



Mercurio

Venus

Tierra

Marte

Júpiter

Saturno

Urano

Neptuno

Astronomía Planetaria

Prof. Dr. César A. Caretta

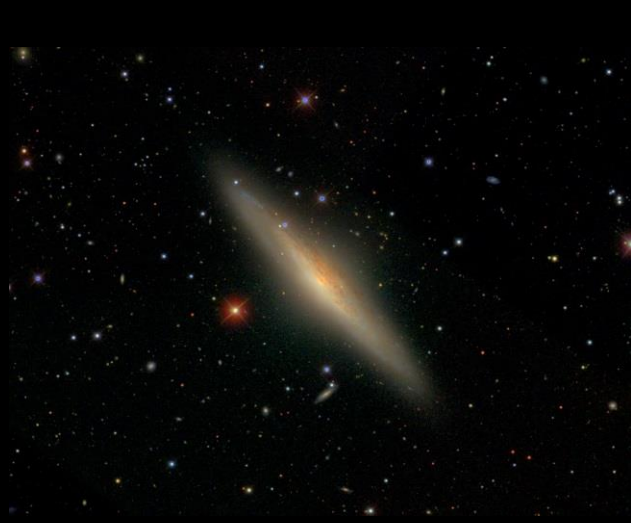
Departamento de Astronomía

DCNE, Campus Gto.,
Universidad de Guanajuato



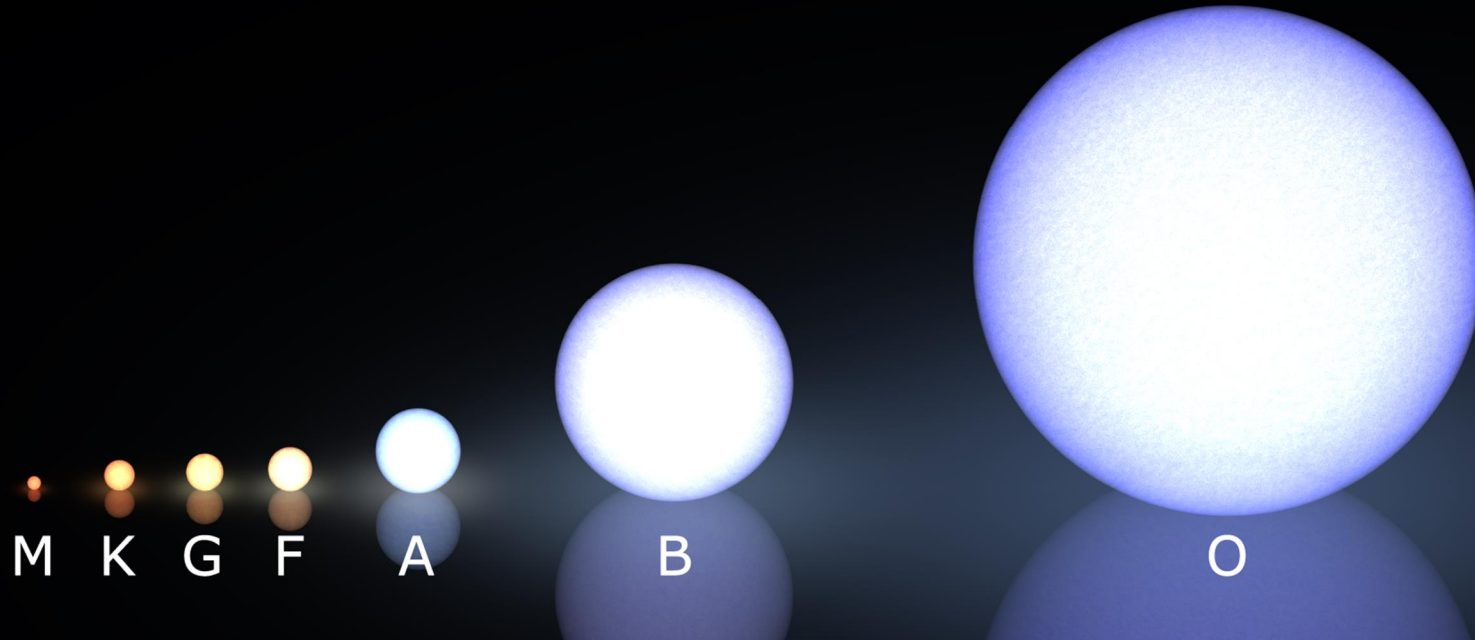
El Universo

Galaxias



Estrellas

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



Ciclo de vida del Sol

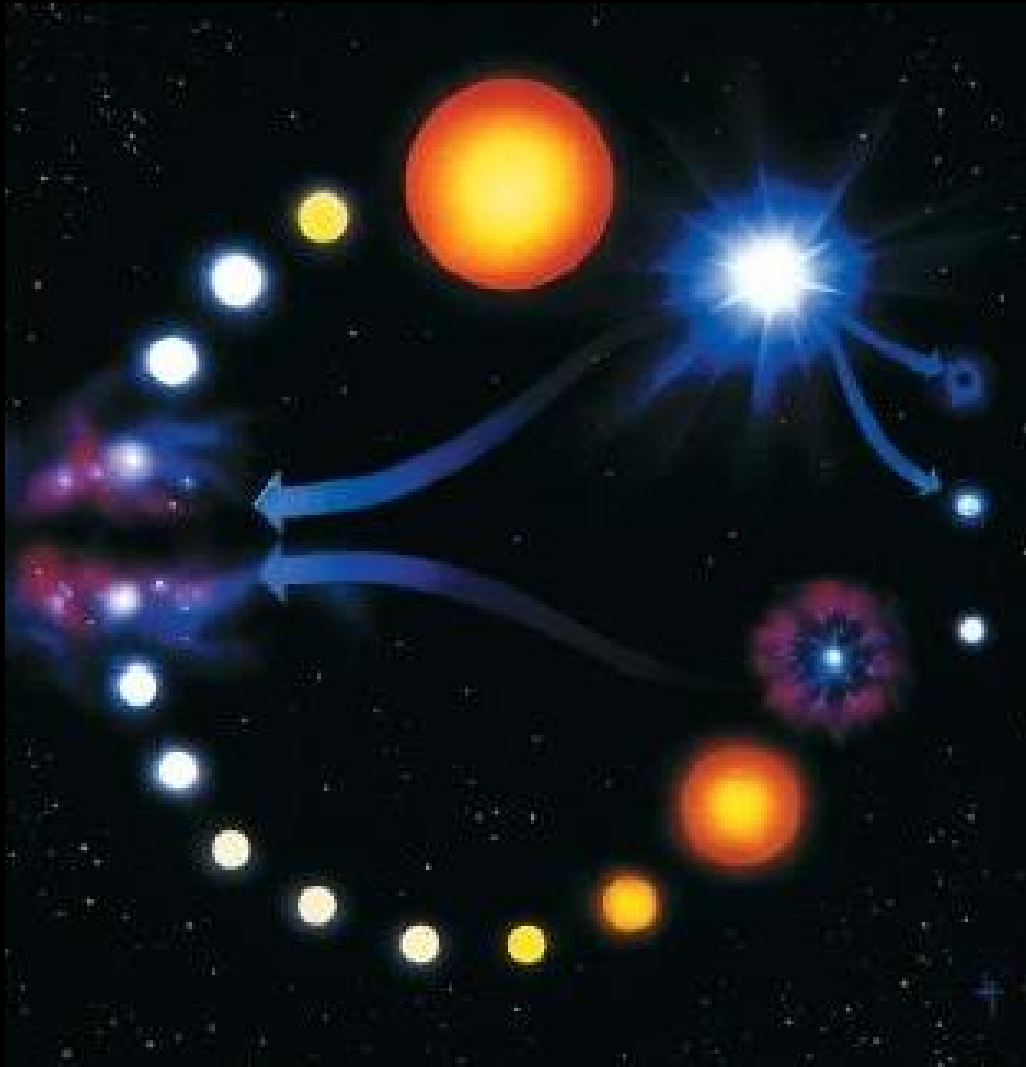


Formación estelar

- “ Fragmento de una Nube Gigante Molecular

Secuencia Principal

- “ Nucleosíntesis de He



Etapas finales de la vida de las estrellas

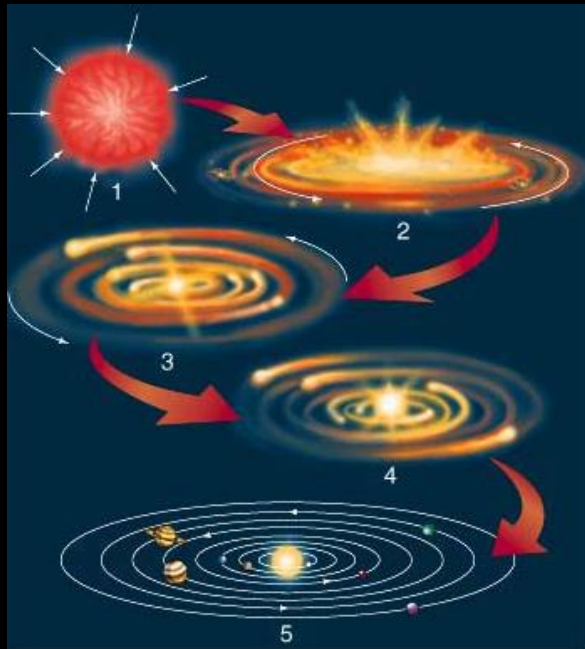
Estrellas de alta masa:

- “ Supergigantes Rojas (elementos mas pesados (C, N, O, Ne, Mg, Si, Ni, Fe, í)
- “ Explosión en Supernova
- “ Pulsar, Estrella de neutrones, Agujero Negro í

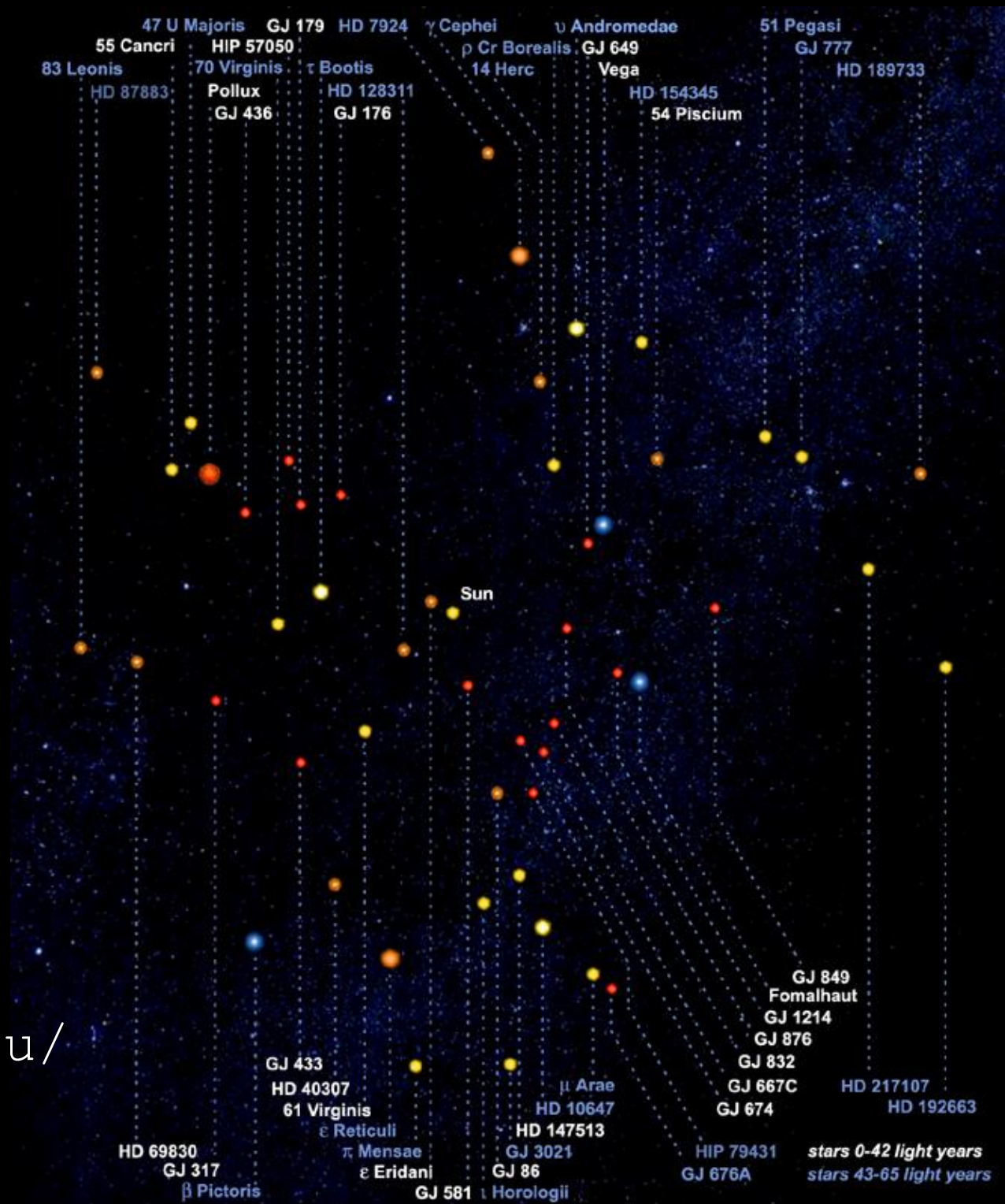
Estrellas de baja masa:

- “ Gigantes Rojas
- “ Nebulosa Planetaria
- “ Enana Blanca

Sistemas Planetarios

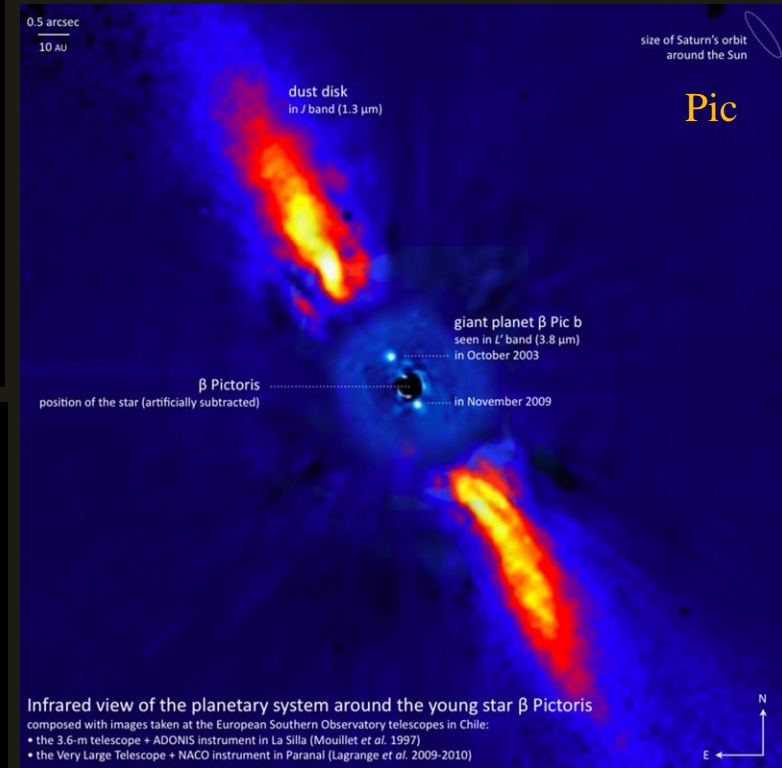
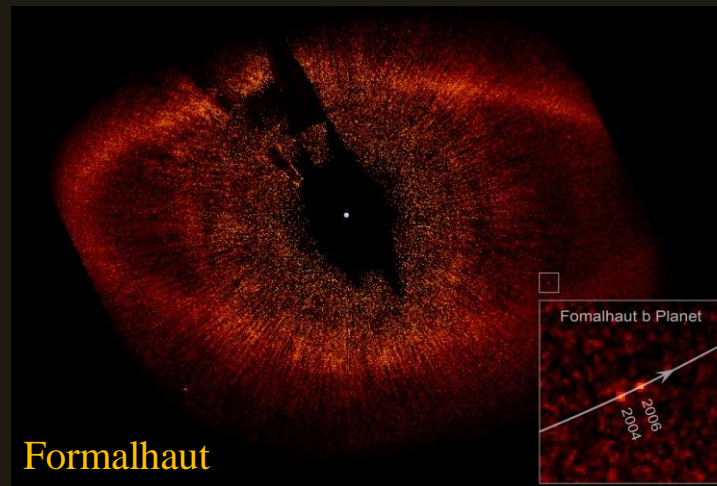
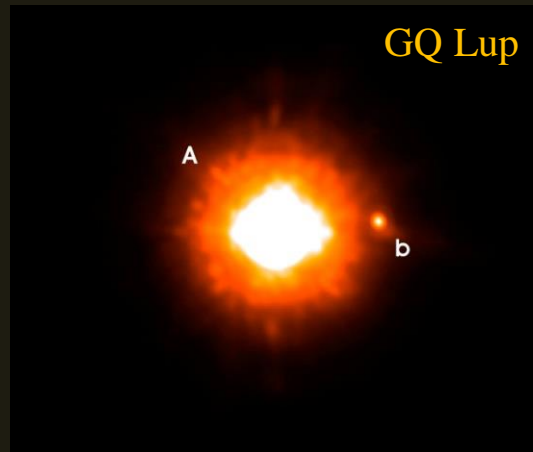
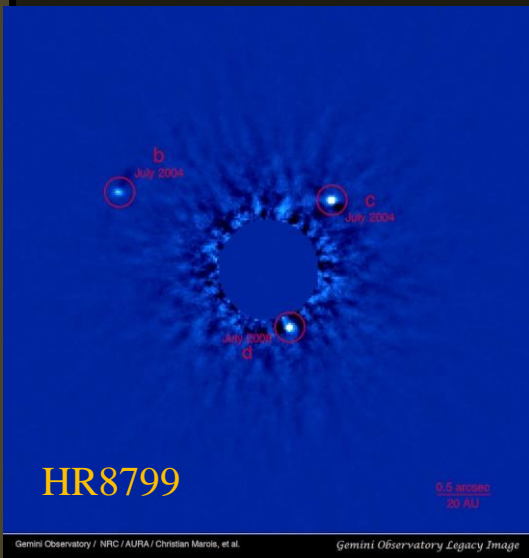


<http://exoplanet.eu/>

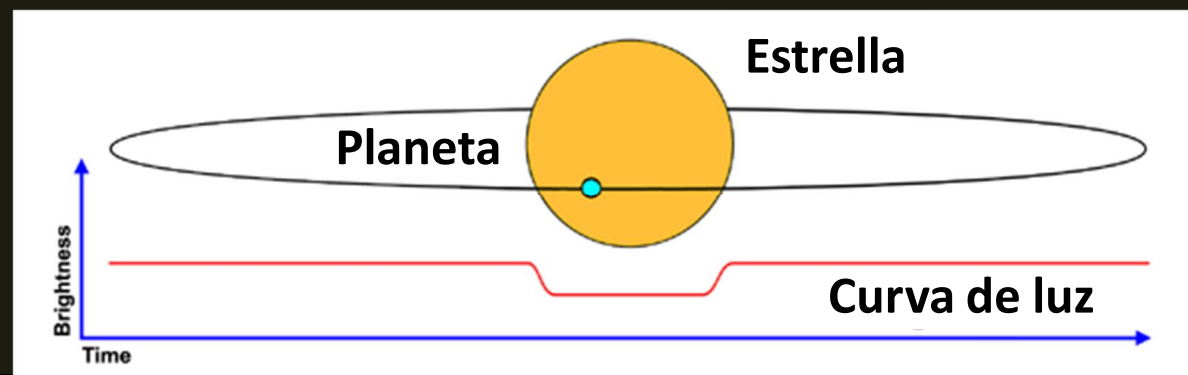


Métodos de detección para planetas extrasolares

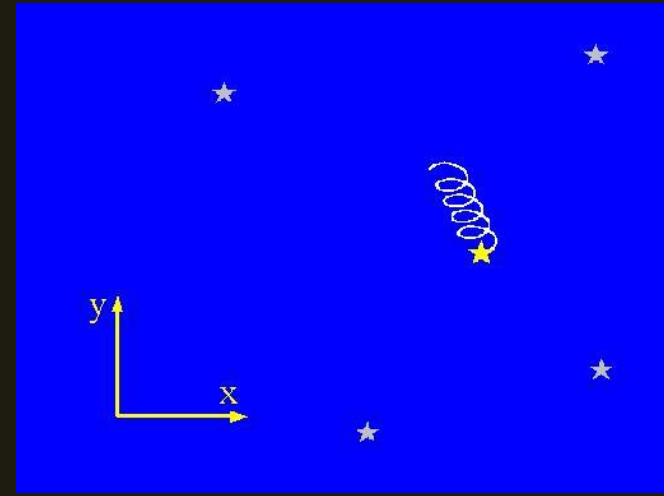
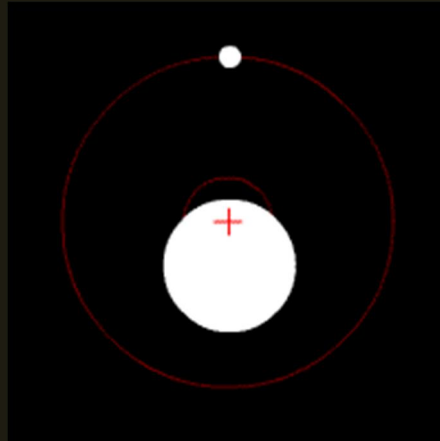
1. imagen directa



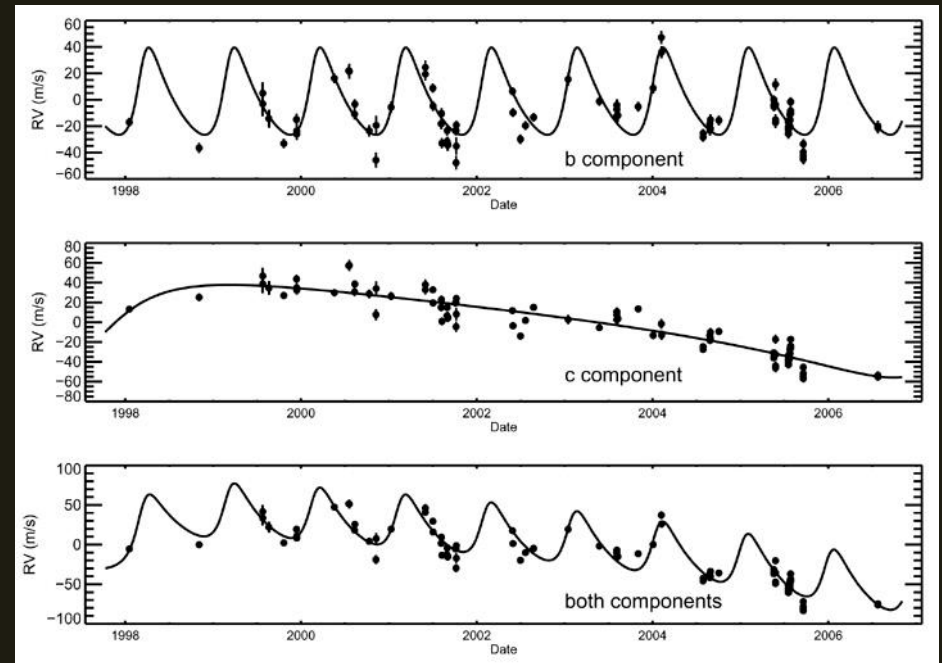
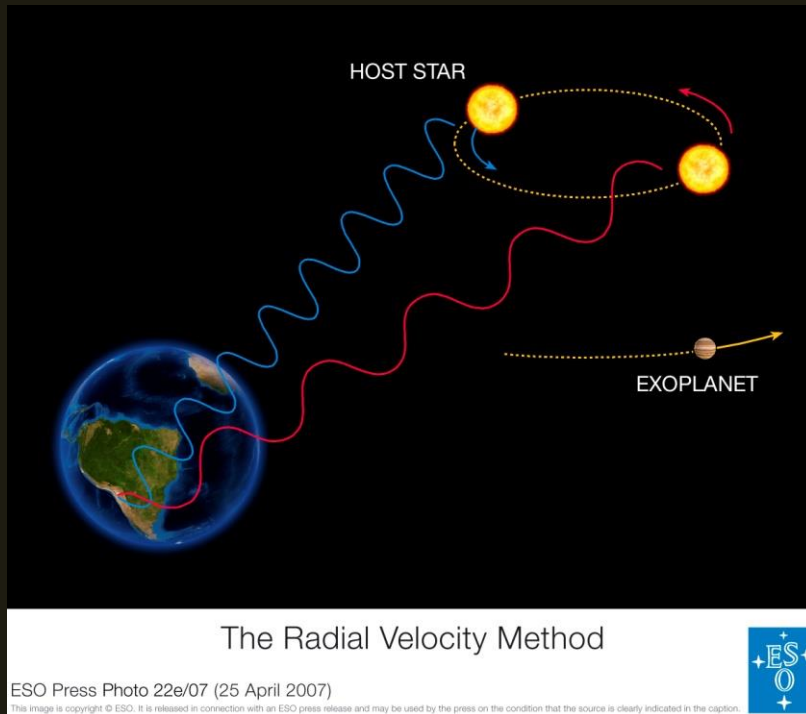
2. transito



3. astrometría



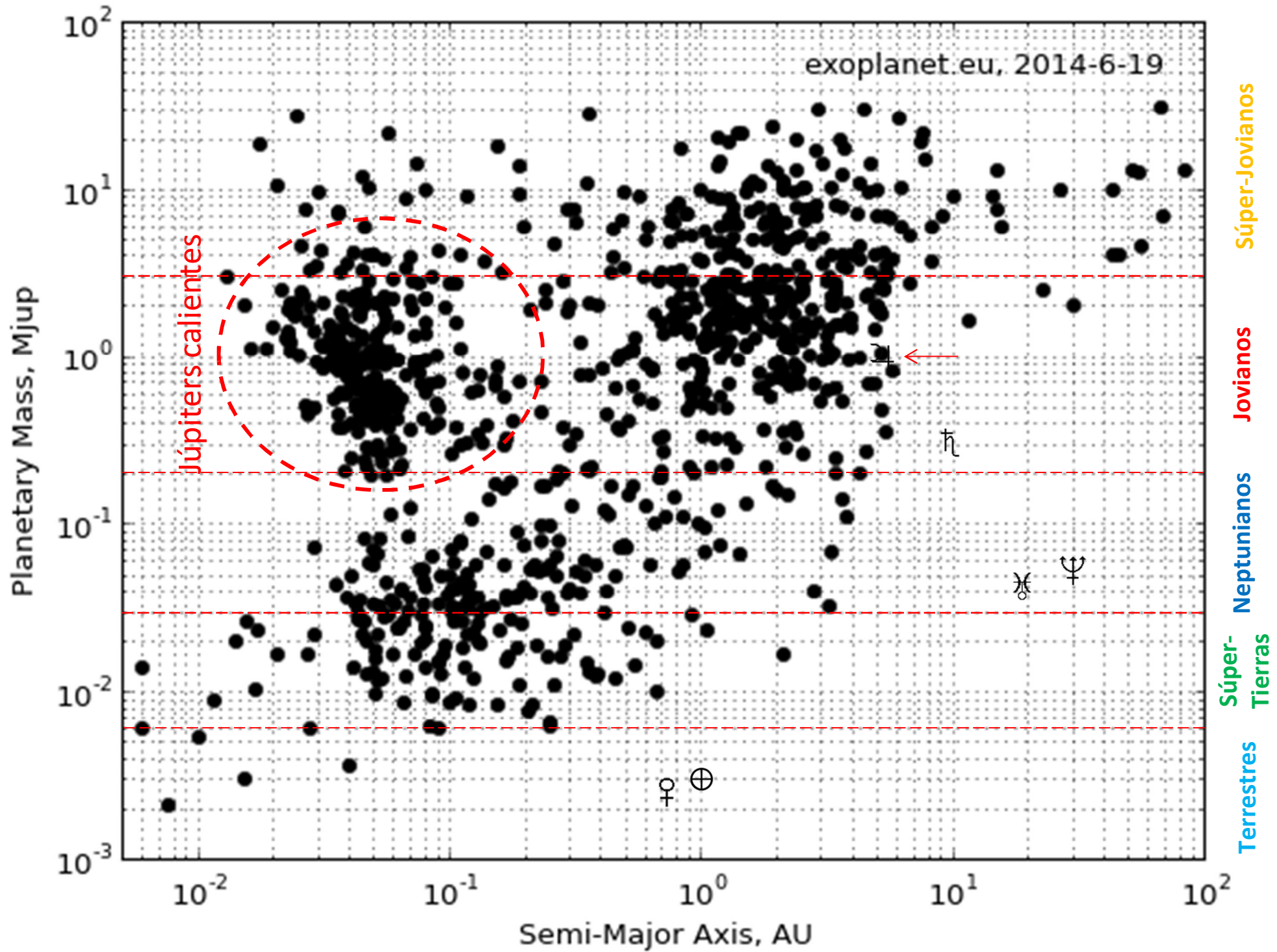
4. velocidad radial



Deteccción de planetas extrasolares (24 de julio de 2018)

Método	Sistemas planetarios	Planetas	Sistemas múltiples
imagen directa	87	94	5
transito	2118	2831	465
astrometría + veloc. radial	564	760	135
microlentes gravit.	75	78	3
pulsares	23	29	5
otros	19	21	2
TOTALES	2852	3811	633

Propiedades de los exoplanetas



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)

Sí



No



Pequeño cuerpo
(asteroide o cometa)



• ¿Fue capaz de despejar la región de su órbita?

(no se encuentra en un Cinturón de Asteroides)

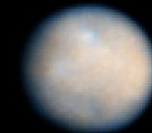
Sí



No



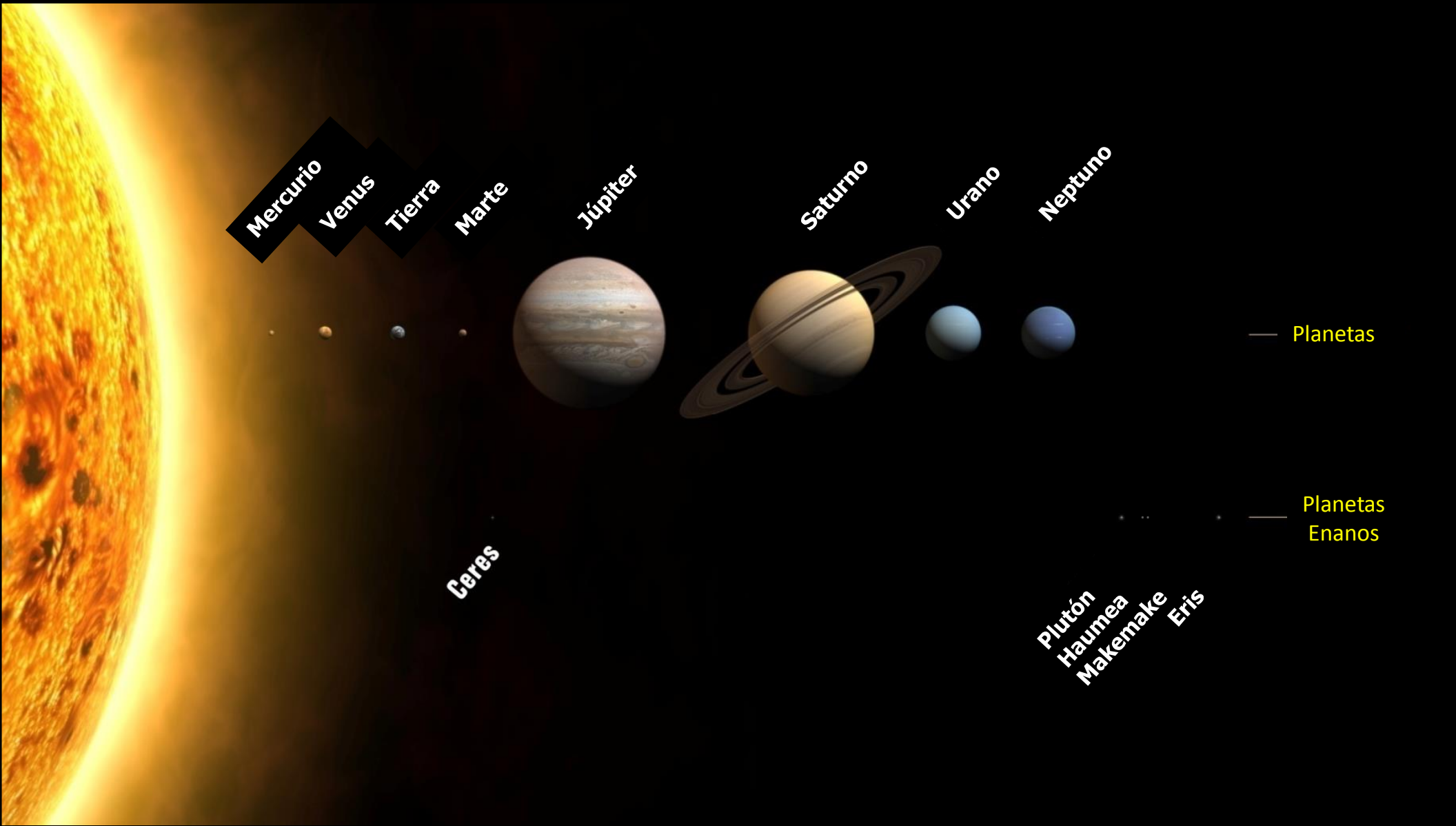
Planeta Enano



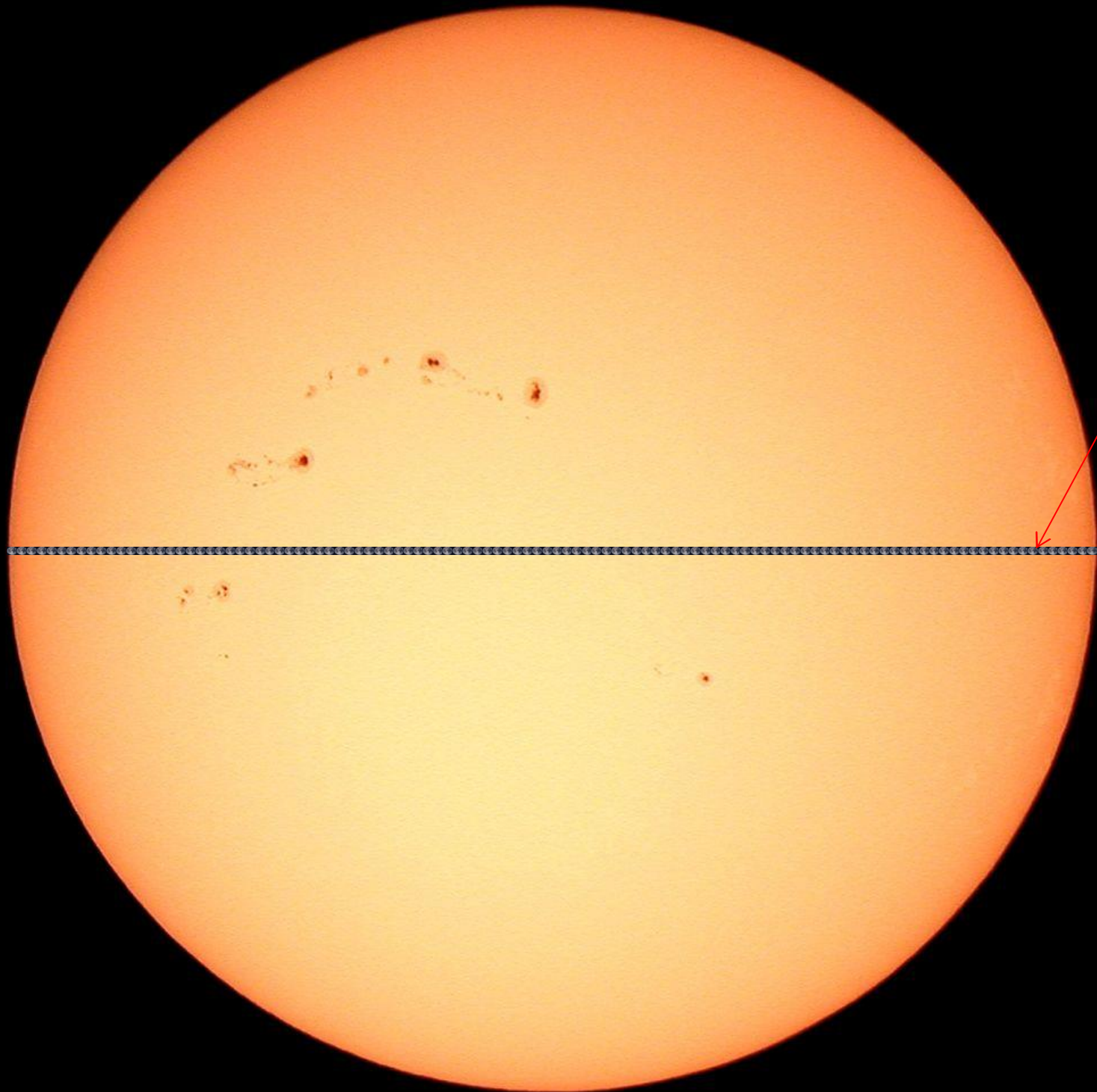
Planeta



El Sistema Solar



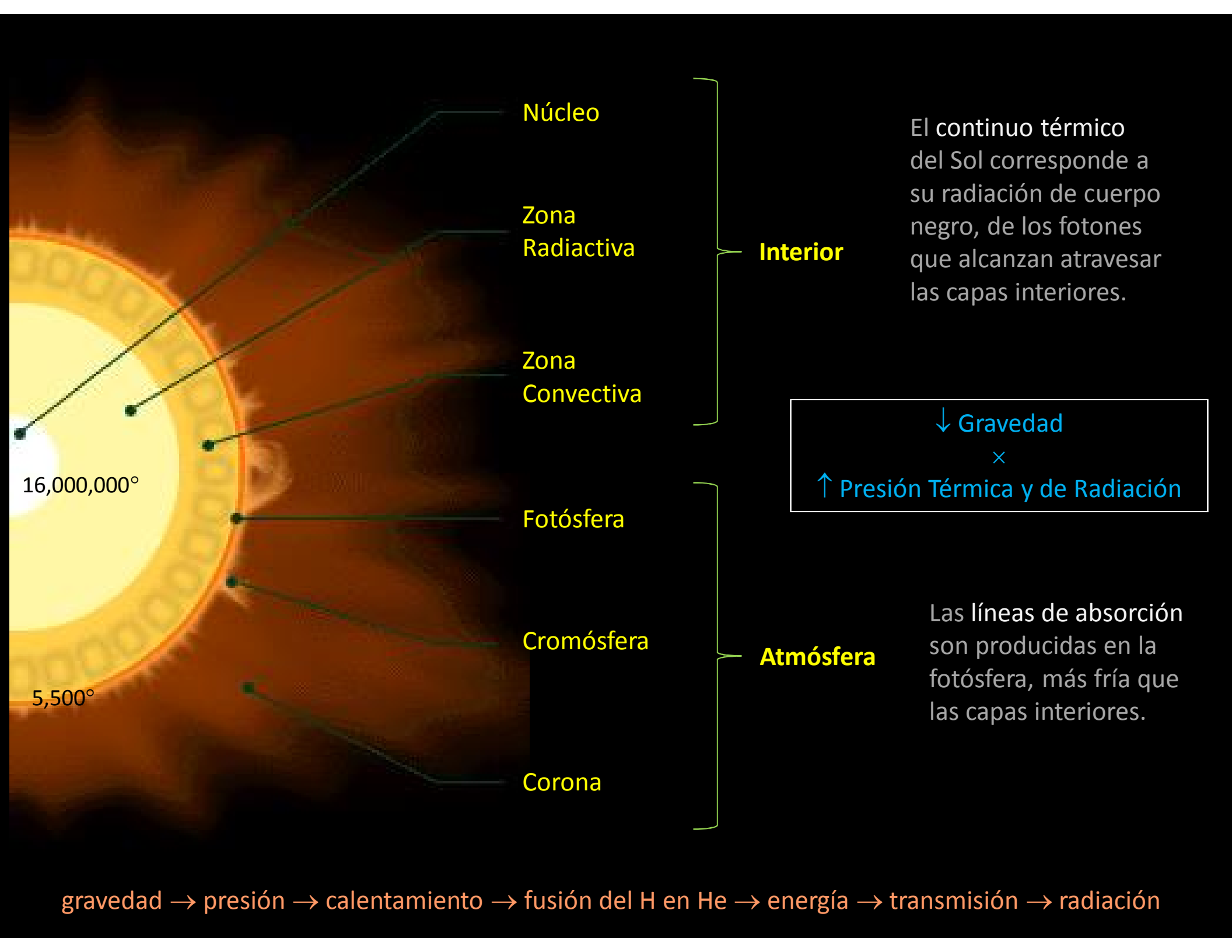
El Sol



"Tierra"

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

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



Núcleo

Zona Radiactiva

Zona Convectiva

Fotósfera

Cromósfera

Corona

Interior

Atmósfera

El continuo térmico del Sol corresponde a su radiación de cuerpo negro, de los fotones que alcanzan a travesar las capas interiores.

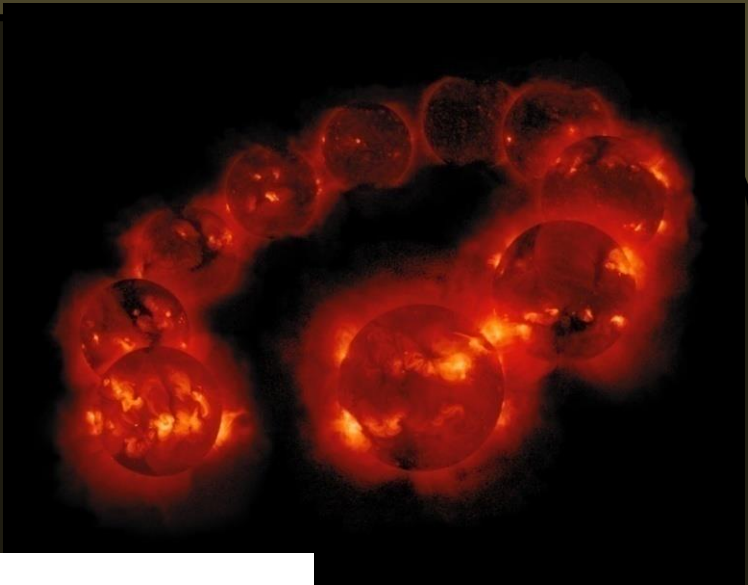
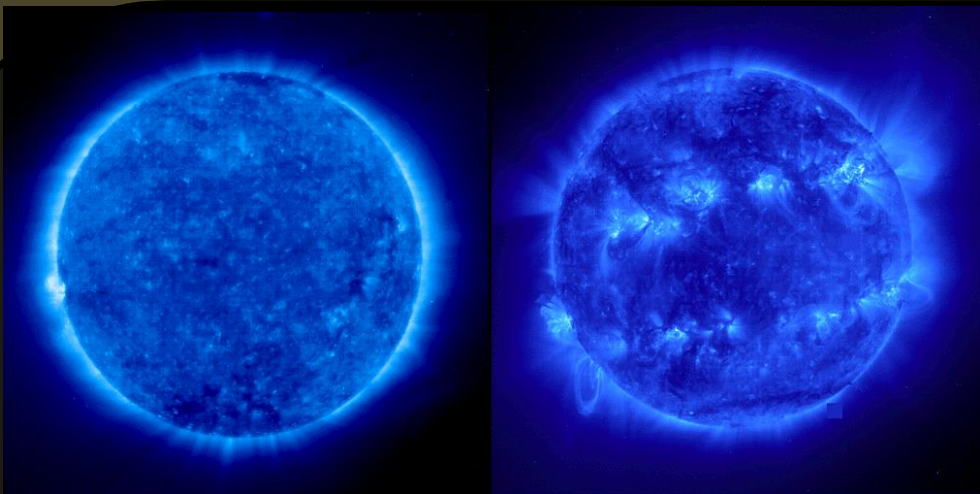
↓ Gravedad
×
↑ Presión Térmica y de Radiación

Las líneas de absorción son producidas en la fotosfera, más fría que las capas interiores.

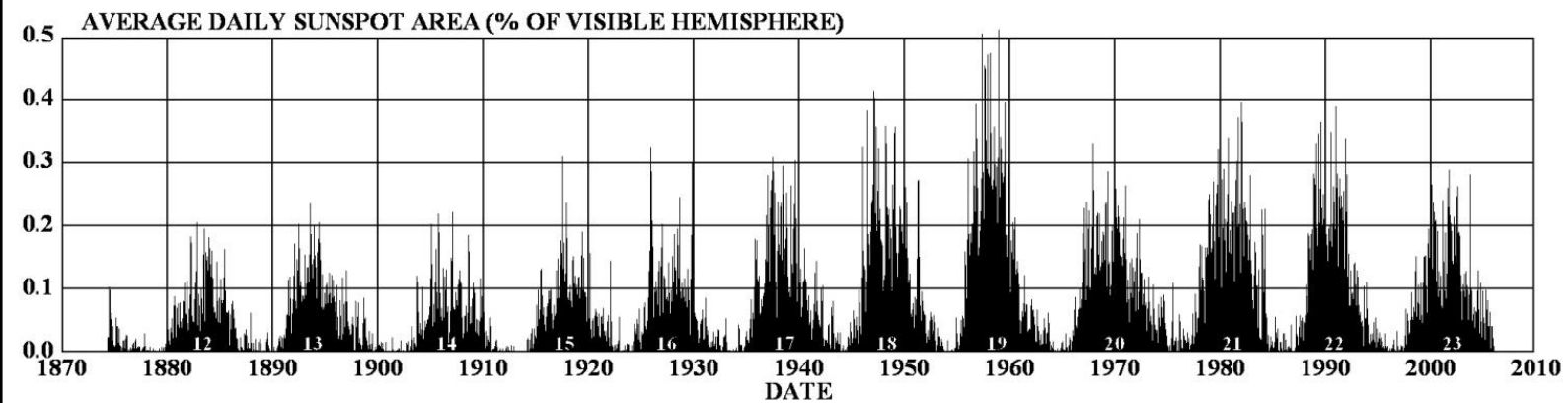
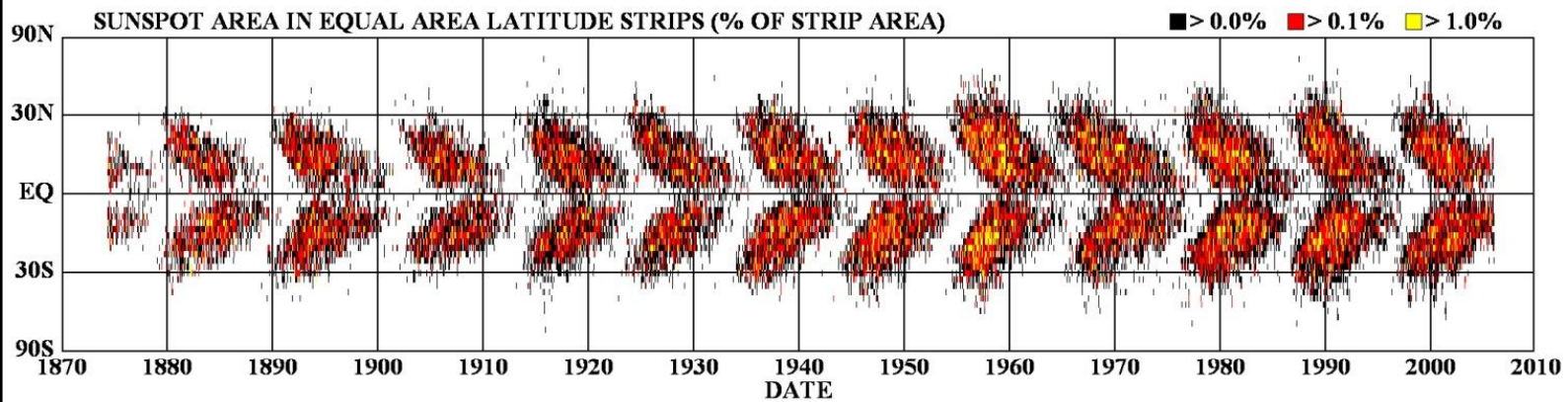
16,000,000°

5,500°

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

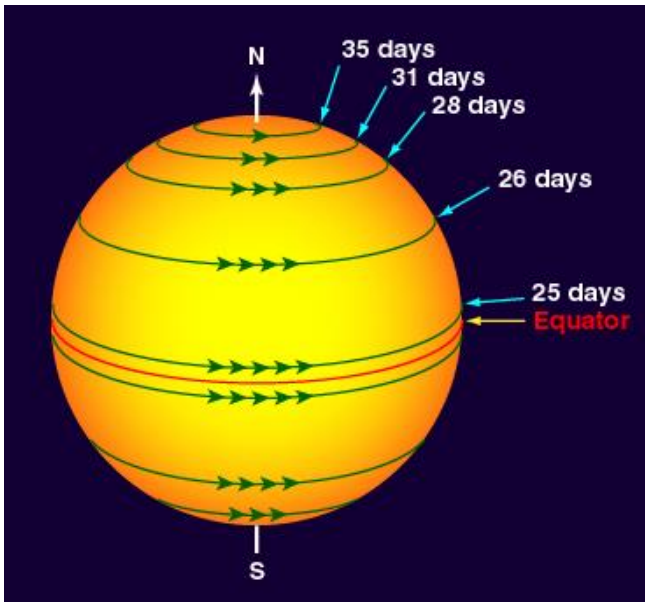


DAILY SUNSPOT AREA AVERAGED OVER INDIVIDUAL SOLAR ROTATIONS

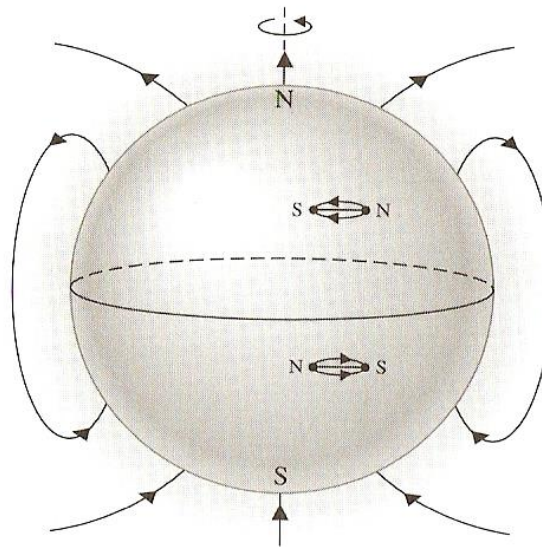


el ciclo solar

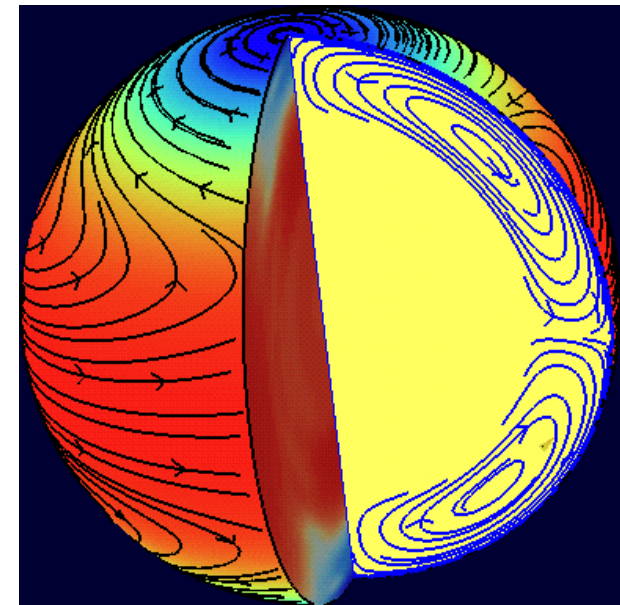
¿Qué produce el ciclo solar?



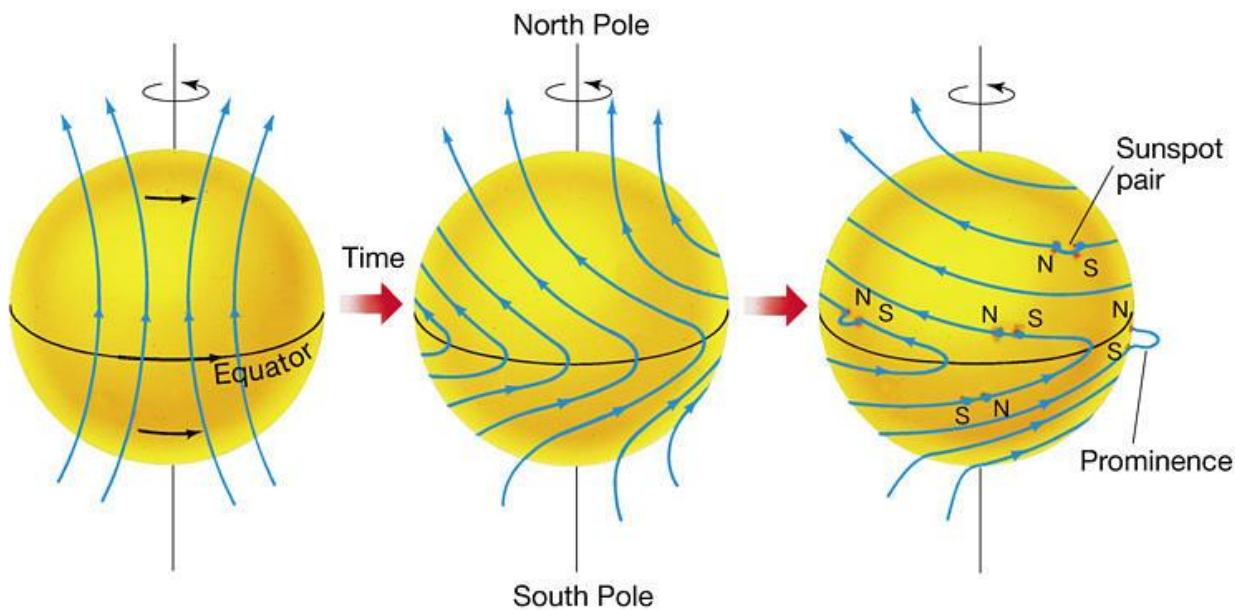
Rotación diferencial



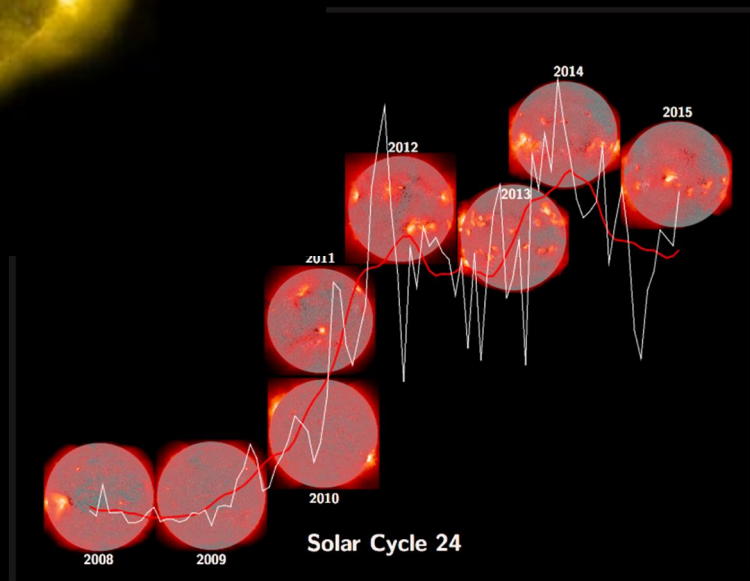
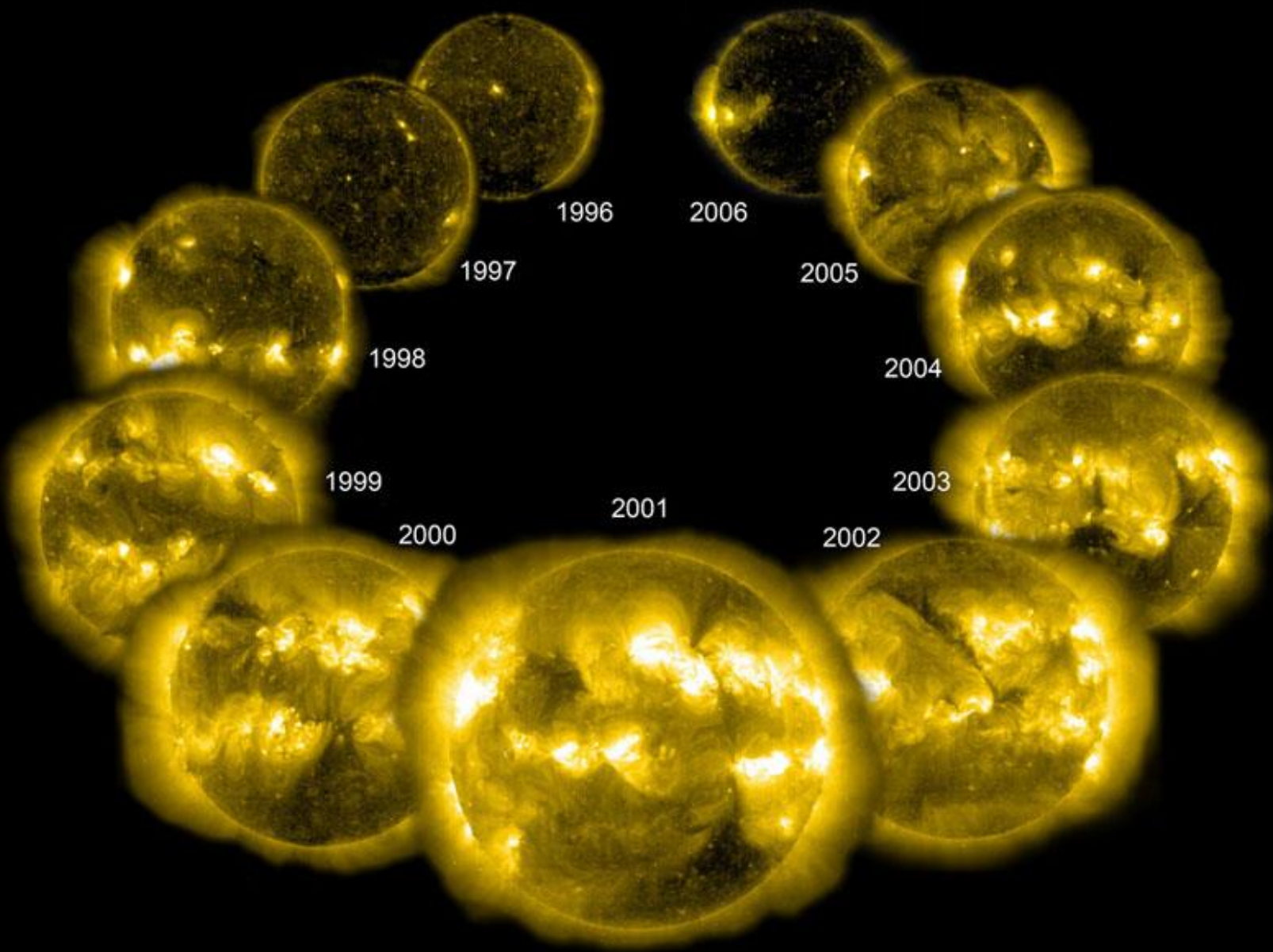
Campos magnéticos



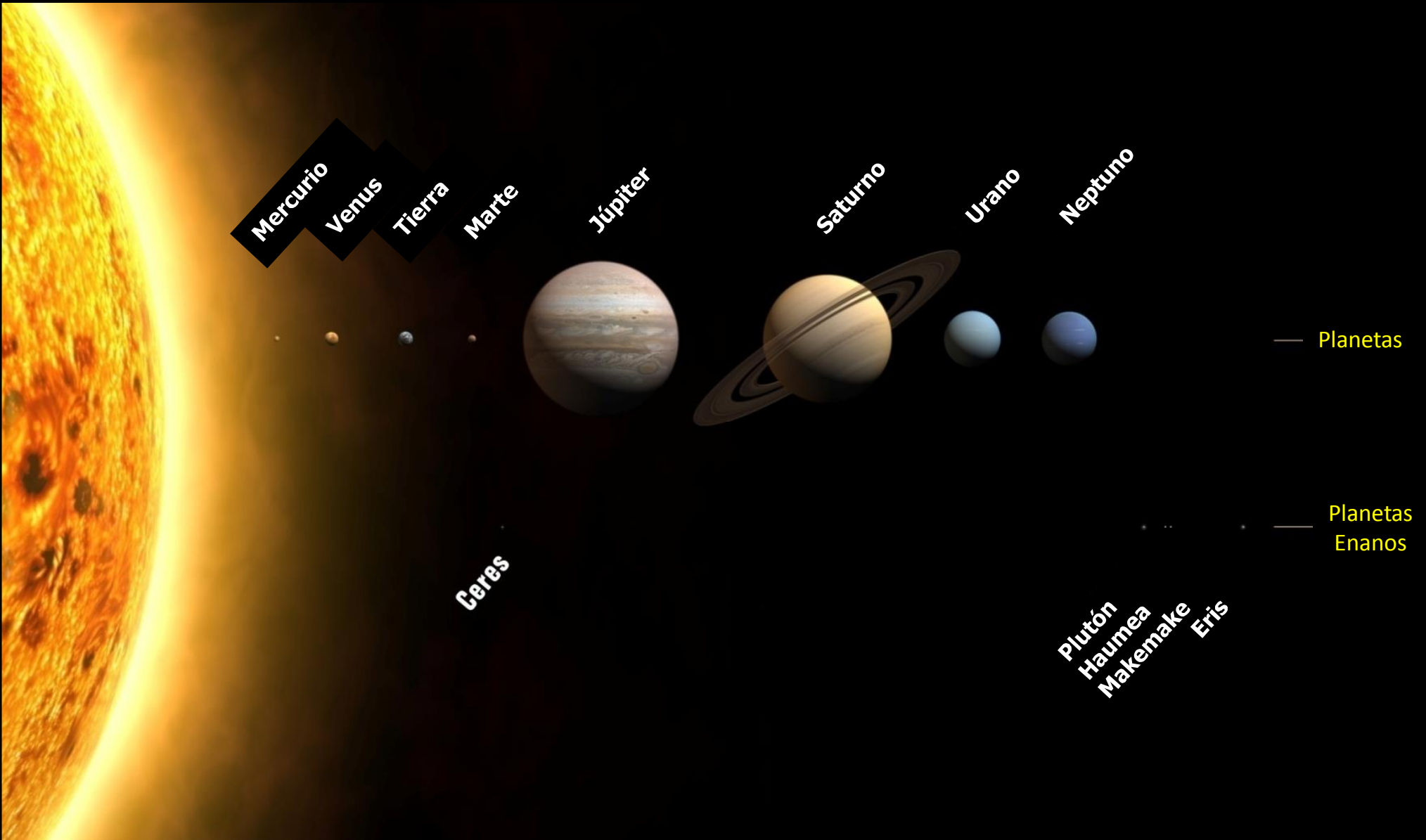
Zona convectiva



Dínamo



Los Planetas



Sol

Ø = 1,400,000 km

Mercurio

Ø = 4,879 km

Tierra

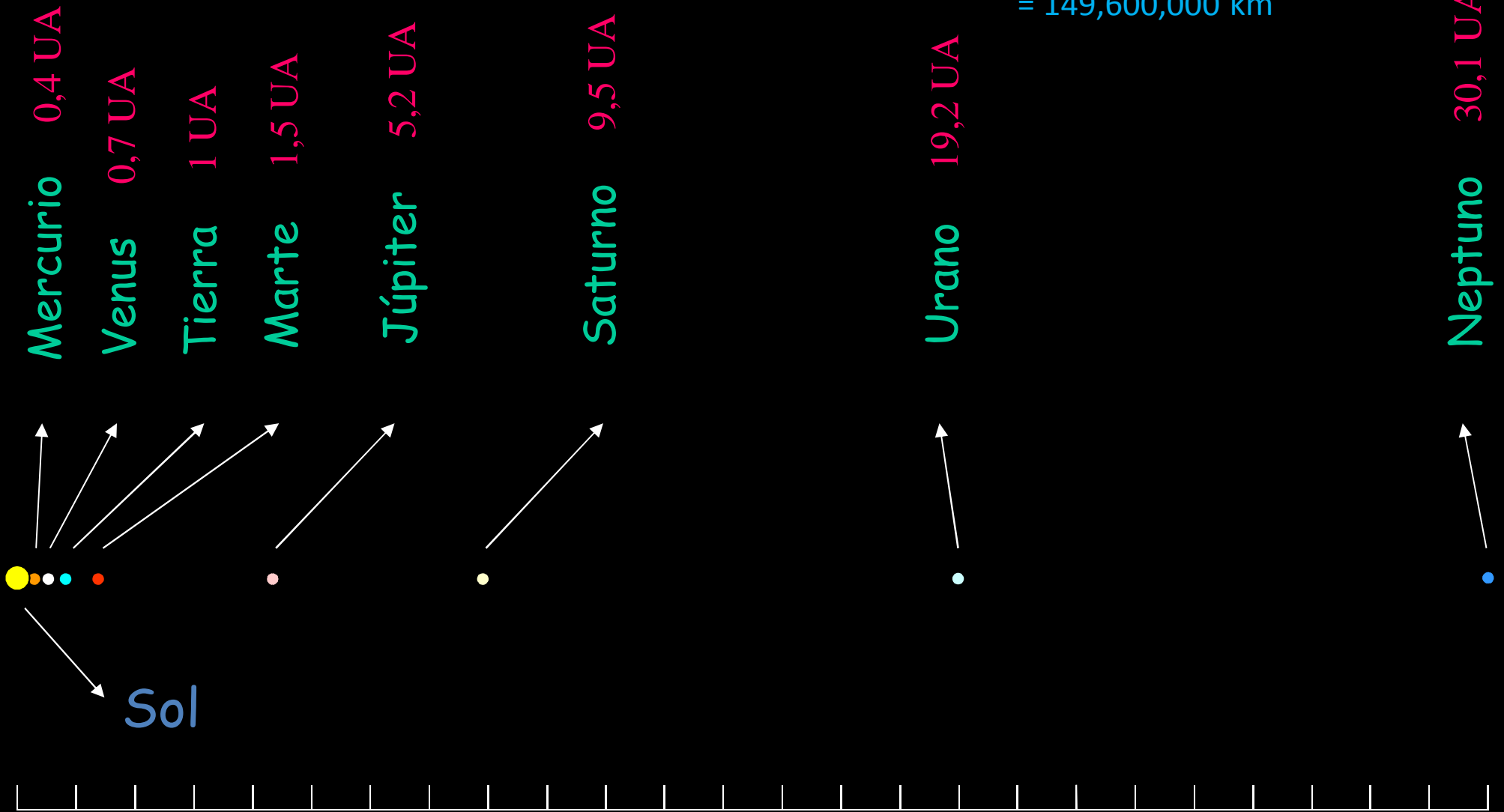
Ø = 12,756 km

Júpiter

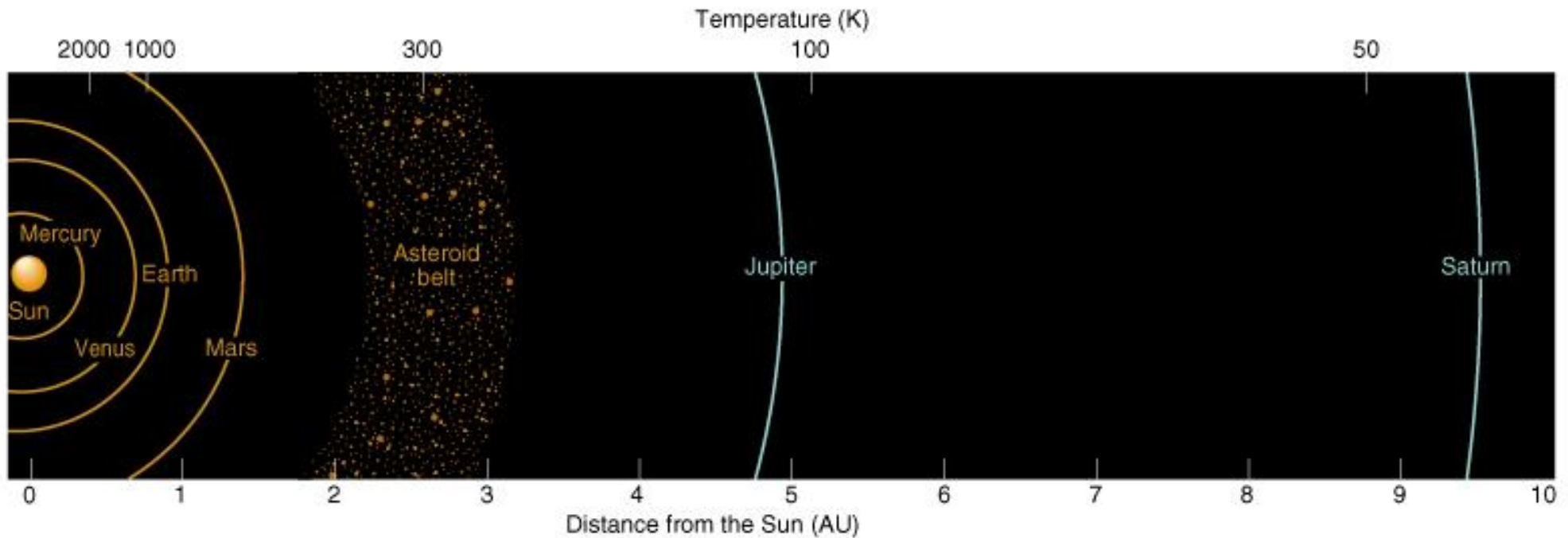
Ø = 142,984 km

Distancias

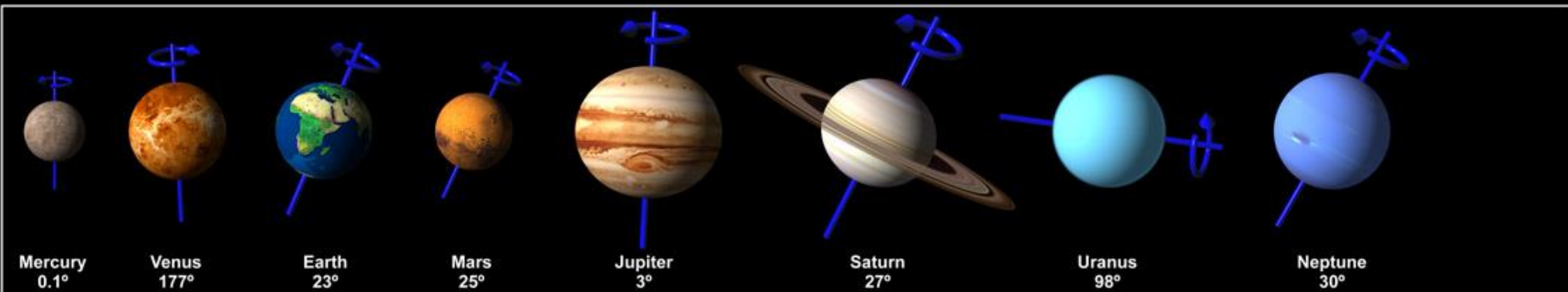
1 Unidad Astronómica (UA)
= 390 × la distancia entre la
Tierra y la Luna
= 11,728 × el diámetro de
la Tierra
= 149,600,000 km



Temperatura y Orientación

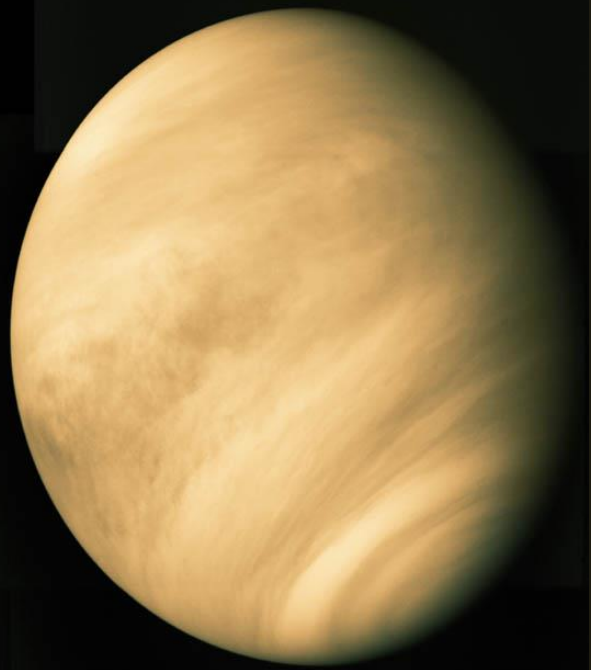
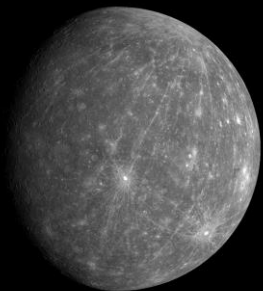


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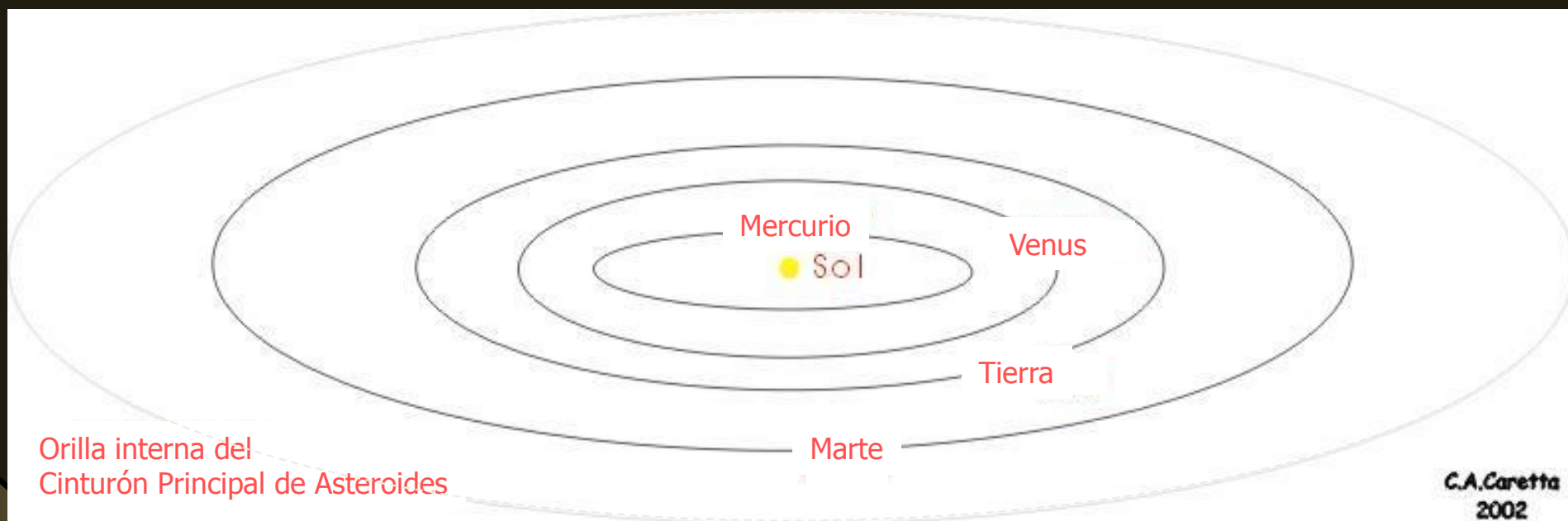


Obliquity of the Nine Planets

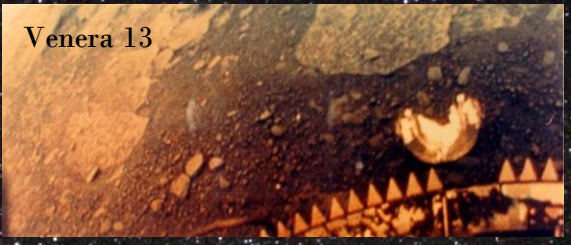
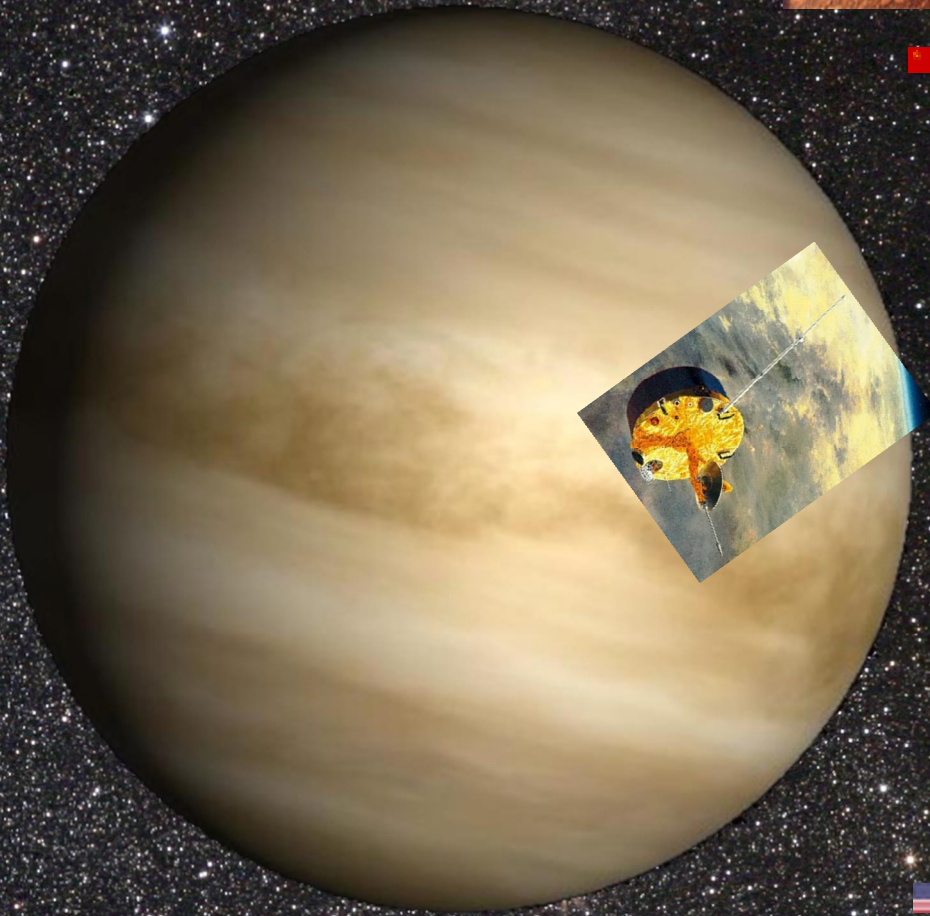
© Copyright 1999 by Calvin J. Hamilton



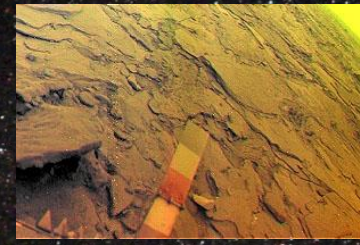
Los Planetas Internos o Rocosos




Venus




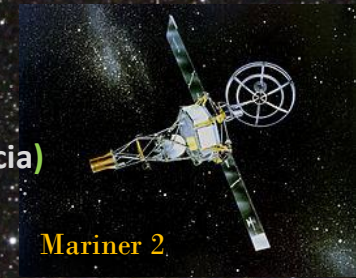
Venera 13




Venera 14


 **Programa Venera** (16: 1–16; 1961–1984; flybys, 1er. poso, orbitador+modulo; $T \sim 455\text{--}485^\circ\text{C}$, $\text{CO}_2 + \text{N}$: 4% + nubes H_2SO_4 , presión: 90 atm, fotos)

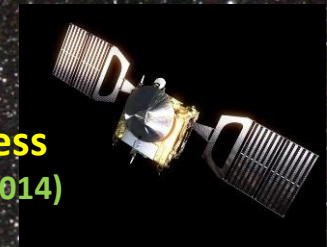
 **Programa Mariner** (4: 1, 2, 5, 10; 1962–1973; flybys, med. masa, campo magnético, asistencia)




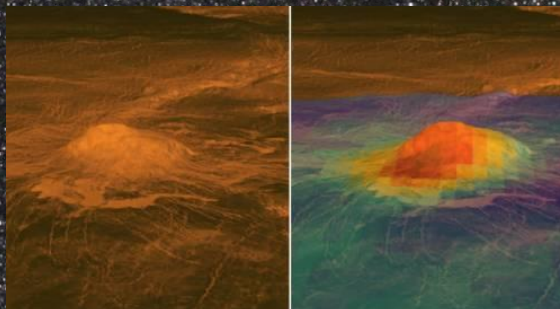
Mariner 2

 **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)

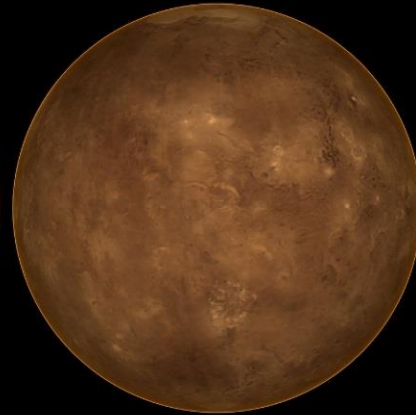
Venus without Clouds



145°E



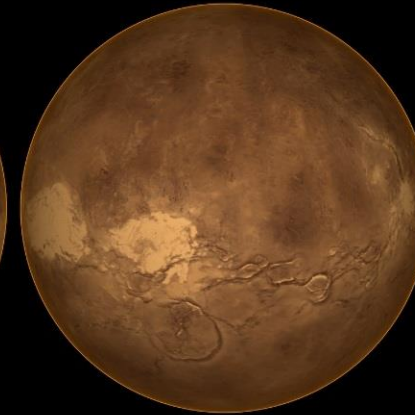
057°E



000°E

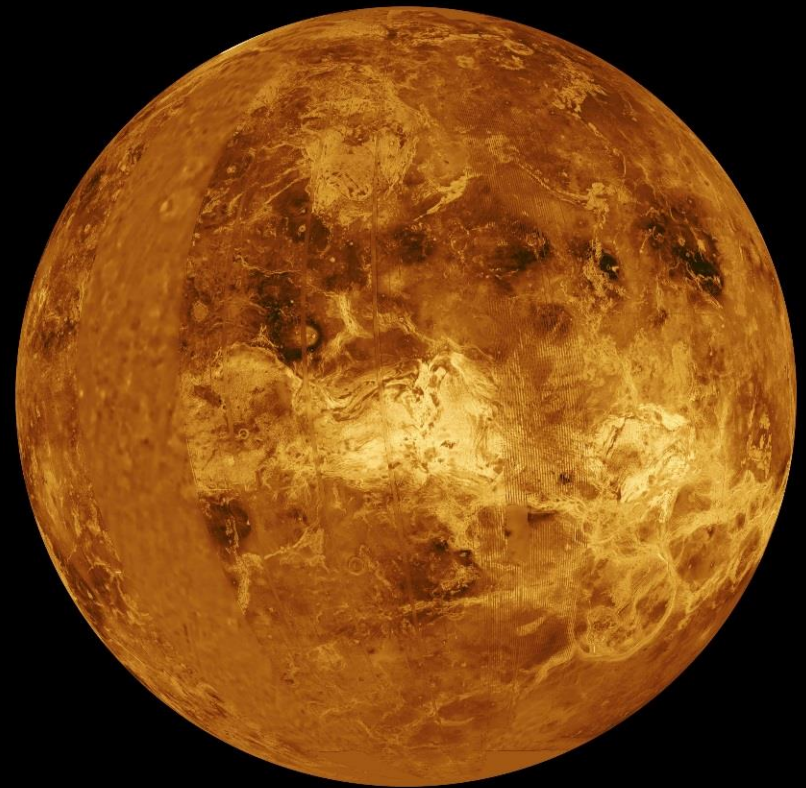
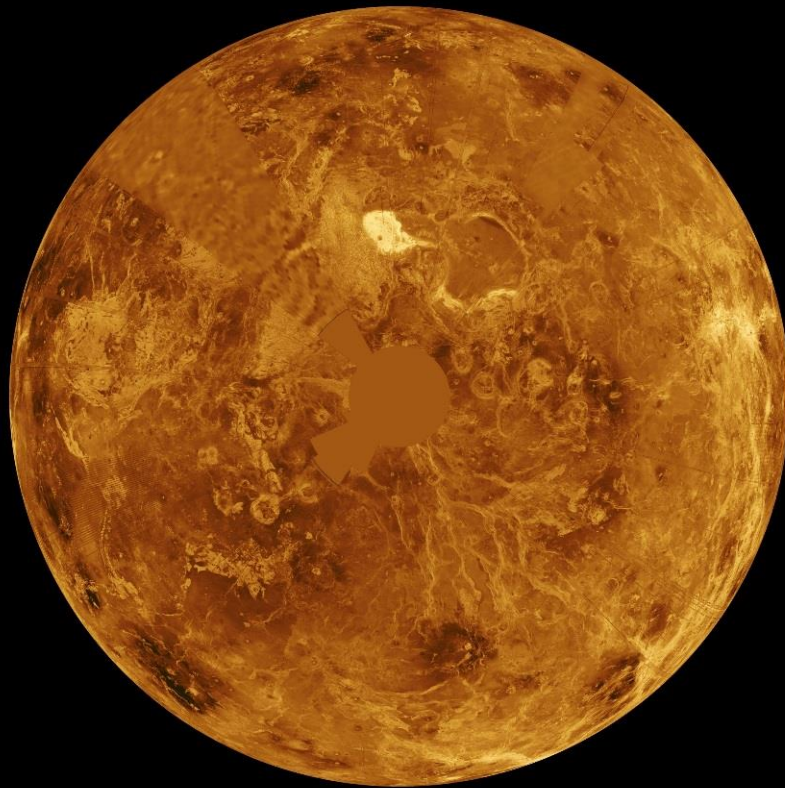


075°W



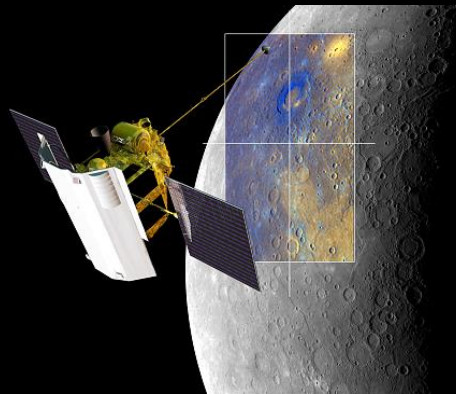
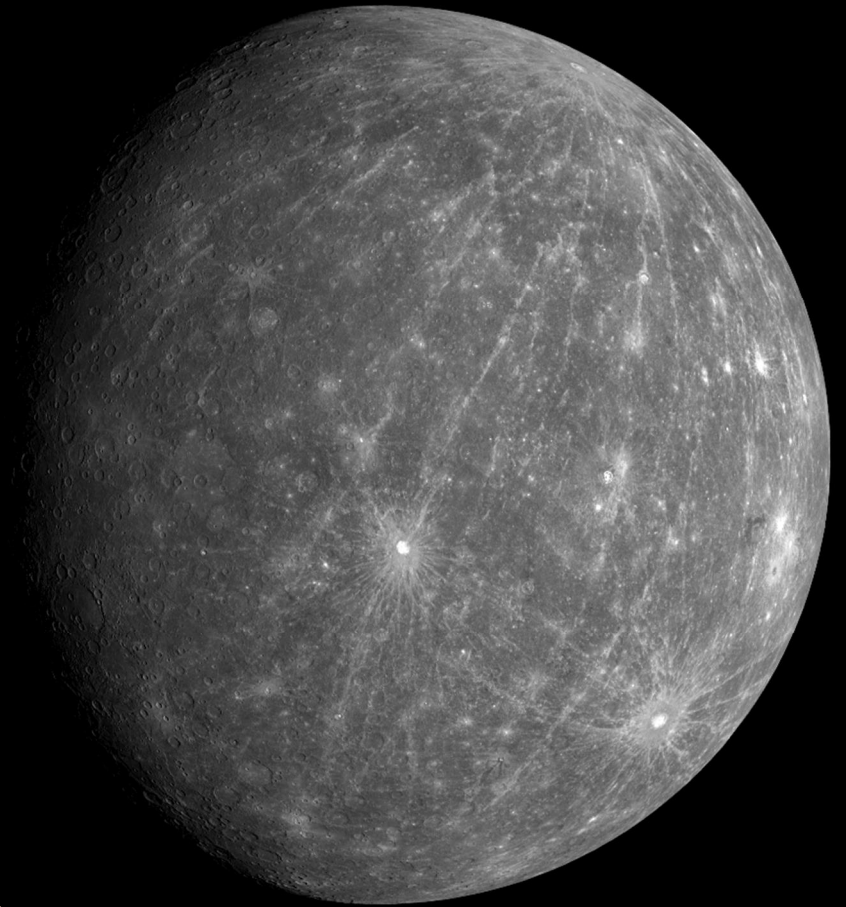
135°W

CREDIT: PHL @ UPR Arcibo (phl.upr.edu), NASA

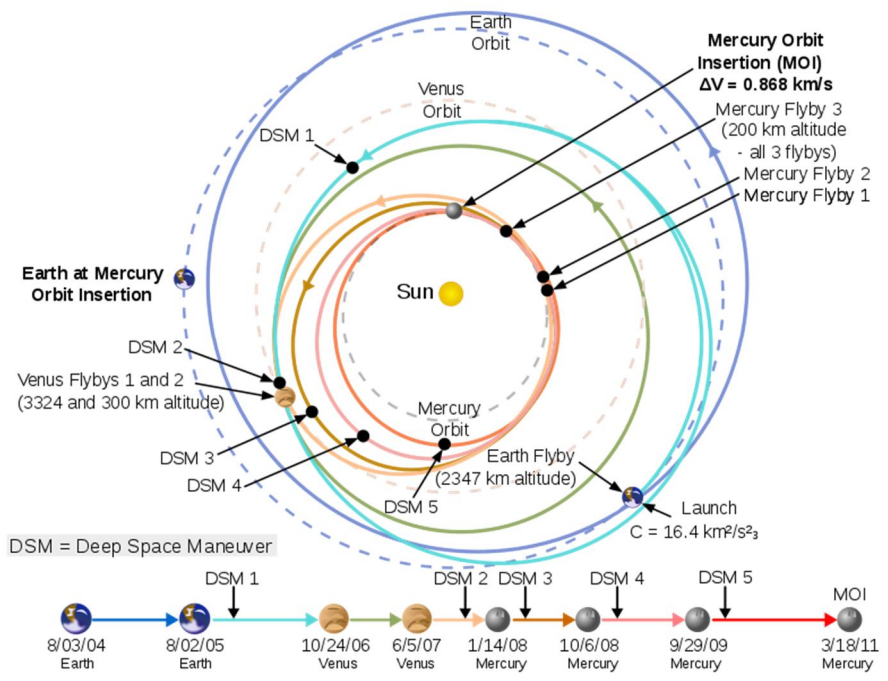


Mercurio

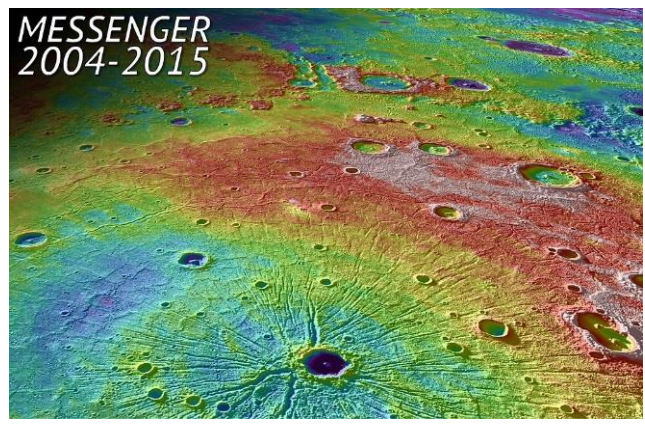
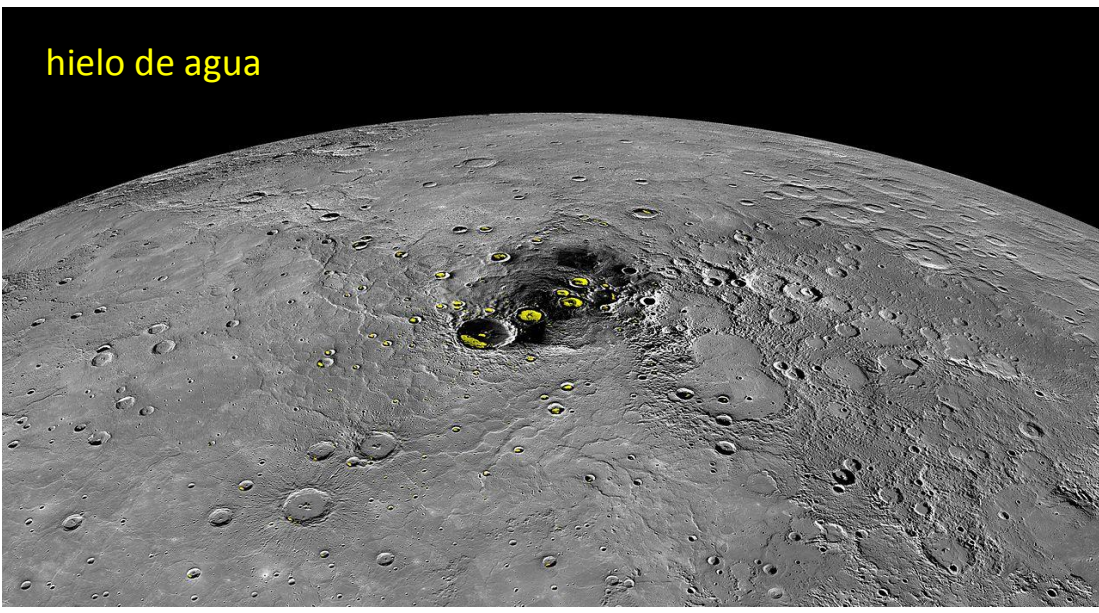
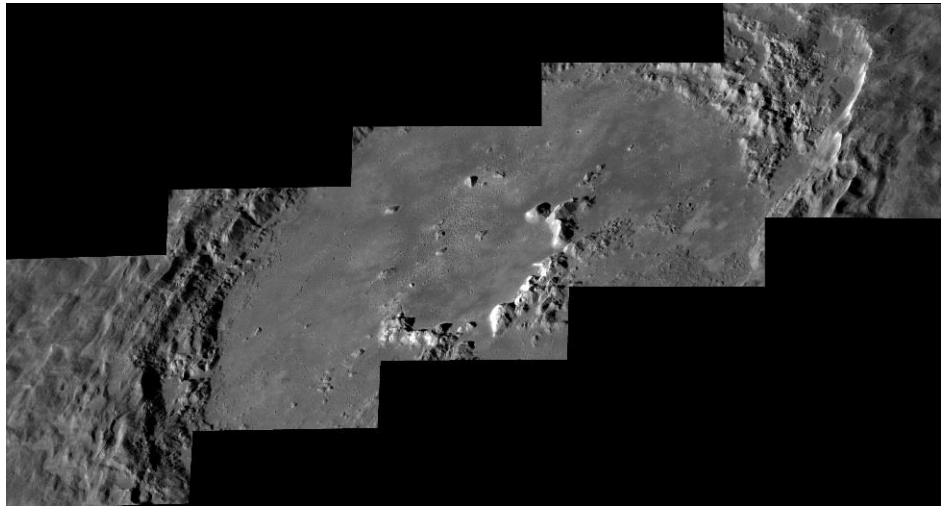
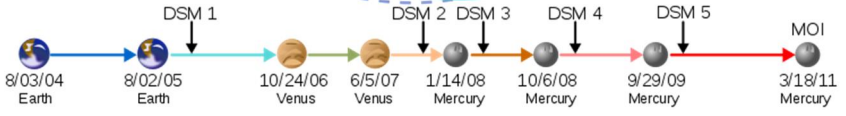
Mariner 10 (1974—1975; asist. grav. Venus, paneles solares como vela solar, 3 flybys, cartografió 40-45% de la superf., magnetosfera y atmósfera)



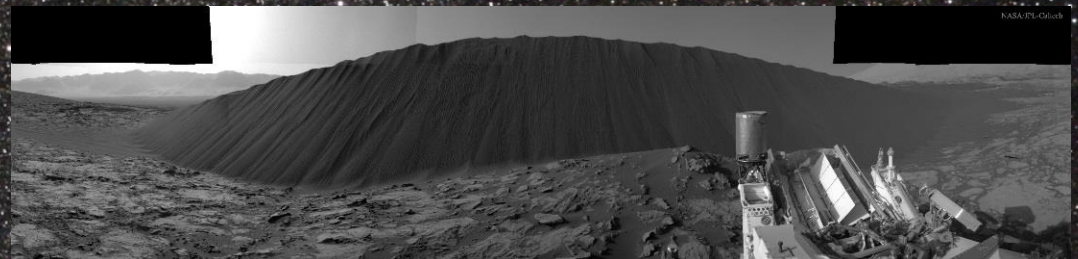
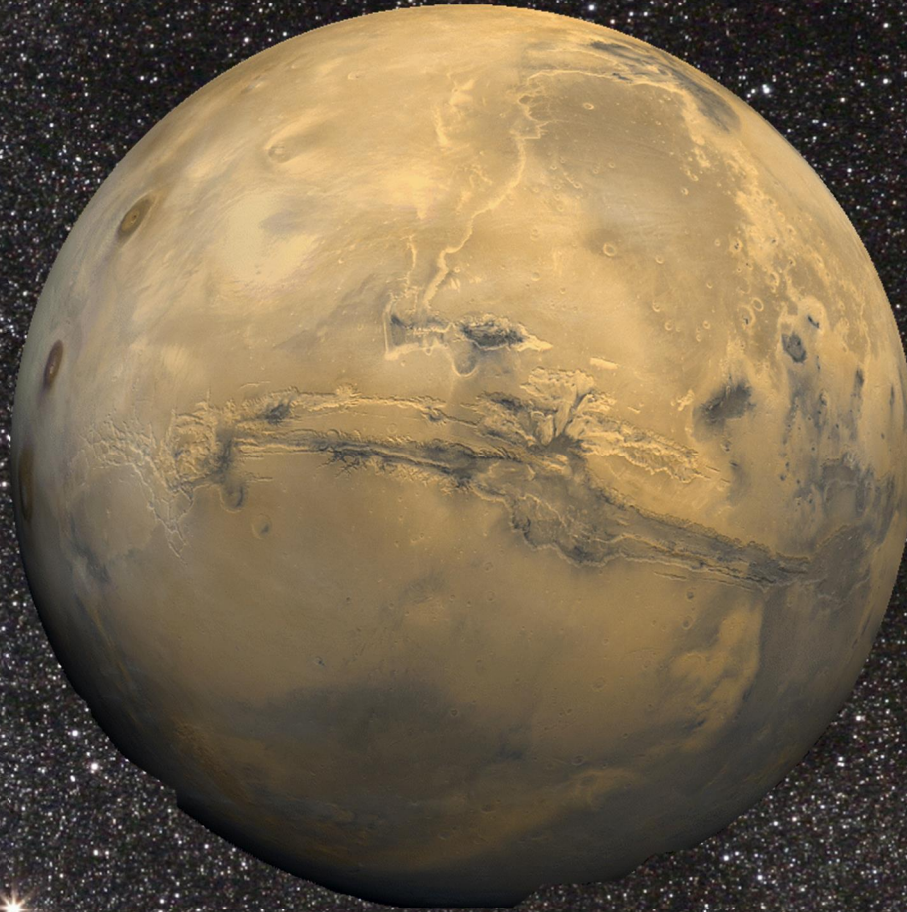
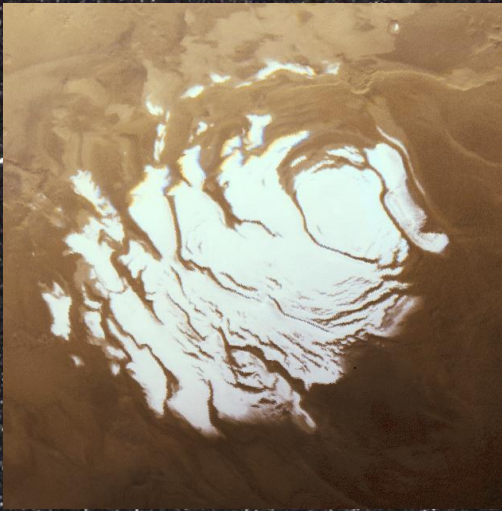
Messenger
(orb.: 2011—2015; asist. grav. + vela solar, mapa global: 250,000 fotos, magnetosfera 1% la de la Tierra, núcleo líquido de hierro, hielo de agua en el polo norte, elementos volátiles en la atm.: H, H₂, He, O, etc; impacto: cráter $\varnothing = 16\text{m}$)



DSM = Deep Space Manuever




Marte

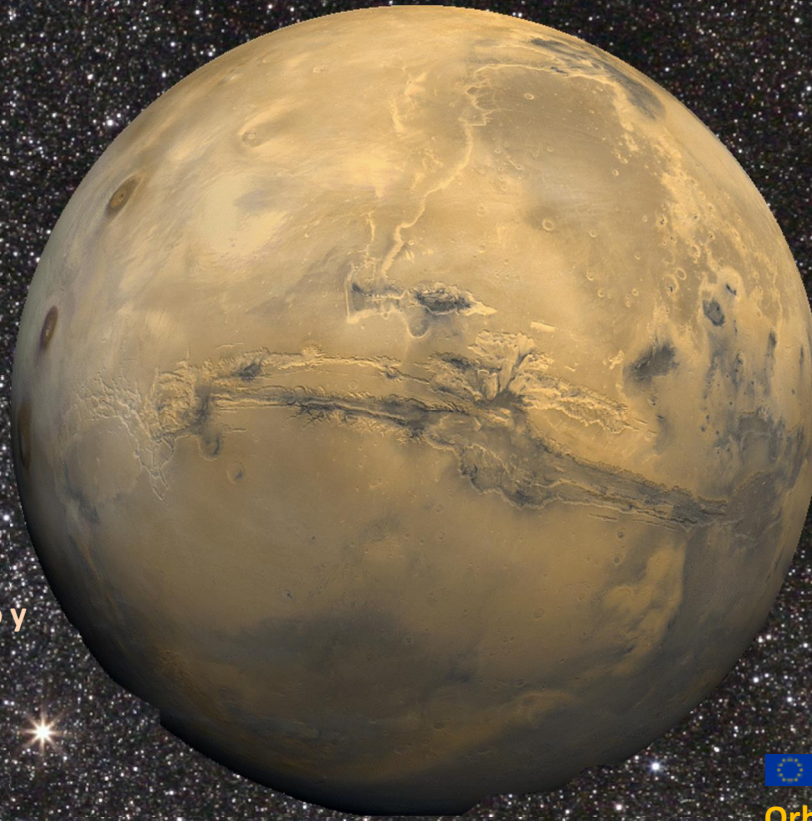



 **Programa Mars** (7: 1—7; 1962—1972;
3 fallos, *flybys*, 1er. amartizaje: Mars 3)

 **Programa Mariner** (6: 3, 4, 6—9; 1964—1972;
2 fallos, *flybys*, 1er. *orbiter* de Marte y del
SS: Mariner 9)


 **Programa Viking**
(2: 1, 2; 1975—1982;
Vorbiter: cartografía,
comunicación con la Tierra;
+ *Vlander*: 1er. estudio biológico y
molecular del suelo:
CO₂ + N: 6%, O₂: 0.3%;
análisis biológicas inconclusas
T: -85 a -29°C; presión 6 mbar;
imágenes meteorológicas)

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




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

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

 **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)

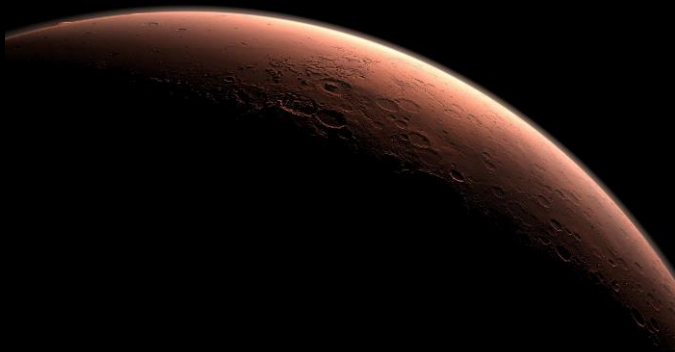
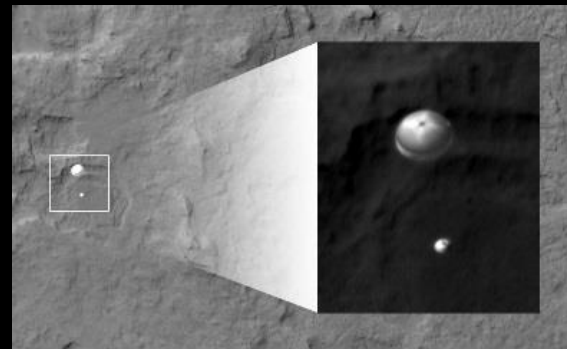
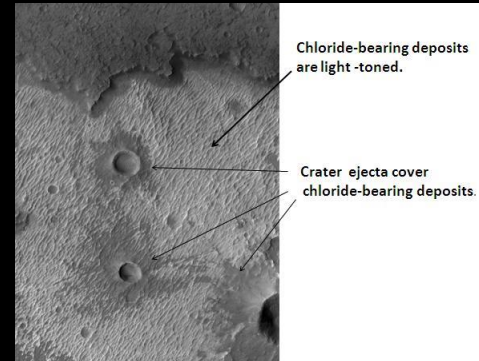
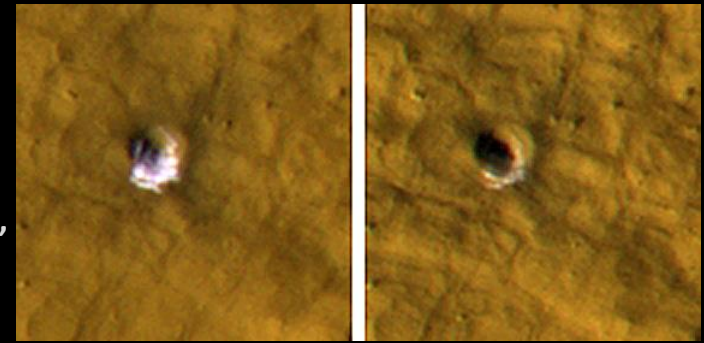
 **Mars Express / Beagle 2** (2003—2009;
Orbitador: OK, *Beagle 2*: fallo al amartizar)

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

Mars Reconnaissance Orbiter (2006—;

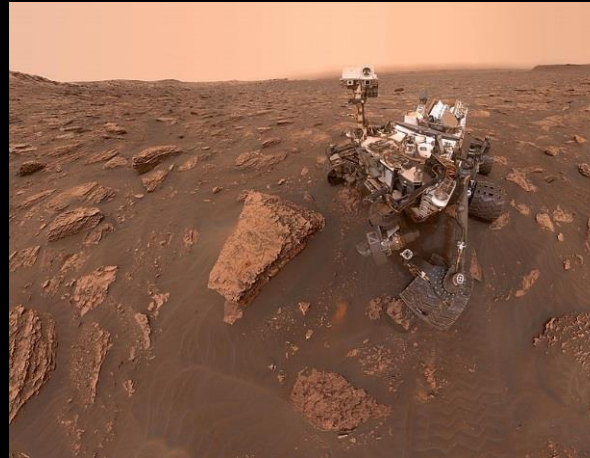
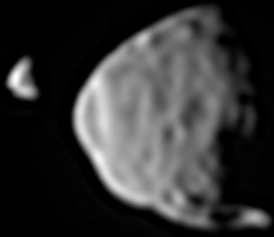
geología, monitoreo del clima, presencia de agua, sitios de poso potenciales

- “ hielo de agua en el polo norte, 821 mil km³, equivale a 30% de Groenlandia,
- “ 5 nuevos cráteres: impactos excavaron hielo de agua,
- “ depósitos de cloruro, usualmente los últimos minerales a condensar de una solución,
- “ avalanchas,
- “ escurrimientos de agua salada en verano)



Phoenix (lander: 2008 may—dic;

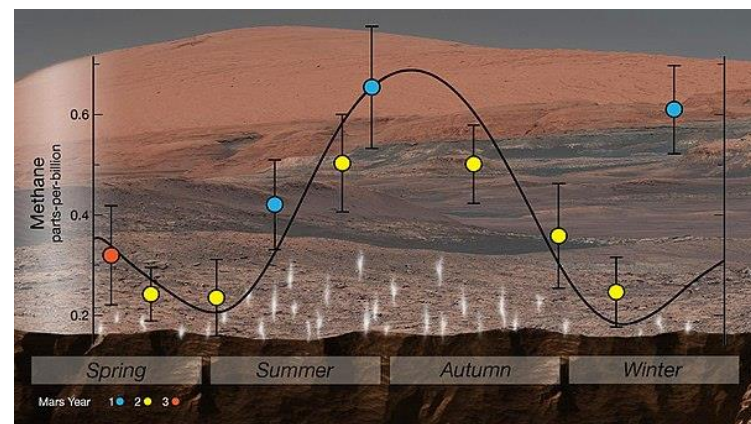
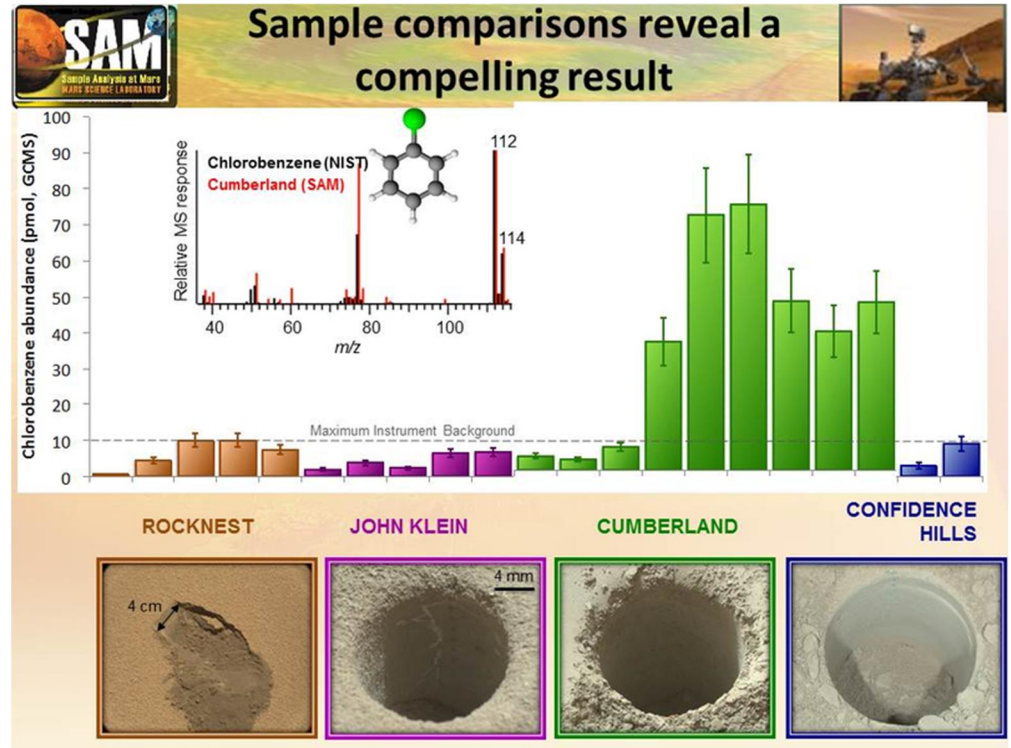
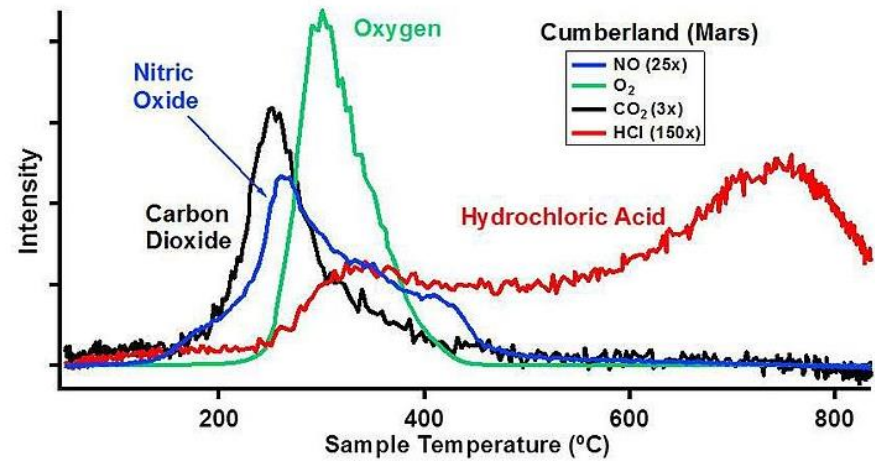
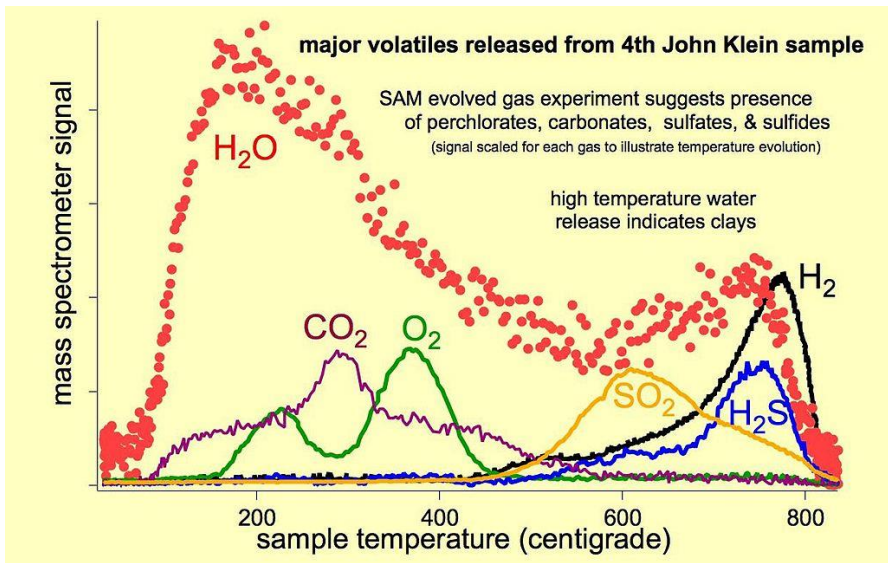
- “ sublimación de hielo de agua sub-superficial,
- “ pH: alcalino 8-9,
- “ nieve que se sublimó antes de llegar al suelo,
- “ carbonato de calcio)

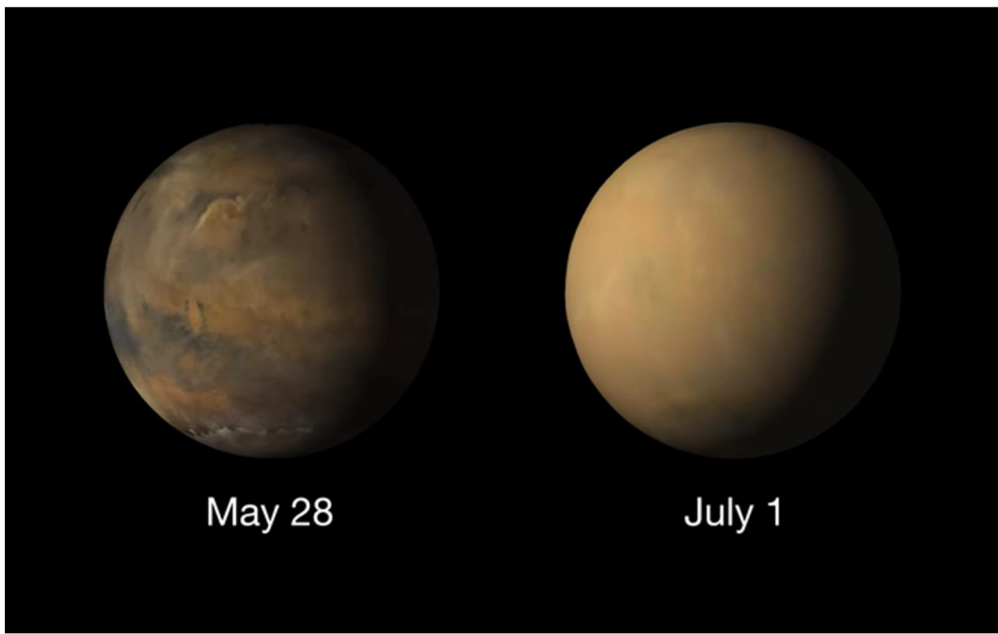


Mars Science Lab. / Curiosity (2012—; clima, geología, análisis biológicos:

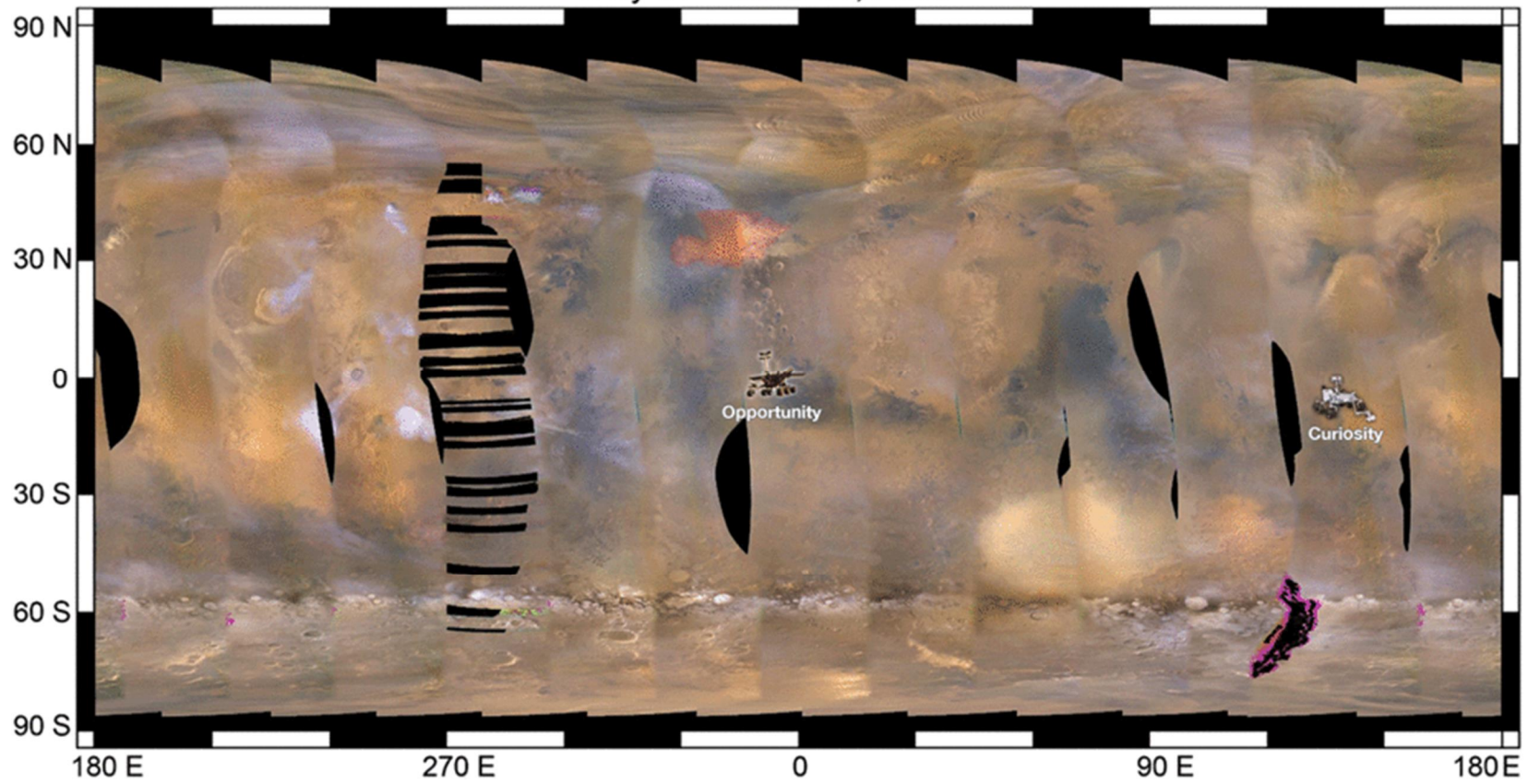
- " 2013 -- hay condiciones, en las rocas, para vida microbiana: **H₂O**, **CO₂**, **O₂**, **SO₂**, **H₂S**: sulfuro de H, **CH₃Cl**: clorometano, **CH₂Cl₂**: DCM
- " 2015 – **NO**: oxido nítrico, **clorobenceno**; 2017 – **B**: boro,
- " 2018 – ciclo estacional de **CH₄**, mol. organ. con S: **tiofeno**, aromáticos: **benceno**, **tolueno**, alifáticos: **propano**, **buteno**)





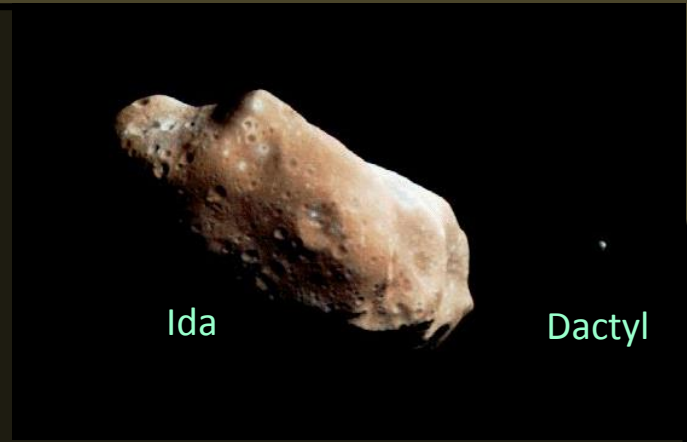
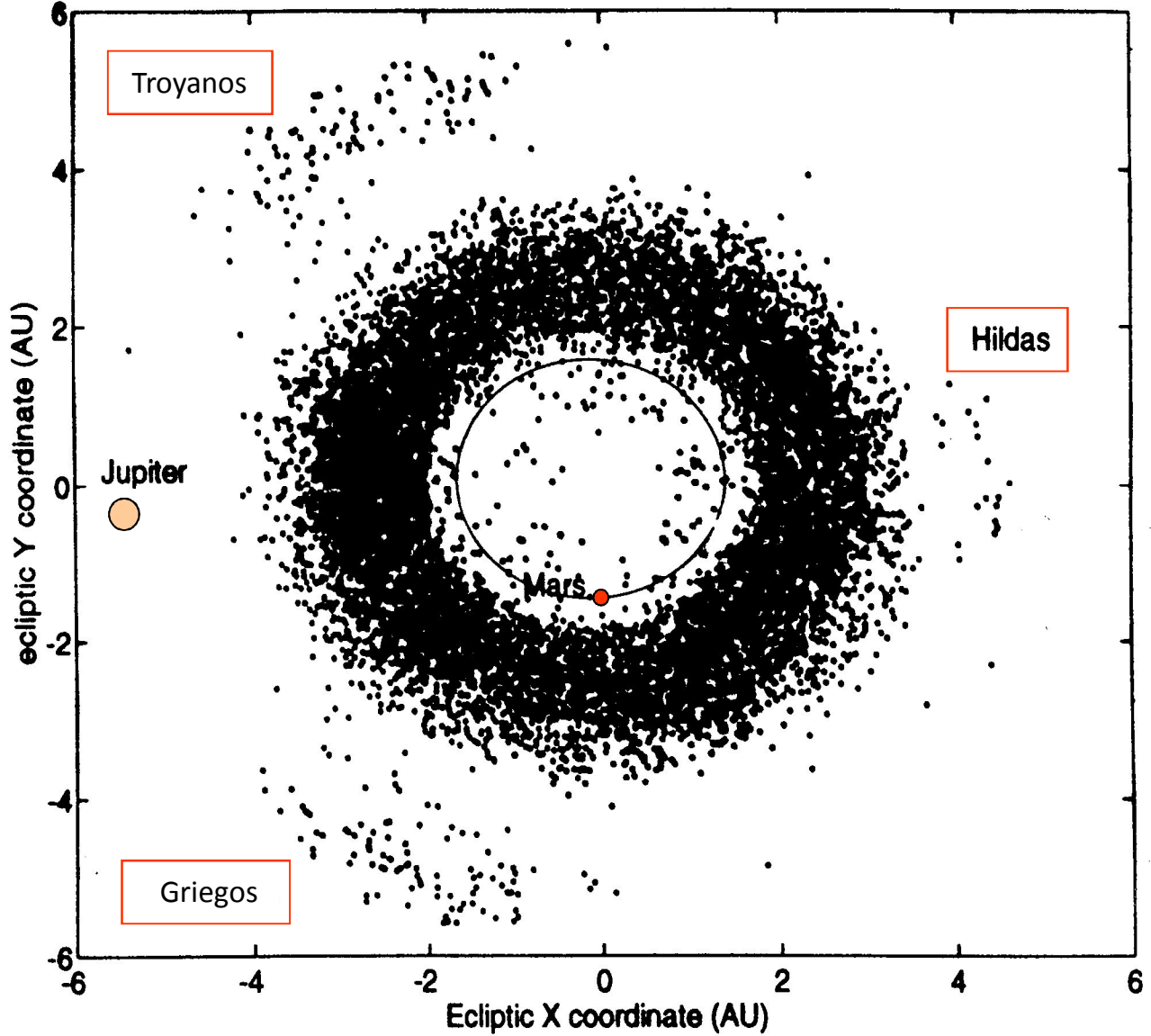


May 31 - June 11, 2018



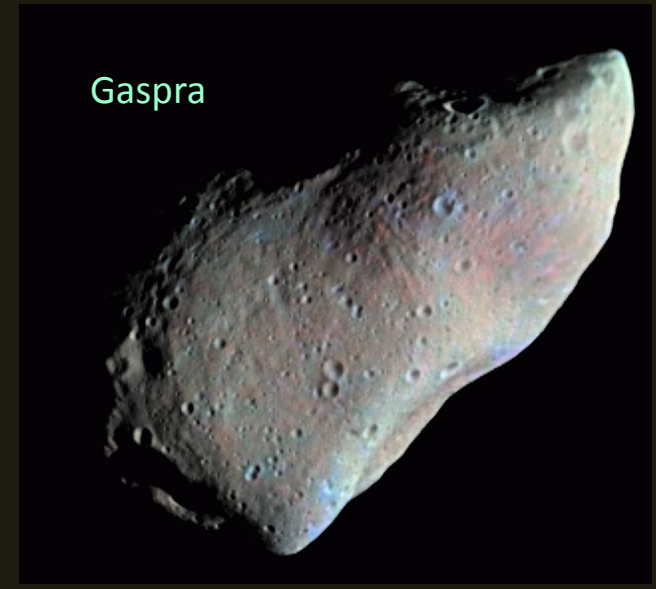
El Cinturón Principal de Asteroides

All asteroids with up to date orbits



Ida

Dactyl



Gaspra



Matilde
(NEO)

Planeta Enano: Ceres

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

NASA (27/sép/2007 –)

+ Vesta (2011-2012)

presència de agua salada en interior,

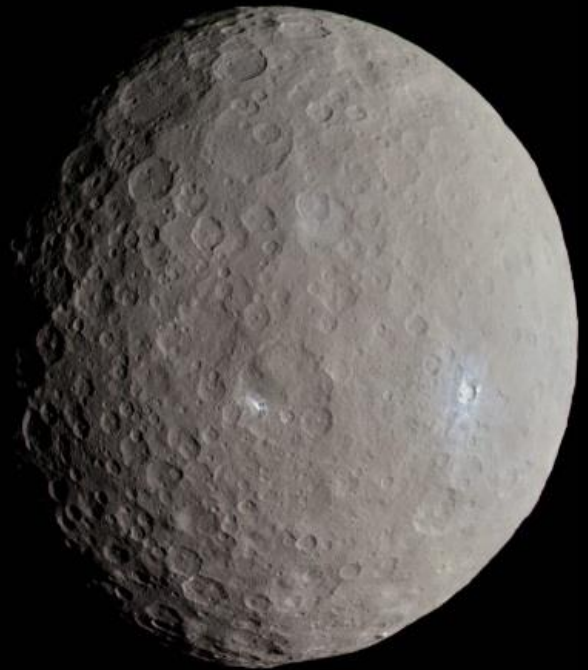
sales de sulfato de magnesio

hexahidrita: $\text{MgSO}_4 \cdot 6\text{H}_2\text{O}$,

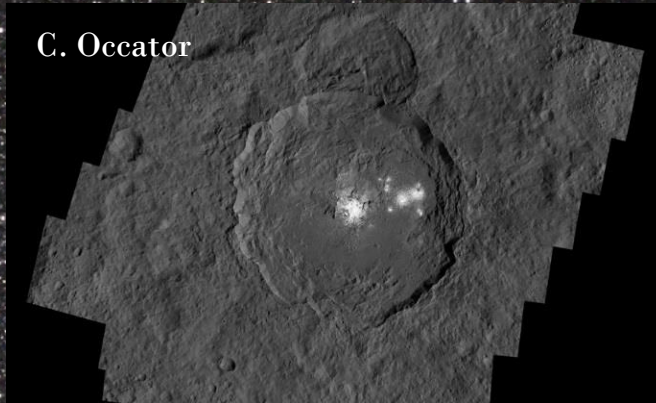
carbonato de sodio: Na_2CO_3 ,

cloruro amónico: NH_4Cl ,

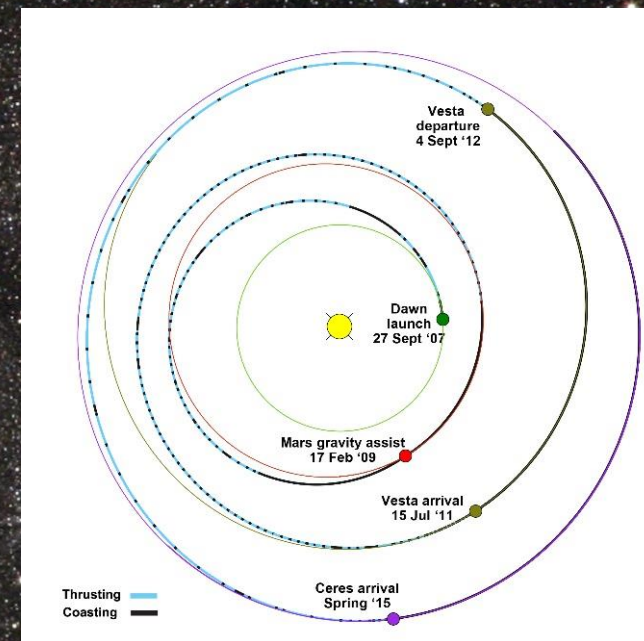
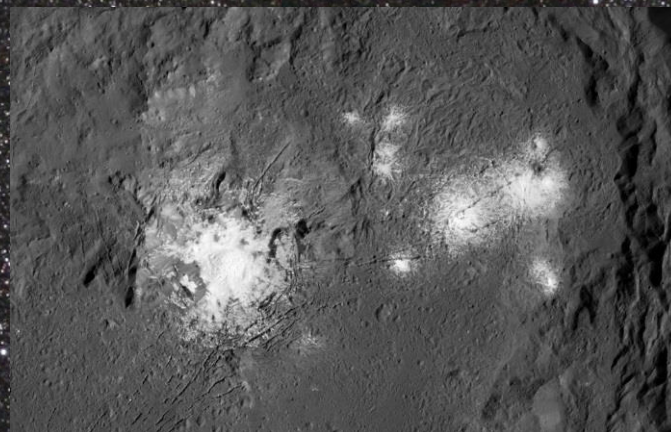
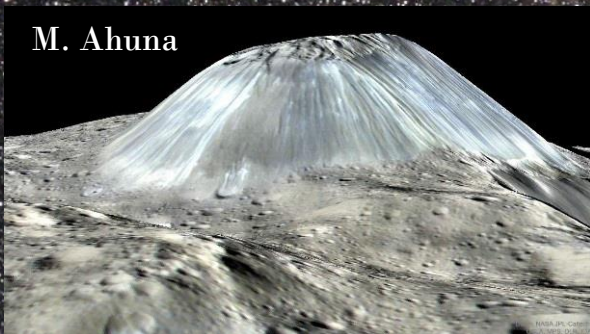
bicarbonato de amonio: NH_4HCO_3)



C. Occator



M. Ahuna



Asteroides visitados por sondas



4 Vesta



21 Lutetia



253 Mathilde



243 Ida / 1 Dactyl



433 Eros



951 Gaspra



2867 Šteins



5535 Annefrank



25143 Itokawa



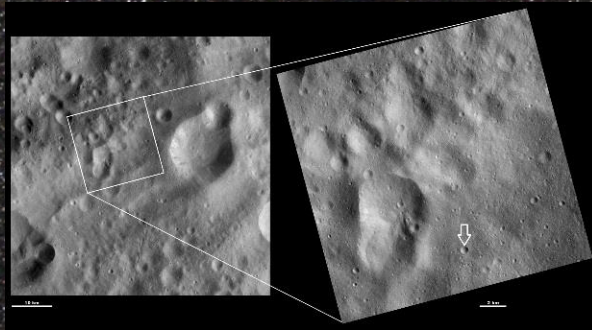
Ceres • January 24, 2004
HSTACS/HRC

Vesta • May 14, 2007
HST WFPC2



Dawn (Vesta, ago/2011-may/2012)

NASA (27/sep/2007 ÷)
+ Ceres (2015-2016) + ...



Galileo (28/ago/1993)
Ida
Dactyl

NEAR (12/feb/2001)

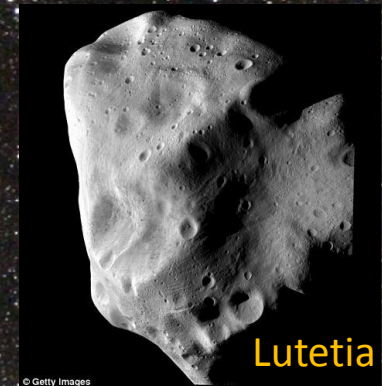


Eros



Steins

Rosetta (05/sep/2008,
10/jul/2010)

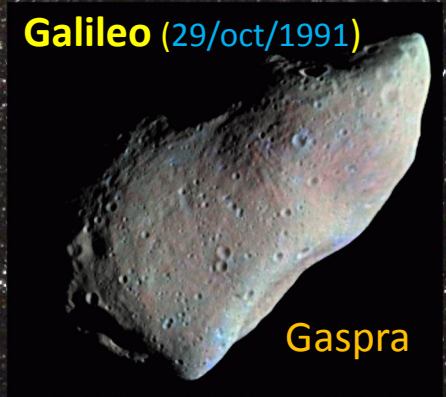


Lutetia

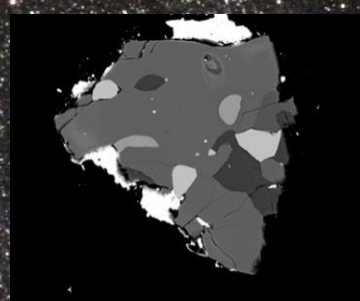
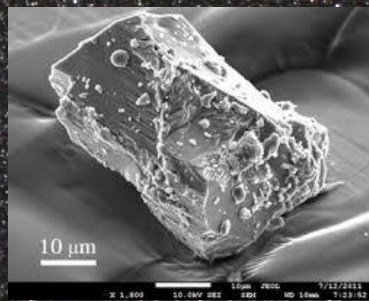
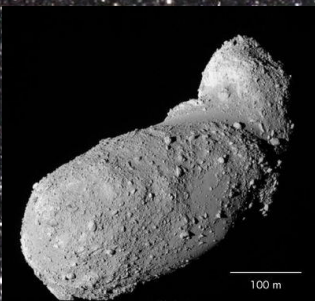
Hayabusa (Itokawa, 19/nov/2005)

JAXA (09/may/2003 – 12/nov/2005)

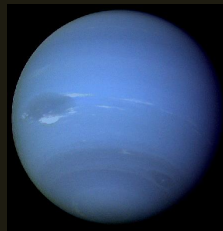
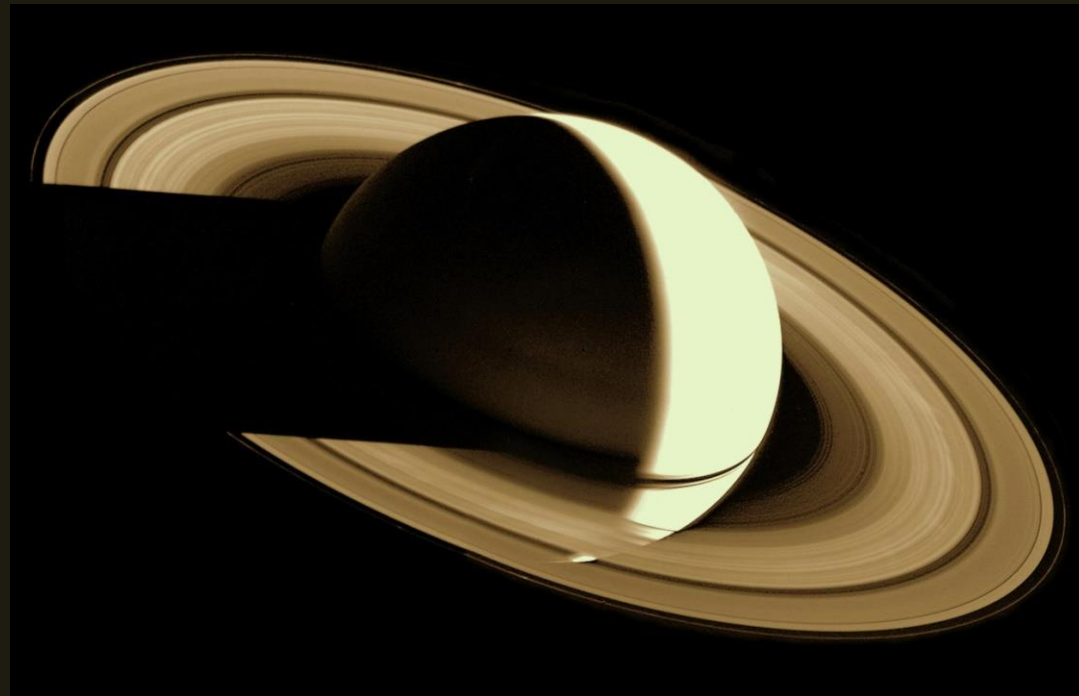
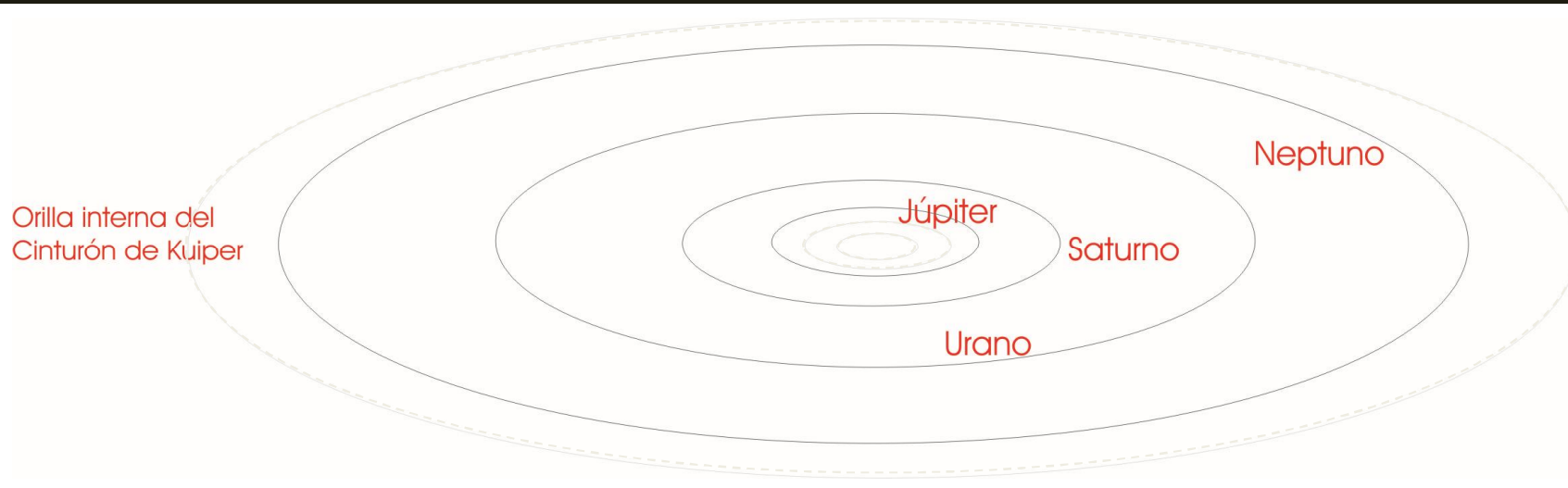
Galileo (29/oct/1991)

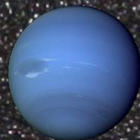
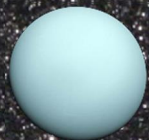
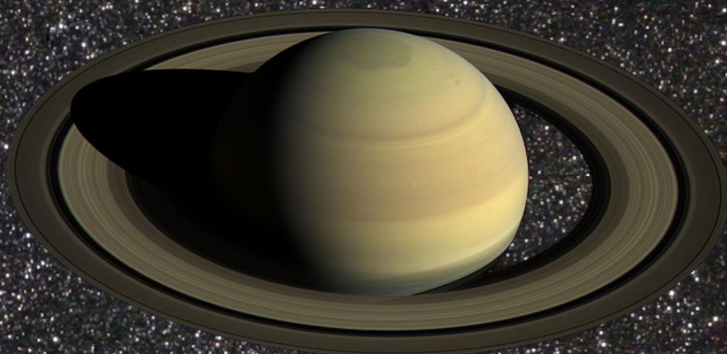


Gaspra



Los Planetas Externos o Gaseosos





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			

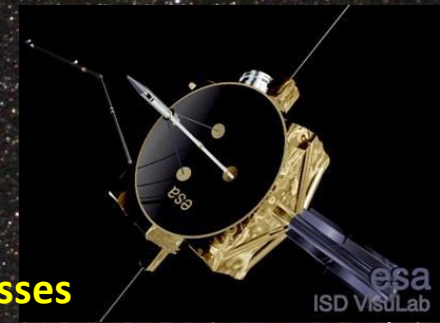
Júpiter



WFC3/UVIS
April 21, 2014



Juno

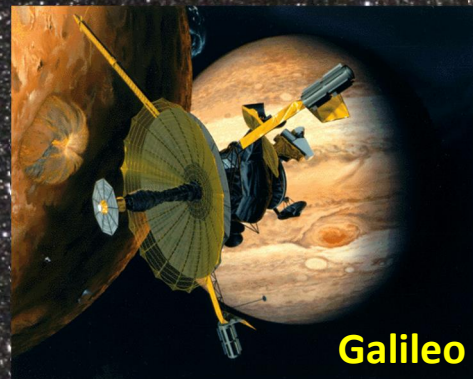


Ulysses

esa
ISD VisuLab



Voyagers I y II



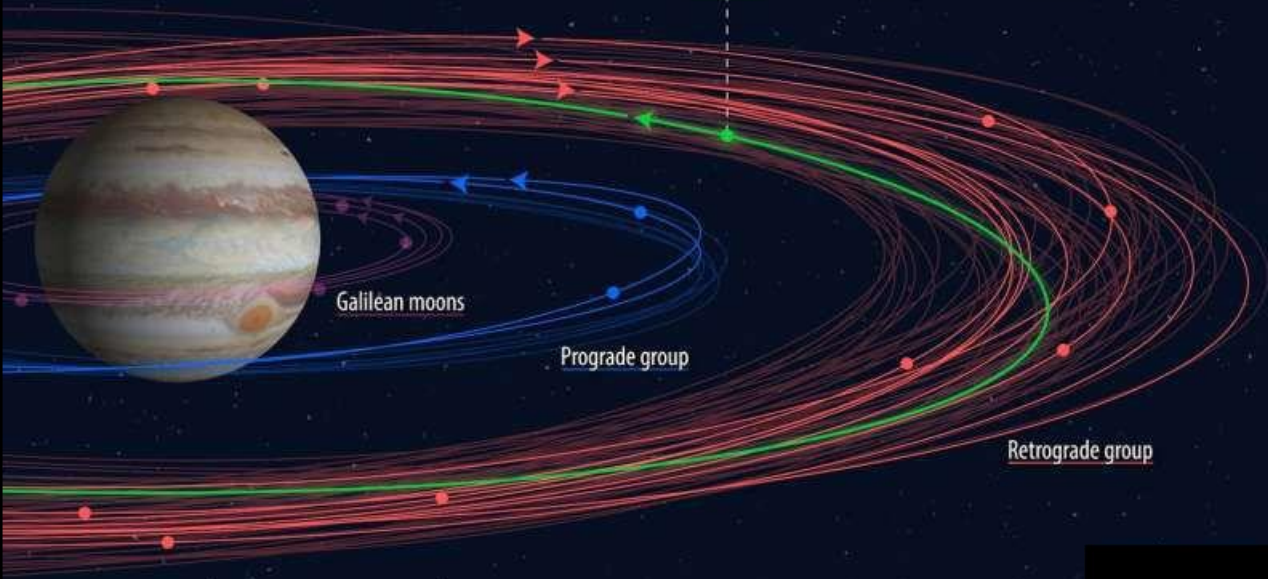
Galileo

Outer Moons of Jupiter

Newly discovered moons shown in bold

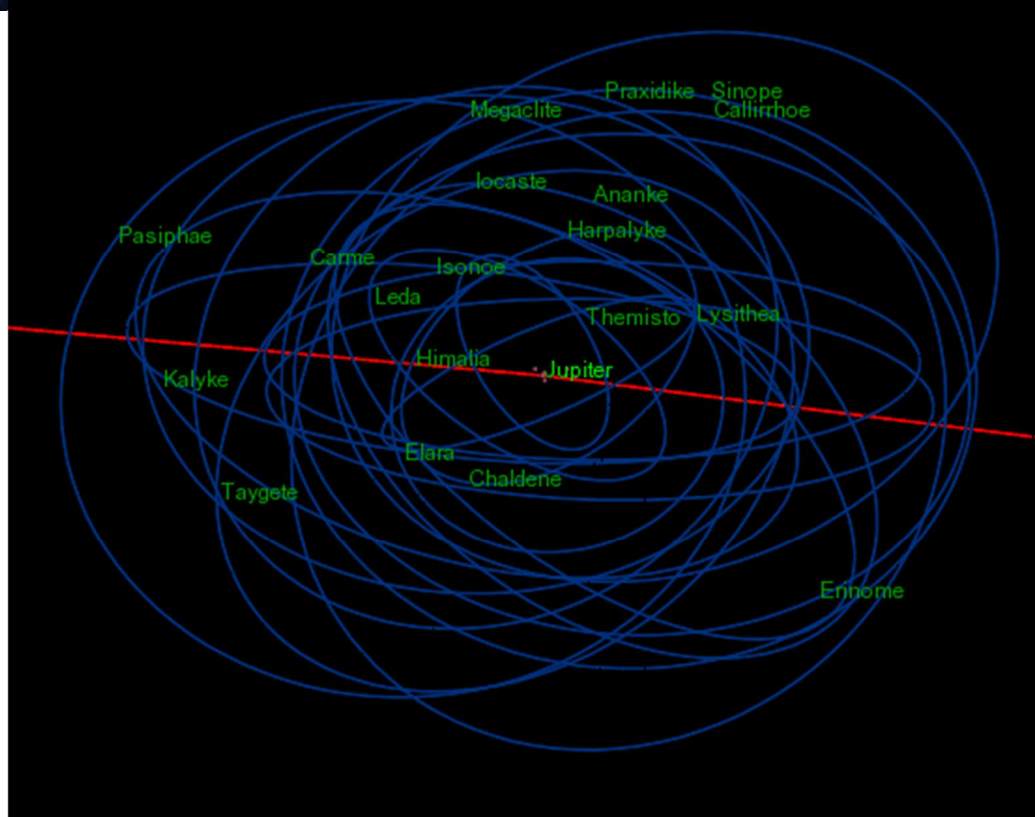
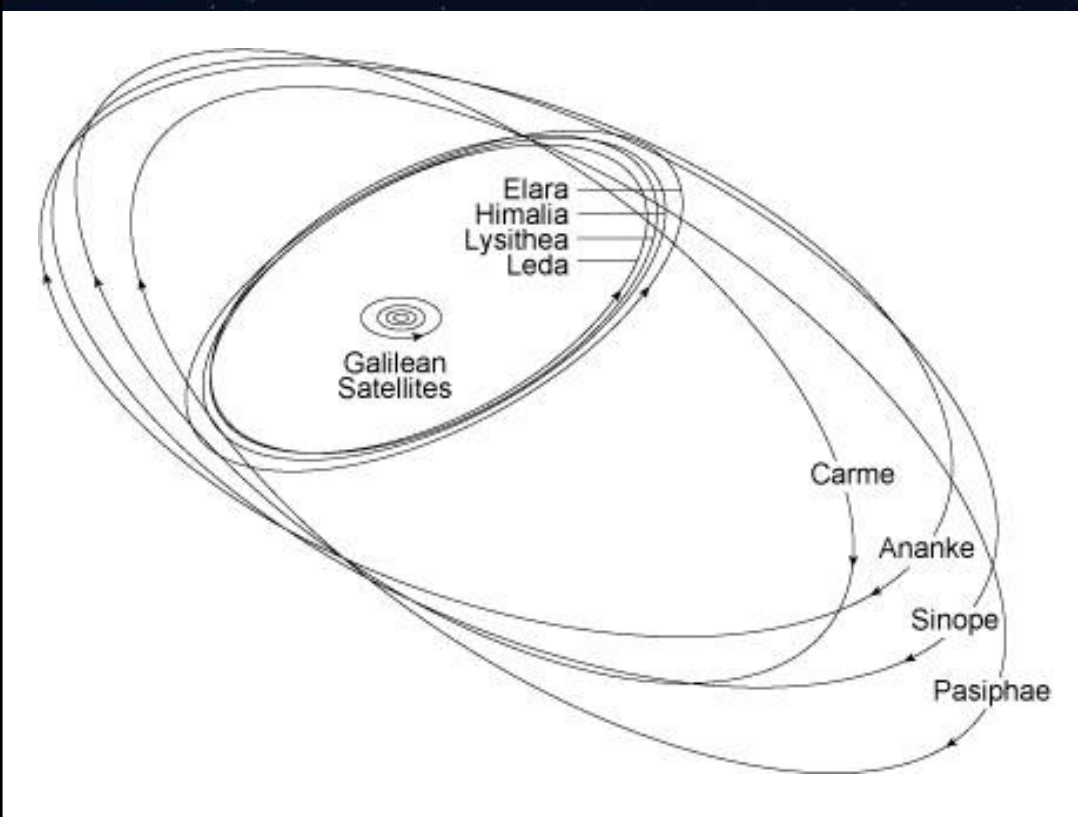
¡FUERA DE ESCALA!

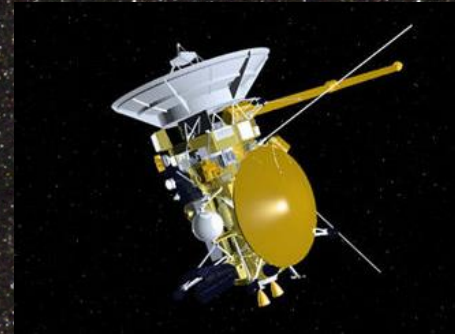
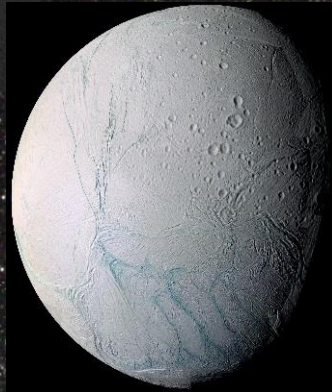
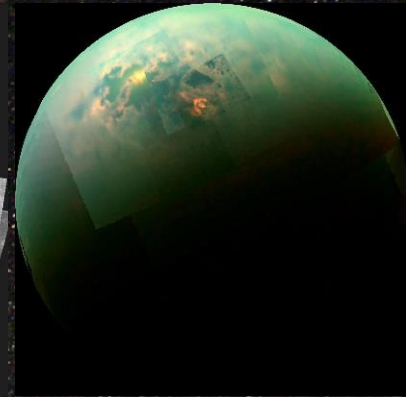
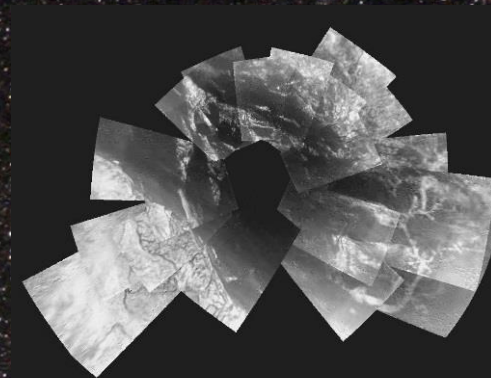
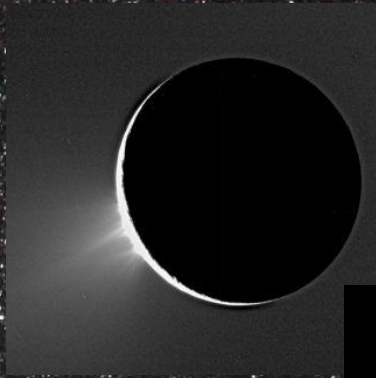
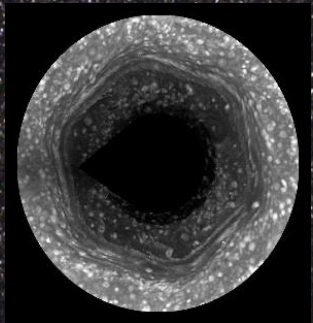
Unlike the group of inner prograde moons, new prograde Valetudo has an orbit that crosses the retrogrades.



LUNAS DE JUPITER

Internos:	4
(Metis, Adrastea, Amalthea, Thebe)	
Galileanos:	4
(Io, Europa, Ganimedes, Calixto)	
Otros progrados:	10
(Leda, Himalia, Lysisthea, Elara, ...)	
Retrogrados:	55
(Iocasta, Ananke, Carme, Sinope, ...)	
TOTAL	79

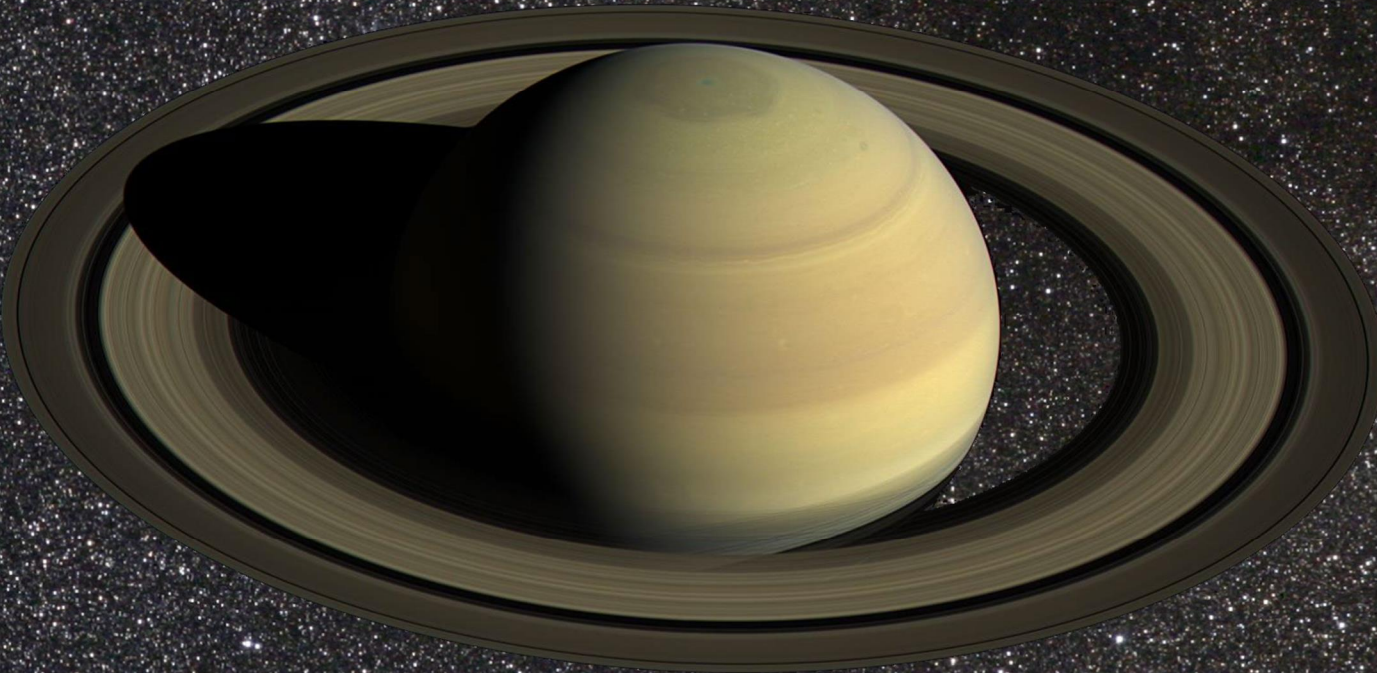




Saturno

Cassini-Huygens

Voyagers I y II

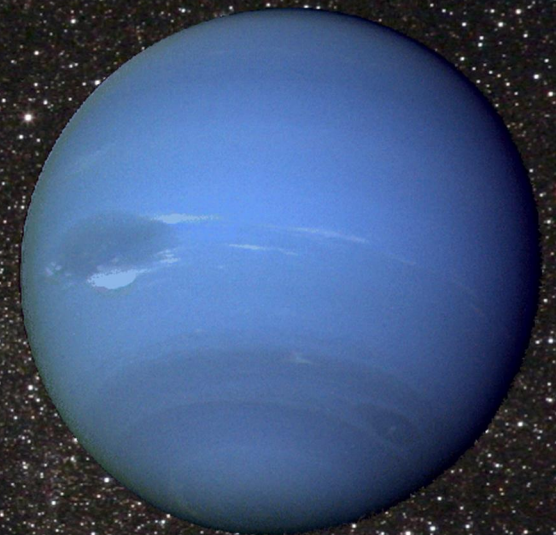


Urano

Voyager II (Urano, 24/ene/1986)

NASA (20/ago/1977 -)

+ Júpiter, Saturno, Neptuno, 106 UA, →ROSS 248



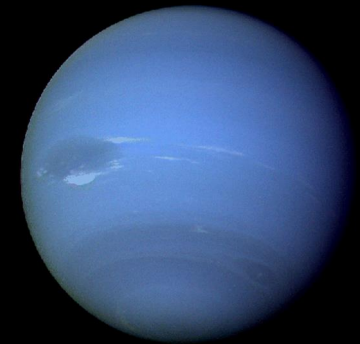
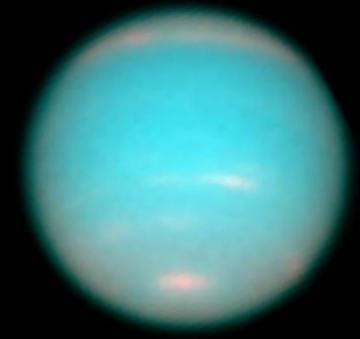
Voyager II (Neptuno, 25/ago/1989)

NASA (20/ago/1977 -)

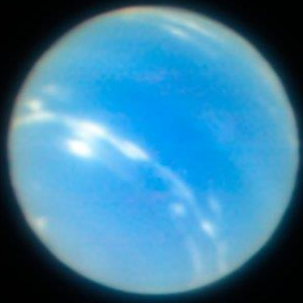
+ Júpiter, Saturno, Urano, 106 UA, →ROSS 248

Neptuno

HST



VLT-4 (Yepun) + MUSE

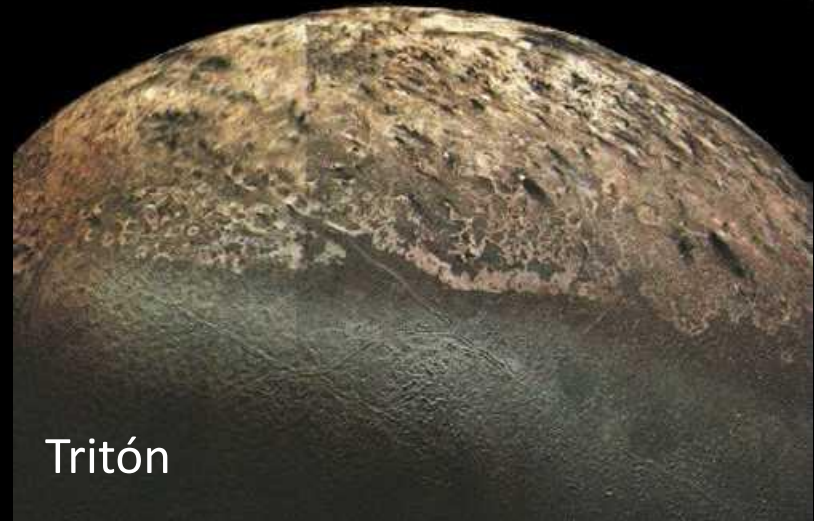
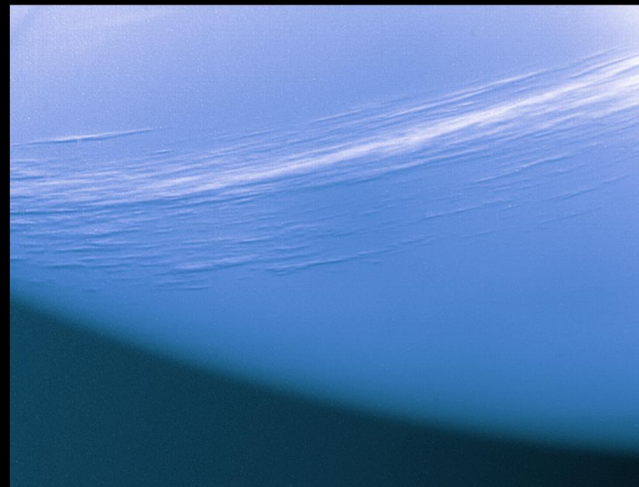
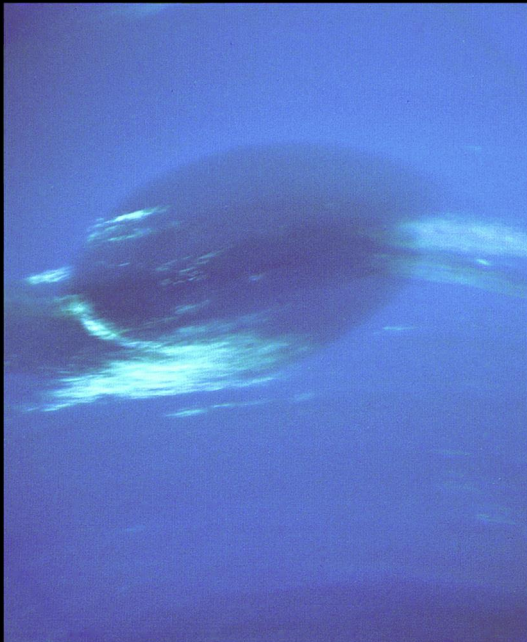


Adaptive optics



No Adaptive optics

Voyager II



Tritón

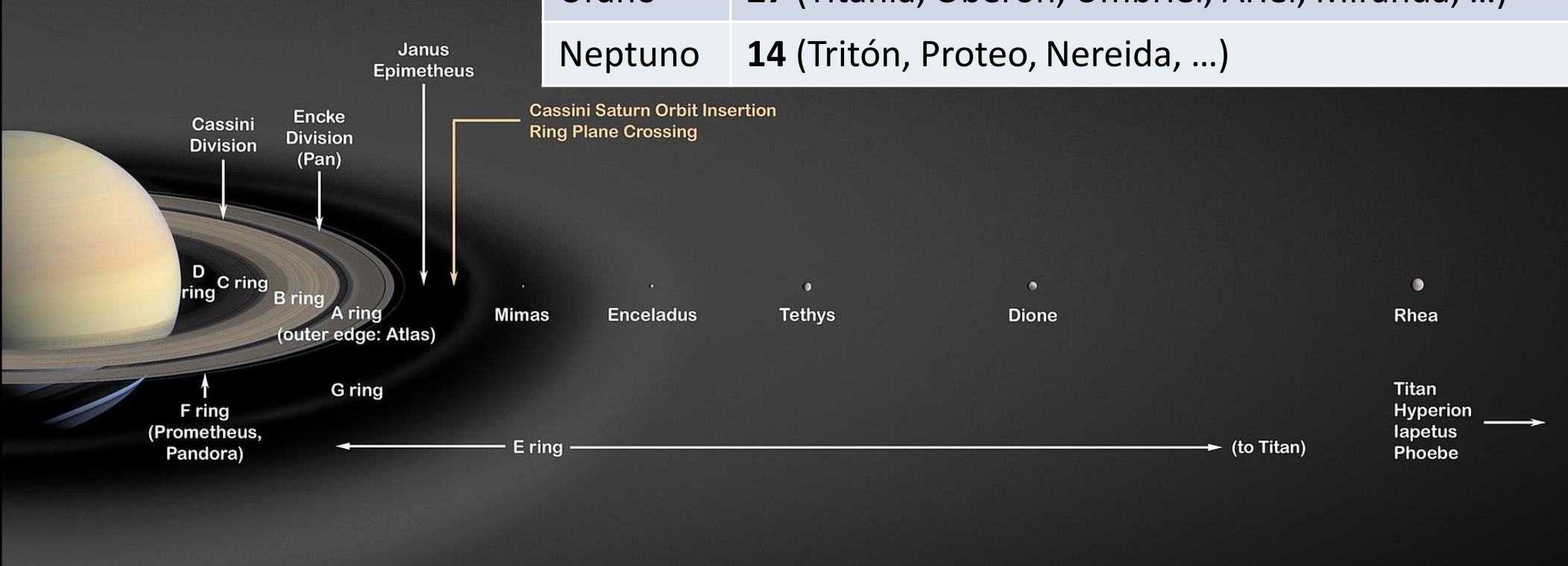


Apollo 17 - Lunar Module Pilot Jack Schmitt is running towards the Lunar Rover

moonpics.com

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, ...)



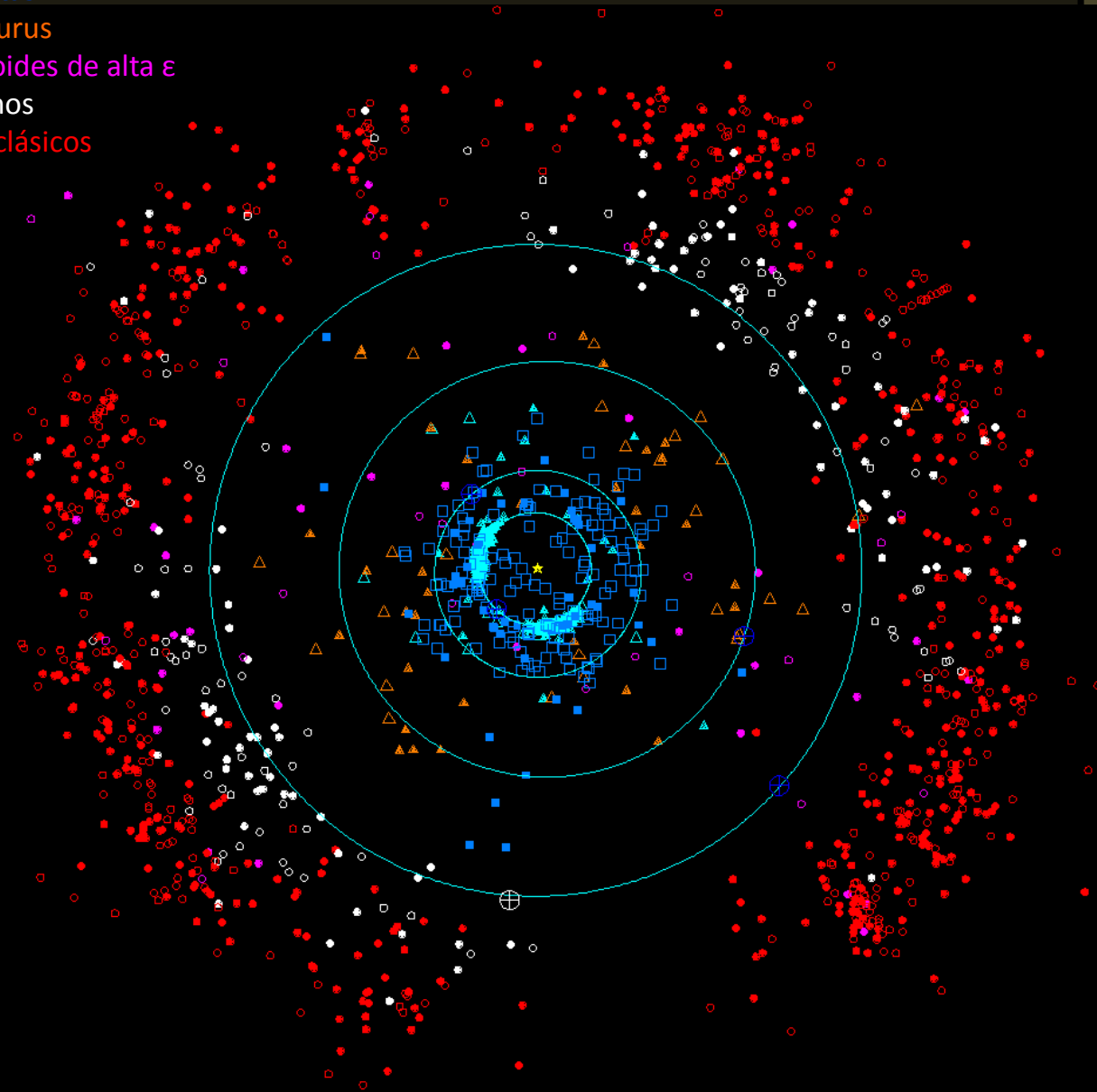
New Horizons



El Cinturón de Kuiper

Orbita de los planetas externos

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



Largest known trans-Neptunian objects (TNOs)



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

Centaurus: orange triangles

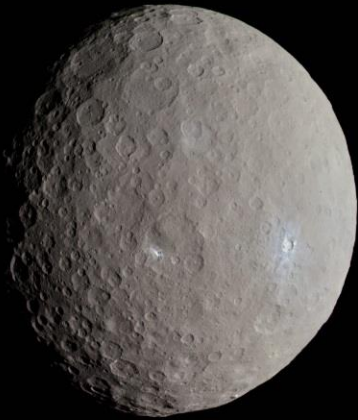
Plutinos: white circles (Pluto itself is the large white crossed circle)

"Classical" TNOs: red circles

Scattered Disk Objects: magenta circles

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

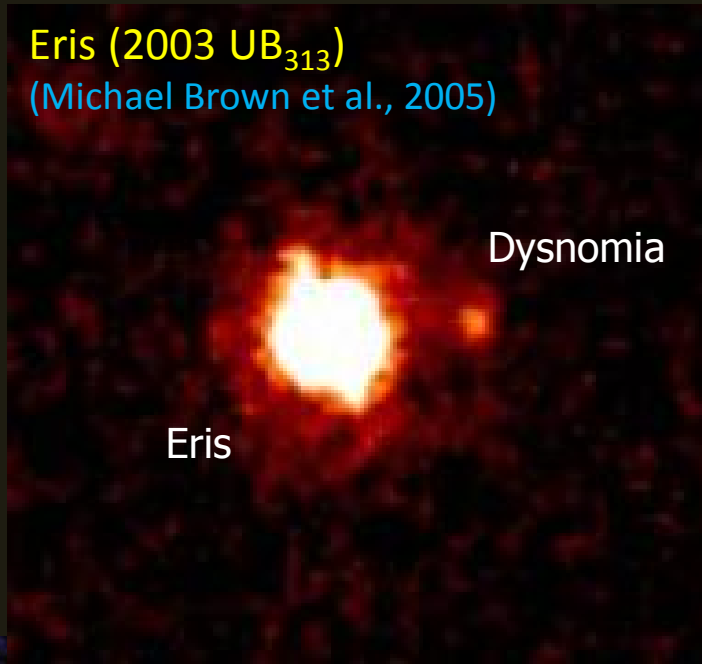
Planetas Enanos



Ceres

(Giuseppe Piazzi, 1801;
sonda Dawn, 2015)

Eris (2003 UB₃₁₃)
(Michael Brown et al., 2005)



Eris

Dysnomia

Makemake (2005 FY₉)

ilustr.

(Brown et al., 2005)



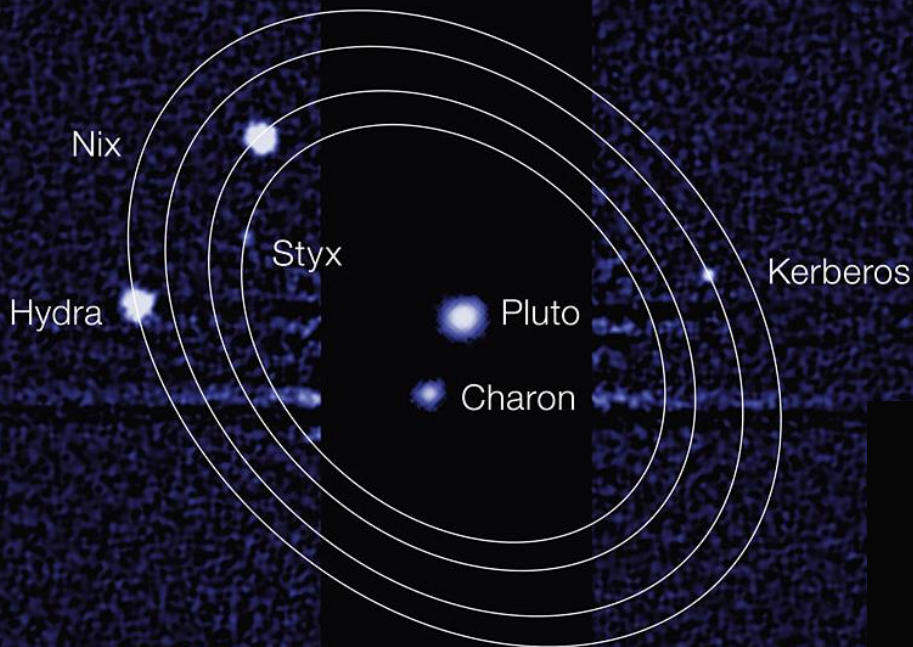
Haumea (2003 EL₆₁)

ilustr.

(Brown et al., 2005;
Ortiz et al., 2005)



Hi'iaka y
Namaka



Caronte

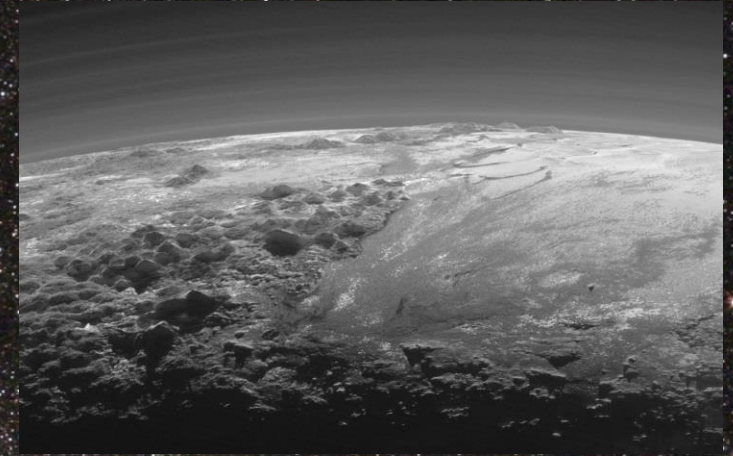
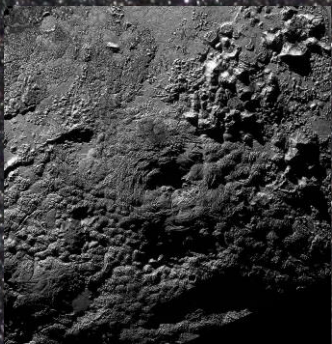


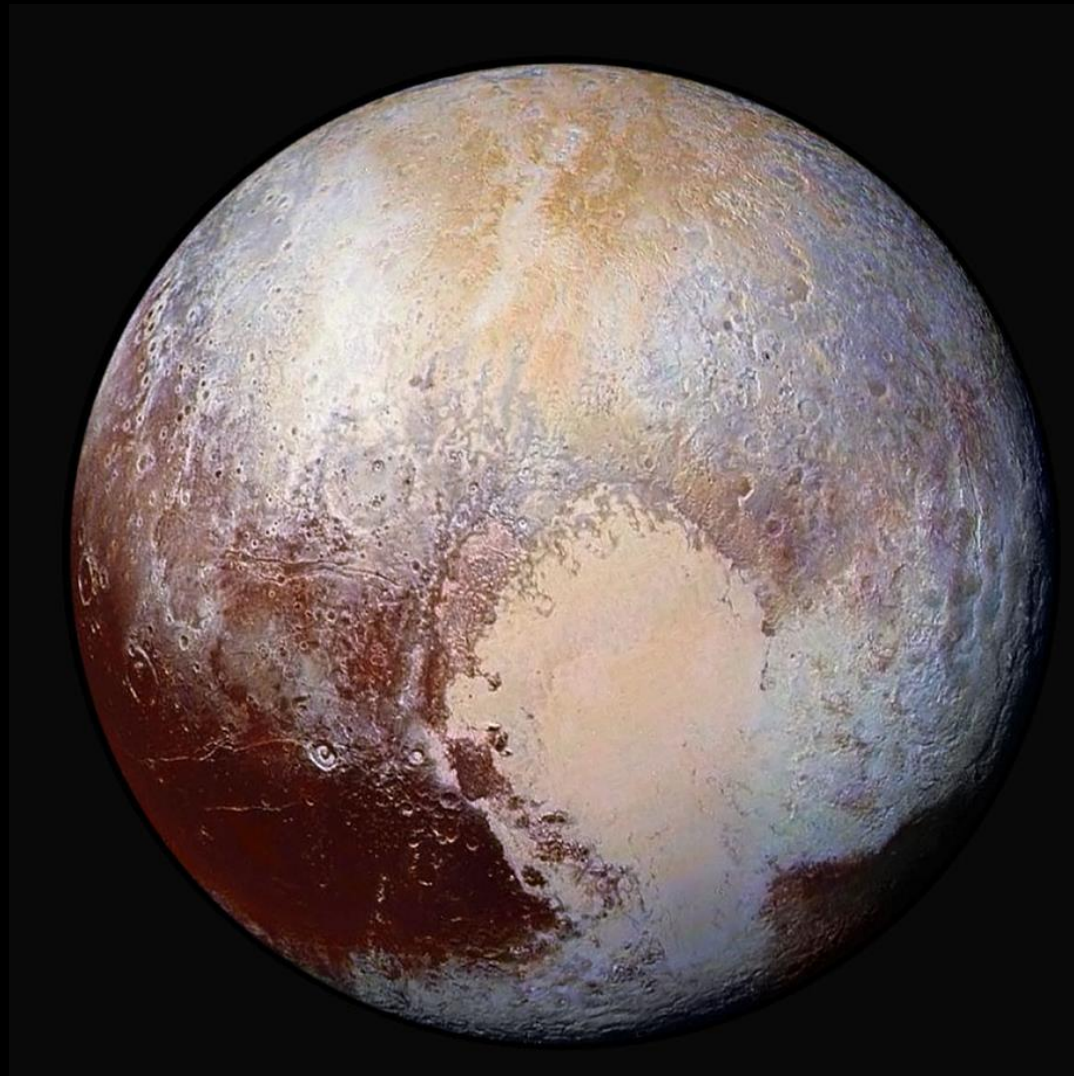
Plutón

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

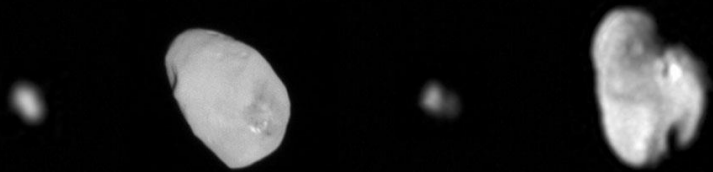
Plutón y Caronte

New Horizons (Plutón, 14/jul/2015)
NASA (19/ene/2006 -)
+ Júpiter, otros objetos del Cinturón de Kuiper





Charon and the Small Moons of Pluto



Styx

Nix

Kerberos

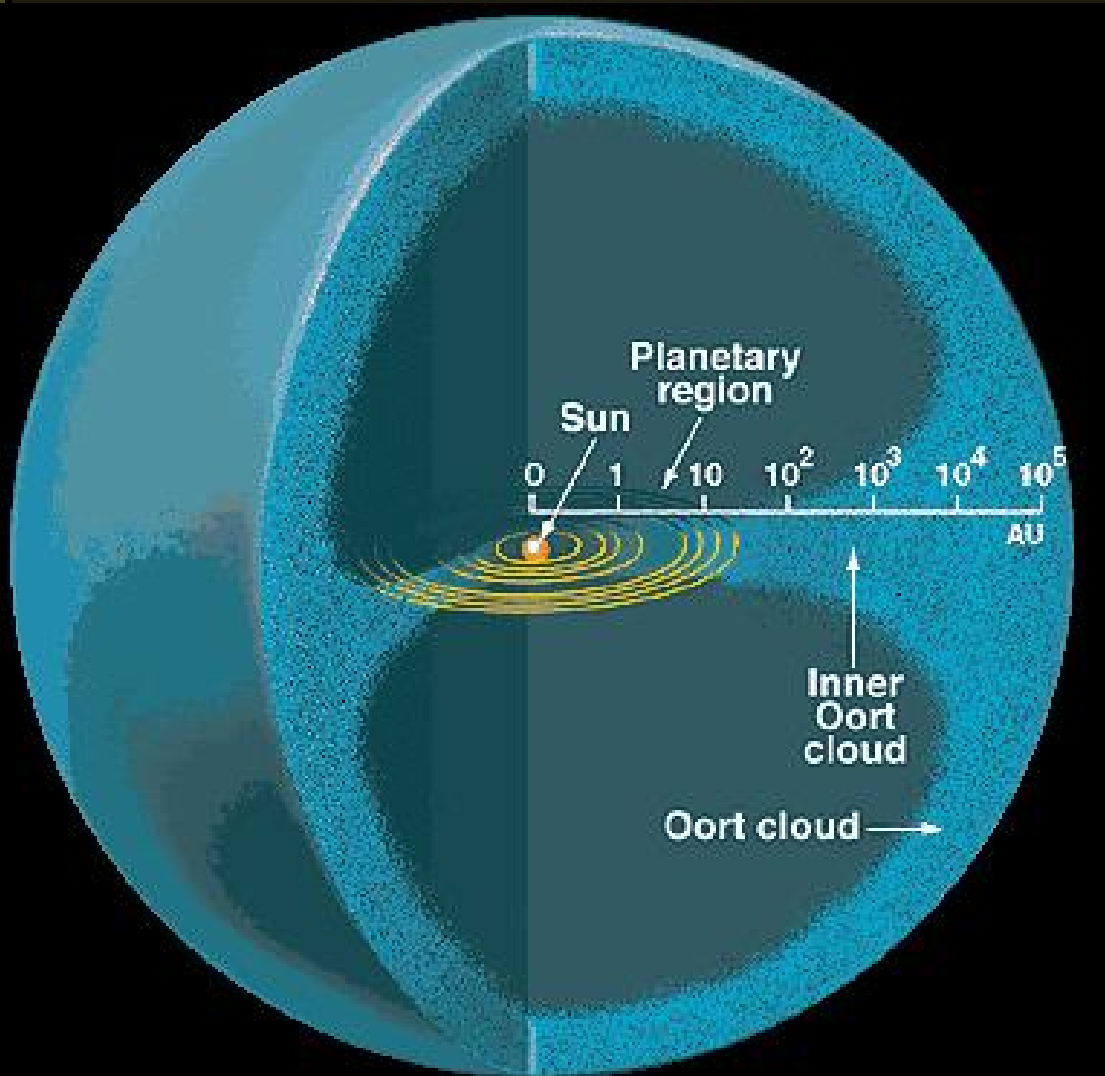
Hydra

Charon

10 miles
10 km

NASA/JHU/APL/SWRI

Los cometas y la Nube de Oort



West (1976)



Hyakutake (1996)

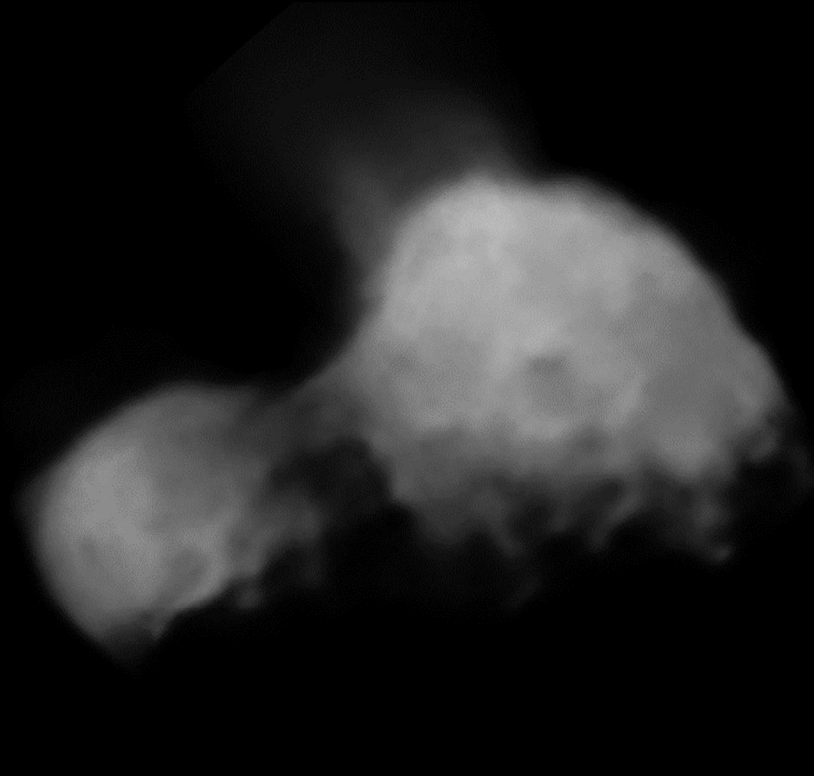
McNaught (2007)



Hale-Bopp (1997)



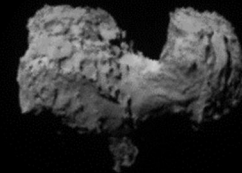
Cometas visitados por sondas



1P/Halley
16 × 8 × 8 km
Vega 2, 1986



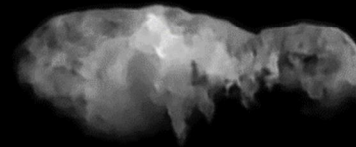
81P/Wild 2
5.5 × 4.0 × 3.3 km
Stardust, 2004



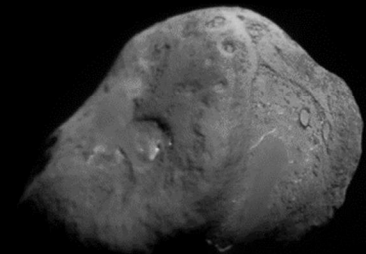
67P/Churyumov-
Gerasimenko
5 × 3 km
Rosetta, 2014



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



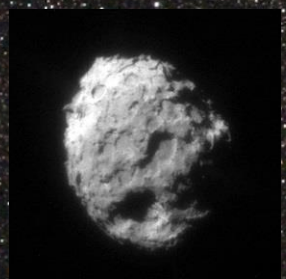
19P/Borrelly
8 × 4 km
Deep Space 1, 2001



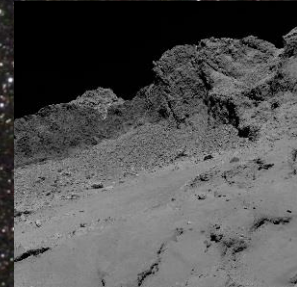
9P/Tempel 1
7.6 × 4.9 km
Deep Impact, 2005



Giotto (Halley, 14/mar/1986)
 ESA (02/jul/1985 – 23/jul/1992)
 + Grigg-Skjellerup (10/jul/1992)



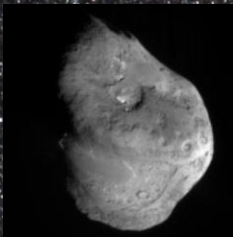
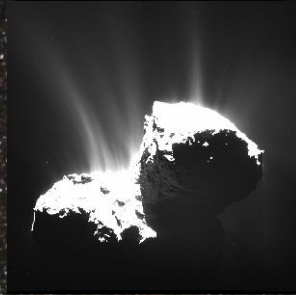
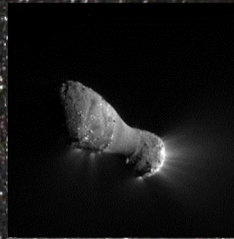
Rosetta + Philae
 (Churyumov-Gerasimenko, 2014-2016)
 ESA (02/mär/2004 – 30/sep/2016)
 + asteroide Steins (2008), asteroide Lutetia (2010)

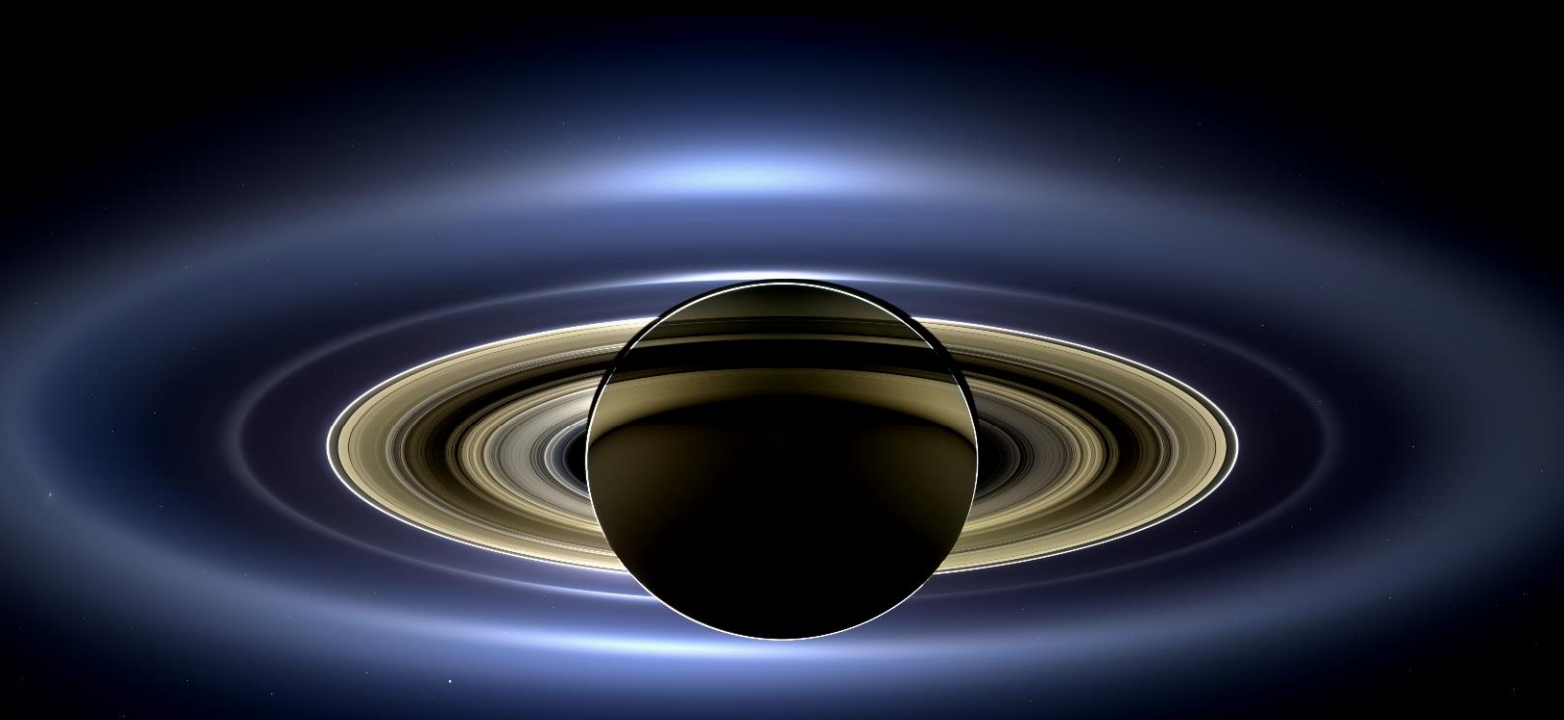


Stardust (Wild2, 15/ene/2016)
 NASA-JPL (07/feb/1999 –)
 + Tempel 1 (feb/2011)



Deep Impact (Tempel 1, 04/jul/2005)
 NASA (12/ene/2005 – 08/ago/2013)
 + Hartley (04/nov/2010)





Fin

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>CO</u> ₂ 4% <u>N</u> ₂
	Tierra	⊕	-	-	1	-	azul	0.37	78% <u>N</u> ₂ 21% <u>O</u> ₂
	Marte	♂	-	-	2	-2.0	rojo	0.15	95% <u>CO</u> ₂ 3% <u>N</u> ₂
Jovianos	Júpiter	♃	-	-	79	-2.7	blanco	0.52	86% <u>H</u> ₂ 14% <u>He</u>
	Saturno	♄	-	-	62	0.7	amarillo	0.47	93% <u>H</u> ₂ 5% <u>He</u>
	Urano	♅	1781	William Herschel	27	5.5	azul	0.51	83% <u>H</u> ₂ 15% <u>He</u>
	Neptuno	♆	1846	J.G. Galle e H.L. d'Arrest	14	7.8	azul	0.41	80% <u>H</u> ₂ 19% <u>He</u>
Enanos	Ceres	♁	1801	Giuseppe Piazzi	0				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.	0				?
	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/cm ³	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	4	0.0002	2.08	0.51	-106
	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 promedio al Sol		período de translación		inclinación de la órbita	excentricidad	velocidad orbital promedio
		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
	Plutón	5 906.38	39.48	í	247.92	17.14	0.249	4.75
	Haumea	6 484.0	43.34	í	285.4	28.19	0.189	4.48
	Makemake	6 850.0	45.79	í	309.9	28.96	0.159	4.4
	Eris	10 210.0	67.67	í	557	44.19	0.442	3.44