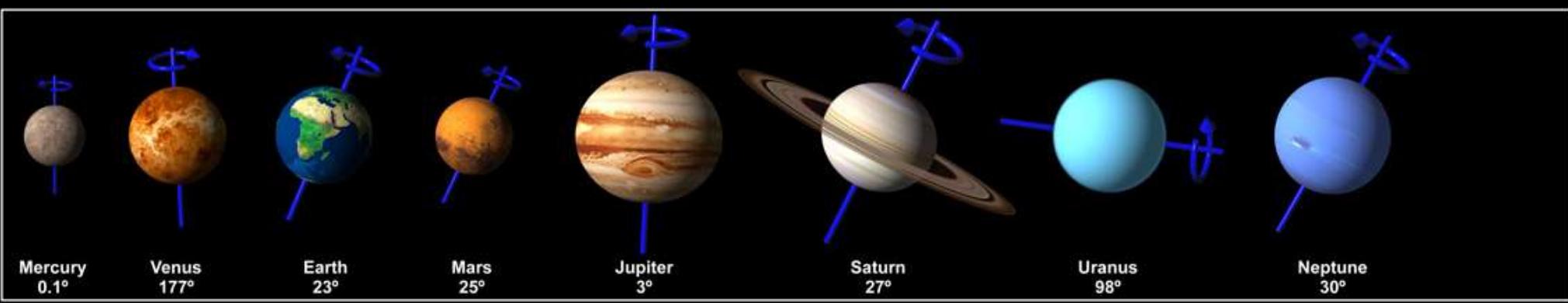
Júpiter
 $\varnothing = 142,984 \text{ km}$

Los Planetas

Temperatura y Orientación

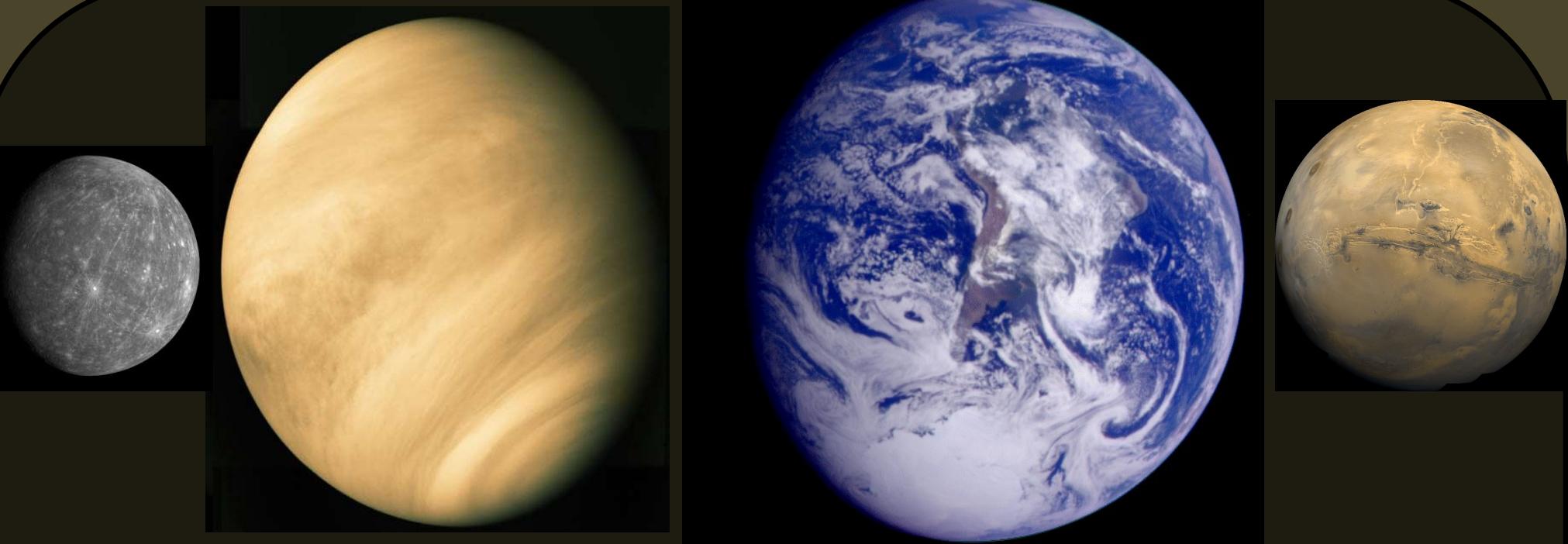


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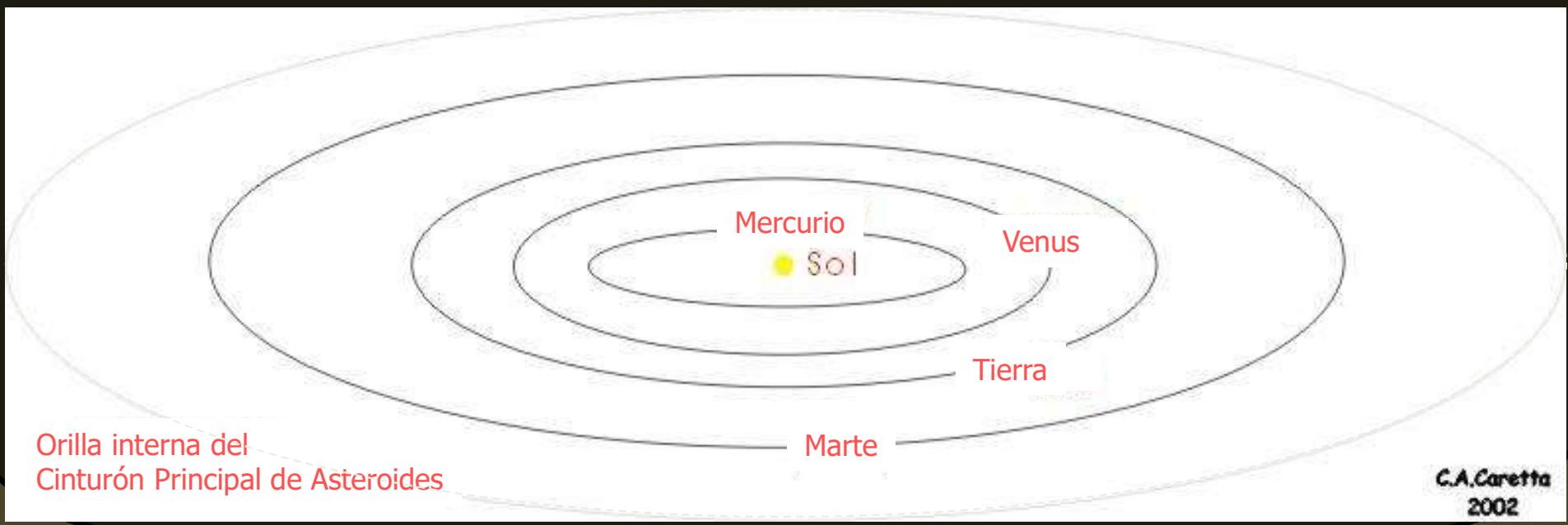


Obliquity of the Nine Planets

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2. Los Planetas Internos o Rocosos

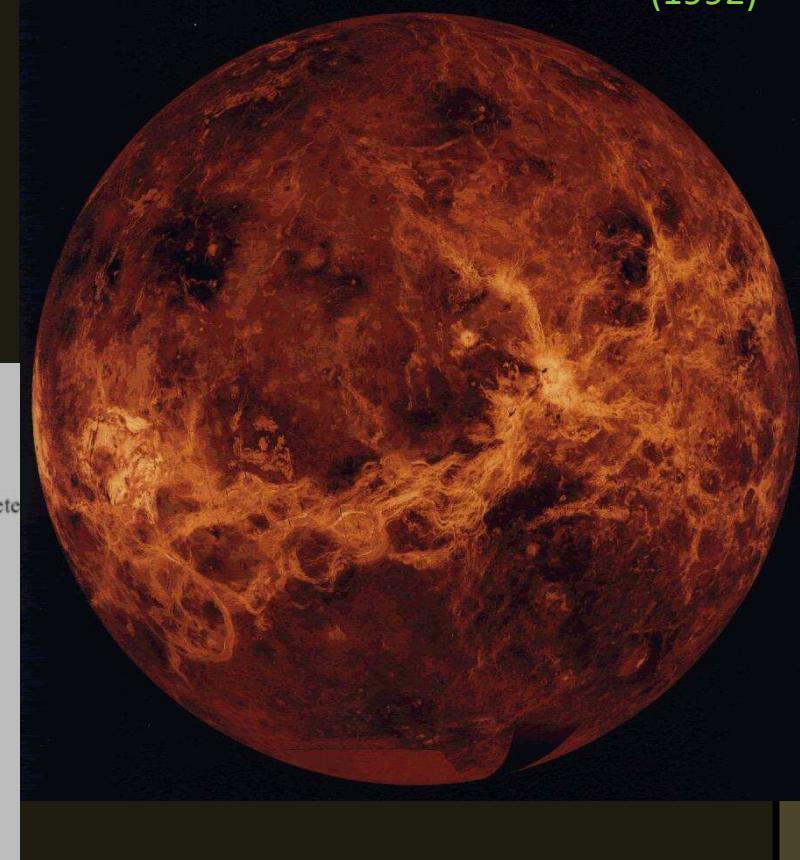
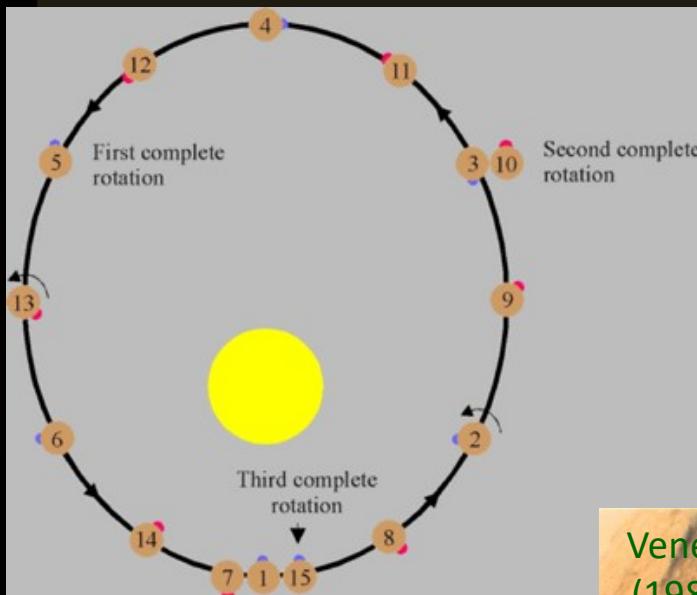


Rocosos Interiores: Mercurio y Venus

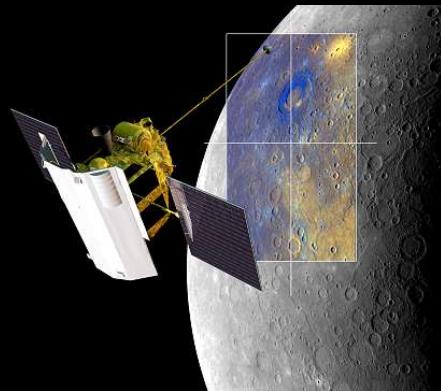
Magellan
(1992)



Transito de Mercurio
(2007)

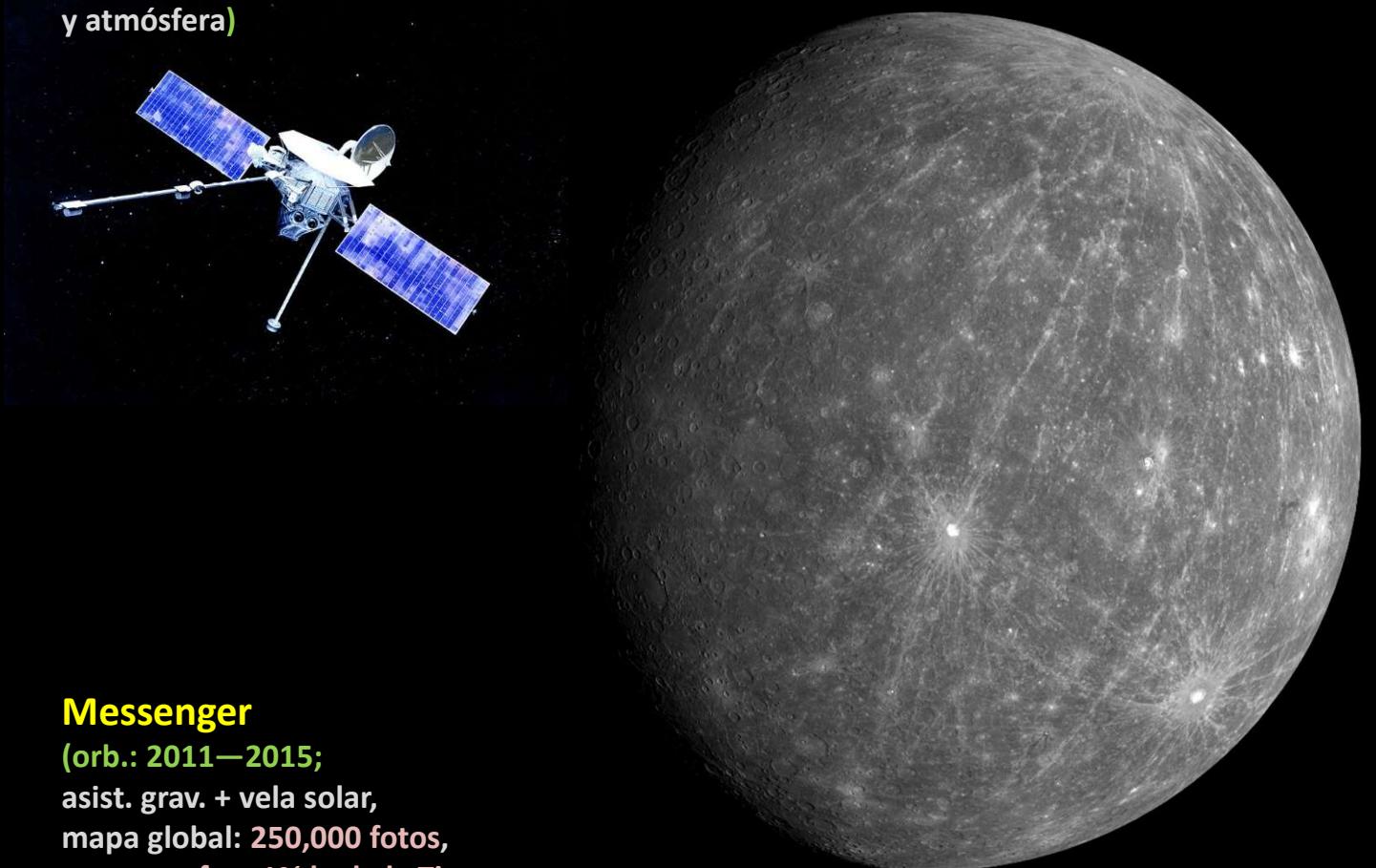


Mercurio



Messenger
(orb.: 2011—2015;
asist. grav. + vela solar,
mapa global: 250,000 fotos,
magnetosfera 1% la de la Tierra,
núcleo líquido de hierro,
hielo de agua en el polo norte,
elementos volátiles en la atm.: H, H₂, He, O, etc;
impacto: cráter Ø = 16m)

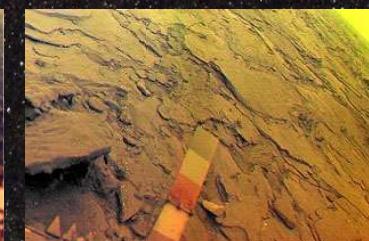
Mariner 10 (1974—1975; asist. grav. Venus,
paneles solares como vela solar,
3 flybys, cartografió 40-45%
de la superf., magnetosfera
y atmósfera)



Venus



Venera 13



Venera 14

■ **Programa Venera** (16: 1–16; 1961–1984;
*flybys, 1ér. poso, orbitador+modulo, T ~ 455–485°C,
CO₂ + N: 4% + nubes H₂SO₄, presión: 90 atm, fotos*)



■ **Programa Mariner** (4: 1, 2, 5, 10; 1962–
1973;
flybys, med. masa, campo magnético, asistencia)

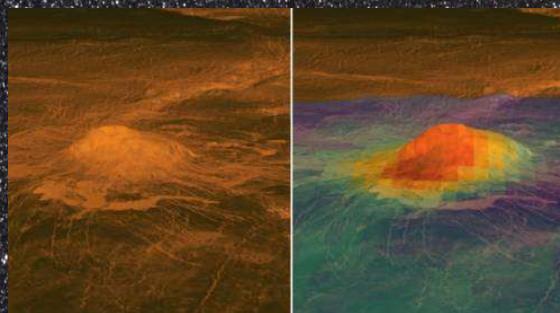


■ **Pioneer-Venus** (2: *orbiter: 1978–1992;
multiprobe, 1978, 4 sondas*)



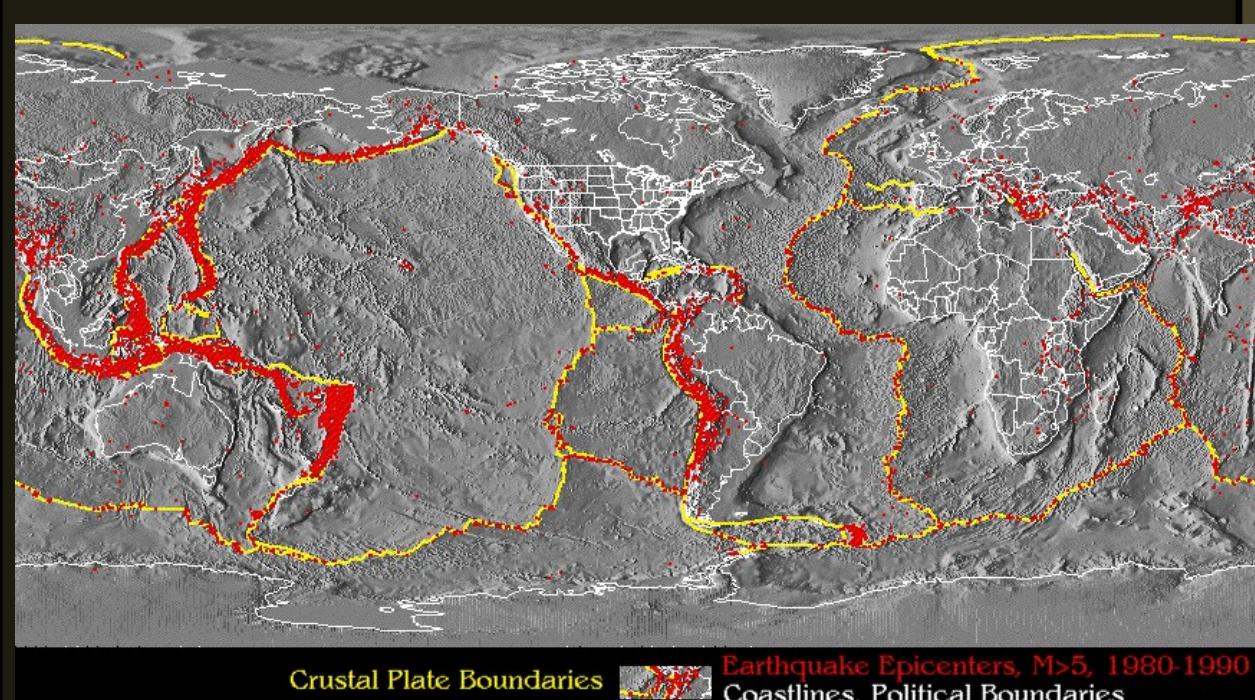
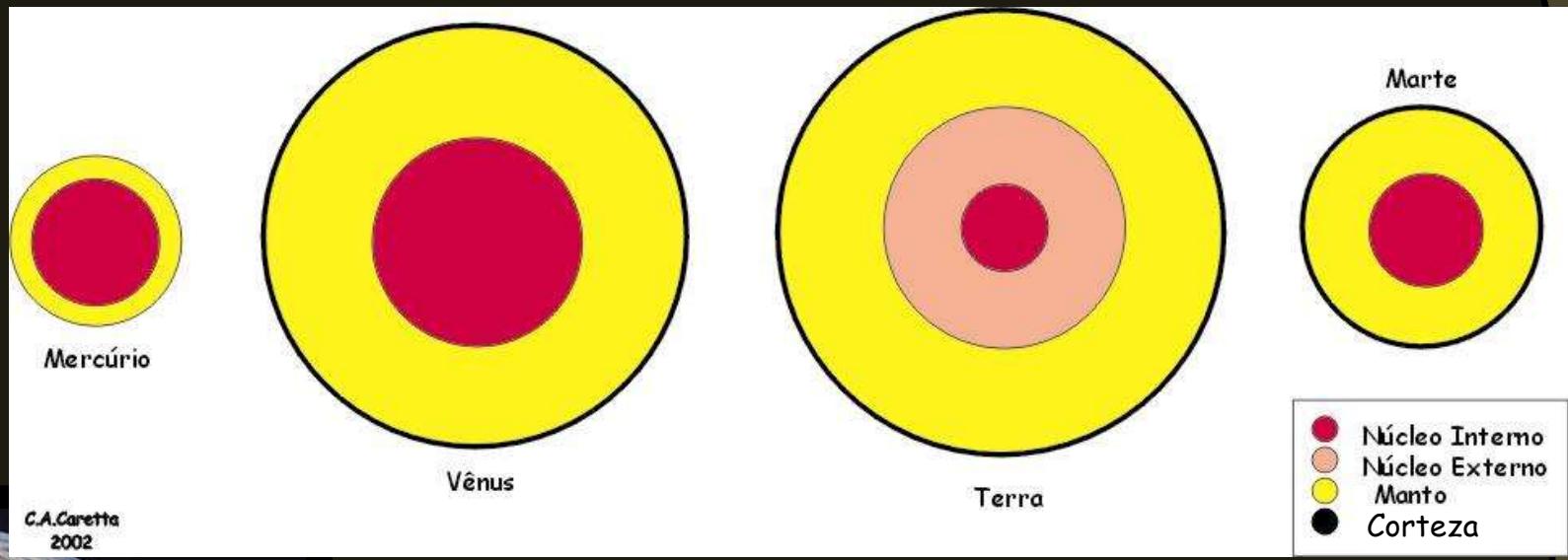
■ **Venus Express**
(orb.: 2006–2014)

■ **Magellan** (orb.: 1990–1994; cartografía
por radar, **volcanismo**
activo sin placas, pocos
cráteres de impacto)



■ **Akatsuki /
Planet-C** (lanz:
2010, *orbit insert.:*
2015–2018)

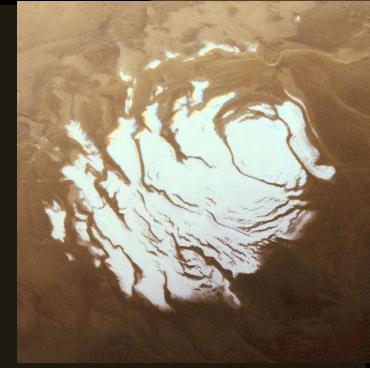
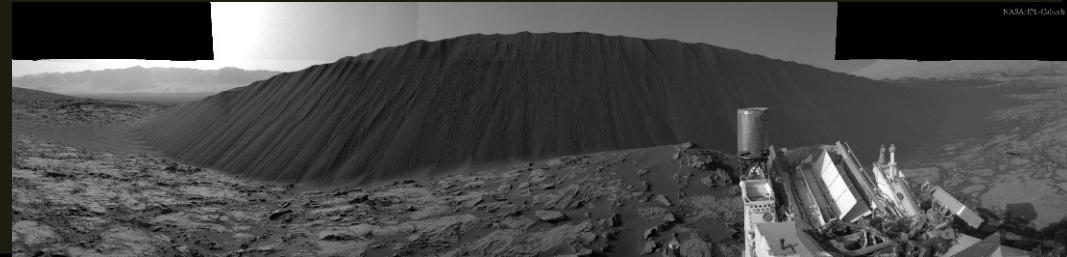
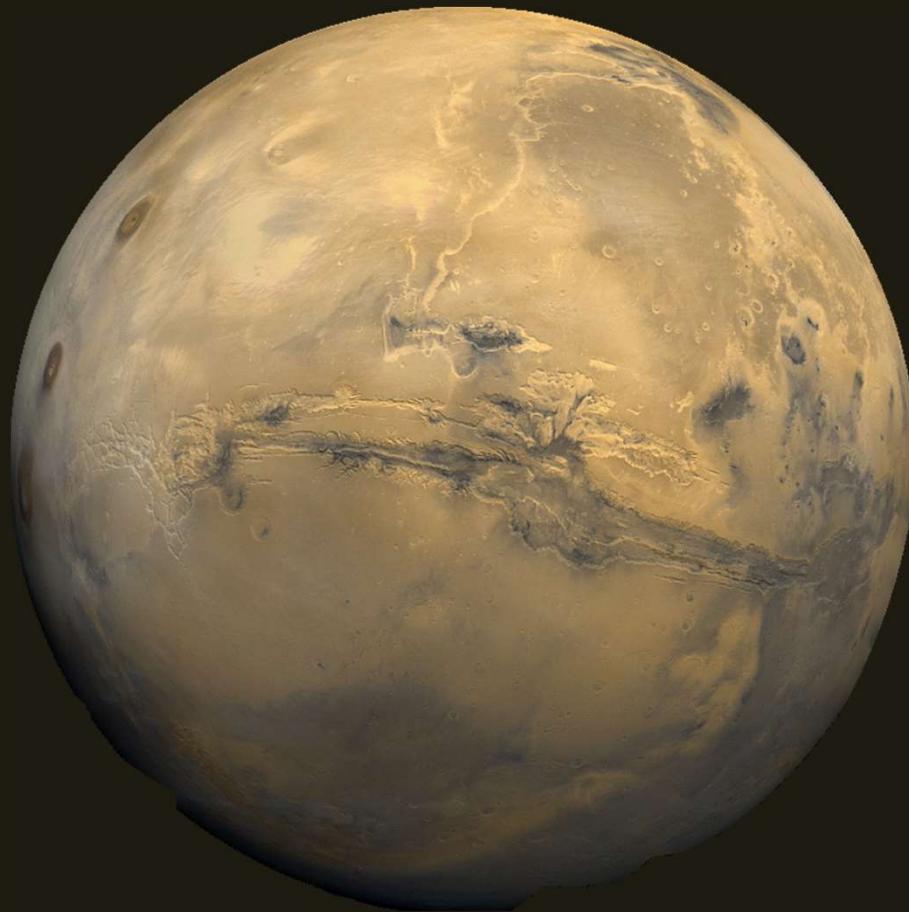
Rocosos: Tierra





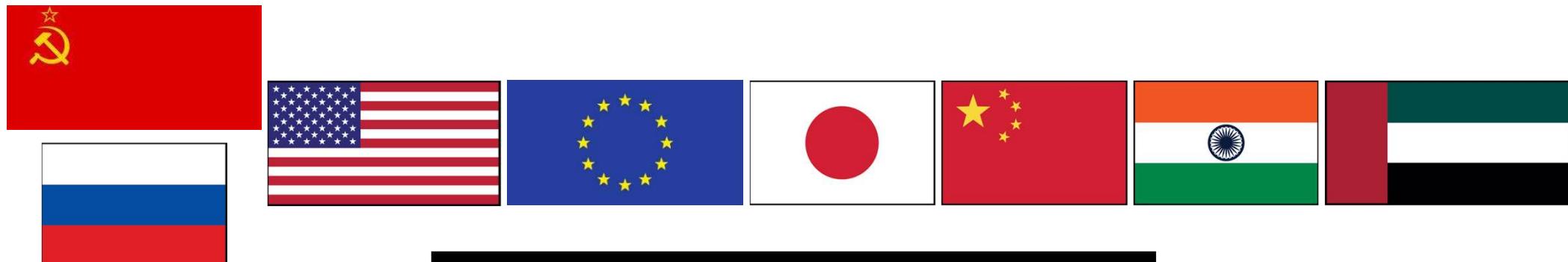
Phobos

Rocoso Exterior: Marte



Exploración espacial de Marte (sondas)

TIPO	Países	N (exitosos)	%
Flyby	Rusia (7), EUA (5), Europa (1)	13 (5)	38.5
Orbitadores	Rusia (6), EUA (10), Japón (1), Europa (2), China (2), India (1), Emiratos Árabes Unidos (1)	22 (13)	59.1
Amartizaje (<i>landers</i>)	Rusia (9), EUA (5), Europa (2), China (1)	16 (5)	31.3
Robots andariegos (<i>rovers</i>)	EUA (5), China (1)	6 (6)	100.0
Helicóptero	EUA (1)	1 (1)	100.0
TOTAL	7 países	¡58!	



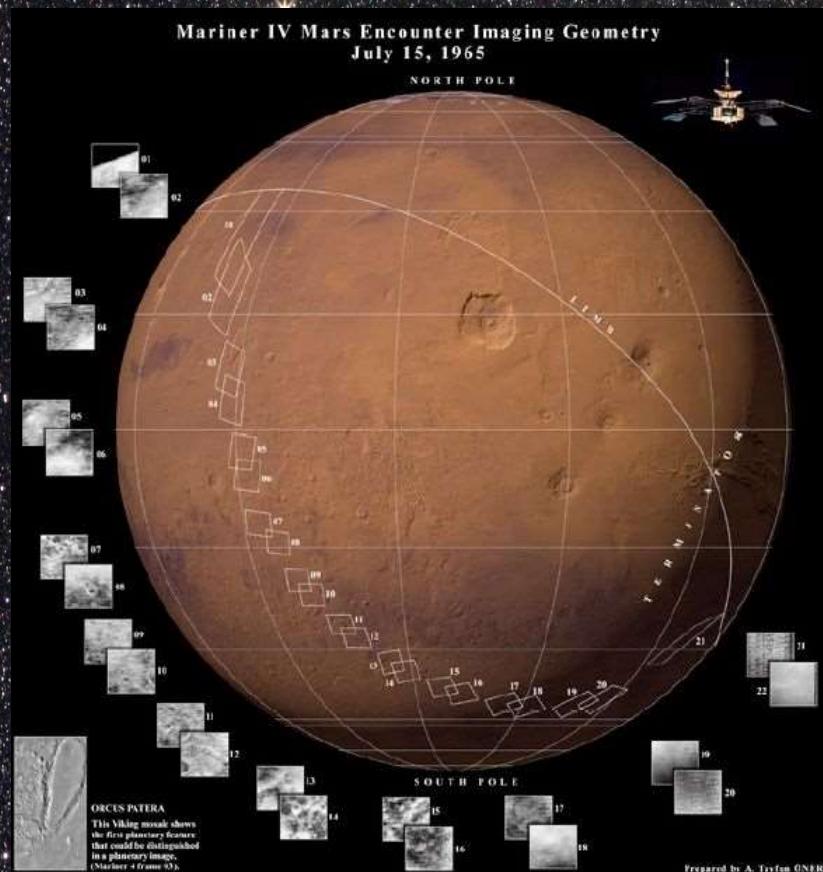
NASA's Perseverance Rover
Sees Solar Eclipse on Mars

■ Programa Mars (7: 1—7; 1962—1972;
3 fallos, flybys, 1er. amartizaje: Mars 3)

Flybys

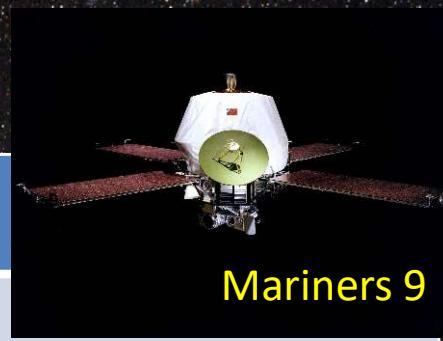
■ Programa Mariner (6: 3, 4, 6—9;
1964—1972;

2 fallos, flybys, 1er. orbiter de Marte y del
SS: Mariner 9)



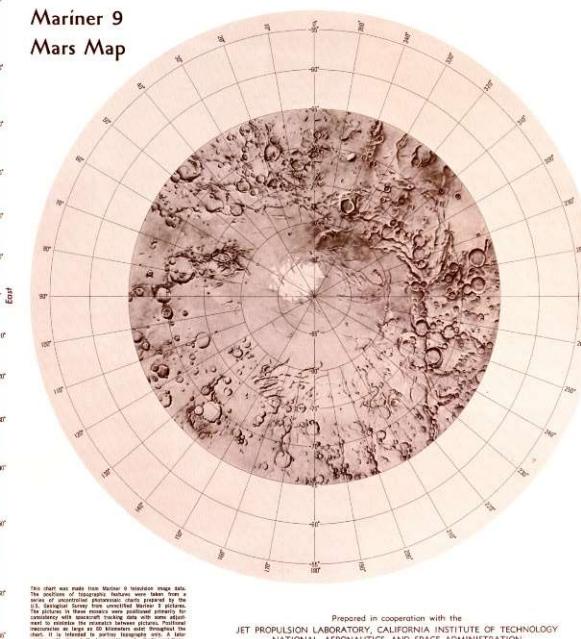
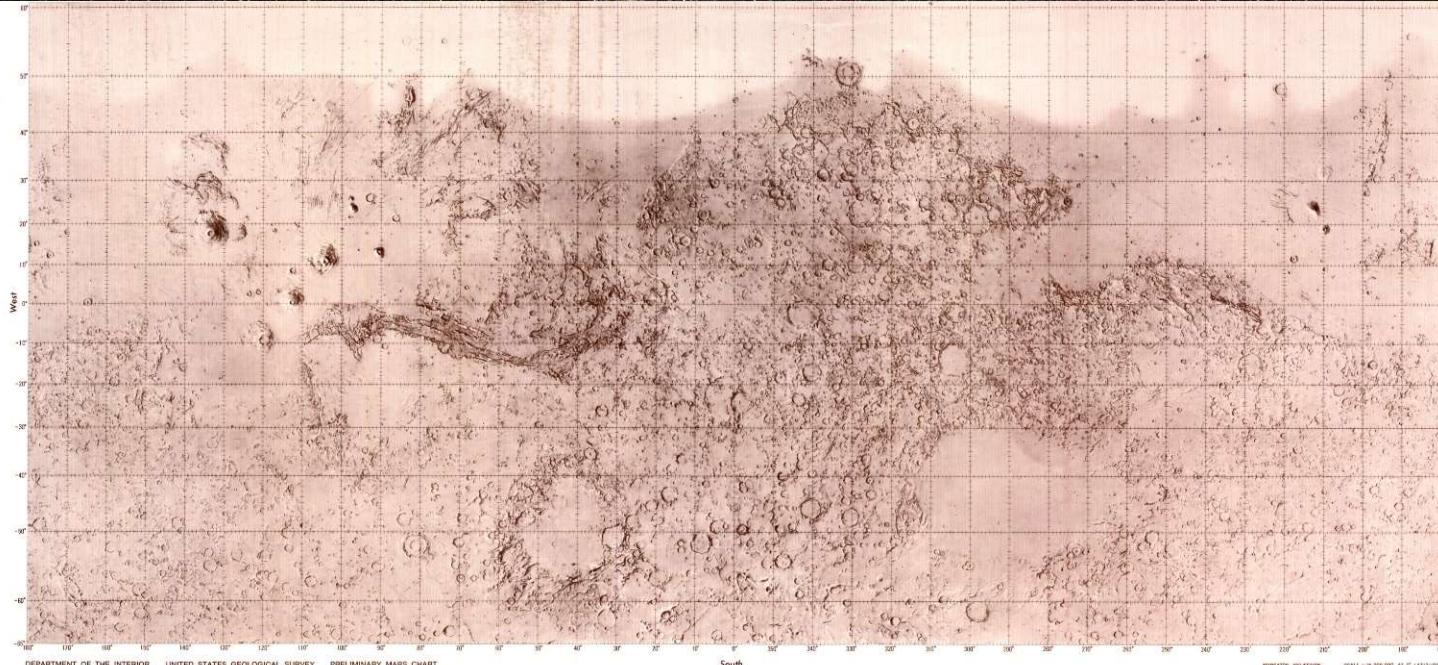
Inicio de la misión	Misión o Serie	N	País	Resultado
10, 14 oct 1960	Mars 1960A, B	2	URSS	✗
24oct, 04nov 1962	Sputnik 22, 24	2	URSS	✗
01 nov 1962	Mars 1	1	URSS	✗
05 nov 1964	Mariner 3	1	EUA	✗
28 nov 1964	Mariner 4	1	EUA	✓ 15jul65: 9,846 km (22 fotos)
30nov64, 18jul65	Zond 2, 3	2	URSS	✗✓
24 feb 1969	Mariner 6	1	EUA	✓ 31jul69: 3,431 km (75 fotos)
27 mar 1969	Mariner 7	1	EUA	✓ 05ago69: 3,430 km (126 fotos: Marte y Fobos)
02 mar 2004	Rosetta	1	ESA	✓ cometa 67P 25feb07: 250 km
27 sep 2007	Dawn	1	EUA	✓ Ceres/Vesta 18feb09: 542 km

Orbitadores



Mariners 9

Inicio de la misión	Misión o Serie	N	País	Resultado
27mar, 02abr 1969	Mars 1969 A, B	2	URSS	✗
09 may 1971	Mariner 8	1	EUA	✗
30 may 1971	Mariner 9	1	EUA	✓ 14nov71: en órbita (7,329 fotos)
21 jul 1973	Mars 4	1	URSS	✗✓ 10feb74: flyby a 2,200 km (20 fotos)
25 jul 1973	Mars 5	1	URSS	✓ 12feb74: órbita por 9 días (60 fotos)
20ago, 09sep 1975	Viking Orbiter 1, 2	2	EUA	✓ 19jun76—07ago80 (~ 37,000 fotos) ✓ 07ago76—27jul78 (~ 19,000 fotos)



 **Mars Global Surveyor** (1996—2006;
orbitador, imágenes, campo magnético)

 **Mars Odyssey** (2001—;
Orbiter: activo, comunicación, mapeo de agua)

 **Nozomi / Planet-B** (1998—2003;
fallo; mal uso de combustible, no alcanzo órbita
en Marte, órbita heliocéntrica)

Inicio de la misión	Inserción orbital	Misión o Serie	Agencia /País	Resultado
25sep1992	-	Mars Observer	NASA	✗ contacto perdido durante el viaje
07nov1996	12sep1997	Mars Global Surveyor (MGS)	NASA	✓ activa por 10 años, hasta 02nov06 (240,000 fotos alta resol.)
16nov1996	-	Mars 96	Roscosmoc	✗ no alcanzó dejar la órbita terrestre
03jul1998	-	Nozomi (Planet-B)	JAXA	✗ tardó 4 años para llegar solo cerca de Marte
11dic1998	-	Mars Climate Orbiter	NASA	✗ destruida en la atmósfr. de Marte (SI ✗ unidades AS)
07abr2001	24oct2001	Mars Odyssey	NASA	✓ sigue activa (estudio del clima y enlace con robots)
02jun2003	25dic2003	Mars Express + Beagle 2	ESA	✓ sigue activa; ✗ <i>lander</i> Beagle 2 no amartizó
12ago2005	17oct2006	M. Reconnaissance Orbiter (MRO)	NASA	✓ sigue activa (mapeo de alta resolución de la superficie – camera HiRISE)

 **Mars Express / Beagle 2** (2003—2009;
Orbitador: OK, *Beagle 2*: falló al amartizar)

 **Mars Reconnaissance Orbiter** (2006—;
geología, monitoreo del clima, presencia de agua,
sitios de poso potenciales)

 **MAVEN** (2013—; orbitador)

 **ExoMars Trace Gas Orbiter, TGO**
(+ Schiaparelli ✗)

(2016 oct — ; Orbitador: pérdida de agua,
Schiaparelli: fallo al amartizar,
nuevo *rover* será lanzado en 2022)

 **Mangalyaan** (M.O.M.= Mars Órbiter Mission; 2014 sep — ; 6 órbitas en la Tierra, cartografía, atmósfera, Phobos 1er. agencia que llegó a Marte en el 1er. intento!)



Inicio de la misión	Inserción orbital	Misión o Serie	Agencia /País	Resultado
08nov2011	-	Yinghuo-1	CNSA	✗ lanzamiento no exitoso (junto con Fobos-Grunt)
05nov2013	24sep2014	Mangalyaan (MOM)	ISRO	✓ camera, análisis atmósf. (CH_4 , H, etc), espectros IR
18nov2013	22sep2014	MAVEN	NASA	✓ análisis de la volatilización de la atmósfera (activa)
14mar2016	19oct2016	Exo Mars TGO + Schiaparelli EDM	ESA + Roscosmos	✓ análisis atmosférica (<i>Trace Gas Orbiter</i>); ✗ <i>lander</i> Schiaparelli destruido durante amartizaje
19jul2020	09feb2021	al-Amal (Hope)	Em. Árabes Un.	✓ estudio del clima marciano
23jul2020	10feb2021	Tianwen-1	CNSA	✓ cameras, magnetómetro, espectrómetro, topografía



 **Al Amal (Emirates Mars Mission "Hope")**
(2021 feb 09: inserción orbital; *Orbiter*)

 **Tianwen-1** (2021 feb 10: inserción orbital;
Polar orbiter, Lander y *Rover*, en proceso)



Amartizajes

Vikings 1 y 2

¼ positivo (metabolismo),
pero no concluyente

 **Programa Viking (2: 1, 2;**

1975—1982;

Vorbiter: cartografía, comunicación con la Tierra;

+ *Vlander*: 1er: estudio biológico y molecular del suelo:

$\text{CO}_2 + \text{N}$: 6%, O_2 : 0.3%; análisis biológicas inconclusas;

T: -85 a -29°C; presión 6 mbar; imágenes meteorológicas)



Inicio de la misión	Misión o Serie	Amartizaje	País	Resultado
10may1971	Cosmos 419		URSS	✗ fallo en el lanzamiento
19may1971	Mars 2		URSS	✗ fallo en el amartizaje
28may1971	Mars 3		URSS	✓ amartizo suavemente, pero perdió contacto después
05, 09 ago1973	Mars 6, 7		URSS	✗ fallo en el amartizaje
07, 12 jul1988	Fobos 1, 2		URSS	✗ sondas perdidas durante el viaje
20ago1975	Viking Lander 1	20Jul1976	NASA	✓ ~2,300 fotos, espectr. masa (13nov82: fallo humano)
09sep1975	Viking Lander 2	04sep1976	NASA	✓ ~2,250 fotos/vídeos, anal. biológ. (13nov82: ídem)
03ene1999	Mars Polar Lander + Deep Space 2	-	NASA	✗ perdida en el amartizaje (<i>lander</i> + 2 microondas)



Phoenix (lander: 2008 may—dic;

- sublimación de hielo de agua sub-superficial,
- pH: alcalino 8-9,
- nieve que se sublimó antes de llegar al suelo,
- carbonato de calcio)

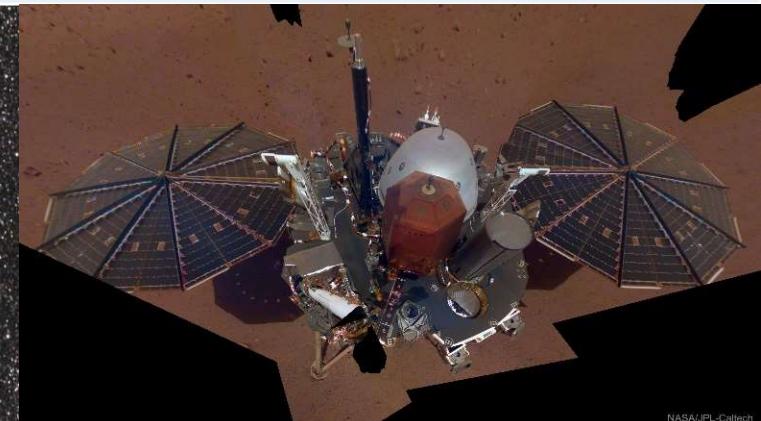


Inicio de la misión	Misión o Serie	Amartizaje	País	Resultado
02jun2003	Beagle 2	-	Reino Unido	✗ perdido durante amartizaje (<i>lander</i>)
04ago2007	Phoenix	25may2008	NASA	✓ cerca del Polo Norte (hasta 25 may 2010)
08nov2011	Fobos-Grunt	-	Роскосмос	✗ lanzamiento no exitoso (muestras de Fobos)
14mar2016	Schiaparelli EDM	-	ESA + Роскосмос	✗ estrelló en Marte el 19 oct 2016
05may2018	Insight + Mars Cube One	26nov2018	NASA	✓ investigaciones sísmicas y geodesía (termómetro, taladro, etc): detectó martemotos (<i>Elysium Planitia</i>)
23jul2020	Tianwen-1	15may2021	CNSA	✓ amartizó el 15may2021



Mars Insight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) (2018 nov —;

- actividad tectónica (SEIS): **martemotos** (más de 200 hasta ahora),
- clima: temperatura, vientos, presión y campo magnético local,
- taladro (HP³, apodado “mole”) no logra avanzar mucho (solo 2-3 cm): suelo muy duro)





Sojourner



Rovers



Spirit

Opportunity

Inicio de la misión	Misión o Serie	Amartizaje	Último contacto	Agencia /País	Resultado
04 dic 1996	Sojourner (Mars Pathfinder)	04 jul 1997	27 sep 1997	NASA	✓ lander (<i>Carl Sagan Memorial Station</i>) + rover (<i>Sojourner Truth</i> , abolicionista/ativista der. mujeres), en <i>Chryse Planitia (Oxia Palus)</i>
10 jun 2003	Spirit (MER-A)	04 ene 2004	22 mar 2010	NASA	✓ Cráter Gusev ()
07 jul 2003	Opportunity (MER-B)	25 ene 2004	10 jun 2018	NASA	✓ Meridiani Planum ()
26 nov 2011	Curiosity (MSL)	06 ago 2012	en actividad	NASA	✓ Cráter Gale ()
23 jul 2020	Tianwen-1	15 may 2021	en actividad	CNSA	✓ Utopia Planitia
30 jul 2020	Perseverance (Mars 2020)	18 feb 2021	en actividad	NASA	✓ Cráter Jezero (cameras, vídeos y movimiento exitosos)



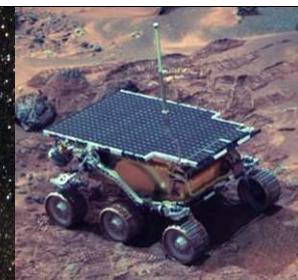
Curiosity



Perseverance



Zhurong



🇺🇸 **Mars Pathfinder / Sojourner** (1996—1997;
1er. *rover* en Marte, bolsas de amortiguamiento para amartizaje,
estudio de las rocas, atmósfera y clima, 16,500 imágenes)

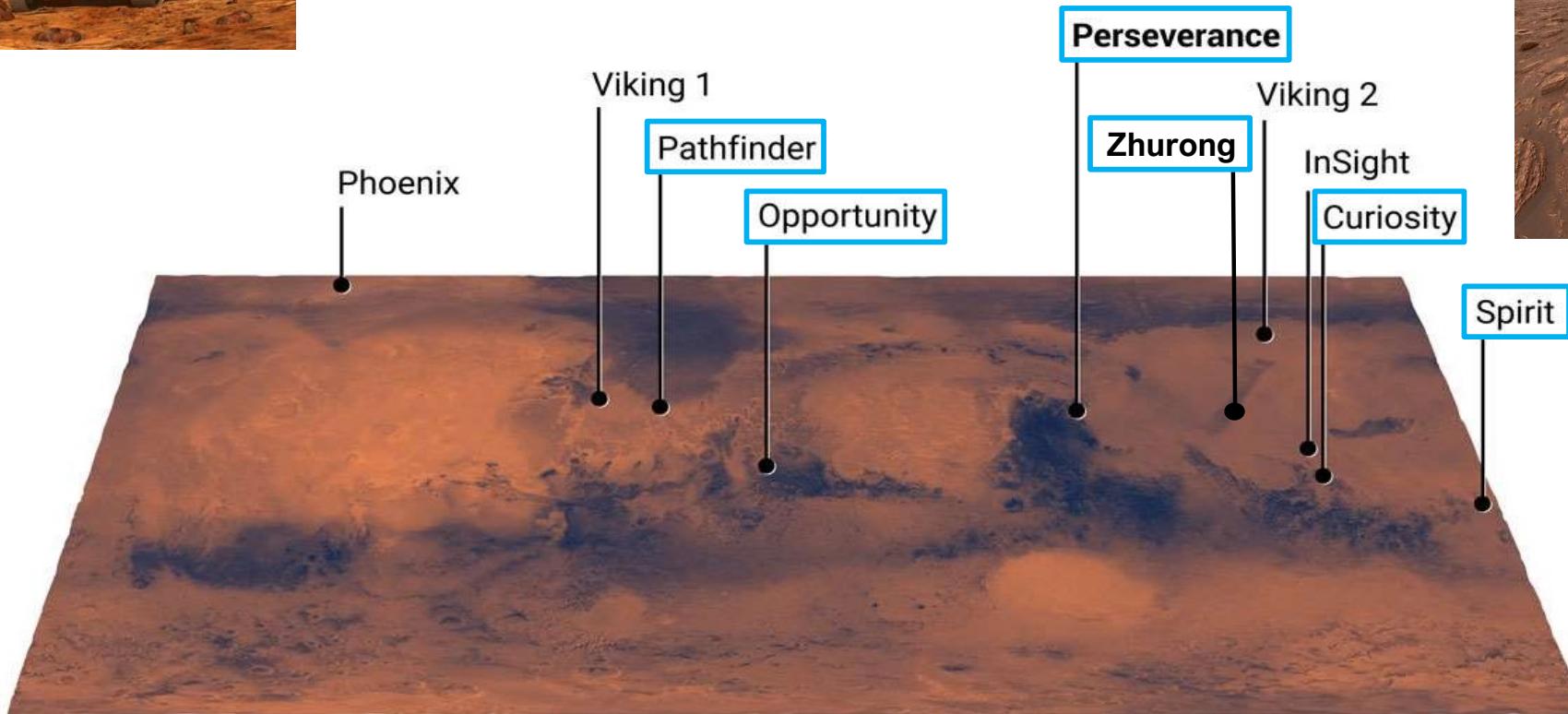
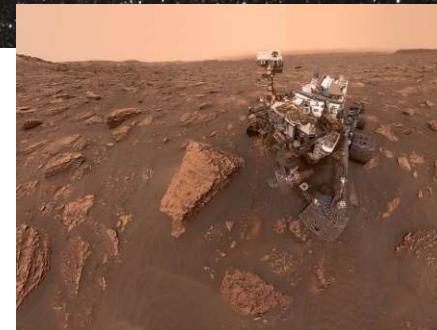
🇺🇸 **Mars Odyssey** (2001—; /
M.E.R.: Spirit + Opportunity (2004—;
Orbiter: activo, comunicación, mapeo de agua;
Spirit: activo hasta 2010, carbonatos y
agua dulce, tempestades de arena;
Opportunity: activo, muchas evidencias de
agua líquida en el pasado)

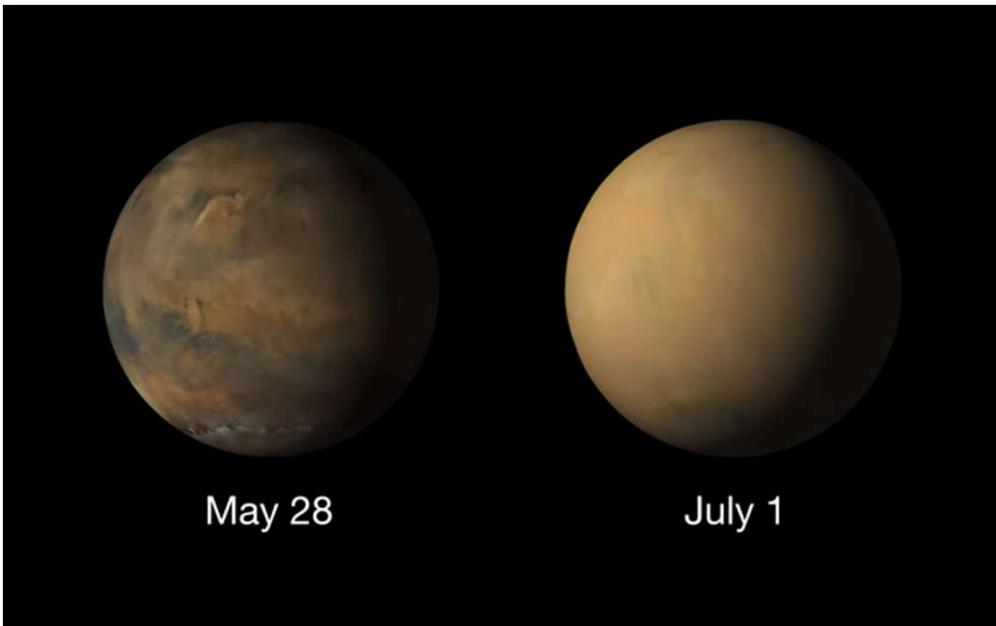


🇺🇸 **Mars Science Lab. / Curiosity** (2012—; clima, geología,

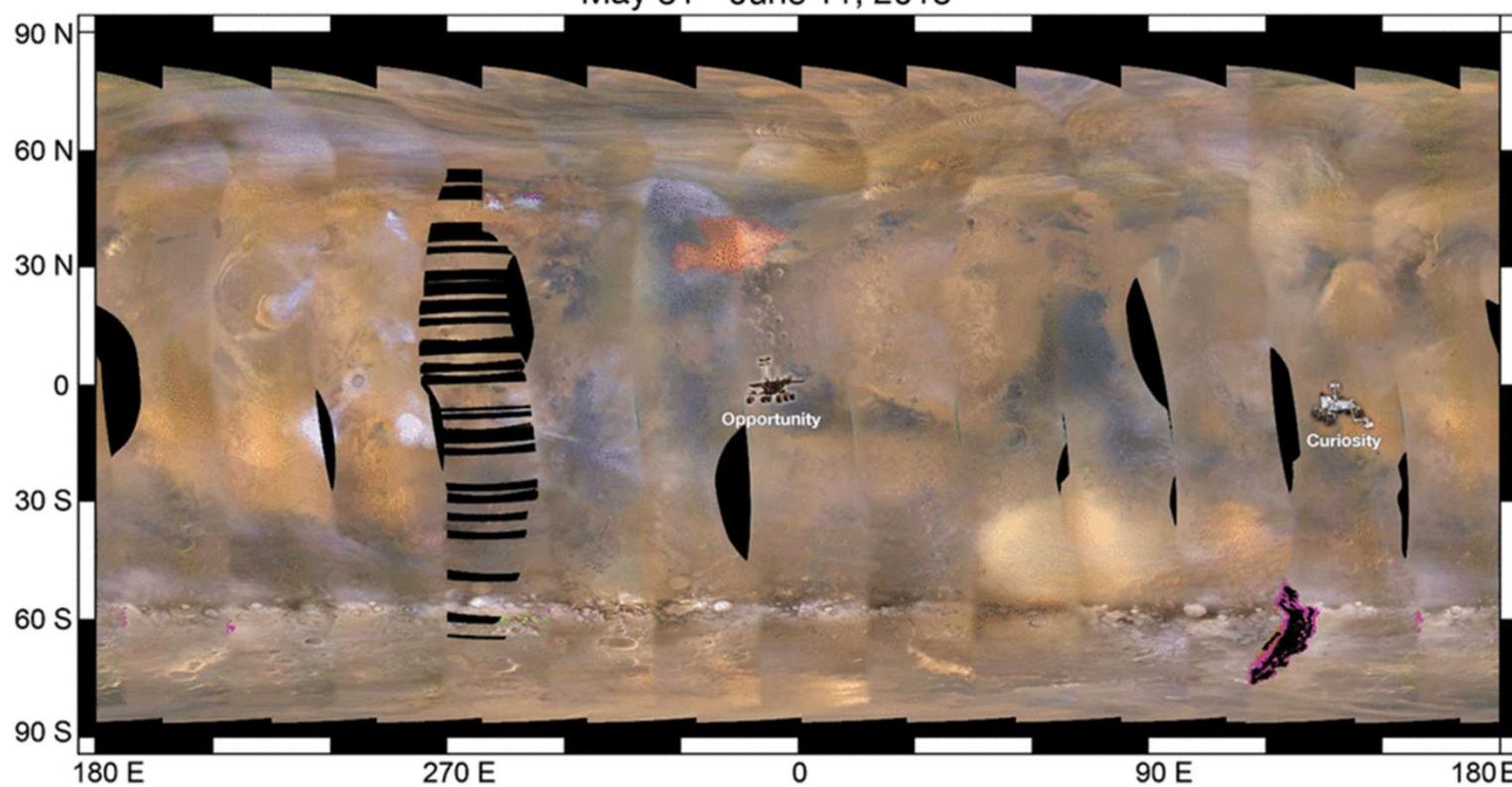
análisis biológicos:

- 2013 -- hay condiciones, en las rocas, para vida microbiana:
 H_2O , CO_2 , O_2 , SO_2 , H_2S ; sulfuro de H, CH_3Cl : clorometano,
 CH_2Cl_2 : DCM
- 2015 – **NO**: óxido nítrico, **clorobenceno**; 2017 – **B**: boro,
- 2018 – ciclo estacional de CH_4 , mol. organ. con S: **tiofeno**,
aromáticos: **benceno, tolueno**, alifáticos: **propano, buteno**)





May 31 - June 11, 2018



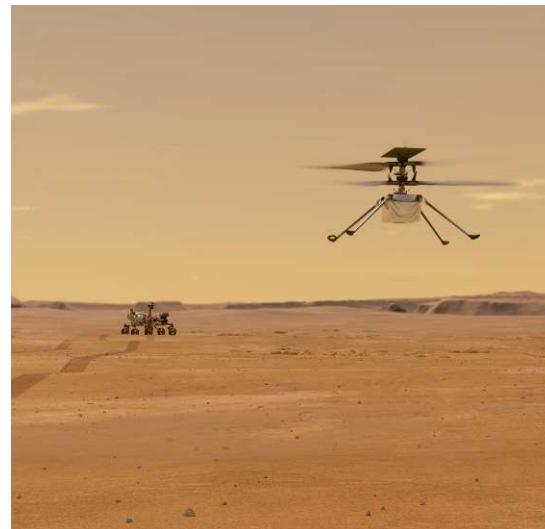


Helicóptero robótico

Inicio de la misión	Misión o Serie	Amartizaje	Primer vuelo	Agencia/ País	Resultado
30 jul 2020	<i>Ingenuity</i> (Mars 2020)	18 feb 2021	19 abr 2021	NASA	✓ 28 vuelos exitosos entre 19abr21 y 29abr22 ($d_{\max} = 704 \text{ m}$, $h_{\max} = 12 \text{ m}$, $t_{\max} = 2^{\min} 49.5^s$).

Características del *Ingenuity*:

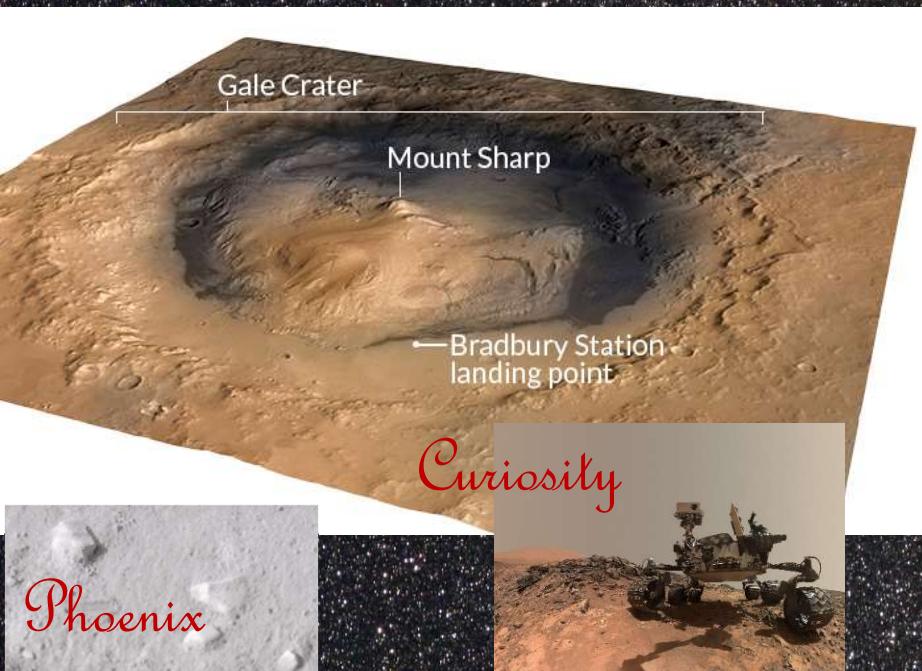
- Peso: 1.8 kg
- Altura: 80 cm, ancho: 1.2 m
- Baterías: 350 W (íones de Li, cargada por panel solar)
- Instrumentos: 2 cameras (color, alta resolución)
- Misión: demostración tecnológica
- Duración prevista:
 - ~ 30 soles ~ 5 vuelos
 - ~ 3 min. cada
 - altitud 3—10m cada
 - dist. máx. ~ 300m cada



Retos:

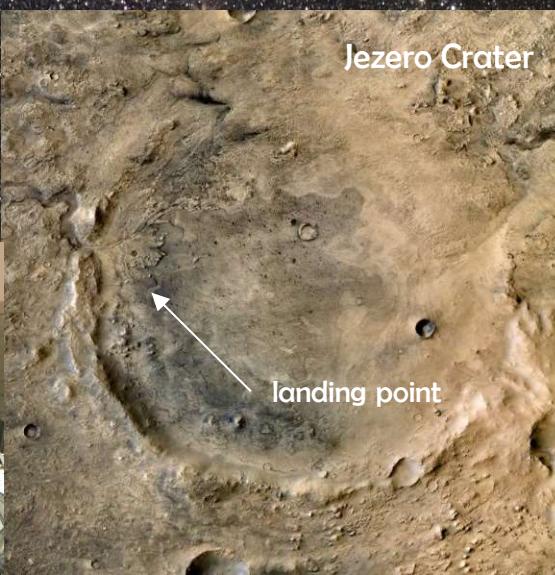
- Gravedad: ~ 1/3 de la terrestre
- Presión atmosférica: ~ 1 % de la terrestre
- Temperatura (noche): ~ -90 °C

Experimentos para detectar vida

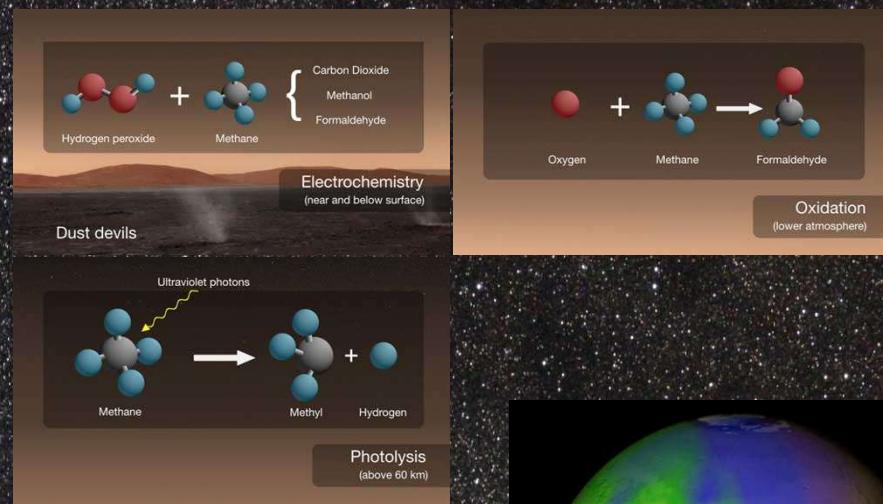
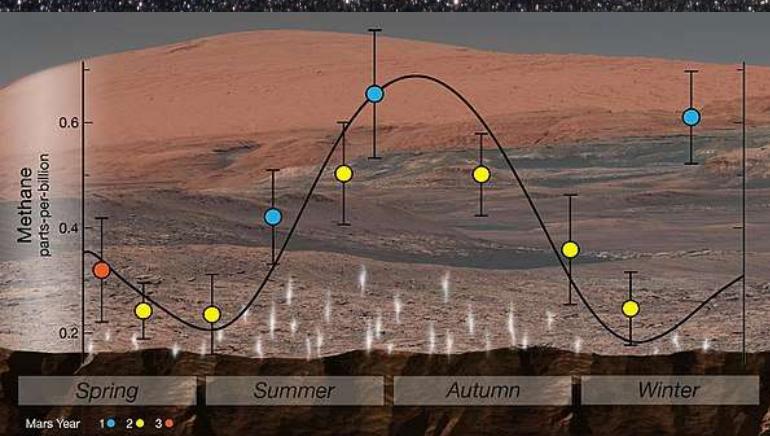


Panorama del pasado:

- búsqueda de agua
- búsqueda de biofirmas en el suelo y rocas
- búsqueda de biomarcadores atmosféricos

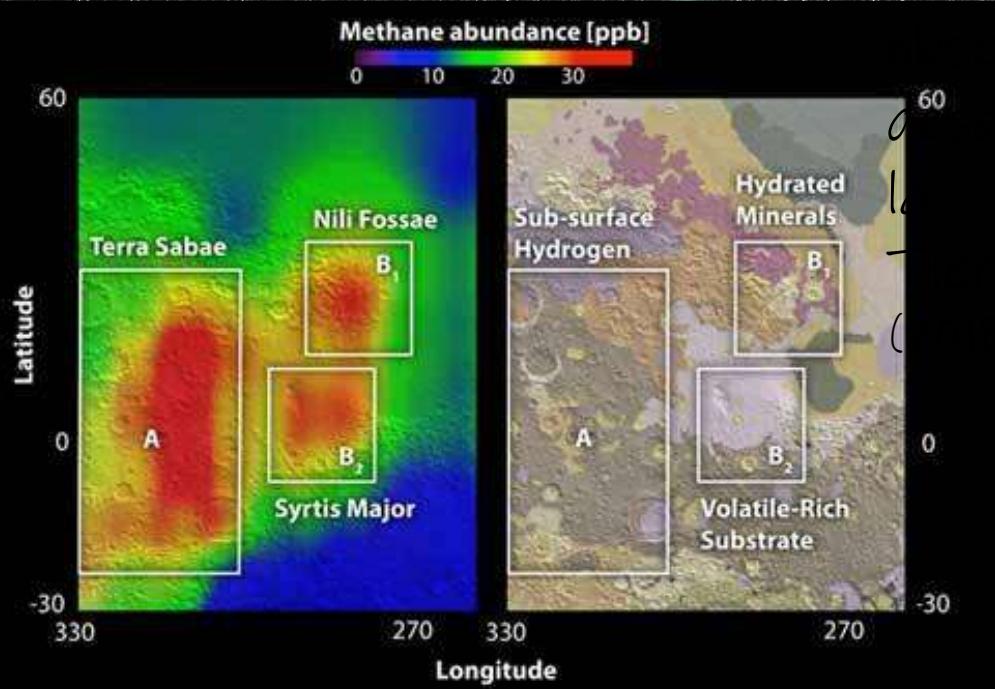
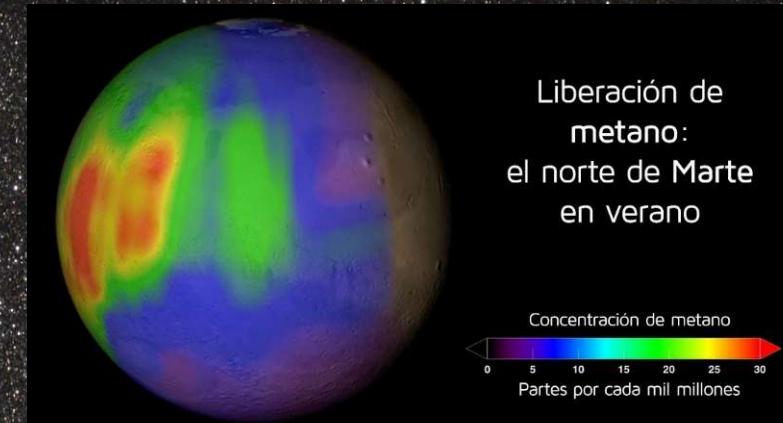


CH_4 estacional (Curiosity, 2018)



Metano

Liberación de metano:
el norte de Marte
en verano

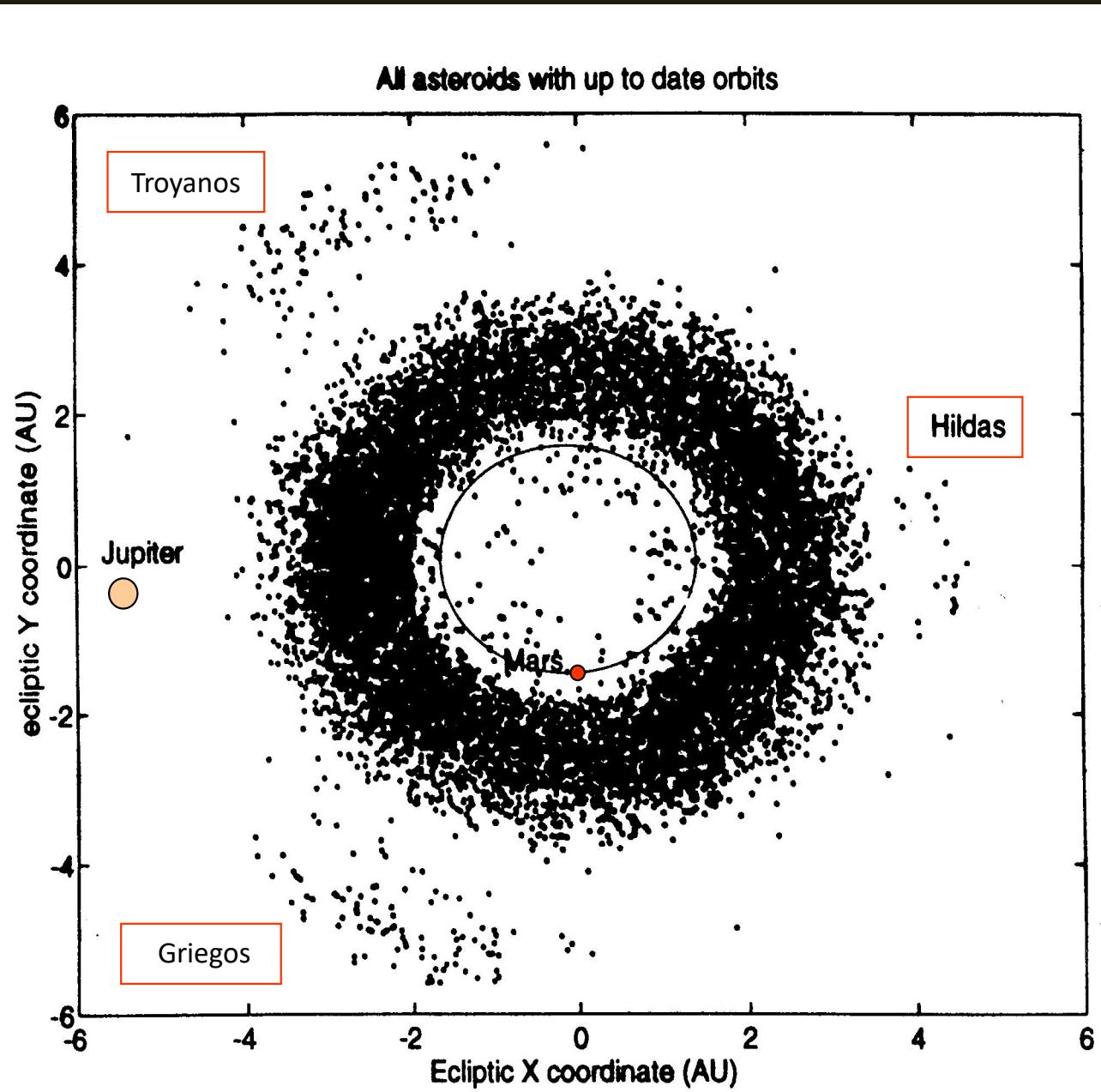


Observaciones e

Panorama actual:

- radiación ionizante (UV, rayos cósmicos, etc)
- percloratos tóxicos en el suelo
- extremadamente seco (excepto polos y permafrost)
- fluctuaciones diurnas extremas de temperatura
- atmósfera de CO_2 y con baja presión
- ...

3. El Cinturón Principal de Asteroides



The four largest asteroids



Ceres

939 km



Vesta

525 km



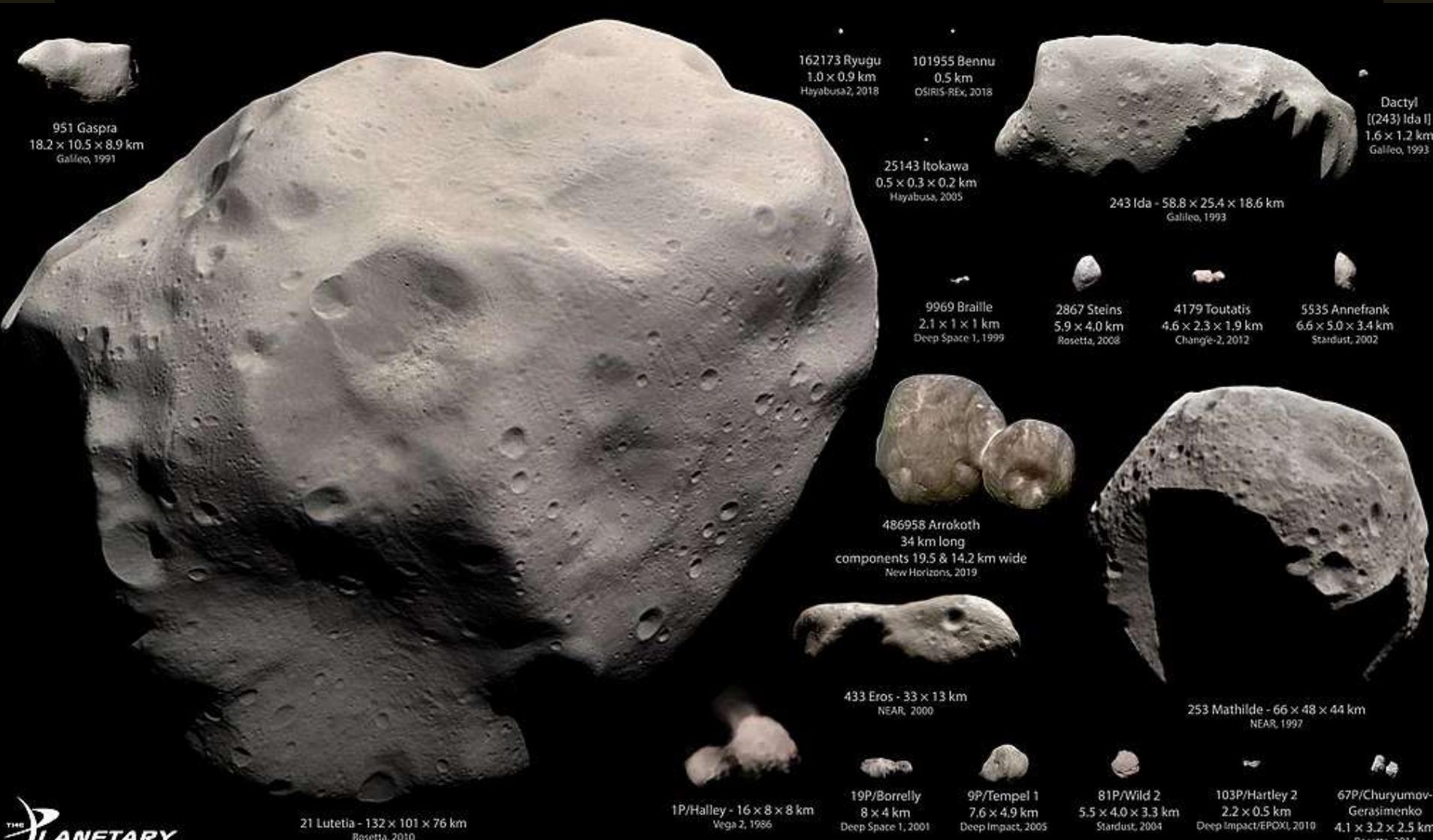
Pallas

512 km

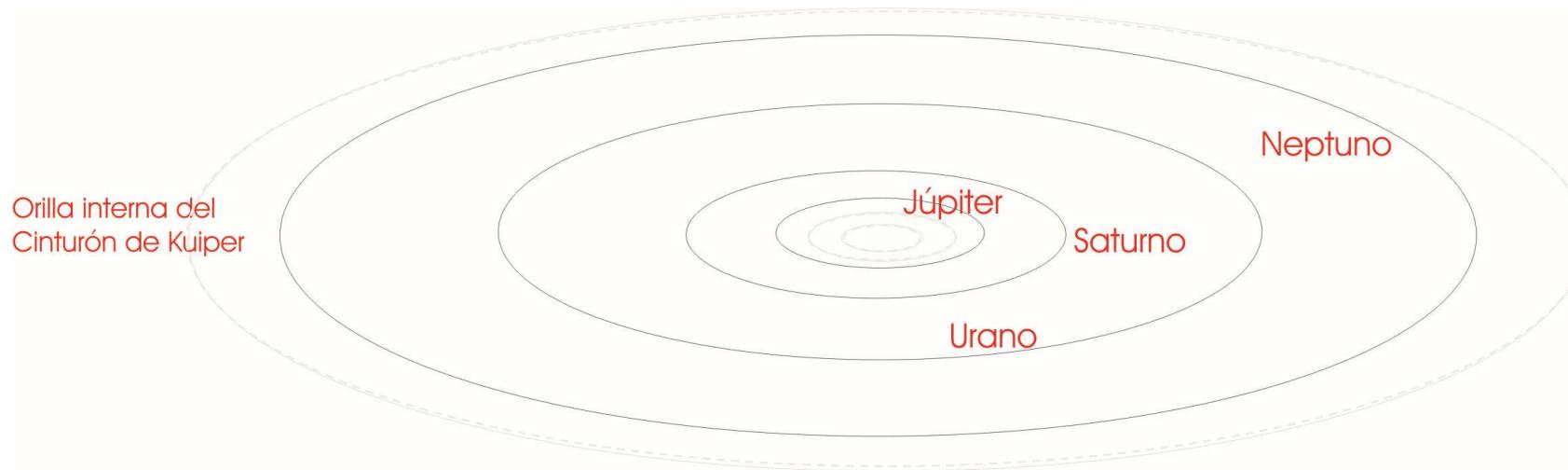
Hygiea

434 km

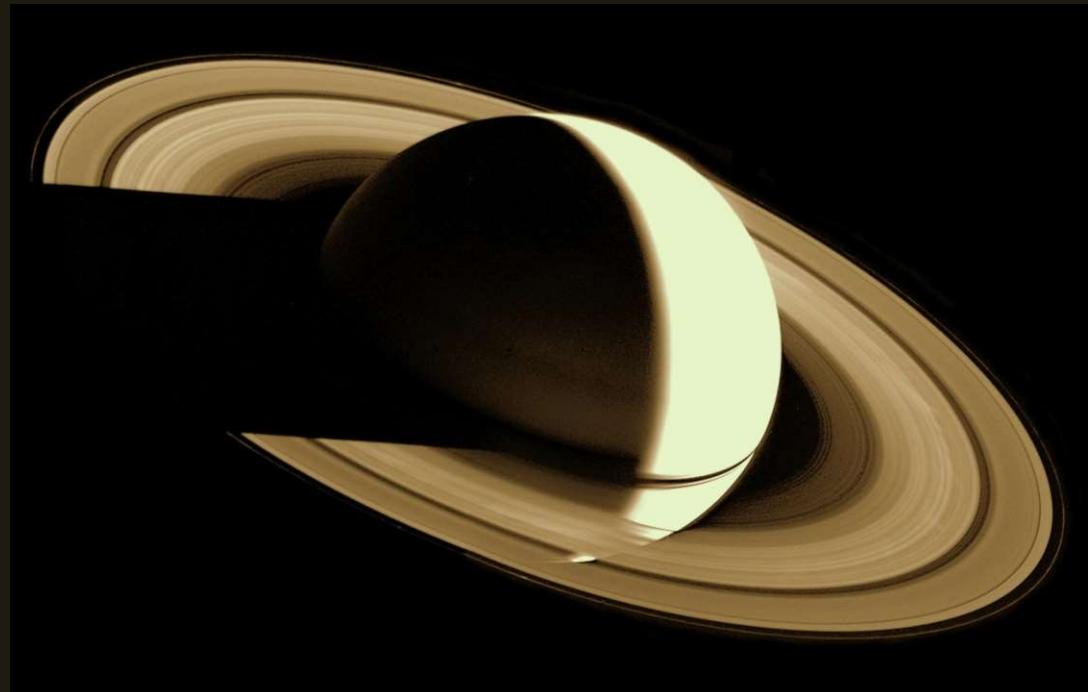
Asteroides visitados (2019)

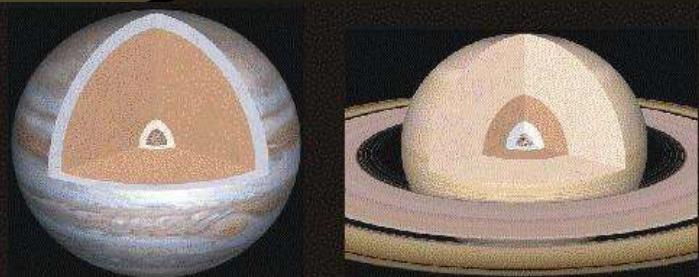


4. Los Planetas Externos o Gaseosos

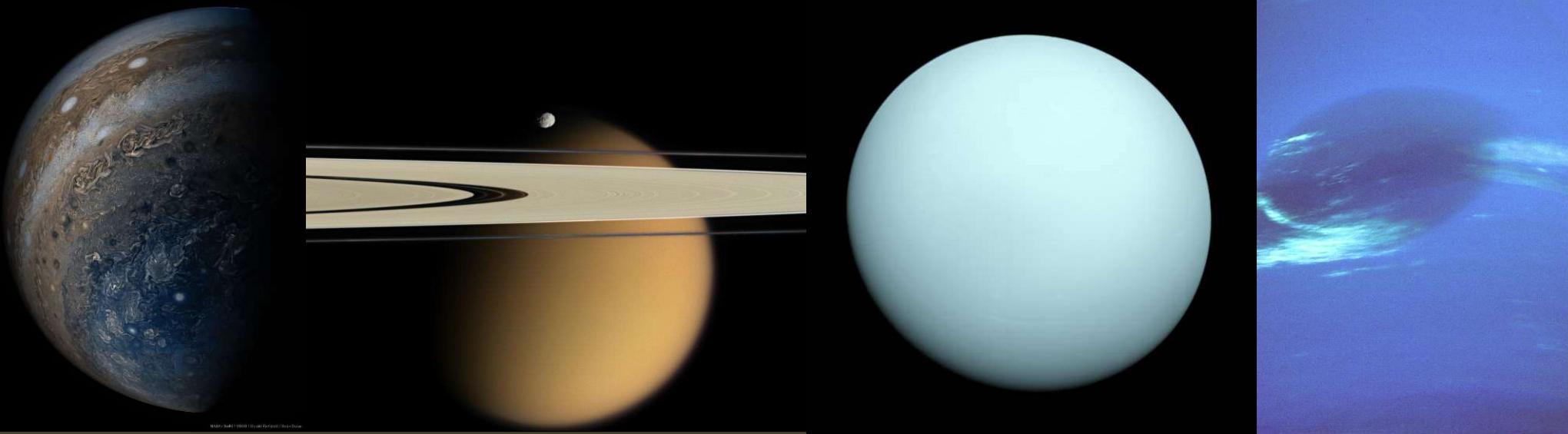
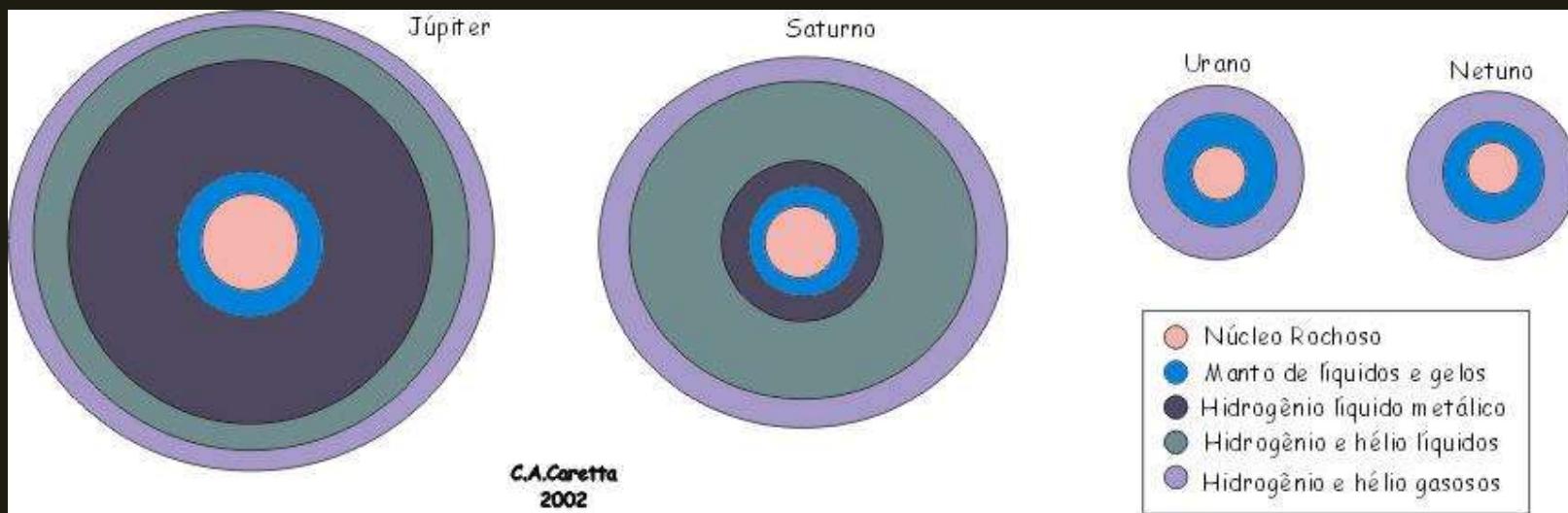


C.A.Caretta
2007





Los Planetas Gaseosos





Los Planetas Gigantes

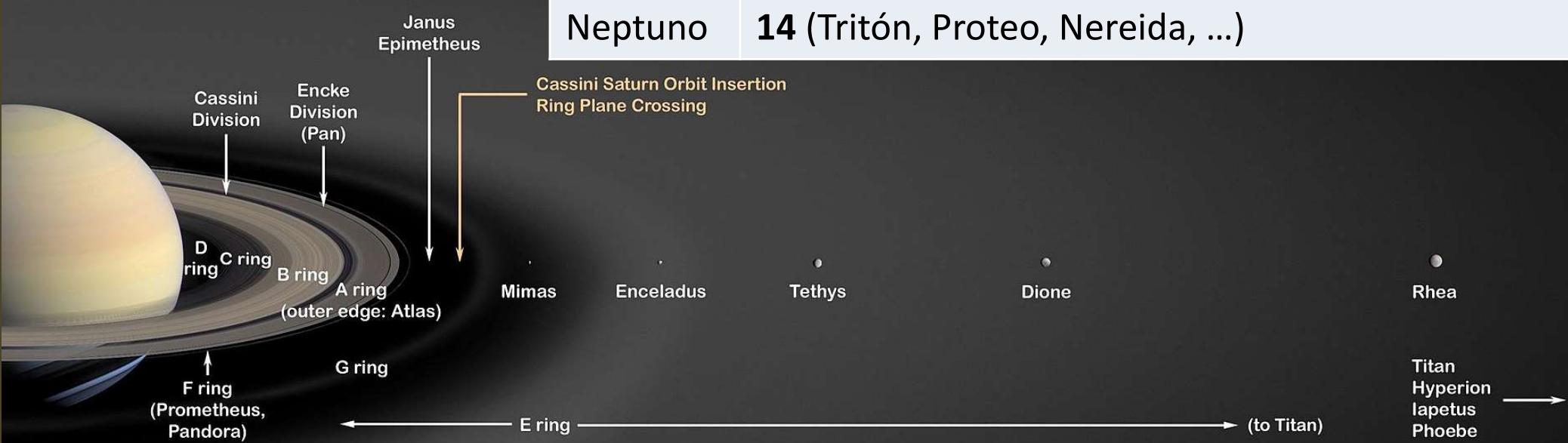


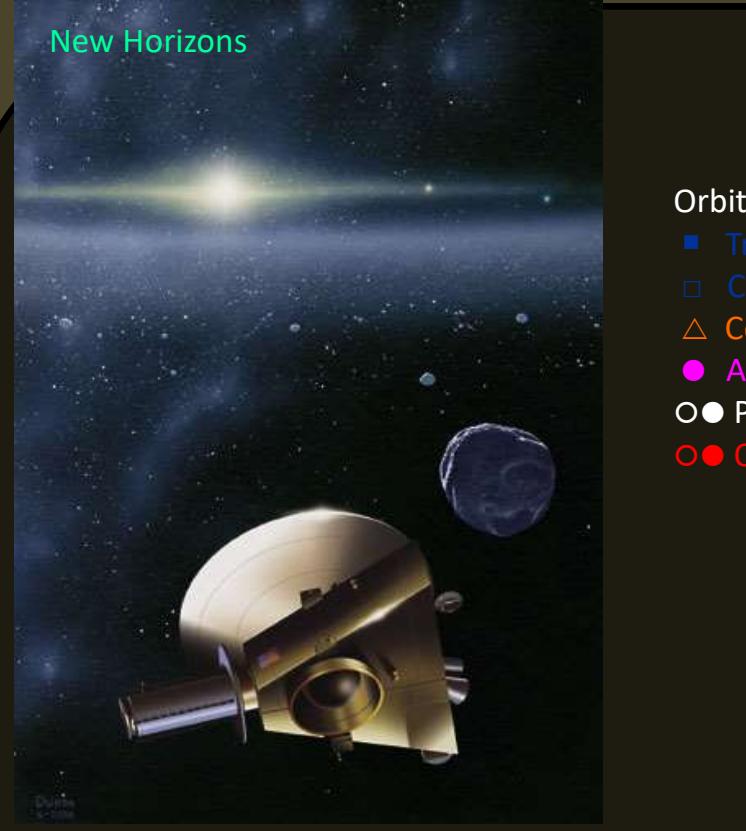
Sistema	Júpiter	Saturno	Urano	Neptuno
Sonda				
<i>Pioneer 10</i>	1973 flyby			
<i>Pioneer 11</i>	1974 flyby	1979 flyby		
<i>Voyager 1</i>	1979 flyby	1980 flyby		
<i>Voyager 2</i>	1979 flyby	1981 flyby	1986 flyby	1989 flyby
<i>Galileo</i>	1995–2003 orbiter; 1995, 2003 atmospheric			
<i>Ulysses</i>	1992, 2004 gravity assist			
<i>Cassini–Huygens</i>	2000 gravity assist	2004–2017 orbiter; 2005 Titan lander		
<i>New Horizons</i>	2007 gravity assist			
<i>Juno</i>		2016– orbiter		



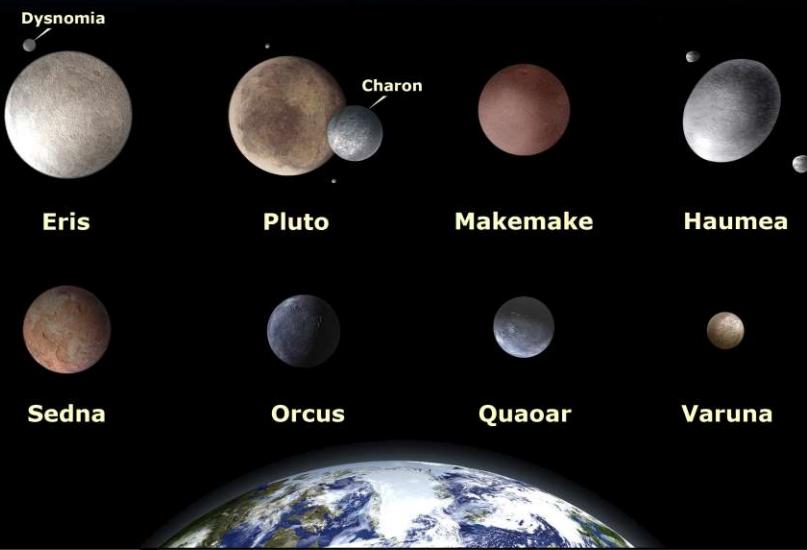
Los Satélites

Tierra	1 (Luna)
Marte	2 (Phobos y Deimos)
Júpiter	79 (Ganimedes, Calixto, Io, Europa, ...)
Saturno	62 (Titán, Rea, Jápeto, Dione, Tetis, Encélado, ...)
Urano	27 (Titania, Oberón, Umbriel, Ariel, Miranda, ...)
Neptuno	14 (Tritón, Proteo, Nereida, ...)





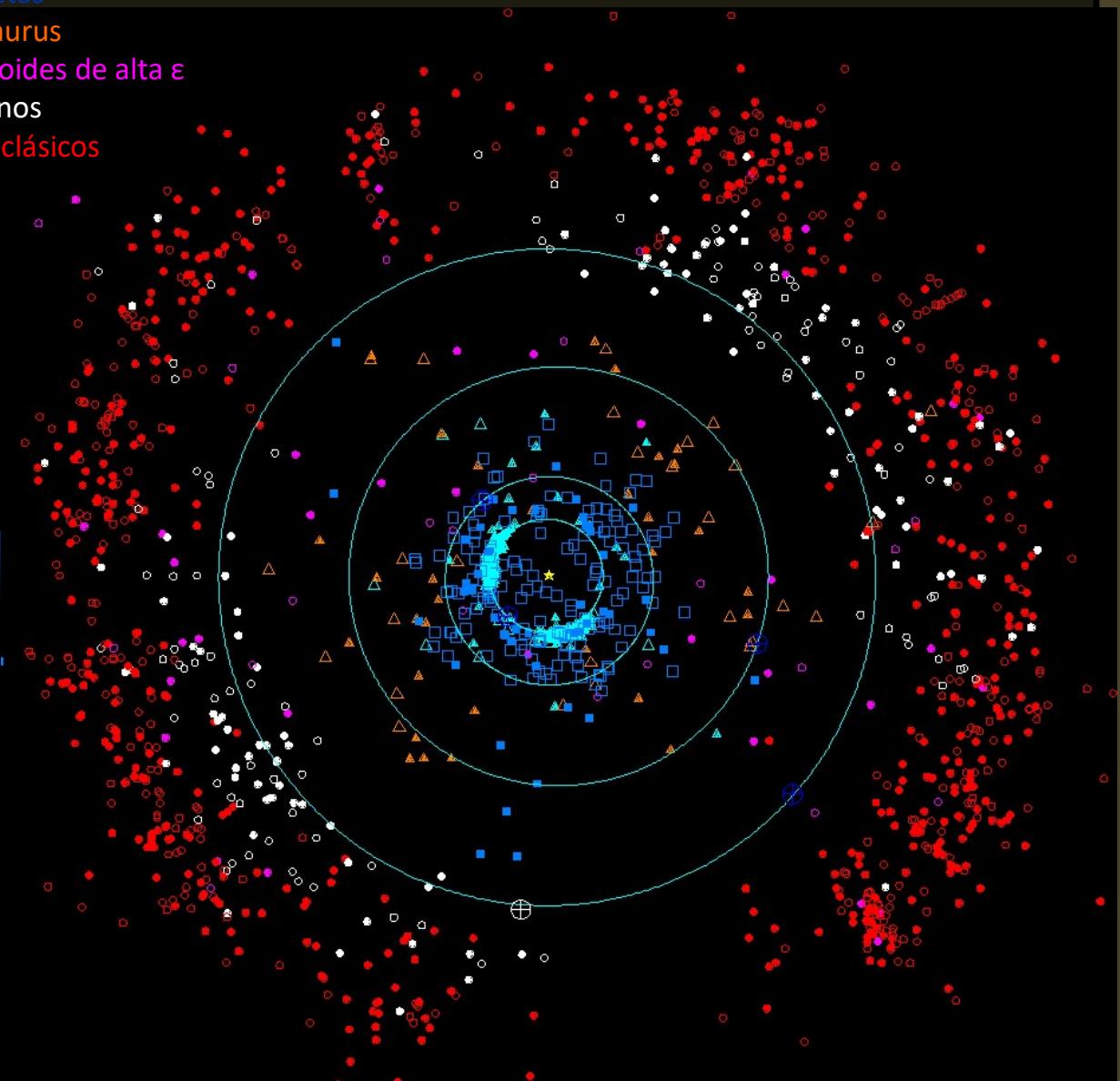
Largest known trans-Neptunian objects (TNOs)



Orbita de los planetas externos

- Trojanos, Hildas
- Cometas
- △ Centauros
- Asteroides de alta ϵ
- Plutinos
- OTN clásicos

5. El Cinturón de Kuiper



Plot prepared by the Minor Planet Center (2006 May25).

Orbita de los planetas externos

- Trojanos, Hildas
- Cometas
- △ Centaurus
- Asteroides de alta ε
- Plutinos
- OTN clásicos

THE OUTER SOLAR SYSTEM

This animation shows the motion of the outer part of the solar system over a 100-year time period. The sun is at the center and the orbits of the planets Jupiter, Saturn, Uranus and Neptune are shown in light blue (the locations of each planet are shown as large crossed circles).

Comets: blue squares (filled for numbered periodic comets, outline for other comets)

High-e objects: cyan triangles

Centaurs: orange triangles

Plutinos: white circles (Pluto itself is the large white crossed circle)

"Classical" TNOs: red circles

Scattered Disk Objects: magenta circles

The individual frames were generated on an OpenVMS system, using the PGPLT graphics library. The animation was put together on a RISC OS 4.03 system using !InterGif.

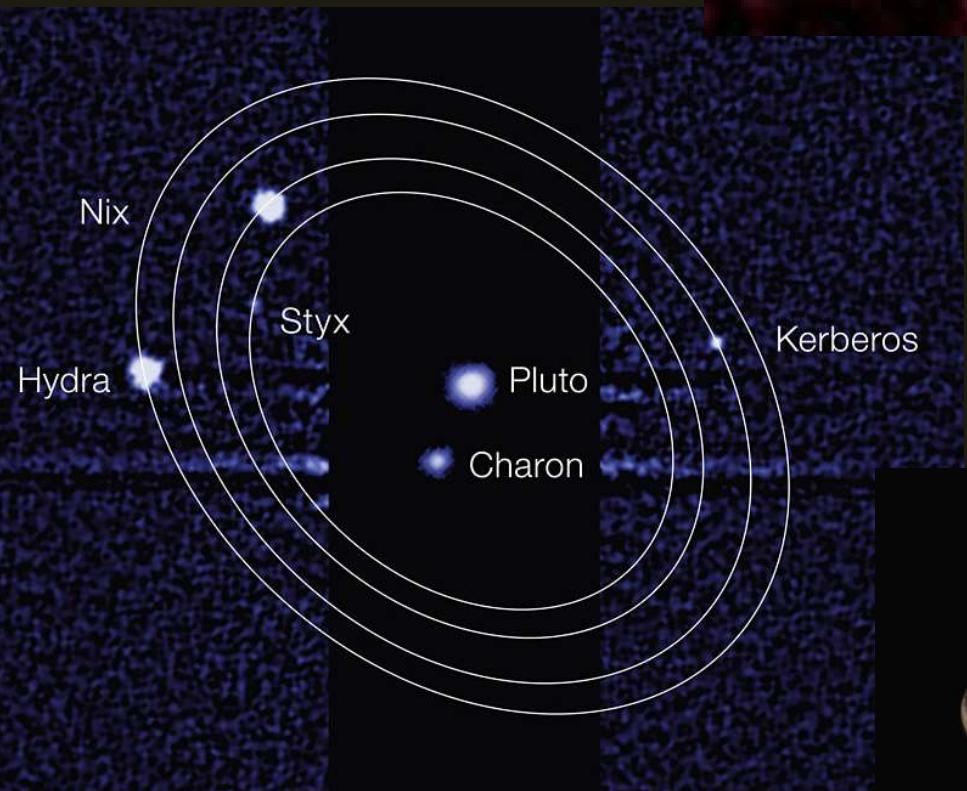
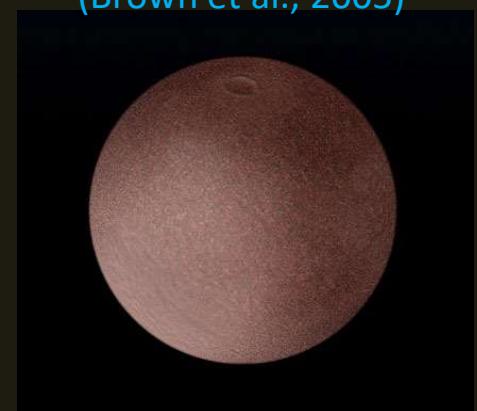
6. Los Planetas Enanos



Ceres
(Giuseppe Piazzi, 1801;
sonda Dawn, 2015)



Makemake (2005 FY₉)
ilustr.
(Brown et al., 2005)



Haumea (2003 EL₆₁)
ilustr.
(Brown et al., 2005;
Ortiz et al., 2005)



Caronte

Plutón
(Clayde Tombaugh, 1930;
sonda New Horizons, 2015)



Los Planetas Enanos

Dawn (Ceres, jul/2015-jan/2016)

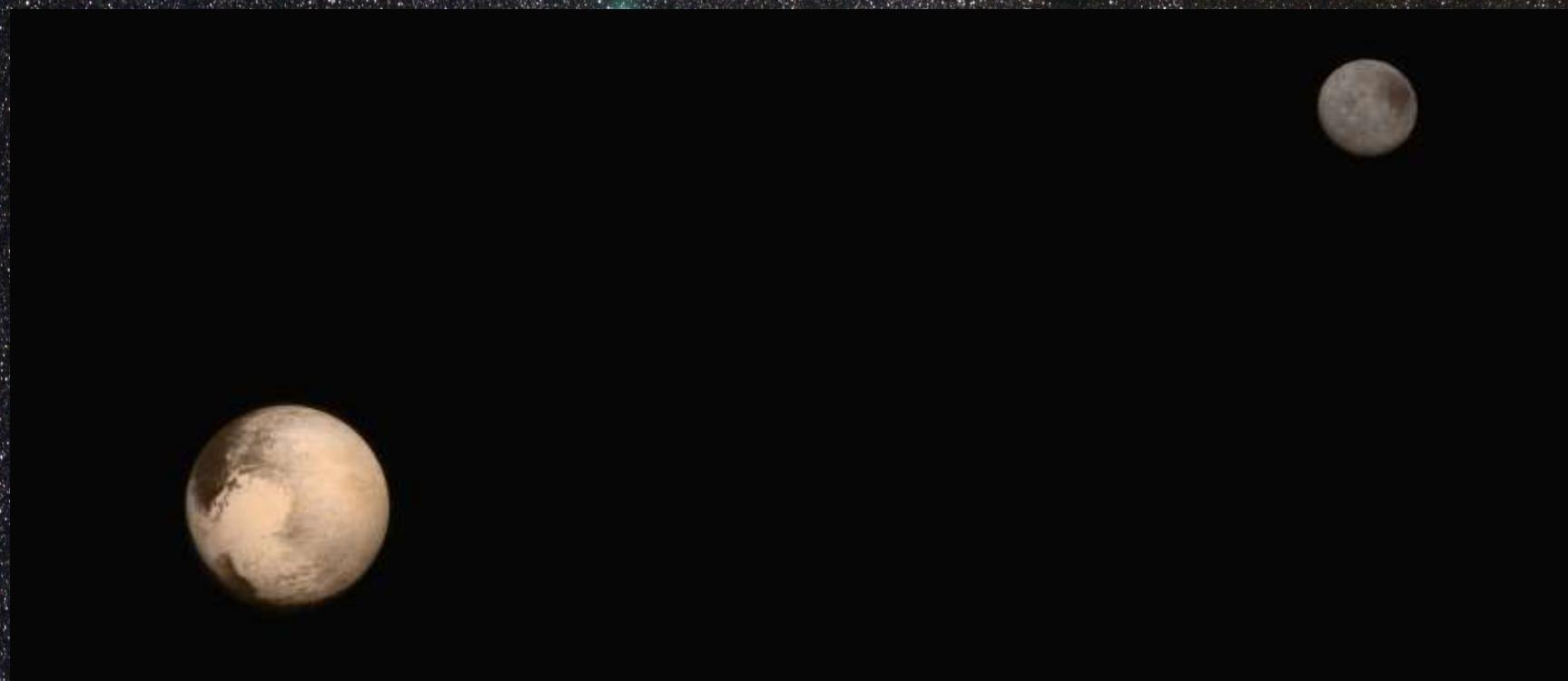
NASA (27/sep/2007 –)

+ Vesta (2011-2012)

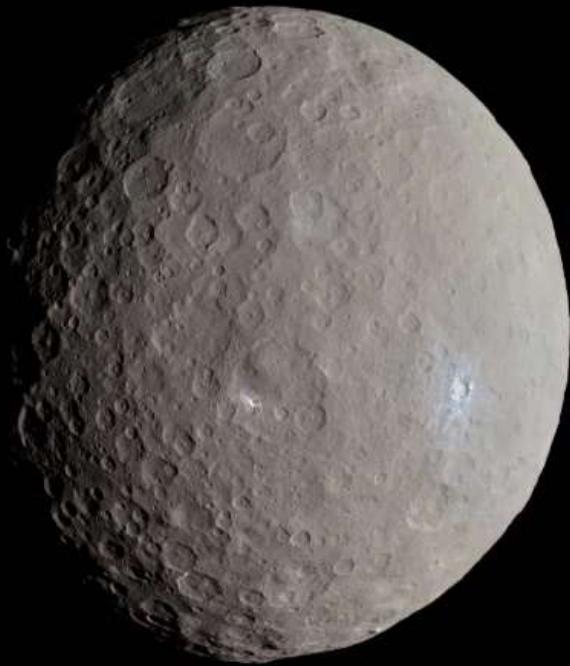
New Horizons (Plutón, 14/jul/2015)

NASA (19/ene/2006 –)

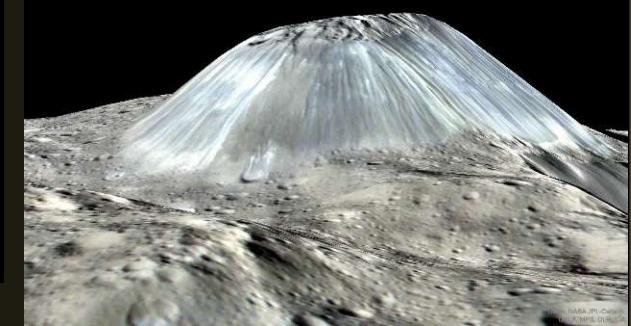
+ Júpiter, otros objetos del Cinturón de Kuiper



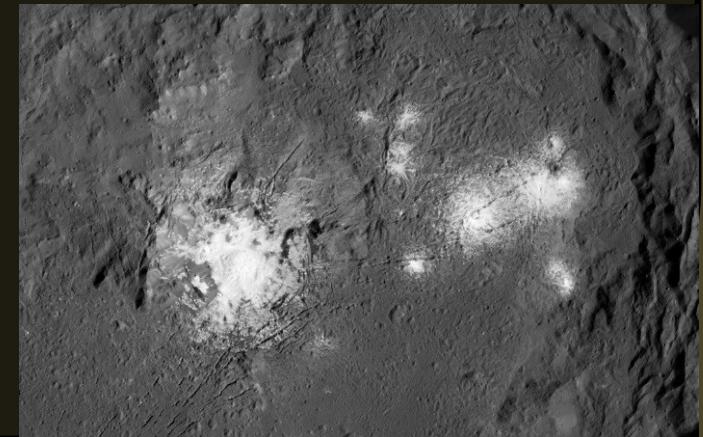
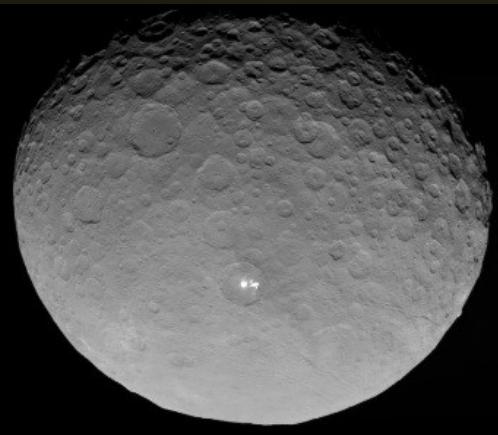
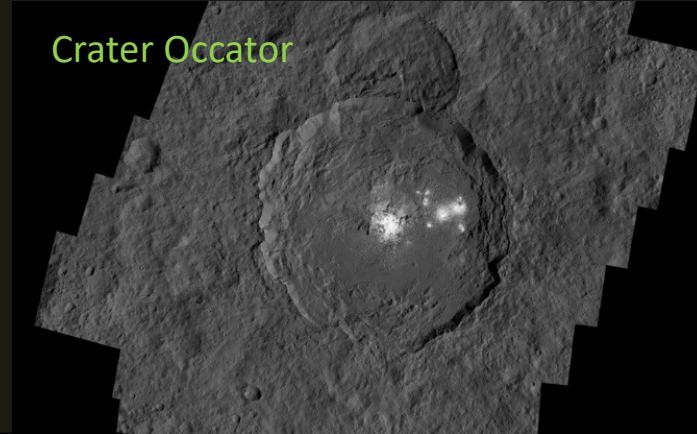
Ceres



Monte Ahuna



Crater Occator



Plutón



Charon and the Small Moons of Pluto

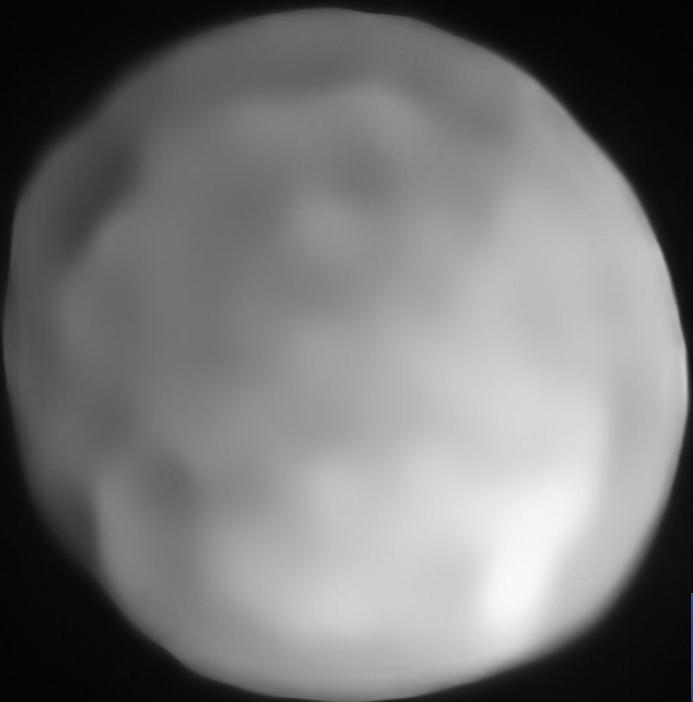


Caronte



NASA, Johns Hopkins U. APL, SwRI

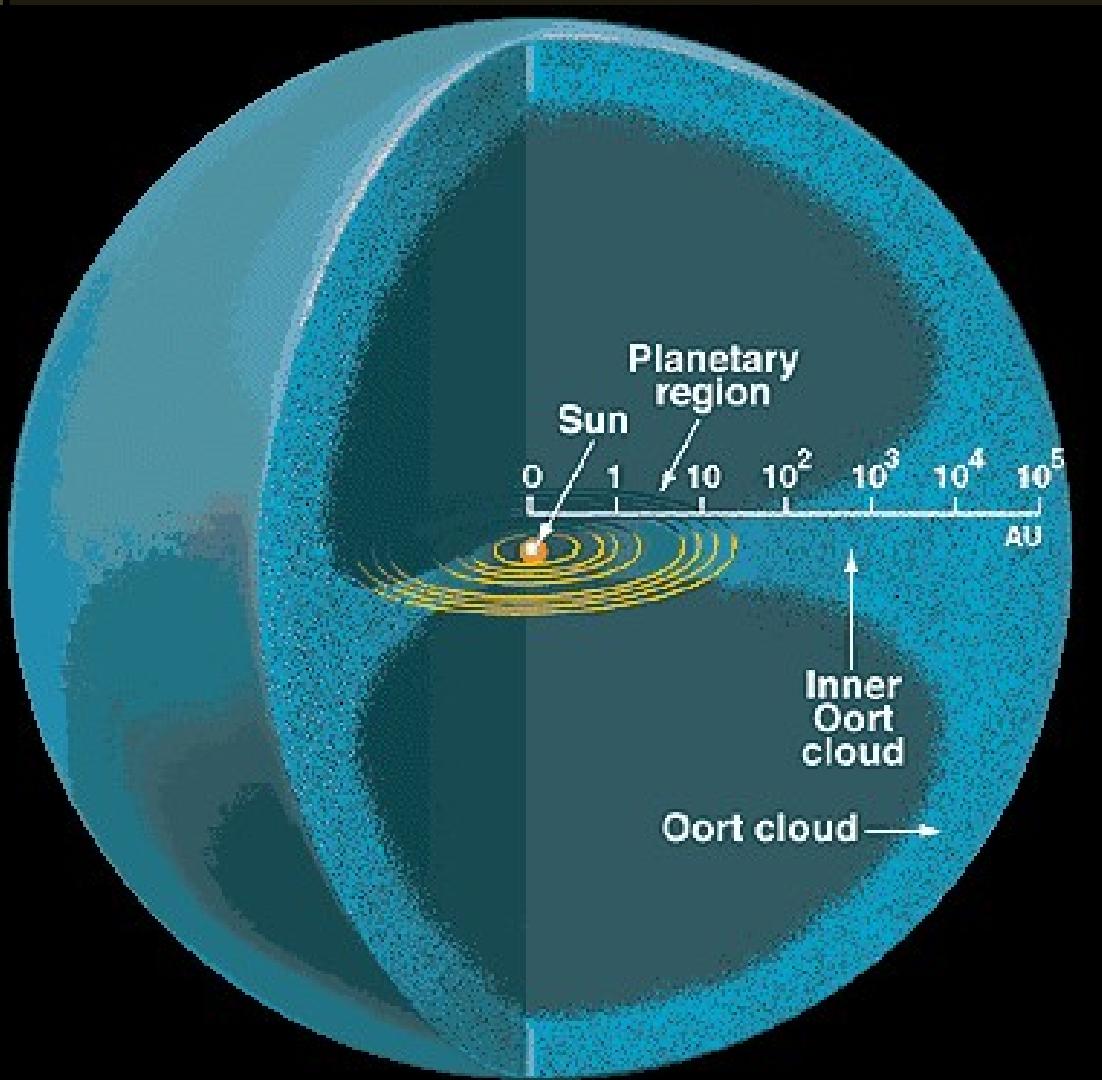
Candidatos a Planetas Enanos



Hygiea
(Annibale D. Gasparis, 1849;
VLT/SPHERE, 2019)



7. Los cometas y la Nube de Oort



West (1976)



McNaught (2007)



Hale-Bopp (1997)



Halley (1910)



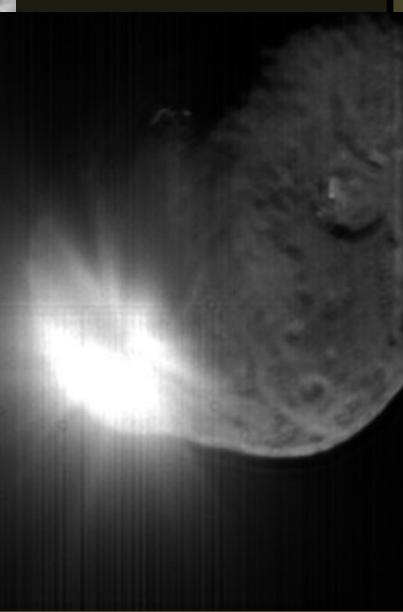
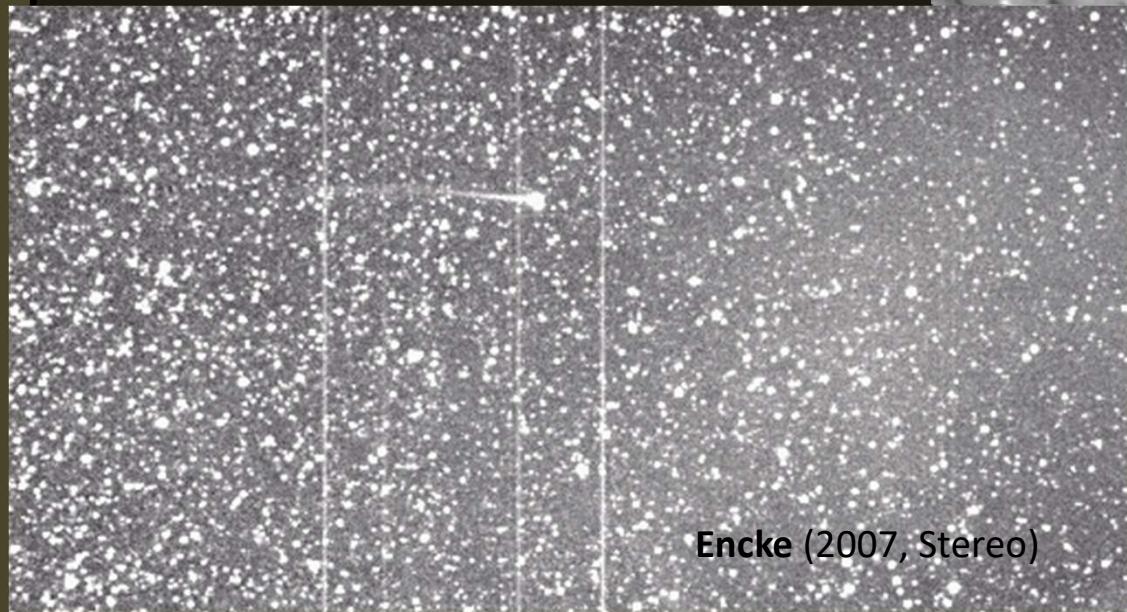
Halley (1986, Giotto)



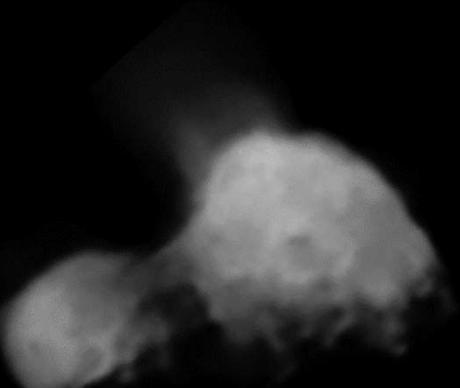
Tempel (2005,
Deep Impact)



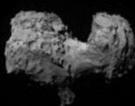
Encke (2007, Stereo)



COMETS VISITED BY SPACECRAFT



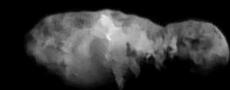
81P/Wild 2
5.5 × 4.0 × 3.3 km
Stardust, 2004



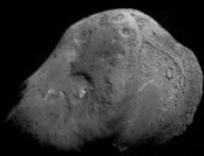
67P/Churyumov-
Gerasimenko
5 × 3 km
Rosetta, 2014



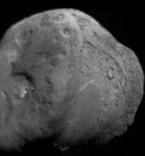
103P/Hartley 2
2.2 × 0.5 km
Deep Impact/EPOXI, 2010



1P/Halley
16 × 8 × 8 km
Vega 2, 1986



19P/Borrelly
8 × 4 km
Deep Space 1, 2001



9P/Tempel 1
7.6 × 4.9 km
Deep Impact, 2005



Modified 2014-08-04. For the latest version of this image, visit planetary.org/cometscale
Image credits: Halley: Russian Academy of Sciences / Ted Stryk. Borrelly: NASA / JPL / Ted Stryk.
Tempel 1 and Hartley 2: NASA / JPL / UMD. Churyumov-Gerasimenko: ESA / Rosetta / NavCam /
Emily Lakdawalla. Wild 2: NASA / JPL. Montage by Emily Lakdawalla.

COMET 67/P • 15 APRIL 2015



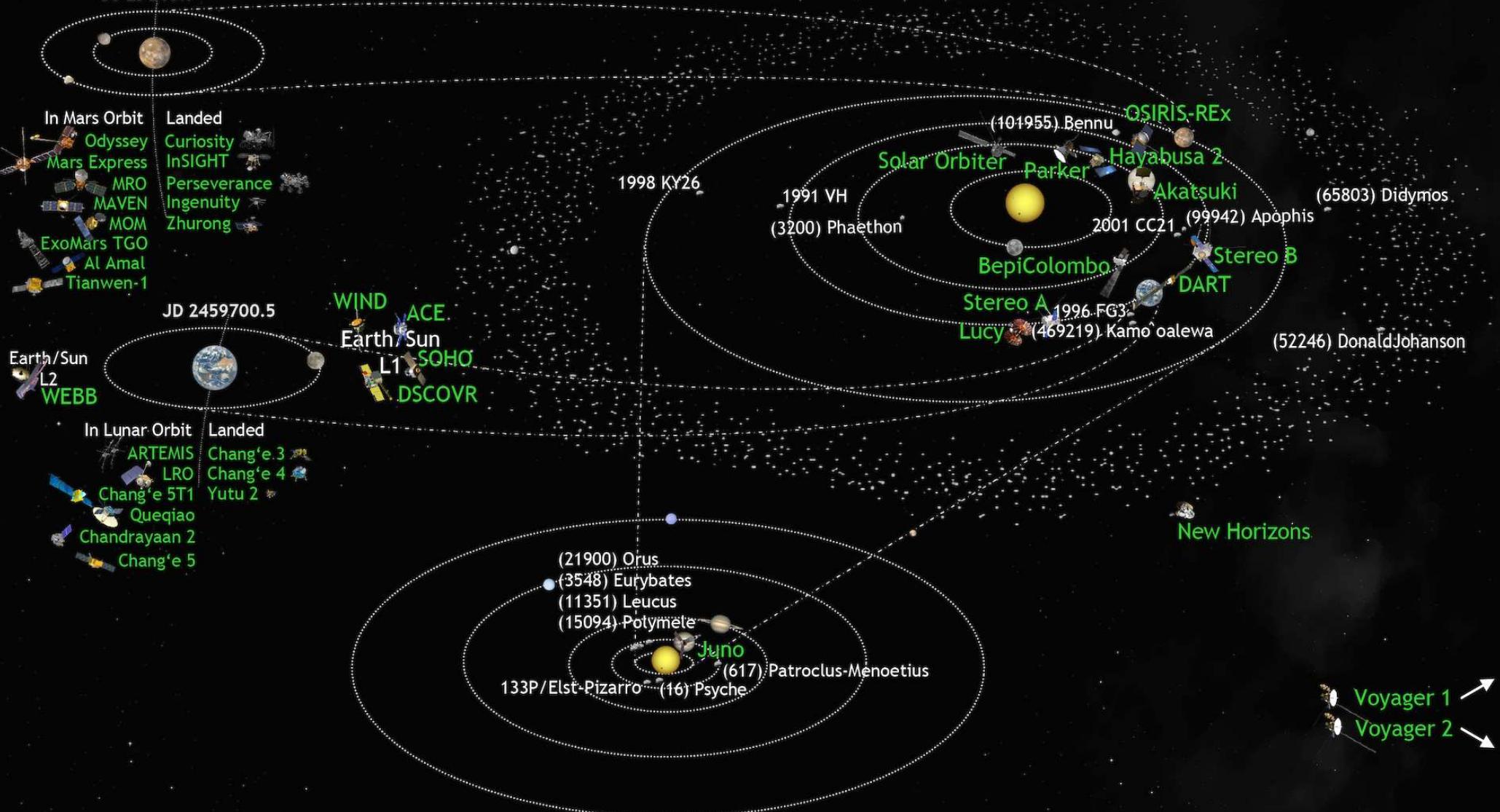
CREDITS: ESA NAVCAM
PROCESSING BY GIUSEPPE CONZO



ESA/Rosetta

Churyumov (2014, sonda Rosetta)





Upcoming Events

2022
Q2: CLPS NOVA-C IM-1 Launch/TD Moon
Jul: Artemis-1 Launch/Flyby Moon
+13 EM-1 Cubesats Launch/OI/Flyby Moon/Heliocentric Orbit
Q3: CAPSTONE Launch/OI Moon
Q3: Aditya L1 Launch to Earth/Sun L1
Q3: CLPS Peregrine Launch/TD Moon
Aug: Luna 25 Lander Launch/TD Moon
Aug: Psyche Launch to (16) Psyche + Janus Asteroid Flyby Probes
Aug: KPLA Launch/OI Moon
Sep: DART Impact (65803) Didymos

SR: Sample Retrieval; OI: Orbit Insertion; App: Approach; Dep: Departure
EDL: Entry, Descent and Landing; TD: Touchdown; EOM: End of Mission

Q4: Hakuto-R M1/Rashid Launch/TD Moon
Oct: Lucy Flyby Earth
SLIM Launch/TD Moon
2023
Apr: JUICE Launch to Jupiter
Sep: OSIRIS-REx EDL Earth
Nov: CLPS VIPER Launch/TD Moon
Nov: CLPS XL-1 Launch/TD Moon
CLPS Prime-1 IM-2 Launch/TD Moon
Chandrayaan 3 Launch/TD Moon
Chang'e 7 Launch/TD Moon
Gateway PPE/HALO Launch to NRHO
2024
Sep: DESTINY+ Launch to (3200) Phaethon

Dec: Lucy Flyby Earth
Artemis-2 Launch Lunar Flyby
Beresheet 2 Launch/TD Moon
Chang'e 6 Launch/SR Moon
CLPS Blue Ghost Launch/TD Moon
CLPS PRISM-1A Launch/TD Moon
ESCAPEADE Launch to Mars
Europa Clipper Launch to Jupiter
Hakuto-R M2 Launch/TD Moon
HERA Launch to Didymos
Luna 26 Orbiter Launch/OI
Lunar Starship Launch/TD Moon
Lunar Trailblazer Launch/OI
MMX Launch to Mars
MOM-2 Launch to Mars
Shukrayaan Launch to Venus

SWFO-L1 Launch to Earth/Sun L1
Zheng He Launch/SR Kamo'alewa
2025
Apr: Lucy Flyby (52246) Donaldjohanson
Artemis-3 Launch/TD/SR Moon
Juno EOM
Lunar Pathfinder Launch/TD Moon
LUPEX Launch/TD Moon
Solar Cruiser Launch to Earth/Sun L1
Bepi-Colombo OI Mercury
Luna 27 Lander Launch
Oryol Test 3 Launch to Moon
2026+
NEO Surveyor Launch to E/S L1
Dragonfly Launch to Titan
Artemis 4/IHAB Launch to Gateway

Heracles Launch/TD Moon
Aug: Lucy Flyby (3548) Eurybates (2027)
Sep: Lucy Flyby (15094) Polymele (2027)
Chang'e 8 Launch/TD Moon (2027)
ERO Launch to Mars (2027)
Artemis 5/ESPRIT Launch to Gateway (2027)
Apr: Lucy Flyby (11351) Leucus (2028)
Nov: Lucy Flyby (21900) Orus (2028)
Comet Interceptor Launch (2028)
SRL Launch to Mars (2028)
VERITAS Launch to Venus (2028)
OSIRIS-REx OI (99942) Apophis (2029)
Dec: Lucy Flyby Earth (2030)
DAVINCI+ Launch to Venus (2030)
Europa Clipper OI Jupiter (2031)
EnVision Launch to Venus (2032)

Sistema Solar

	Planeta	símb.	descubr.	descubridor	núm. de satélites	magnitud*	color§	albedo#	atmósfera
	Sol	⊕	-	-	9	-26.8	amarillo	-	-
Terrestres	Mercurio	☿	-	-	0	-1.9	naranja	0.11	mínima
	Venus	♀	-	-	0	-4.4	blanco	0.65	96% <u>CO₂</u> 4% <u>N₂</u>
	Tierra	⊕	-	-	1	-	azul	0.37	78% <u>N₂</u> 21% <u>O₂</u>
	Marte	♂	-	-	2	-2.0	rojo	0.15	95% <u>CO₂</u> 3% <u>N₂</u>
Jovianos	Júpiter	♃	-	-	79	-2.7	blanco	0.52	86% <u>H₂</u> 14% <u>He</u>
	Saturno	♄	-	-	62	0.7	amarillo	0.47	93% <u>H₂</u> 5% <u>He</u>
	Urano	♅	1781	William Herschel	27	5.5	azul	0.51	83% <u>H₂</u> 15% <u>He</u>
	Neptuno	♆	1846	J.G. Galle e H.L. d'Arrest	14	7.8	azul	0.41	80% <u>H₂</u> 19% <u>He</u>
Enanos	(1) Ceres	♀	1801	Giuseppe Piazzi	0			0.09	ninguna
	(10) Hygiea	₩	1849	Annibale D. Gasparis	0	10.2		0.07	ninguna
	Plutón	♺	1930	C.W. Tombaugh	5	13.6	blanco	0.55	temporaria
	Haumea		2005	J.L.Ortiz et al.	2				?
	Makemake		2005	M. Brown et al.	1				?
	Eris		2003	M. Brown et al.	1				?

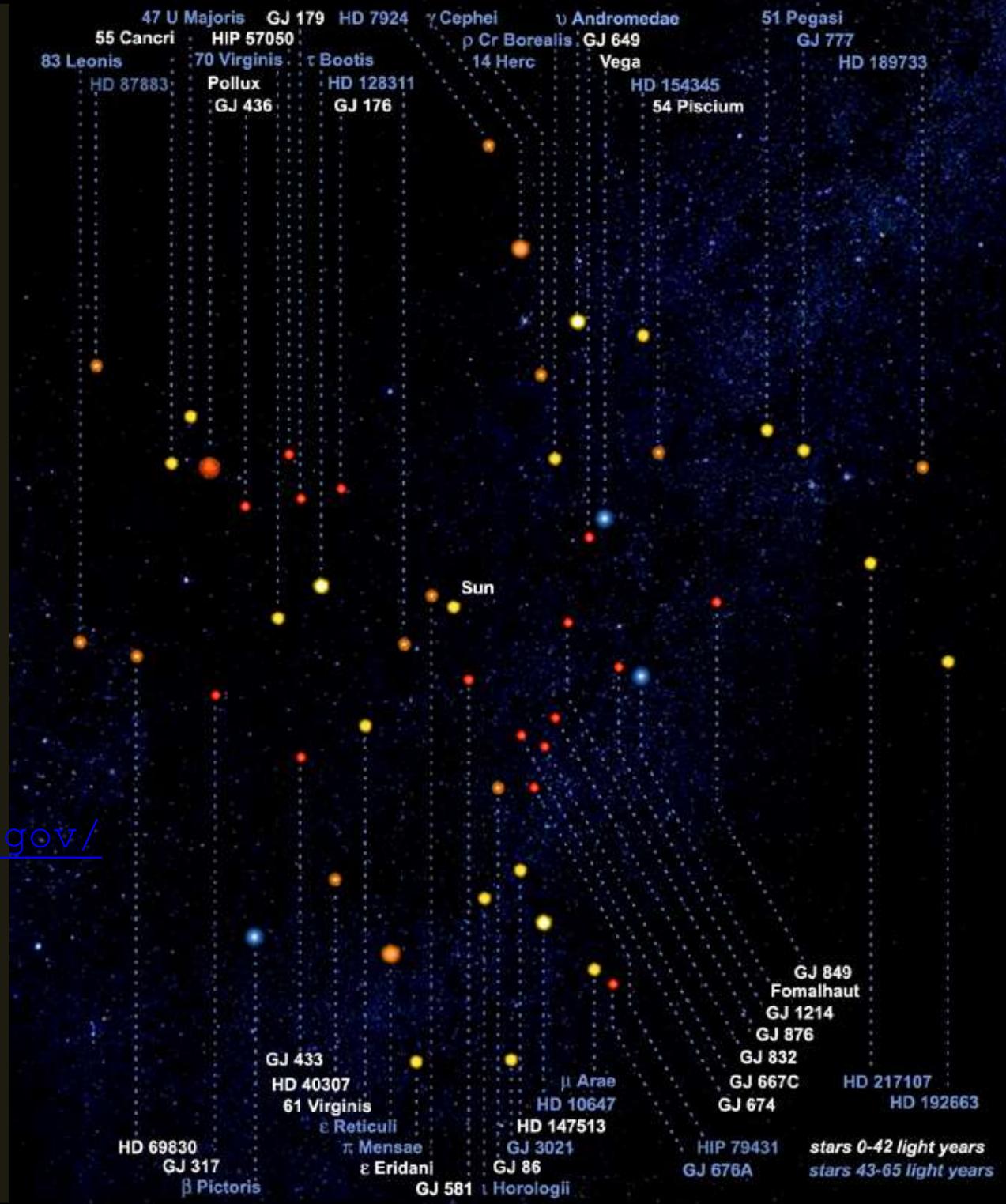
Sistema Solar

		diámetro ecuatorial		período de rotación	inclinación del eje	masa	densidad	velocidad de escape	temperat. superficial
		en km	en diámetros de la Tierra	en días siderales	en grados	en masas de la Tierra*	en g/cm³	en km/s	en °C
	Sol	1 392 000	109	25-36	-	332 946	1.41	617.7	5 505
Terrestres	Mercurio	4 879.3	0.382	58.65	0.0	0.055	5.43	4.25	167
	Venus	12 103.2	0.949	-243.02	177.36	0.815	5.24	10.36	457
	Tierra	12 756.2	1.000	0.9973	23.45	1.00	5.52	11.18	14
	Marte	6 794,0	0.532	1.0260	25.19	0.107	3.94	5.02	-46
Jovianos	Júpiter	142 985	11.209	0.4135	3.12	317.9	1.33	59.54	-121
	Saturno	120 534	9.449	0.4440	26.73	95.2	0.70	35.49	-139
	Urano	51 115	4.007	-0.7183	97.86	14.5	1.30	21.29	-197
	Neptuno	49 533	3.883	0.6713	29.58	17.1	1.76	23.71	-201
Enanos	Ceres	942	0.08	0.38	3	0.0002	2.16	0.51	-106
	Hygiea	434	0.03	0.59	?	0.00001	1.94	?	?
	Plutón	2 296	0.19	-6.39	119.6	0.0022	2.05	1.23	-233
	Haumea	1150	0.37×0.16	0.16	?	0.0007	2.6-3.3	0.84	-235
	Makemake	1500	~0.12	?	?	0.0007	2.0	0.8	-243
	Eris	2400	0.19	~ 0.3	?	0.0025	2.25	1.37	-243

Sistema Solar

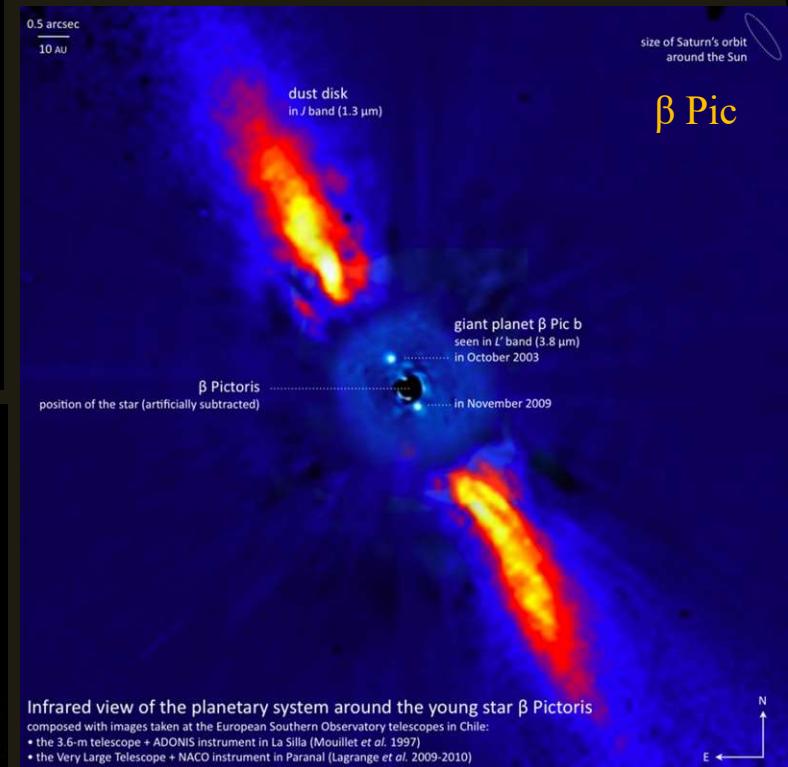
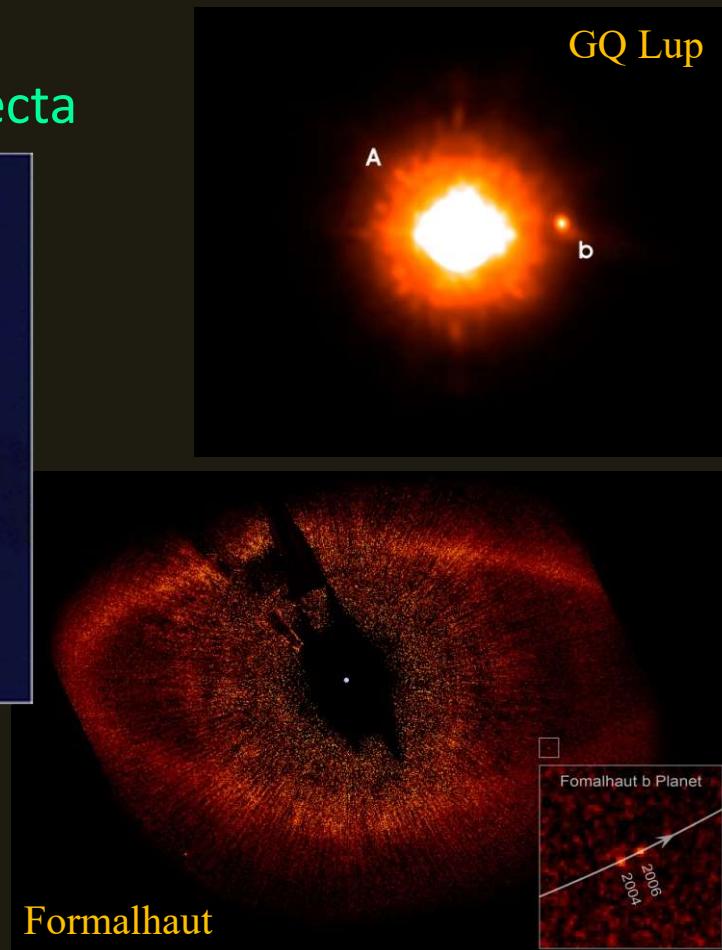
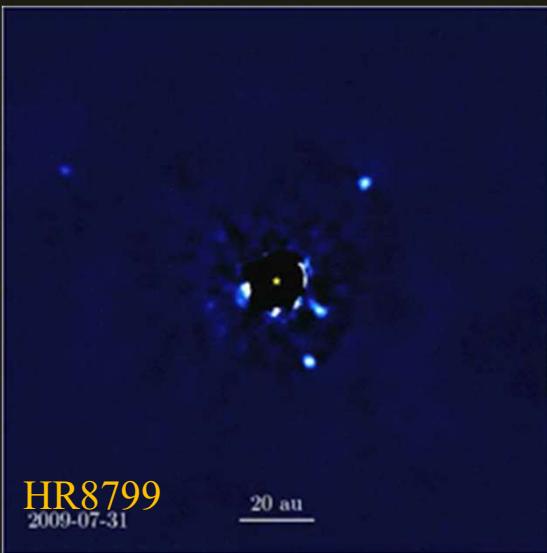
		distancia promedia al Sol		período de translación		inclinación de la órbita	excentricidad	velocidad orbital promedia
		en millones de km	en UA	en días	en años	en grados		en km/s
	Sol	-	-	-	-	-	-	-
Terrestres	Mercurio	57.91	0.39	87.97	0.241	7.005	0.206	47.87
	Venus	108.21	0.72	224.70	0.615	3.395	0.007	35.02
	Tierra	149.60	1.00	365.25	1.000	0.000	0.017	29.79
	Marte	227.94	1.52	686.98	1.881	1.851	0.093	24.13
Jovianos	Júpiter	778.41	5.20	4 332.7	11.863	1.305	0.048	13.06
	Saturno	1 426.73	9.54	10 759.5	29.447	2.484	0.054	9.66
	Urano	2 870.97	19.19	30 685	84.017	0.770	0.047	6.80
	Neptuno	4 498.25	30.07	60 190	164.79	1.769	0.009	5.44
Enanos	Ceres	413.7	2.766	1 679	4.599	10.59	0.080	17.88
	Hygiea	469.6	3.139	2 032	5.563	3.84	0.115	?
	Plutón	5 906.38	39.48	...	247.92	17.14	0.249	4.75
	Haumea	6 484.0	43.34	...	285.4	28.19	0.189	4.48
	Makemake	6 850.0	45.79	...	309.9	28.96	0.159	4.4
	Eris	10 210.0	67.67	...	557	44.19	0.442	3.44

B) Otros sistemas planetarios

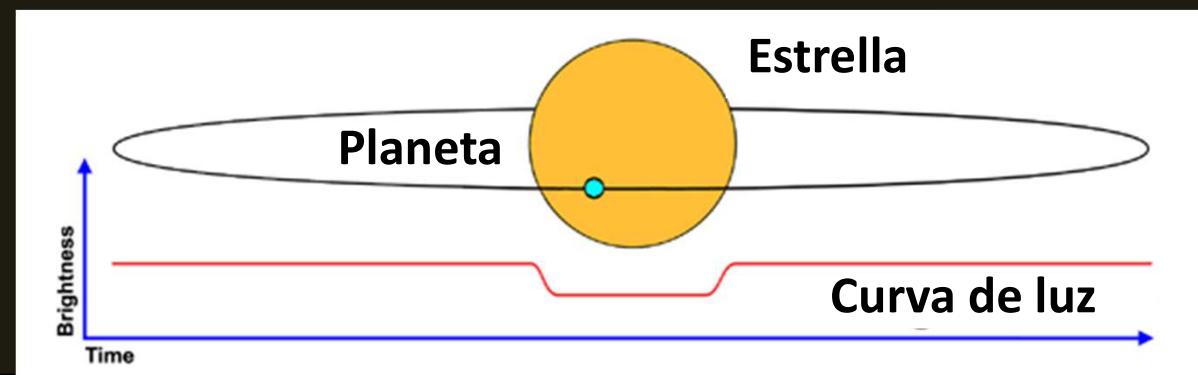


B1) Métodos de detección para planetas extrasolares

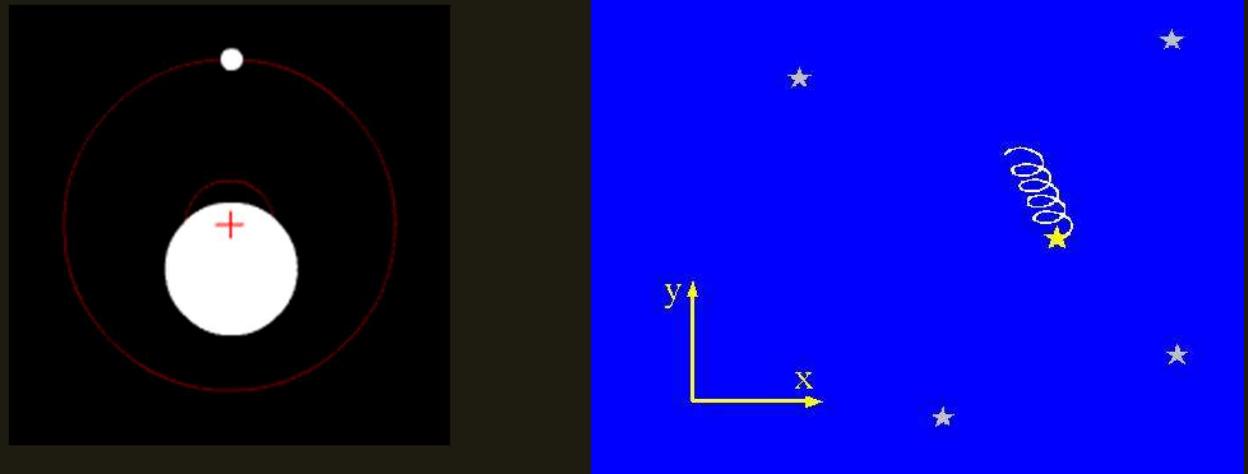
1. imagen directa



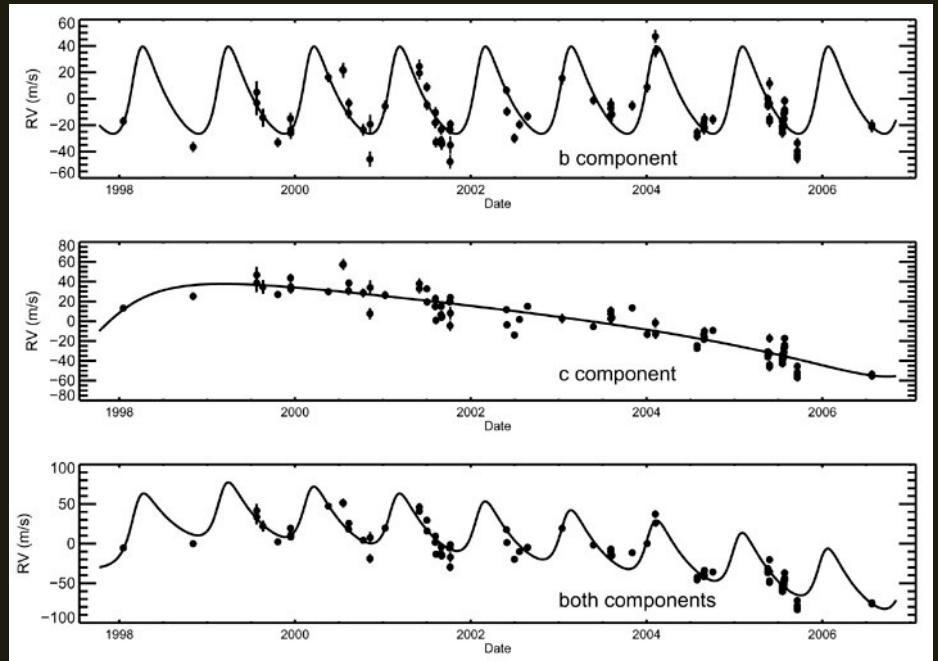
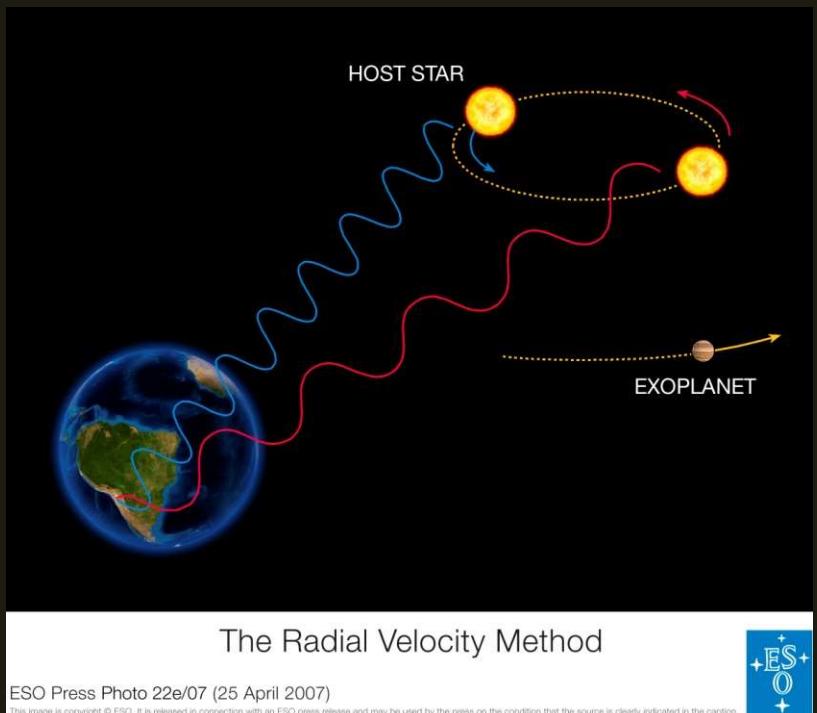
2. transito

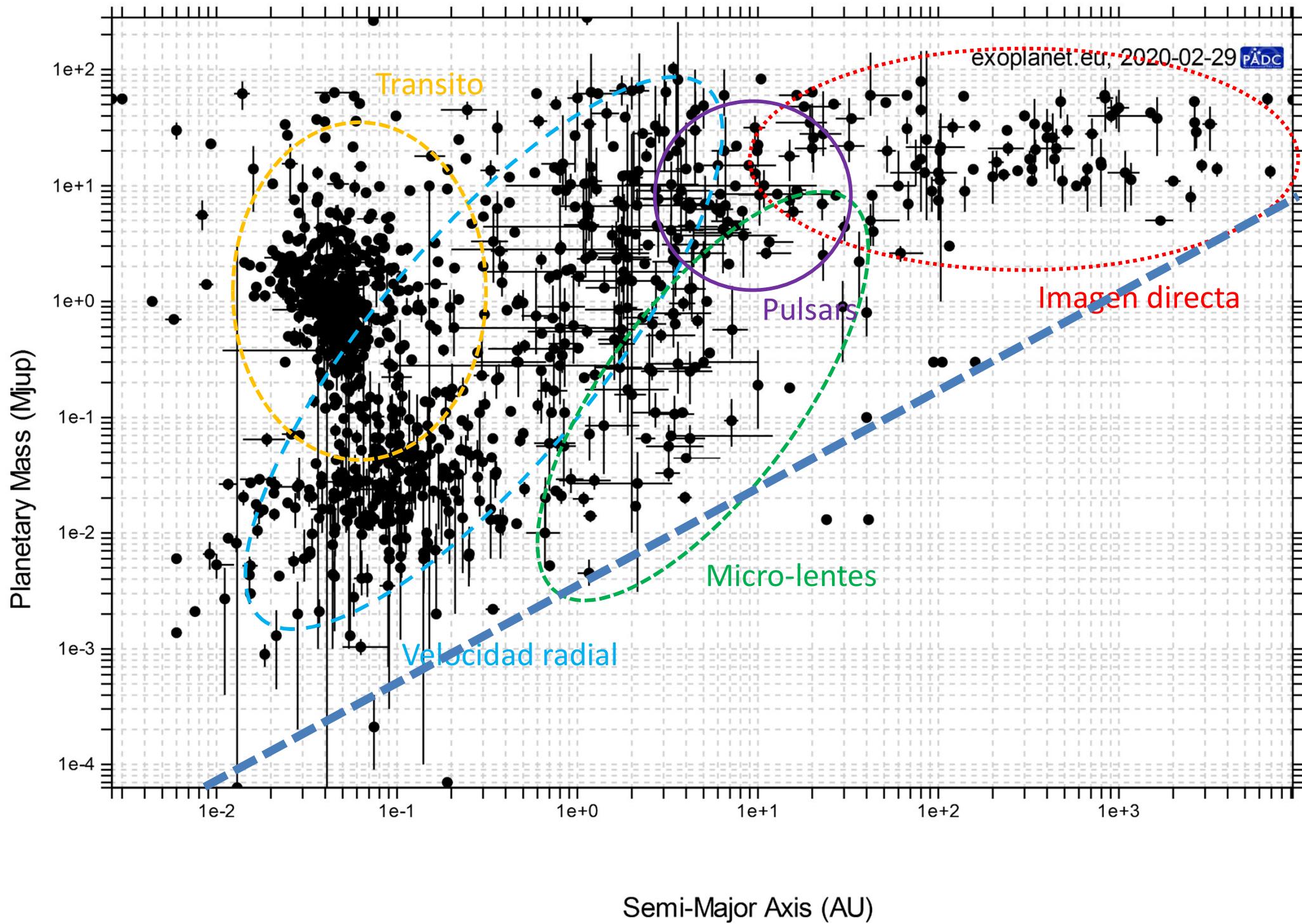


3. astrometría



4. velocidad radial





Detección de planetas extrasolares

(12 de mayo de 2022)

Método	Sistemas planetarios	Planetas	Sistemas múltiples
imagen directa	861	1193	185
transito	2659	3532	570
astrometría + veloc. radial	746	1014	176
microlentes gravit.	172	192	10
pulsares	40	47	5
otros	46	52	6
TOTALES	3707	5031	823

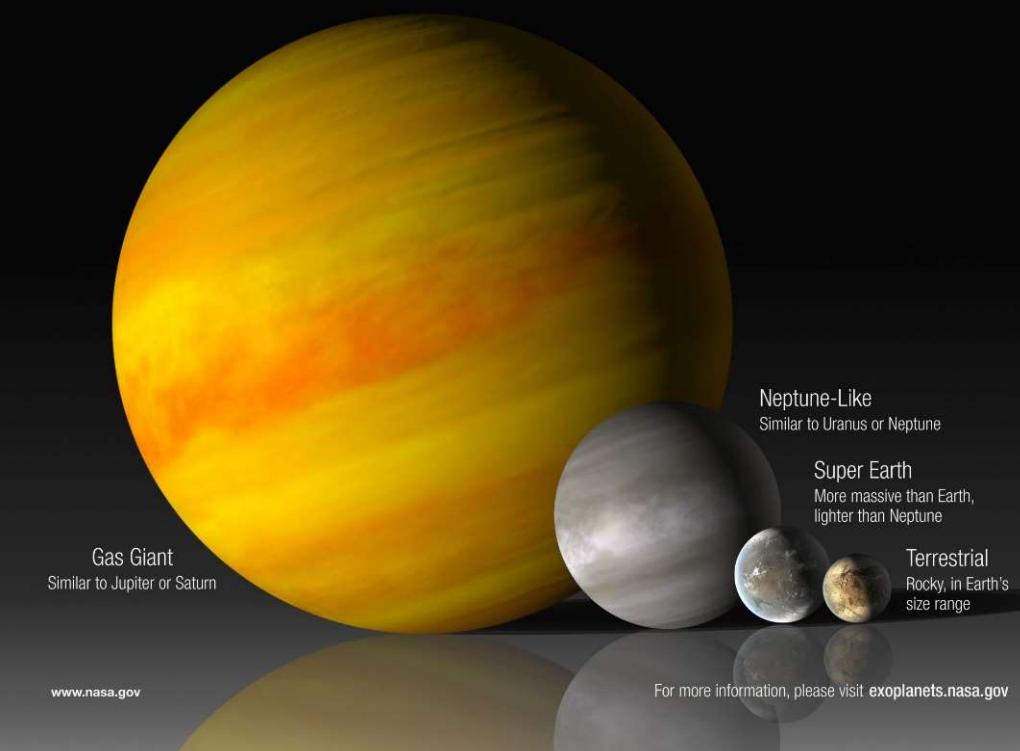
Clase	Masa (M_{Tierra})	Masa ($M_{Júpiter}$)	Exemplo
Terrestre	0.05 – 2		Mercurio, Tierra
Súper-Tierra	2 – 10		
Gigante Congelado	10 – 60		Urano, Neptuno
Gigante Gaseoso	60 – 1 000	0.2 – 3	Saturno, Júpiter
Súper-Joviano	1 000 – 8 000	3 – 25	
Enana Café (estrella)		13 – 80	

National Aeronautics and
Space Administration



What's Out There? Exoplanet Types

B2) Clasificación de exoplanetas





30% **GAS GIANT**

The size of Saturn or Jupiter (the largest planet in our solar system), or many times bigger. They can be hotter than some stars!



31% **SUPER-EARTH**

Planets in this size range between Earth and Neptune don't exist in our solar system. Super-Earths, a reference to larger size, might be rocky worlds like Earth, while mini-Neptunes are likely shrouded in puffy atmospheres.



4% **TERRESTRIAL**

Small, rocky planets. Around the size of our home planet, or a little smaller.

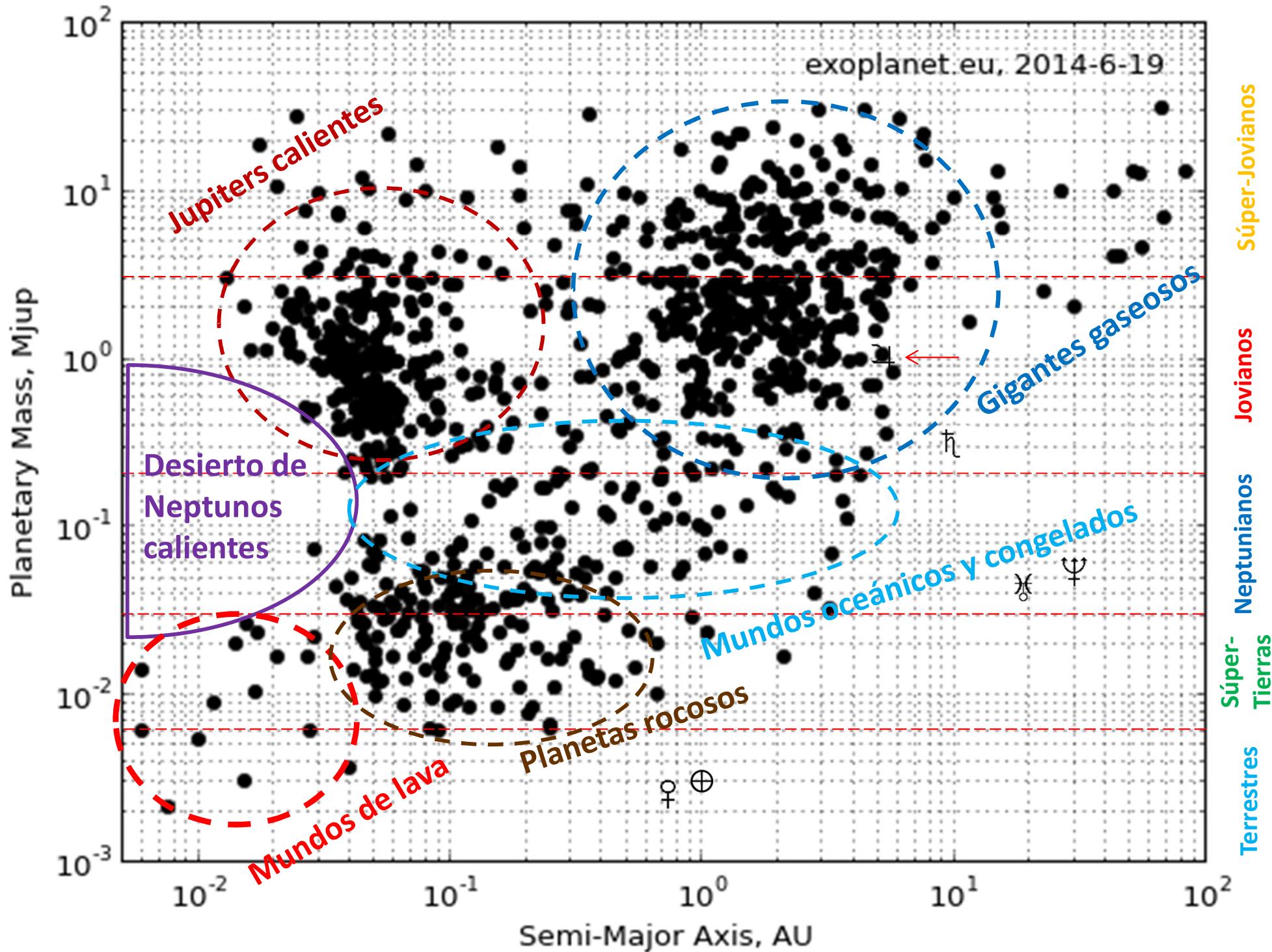


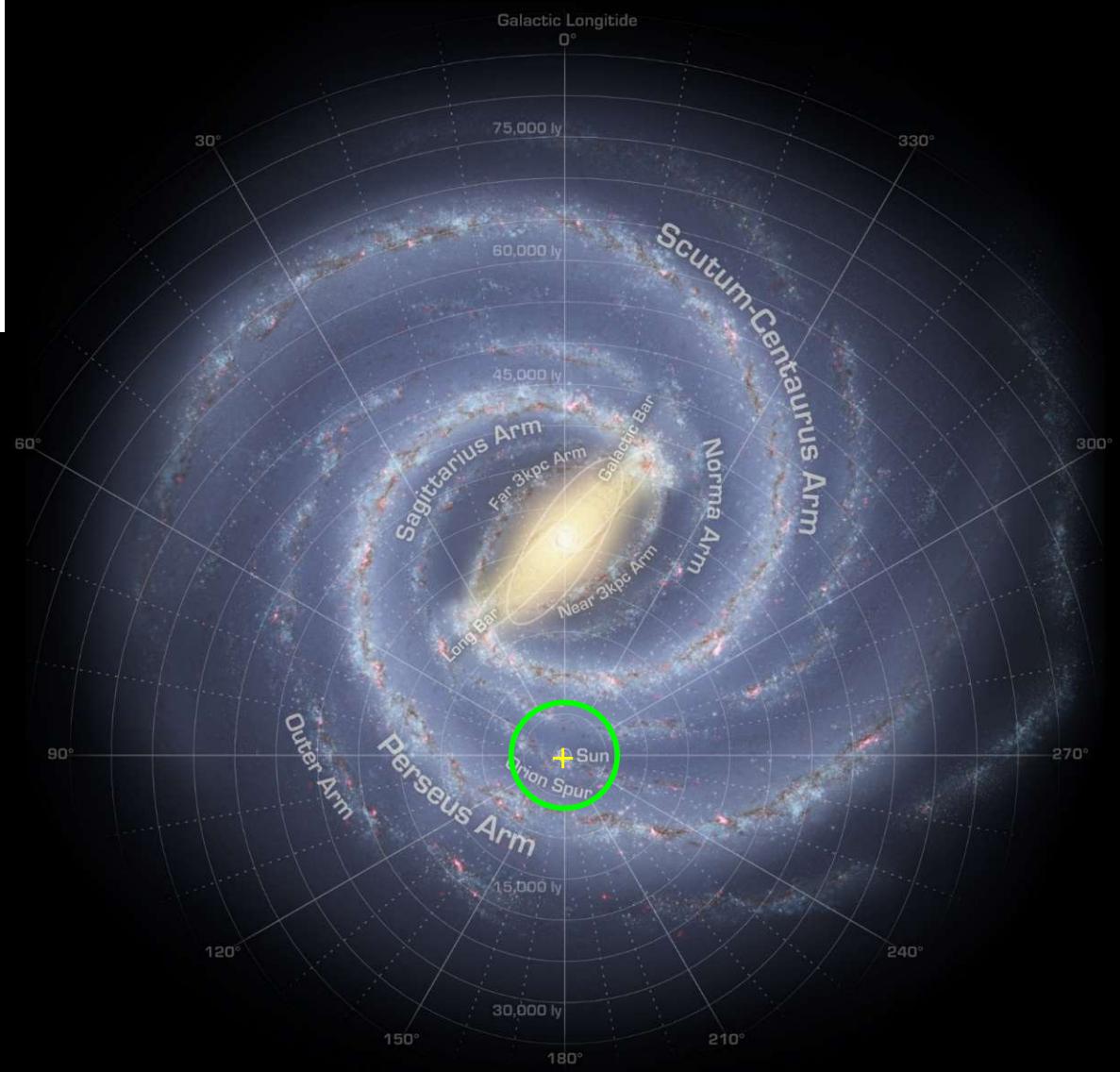
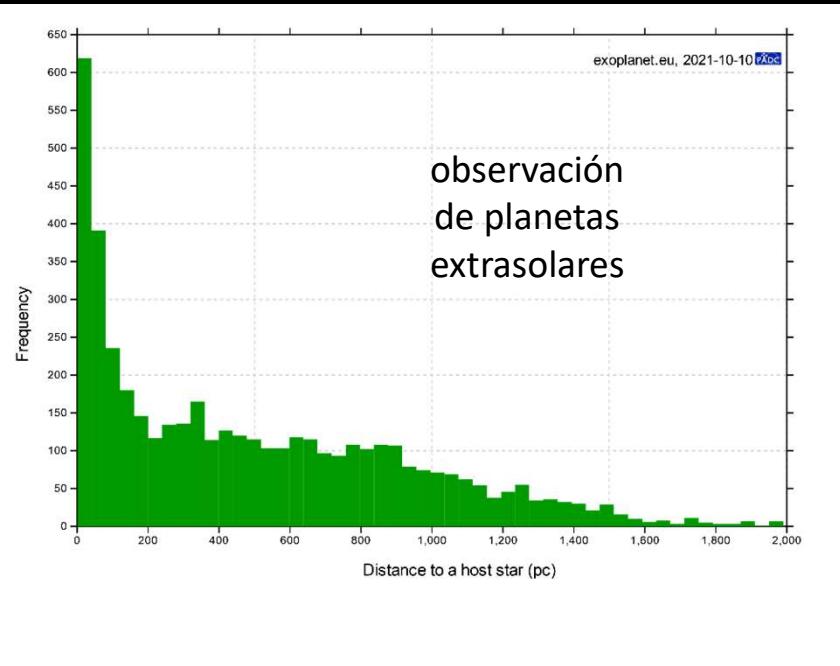
35% **NEPTUNE-LIKE**

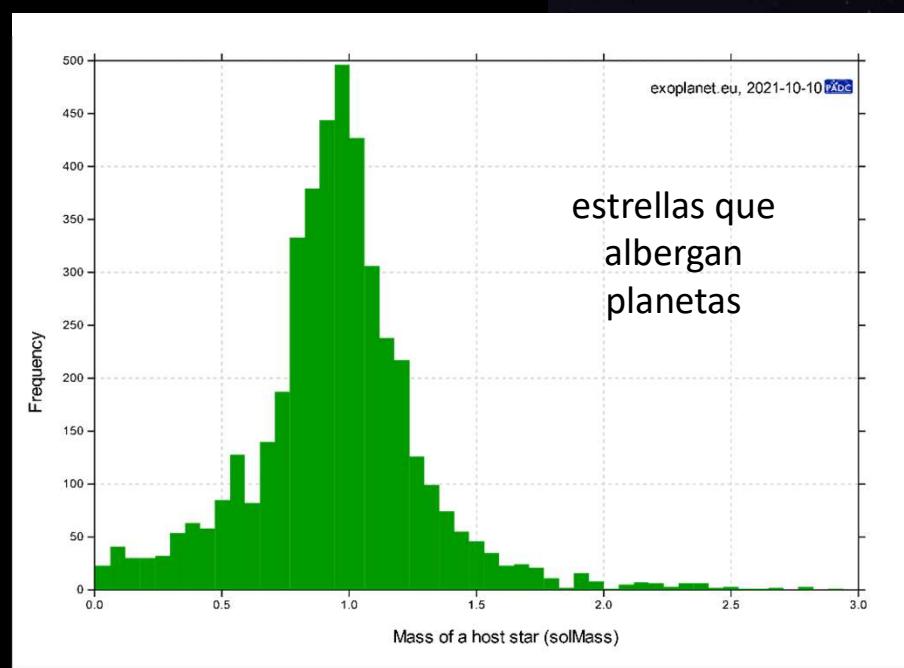
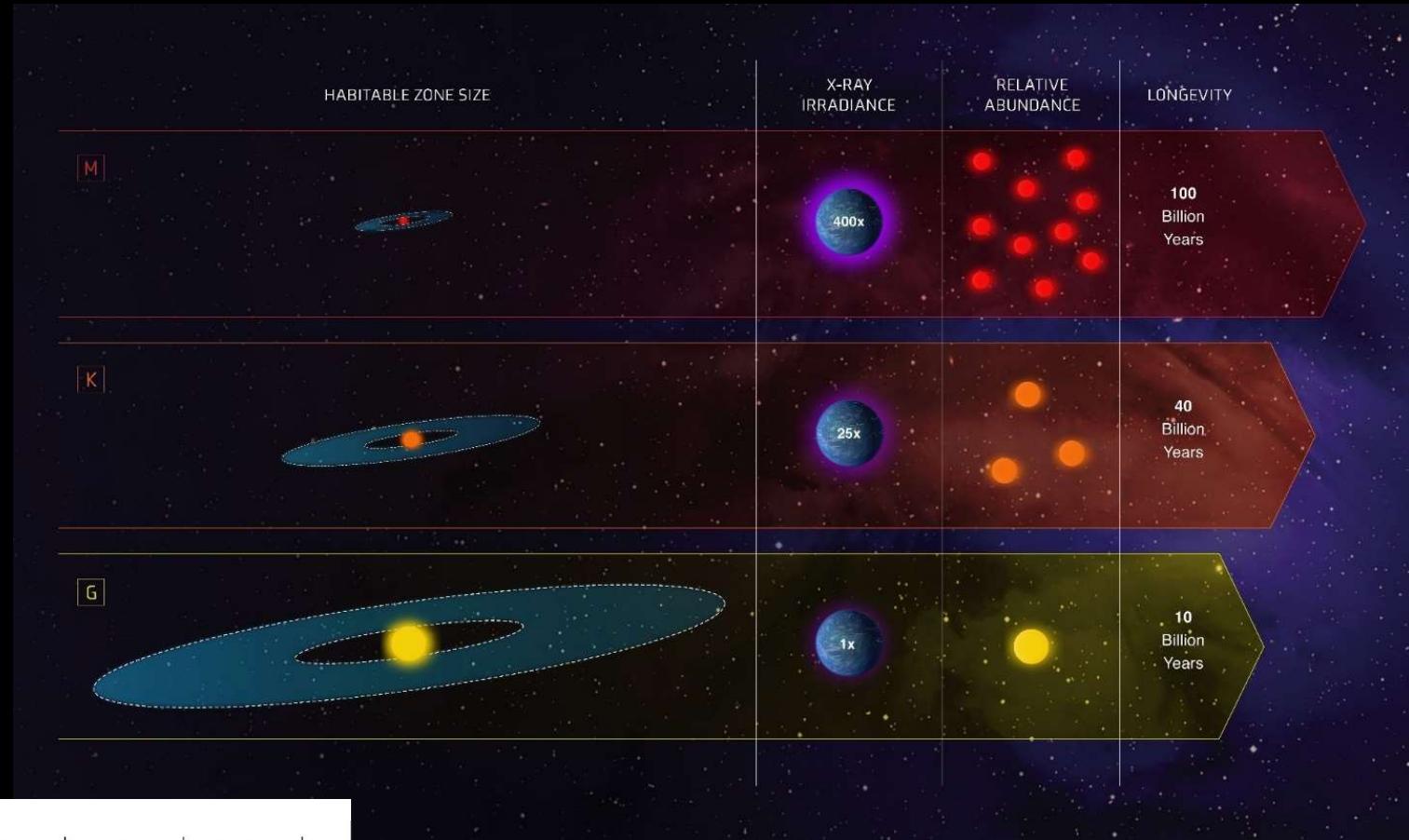
Similar in size to Neptune and Uranus. They can be ice giants, or much warmer. "Warm" Neptunes are more rare.

5000+ PLANETS FOUND

B3) Propiedades de los exoplanetas





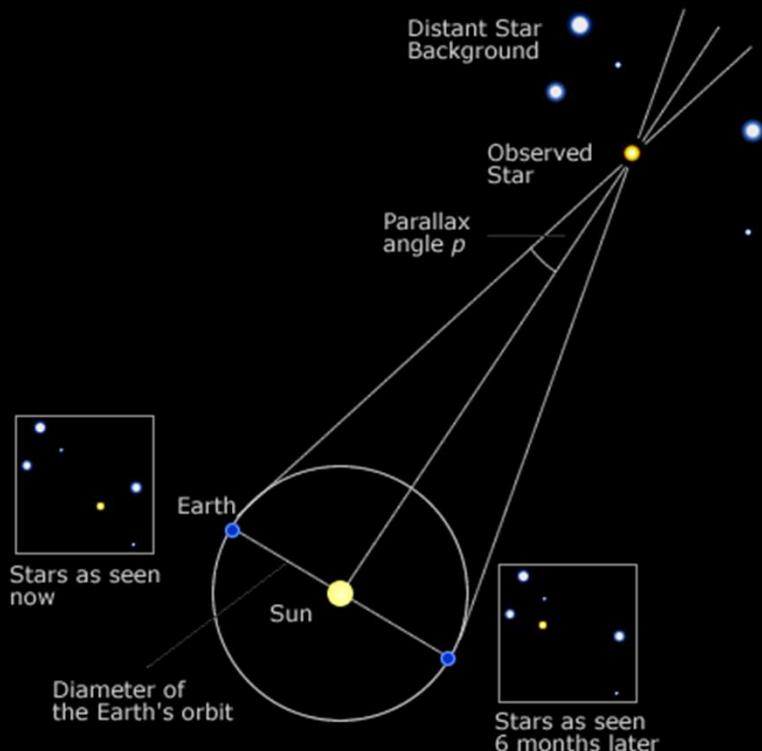


B4) Como se miden las propiedades orbitales y físicas de los exoplanetas

1. Propiedades de la estrella huésped (distancia y masa)

Distancia de la estrella

- Método de paralaje

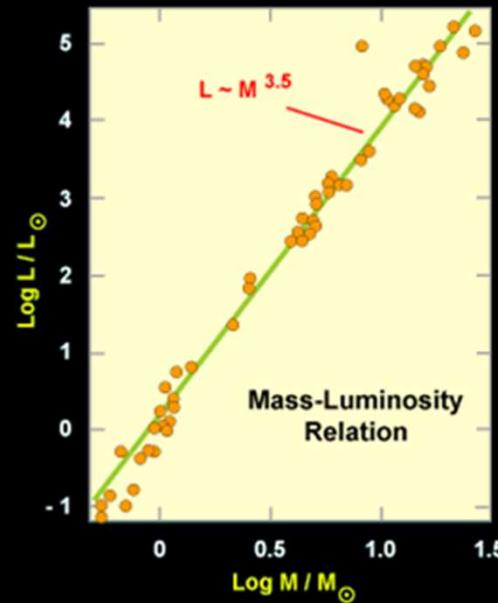


Masa de la estrella

- Luminosidad aparente + distancia → Luminosidad absoluta

$$(m - M) = 5 \log_{10}(d) - 5$$

- Relación masa-luminosidad → Masa



2. Propiedades orbitales del exoplaneta (periodo y semi-eje mayor de la órbita)

Periodo del exoplaneta

- Directamente de las observaciones

$$P^2 = \left[\frac{4\pi^2}{G(M+m)} \right] a^3$$

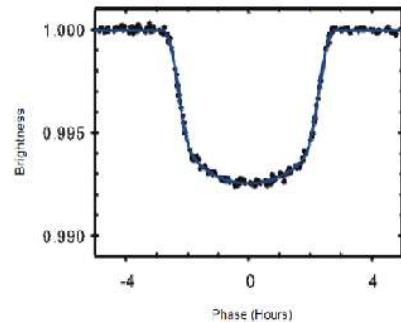
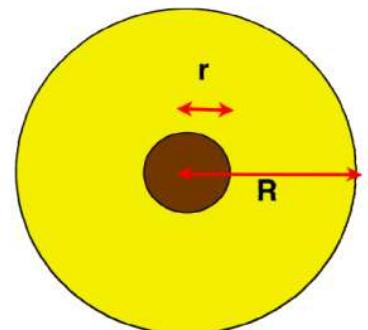
Semi-eje mayor del exoplaneta

- Utilizando la Tercera Ley de Kepler

3. Propiedades físicas del exoplaneta (masa, radio y densidad)

Masa del exoplaneta

- Método de velocidad radial → velocidad de la estrella
- Conservación del *momentum* → masa del planeta



$$Drop = r^2 / R^2$$

$$V_p = \sqrt{\frac{GM_*}{a}}$$

then, conservation of momentum:

$$M_p V_p = M_* V_*$$

we can get M_p

$$M_p = M_* \left(\frac{V_*}{V_p} \right)$$

but we really get $M_p \sin(i)$

$$M_p \sin i = M_* \left(\frac{V_* \sin i}{V_p} \right)$$

Radio del exoplaneta

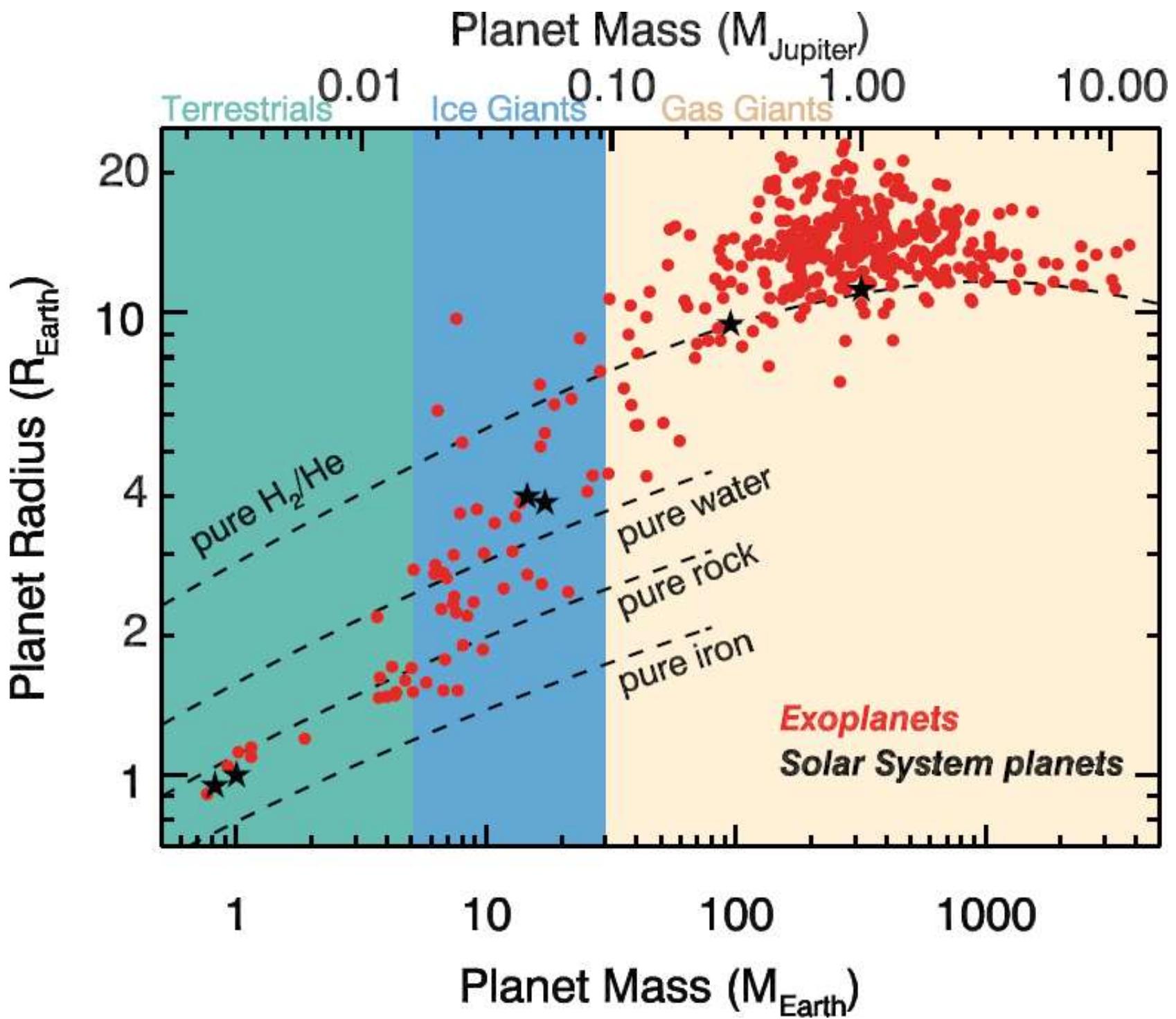
- Ley de Stefan-Boltzmann → radio de la estrella

$$L = 4\pi R^2 \cdot \sigma T^4$$

- Método de transito → radio del exoplaneta

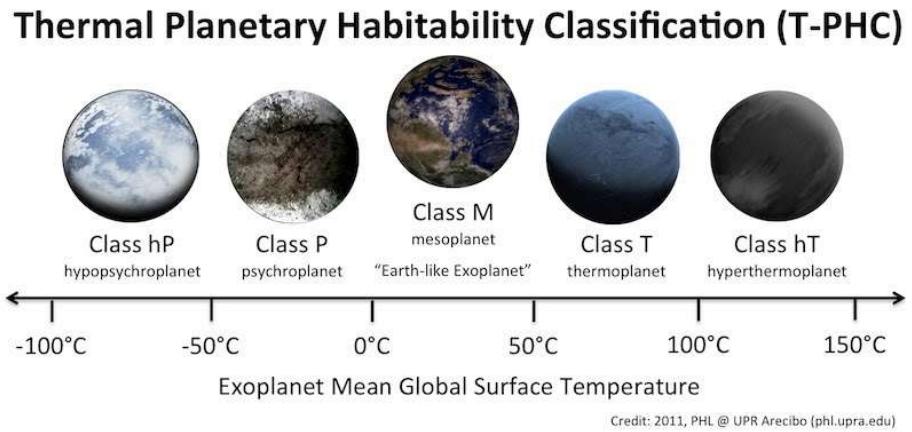
Densidad del exoplaneta

- Masa/Volumen



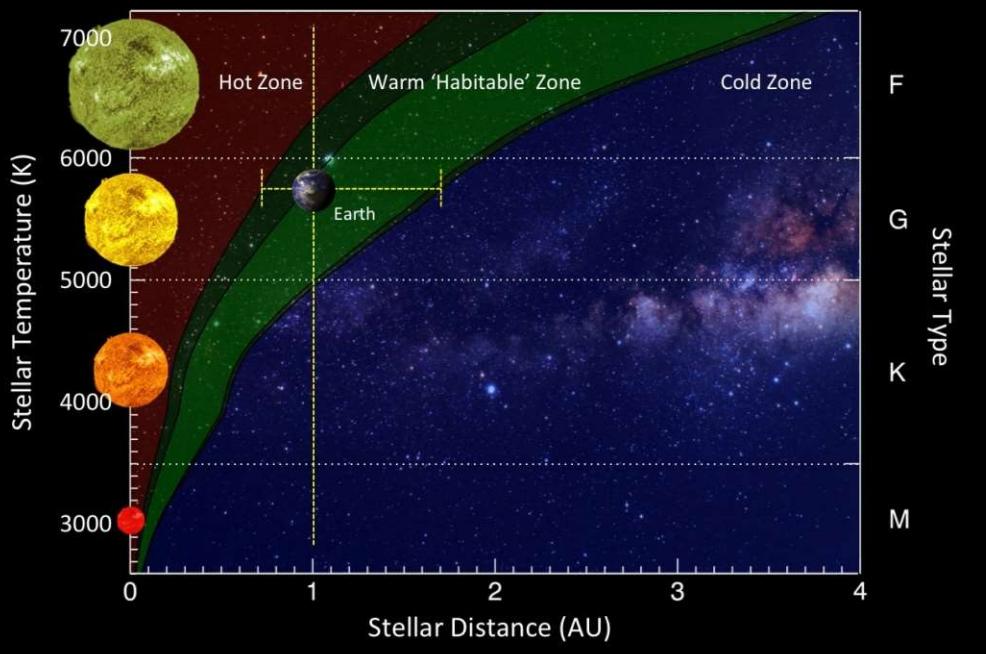
B5) Condiciones para la existencia de vida

1. Fuente de energía (baja entropía local)
2. Agua líquida (temperatura)

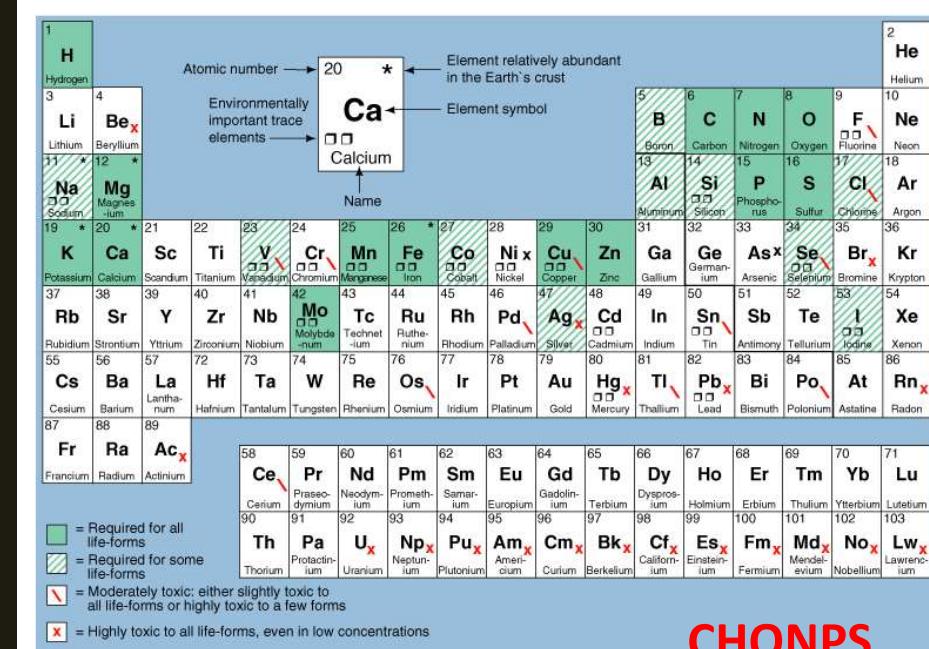


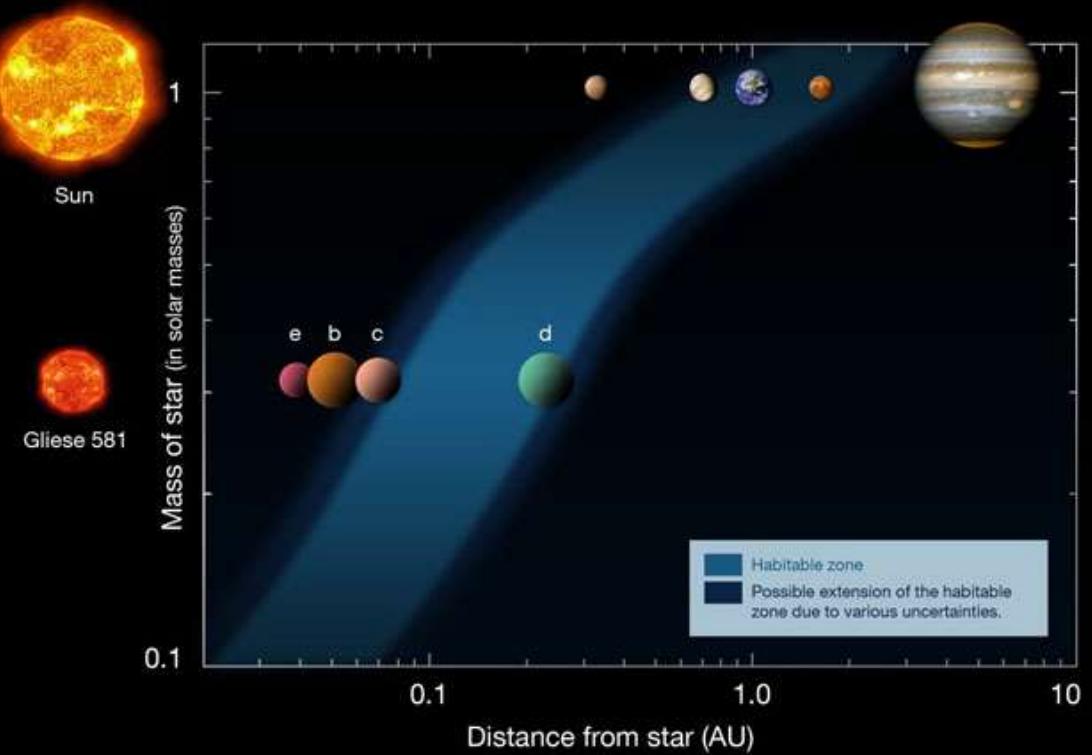
3. Composición química adecuada (moléculas complejas: lípidos, nucleótidos y aminoácidos)
4. Reproducción y evolución (selección natural)

Zona Habitable para estrellas de la Secuencia Principal

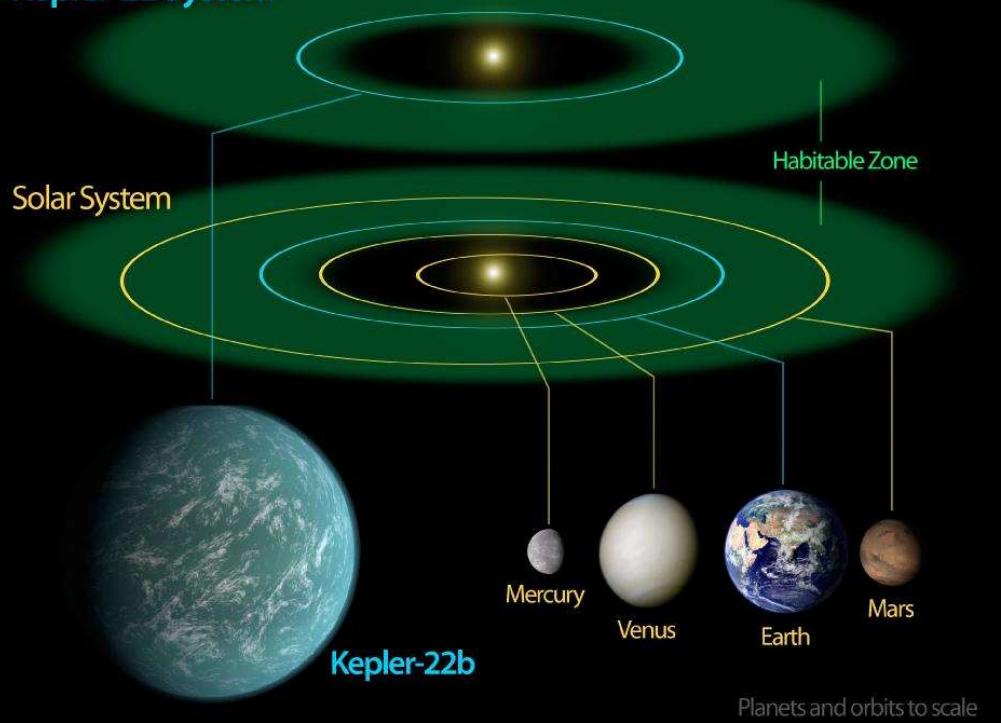


CREDIT: PHL @ UPR Arecibo

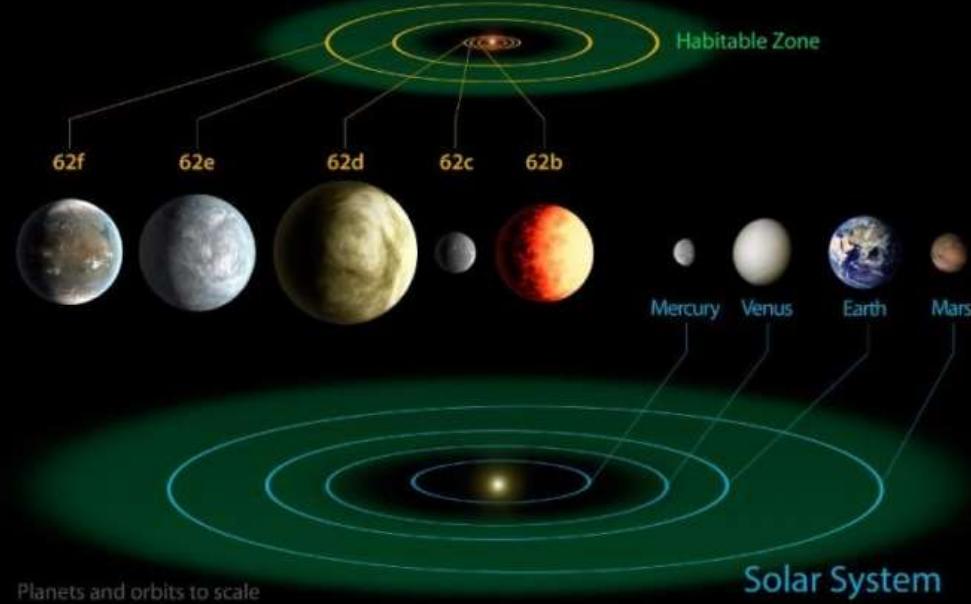




Kepler-22 System



Kepler-62 System



Sistema TRAPPIST-1

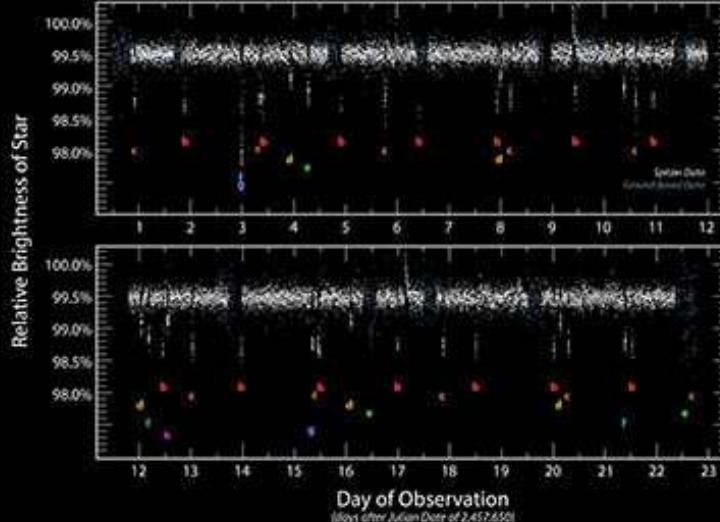
TRAPPIST-1 System



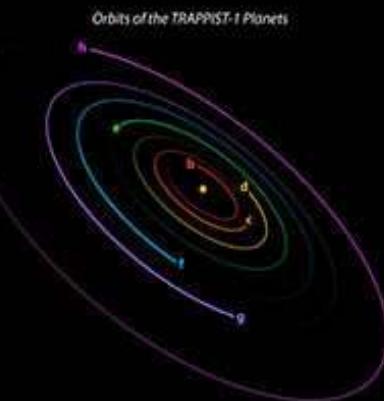
Inner Solar System



Illustration



500 Hours of Exoplanet Transits in the TRAPPIST-1 System
NASA/JPL-Caltech/M. Gillon (Univ. of Liege, Belgium)

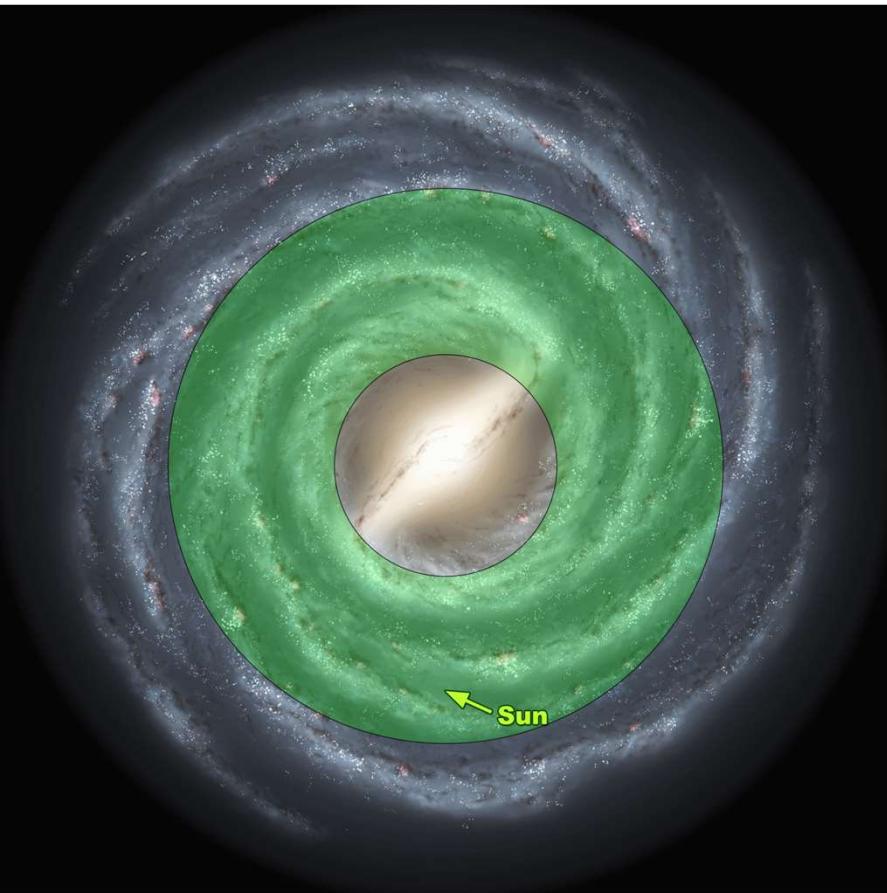


Spitzer Space Telescope • IRAC

Número de Planetas	Cantidad de Sistemas
8	2 (Sol y Kepler-90)
7	3
6	4

Planet	Mass (M_{Jup})	Radius (R_{Jup})	Period (day)	a (AU)	e	i (deg)	Ang. dist. (arcsec)	Discovery	Update
TRAPPIST-1 h	—	0.0674	20	0.063	—	89.8	—	2017	2017-09-01
TRAPPIST-1 g	0.00422	0.1005	12.35294	0.0451	0	89.71	—	2017	2017-09-01
TRAPPIST-1 f	0.0021	0.09323	9.20669	0.0371	0	89.68	—	2017	2017-09-01
TRAPPIST-1 e	0.002	0.0819	6.099615	0.02817	0	89.86	—	2017	2017-09-01
TRAPPIST-1 d	0.0013	0.0689	4.04961	0.02144	0	89.75	—	2016	2017-09-01
TRAPPIST-1 c	0.00434	0.09421	2.4218233	0.01521	0	89.67	—	2016	2017-09-01
TRAPPIST-1 b	0.0027	0.09689	1.51087081	0.01111	0	89.65	—	2016	2017-09-01

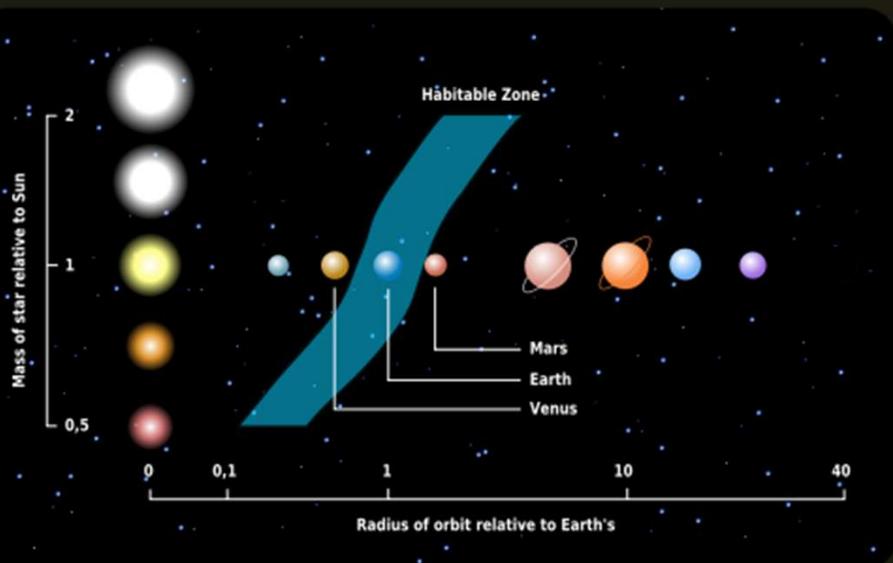
Zona de habitabilidad galáctica



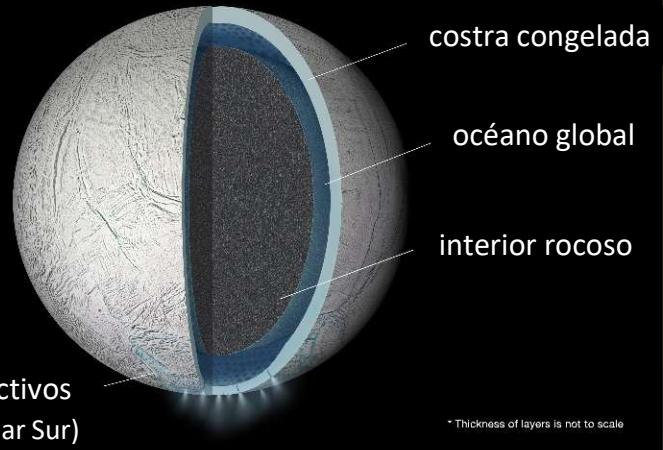
Las estrellas de galaxias **elípticas** y **cúmulos globulares** son dominantemente viejas y **pobres en metales** (se formaron básicamente de material primordial) y, por lo tanto, no son adecuadas para desarrollar vida. Los discos de galaxias espirales son mas promisores.

En una galaxia **disco**, las partes muy externas también tienen baja formación estelar y, así, también baja metalicidad. Las parte muy internas presentan otros problemas: la alta densidad estelar y fenómenos explosivos producen mucha radiación nociva. Luego, hay una **Zona de Habitabilidad Galáctica** con condiciones adecuadas para albergar la vida.

Los mejores candidatos para albergar vida en nuestro Sistema Solar

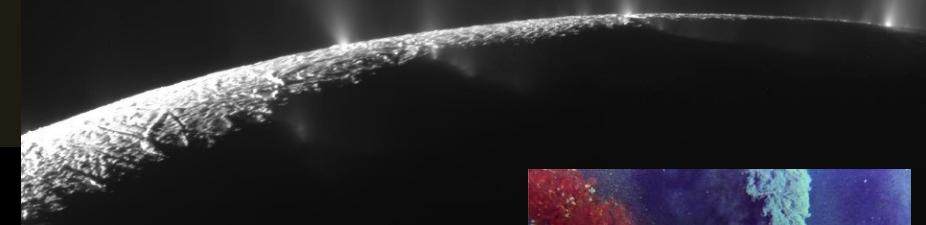
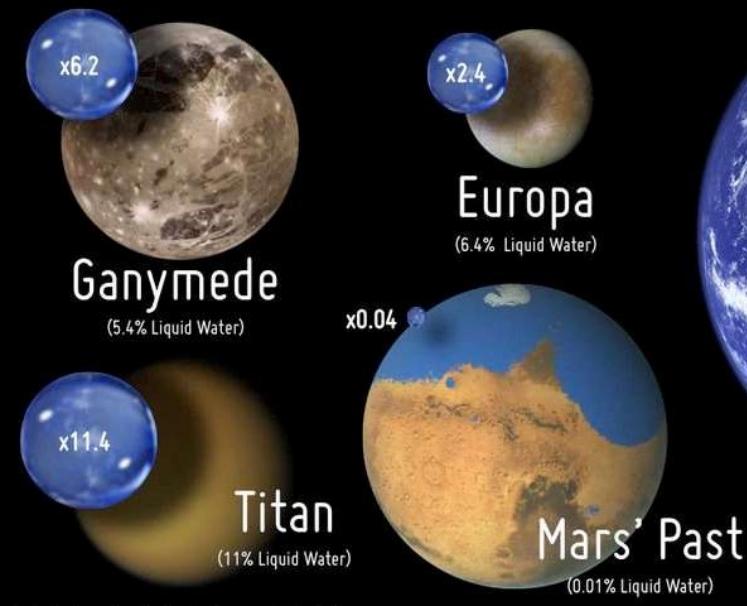


ENCELADUS

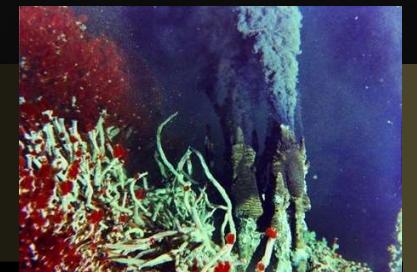


chorros activos
(Región Polar Sur)

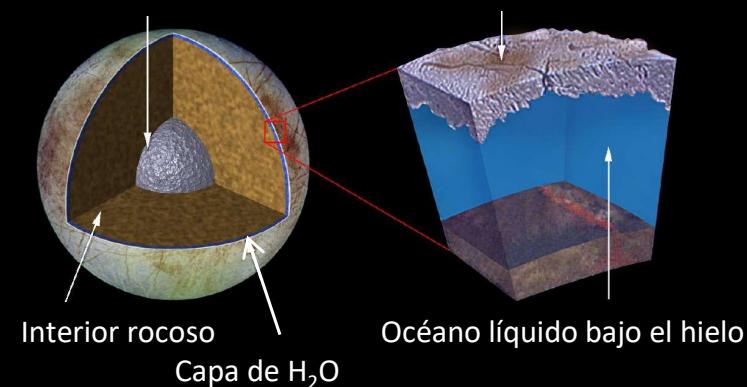
Oceans of the Solar System



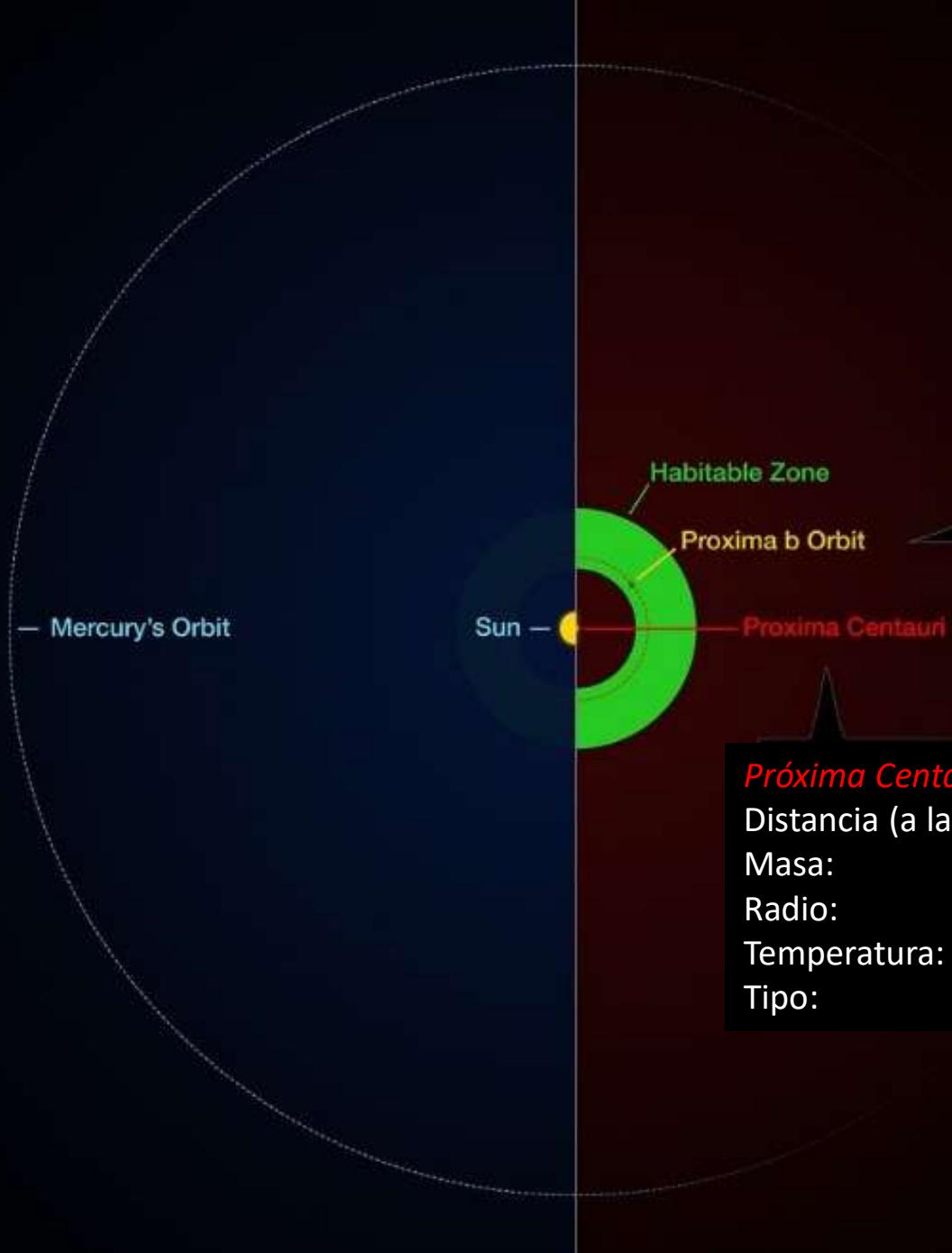
Núcleo metálico



Capa de hielo



El candidato más cercano



Próxima Centauri b

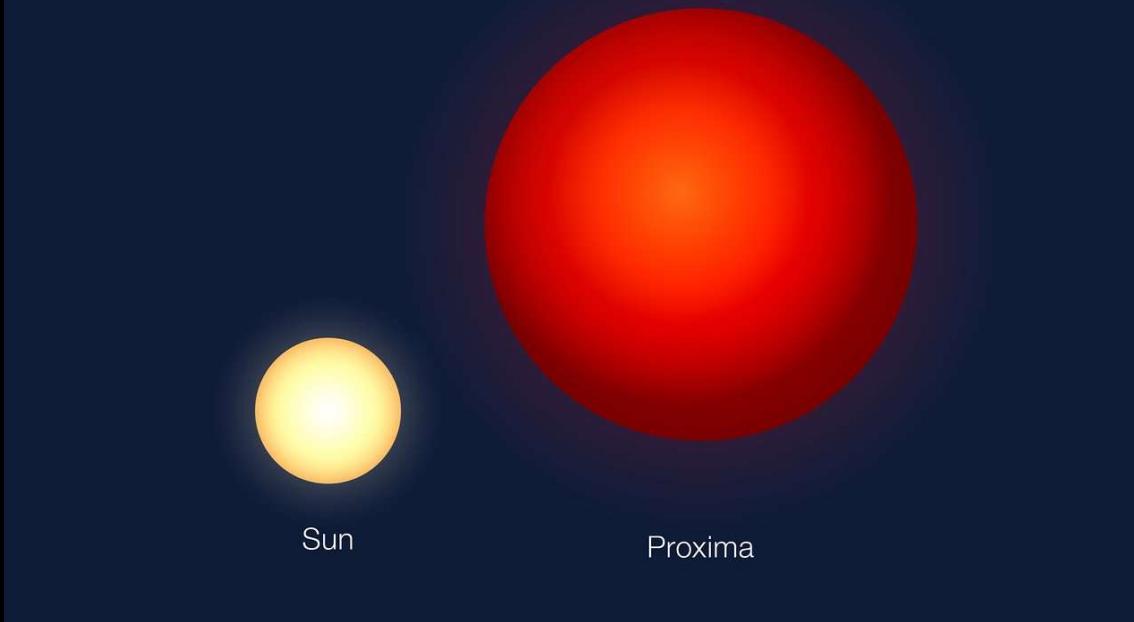
Descubierta:	2016
Masa:	$1.3 M_{\oplus}$
Semi-eje mayor:	0.05 UA
Periodo orbital:	11.2 días \oplus
Excentricidad:	0

Próxima Centauri (★)

Distancia (a la Tierra):	1.295 pc (4.22 años-luz)
Masa:	$0.12 M_{\odot}$
Radio:	$0.14 R_{\odot}$
Temperatura:	3050 K
Tipo:	M5

Sun angular diameter = $32' = 0.5^\circ$

Proxima angular diameter = $96' = 1.5^\circ$



Earth

Proxima b
(artistic representation)

B6) LA ECUACIÓN DE DRAKE (numero de 'civilizaciones' en la Galaxia)

What is the Drake equation?

It's an equation developed by Frank Drake, that have the propose of estimate the potential number of intelligent alien civilizations in the our galaxy.

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

How it does work?

$$R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L = N$$

the average rate of star formation **every year** in our galaxy



the fraction of those stars that **have planets**



the average number of planets that can **support life** in star that has planets



the fraction of planets that **actually develop life**



the fraction of planets with life that actually go on to **develop intelligent life**



the fraction of intelligent life that release **detectable signs of their existence in space**



the expected lifetime of such a civilization for the **period that it can communicate across the space**



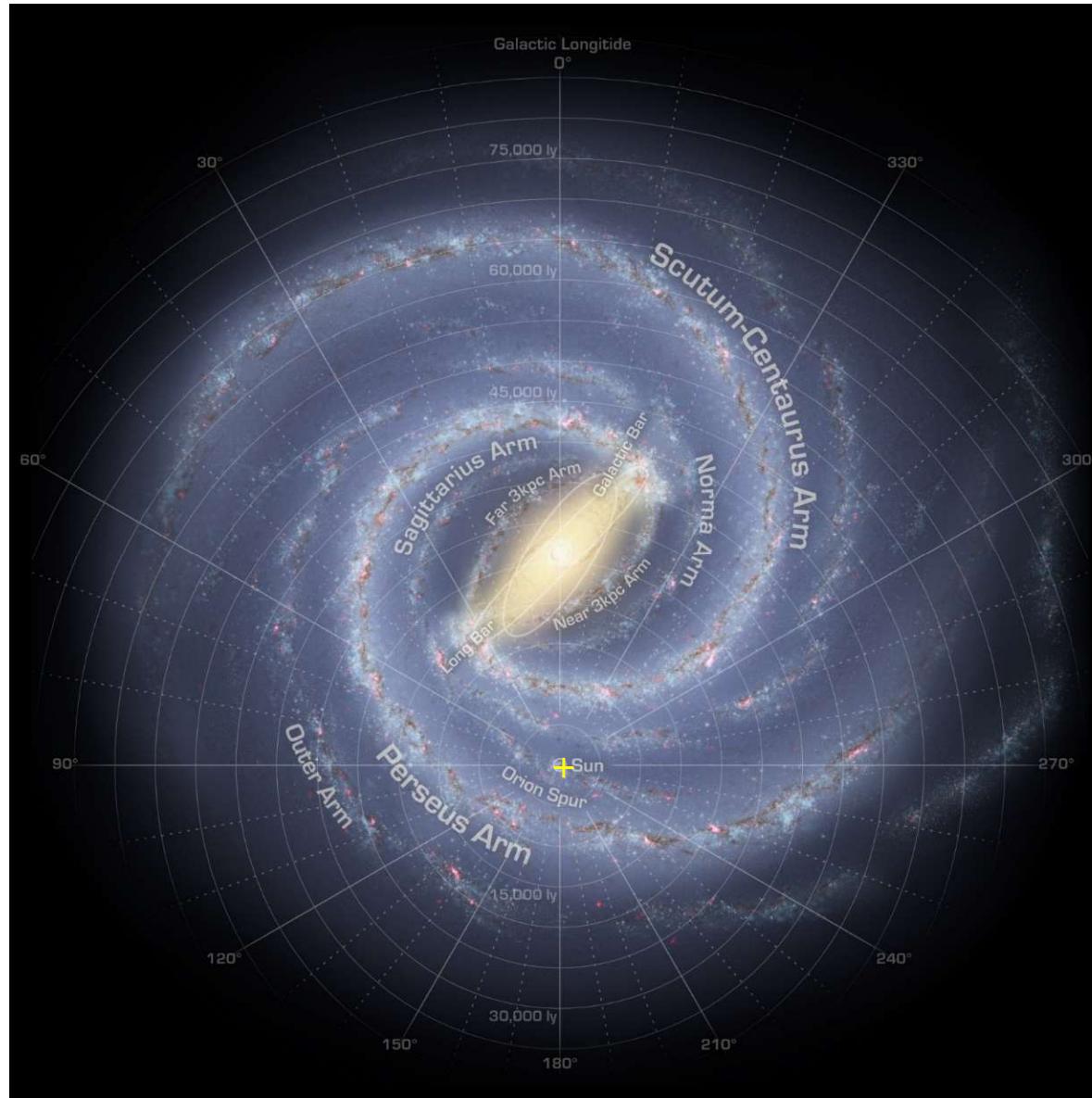
the number of civilizations in **our galaxy** with which communication might be possible

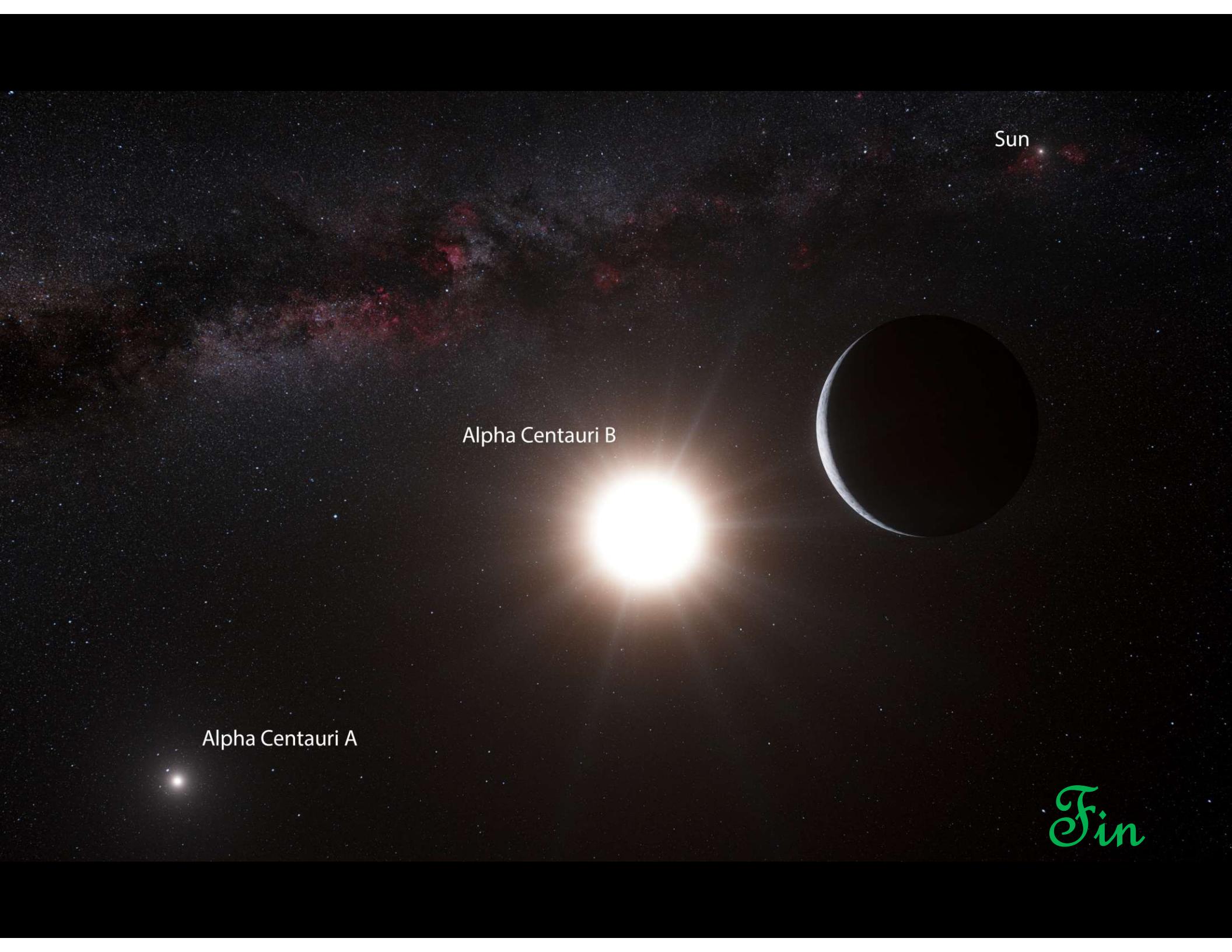


TABLE 1 Factors Involved in the Drake Equation

Factor	Plausible Lower Limit	Plausible Upper Limit
Stars with planets	0.01	0.3
Stars with habitable conditions on one planet	0.1	0.7
Habitable conditions last long enough for life to evolve	0.1	1.0
Probability that life actually does evolve	0.1	1.0
Favorable conditions last long enough for intelligence to evolve	0.1	0.9
Probability that intelligence does evolve	0.1	1.0
Probability that intelligent life endures	0.0000001	0.1
Product = fraction of stars with planets that now bear intelligent life	10^{-14}	0.02
Probable distance to nearest civilization	3×10^6 pc	5 pc

1 civilización cada
1 000 galaxias ↔ 1 civilización cada
50 estrellas





A dark, star-filled space scene. In the center-left, a bright yellow-orange star is labeled "Alpha Centauri A". To its right and slightly above is a smaller, dimmer yellow-orange star labeled "Alpha Centauri B". In the top right corner, a large, dark circular object represents the "Sun". The background is filled with numerous small white stars of varying brightness. A faint, reddish-brown nebula or galaxy is visible in the upper left. The overall atmosphere is deep and mysterious.

Sun

Alpha Centauri B

Alpha Centauri A

Fin