

News & Updates

Update on superluminal neutrinos

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New data from OPERA's sister experiment ICARUS have failed to yield any evidence for superluminal neutrinos. More precisely, ICARUS has shown that neutrinos traveling from CERN to Gran Sasso do not visit earth-neutrino pairs. Deviation of such pairs is expected if the neutrinos travel faster than the speed of light, according to a [paper](#) published recently by Andrea Gamba and Massimo Malabar.

Faster-than-light neutrino puzzle claimed solved by special relativity

Technology Review [View](#) [Print](#) [Email](#) [Share](#)
Ronald van Elburg at the University of Groningen in the Netherlands has suggested that one effect that the OPERA team seems to have overlooked: the relativistic motion of the GPS clocks. Although the speed of light does not depend on the frame of reference, the time of flight does. In this case, there are two frames of reference: the experiment on the ground and the clocks in orbit. If these are moving relative to each other, then this needs to be factored in. [More](#)

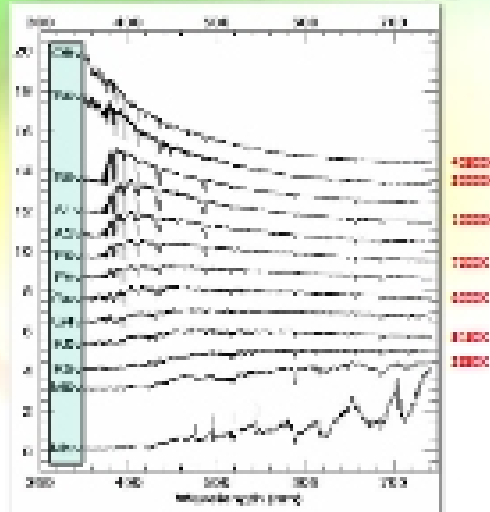
Spiral arms point to possible planets in a star's dusty disk

NASA Goddard Space Flight Center [View](#) [Print](#) [Email](#) [Share](#)
SPITZER A new image of the disk of gas and dust around a sun-like star is the first to show spiral-arm-like structures. These features may provide clues to the presence of protoplanets or even young planets. A new infrared image from the National Aeronautics and Space Administration's Spitzer shows a pair of spiral features arcing along the outer disk. Theoretical models show that a high-mass protoplanet may produce a spiral arm on each side of a disk. The structures around HD 335692 do not form a matched pair, suggesting the presence of two unequal worlds, one for each arm. [More](#)

Today's Learning Goals

- **The H-R Diagram**
 - The Main Sequence (93% of all stars)
 - Red Giants and white dwarfs (7%)
 - Correlations of properties (ctd)
- **Clusters: Clues to Stellar Evolution**
 - Evolutionary pathways in the H-R diagram
 - Track by initial stellar mass
- **Star formation**
 - Cloud condensation, heating, onset of opacity
 - Making solar systems
 - Formation paths end at the Main Sequence

Spectra & Spectral types



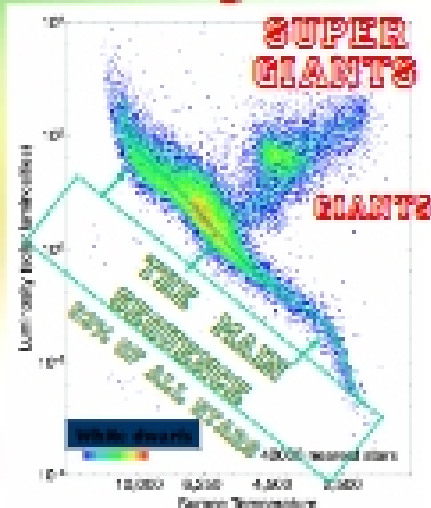
The Hertzsprung-Russell Diagram: A correlation study of stellar luminosities and temperatures

Intro to the "H-R" Diagram

Correlation graph of stellar **Luminosity Vs Color or Temperature**

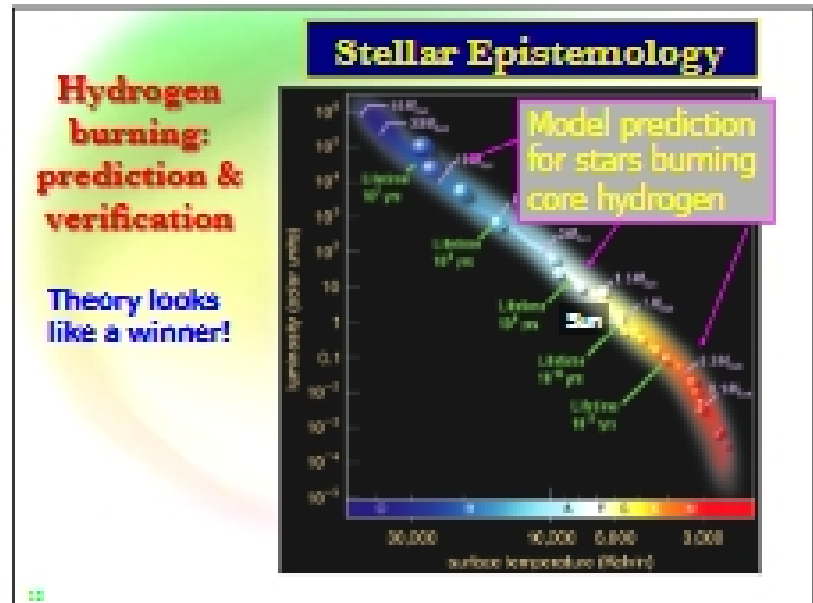
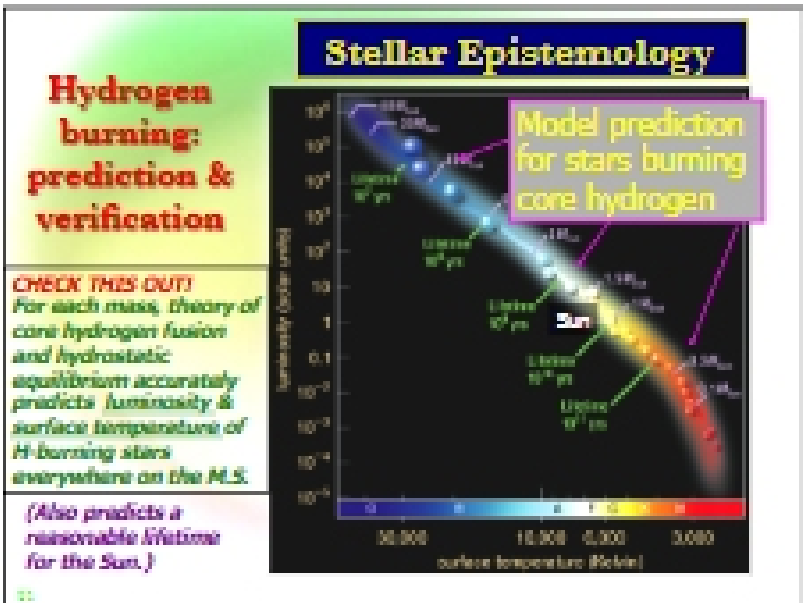
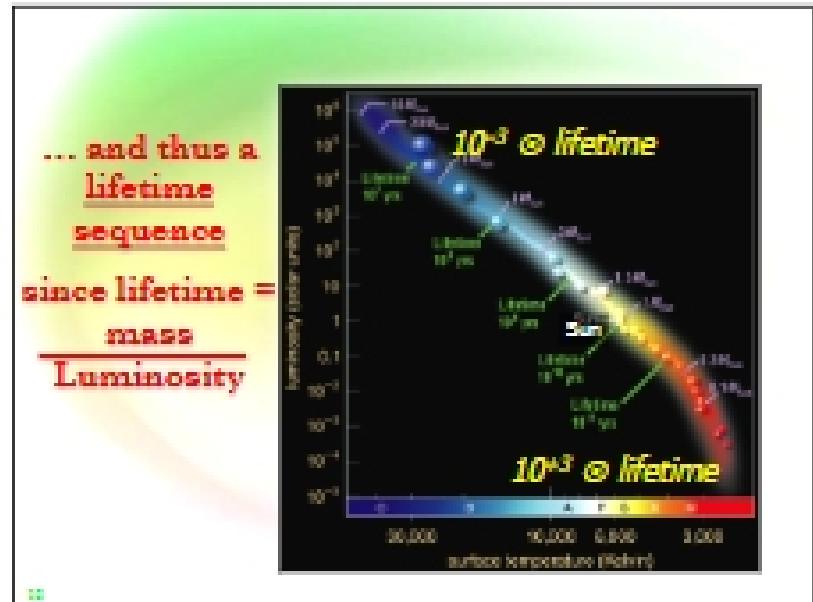
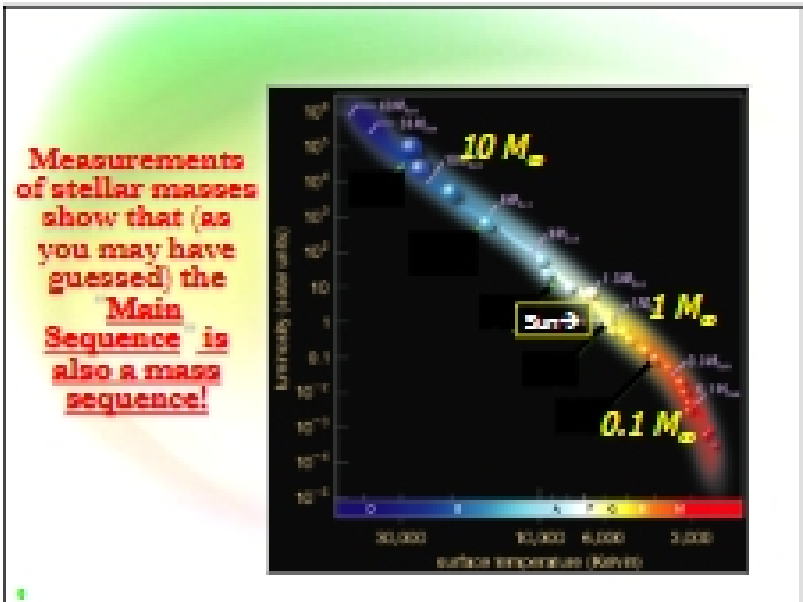
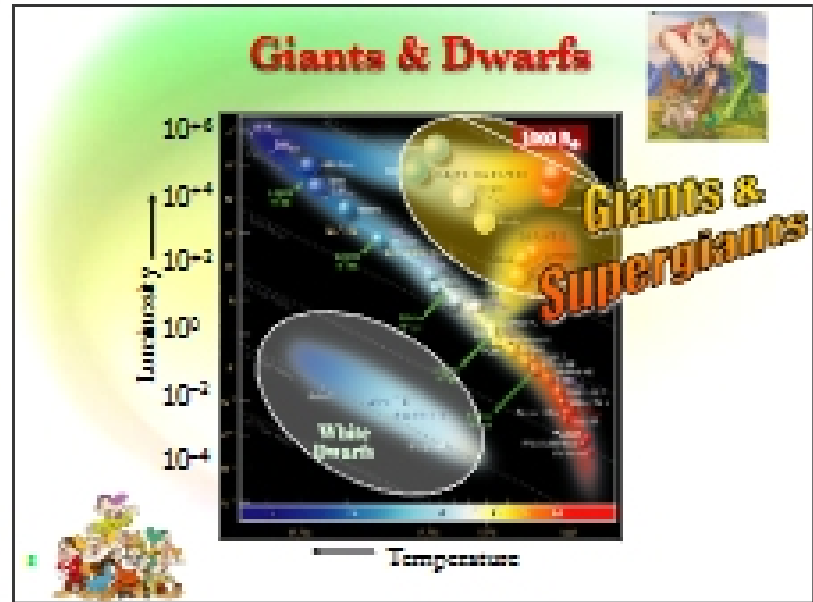
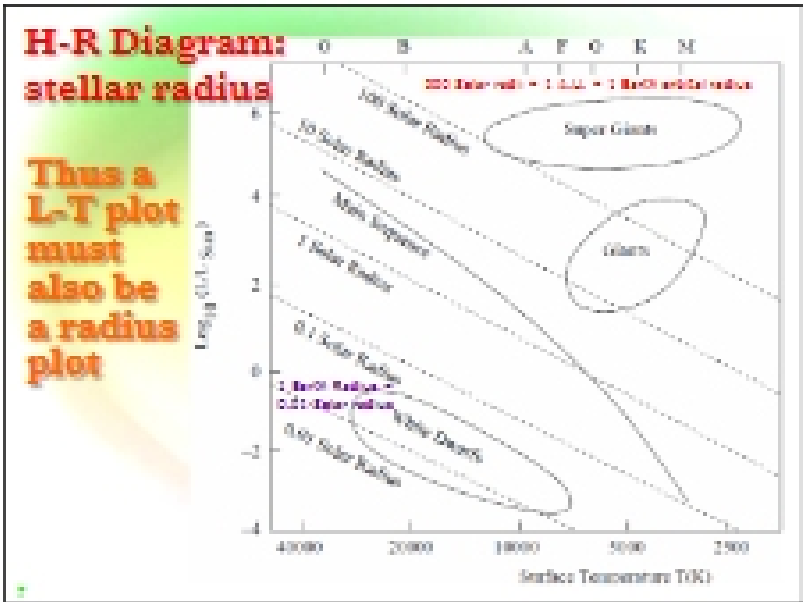
What are the patterns in the data?

Revealed patterns are vital clues to how stars are structured and evolve.



One correlation among ALL stars is required by basic physics!

- Stellar radii r , luminosities L , and temperatures T are linked inexorably.
- $$L = (\sigma T^4) * (4\pi r^2)$$
 - where σ is a constant of proportionality
 - L is the energy emitted per second in all directions (watts)
 - σT^4 is the energy radiation per square meter (watts per meter²)
 - $4\pi r^2$ is the star's surface area (meter²)
- Measure any 2 and derive the 3rd.
- Interdependencies and correlations go together. If you find a correlation you can infer some sort of relationship



The "Other" stars

- Giants and supergiants are HUGE — more than large enough fill the Earth's orbit.
- White dwarfs are tiny — roughly the size of the Earth, and masses $< 1.4 M_{\odot}$
- Unlike M.S. stars, there is no "sequence" of R.G.'s and w.d.'s with mass or age

As we shall see...

theory implies that these "odd" stars derive their energy in several different ways... sometimes several ways at once!

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The "Other" stars

- To answer these questions we need more clues from the data.
- For this we will use **CLUSTERS** of stars. (*section 15.3*)
- Then, with some physics and some good guesswork, we might be able to build a predictive theory that can be tested and constrained by the data
- *This will take us to Chapters 16 – 17*

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Clusters: Nature's gift to astronomers

Unlike random stars in the field, all of the stars in a cluster formed from the same cloud at the same time. **Cluster stars have the same distances and ages.**

So their H-R Diagrams may be revealing!

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Age groups: Nature's gift to sociologists

- If you can't wait for people to evolve, then let's compare the attributes of samples of people with the same birth history:
 - compare cohorts born in 1920, 1950, 1990...
 - discover: height and weight increase
 - gender, skin color, number of feet and toes don't evolve
- Fortunately, human birthplace doesn't seem to matter much!
 - the fundamental process(es) of human ageing are universal.

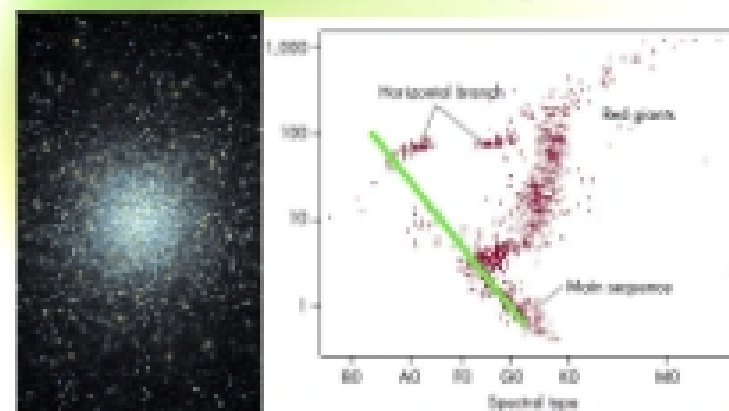
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Clusters: Nature's gift to astronomers

- All of the stars in a cluster are born at the same time place, and from the same material.
 - The stars form a homogeneous statistical "population" of the same age and composition but different initial masses
- All cluster stars start their evolution at the same time, wandering through the H-R diagram.
 - Critical clues to patterns of change for stars of various masses emerge.
- By comparing the H-R diagrams of clusters of different ages we may be able to identify the evolutionary trends of stellar lives

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Clusters: The color-luminosity pattern



Cluster M3 and its H-R Diagram

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