VARIABLE STARS Variable Stars and Their Relation to Stellar Evolution

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BRIEF



Overview







Pre-Main Sequence: T Tauri & FU Orionis

Two of the main winter constellations, Taurus and Orion, contain new star forming regions.

For example, the Orion Nebula is home to an enormous number of young stars, and it is the light of the most massive of these stars that causes the nebula itself to glow.





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Pre-Main Sequence: T Tauri & FU Orionis

The most famous class of the pre-main sequence nebular variables are the **T Tauri stars.**

These appear similar to "normal" stars except for they are:

- Highly variable
- Less bright than expected from a star of their size and color
- Lie near gaseous nebulae

Their variability can be caused by a number of things but much of it is related to accretion of the protostar gas and dust falling on the protostar and accelerating.

As it falls toward the protostar, it heats up and as it gets hotter, it gives off more and more light until it impacts the surface, where it gives off even more light.

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Pre-Main Sequence: T Tauri & FU Orionis

Some pre-main sequence protostars are extreme in their lity: FU Orionis stars (or FUORs) and UX Orionis JXORs). haracteristics: Very large and very long-term brightness variations Can brighten by more than a factor of 100, and then fading variability: FU Orionis stars (or FUORs) and UX Orionis stars (UXORs).

FUORs

Characteristics:

- ٠ again over a course of years or decades.
- Origins of variations are believed to be rapid accretion of ٠ circumstellar material onto the young protostar for a period of a few years.
- Seem to be accreting material at a more rapid rate than • other protostars. This results in a larger release of energy as light and heat.

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Pre-Main Sequence: T Tauri & FU Orionis

Some pre-main sequence protostars are extreme in their variability: **FU Orionis stars** (or FUORs) and **UX Orionis stars** (UXORs).

UXORs

Characteristics:

- Almost the opposite of FOURs
- Variable on very short timescales, getting *dimmer* rather than brighter.
- Believed to be stars with circumstellar disks (as all protostars are at one point) where the disk is clumpy rather than uniform. Some of these clumps are large enough to partially obscure the protostar as they orbit around it, causing the star to dim.
- Believed that the clumps eclipse their parent star relative to our line of sight.

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The Main Sequence

Recall life on the *main sequence* begins at the point when hydrogen burning first begins, and ends when it runs out of hydrogen in its core.

Stars on the main sequence change very little over this span of their lives, although lots of important changes are happening during the fusion process.

Through Helio-seismology (measurements of pulsations of the Sun) we understand that stars fluctuate and pulsate.

The appearance and disappearance of "starspots" (Sun Spots on stars) results in a large change in brightness. These changes can even be periodic if the star is rotating and the spot survives for several rotation periods of the star. We can see variability due to star spots

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The Main Sequence

Delta Scuti stars: Pulsating Stars on the Main Sequence

Characteristics:

• About 1.5 to 3 times as massive as the Sun with varying pulsation periods.

RS Canum Venaticorum (RS CVn) and BY Draconis: Starspots

Characteristics:

• Dimming due to star spot variability.

UV Ceti: Stars w/ strong magnetic fields where flares are suspected

Characteristics:

- Strong magnetic fields
- Variations in time that may be recurring as the 22-year solar cycle is.





After the Main Sequence

At the end of Hydrogen fusion in the core, the Star attempts to regain its balance of internal pressure vs. gravity as other forms of fusion start.

The star will change dramatically in appearance during this time as it becomes a **red giant**, expanding in diameter, increasing in luminosity, and cooling in temperature.

Many stars going through these changes become true variable stars, or if currently variable, that variability may change or even cease altogether.

A main part of the H-R diagram post-main sequence that contains many variable stars is the **Instability strip.**





After the Main Sequence

Instability strip.

In the instability strip, a star may begin to pulsate as heat/energy from inside the star may become trapped thus increasing its temperature and pressure and making the star **pulsate**.

Research indicates that only stars within the instability strip have this pulsating layer at just the right depth to be observable to us.

Stars more than a few times the mass of the Sun cross the instability strip after the main sequence. These are the **Cepheid variables**, named after the class prototype delta Cephei.





After the Main Sequence

Instability strip - Cepheid variables

Characteristics:

 The period, time it takes them to complete one pulsation cycle, is proportional to the luminosity or absolute brightness of the star. If we can measure the period of the star, then we know its luminosity. This is known as the **period-luminosity** or **P-L** relation.

Instability strip - delta Scuti & RR Lyrae

Characteristics:

- Pulsate for exactly the same physical reason as the Cepheids, and both have their P-L relations.
- Used to measure distances within the Milky Way, and RR Lyrae stars are useful for measuring distances to globular clusters. Of the three, the Cepheids are the most luminous, and so we can see them at greater distances, often in galaxies millions of light + years away.
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After the Main Sequence

Instability strip – Non-regular pulsators

Characteristics:

- Not all pulsating stars are regular with well-defined period
- Most stars outside the instability strip are not strong and regular pulsators.
- Some red giant stars are pulsating variables, but don't have very strict periods, and don't have large amplitudes.

Instability strip – S Doradus stars

Characteristics:

- Enormous outbursts capable of blowing off their own outer layers into space.
- Example: Eta Carinae in the southern hemisphere & P Cygni in the northern hemisphere
- Occasionally undergo enormous eruptions, once every few centuries.





After the Main Sequence – Asymptotic Giant Branch

After the Giant Branch of the HR Diagram, high mass stars will pass through the Asymptotic giant branch (or **AGB**) in the last stage of stellar evolution where thermonuclear reactions are still occurring within.

Each layer of fusion is pushed to an outer layer, shells, by a new fusion process in the core. These burning shells are the main reason why AGB stars are so luminous; because the shell is closer to the surface, the outer layers become much hotter and so the star puffs up to enormous size.





After the Main Sequence – Asymptotic Giant Branch

Despite their size, they are very cool stars on the surface, and thus appear reddish in color.

Life on the AGB is short and some changes that occur to these stars on the AGB happen over a few centuries or a few decades.

AGB stars undergo occasional events called thermal pulses, where the layer of helium surrounding the core suddenly undergoes thermonuclear burning, causing large changes to the star's structure, its luminosity, and its temperature: *thermal pulses.*

Mira is the prototypical variable star in this phase.

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After the AGB

The last stage of a star's life as a self-contained star may be the RV Tauri stage, characterized by pulsations with periods between 30 and 150 days.

Some RV Tauri stars are known to have dust shells around them, and are headed toward becoming planetary nebulae and white dwarfs.

Their pulsations aren't regular, but instead seem to be chaotic with fairly regular cycles of maxima and minima and lightcurves that often don't repeat from one cycle to the next.





The End of Life

The last phases of a star's life depends on its mass.

Higher mass stars will end as supernovas.

Lower mass stars will shed the entirety of their outer shells leaving a white hot carbon shell called a White Dwarf.

Either of these paths can be studied through Supernova or Novae.





Summary

Stellar evolution is part and parcel with variability.

It is the underlying physical processes that cause the variability of these intrinsically variable stars.

Any of these examples can be lifelong, or event spurred, areas of study.

Their results are essential to better understanding current stellar theories.



Questions?