Starlight in the Night: Discovering the secret lives of stars

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Fossil Butte National Monument
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The lives of the stars, in the skies over Fossil Butte!

- Stellar evolution
- Birth of stars
- Groups of stars
- Death of stars
**Recycling in the Universe**

- Stellar evolution is a large process of recycling.
- Remnants remove material from the loop.
**Birth of Stars**

- Stellar birth begins in vast **molecular clouds** in space
- **Gravity** causes the cloud to begin to collapse inward, forming a **protostar**
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M16 (Eagle Nebula)
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As stars are born, their light and winds blow out surrounding nebula, making it luminous.

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• Stars often form in pairs, and orbit each other the same way planets orbit our Sun.

• These are called binary stars.

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Near the ends of their lives, the outer layers of the star are shed and become **planetary nebulae**

They have **nothing to do with planets** — they look like planets in the telescope!

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After the planetary nebula phase, nuclear burning slows and gravity begins to win.

Star collapses, but gravity can’t compress the atoms beyond a certain point (this is called “degeneracy pressure”).

Final remnant is about the size of the Earth.

White Dwarf (the Sun will become one of these)
• For **massive stars**, the end of its life is catastrophic: a **supernova explosion**!

• Luminosity of explosion is **10 billion times** the luminosity of the Sun (a supernova can outshine its parent galaxy for a short time)

• The explosion distributes the heavy elements out into the galaxy (gold, uranium, etc)
Supernova Remnant

• The explosion creates a supernova remnant!
Supernova Remnants

SN1054 (Crab Nebula)

SN 185

SN 1572 (Tycho’s SN)

SN 1604 (Kepler’s SN)

Cygnus Loop (Veil Nebula)

N63A (LMC)
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Supernovae destroy most of the outer layers of a star, but compress the core to tiny size.

Most supernovae core become neutron stars.

A neutron star has a diameter of only 10 kilometers. It will fit between Kemmerer and Fossil Butte!
A star shrunk to tiny size!

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Pulsars

• Emission along the magnetic axis (no one knows how!)

• If neutron star is spinning, the emission axis points in different directions at different times

• If you are in the right place, the emission sweeps across you
Pulsar Discovery

• First pulsar discovery made by Jocelyn Bell at Cambridge in 1967

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Once we decided pulsars were neutron stars, we wanted to find more!

Look in supernova remnants!

Crab Pulsar soon discovered, with a 0.33 second rotation period
Kinds of Pulsars

• Most known pulsars are radio pulsars – you can only see them in radio pulses

• The Crab radiates in radio waves, x-rays, and optical light!

• The Songs of the Crab
Black hole observer’s report

Image credit: M. Larson
Looking for Black Holes

• How do we detect black holes in the galaxy?
  • Look for their interactions with other objects!
  • Look for events that require high energy or strong gravity!
**Candidate: Cygnus X-1**

- Binary x-ray source, 8.8 mag optical blue supergiant
- Invisible companion is a 7-10 solar mass black hole – the closest black hole candidate to Earth!
Last Thoughts...

- Carl Sagan once wrote (*Cosmos*): “The desire to be connected with the Cosmos reflects a profound reality: we are connected. Not in trivial ways... but in the deepest ways.”

- In the lives of stars we see reflections of our own lives on Earth — stars are born, live long and lustrous lives, and eventually die, returning once again to the Cosmos from whence they came.