AST 221 - Stars and Planets

Fall 2017 – Marten van Kerkwijk

www.astro.utoronto.ca/~mhvk/AST221/

What is a star?

Star - Wikipedia - Mozilla Firefox

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Wiki Loves Monuments: Photograph a monument, help Wikipedia and win!

Star

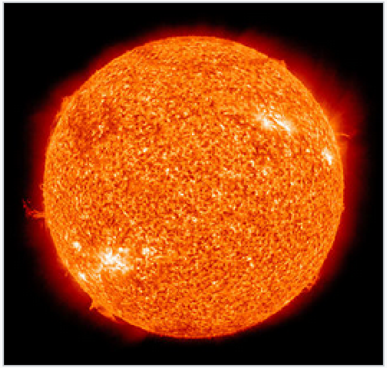
From Wikipedia, the free encyclopedia

This article is about the astronomical bodies. For other uses of "star" or "stars", see Star (disambiguation).

A **star** is a luminous sphere of plasma held together by its own gravity. The nearest star to Earth is the Sun. Many other stars are visible to the naked eye from Earth during the night, appearing as a multitude of fixed luminous points in the sky due to their immense distance from Earth. Historically, the most prominent stars were grouped into constellations and asterisms, the brightest of which gained proper names. Astronomers have assembled star catalogues that identify the known stars and provide standardized stellar designations. However, most of the stars in the Universe, including all stars outside our galaxy, the Milky Way, are invisible to the naked eye from Earth. Indeed, most are invisible from Earth even through the most powerful telescopes.

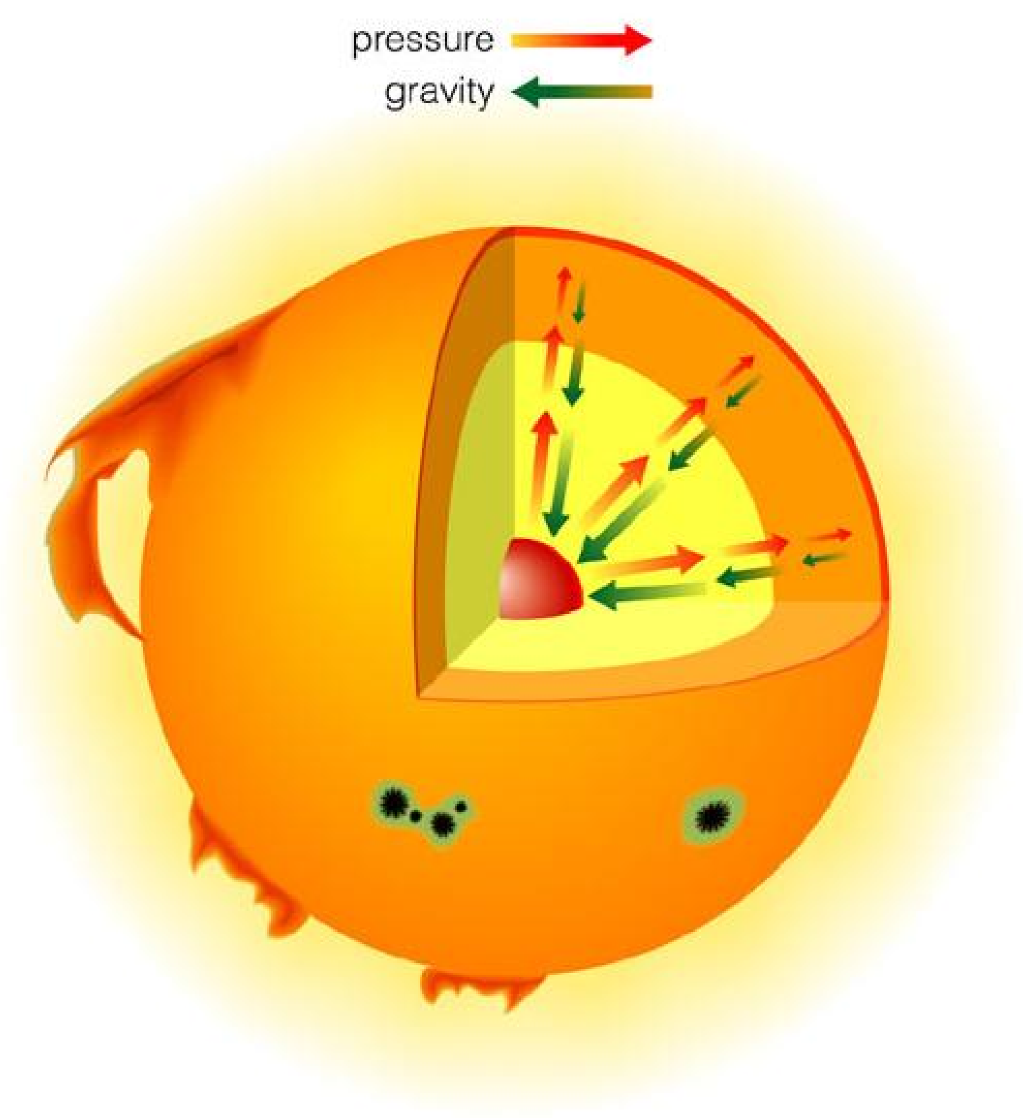
A star-forming region in the Large Magellanic Cloud.

For at least a portion of its life, a star shines due to thermonuclear fusion of hydrogen into helium in its core, releasing energy that traverses the star's interior and then radiates into outer space. Almost all naturally occurring elements heavier than helium are created by stellar nucleosynthesis during the star's lifetime, and for some stars by supernova nucleosynthesis when it explodes. Near the end of its life, a star can also contain degenerate matter. Astronomers can determine the mass, age, metallicity (chemical composition), and many other properties of a star by observing its motion through space, its luminosity, and spectrum respectively. The total mass of a star is the main



False-color imagery of the Sun, a G-type main-sequence

Star's life: Protracted battle with gravity



ALWAYS

To support weight:

⇒ need high pressure

MOSTLY

⇒ need high temperature

⇒ will loose energy

⇒ need energy source:
- Gravitational contraction
- Nuclear fusion

Ultimately,
Can something else than thermal pressure balance gravity?

What is a planet?

Planet

From Wikipedia, the free encyclopedia

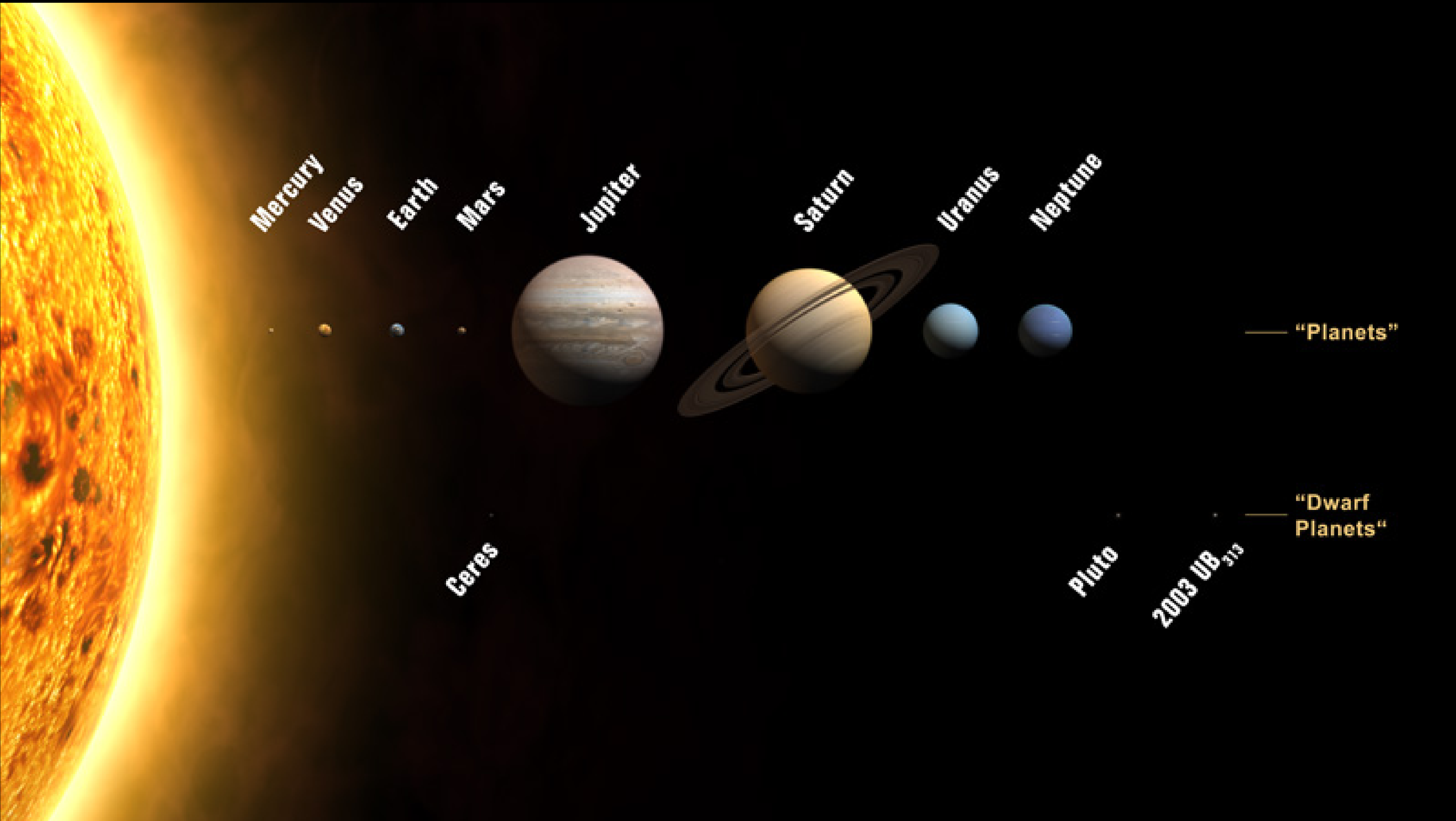
This article is about the astronomical object. For other uses, see Planet (disambiguation).

A **planet** is an astronomical body orbiting a star or stellar remnant that

- is massive enough to be rounded by its own gravity,
- is not massive enough to cause thermonuclear fusion, and
- has cleared its neighbouring region of planetesimals.[a][1][2]

The term *planet* is ancient, with ties to history, astrology, science, mythology, and religion. Several planets in the Solar System can be seen with the naked eye. These were regarded by many early cultures as divine, or as emissaries of deities. As scientific knowledge advanced, human perception of the planets changed, incorporating a number of disparate objects. In 2006, the International Astronomical Union (IAU) officially adopted a resolution defining planets within the Solar System. This definition is controversial because it excludes many objects of planetary mass based on where or what they orbit. Although eight of the planetary bodies discovered before 1950 remain "planets" under the modern definition, some celestial bodies, such as Ceres, Pallas, Juno and Vesta (each an object in the solar asteroid belt), and Pluto (the first trans-Neptunian object discovered), that were once considered planets by the scientific community, are no longer viewed as such.

What is a planet?



AST 221 - Stars and Planets

1) Introduction to astronomy
   concepts & phenomena

2) Solidify 1st year physics & math
   application & understanding

3) Problem solving skills
   intuition & estimation

This is a quantitative course.

Applied physics!

laws of gravity, Kepler's laws
hydrodynamics, hydrostatic equilibrium
radiation, interaction of light and matter
nuclear physics, quantum physics
matter-matter interaction, equation of state
optics, duality of photons

AST 221 - Stars and Planets

www.astro.utoronto.ca/~mhvk/AST221/

Book: Introduction to Modern Astrophysics, 2nd edition, Carroll & Ostlie, Addison-Wesley

Lectures: MWF12, Cody Hall (AB 107)
(MW lectures and F tutorial, typically)

Lecturer: Marten van Kerkwijk
Office hours: MF, after class, or by appointment

TAs: Ryan Cloutier
Sasha Kostenko

Be there

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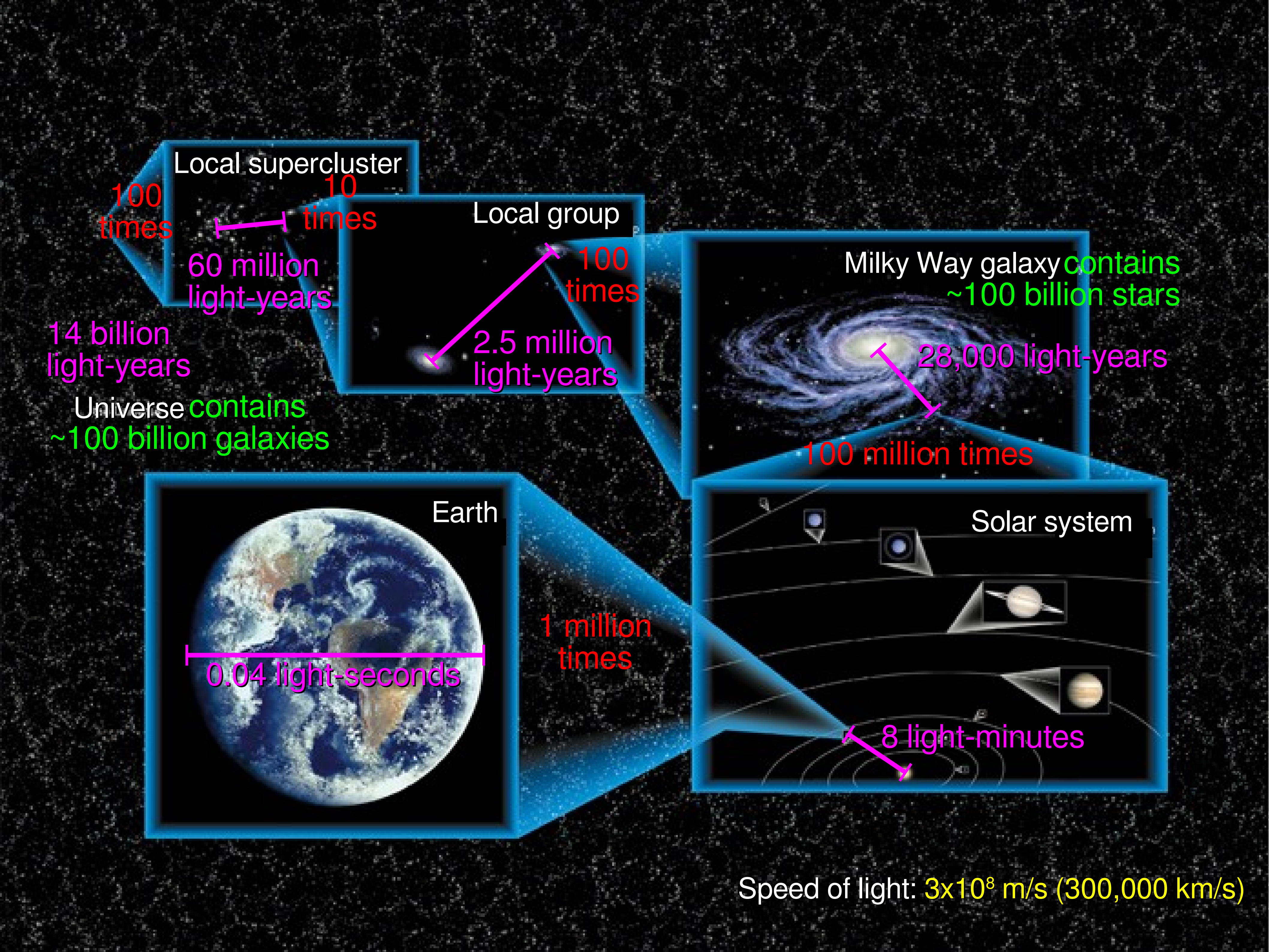
first one posted!

Problem sets (35%)	five sets, due every other Friday; discussion OK, but write up yourself!
Presentation (10%)	~10 minutes, half talk, half discussion; joint with another student; see web site
Midterm (20%)	In-class, 50-minute, open-book exam
Final (35%)	3-hour, calculator-only exam (will get list of constants)



Local supercluster
100 times
10 times
60 million light-years
Local group
100 times
2.5 million light-years
Milky Way galaxy contains ~100 billion stars
28,000 light-years
14 billion light-years
Universe contains ~100 billion galaxies
100 million times
Earth
0.04 light-seconds
1 million times
Solar system
8 light-minutes
Speed of light: 3x10^8 m/s (300,000 km/s)

Distance measures

AU: astronomical unit, mean Earth-Sun distance (1.496×10^{11} m)

Mercury 0.4 AU ; Mars 1.5 AU; Pluto 39.5 AU

pc: parsec, *defined* as the distance at which 1 AU is 1"

1 parsec = 1 AU * 180*60*60/π ~ 200,000 AU ~ 3×10^{16} m

closest star – α Cen system, Proxima Centauri: 1.3 pc (4.3 light-yr)
galactic center: ~8 kpc
nearest small galaxy – Large Magellanic Cloud: ~50 kpc
nearest normal galaxy – Andromeda: ~780 kpc
observable universe: ~4 Gpc (speed of light x age of universe of 13 Gyr)

arcsecond ("): a circle 360 deg(°); each deg (°) has 60 arcminutes ('), each arcminute (') has 60 arcseconds (")

1 radian = 180/π deg;
whole sky: 4π ster-radian = 4 π (180/π) (180/π) = $360^2/\pi \sim 4 \times 10^4$ square degrees
angular resolution of human eye ~ 1 arcminute
(diffraction limit of 6 mm pupil & matched cone size in retina)
⇒ precision of pre-telescope astronomy
best current day angular resolution ~ milli-arcsecond

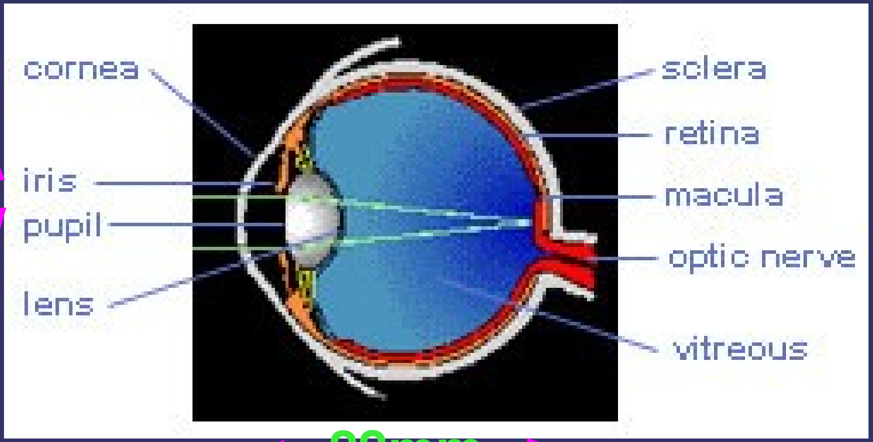
Brightness measure

magnitude: a logarithmic brightness scale
difference of 5 mag. = factor 100 in brightness
larger values are *dimmer*

apparent magnitude (m): brightness as observed
Sun $m_V = -26.74$, Sirius (brightest star on sky) $m_V = -1.46$
human eyes see down to $m_V = +6$ (telescope down to m=+30)

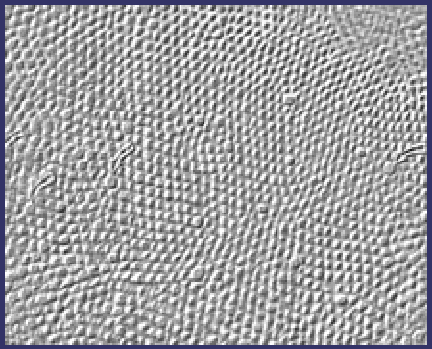
absolute magnitude (M): m at 10pc, intrinsic brightness
Sun $M_V = +4.83$, Sirius $M_V = +1.43$
$m-M = 5 \log_{10} (d/10pc)$

6mm



22mm

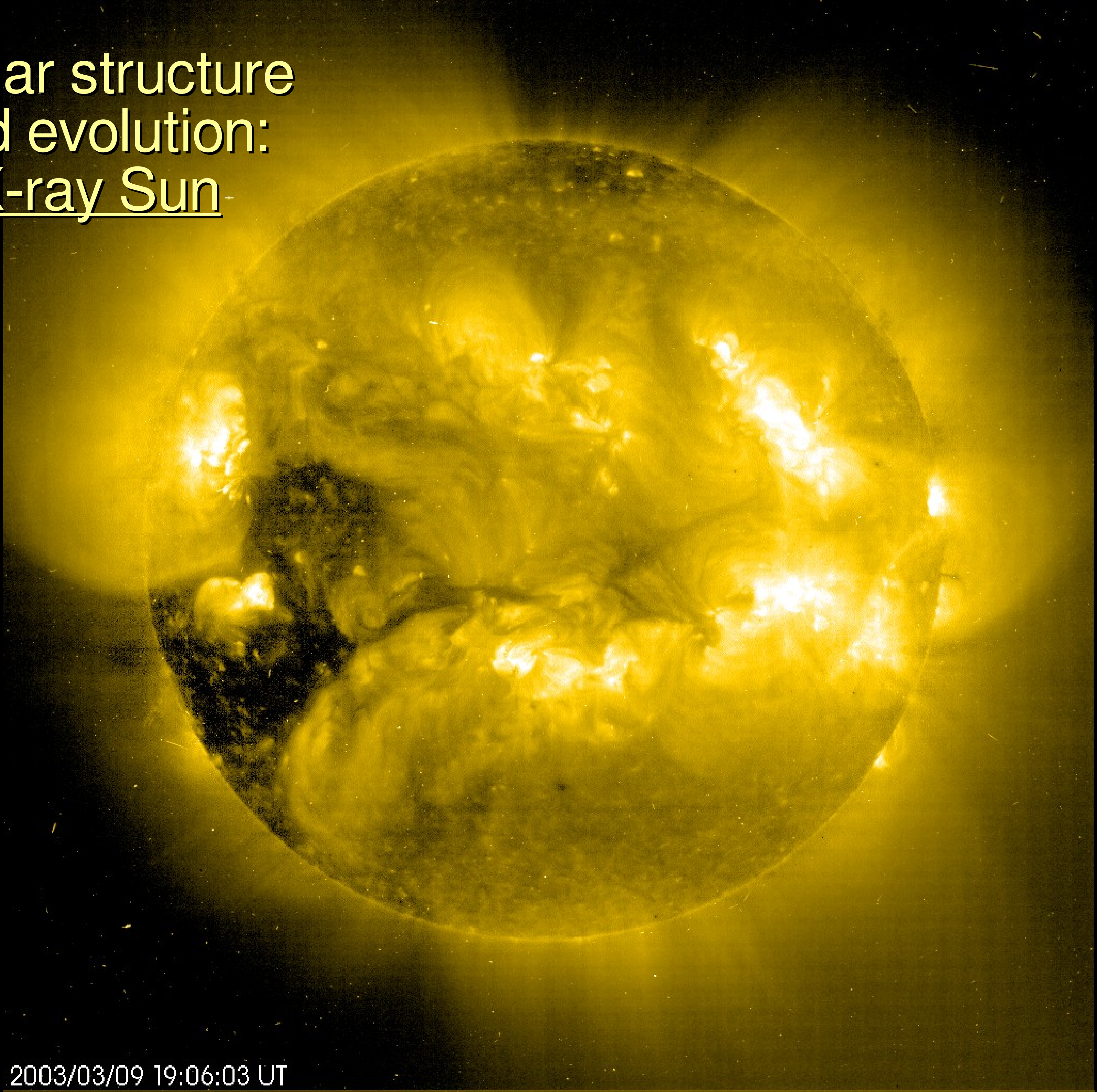
Cones on retina



5 μm = 0.005 mm

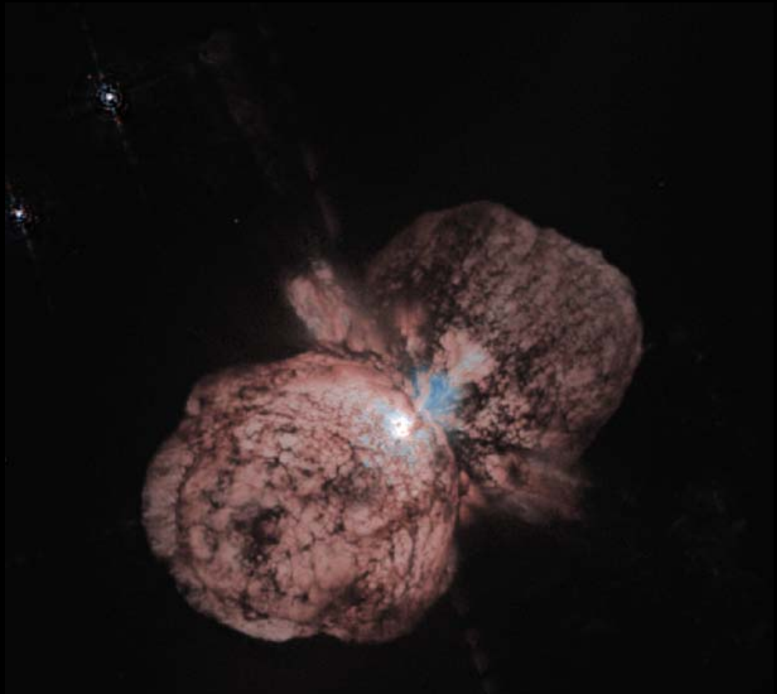
Stellar birth in M 17

Stellar structure and evolution: X-ray Sun

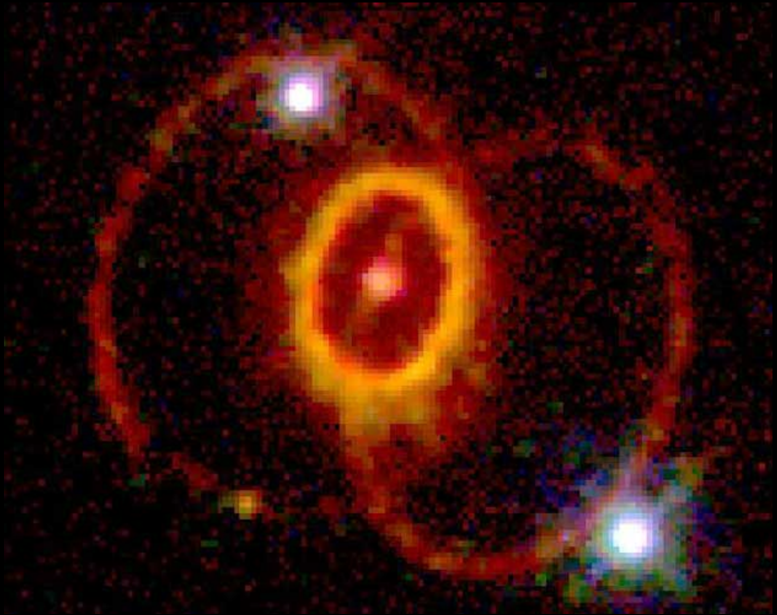


Stellar death

Lost envelope in the Helix nebula

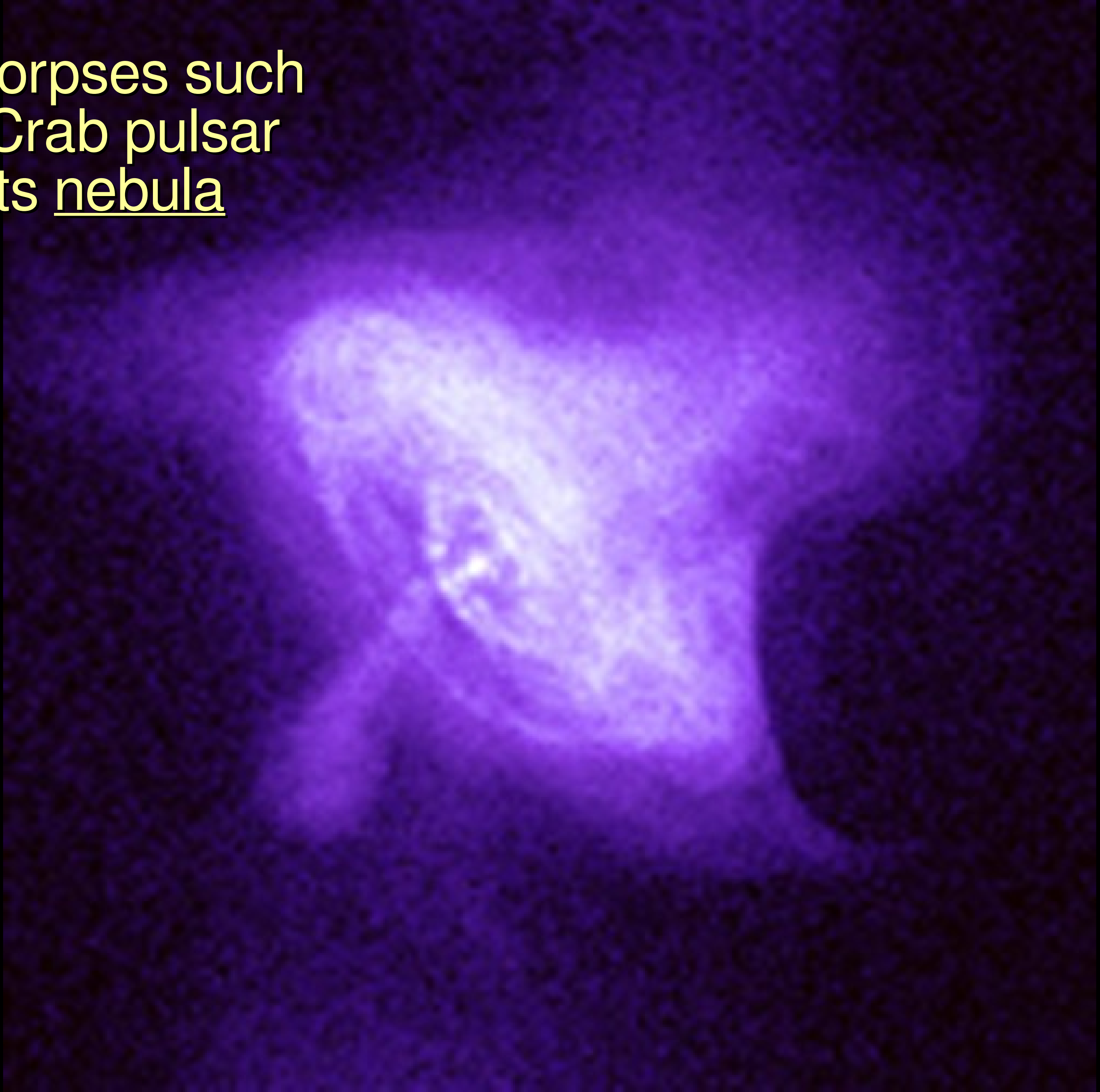


Death throws of Eta Carinae



Mysterious rings in SN 1987A

Stellar corpses such as the Crab pulsar and its nebula



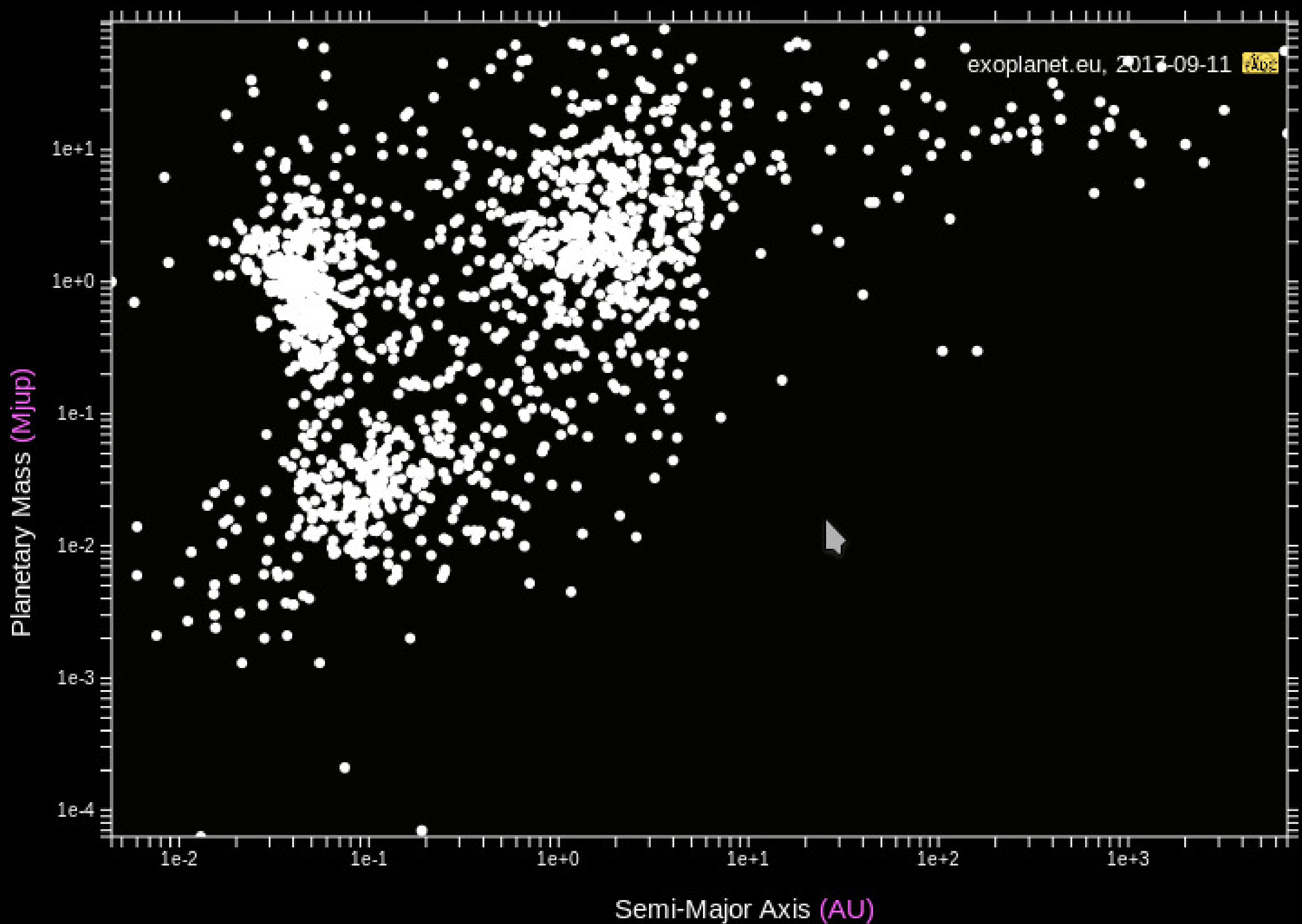
Planets and their formation

"Hamburger," a proto-planetary nebula

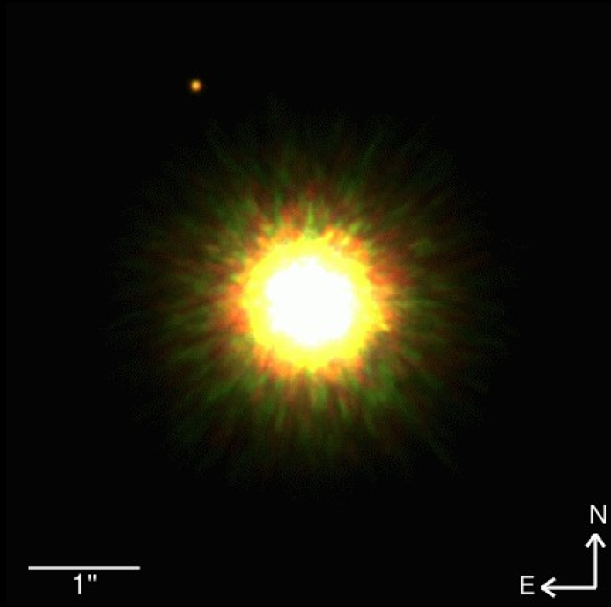
Earth from the Moon

Saturn and its rings

Extra-solar planets



2M J1207B, first directly imaged one



1RXS J1609B, first one around a solar-mass star

History of the Universe in 200 words or less

Quantum fluctuation. Inflation. Expansion. Strong nuclear interaction. Particle-antiparticle annihilation. Deuterium and helium production. Density perturbations. Recombination. Blackbody radiation. Local contraction. Cluster formation. Reionization? Violent relaxation. Virialization. Biased galaxy formation? Turbulent fragmentation. Contraction. Ionization. Compression. Opaque hydrogen. Massive star formation. Deuterium ignition. Hydrogen fusion. Hydrogen depletion. Core contraction. Envelope expansion. Helium fusion. Carbon, oxygen, and silicon fusion. Iron production. Implosion. Supernova explosion. Metals injection. Star formation. Supernova explosions. Star formation. Condensation. Planetesimal accretion. Planetary differentiation. Crust solidification. Volatile gas expulsion. Water condensation. Water dissociation. Ozone production. Ultraviolet absorption. Photosynthetic unicellular organisms. Oxidation. Mutation. Natural selection and evolution. Respiration. Cell differentiation. Sexual reproduction. Fossilization. Land exploration. Dinosaur extinction. Mammal expansion. Glaciation. Homo sapiens manifestation. Animal domestication. Food surplus production. Civilization! Innovation. Exploration. Religion. Warring nations. Empire creation and destruction. Exploration. Colonization. Taxation without representation. Revolution. Constitution. Election. Expansion. Industrialization. Rebellion. Emancipation Proclamation. Invention. Mass production. Urbanization. Immigration. World conflagration. League of Nations. Suffrage extension. Depression. World conflagration. Fission explosions. United Nations. Space exploration. Assassinations. Lunar excursions. Resignation. Computerization. World Trade Organization. Terrorism. Internet expansion. Reunification. Dissolution. World-Wide Web creation. Composition. Extrapolation?