# Notes About the Spectra and their Analysis

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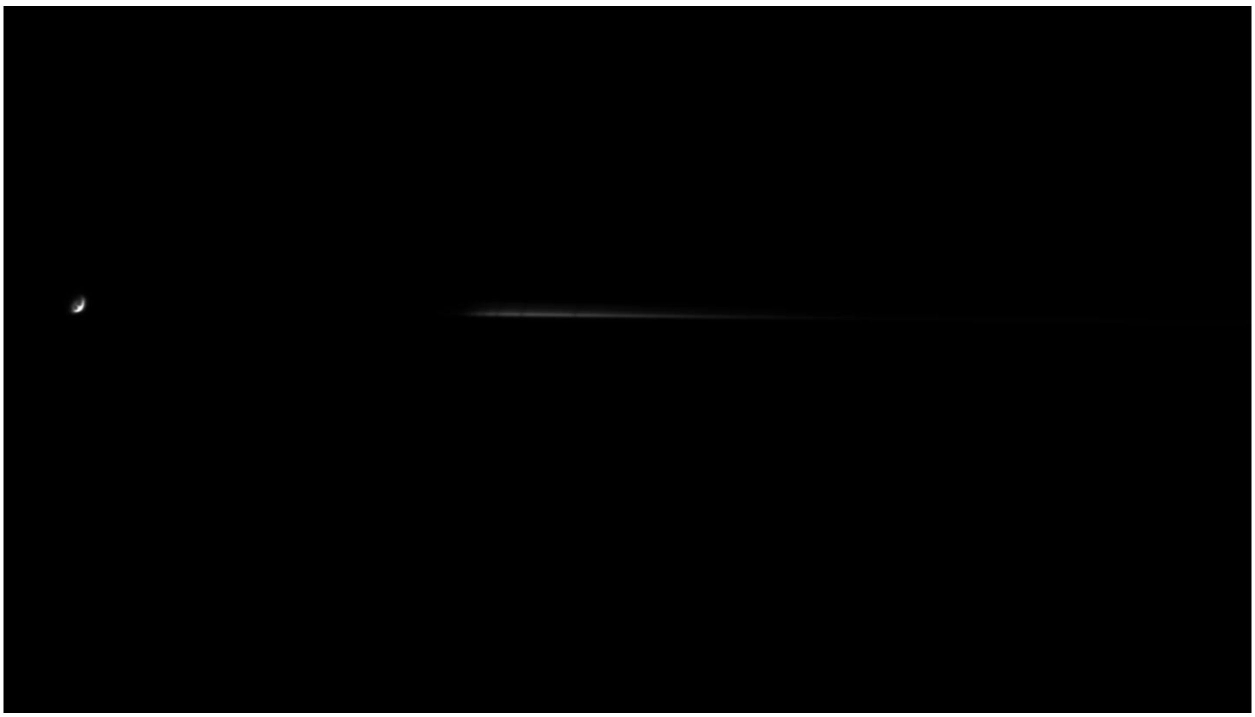
There are a couple things about the spectra or their acquisition and analysis that bear mentioning. A lot of this information is presented in books on astronomy, and may already be known to you. However, it is included here for those who may not be aware of it.

## *Image Defects*

The f/5 fast reflector that was used to obtain these spectra is not without its faults (as no scope is). The most impactive idiosyncrasies seem to be coma and field curvature. Coma creates a “gull-winged” image defect that worsens the nearer the object is to the edge of the field (or the farther from the center). Field curvature is due to the fact that the focal “plane” is actually not perfectly flat (at least, not without an additional lens/corrector being added to the optical system to compensate for it). So, you end up with the central area of the field of view being in focus, but the outlying areas are not.

To demonstrate this, consider this stacked image of a star and its spectrum:



This is a stacked capture of Alpheratz (Alpha Andromedae), a late B-type star. If you look closely, you can see that the spectrum appears to be fairly well focused. This is our main goal, since that is what we will analyze. Several of the bold hydrogen Balmer absorptions can already be seen in the spectrum as dark gaps in the band of light. Now, look at the star itself to the left. Why is the star not a point, but shows up instead as having wings? This is due to the image defects of the stystem.

In order to place the spectrum near the center of the camera field, the star must be moved to the left edge. This is where the defects make themselves fully manifest, so the star appears distorted. However, for our purposes this is largely irrelevant. As long as we can later identify what the “center” of the star is so we can perform a calibration, then we are golden.

The reason I mention this is because of the FOCUS. Obtaining the best possible focus for the spectrum (not the star!) is vital. So, if you are using a telescope that suffers from these types of image defects (because of its design or flaws in its manufacture), then take extra care when focusing. Get the SPECTRUM as sharply focused as possible and ignore the star. For most stars (except O- and early B-types), you can usually see small gaps or dips in the spectrum intensity through the camera preview. Use these to inform your focusing.

## *Stretching of Hα and Terrestrial $O_2$ Lines*

One peculiarity I can consistently see in my spectra is an apparent stretching in the red end of the spectrum. This causes the Hα and Terrestrial $O_2$ lines to appear much broader than expected. This may be partially due to the image defects discussed above, but may also be due to errors introduced when creating the instrument response curve. It is my intention to eventually track down the cause of this defect, but I must report that this will not occur until I have completed my initial constellation survey.

So, for the time being I beg your indulgence. Simply accept it as a consequence of my equipment and processing skills (or lack thereof).

## *Stellar Classification*

Stars are grouped into Stellar Types. Originally, these were arranged alphabetically by how strong their hydrogen Balmer absorptions were. The “A” stars had the strongest absorptions, followed by the “B” stars, and so on down the alphabet. However, it became apparent afterward that the different types actually represented a temperature scale when arranged differently. When arranged in this new way, with unnecessary types omitted, the order of temperature became:

**O-B-A-F-G-K-M**

This is a simple qualitative temperature scale, from hottest to coolest. This can be remembered via an old memory trick: “Oh, Be A Fine Girl/Guy, Kiss Me!” The hottest stars are referred to as “early” types, whereas the cooler stars are referred to as “late” types.

Within each type, a number is assigned ranging from 0 to 9. These represent smaller steps in the temperature scale. So, an A1 star is hotter than an A7 star, and a G0 star is hotter than a G5 star. In this way, a simple shorthand notation can qualitatively tell you where a star sits on the overall temperature scale. In a like manner to the types above, a B0 star is an “earlier” type than a B8 star.

Though I do not address this in my reports, it may be helpful to know that stars are also classified by their luminosity. In the most general sense, luminosity is a measure of how much total energy the star gives off. Smaller stars are less luminous than larger ones as they have less surface area radiating energy. Stars are grouped into “luminosity classes” indicated by roman numerals as follows:

| ***Luminosity Class*** | ***Star*** |
|---|---|
| 0 | Hypergiant |
| I | Luminous Supergiant |
| II | Bright Giants |
| III | Normal Giants |
| IV | Subgiants |
| V | Dwarfs or Main Sequence Stars |

This is not a complete list, but it should give you the general idea. This luminosity class is appended to the star's abbreviated type and number. For example, our Sun is a G2V star. Vega is an A0V star. Caph (Beta Cassiopeia) is an F2III star. Additional prefixes and suffixes can also be found attached to a star's classification, but these are really beyond the scope of the simple surveys I have conducted. Additional literature can be consulted for a full, detailed list of this notation.

A star's luminosity class can have an impact on features of its spectrum. Lines can be broadened, or perhaps rendered more shallow. However, I have again elected to mostly ignore this aspect during the surveys. Working with such low-resolution spectra, and not performing a normalization on the resulting curves, would make it very difficult to point out that a specific star belongs to a certain luminosity class based on the depths of un-normalized absorptions. However, it bears mentioning here so that you may know what these letters and numbers mean (even of only partially).

These two criteria together—the temperature rating and the luminosity class—constitute the two-dimensional MK, or Morgan-Keenan, classification system. The abbreviated notation provides an "at-a-glance" idea of a star's temperature and its luminosity class.

For the purposes of my own modest surveys, I usually just prefer to state a star's type letter, such as F or A, and a generalization of whether it is an "early," middle," or "late" example of that type. Here is a key to those references:

| ***Number*** | ***Designation*** |
| --- | --- |
| 0 | Very Early |
| 1-3 | Early |
| 4-6 | Middle |
| 7-8 | Late |
| 9 | Very Late |

This scale is of my own devising, and not official in any sense that I am aware of. So, if my analysis announces that a star is a late G-type star, then it is a G7 or G8 star. A G9 star would be considered a very late star. Getting more detailed than this with a simple, low-resolution spectrum seemed unnecessary and so was omitted.

## *Metals*

The term "metals" is used often in astronomy and astrophysics. However, the term means something quite different to us than it does to, say, a chemist. **Any** element that is heavier than hydrogen or helium is referred to as a metal. Thus we omit the two most common elements in our universe—hydrogen and helium. By this, many elements that are not considered metals elsewhere, such as nitrogen or oxygen, are called "metals" in the context of astronomy.

The ages and generations of stars are often determined by their metal content using this definition. Metal-rich stars are those with higher concentrations of elements heavier than hydrogen and helium, whereas metal-poor stars have low concentrations of them.

When identifying absorptions in spectra, it is common to refer to metals separately from hydrogen and helium. Bear this in mind when reviewing these spectra or evaluating your own.

## *Wien's Law*

Wien's Law was derived to demonstrate how temperature affects the peak energy wavelength of a blackbody. A blackbody is a theoretical body that absorbs 100% of the energy it receives when it is in thermal equilibrium. The Law dictates a lower peak energy wavelength as the temperature increases. Wien's Law is a simple mathematical formula that can be used for predicting the temperature based on the body's peak energy wavelength. The formula is very simple:

**T=(28,978,200/Peak Wavelength)**

For this simple equation, the temperature (T) is in Kelvin, and the Peak Wavelength is in Angstroms. So, if you know the peak wavelength, then you can very easily determine the temperature.

Though no star is truly a blackbody, if an assumption is made that it *is* one, then a rough estimate of its temperature can be calculated. More precisely, we are calculating the temperature *it would have if it were a blackbody*. This is called the Effective Temperature.

The problem with this assumption lies in the fact that stars are not blackbodies. Now, for some stars, the estimates can be pretty close. For others, though, they are wildly inaccurate. For relatively cooler stars—those classified as F-G-K-M—the estimates can sometimes be pretty close. For hotter stars—those classified as O-B-A—they are not. In fact, the earlier the star type, the more inaccurate Wien's Law will be in predicting its temperature. This discrepancy can also be partly explained by the fact that the equipment used is not sensitive to ultraviolet wavelengths. The hotter stars often have their highest energy output at lower wavelengths than the camera can register.

In my brief interpretations, I calculate the effective temperature of each target. This was initially done for my own benefit, so that I could see firsthand how close (or not) the estimates were for different types of stars (within the confines of the equipment utilized). Later on, I continued to include these estimates for the sake of consistency. Actual stellar temperature estimates are usually based on ratios of absorption strengths for more than one line, which would require both a higher resolution spectrum, and a careful normalization of the spectral curve so that the relative strengths of features are all shown to a consistent and standard level. Neither of these is currently within my grasp, so we work with what we have.

## *Conclusion*

Of course, the topics touched upon here can be expanded, even greatly so, and there are innumerable books dedicated to doing just that. Two of these are listed in the Bibliography below. My goal here is to give the most basic overview—just enough to help a newcomer understand the information presented in the reports. If anyone encounters questions along the way, feel free to contact me. I hope these brief notes prove useful.

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## *Bibliography*

*Spectral Atlas for Amateur Astronomers* by Richard Walker
*Spectroscopy for Amateur Astronomers* by Marc F. Trypsteen and Richard Walker