Astronomy & Astrophysics
Lecture 1

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National Centre for Radio Astrophysics
Tata Institute of Fundamental Research
Pune

Lecture schedule

NCRA • TIFR

- Mondays, Tuesdays, Wednesdays and Thursdays from 12:30 – 13:30.

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- Website will be up soon.

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- *Theoretical astrophysics* deals with building numerical or analytical models to explain the observations.

Applied physics

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- There is no branch of physics which does not find application in some astrophysical problem or other.

Physics in extreme conditions

- Physical laws applied well beyond the limits for which they have been verified in laboratory.

  For example, the intergalactic space has $\rho \sim 10^{-29}$ gm cm^{-3} which is emptier than any vacuum created on earth. On the other extreme, objects like neutron stars have $\rho \sim 10^{15}$ gm cm^{-3} which is similar to nuclear matter.

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- Usually, we assume that the standard laws of physics apply to the Universe as a whole. “New physics” is rarely applied in astrophysics.
- We also assume that we are in no favoured position in the Universe.

Astronomical objects

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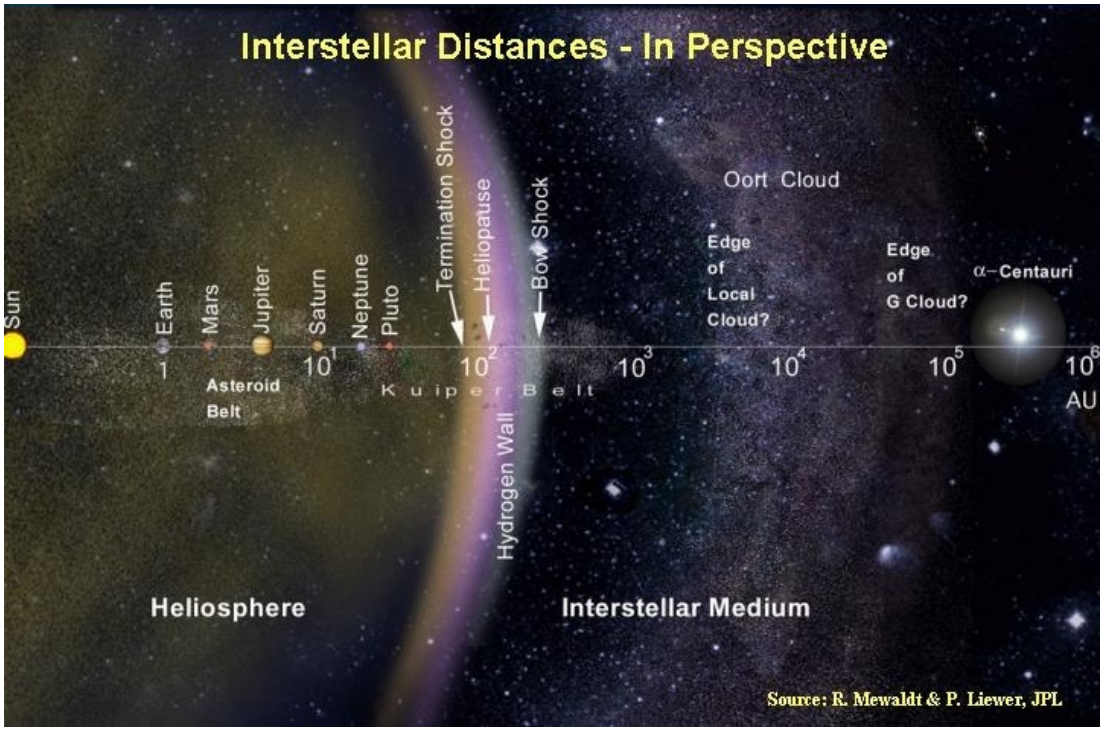
- Diffuse/extended objects, e.g., interplanetary medium / dust, accretion disc, interstellar medium, intergalactic medium.

The Sun

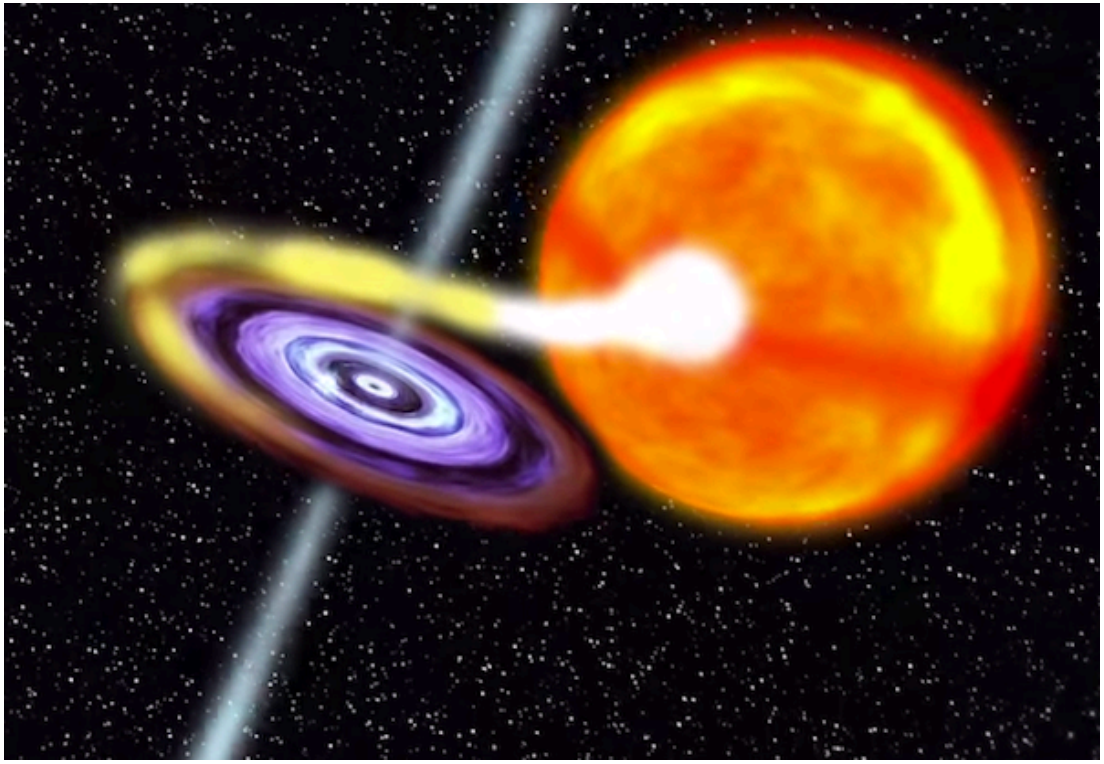
- Radius $\approx 7 \times 10^{10}$ cm.
- Average distance between the Earth and the Sun 1 AU $= 1.50 \times 10^{13}$ cm.
- Size of the solar system $\sim$ 50 AU (distance to Pluto).
- Mass $1 M_\odot = 2 \times 10^{33}$ g.

Stars



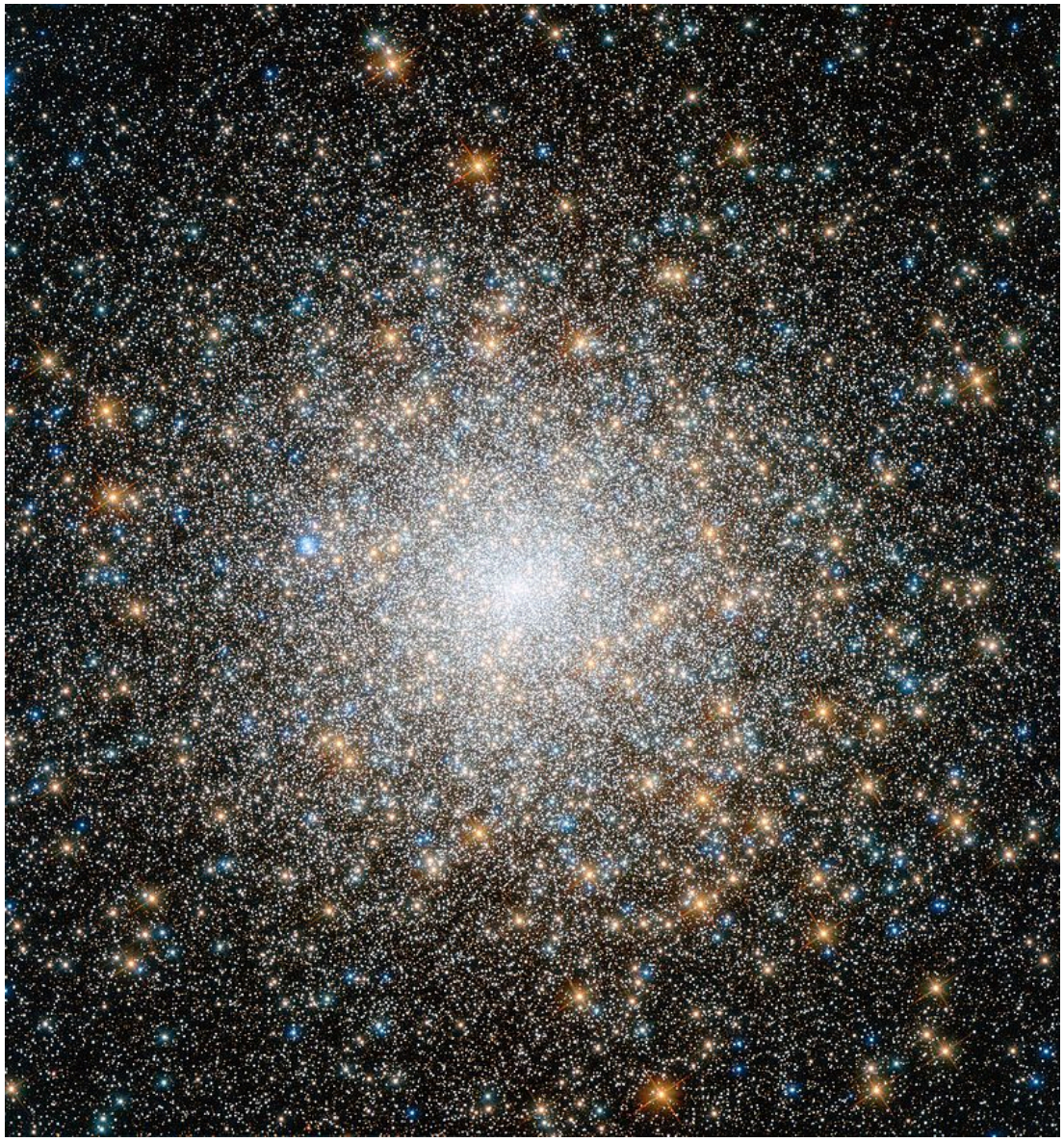
- Nearby stars at distance $\gtrsim 10^{18}$ cm.
- Define parsec = 3.09×10^{18} cm.
- Stars have a wide range of masses and properties

Binary stars



- About $\sim$ 30% of stars are in binary systems.
- Interaction between stars.
- Examples: Sirius, Cygnus X-1, . . .

Star clusters



- Large group of stars, few to millions stars in a cluster.
- Size $\sim$ few pc.
- Globular cluster: old stars, gravitationally bound.
- Open cluster: younger stars, loosely bound

Stellar remnants

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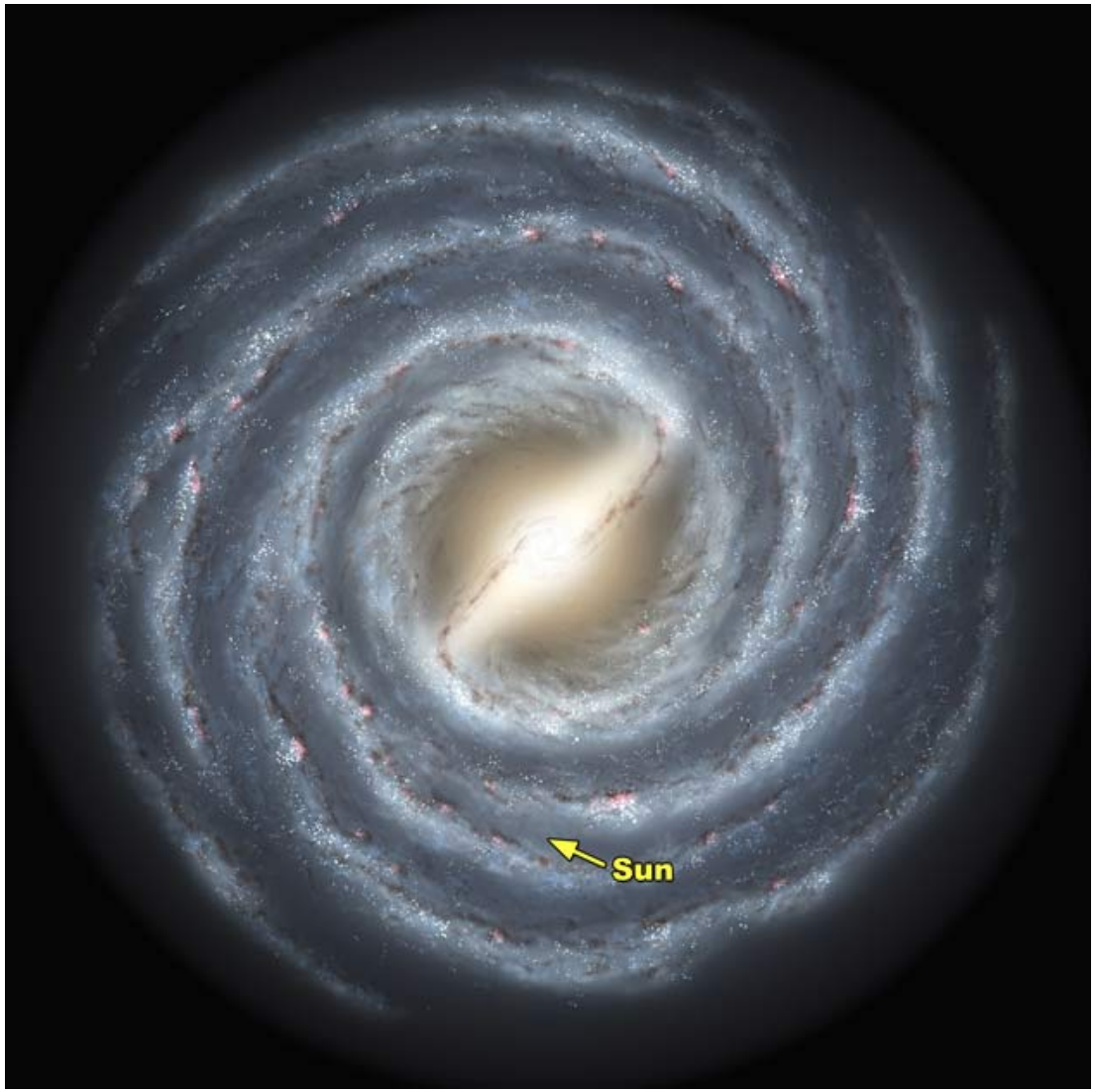
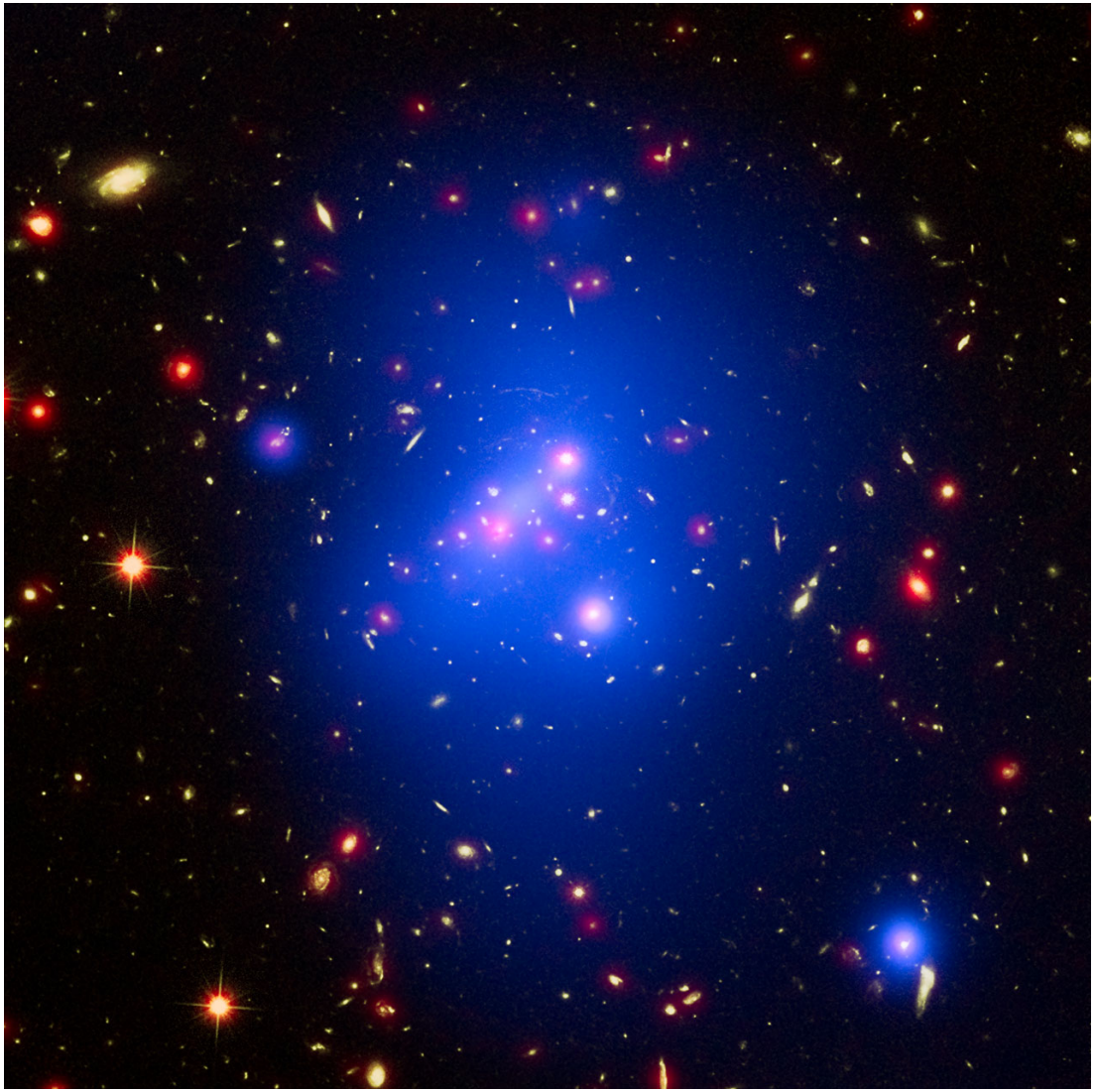
- End stages of stars.
- Examples: white dwarfs, neutron stars, black holes.
- Also supernova explosions (intermediate stage).

Galaxies



- System of stars, remnants, (interstellar) gas and also dark matter.
- Wide range of sizes, between 10^8 to 10^{14} stars.
- Different morphologies.
- Our galaxy: the Milky Way. Disk-like shape with radius $\sim$ 10 kpc, and thickness $\sim$ 100 pc.

Galaxy clusters



- Gravitationally bound system of galaxies, can contain hundreds to thousands galaxies.
- Intra-cluster gas.
- One of the most largest known structures (also have super-clusters).

Large-scale structure

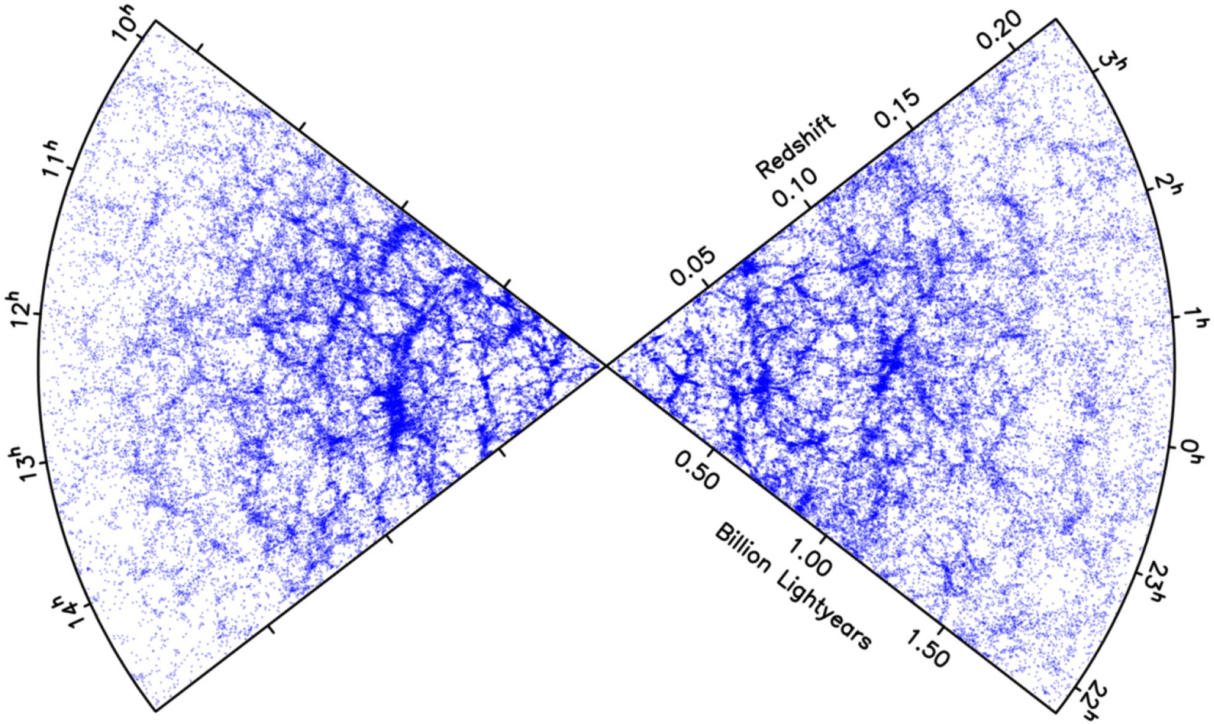
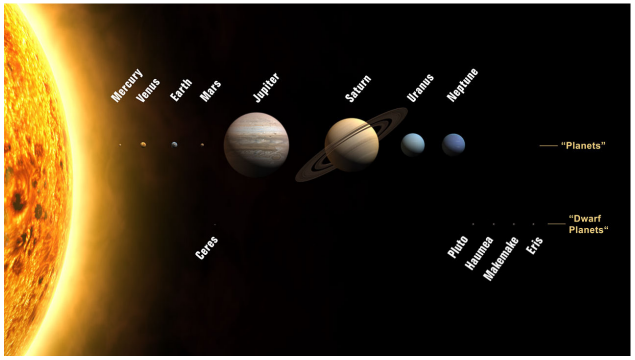


Image from 2dFGRS website

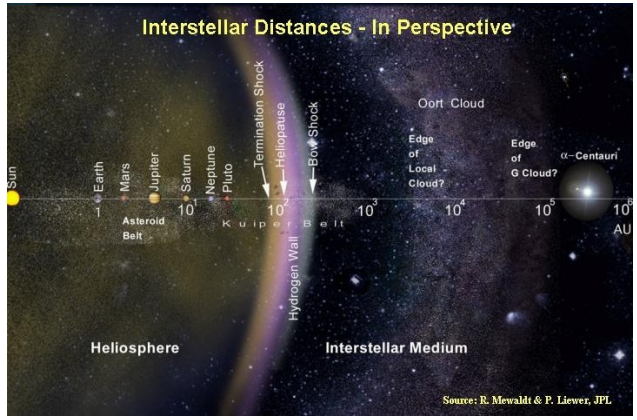
1 Lightyear = 0.3 pc

Galaxies are not uniformly or randomly distributed, they form the “large-scale structure”

Size and distance scales

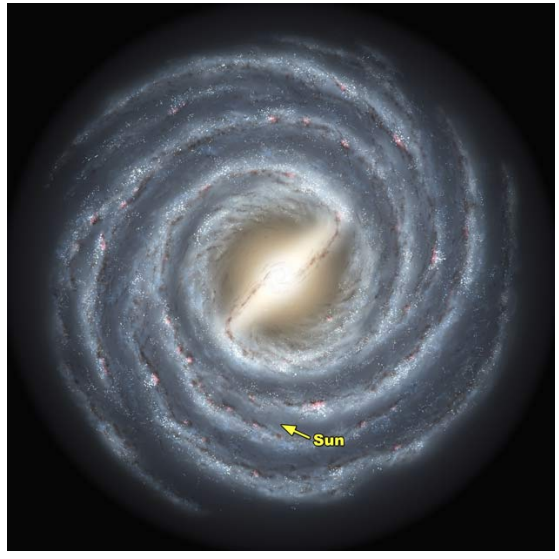


Solar system 1 AU $\sim 10^8$ km



Nearby stars $\sim$ parsec (pc) $= 3.1 \times 10^{13}$ km

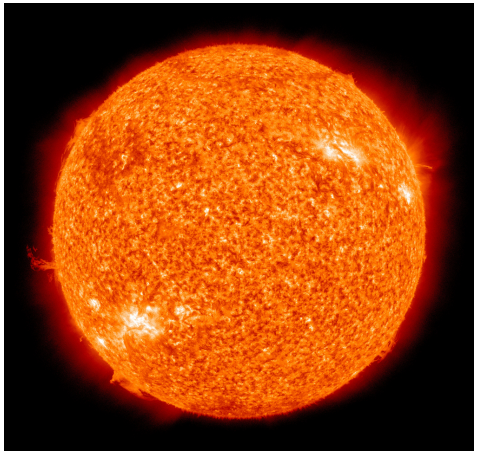
Galaxy $\sim$ 10 kpc



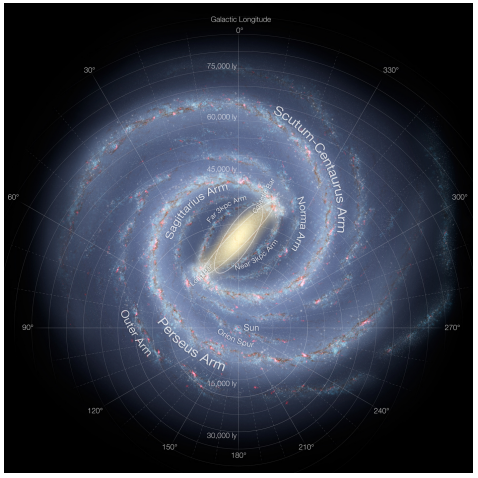
Distant galaxies $\sim$ 10 Mpc

Images: Wikipedia / NASA website

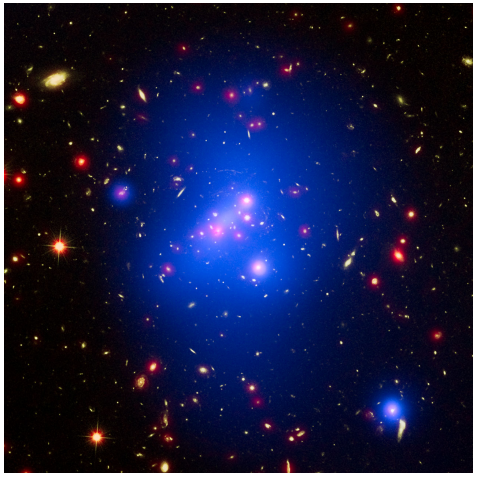
Mass scales



Star $M_\odot = 2 \times 10^{33}$ gm



Galaxy $\sim 10^9 - 10^{11} M_\odot$



Galaxy cluster $\sim 10^{15} M_\odot$

Images: Wikipedia

Cosmic archeology

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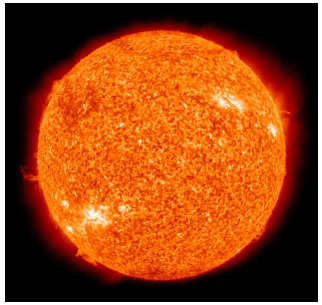
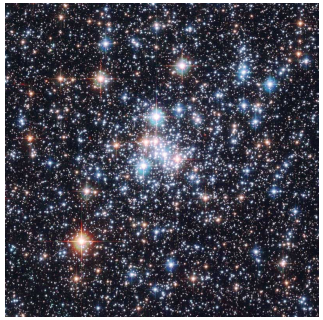
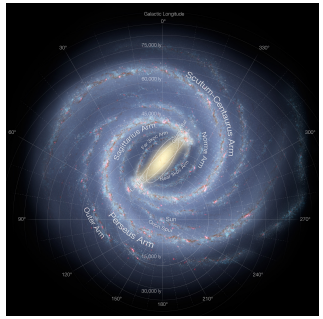
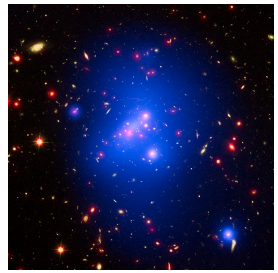
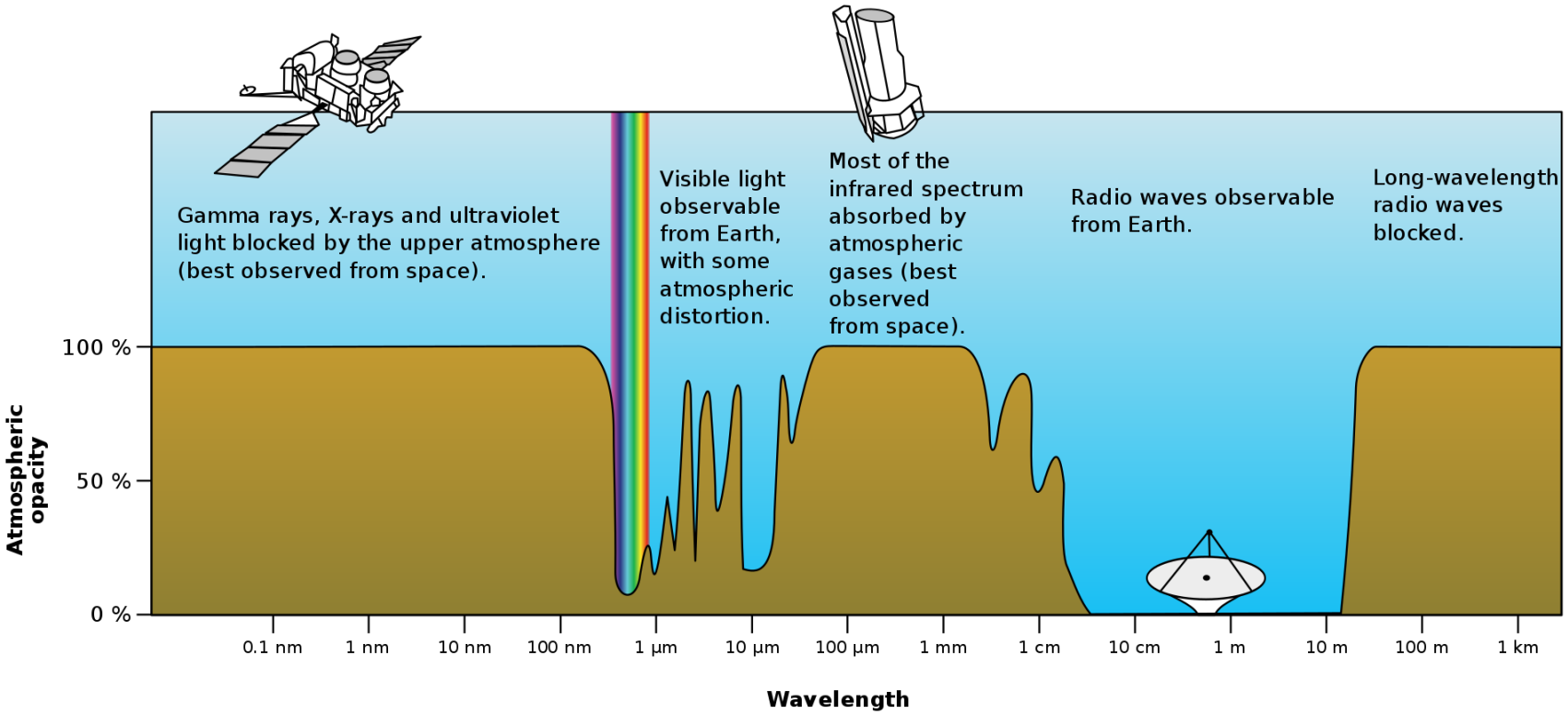
	Sun	Nearby stars	Galactic centre	Distant galaxies
8 minutes ago				
$\sim$ 10 years ago				
$\sim 10^4$ years ago				
$\sim$ billion years ago				

Electromagnetic spectrum



- Radiation with energies larger than $\sim$ 10 eV are absorbed by neutral atoms (leading to ionization of upper layers), thus observations of $\lambda < 1000$ Å $\sim 10^{-5}$ cm is not possible from ground.
- Further, rotational and vibrational levels of various multi-atomic molecules (e.g., CO_2 and H_2O, energy levels $\sim 0.001 - 1$ eV) fall within Infra-red band ($\lambda \sim 0.0001 - 1$ cm), which causes absorption at these wavelengths.
- Wavelengths larger than 10 m are reflected by the ionosphere because of plasma effects. Hence one cannot do radio observations at very high wavelengths.

Types of observations

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- **X-ray and γ-ray:** Space-based observations. Compact binary stars and supernova remnants are sources of such high energy radiation.

Topics to be covered

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- Introduction and overview

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- Gravity

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- Radiation

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- Gravity
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- Galactic physics

Suggested references

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- T. Padmanabhan, *Theoretical Astrophysics, Volumes I and II*, Cambridge University Press
- Arnab Rai Choudhuri, *Astrophysics for Physicists*, Cambridge University Press