Cosmic Mining:
Wolf-Rayet Stars

Tahrim Izm Syeda Pranavi Nabeeha

Woodford County High School

Summary

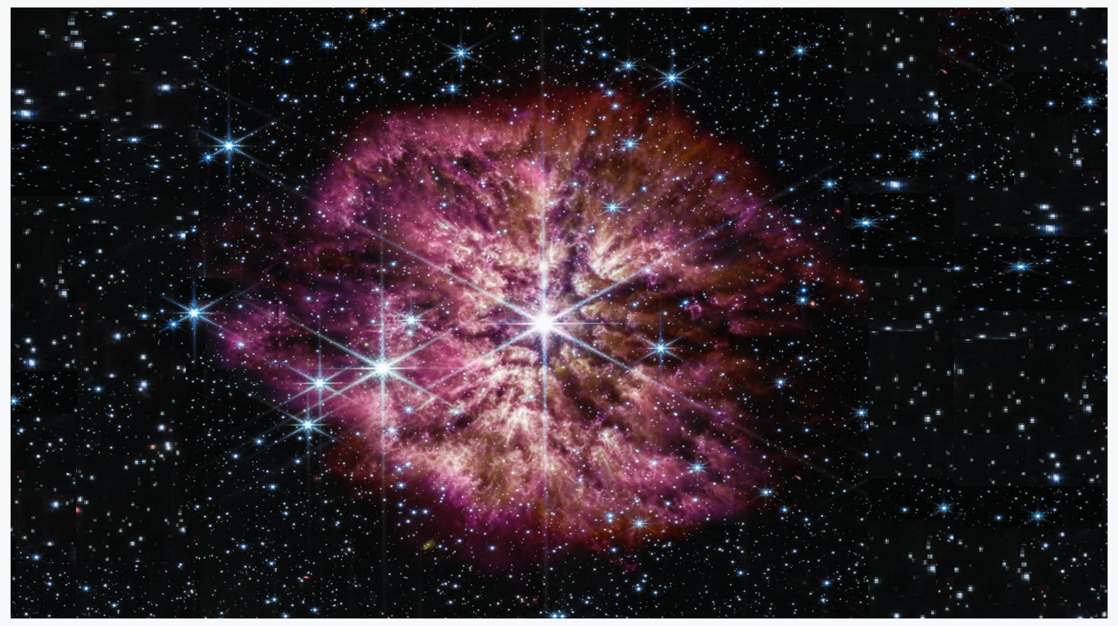
As part of the Cosmic Mining project, we were tasked with investigating the infrared spectra of 50 stellar objects, as observed by the Spitzer Space Telescope. We classified various stellar objects, such as nebulae, main sequence stars and other interesting objects -- one such object being Wolf-Rayet (WR) stars.

The aims of our investigation were :

- To find out what Wolf-Rayet stars are, and their properties
- To find out what O-type stars are and their properties
- To describe how O-type stars evolve into WR stars
- To compare the spectra of O-type and WR stars

Overall, the Cosmic Mining project provided valuable insights into the life cycle of stars and their unique properties. By studying the spectra of these celestial objects, we learned about Wolf-Rayet stars and were able to gain a better understanding of their origins and evolution processes.

WR 140 – the brightest Wolf-Rayet star in the Northern hemisphere



WR 124- WR 124 is surrounded by an intensely hot nebula.

Average Star Life Span

The lifespan of a star depends on its mass and the balance between gravity and nuclear fusion reactions that sustain it.

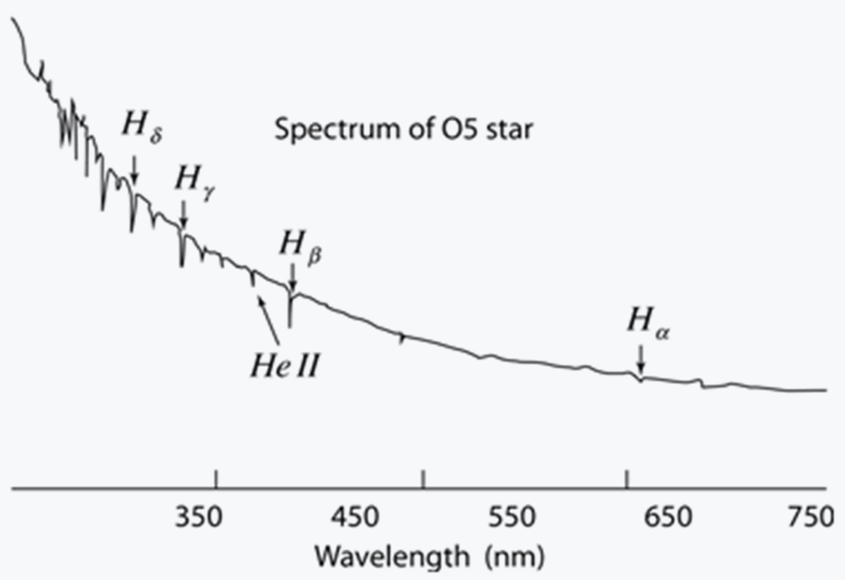
- The average lifespan of a star varies depending on its mass:
  - Most common type of star, like our Sun, has a lifespan of about 10 billion years due to the balance between nuclear fusion reactions and gravity.
- More massive stars have a much shorter lifespan due to their greater gravitational pull:
  - Wolf-Rayet stars, very massive stars, have a lifespan of only a few hundred thousand years.
  - These stars lose their outer layers in massive, luminous explosions known as supernovae.
- Different types of stars have different lifespans:
  - Red dwarf stars, the most common type of star in our galaxy, have a very long lifespan.
  - They can burn their fuel slowly for trillions of years, and none of them have died yet since the universe is about 13.8 billion years old.
- Blue supergiant stars, also massive, have a much shorter lifespan:
  - They consume their fuel much faster and only live for a few million years.
  - These stars are some of the brightest and most massive objects in the universe and can end their lives in dramatic supernova explosions.

Properties of O-Type Stars

O-type stars are a type of very massive and hot stars, characterized by strong ionized helium lines on their spectra and a blue colour. O-type stars are among the brightest and most massive stars in the universe, with masses more than 15 times that of the Sun.

O-type stars have surface temperatures of around 30,000 -60,000K, which causes them to emit ultraviolet radiation. They are also extremely luminous, with luminosities up to a million times that of the Sun. Because of their high temperatures and luminosities, O-type stars have a very short lifespan, typically only a few million years before they use up their nuclear fuel and explode as supernovae.

O-type stars do have hydrogen emissions. In fact, hydrogen emission is one of the characteristic features of O-type stars, although they are very few in number. These stars are very hot and massive, and they emit intense ultraviolet radiation that ionizes the surrounding gas, producing H regions. The ionized gas in these regions emits light at specific ultraviolet wavelengths.



Process of Evolving from O-Type

WR stars are thought to descend from O-type stars that have lost their outer hydrogen layers to reveal an exposed helium core. They can be classified into two main types – WN stars, which have mainly nitrogen emission lines, and WC stars, which have no nitrogen but are dominated with carbon and oxygen emission lines. For example, WR-124 originated from a WNh star – a WN star with hydrogen lines in its spectra too – while WR-140 came from a main sequence O-type star.

Massive main-sequence stars:

- Produce an extremely hot core that quickly fuses hydrogen.
- Causes convection throughout the star and mixes helium with the surface.

Enhancement of heavy elements in the atmosphere:

- Creates strong stellar winds, which result in emission line spectra.

Transformation into advanced O-type stars:

- Potentially becomes WNh stars if stellar winds increase further (e.g., WR 140 star).

Dust production mechanisms and concentric shells:

- Observed with the star.
- Uncertain how these shells are formed.
- Speculations that they may result from the interaction of stellar winds in a binary system.

O-type stars' continuum are falling, as they are hot. They possess hydrogen (H), neutral Helium (HeI), singly ionized helium (HeII) as well as SiIV at 4089Å and CIII at 4068, 4647, 4651Å (absorptions). There are three subclasses: Of, O(f) and O((f)).

Properties of Wolf-Rayet Stars

Wolf-Rayet stars are an uncommon type of star with a unique spectra that displays broad emission features of ionized helium and highly ionized nitrogen or carbon. They have a surface temperature range from 20,000 K to around 210,000 K, significantly hotter than other types of star. These stars are named after French astronomers Charles Wolf and George Rayet and have a limited population, with only 500 in the Milky Way and a few hundred in surrounding galaxies. Wolf-Rayet stars have unlimited brightness and can glow at tens of thousands to several million times the brightness of the sun. They are evolved, massive stars that have completely lost their outer hydrogen, leaving heavier elements located in the core.

Some key points about Wolf-Rayet stars:

- Emit powerful winds stimulated by intense radiation pressure.
- Have particularly brief lifetimes and are thought to have descended from a classification of O stars which have lost their outer hydrogen revealing a helium core.
- Have two main classifications based on their spectra: WN stars dominated by helium and nitrogen emission lines, and WC stars showing no nitrogen but dominated by helium, carbon, and oxygen emission lines.
- Predicted to occur in binary systems, with 50% of Wolf-Rayet stars believed to be in this configuration.
- End their lives in a massive supernova explosion, moving at millions of miles per hour, and releasing their elements as a supernova.
- Have a blue-coloured appearance due to their high surface temperature, and their spectra show emission lines rather than absorption lines with peaks in their graph structure.

Comparison of Wolf-Rayet Spectra

Similarities:

- No red excess
- No stellar component
- Unknown redshift
- No oxygen-rich feature at 10 microns or 18 microns
- Presence of [S III] and [Si II]

WR124:

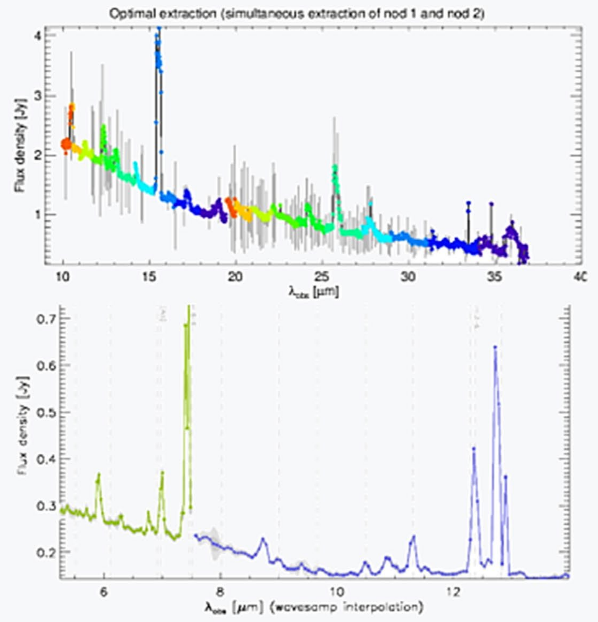
Atomic emission features:

- 12.8 microns: presence of neon (**Ne II**)
- 18.71 microns: presence of sulfur (**S III**)
- 33.48 microns: presence of sulfur (**S III**)
- 34.81 microns: presence of silicon (**Si II**)
- Flat
- WNh type Wolf-Rayet:
- Late-stage star; dying

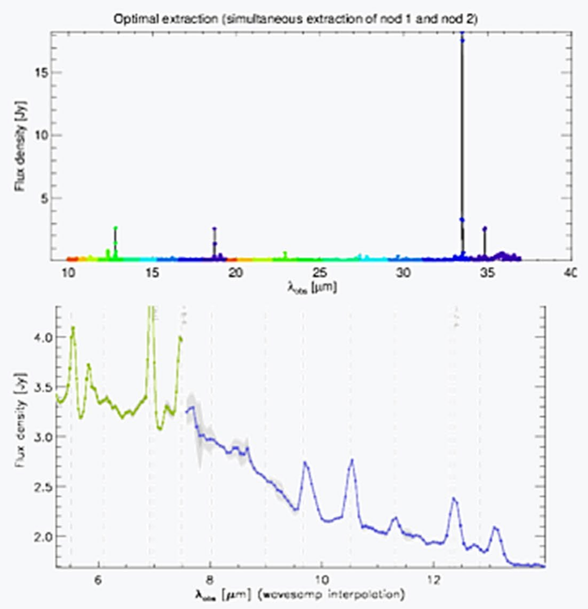
WR140:

Atomic emission features

- 10.51 microns: presence of sulfur (**S IV**)
- 15.56 microns: presence of neon (**Ne III**)
- 25.91 microns: presence of oxygen (**O IV**)
- 33.48 microns: presence of sulfur (**S III**)
- 34.81 microns: presence of silicon (**Si II**)
- Falling
- Came from the average O type star; not a specific type of Wolf-Rayet



WR140- Spectra in Low Resolution and High Resolution



WR124- Spectra in Low Resolution and High Resolution

References

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