The Analysis of Spectra collected by the Spitzer Space Telescope

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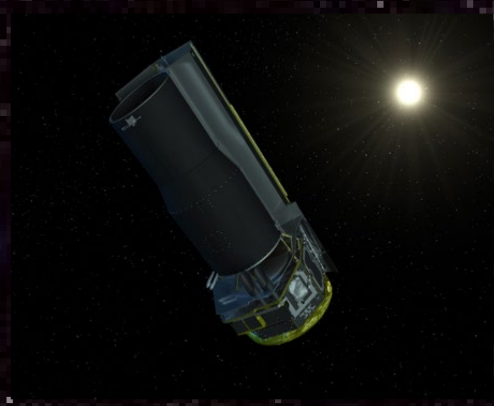
Spitzer Space Telescope

- The Spitzer Space Telescope, also known as the space infrared telescope facility, was launched in August of 2003, and was deactivated in January of 2020. It was originally designed to operate for 2.5 years.
- The primary mirror of the telescope is 85cm and is made from beryllium and cooled to -238°C.
- The telescope carries an Infrared Spectrograph that operated on wavelengths of 5.3-40 µm in 4 modules of different resolutions. Modules included detectors of 128x128 pixels.

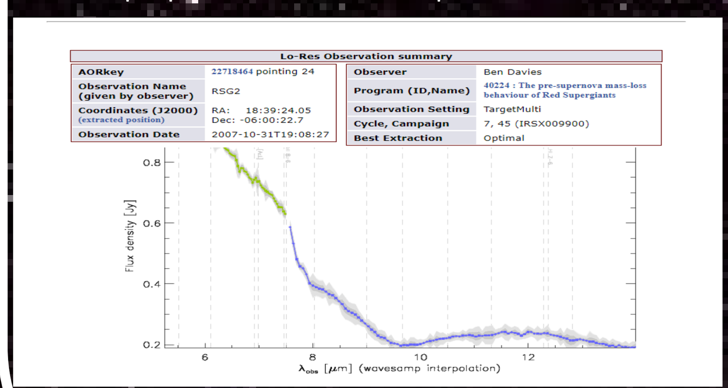


The James Webb Space Telescope

- The James Webb telescope was launched in December of 2021, 41 years after the Hubble space telescope. The JWT is planned to be used for 5-10 years.
- The James Webb has a 6.5 metre mirror, made from 18 different segments, which it uses to explore space in a higher resolution and better quality than the Hubble in the infrared. Its instruments are able to provide spectrographs which are studied back on earth.
- JWST is equipped with a fine guidance sensor/near infrared imager and slit-less spectrograph which can point precisely and obtain the high-quality images. The JWT uses a mercury-cadmium-telluride detector for its near-infrared sensor.

Identification of Features

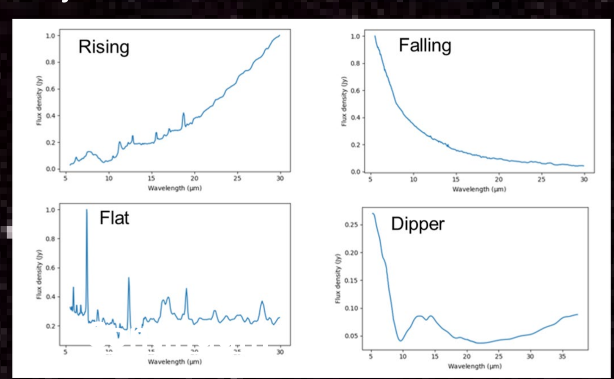
In order to start analysing spectral data and classifying the objects being viewed, a good understanding of the FEATURES that make up the data is necessary. The features in spectral analysis are specific shifts in the graph or ways that the graph flows that tell us a lot about what an object is, and the unique properties that make it special.



Actual Data

The Graph:

Before any features are analysed, first of all we must be familiar with the graph itself. The graph is a flux density-Wavelength graph. The graph represents the energy emitted by an object (flux density) for each wavelength of light in a specific region. Hotter objects emit more light at shorter wavelengths than colder objects.

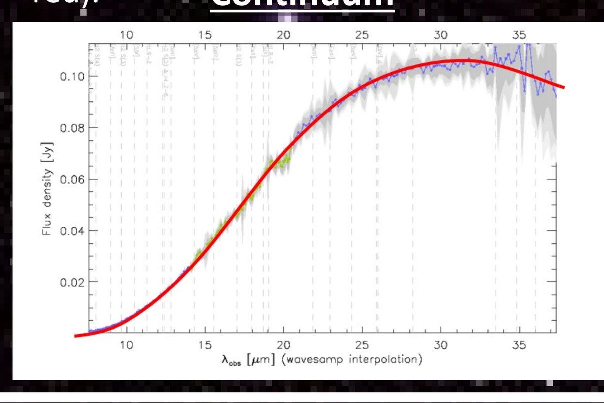


4 types of continuum

The features:

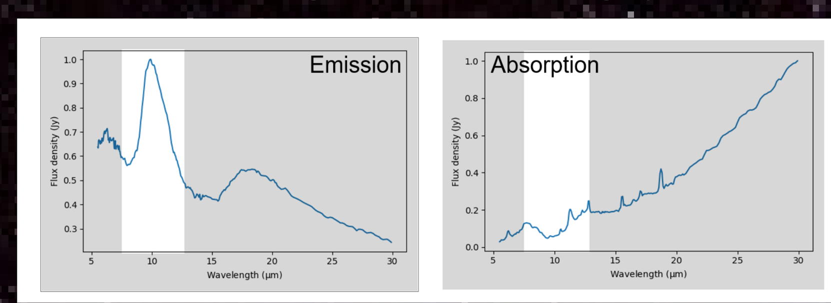
The first feature that is needed, is the continuum. The continuum is very important in understanding where a feature such as an absorption or emission is, and it provides a guideline for other important decisions when it comes to classification. The continuum can be seen as an imaginary line that isn't in the graph itself, but instead we draw to follow the general curve of the graph. A continuum looks like this (in red).

Continuum



The next key features come in a pair, and they are absorption and emissions. Absorptions can be viewed as the object releasing less energy, almost as if it were "eating the energy, therefore absorbing it". On the other hand, emissions are the object releasing energy, which are shown as rises in the graph, which are often sharp and extreme.

After this, there are the continuum-based features, such as stellar component or red excess. A stellar component is when the continuum starts high in the start of the graph and gently falls. A red excess is when the continuum finishes high in the end of the graph.

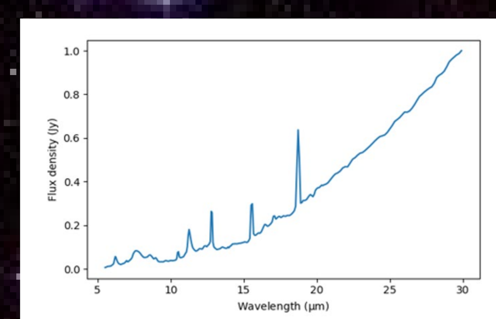


Emission/ Absorption

There are also atomic emission lines, which are tall and thin lines that shoot up off from the line of the graph as large emissions.

In addition, there is spectral noise which are outside factors (e.g., dust) that affect the data collected and make the true values unable to be recorded properly

Finally, red shift. The red shift value can be found on the CASSIS website by scrolling down below the graph and clicking on the sentence which says, "click here to access the pipeline information".

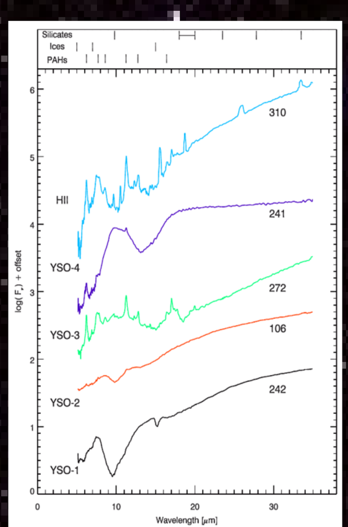


Atomic Emission

Classification

Forming Star

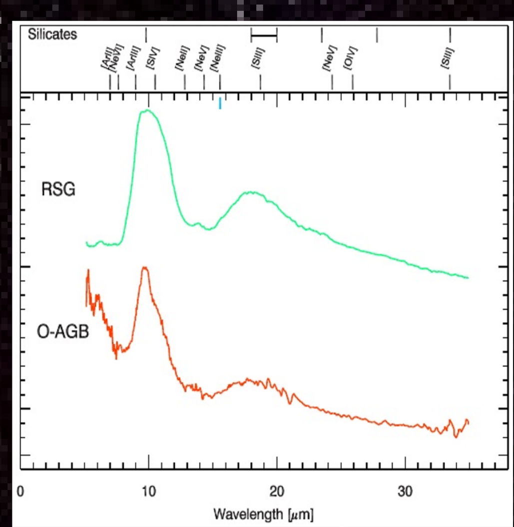
There are many types of Forming Star including: YSO-1, YSO-2, YSO-3, YSO-4, and HII. The types we focused on for our project were specifically YSO-1 and YSO-2.



YSO stands for Young Stellar Object which denotes a star early in its stage of evolution. A YSO-1 tends to be really cold with lots of dust present which causes broad spectral features. To identify a YSO-1 there must be a broad absorption in the spectra at 10 microns and another absorption at 15 microns. A YSO-2 on the other hand tends to only have the broad absorption at 10 microns. Forming Stars in general have an increasing continuum and continue to increase past 30 microns. If these conditions are not the case, then the spectra cannot be classified as a Forming Star.

Evolved Star

The sub-categories of Evolved Stars are Red Super Giant (RSG) and Carbon or Oxygen Rich Asymptotic Giant Branch (AGB). For this project we focused on the Carbon Rich/Oxygen Rich Stars and had to differentiate between the two. The interior structure of an AGB is characterised by a central and largely inert core of carbon or oxygen.



Carbon-Rich Evolved Stars have an absorption at 13.7 microns while Oxygen-Rich Evolved Stars have broad emissions at 10 microns and 18 microns which are described as "camel humps". Evolved Stars in general have a decreasing continuum and an absorption at 6 and 8 microns. If these absorptions aren't present, the spectra cannot be classed as an Evolved Star. After 15 microns, Evolved Stars also usually have a more gradual continuum.

Planetary Nebulae

A Planetary Nebulae is a type of emission nebula consisting of an expanding, glowing shell of ionised gas ejected from red giant stars late in their lives. Planetary Nebulae have an increasing continuum and flatten/dip past 30 microns.

Ordinary Star

Ordinary Stars have a decreasing continuum with no large emission or absorptions throughout the spectra. These are the easiest stars to identify due to the lack of features and easy-to-identify continuum.

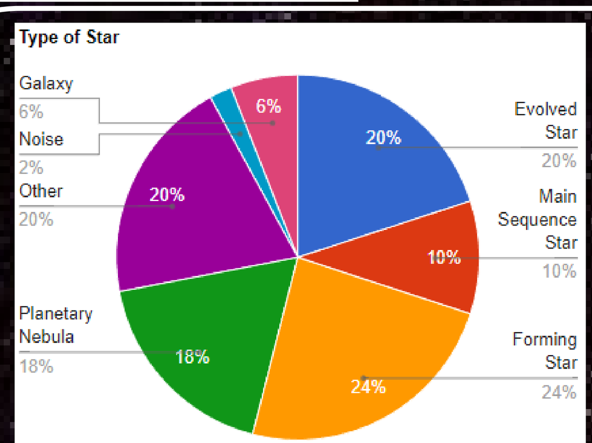
Unusual Objects

Some of the spectra picked up can be unusual objects that are classed as "other" during this project as we are not focused on these objects. One example is a R Coronae Borealis Variable Star where light given out by the star changes over time. Another example are Blue Supergiant Stars which are very large and bright stars that burn through their helium very quickly.

Spectral Noise

Sometimes it is not possible to make definite classification due to the measurements being too noisy. If the CASSIS "error bars" are too broad it can be hard to predict where the continuum lies.

Our Data

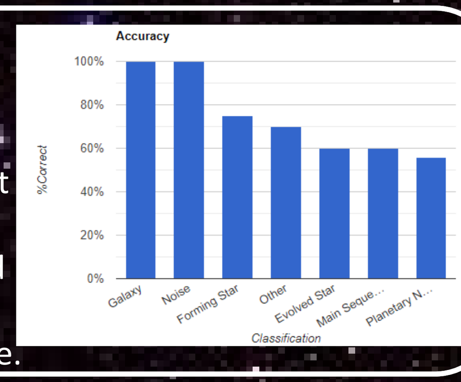


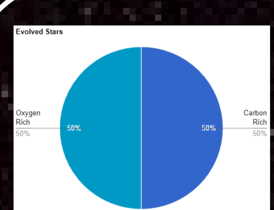
Our research, as shown above, has found that the most common astronomical object in the spectra captured by the Spitzer Space Telescope is the Forming Star/Protostar, at 24% of the total spectra. Close behind are Evolved Stars at 20% and Planetary Nebulas at 18%. Main Sequence Stars such as the Sun make up 10% of the astronomical objects observed with only 6% being identified as Galaxy's. This Leaves 20% of the spectra as unidentified object and 2% as random noise.

Accuracy

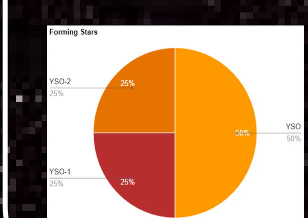
After getting the results back, we found that we were most accurate in identifying Galaxies and Noise with an 100% accuracy due to their distinct features and low probability.

Out of the more probable astronomical bodies, we were most likely to correctly identify Forming Stars with Other Unusual Objects not far behind with 75% and 70% accuracy respectively. We performed worse at identifying Planetary Nebulae with only a 56% success rate.





Of the 10 Evolved Stars Observed, 5 were Oxygen Rich while 5 were Carbon Rich, providing a 50/50 split.



Class 0 Young Stellar Objects dominate the forming stars, taking up 50% of the share while Class 1 and Class 2 YSO Stars equally take up the rest of the percentage.

Common Errors

Confusing Atomic Emission Features with Noise – Areas of Noise are enveloped by grey uncertainty while Atomic Emission Features are distinct narrow spikes.

Not recognising Broad Features – Features can be both absorptions and emissions and can also be quite subtle and hard to identify.

Next Steps

After analysing our data, we have been able to identify our major errors and become more proficient at both drawing a continuum and recognising features such as Stellar Components, Red Excess and Atomic Emission Features. This project has allowed us to develop our teamworking skills as a lot of co-ordination is required to collectively analyse and decipher spectra in an efficient manner.

It has also given us vital insight into the current developments of the Physics world with the new success of the James Webb Telescope replacing Spitzer Space Telescope.

This has bolstered our interest in the subject and has got us excited to receive more data to analyse and identify. We will carry all our knowledge from our research so far and use it to better identify spectra in the future, as well as in any other physics ventures that we are sure to pursue in the future.

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Special Thanks: Hassan Ali