EXOTIC TYPES OF STARS

Today’s slides borrow heavily from Stars, part of the “Voyage Through the Universe” series, by the editors of Time-Life Magazine.

An artist's rendering of a pulsar sucking matter off its companion star. NASA - Dana Berry

Variable Star

height

Variable Star

time
WOLF-RAYET STARS

- Humungous stars, near death or “born old” already, based on the size
  - >20 solar masses but can be Sun radius
- Violent solar winds strip 1/100,000 solar mass/year @0(1,000 km/s)
  - Not much? Billion times Sun’s rate!
- R136a1 example of one
  - Most massive star, period
  - 256 times mass of our Sun
- Extremely hot surfaces
  - Up to 100,000 degrees K
- Extremely luminous
  - Thousands-millions X Sun
- Blue and red supergiants

Credit: left: NASA/Dana Berry/SkyWorks Digital; right: Y. Grosdidier (U. Montreal) et al., WFPC2, HST, NASA
- Energy sources first observed by radio telescopes in the 1960s
- Emit radiation in bursts of extraordinary regularity
  - Their signals repeat at intervals ranging from several seconds to mere thousandths of a second in period.
  - So precise were the first pulsars’ repeat times that their discoverers were half-tempted to attribute them to intelligent extraterrestrial beings
- Ultimately the mysterious signals were found to be something equally sought after: proof of the existence of neutron stars
  - First predicted in the 1930s as the cores that would be left after massive stars exploded as supernovae (GR)
- The dense compression of matter inside a neutron star gives it a magnetic field that is a trillion times as powerful as the field of an ordinary star (neutron=neutral, but charged quarks are inside)
  - Emits conical beams of radio waves from its two magnetic poles
  - The simplest model of pulsar behavior envisions the object as a dense, rotating sphere of neutrons, acting like massive cosmic deadly magnet
This magnetism, in combination with the star’s extremely rapid rotation, produces a kind of dynamo effect

- A spinning neutron star hurls electrically charged electrons (negatively charged), protons (positive) from its surface
- Spiraling along the star’s magnetic lines of force at speeds approaching that of light, these particles emit electromagnetic energy of various types, including radio waves, x-rays, and gamma-rays

According to one theoretical model, the energy fans out from each of the neutron star’s magnetic poles like two powerful beams, which the star’s rotation transforms into a repeating beam like that of a lighthouse

- The model accounts for most of the more than 1,600 pulsars so far detected, but the galaxy is host to examples that wriggle out of this ingenious mold and demand some special explanations

In special case of magnetars, magnetic fields of up to a trillion Tesla are possible (compare to Earth field of half Gauss, where 1 Gauss = 1/10,000 Tesla, or world records O(10 - 50) Tesla!!!!
If the magnetic axis of the star coincided with the axis of rotation, no pulsating effect would result.

- The emitted energy would simply radiate steadily.
- Because the star’s rotational and magnetic axes do not coincide, each beam rotates as the pulsar spins, like the rotating beam of a lighthouse.

Observers on Earth can only detect the emissions when the axis of the cone points directly earthward.

- Radio telescopes will record a pulse each time a beam of radiation sweeps across them.
- Astronomers can calculate how fast the pulsar is rotating from the period between pulses.
Radio pulses from the neutron star illustrated on last slide are represented at right
- Weaker pulses, called interpulses, alternate with stronger ones
- An indication that the beams of radiation emanating from the star’s two magnetic poles may be of different intensities

Electrons and protons in grip of the neutron star’s powerful magnetic field are accelerated to near the speed of light along spiral pathways (~aurora)
- Producing cones of radiation that beam out in line with magnetic axis of the star (safe at a distance)
THE SPECIAL CASES

- Quintuple signals from a lone star (PSR 1237 + 25). Mysterious...

- Pulsars in pairs, like PSR 1913 + 16, which likely has a non-pulsar neutron star companion. It has a periodicity to its period!
  - Can see Doppler shift as its orbit takes it closer or farther from the Earth
  - Seems to be losing energy in accordance with GR gravity wave prediction.

- Millisecond pulsars, such as 1937 + 21. Bests an atomic clock?
  - It is not only precise, but it is also incredibly fast
  - A bit of an enigma, because pulsars should slow down as they age, and this particular pulsar has no supernova debris cloud, so is most likely old
  - Theory: accreted matter from long-dead partner?

- Magnetars (pulsar sub-class): superconducting electric currents?
When pulsars were first discovered, we had to consider the possibility that alien life was responsible!

When detecting/observing new and/or strange signals from (unknown) astronomical/astrophysical phenomena, how could one in theory tell the difference between something that is naturally occurring versus something of alien origin (by which I mean created by sentient, intelligent life-forms artificially)

Very open-ended question. (Think deeply about it!)
Which fundamental element is responsible for variable stars?
- A. Hydrogen
- B. Helium
- C. Carbon
- D. Oxygen

The older that a star cluster is the more _______ stars it has.
- A. Dwarf
- B. T Tauri
- C. Red giant
- D. Nova

Rank these processes in order of increasing energy production.
- A. Chemistry, fission, fusion, antimatter annihilation
- B. Fission, chemistry, antimatter annihilation, fusion
- C. Chemistry, fission, antimatter annihilation, fusion
- D. Chemistry, fusion, fission, antimatter annihilation
Variable stars will pulsate due to doubly-ionized helium (He III), neutral in normal stars is this regime in the outermost regions.

Star contracts. Density, heat of singly-ionized layer (He II) up. Gets more ionized. Stellar opacity increases. Energy flux is now more effectively absorbed.

Temperature of star rises and it begins to expand. After expansion, He III recombines into He II and opacity of star drops.

This lowers surface temperature of star. The outer layers contract and cycle begins anew. (Such stars are not on main sequence.)
**BEHAVIOR**

![Graph showing the behavior of Cepheid variables](http://abyss.uoregon.edu/~js/ast122/lectures/lec15.html)

*Cepheid* variables: outward pressure (P) and inward gravity compression are out of sync, so star changes size and temperature: it **pulsates**.  
*RR-Lyrae* variables are smaller and have pulsation periods of less than 24 hours. Also, their light curve looks different from the Cepheid light curve.
**FAMOUS EXAMPLES**

- **RR Lyrae variables**, short range standard candles (giants)
- **Classic Cepheid stars**, longer-range standard candles (supergiants)
- **W Virginis variables**
  - Cepheid-like, but dimmer
- **RV Tauri variable stars**
- **Delta Scuti (near main)**
  - SX Phoenicis
  - Rapidly oscillating Ap
- **Lots more types. Not all from helium++ ions, and some are irregular.**
Twenty-five years after supernova 1987A

Homework #11

Put three grains of sand inside a vast cathedral, and the cathedral will be more closely packed with sand than space is with stars.
- James Jeans, 1877 - 1946

There is just one thing I can promise you about the outer-space program: your tax dollar will go farther.
- Wernher von Braun, 1912 - 1977