ON THE TOPIC OF ZOMBIES & STARS

By: David, Kevin, Trisha

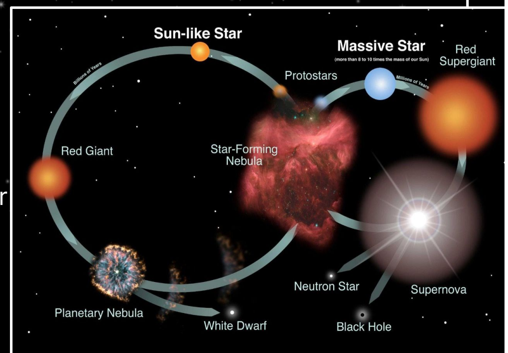
01
Star Formation

Life Cycle of Stars?

How do stars meet the definition of “alive”? Metabolism as seen with the expenditure of energy, a birth and a death (aging) and the explosive star reproduction cycle

Stars are formed from nebulae within the galaxy that are rich in Helium and Hydrogen, and typically stay as nebulas unless an outside force influences the particles, like colliding with another gas cloud which can combine clouds and form clumps or through material being added due to a solar event like shockwaves from a supernova that can fragment clouds causing them to collapse due to gravity or simply be feed matter from a giant star

- This is due in part to the “turbulence” caused by the angular momentum inside the nebula that resists the force of gravity until enough material is present to overcome this pressure
- This explains the relatively low star formation rate of our galaxy despite mass concentrations of gas proofing the theory of turbulence-regulated star formation (Federrath, 2018)



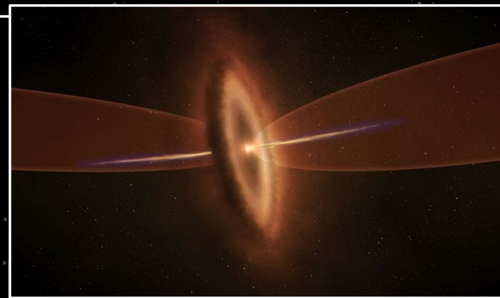
Role of Gravity

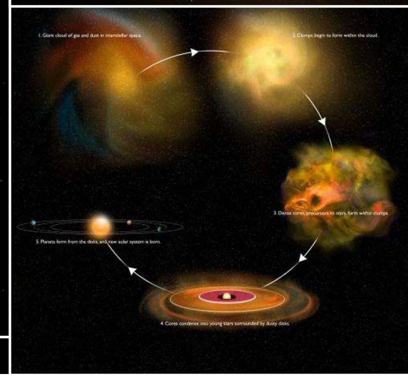
Gravity plays a crucial role within the formation of stars as it serves as the main source for nebula collapse but also in the attraction of matter toward the H clump when an event allows gravity to overcome the pressure of the cloud

- Each reaction produces more mass within the clump and thus the gravitational pull increases drawing in more material making gravity a runaway force as it aids in the further growth and contraction of the cloud core.
- Cores of these clumps referred to as Protostars form within these nebula and temperature increases as particles collide more often as the increase in mass accelerates gravitational collapse and are visibly infrared due to the heat produced from the collisions (Kuhn, 2022)

Protostars/T Tauri Stars

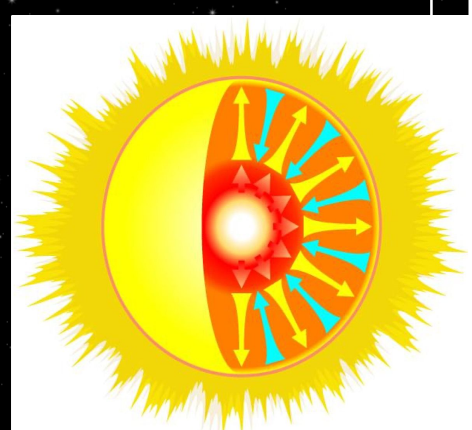
The rotation rate of the protostar increases which creates a circumstellar disk with an inner protostellar disk feeding the protostar (accretion disk) with a secondary disk flattening into a protoplanetary disk which bottlenecks the protostellar wind to the poles which can produce "jet" if intense enough as the star tries to slow down its angular motion to prevent ripping itself apart (Larson, 2001)
- More unique elements lead to different core compositions leading to even more diversity of elements with heavier elements requiring more energy to create the same amount of pressure that fights against gravity. Star is late-term and will begin fusion shortly (1000's of years)





Fusion Ignition

- Stellar nucleosynthesis is the creation of chemical elements by nuclear fusion reactions within stars. Stellar nucleosynthesis has occurred since the original creation of hydrogen, helium and lithium during the Big Bang in the Era of Nucleosynthesis
- Star formation for a sun-like star would take an approximate million years while more larger stars would take less; however the larger the star the more energy used to prevent gravity collapsing the star, with longevity favoring smaller stars but take longer to form and start fusion. (Larson, 2015)
- Once temperatures reach 10 million Kelvin finally Hydrogen atoms may fuse into Helium releasing massive amounts of energy and beginning the extended main sequence of the star with gravity, outward pressure, Helium and Hydrogen all balanced (Hydrostatic equilibrium).



Death of the Stars

The fate of the Stars rest solely on its mass. When a star runs out of hydrogen fuel the path it takes is dependent on its size. (NASA, April 10,2025.).

Low mass stars can shine for trillions of years.

High mass stars can shine less than a few million years.

What Star death looks like.
Hubble monitored and observed this double star system which has been prone to outburst.

The death of a star. Adapted from *The Death Throes of Stars*, by NASA, n.d.
https://science.nasa.gov/mission/hubble/science/science-highlights/the-death-throes-of-stars/

Death of Low Mass Stars

Low mass stars (like the sun) are less than 8 Solar masses

Over extended times they exhausts hydrogen fuel and expands into a red giant.

Outer layer sheds to form Planetary Nebula. . 21.3 (OpenStax, 2016)

Core Contracts and becomes a White Dwarf

Eventually cools into a Black Dwarf which takes Trillion of years to cool.

21.3 (OpenStax, 2016)

Death of High Mass Stars

High-Mass stars (8+ Solar Mass)
Burn heavier elements (helium, carbon, oxygen. ect..)
Core undergoes multiple fusion stages creating heavier elements.
Once it hits iron it cannot gain any energy from it and the core collapses.
Leading to a supernova explosion.
Space is then enriched with heavy elements.

The stars are either turned into a neutron star or become a black hole.

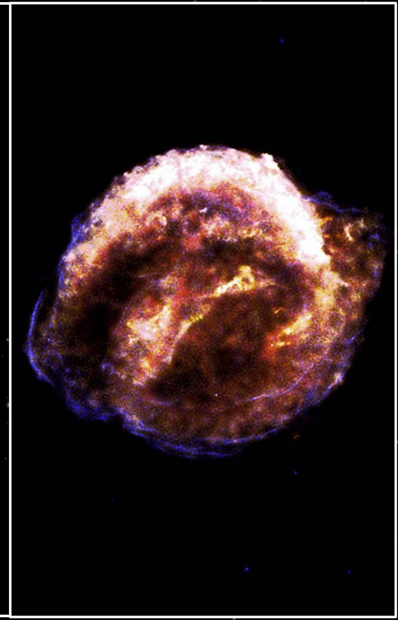
The element that are thrown into space allow for new stars, planets and life. (OpenStax, 2022, 23.5)

“We are essentially essentially made of stardust” (Carl Sagan)

02 Kepler’s Supernova

SN 1604

- The most recent supernova to undoubtedly occur in the Milky Way.
- Observed by Kepler and many other astronomers.
- Believed it to be the appearance of a new star. *De Stella Nova*.
- This supernova was brighter than Jupiter and was even visible for three weeks in the daytime with the naked eye.
- 20,000 light-years away.



03 Betelgeuse

What is Betelgeuse?

Betelgeuse is a red supergiant located in the Orion constellation. ~640 light-years.

Due to its large mass it requires more fuel to maintain hydrostatic equilibrium.

Life expectancy of ~10 million years. Our sun is expected to last ~10 **billion** years.

Near the end of its life, expected to die within the next 100,000 years. A massive amount of time for us, but little to a star.

Observationally significant owed to its proximity, size, and stage in lifecycle.

Semi variable star, meaning its brightness varies. In 2019 Betelgeuse dimmed more than we've ever recorded.

The Great Dimming

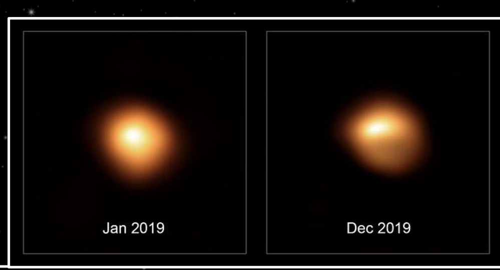
In 2019 Betelgeuse dimmed by an unprecedented factor of three. Magnitude 0.5 -> 1.7

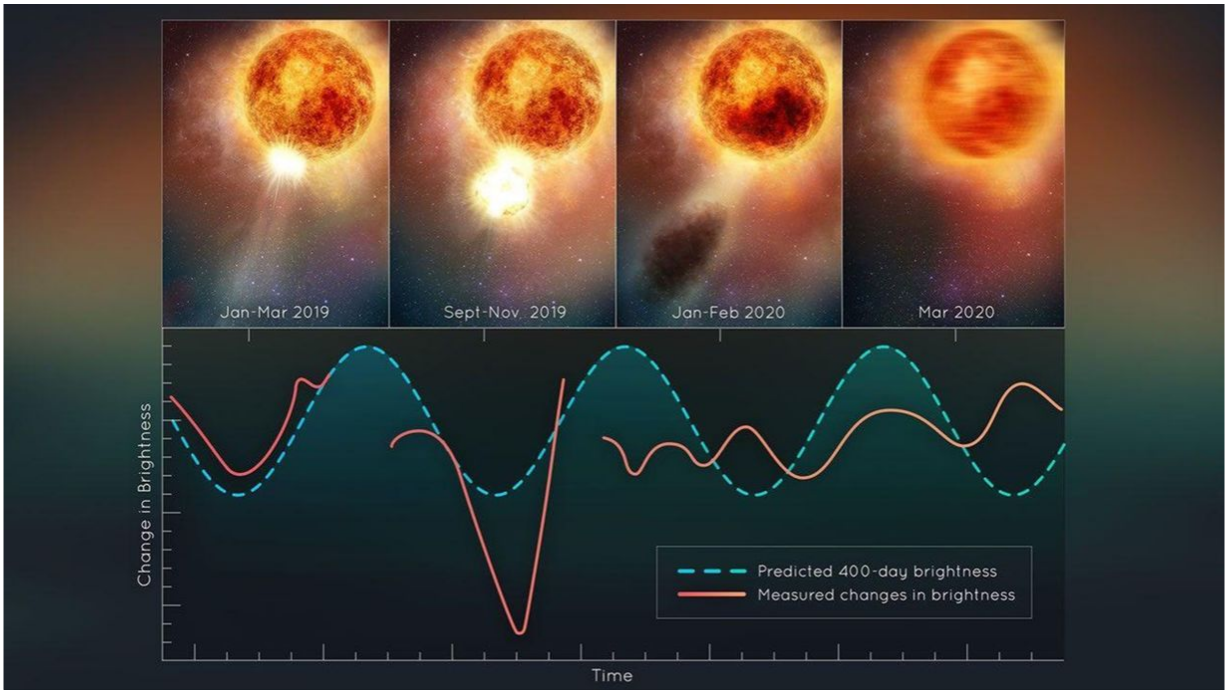
Caused by a huge surface mass ejection.

Mass cooled into dust which absorbed light.

Simulations of a red supergiant show they dim significant in the year they go supernova. ~100x fainter.

Not an indication of imminent death.



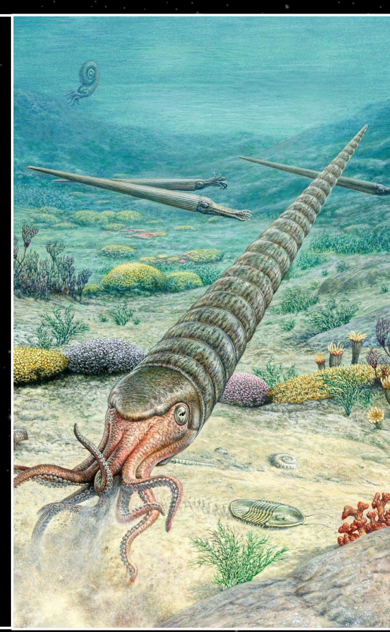


Near-Earth Danger

Gamma bursts from a hypernova could've caused the Late Ordovician mass extinction.

The light of a type II supernova can pose a danger if it's within 160 light-years from Earth.

Betelgeuse's death is not expected to have any impact on the Earth's biosphere.



Zombie Star

All red supergiants have already exited the main sequence. Betelgeuse’s time spent as an RSG estimated through:

- mass loss rate, and surrounding circumstellar material
- amount of heavy elements in its surface

A controversial study suggests Betelgeuse to have already begun carbon burning. Less than ~300 years until depleted of carbon.

Less than a few decades of heavy element fusion before going supernova.