

# Taller de Astronomía



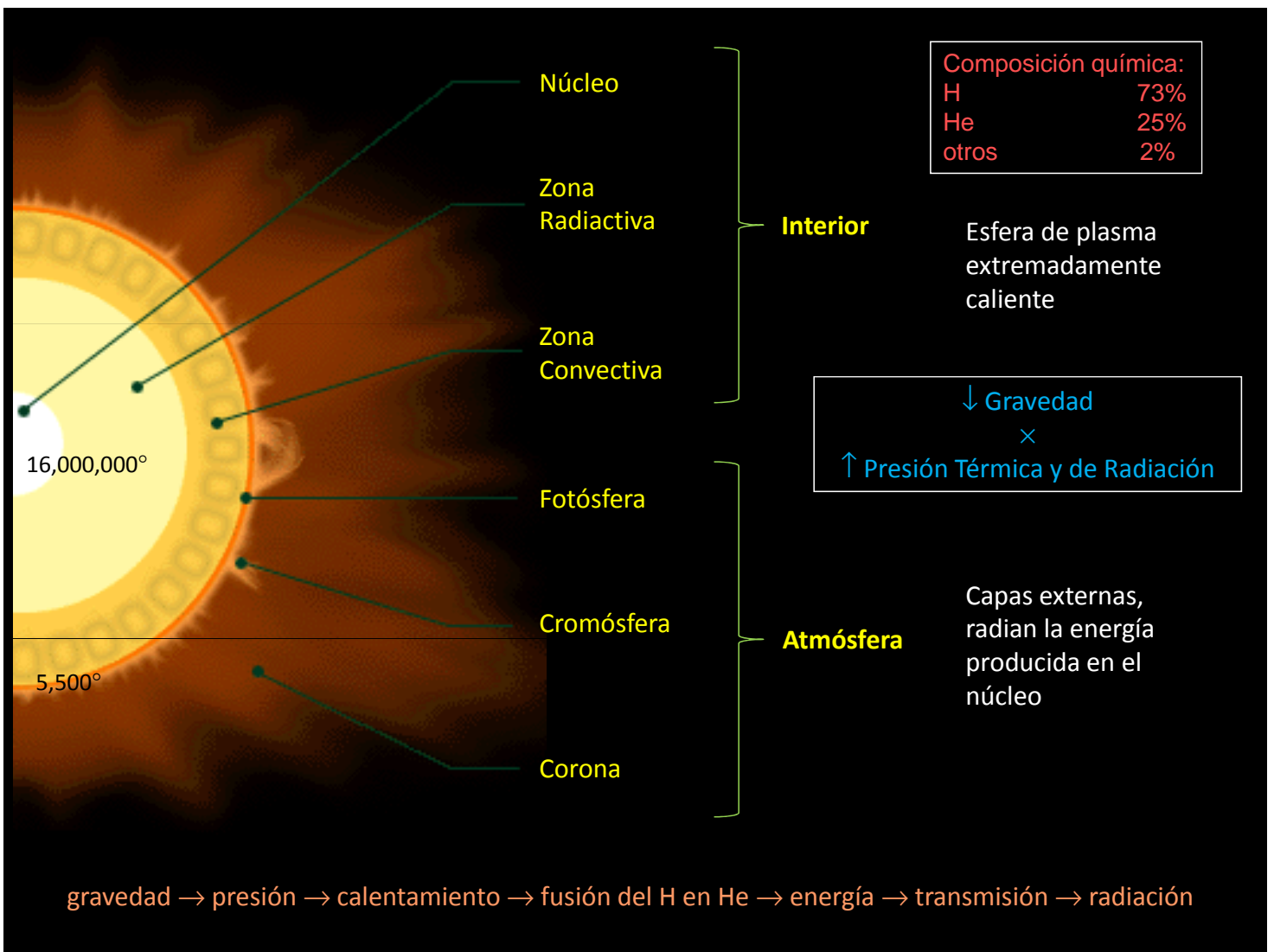
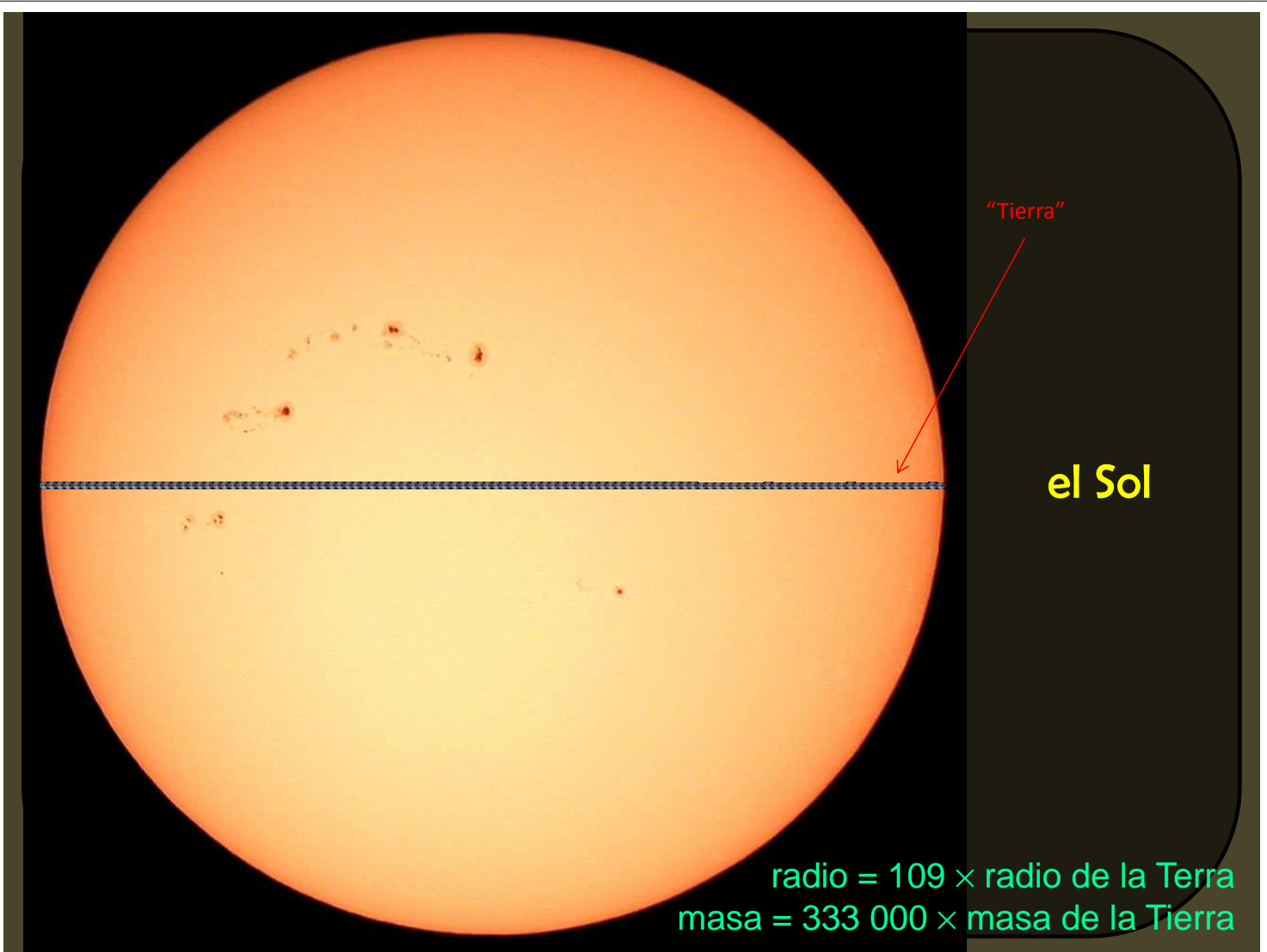
ilustración de un sistema planetario hipotético

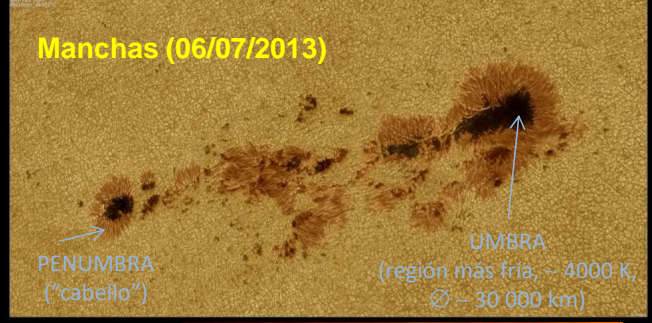
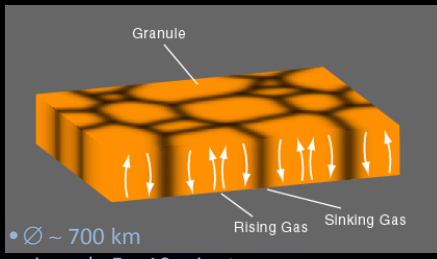
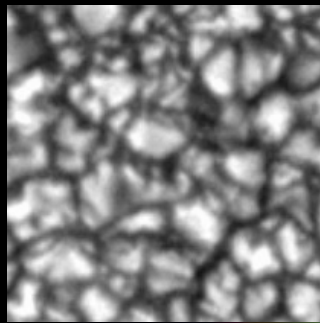
## 2. Sistemas Planetarios

Prof. Dr. César A. Caretta – Departamento de Astronomía, UGto.

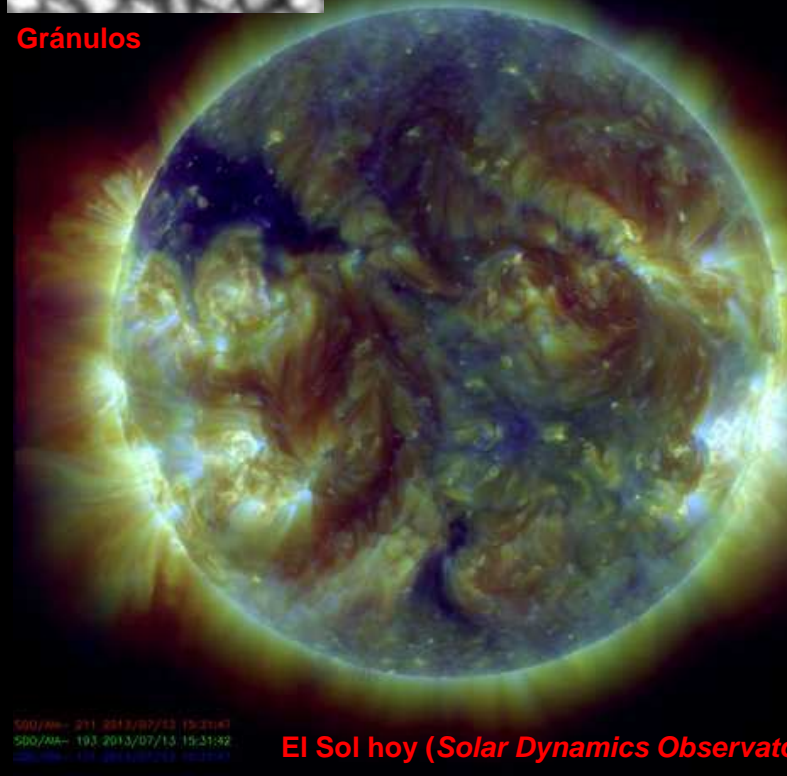
### El Sistema Solar



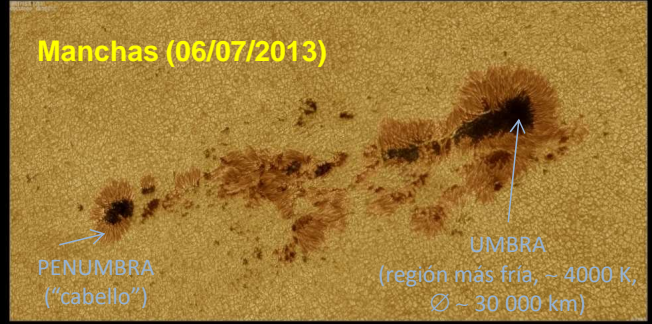
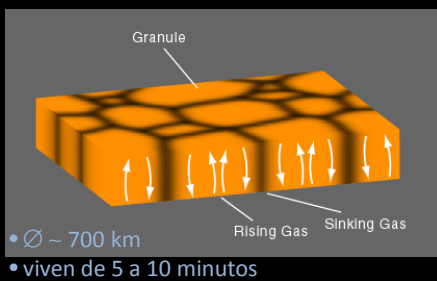
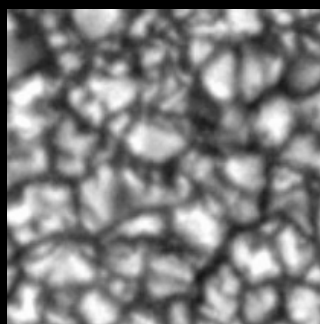
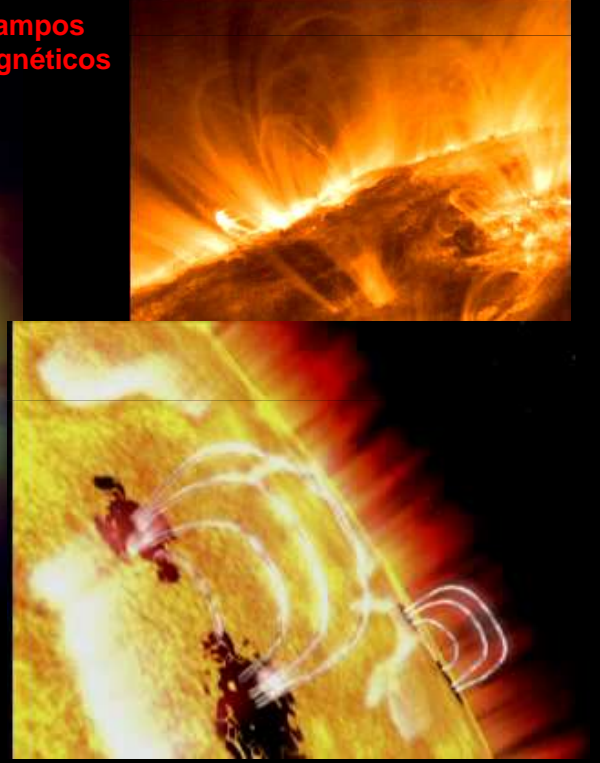




**Gránulos**



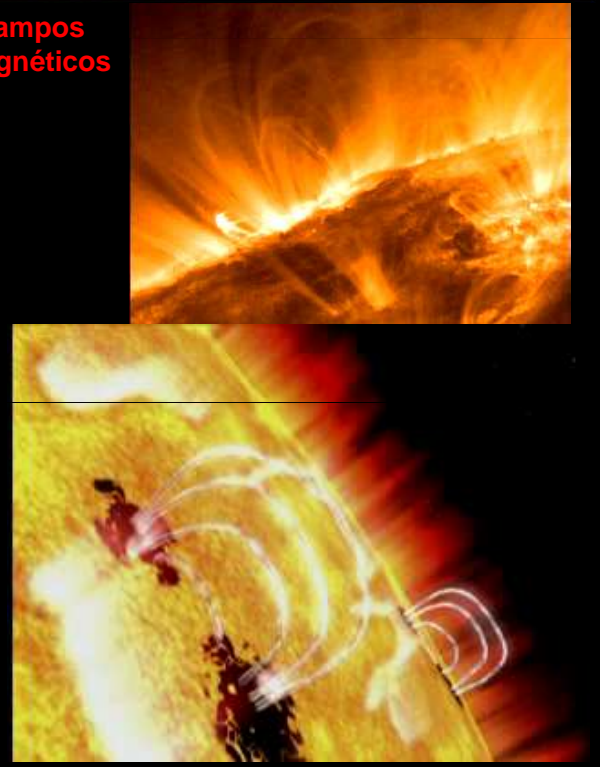
**Campos magnéticos**

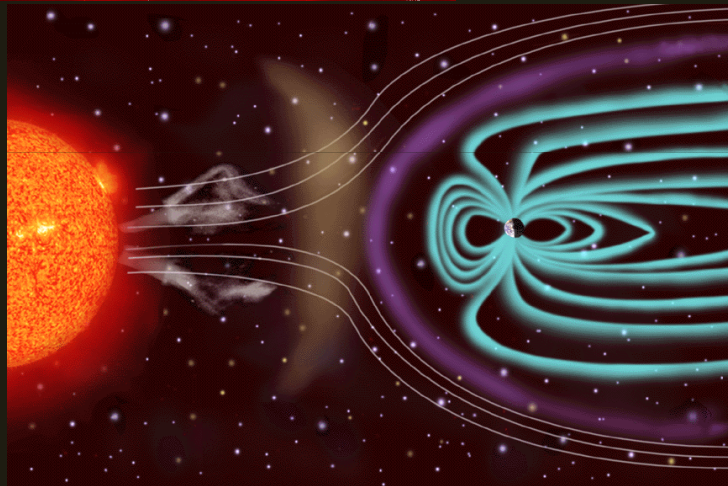
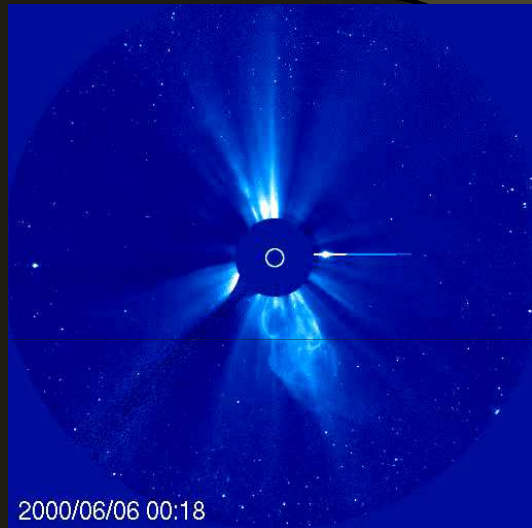
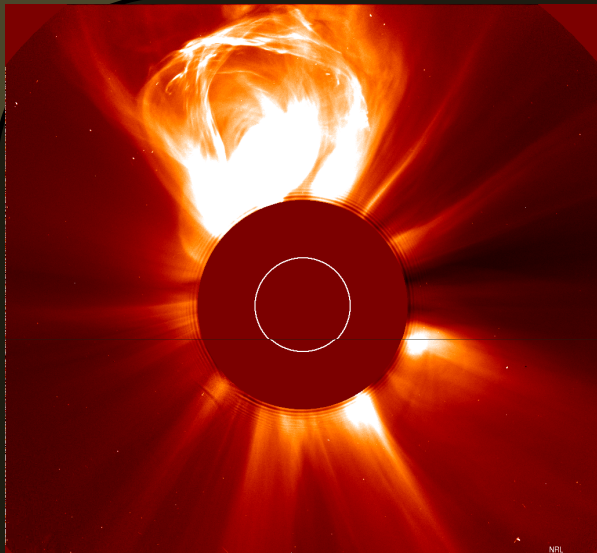


**Gránulos**

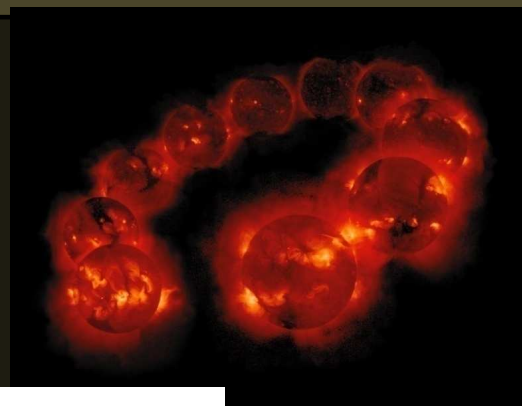
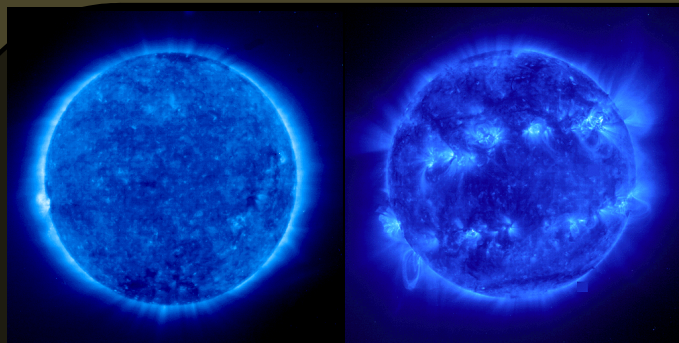


**Campos magnéticos**

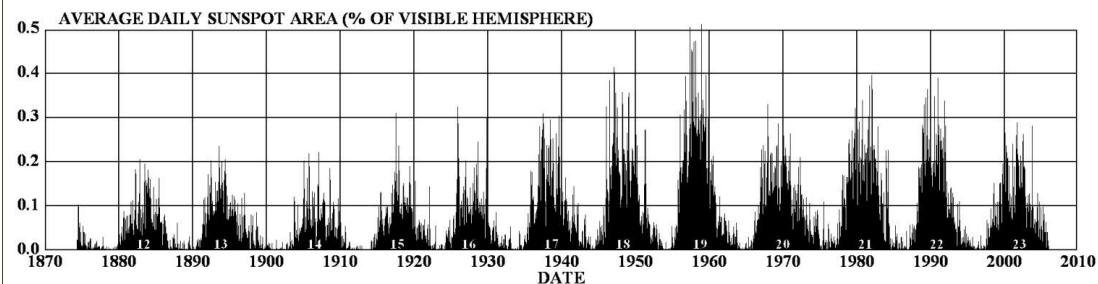
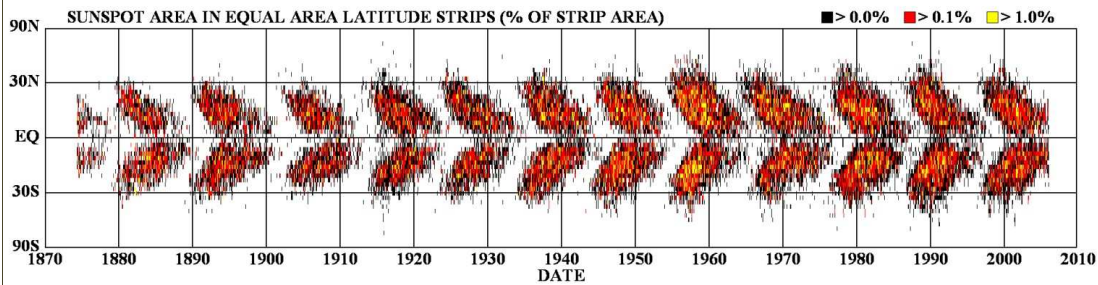




**viento solar,  
eyecciones coronales  
y el clima espacial**

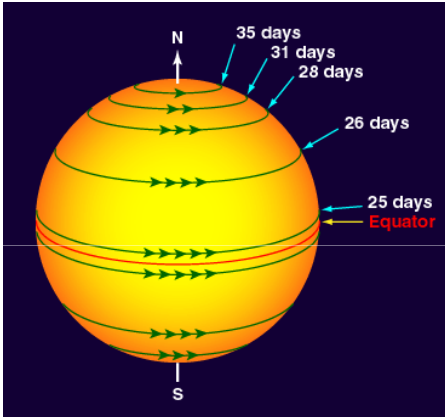


**DAILY SUNSPOT AREA AVERAGED OVER INDIVIDUAL SOLAR ROTATIONS**

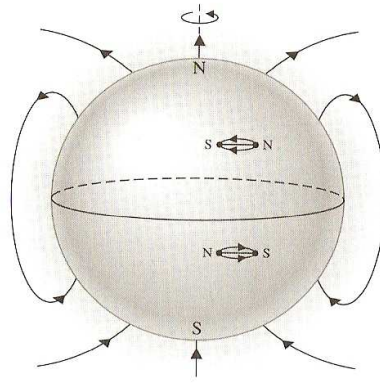


**el ciclo  
solar**

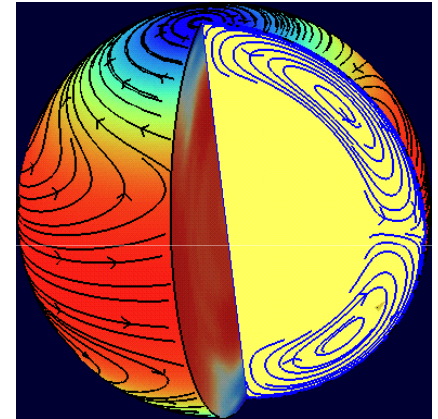
## ¿Qué produce el ciclo solar?



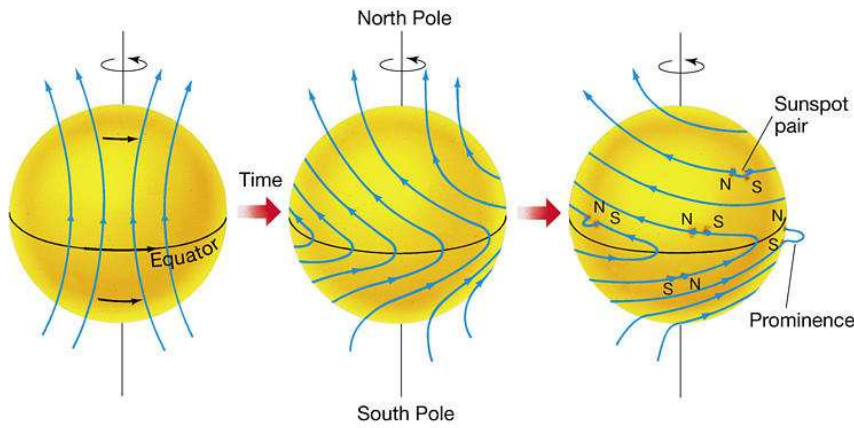
Rotación diferencial



Campos magnéticos

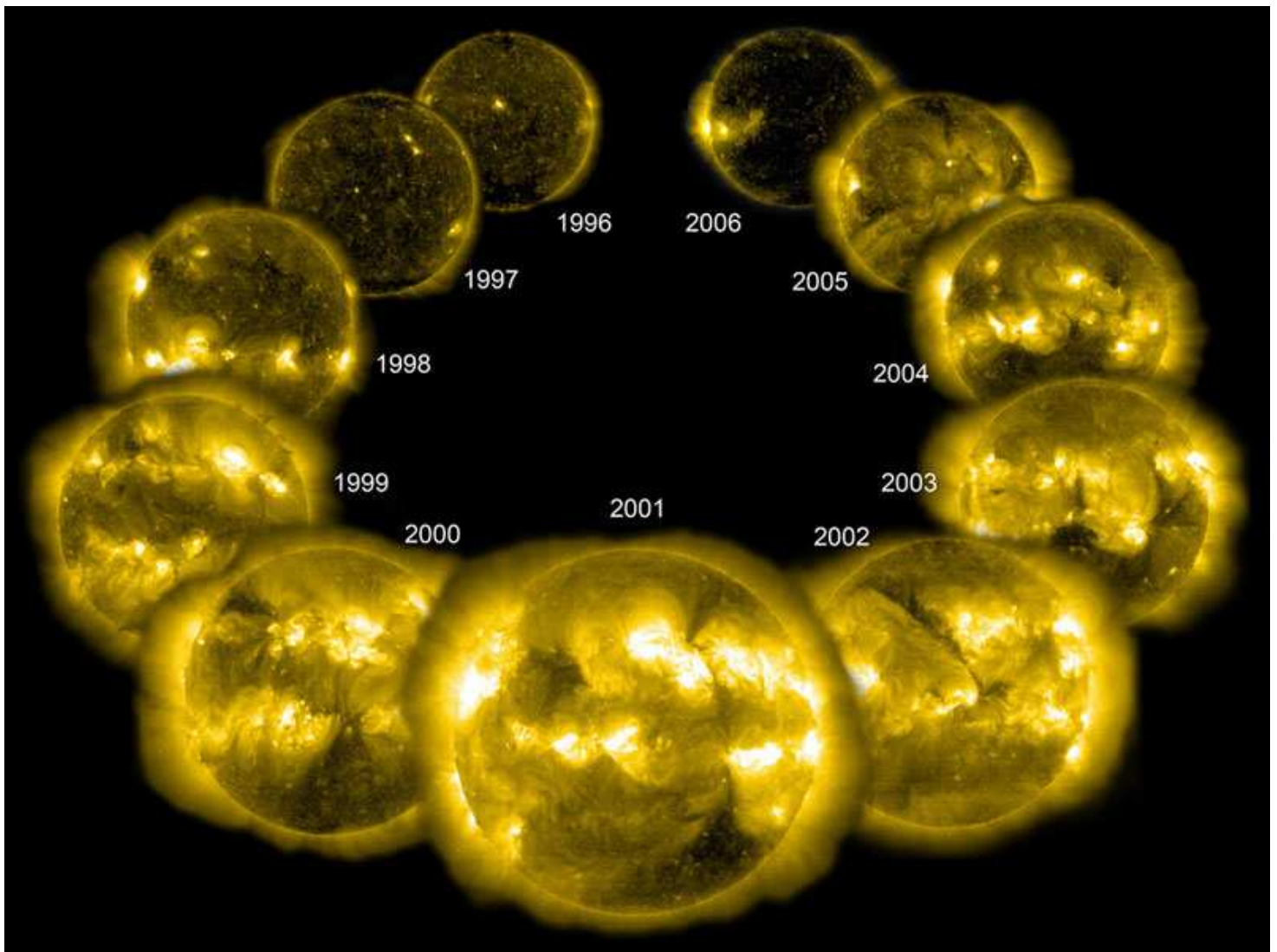


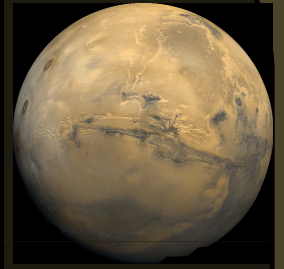
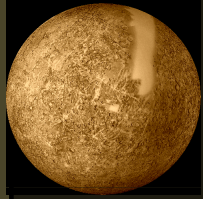
Zona convectiva



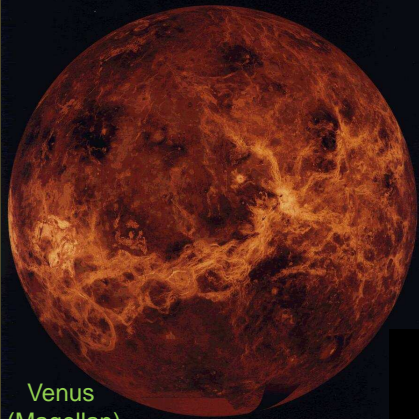
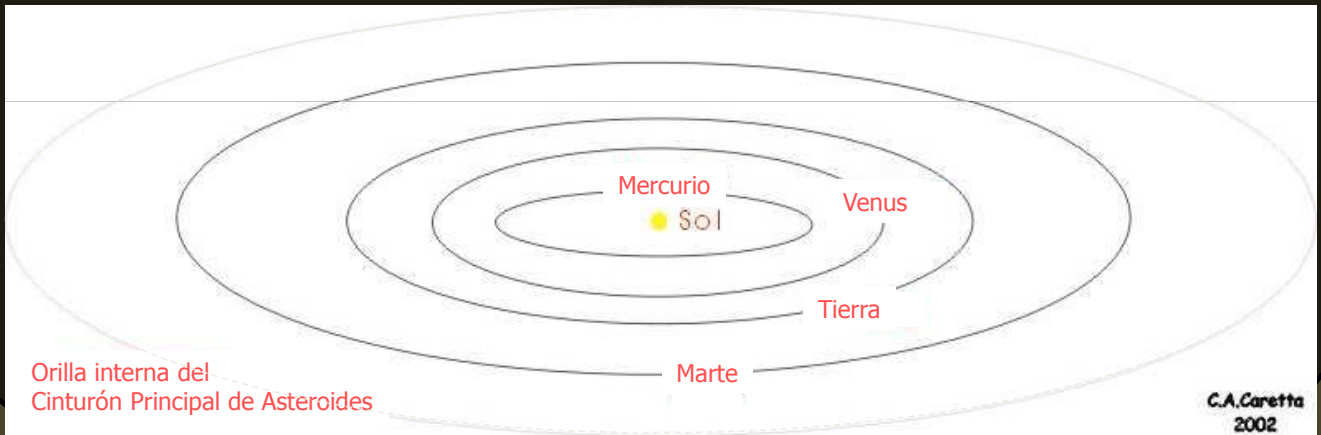
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Dínamo





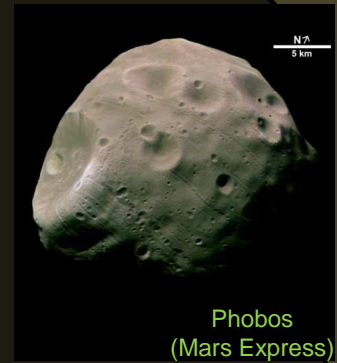
## Los Planetas Internos o Rocosos



Venus (Magellan)



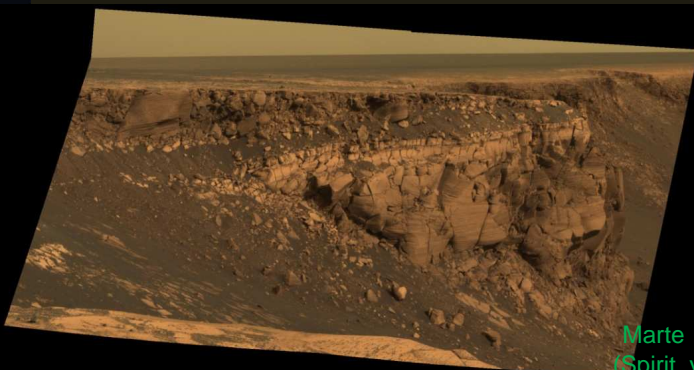
Venus (Venera)



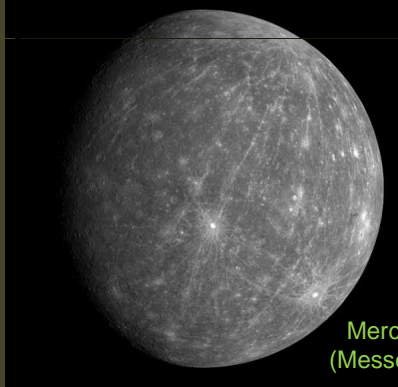
Phobos (Mars Express)



Mercurio (transito 2003)



Marte (Spirit y Opportunity)



Mercurio (Messenger)



# El Cinturón Principal de Asteroides



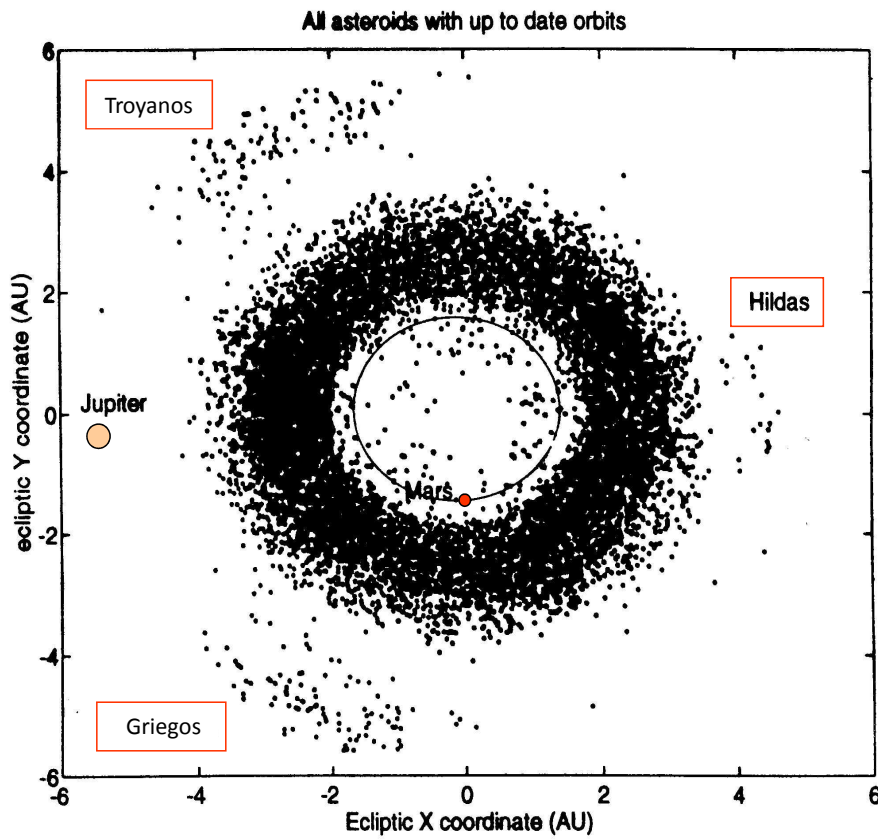
Ida

Dactyl

Gaspra



Matilde (NEO)



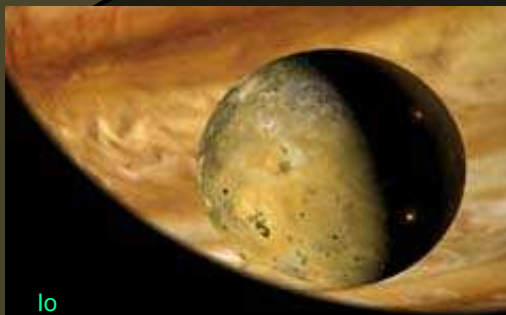
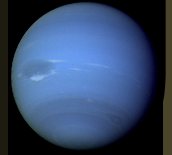
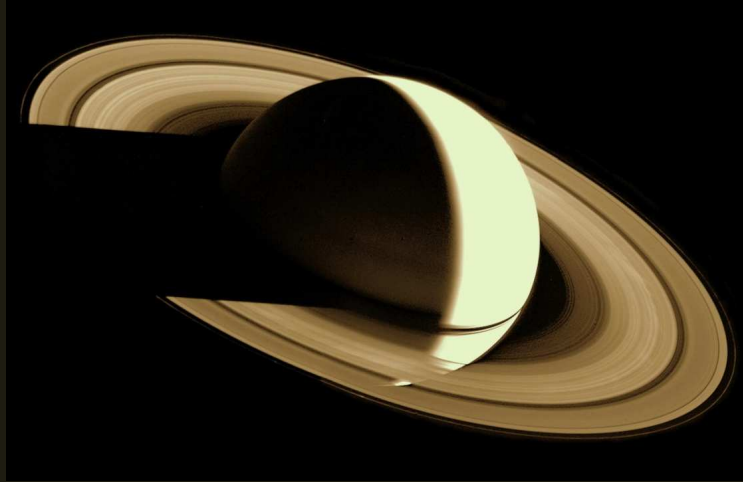
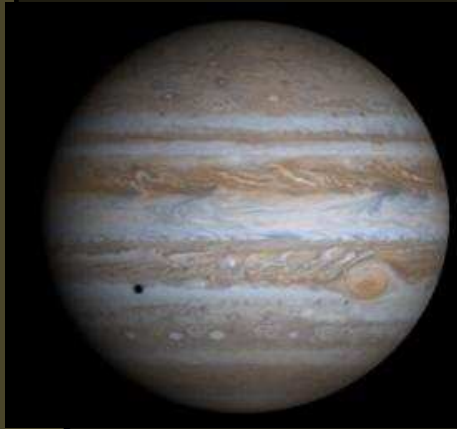
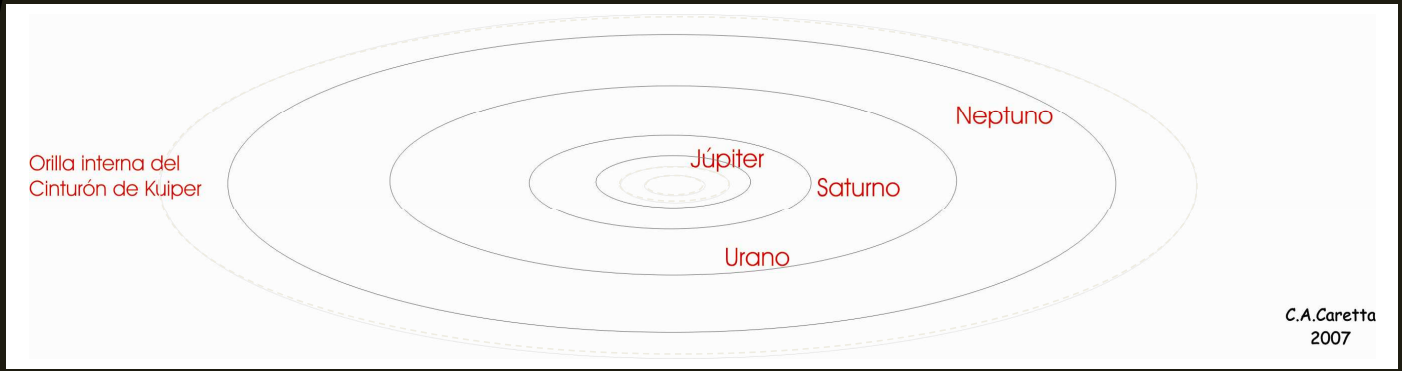
Ceres • January 24, 2004  
HST ACS/HRC

Vesta • May 14, 2007  
HST WFPC2

- 243 Ida - 58.8 × 25.4 × 18.6 km  
Galileo, 1993
- 9969 Braille - 2.1 × 1 × 1 km  
Deep Space 1, 1999
- 5535 Annefrank - 6.6 × 5.0 × 3.4 km  
Stardust, 2002
- 2867 Steins - 5.9 × 4.0 km  
Rosetta, 2008
- 433 Eros - 33 × 13 km  
NEAR, 2000
- 25143 Itokawa - 0.5 × 0.3 × 0.2 km  
Hayabusa, 2005
- Dactyl (243) Ida II - 1.6 × 1.2 km  
Galileo, 1993
- 1P/Halley - 16 × 8 × 8 km  
Vega 2, 1986
- 253 Mathilde - 66 × 48 × 44 km  
NEAR, 1997
- 951 Gaspra - 18.2 × 10.5 × 8.9 km  
Galileo, 1991
- 21 Lutetia - 132 × 101 × 76 km  
Rosetta, 2010
- 199 Borrelly - 8 × 4 km  
Deep Space 1, 2001
- 997 Tempel 1 - 7.6 × 4.9 km  
Deep Impact, 2005
- 81P/Wild 2 - 5.5 × 4.0 × 3.3 km  
Stardust, 2004

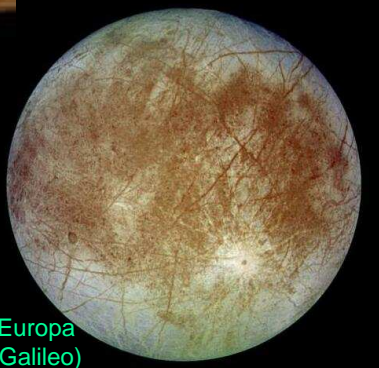
4 Vesta

# Los Planetas Externos o Gaseosos

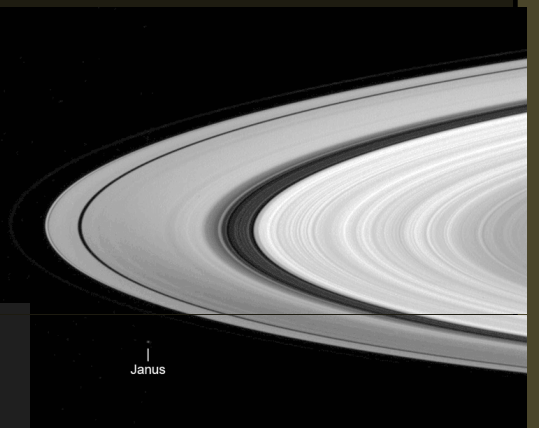


Io

Saturno (Cassini)



Europa (Galileo)



Titán (Huygens)

## Satélites (2013)

Júpiter	66
Saturno	61
Urano	27
Neptuno	13

ES0 PR Photo 31h/02 (29 December 2002) © European Southern Observatory

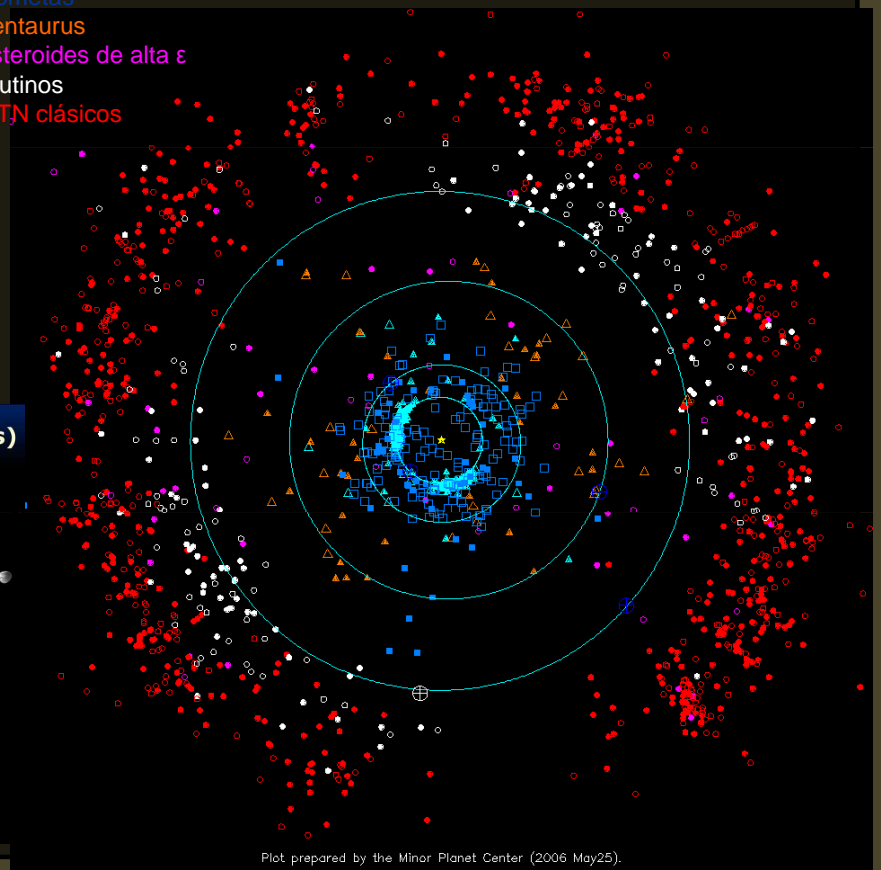




# El Cinturón de Kuiper

Orbita de los planetas externos

- Trojanos, Hildas
- Cometas
- △ Centaurus
- Asteroides de alta  $\epsilon$
- Plutinos
- OTN clásicos



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

## Largest known trans-Neptunian objects (TNOs)



Orbita de los planetas externos

- Trojanos, Hildas
- Cometas
- △ Centaurus
- Asteroides de alta  $\epsilon$
- 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

Centaur: 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.

# Los Planetas Enanos (2009)



**Ceres**  
(Giuseppe Piazzi, 1801)

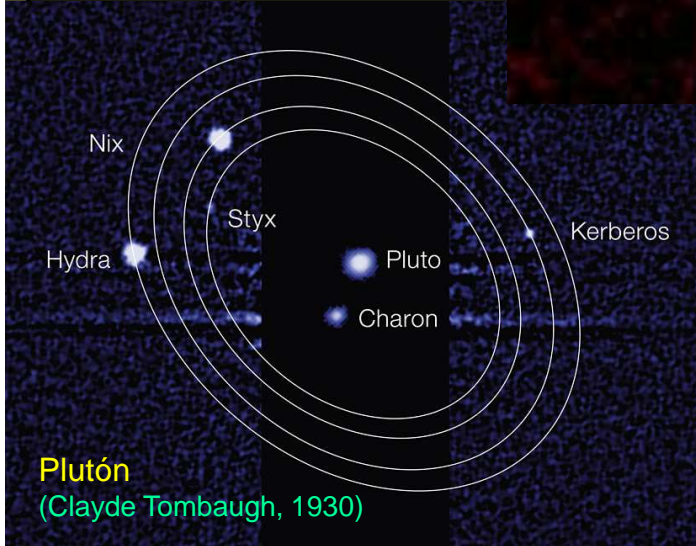


**Eris**  
Dysnomia

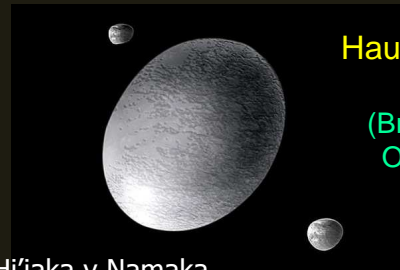
**Eris (2003 UB<sub>313</sub>)**  
(Michael Brown et al., 2005)



**Makemake (2005 FY<sub>9</sub>)**  
ilustr.  
(Brown et al., 2005)



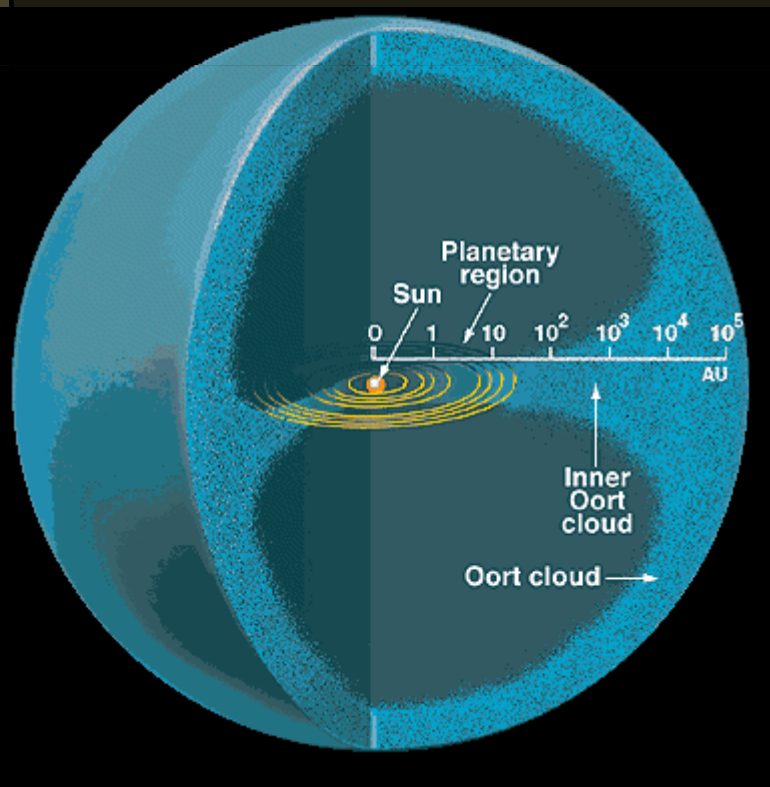
**Plutón**  
(Clayde Tombaugh, 1930)



Hi'iaka y Namaka

**Haumea (2003 EL<sub>61</sub>)**  
ilustr.  
(Brown et al., 2005;  
Ortiz et al., 2005)

# Los cometas y la Nube de Oort



West (1976)



Hyakutake (1996)



McNaught (2007)



Hale-Bopp (1997)



Halley (1910)

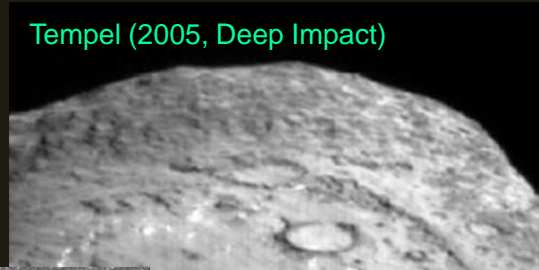


LAKE PARK, MAY 1210.

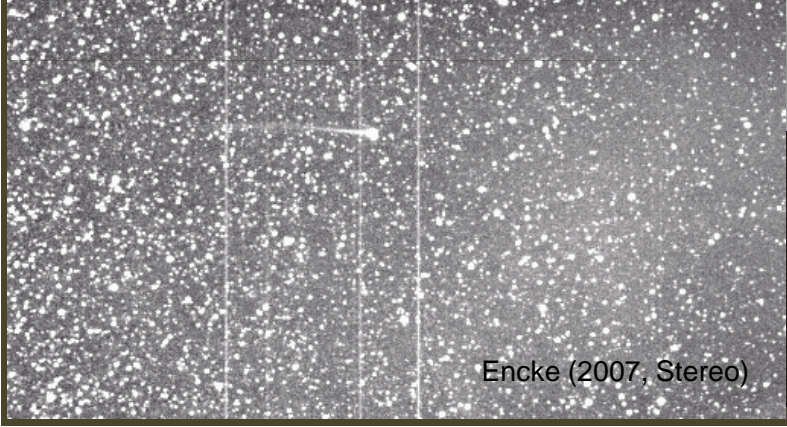
LAKE VIEW, O.



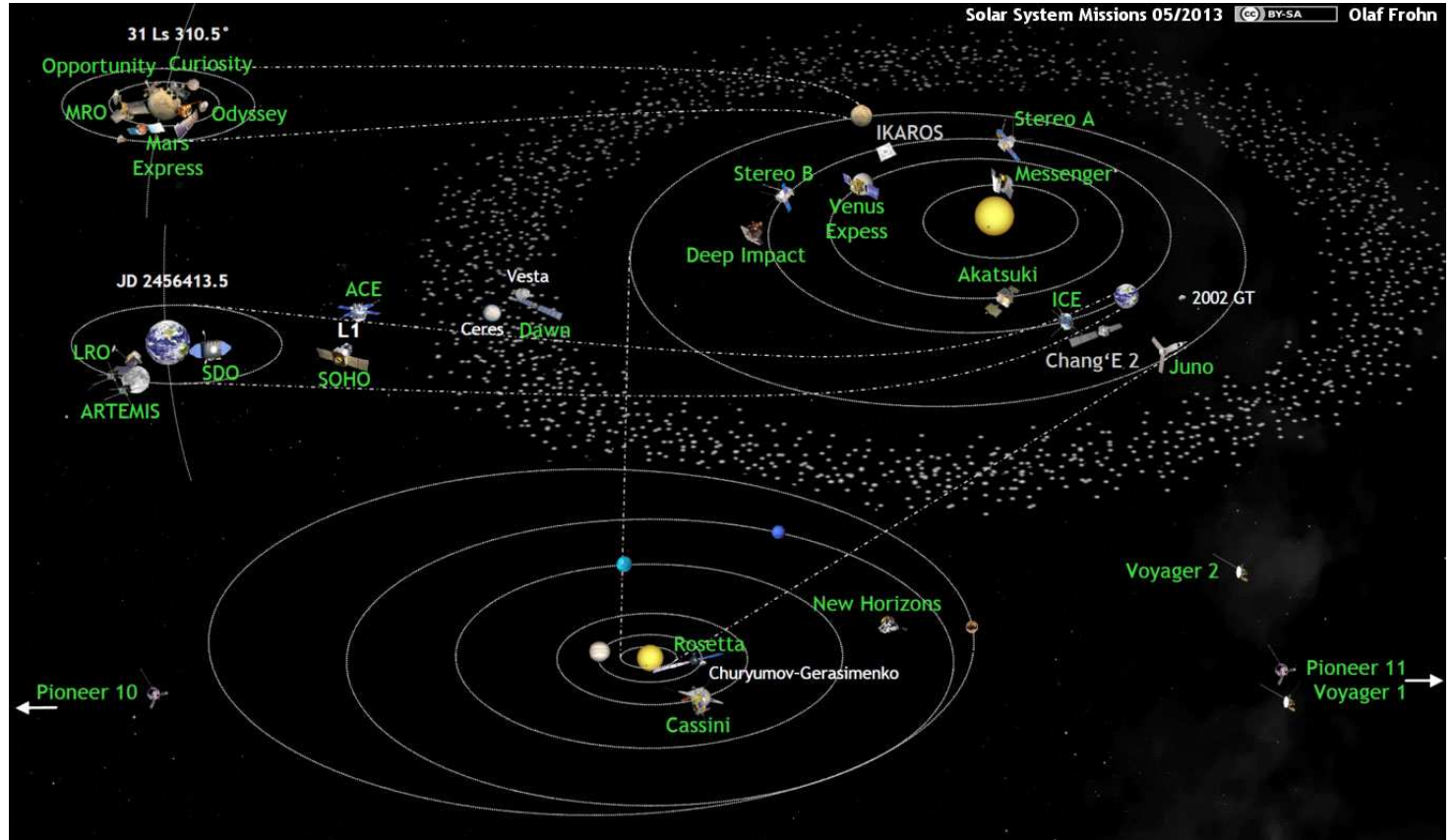
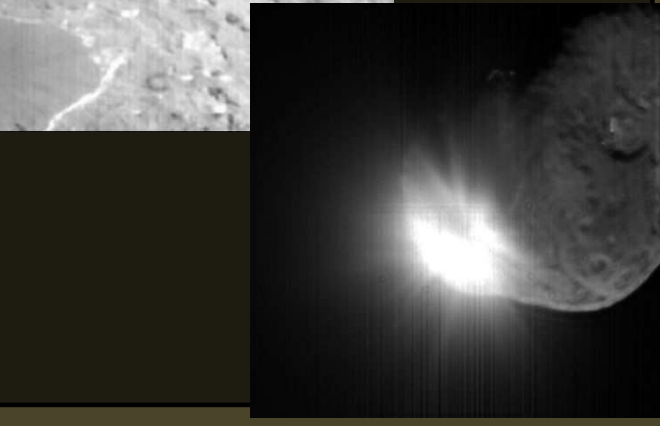
Halley (1986, Giotto)



Tempel (2005, Deep Impact)



Encke (2007, Stereo)



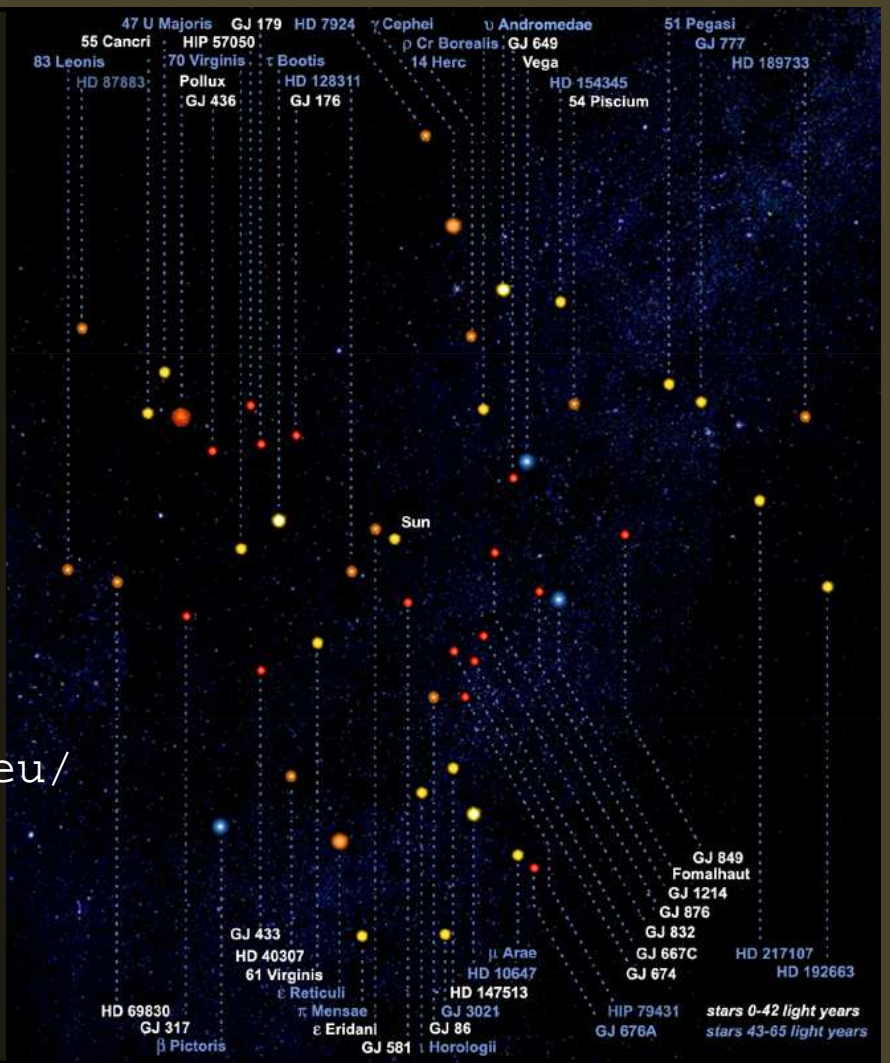
**Upcoming Events**

<p><b>2013</b></p> <p>Şep: LADEE Launch/OI Moon</p> <p>Oct: Juno FB Earth</p> <p>Nov: MAVEN Launch</p> <p>Nov: Mars Orbiter Mission Launch</p> <p>Dec: Chang'E 3 Launch/SL Moon</p>	<p><b>2014</b></p> <p>Jan: Rosetta Wake-up</p> <p>May: Rosetta App Churyumov-Ger.</p> <p>Aug: ICE FB/OI? Earth</p> <p>Aug: Rosetta OI Churyumov-Ger.</p> <p>Nov: Rosetta/Philae SL Chu-Ger.</p> <p>Nov: Sunjammer Launch.</p>	<p>Nov: DSCOVR Launch</p> <p>Dec: Hayabusa 2 Launch</p> <p><b>2015</b></p> <p>Feb: Dawn OI Ceres</p> <p>Jul: New Horizons FB Pluto</p> <p>Aug: Bepi-Colombo Launch</p> <p>Nov: Akatsuki OI Venus</p> <p>Chang'E 4 Launch/SL Moon</p> <p>Luna Glob 1 Launch</p>	<p><b>2016</b></p> <p>Jan: Exomars-TGO Launch</p> <p>Mar: InSIGHT Launch</p> <p>Jul: Juno OI Jupiter</p> <p>Sep: OSIRIS-REX Launch</p> <p>Luna-Glob 2 Launch</p> <p><b>2017</b></p> <p>Sep: Cassini EOM</p> <p>Oct: Juno EOM</p>	<p>Solar Orbiter Launch</p> <p>Orion EM-1 Launch/FB Moon</p> <p><b>2018+</b></p> <p>Chang'E 5 Launch/SL Moon</p> <p>Deep Impact FB Earth</p> <p>Solar Probe Plus Launch</p> <p>Exomars Rover Launch</p> <p>Deep Impact FB 2002 GT (2020)</p> <p>(US Mars Rover) Launch (2020)</p>
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FB: Flyby; OI: Orbit Insertion; App: Approach; Dep: Departure;  
EDL: Entry, Descent and Landing; SL: Soft Landing; EOM: End of Mission

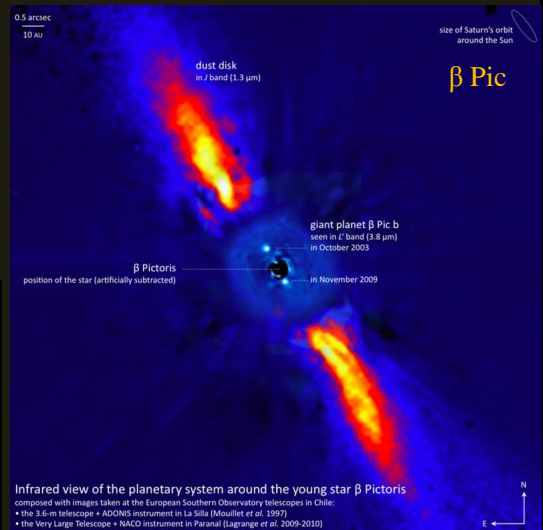
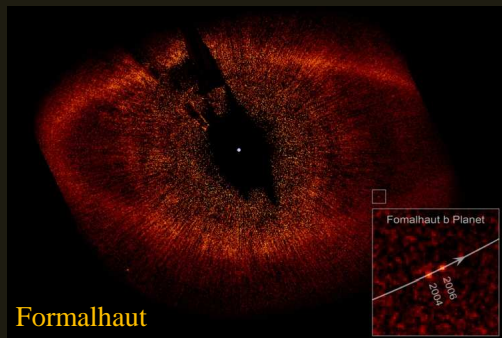
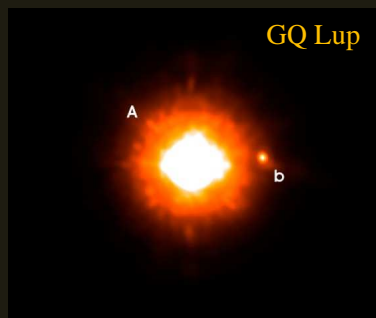
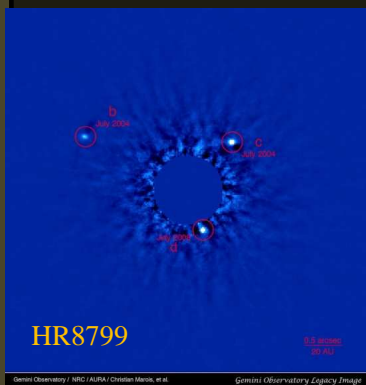
# Otros sistemas planetarios

<http://exoplanet.eu/>

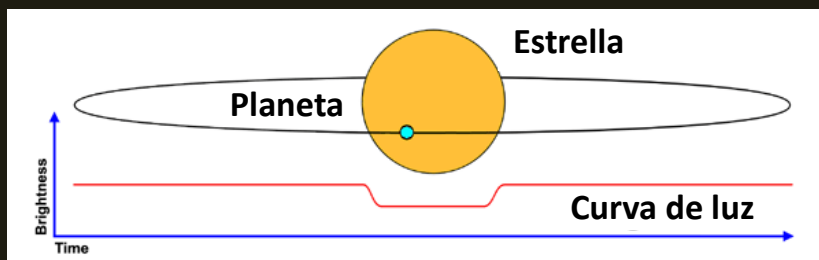


# Detección de planetas extrasolares

## 1. imagen directa

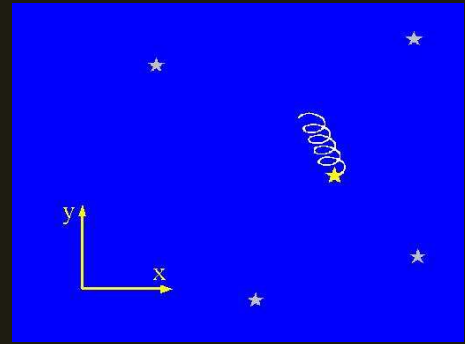
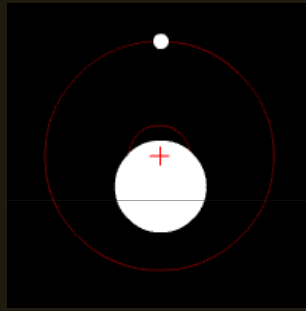


## 2. transito

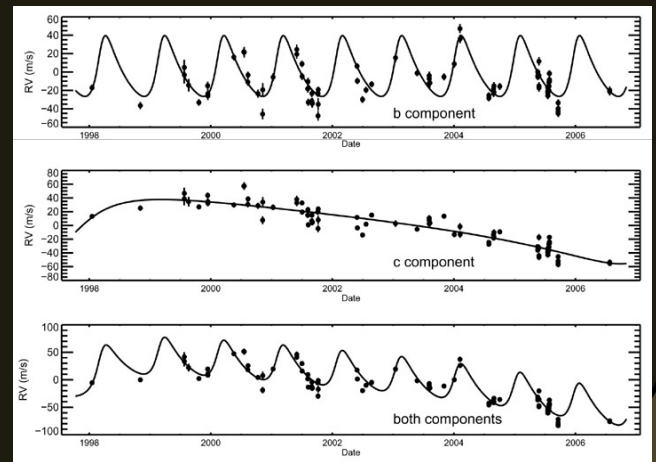
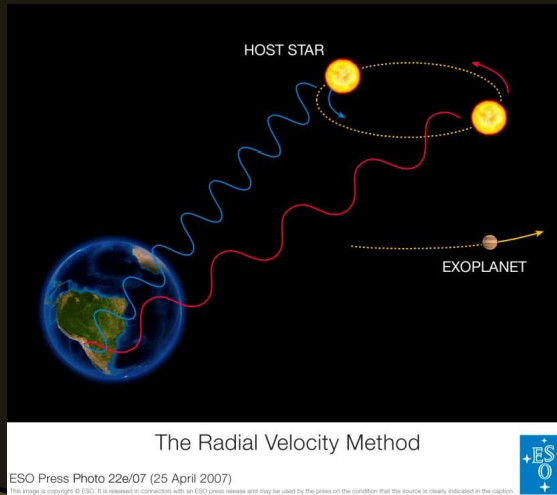


# Detección de planetas extrasolares

## 3. astrometría



## 4. velocidad radial



# Detección de planetas extrasolares (14 de julio de 2013)

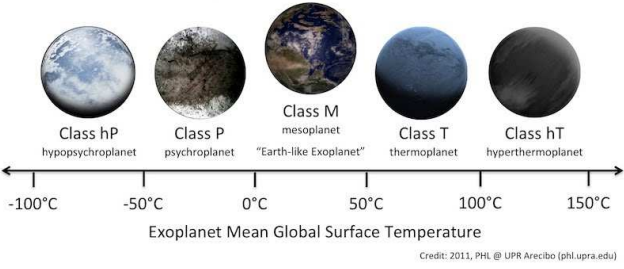
Método	Sistemas planetarios	Planetas	Sistemas múltiples
imagen directa	30	34	1
transito	250	313	40
astrometría + veloc. radial	398	528	91
microlentes gravit.	19	21	2
pulsares	12	15	2
<b>TOTALES</b>	<b>703</b>	<b>911</b>	<b>140</b>

# Condiciones para la existencia de vida

1. Fuente de energía

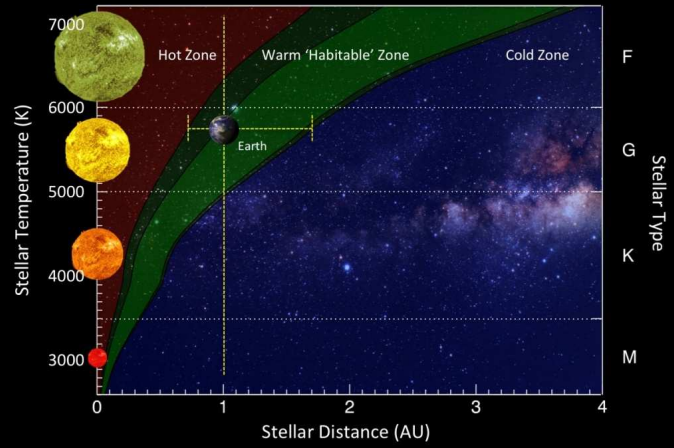
2. Agua líquida (temperatura)

## Thermal Planetary Habitability Classification (T-PHC)



3. Composición química adecuada

## Habitable Zone of Main Sequence Stars



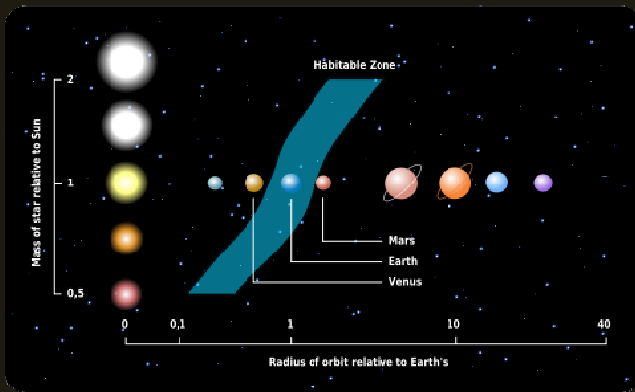
Periodic table with color-coded elements:

- Green box: Required for all life-forms
- Yellow box: Required for some life-forms
- Red box: Moderately toxic; either slightly toxic to all life-forms or highly toxic to a few forms
- Black box with 'x': Highly toxic to all life-forms, even in low concentrations

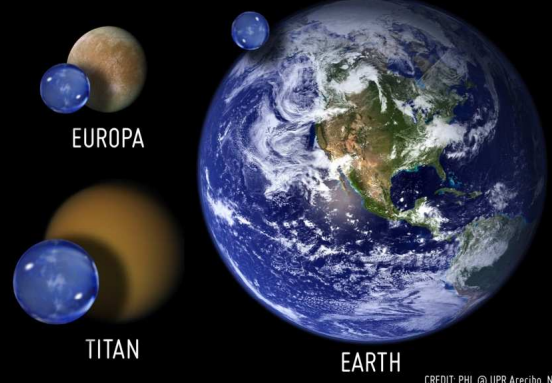
Key elements highlighted: H, C, N, O, P, S, Ca, Fe, Cu, Zn, Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe, Cs, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr.

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# Condiciones para la existencia de vida



## Liquid Water in the Solar System



## Current Potentially Habitable Exoplanets

Ranked in Order of Similarity to Earth

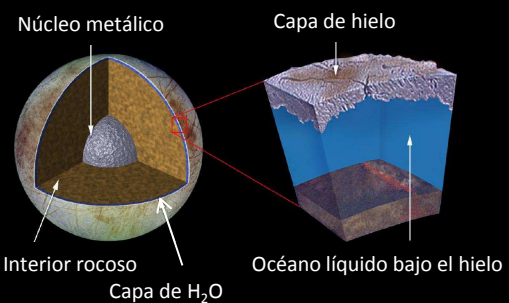
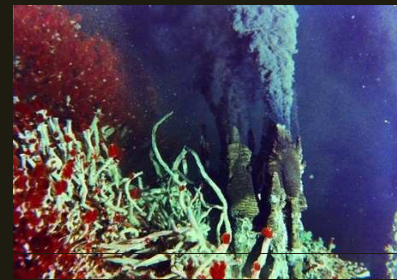
#1	#2	#3	#4	#5	#6
Kepler-62 e 0.83	Gliese 667C c 0.82	Gliese 581 g* 0.82	Tau Ceti e* 0.77	Gliese 667C f 0.76	Kepler-22 b 0.75
Gliese 163 c 0.74	HD 40307 g* 0.72	Kepler-61 b 0.72	Kepler-62 f 0.67	Gliese 667C e 0.60	Gliese 581 d 0.53

Earth 1.00  
Mars 0.64  
Neptune 0.28  
Jupiter 0.16

\*planet candidates

Number below the names is the Earth Similarity Index (ESI)

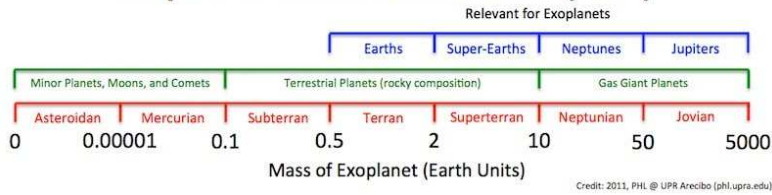
CREDIT: PHL @ UPR Arecibo (phl.upr.edu) June 26, 2013



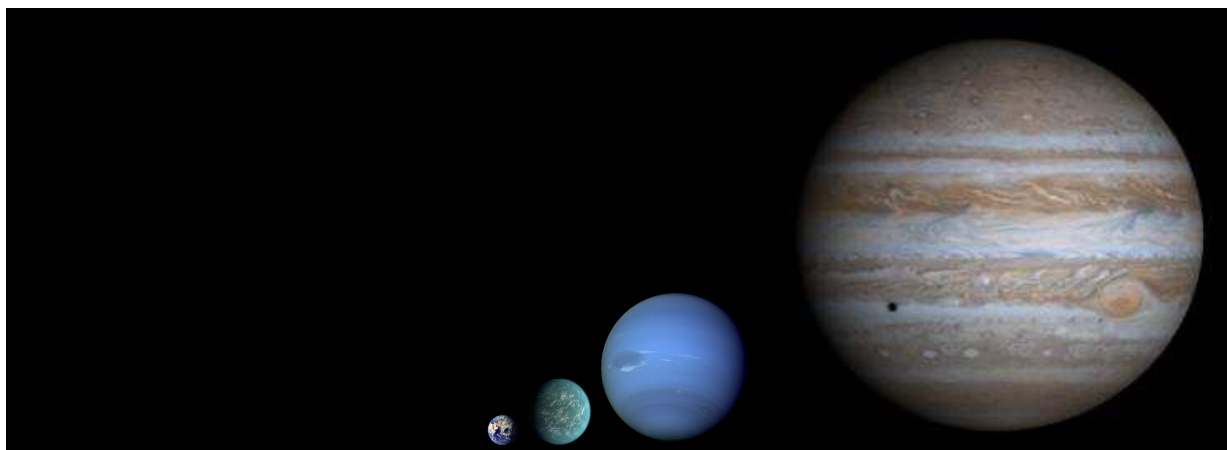
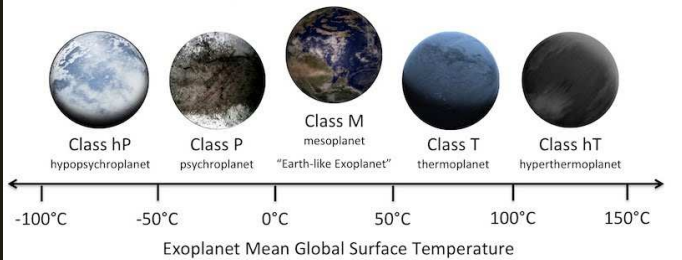
# Clasificación de exoplanetas

Clase	Masa ( $M_{\text{Tierra}}$ )	Masa ( $M_{\text{Júpiter}}$ )	Ejemplo
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	

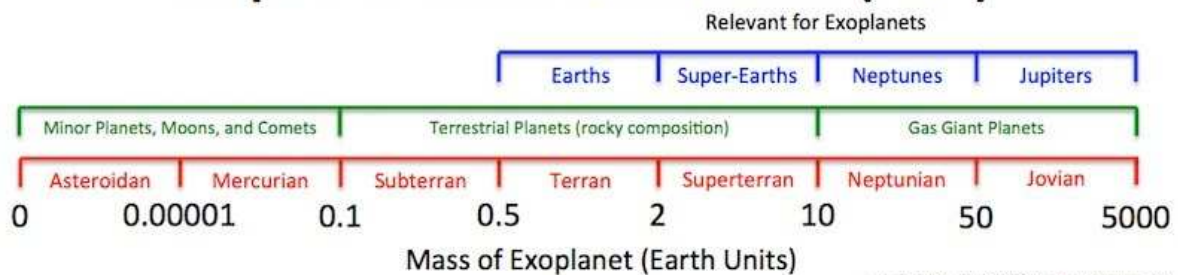
## Exoplanets Mass Classification (EMC)



## Thermal Planetary Habitability Classification (T-PHC)

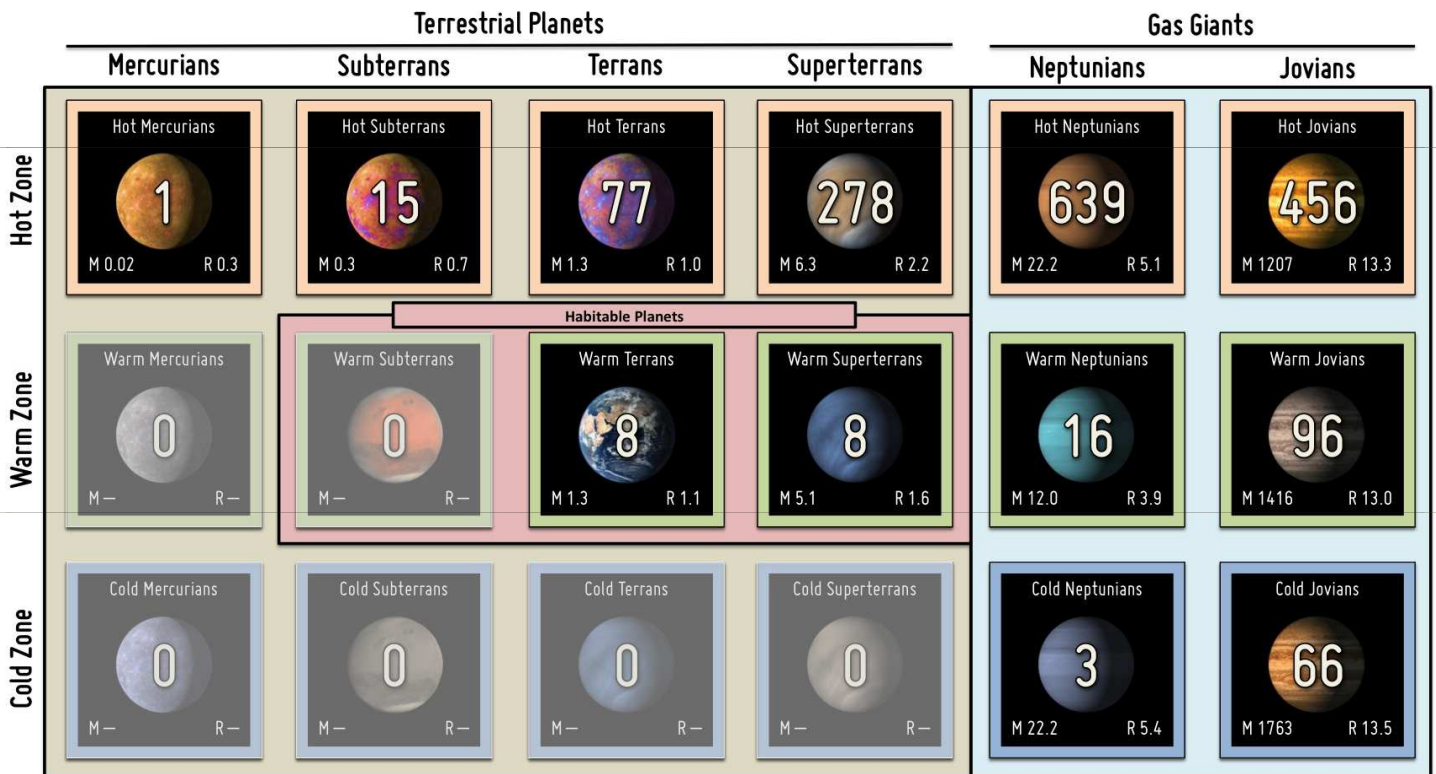


## Exoplanets Mass Classification (EMC)



# Distribución de los exoplanetas

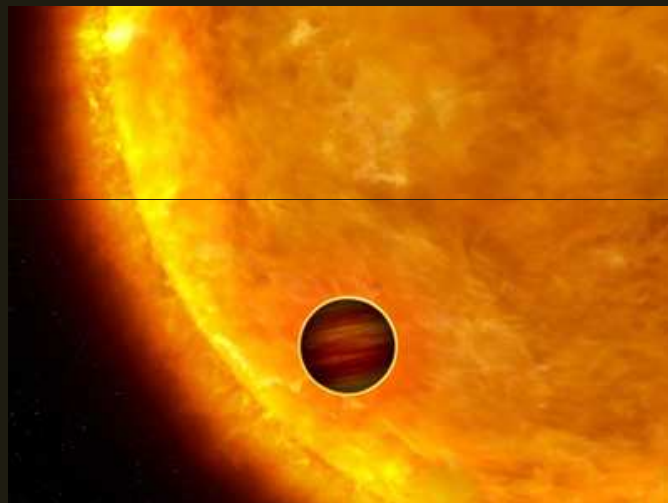
## The Habitable Exoplanets Catalog: Periodic Table of Exoplanets



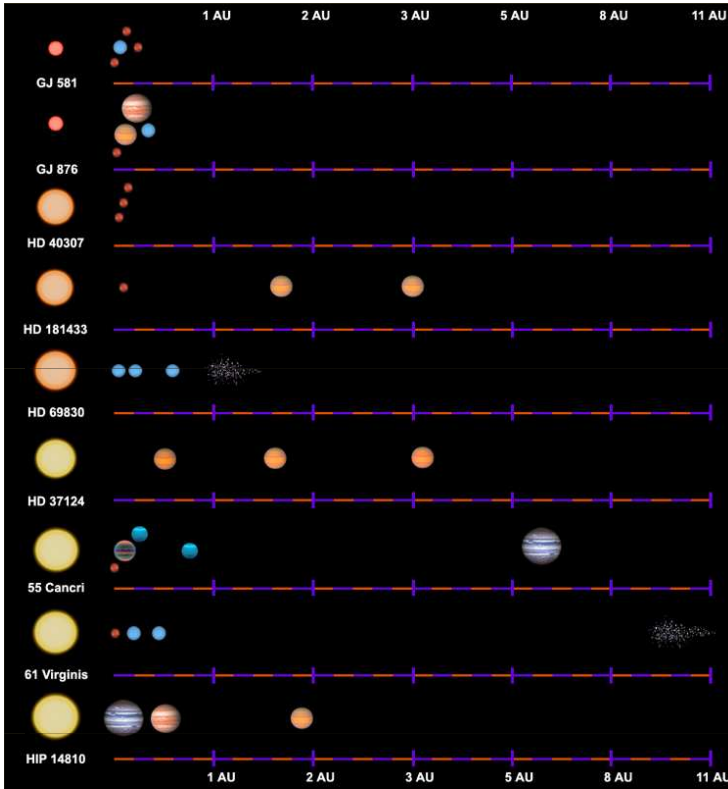
(CC) Planetary Habitability Laboratory, (phl.upr.edu) Dec 2011

## Características de los exoplanetas

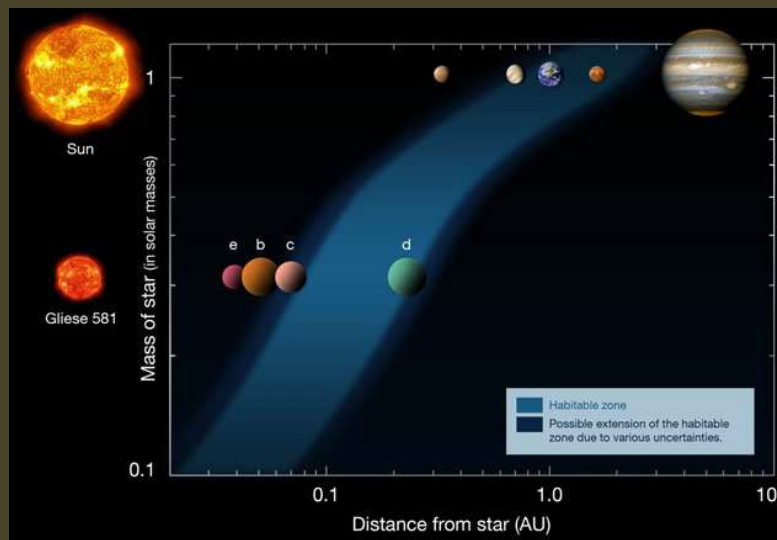
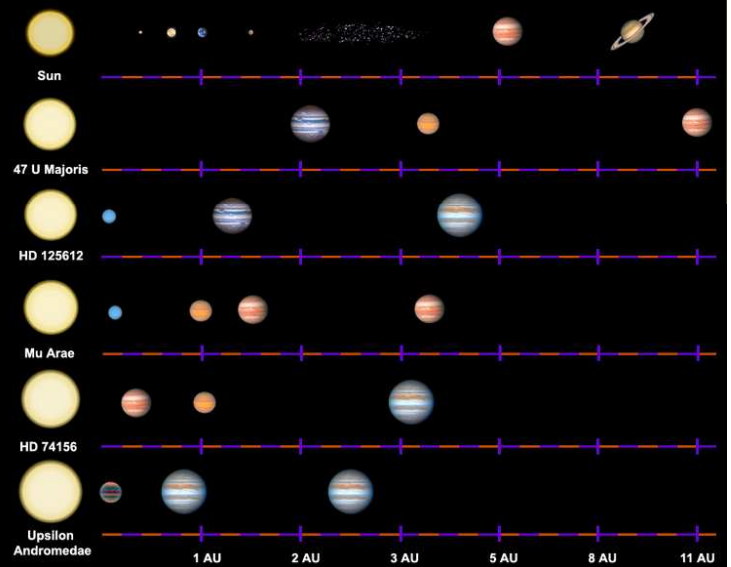
1. Grandes masas ( $5 M_{\oplus}$  --  $25 M_{jup}$ ) ← sesgo observacional
  2. Grandes elipticidades
  3. "Júpiteres calientes"
- ¿Sería el Sistema Solar "raro"?





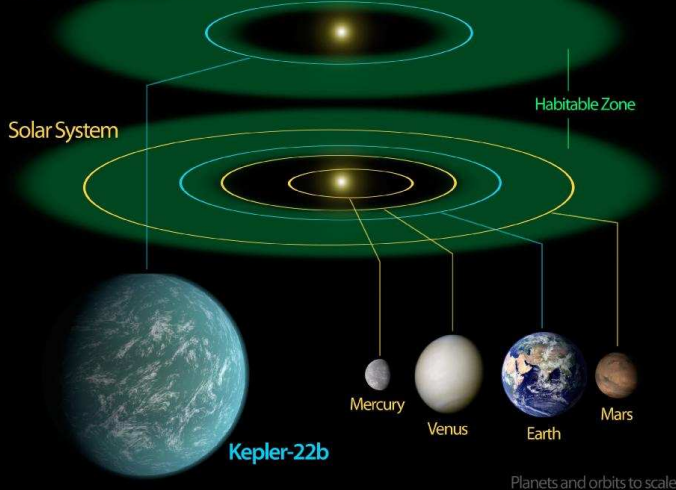


## Sistema múltiples

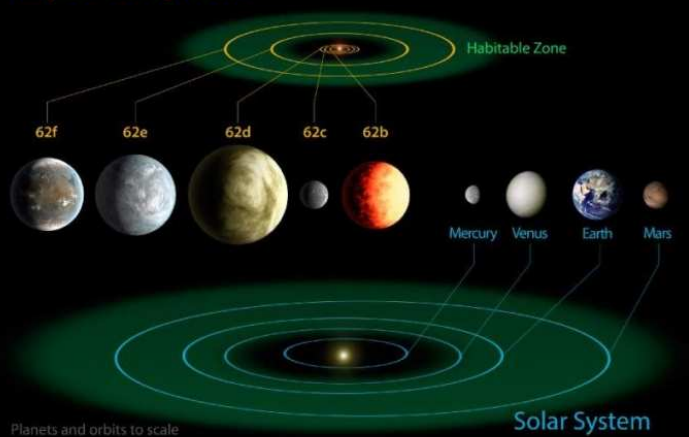


## Sistema múltiples

### Kepler-22 System



### Kepler-62 System



## Proyecto de Investigación Científica

1. Identificación de un problema o cuestión científica (hipótesis inicial)
2. Construcción de un experimento (metodología)
3. Realización del experimento (obtención de datos)
4. Análisis de los datos (ajustes y correcciones)
5. Obtención y análisis (estadístico) de los resultados
6. Conclusiones y discusión

## Mini-proyecto: “caracterización de los exoplanetas”

<http://exoplanet.eu/>  
<http://phl.upr.edu/>

1. Hacer una grafica (correlación) de distancia a la estrella (semieje mayor)  $\times$  masa para los planetas extrasolares que poseen esa información (en escala logarítmica)
2. Identificar donde se quedarían los planetas del Sistema Solar en esa grafica
3. Buscar entre los sistemas múltiples el que mas se asemeja al Sistema Solar
4. Buscar el planeta mas parecido (en términos de masa) al planeta Tierra
5. Hacer otra grafica que les parezca interesante

# Sistema Solar

	Planeta	símb.	descubr.	descubridor	núm. de satélites	magnitud*	color <sup>s</sup>	albedo <sup>#</sup>	atmósfera
	Sol	☉	-	-	9	-26.8	amarillo	-	-
<b>Terrestres</b>	Mercurio	☿	-	-	0	-1.9	naranja	0.11	mínima
	Venus	♀	-	-	0	-4.4	blanco	0.65	96% <u>CO<sub>2</sub></u> 4% <u>N<sub>2</sub></u>
	Tierra	♁	-	-	1	-	azul	0.37	78% <u>N<sub>2</sub></u> 21% <u>O<sub>2</sub></u>
	Marte	♂	-	-	2	-2.0	rojo	0.15	95% <u>CO<sub>2</sub></u> 3% <u>N<sub>2</sub></u>
<b>Jovianos</b>	Júpiter	♃	-	-	66	-2.7	blanco	0.52	86% <u>H<sub>2</sub></u> 14% <u>He</u>
	Saturno	♄	-	-	61	0.7	amarillo	0.47	93% <u>H<sub>2</sub></u> 5% <u>He</u>
	Urano	♅	1781	William Herschel	27	5.5	azul	0.51	83% <u>H<sub>2</sub></u> 15% <u>He</u>
	Neptuno	♆	1846	J.G. Galle e H.L. d'Arrest	13	7.8	azul	0.41	80% <u>H<sub>2</sub></u> 19% <u>He</u>
<b>Enanos</b>	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 <sup>3</sup>	en km/s	en °C
	Sol	1 392 000	109	25-36	-	332 946	1.41	617.7	5 505
<b>Terrestres</b>	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
<b>Jovianos</b>	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
<b>Enanos</b>	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
	<b>Sol</b>	-	-	-	-	-	-	-
<b>Terrestres</b>	<b>Mercurio</b>	57.91	0.39	87.97	0.241	7.005	0.206	47.87
	<b>Venus</b>	108.21	0.72	224.70	0.615	3.395	0.007	35.02
	<b>Tierra</b>	149.60	1.00	365.25	1.000	0.000	0.017	29.79
	<b>Marte</b>	227.94	1.52	686.98	1.881	1.851	0.093	24.13
<b>Jovianos</b>	<b>Júpiter</b>	778.41	5.20	4 332.7	11.863	1.305	0.048	13.06
	<b>Saturno</b>	1 426.73	9.54	10 759.5	29.447	2.484	0.054	9.66
	<b>Urano</b>	2 870.97	19.19	30 685	84.017	0.770	0.047	6.80
	<b>Neptuno</b>	4 498.25	30.07	60 190	164.79	1.769	0.009	5.44
<b>Enanos</b>	<b>Ceres</b>	413.7	2.766	1 679	4.599	10.59	0.080	17.88
	<b>Plutón</b>	5 906.38	39.48	...	247.92	17.14	0.249	4.75
	<b>Haumea</b>	6 484.0	43.34	...	285.4	28.19	0.189	4.48
	<b>Makemake</b>	6 850.0	45.79	...	309.9	28.96	0.159	4.4
	<b>Eris</b>	10 210.0	67.67	...	557	44.19	0.442	3.44