ZZ Ceti (ZZ)

ZZ Ceti are a class of non-radial pulsating white dwarf stars. Falling in the instability strip of the Hertzsprung-Russell diagram, these stars pulsate with periods of minutes (mostly, up to 25 minutes). These stars are difficult to study because of their faintness and small/rapid variability. They are characterized by modest luminosity variations (from 0.001 to 0.2 V magnitudes). Sometimes, up to 1m outbursts are detected, which can be explained by the close presence of an UV Cet component.

ZZ Ceti stars are divided into three subclasses:

- **ZZA** – hydrogen variables of spectral type DA, having only hydrogen absorption lines in the spectrum (ZZ Cet).
- **ZZB** – Helium variables of spectral type DB, having helium absorption lines in the spectrum (e.g. V1063 Tau).
- **ZZO** – variables of DO spectral type showing HeII and CIV absorption lines in their spectra.

On the H-R diagram, ZZ stars occupy the lower left part, and lie in a band roughly parallel to the main sequence, but several magnitudes below it.

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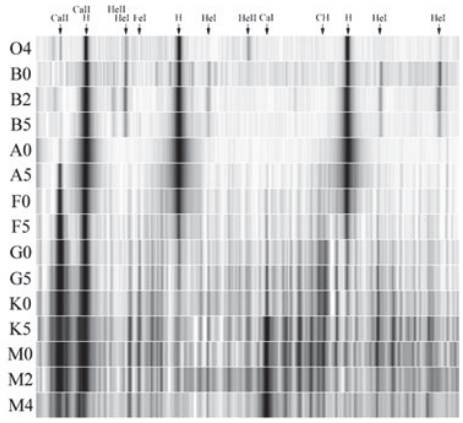
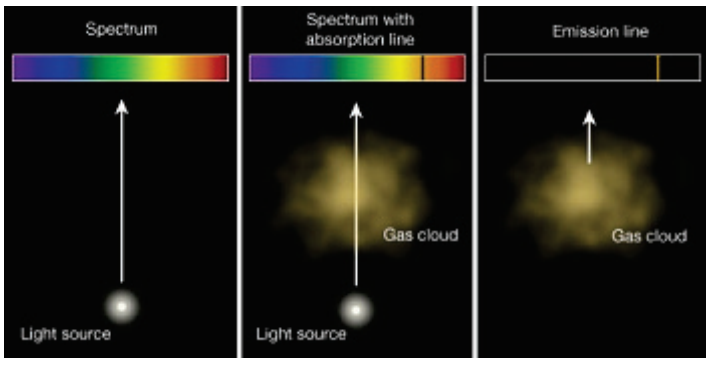
Stellar spectral classification: a brief story of early steps



Stellar spectra sequence, O to M.

While *Isaac Newton* (1643 – 1727) observed the continuous spectrum of the Sun, he missed the discovery of absorption lines. In 1802, *William Hyde Wollaston* (1766-1828) reported dark gaps between colors in the continuous spectrum. Later, *Joseph von Fraunhofer* (1787-1826) observed the Solar spectra more detailed and found that the dark gaps are different in strength. German physicist *Gustav Kirchhoff* (1824-1887) published his fundamental work in 1859, which explained the nature of the Fraunhofer lines in the solar spectrum and the composition of its atmosphere. In the 1860's, *William Huggins* (1824-1910) and his wife Margaret used spectroscopy to determine that the stars are composed of the same elements as found on Earth. Another classification scheme was proposed by Father *Angelo Secchi* (1818-1878) from Italy in 1863, who visually observed prismatic spectra of about 4000 stars and divided them into groups. By 1868, his classification defined four classes of stars. Group I was reserved for “blue-white stars showing hydrogen lines”, Group II represented stars with numerous metallic lines and yellow or orange stars like Capella or the Sun; Group III was added for orange to red stars. Group IV comprised of carbon stars. In 1877, Secchi added a fifth class for emission-line stars.

In the early XX century, astronomers began photographing the spectra of stars, but the diversity of spectral features was too confusing and complex to explain. *Edward Pickering* (1846-1919) re-arranged the spectral sequence, taking into consideration the changes in other lines. Building upon this idea, a team of astronomers at the Harvard Observatory, led by *Annie Cannon* (1863-1941), grouped similar appearing spectra together, designated by letters: A, B, C, etc. They also started a project on spectra classification. Soon, a smooth sequence of spectral types was found, and the assigned letters combined into O-B-A-F-G-K-M. For better distinction, the classes were further divided into subclasses, marked from 0 to 9 within the class. The results of that work, the Henry Draper Catalog, was published between 1918 and 1924.



An example of Kirchhoff’s three laws of spectroscopy. Image credit: The Pennsylvania State University

The early Harvard spectral classification system was based on the appearance of the spectra, but the physical reason for these differences in spectra were not understood until the 1930’s and 1940’s. Then it was realized that the main thing that determined the spectral type of a star was its surface temperature. *Cecilia Payne* (1900-1979) took the data from the HD catalog and discovered its physical significance: the great variation in stellar absorption lines was due to different amounts of ionization (differing temperatures), not different abundances of elements.

The spectral classification system used today is a refinement called the MK system, introduced in the 1940’s and 1950’s by Morgan and Keenan at Yerkes Observatory. A new feature was added to the classification – stellar luminosity classes (I to V), showing that stars with the same temperature can have different sizes.