Spica's HII Region

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Abstract

The geometry of stars and their surrounding regions will always be a challenge due to the way we can conduct direct observations from Earth. This situation is aided in the case of certain stars that produce a cloud of ionized material around them, the properties of which can be analyzed. It is known from observations by the Wisconsin Hα Mapper (WHAM) that the area around the star Spica is one such region which has a concentration of ionized hydrogen and its brightness is roughly 5 Rayleighs (Reynolds 1985). In the following years the same author made observations of different line brightness ratios including a Sulphur line (Reynolds 1988). Our goal is to use the photoionization modelling software Cloudy (version 17.01, Ferland 2017) to constrain the geometry of this region by ionizing a cloud using realistic stellar atmospheres and fitting Reynolds' observations. We vary the star's intensity on the cloud as well as the hydrogen number density. We have been able to fit Reynolds' observations of both Hα and a sulphur emission line giving a spacing on the order of a parsec for the star to the inner face of its nebula and a hydrogen number density of about 0.5 cm^{-3}.

What is Cloudy?

Cloudy is a photoionization simulator built by Dr. Gary Ferland of the University of Kentucky. It allows its user to specify a radiation source and properties of the target gas. Properties we have varied include; filling factor (a measure of "clumpiness"), number density of hydrogen, kinetic temperature, elemental abundances, and covering factor (how much of the radiation source's sky is covered by gas). The user can also specify what calculated parameters of the ionized gas will be outputted in the code's various files, as well as convergence and stopping parameters and boundaries.

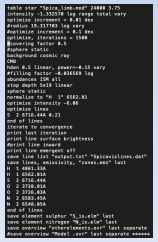
Background

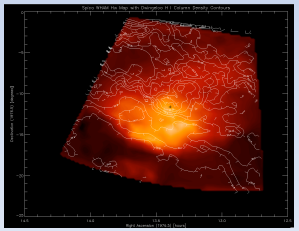
Spica was first noticed as a potential ionized gas region in 1974 due to a lower density of neutral gas in the area (Fejes 1974; Reynolds 1985). Since then WHAM has come online and more detailed observations have been made which produced the 5 Rayleigh (5R) value referenced previously.

Spica is a high galactic latitude star, meaning it is far from the disk of our Galaxy allowing for its study due to the lack of significant interstellar extinction. For reference, Reynolds (1984) gives the background hydrogen radiation levels as 1.4R.

Spica itself is an interesting star. It is a von Zeipel binary star, which means the two stars of the system orbit close enough to distort each other's shapes. In previous work, Dr. Aufdenberg was able to compile model atmospheres and spectra for these stars and produce one that matches the star's observed spectrum (in prep). It is these model spectra which we have been using to irradiate the model nebulae.

Upon matching the observations of the hydrogen and sulphur lines, we had Cloudy output a table of volume emissivities, a measure of the power output per unit volume of the gas. Following Cloudy's manual, we have then begun to build our own surface brightness plots.





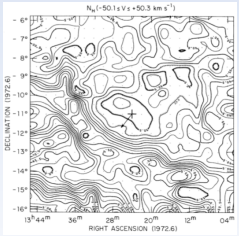


Figure 1 *(left top):* Sample Cloudy input script.

Figure 2 (*above*): WHAM map of Spica region ionized hydrogen (Haffner 2000)

Figure 3 (*left bottom*): 1973 plot of neutral hydrogen density in the vicinity of Spica (Fejes 1974).

Methods

Following the example of Park (2010), we integrate the volume emissivities along various lines-of-sight through the cloud to construct projected radial surface brightness plots. These plots are done according to the following equation where it is indicated that the emissivities are also a function of wavelength. That is, they vary from spectral line to spectral line.

$$S = \frac{1}{4\pi}\int \varepsilon(\lambda)dr$$

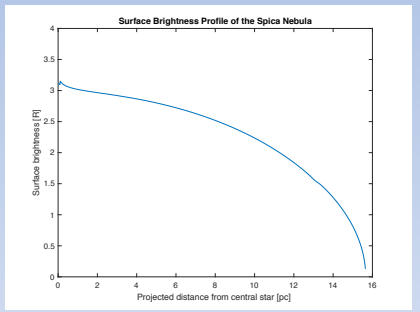


Figure 4: Surface brightness plot for Hα produced by integrating Cloudy volume emissivity data

The plot above was produced by integrating various lines of sight through the model nebula, in this case 1000 different parallel rays. The nebula itself spans more than 10º across the sky and is therefore spatially resolved. This plot is then an approximation to a sufficiently distant nebula, one our future work intends to resolve.

References

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