ASTR 3730

Astrophysics 1 - Stellar and Interstellar

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Part one of a year-long introduction to *astrophysics:*

Aim - develop physical understanding of:

- How astronomical objects produce radiation
- Formation, structure, evolution and death of stars
- Star clusters and our own galaxy, the Milky Way

Topics

This week:

- What do we mean by astrophysics?
- Tour of the Universe
- Review of astronomical units - magnitude system etc

Radiation processes - how does a gas at specified (□, T, B) radiate? Conversely, measure radiation - what can we infer about physical conditions in the source?

Structure of stars - best understood problem in astrophysics

Star formation - many unsolved problems, discuss also brown dwarfs, protoplanetary disks, extrasolar planets (briefly!)

Stellar evolution and stellar remnants - white dwarfs, neutron stars, black holes

Star clusters and structure of the Milky Way

Astrophysics

Application of the laws of physics to understand the behavior of astronomical objects, and to predict new phenomena that could be observed.

Physical conditions in astronomical objects are very diverse:

- Temperatures: 3 K (microwave background radiation); 10 K (molecular gas in star forming region); 10^{12} K (gas near a black hole.
- Densities as high as 10^{15} g cm^{-3} in neutron stars
- Velocities above 0.99 c (speed of light)

Most branches of physics find some application in astronomy.

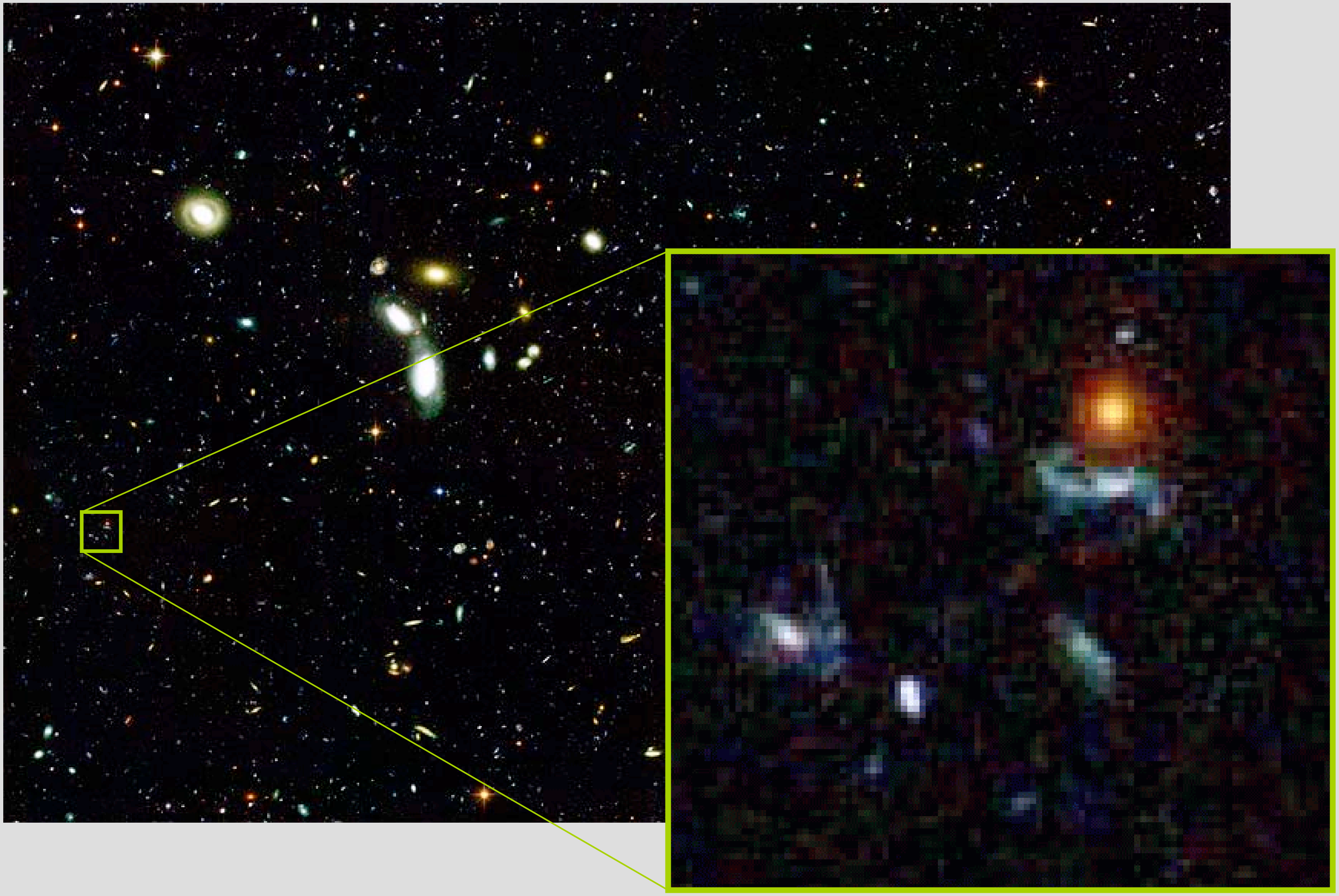
Astrophysics

Main difference between astrophysics and other branches of physics: **controlled experiments are (almost) never possible**.

This means:

- If many different physical effects are operating at the same time in a complex system, can't isolate them one by one.
- Knowledge of rare events is limited - nearest examples will be distant. e.g. no supernova has exploded within the Milky Way since telescopes were invented.
- Need to make best use of all the information available - many advances have come from opening up new regions of the electromagnetic spectrum.
- Statistical arguments play a greater role than in many areas of lab physics.

One of the deepest views of the Universe



Great Observatories Origins Deep survey data

Examples: The Sun

Physical conditions in the center of the Sun are:

- Temperature $T \sim 1.5 \times 10^7$ K
- Density $\rho \sim 150$ g cm^{-3}

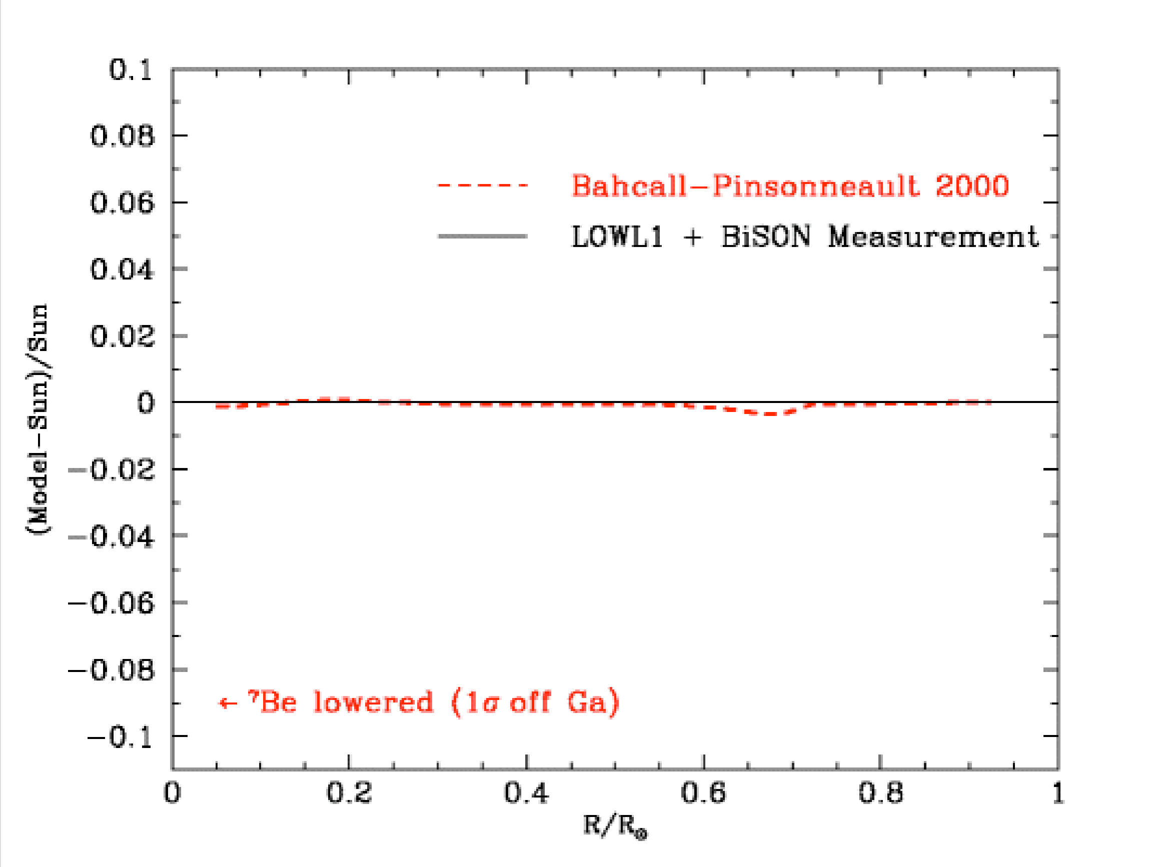
Temperature (and to a lesser extent density) is well within range accessible to lab experiments.

→ High confidence that we understand most of the basic physics (i.e. what are the laws) pretty well

Numerous excellent observations also available.

Detailed comparison between theory and observations is possible.

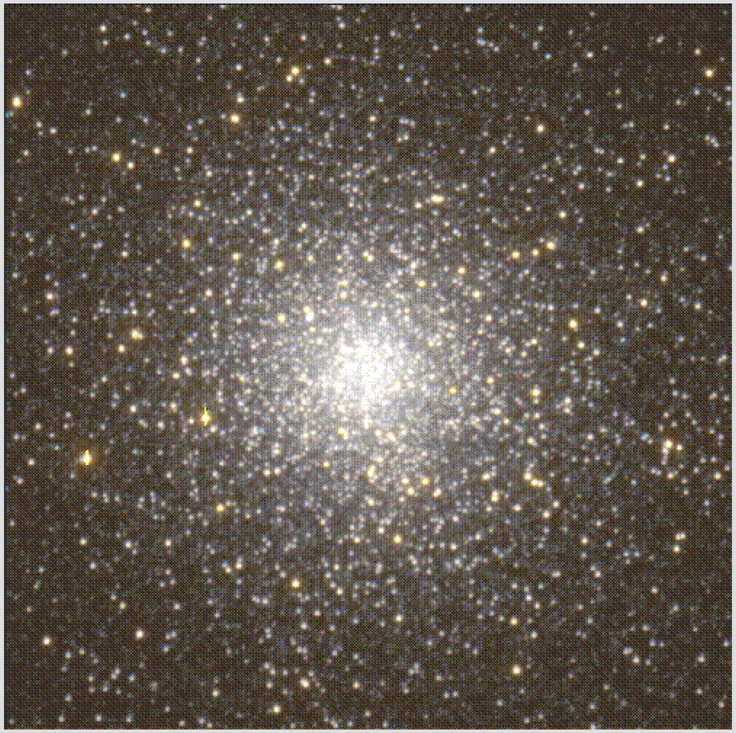
Examples: The Sun



Result of a comparison of the measured and predicted sound speed at different radii within the Sun.

Examples: A globular cluster

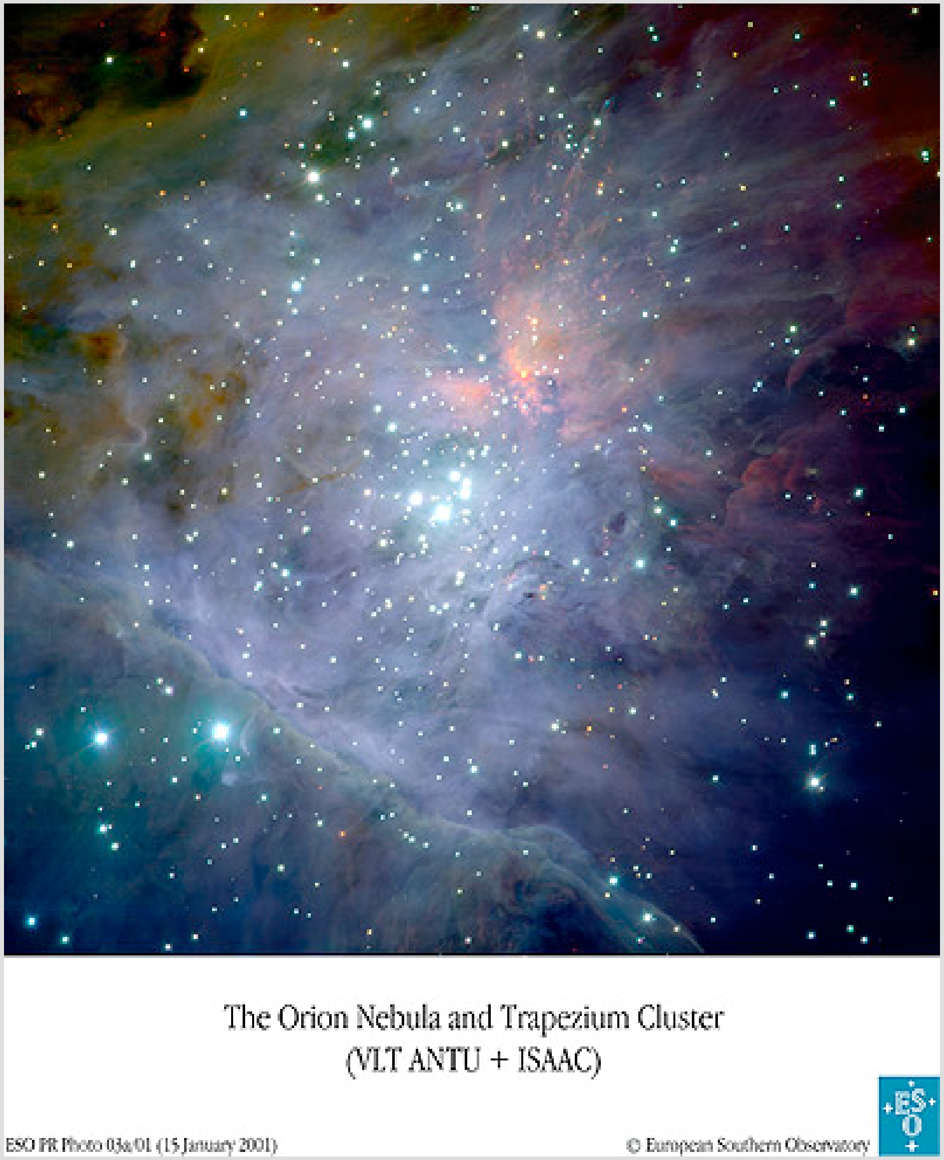
Globular cluster 47 Tucanae



Globular clusters contain 10^5 - 10^6 old stars in a compact, often roughly spherical cluster.

Not much gas, dark matter, or influence from outside.

Examples: Star Formation



Examples: Stellar remnants

Neutron stars can have magnetic fields >> lab conditions:

- Earth's magnetic field ~10^{-4} Tesla (1 Gauss)
- Strongest magnets ~40 T (4×10^5 G)
- **Magnetar** ~10^{11} T (10^{15} G)

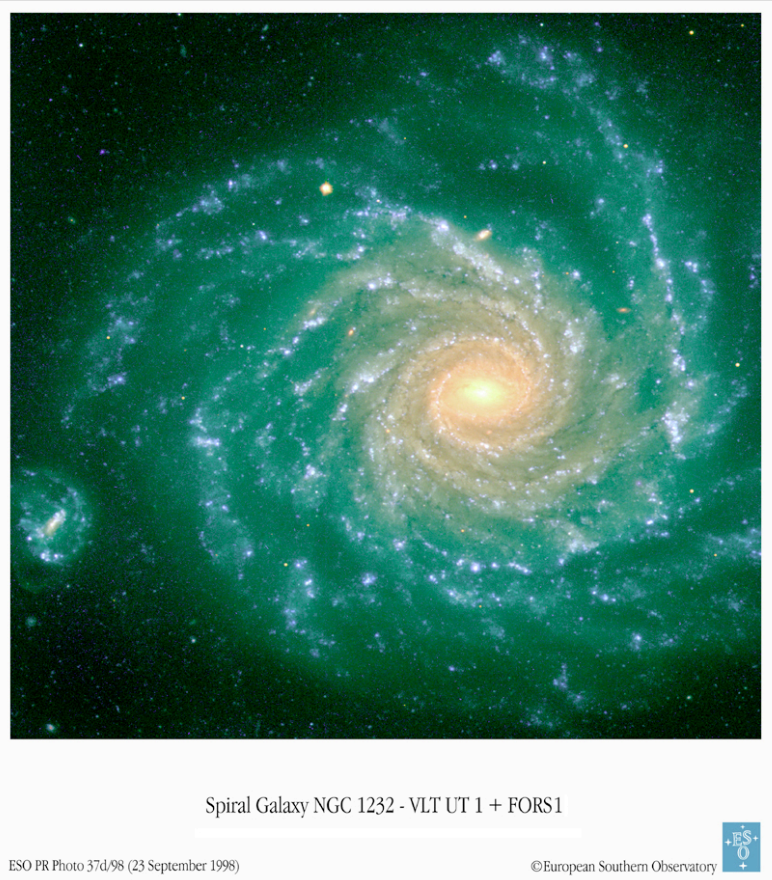
Black holes produce gravitational fields enormously stronger than any found in the Solar System.

Both cases think we know the physics needed to understand these objects:

- matter in superstrong magnetic fields (Quantum electro- -dynamics)
- Black Holes (General Relativity)

But untested in the lab - ideally would hope observations could test theory in new regimes.

Examples: Cosmology



Observations of the rotation curves of spiral galaxies suggest presence of **dark matter** - probably in the form of an unknown elementary particle.

Observations of the brightness of distant supernovae suggest presence of **dark energy** - not understood at all.

Astronomical observations hint at presence of new physics, which may be testable in the lab in the future.