

# Cielo, and our connection to the cosmos

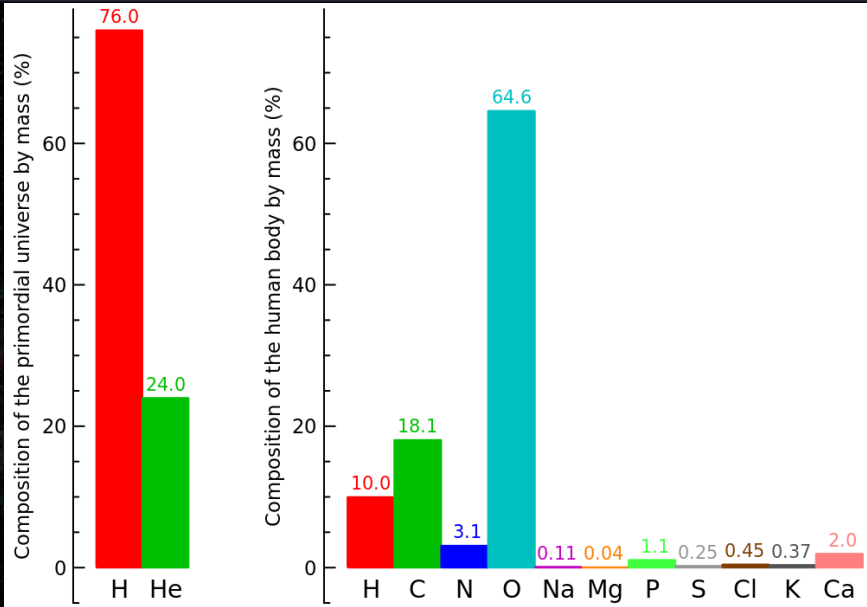


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# Outline

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  - Human beings and the universe
  - ESO observatories in Chile
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  - Supernovae
- 4 The formation of stars and planets
  - The formation of stars
  - The formation of planets

# Composition of the early universe and human beings



# ESO La Silla observatory

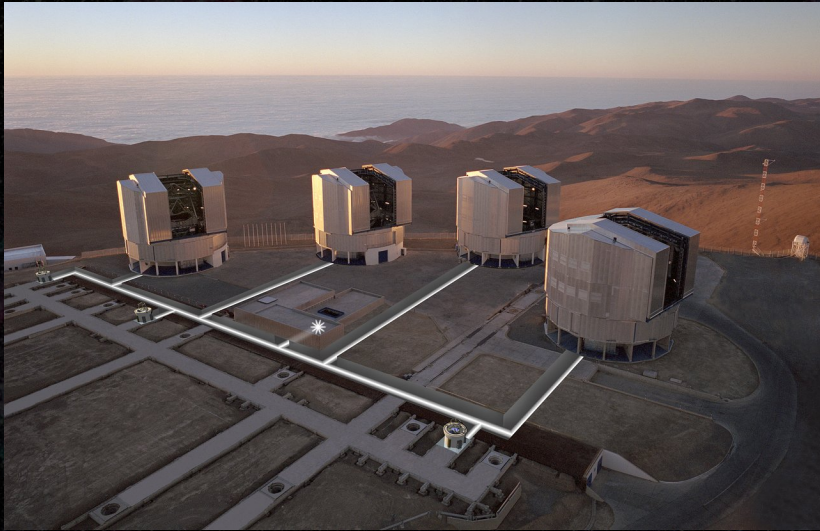




# ESO VLT Paranal



# VLT interferometry

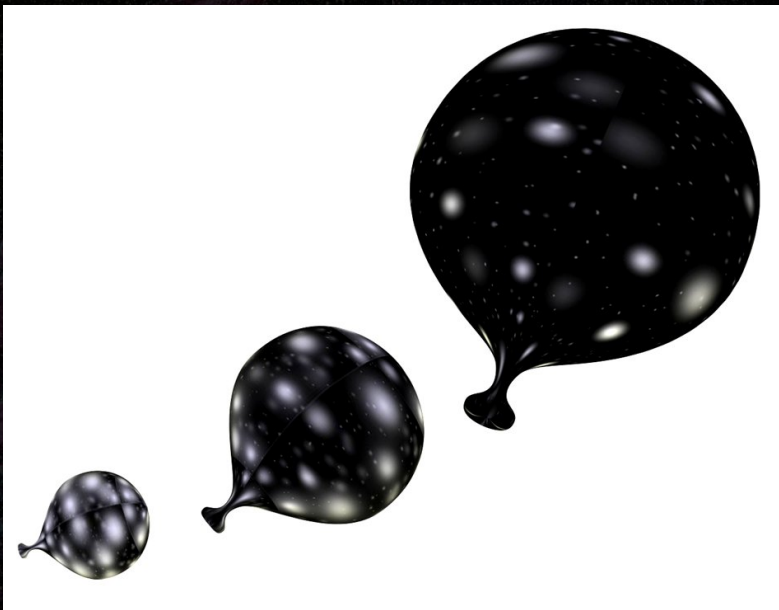


# The expanding universe ( $\sim 10$ k galaxies)

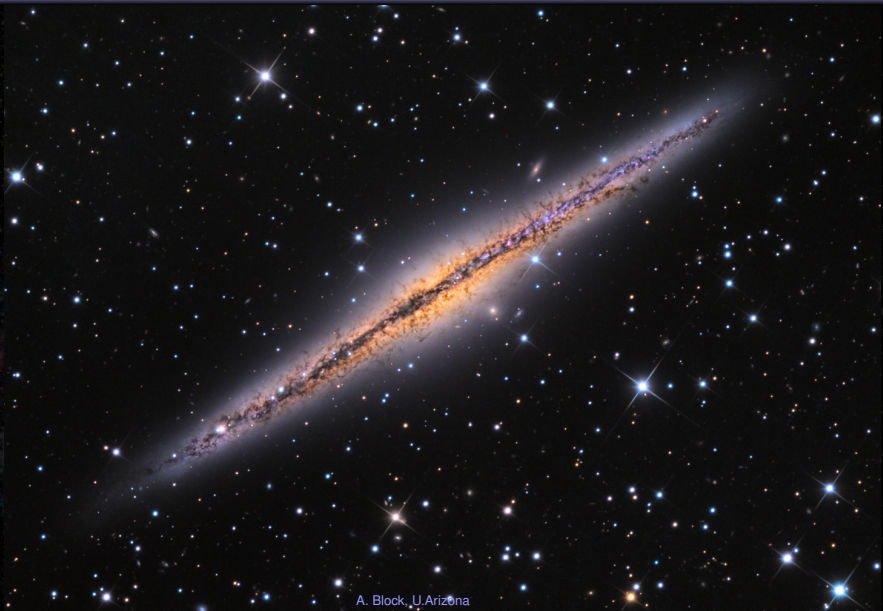


Hubble UltraDeepField: HST/NASA

# The expanding universe



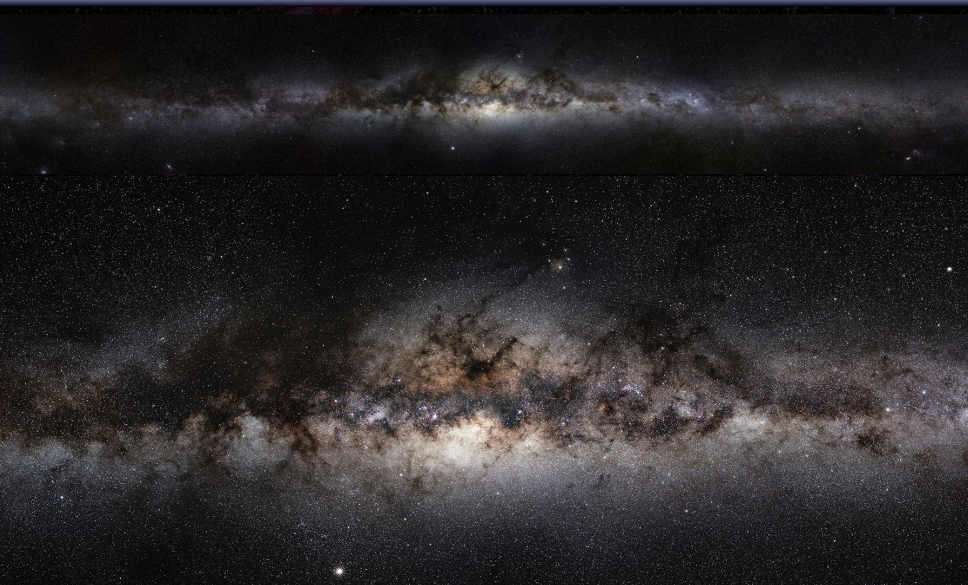
# The galaxy NGC 891



A. Block, U.Arizona



# The Milky Way

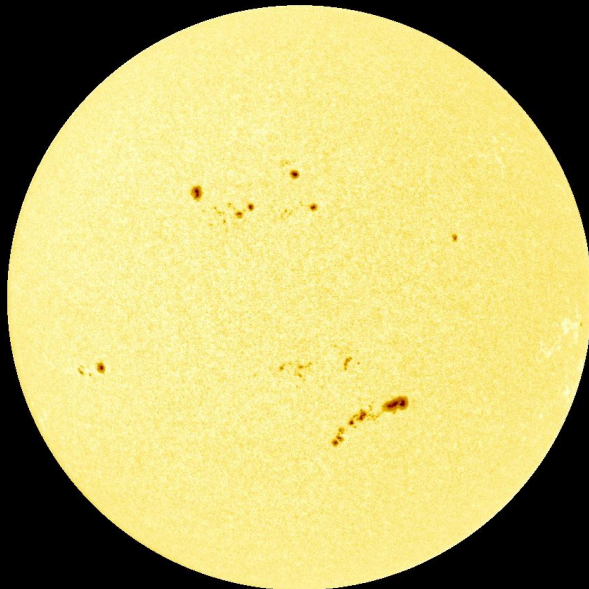




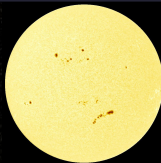
# The galaxy M 83



# The Sun

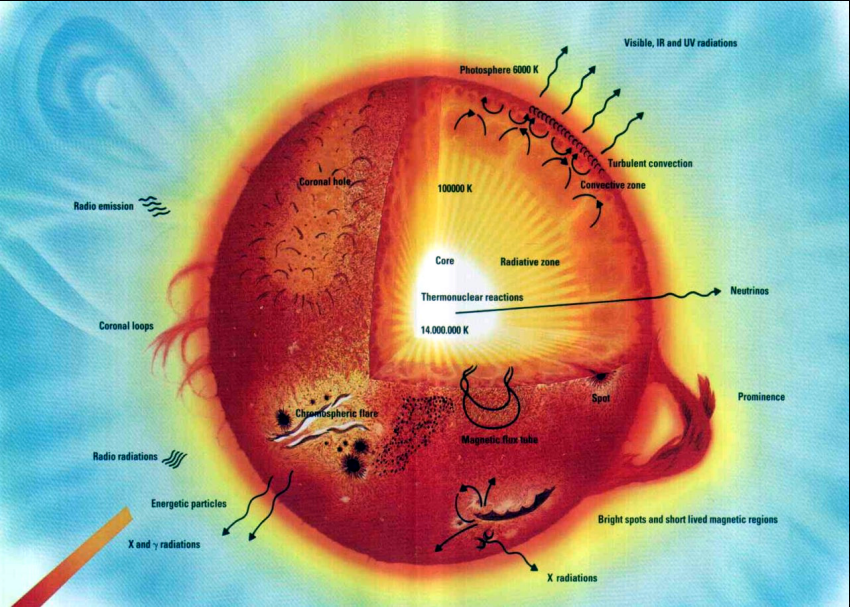


# The Sun



Quantity		Unit	Earth
Mass	$M_{\odot}$	$1.99 \times 10^{30}$ kg	$333\,000 M_{\oplus}$
Radius	$R_{\odot}$	696 000 km	$109 R_{\oplus}$
Density	$\bar{\rho}_{\odot}$	1.4 g/cm <sup>3</sup>	$0.26 \bar{\rho}_{\oplus}$
Luminosity	$L_{\odot}$	$3.85 \times 10^{26}$ W	$\sim 3 \times 10^9 "L_{\oplus}"$
Temperature:			
– surface:	$T_{\text{surf},\odot}$	5500°C	15°C
– centre:	$T_{\text{c},\odot}$	$\sim 16 \times 10^6$ °C	$\sim 7000$ °C

# Structure of the Sun



# Hydrogen fusion

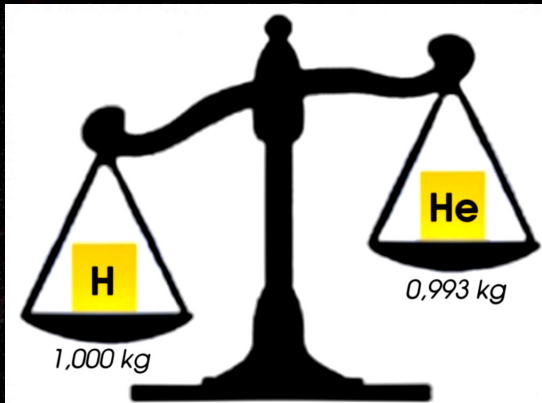
**4 Protons**



**Helium**



**Light!**





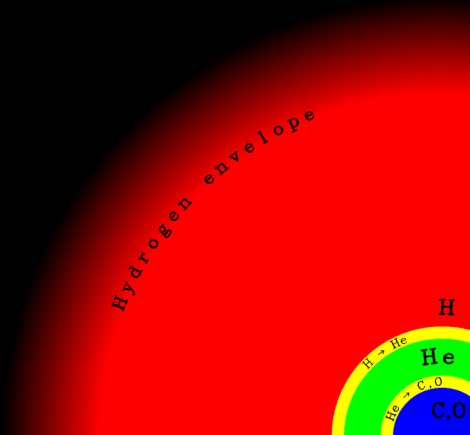
# Main-sequence stars

Properties of single stars with solar metallicity halfway the main sequence ( $X_c = 0.35$ ):

M ( $M_\odot$ )	age (Myr)	R ( $R_\odot$ )	L ( $L_\odot$ )	$T_s$ (K)	$T_c$ (MK)	Number density (w.r.t. $1 M_\odot$ )
0.5	52 600	0.50	0.05	3860	9.8	7.07
0.8	11 600	0.79	0.38	5100	13.4	2.34
1.0	4900	1.01	1.05	5810	15.9	1.00
1.5	1660	1.95	6.75	6660	20.9	0.131
2.0	582	2.23	20.4	8230	22.5	0.0232
2.5	405	2.80	57.8	9530	24.1	$9.59 \times 10^{-3}$
3.0	246	3.09	120	10 800	25.2	$3.80 \times 10^{-3}$
5.0	70.6	4.19	895	15 400	28.6	$3.27 \times 10^{-4}$
10.0	12.7	5.74	8590	23 100	32.8	$1.16 \times 10^{-5}$
20.0	5.18	8.78	67 900	31 300	37.0	$9.3 \times 10^{-6}$
50.0	2.41	15.9	527 000	39 000	41.4	$5 \times 10^{-7}$



# Evolution of a one-solar-mass ( $1 M_{\odot}$ ) star



**Phase:**

Hydrogen fusion

Helium fusion

**Temperature:**

$T \gtrsim 7$  million $^{\circ}$ C,

$T \gtrsim 200$  million $^{\circ}$ C,

**Time scale:**

$\tau \approx 7 + 4$  billion yr

$\tau \approx 200 + 25$  billion yr

**Reactions:**

$4H \rightarrow He$

$3He \rightarrow C,$

$C + He \rightarrow O$

# Planetary nebulae

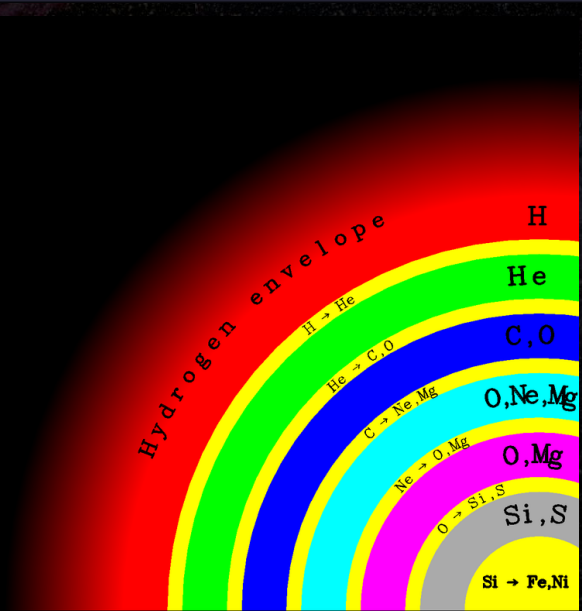


Cat's eye nebula (HST/NASA)



Butterfly nebula (HST/NASA)

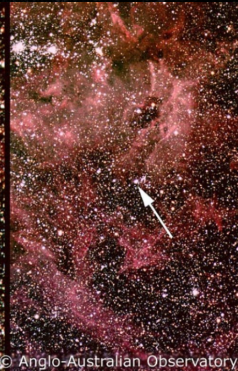
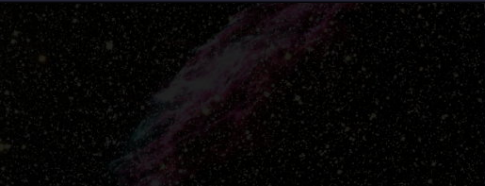
# Onion structure for massive stars



# Nuclear-fusion stages of a $10 M_{\odot}$ star

Stage	Net reactions	T (K)	$\tau$
Hydrogen fusion	$\text{H} \rightarrow \text{He}$	$> 7 \times 10^6$	10 Myr
Helium fusion	$\text{He} \rightarrow \text{C, O}$	$> 2 \times 10^8$	1 Myr
Carbon fusion	$\text{C} \rightarrow \text{Ne, Mg}$	$> 8 \times 10^8$	1 kyr
Neon fusion	$\text{Ne} \rightarrow \text{O, Mg}$	$> 1.5 \times 10^9$	1 month
Oxygen fusion	$\text{O} \rightarrow \text{Si, S}$	$> 2 \times 10^9$	2 years
Silicon fusion	$\text{Si} \rightarrow \text{Fe, Ni}$	$> 3.3 \times 10^9$	3 days

# Supernova



© Anglo-Australian Observatory

VLT/ESO

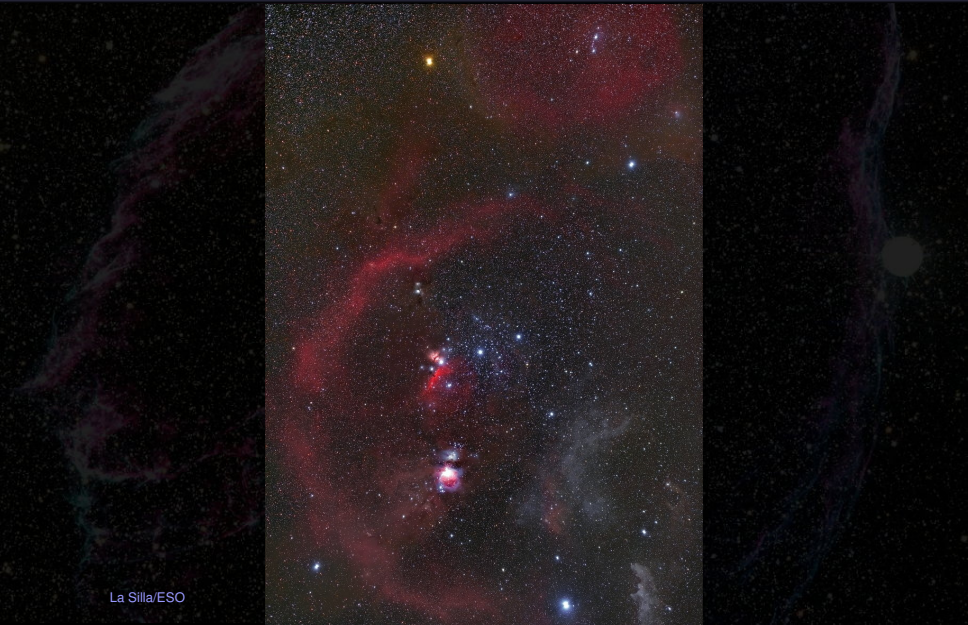


# The Cygnus loop ( $\sim 5000\text{--}8000$ yr)





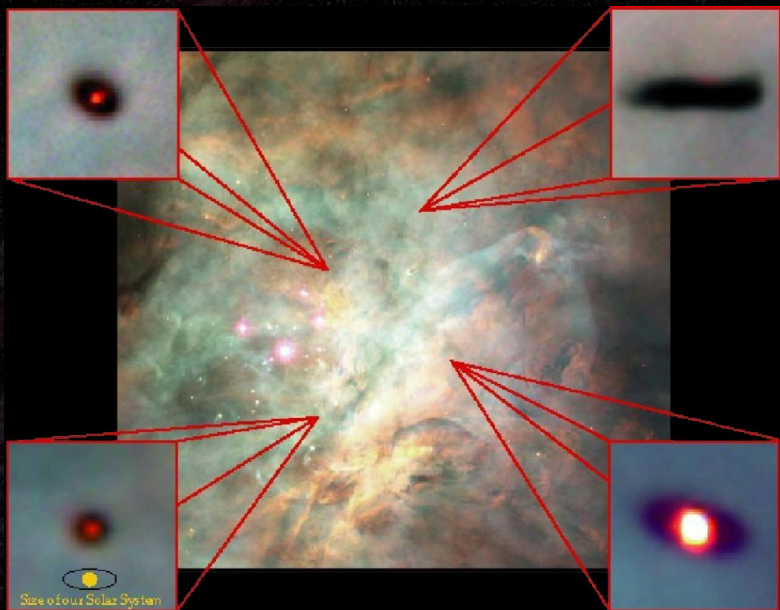
# The constellation of Orion



# The Orion nebula



# Star formation in the Orion nebula ( $\sim 10\text{--}300$ kyr)

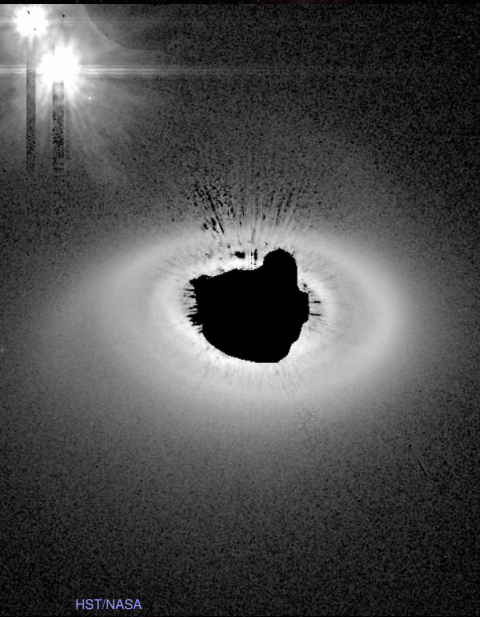


# The Pleiades ( $\sim 100$ Myr)

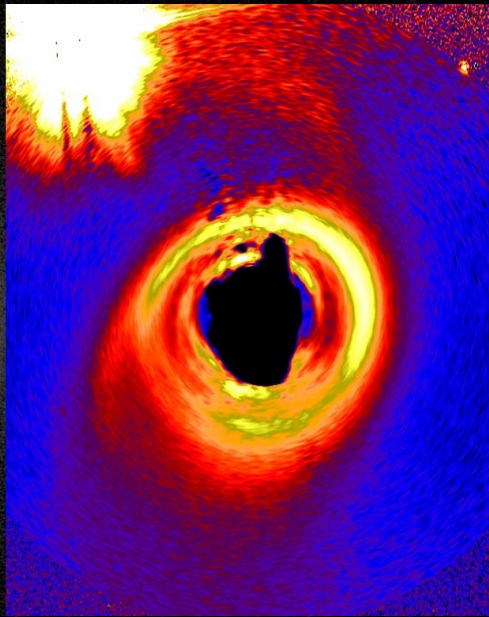




# The formation of a planetary system



HST/NASA



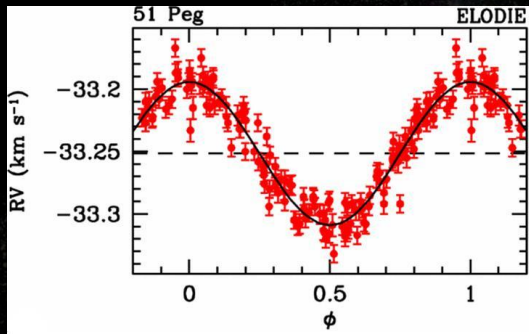
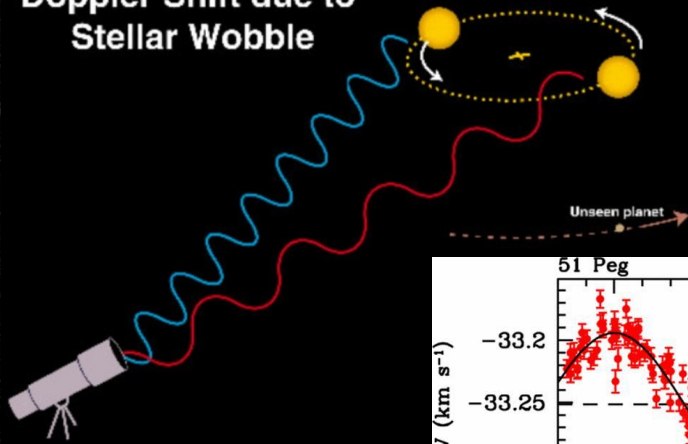
# The formation of a planetary system



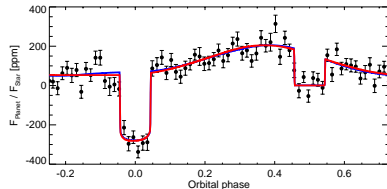
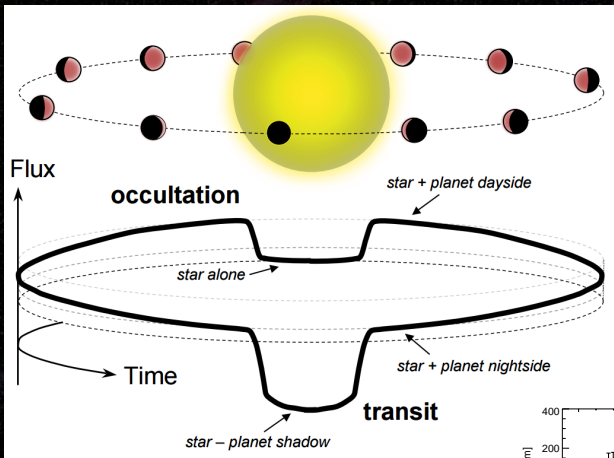


# Exoplanet discovery due to Doppler shifts

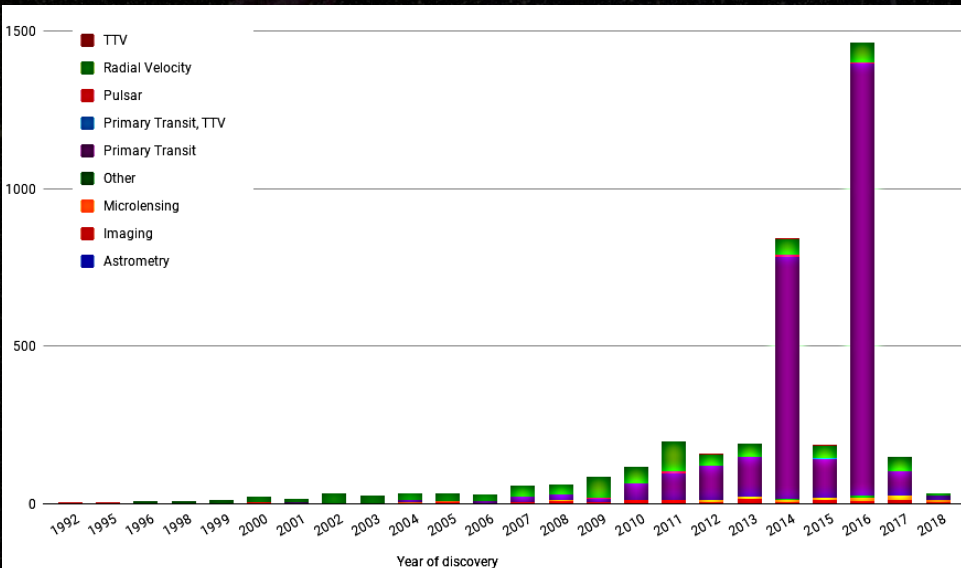
## Doppler Shift due to Stellar Wobble



# Exoplanet discovery due to transits



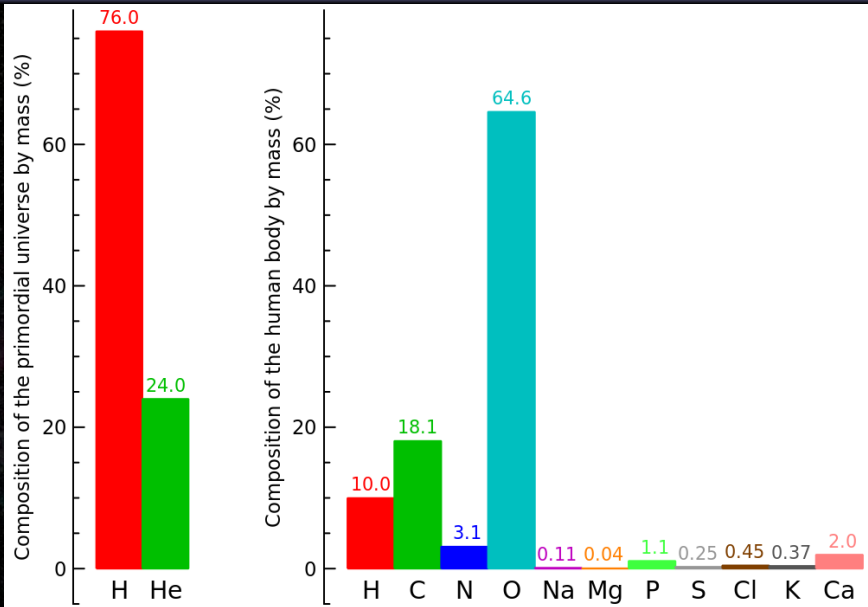
# Exoplanet discoveries



# Planets in the solar system



# Composition of the early universe and human beings





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- Actuele, eenvoudig en lastiger waar te nemen hemelverschijnselen
- Zichtbaarheid van Zon, Maan, planeten, meteoren, kometen, deepsky, ISS, ...
- Astrokalenders, hemelkaarten, maanfasen, hemel vannacht, waarneemweer, tabellen
- Apps (Android/Apple), Facebook, Twitter
- ~ **9000 pagina's**; **Geen reclame**
- **1–2 miljoen** bezoekers per jaar

**hemel.waarnemen.com**  
**astrokalender**

*Tijdstippen zijn in Midden-Europese zomertijd (MEZT)*

**maandag 19 augustus**

 **03.26: De Maan** is in het punt van zijn baan dat het dichtst bij de Aarde ligt: het **perigeum**. De afstand tussen de Aarde en de Maan bedraagt 362264 km. De **schijnbare diameter** van de Maan is groter dan gemiddeld (32'59,1"), door de kleinere afstand. De Maan is op dit moment **wassend**, voor 94% verlicht en hij is vrijwel de gehele nacht zichtbaar; 's avonds in het (zuid)oosten en tegen de ochtend in het westen of

This lecture on <http://hemel.waarnemen.com/lectures>

# Star gazing in Nijmegen



M. van der Sluys

Last Friday of the month, Sep.–Nov., Jan.–Mar.  
**Next: November 30**

<https://www.ru.nl/astrophysics/outreach-public/>  
<http://hemel.waarnemen.com/lectures>