A survey on the spectrum of 23 Non-YSO (Young Stellar Objects) emission sources in the Orion Nebula Cluster

- Serat Saad

Final Project (ASTR 8060)

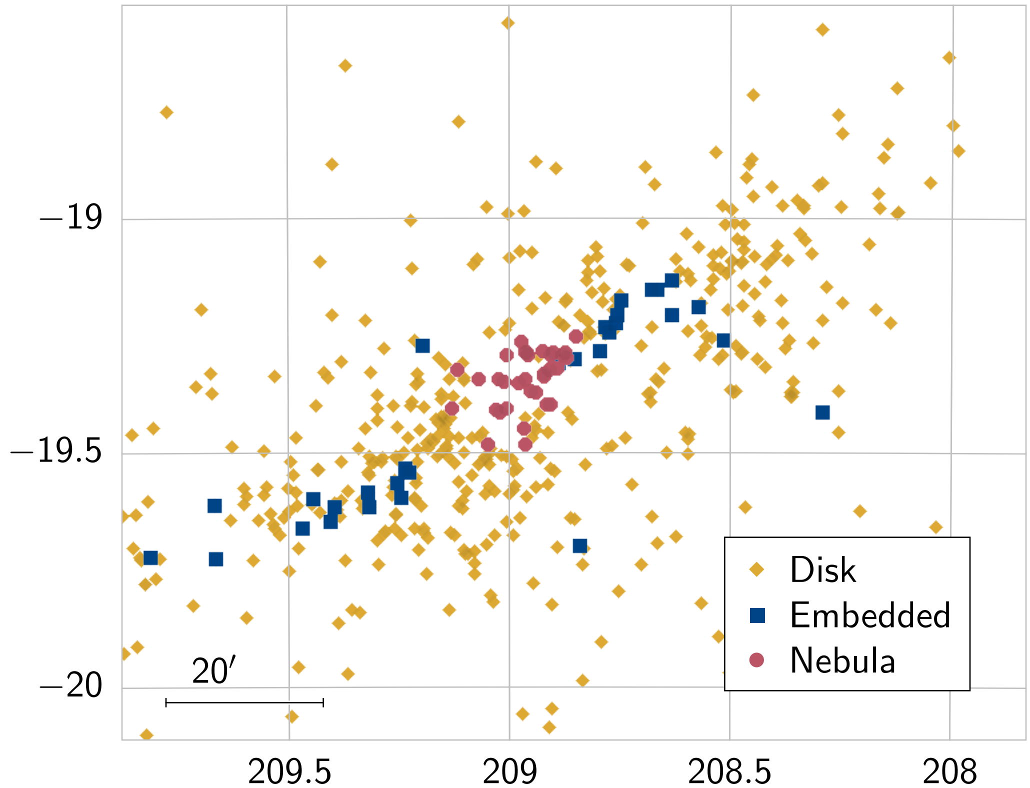

Figure 1: Disk, embedded, and nebula sources in the Orion nebula region (adapted from Kounkel et al, 2023)

Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

Orion Nebula Cluster, known for its rich population of Young Stellar Objects (YSOs), presents a unique opportunity to study star formation processes. This region's diverse star-forming environments make it ideal for analyzing the spectra of Class I and II YSOs, which are known for their stellar disks and accretion processes. We have already been able to do a low resolution spectra survey to separate the disk sources and other sources in that region (Kounkel et al, 2023). During this survey, it has been found that a total 23 of the sources in that region shows emission spectrum but are not YSO candidate. These sources have been identified as non YSO based on their spectra, specially the Hα emission line and LiI absorption line. The true nature of their disk is still unknown because of previous low spectrum survey. The the resolution of the spectrum of all sky survey that was done in that previous study was very low ($R \approx 1800$). So, there's a high chance that the spectrum has been wrongly identified as a non YSO. But an alternate hypothesis can also be that the objects are actually not YSO and are OB stars or any other disk emission sources. The objective of this study is to understand these accretion processes of these sources better by calculating the veiling of spectra (like Gregory et al, 2023).

Veiling: Veiling is the ratio of accretion flux to photospheric flux at a given wavelength which provides insights into the strength of accretion disks.

So, if veiling is r_λ, accretion fluf is $F_{acc,\lambda}$ and photospheric flux is $F_{phot,\lambda}$,

$$r_\lambda = F_{\mathrm{acc},\lambda}/F_{\mathrm{phot},\lambda}$$

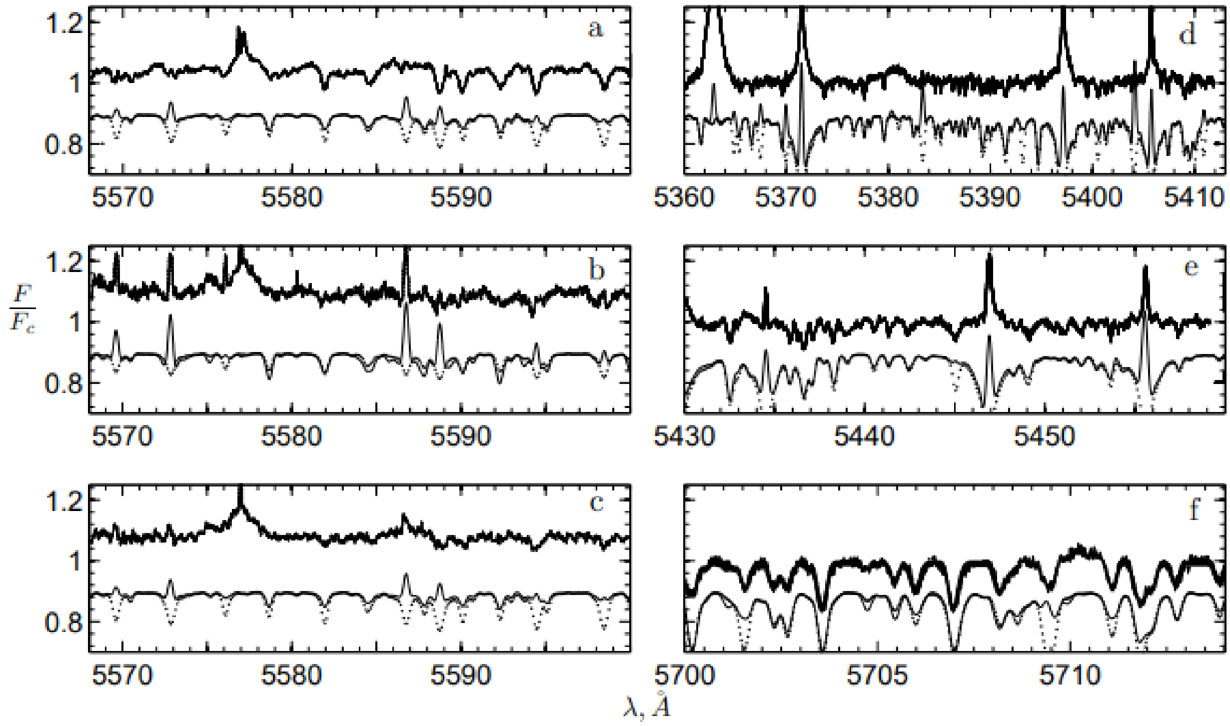

Figure 2: Calculated and observed spectra of heavily veiled six different sources (adapted from Dodin et al, 2012). The thick curve indicates the observed spectrum, while the thin solid line indicates the spectra of the models from the table. The dotted line indicates the spectra of the same models calculated by disregarding the emission in lines.

By comparing observed spectra to established models, we aim to derive the accurate veiling of the sources which will help us classify the strength and nature of the accretion disk. This strength and nature of the disk will lead us to find out certain characteristics of the stars like calculating the disk temperature and surface gravity by comparing it with exisiting models (like Campbell H, 2023). These characteristics will lead us to further conclusion on how we can compare them with Young Stellar Object (YSO) emission.

References

Campbell, H., Khilfeh, E., Covey, K. R., et al. 2023, ApJ,900 942, 22.

Dodin, A. V., & Lamzin, S. A. 2012, Astronomy Letters, 38, 649.

Gregory J. Herczeg et al 2023 ApJ 956, 102.

Kounkel, M., Stassun, K. G., Hillenbrand, L. A., et al.928 2023a, AJ, 165, 182.

Kounkel, M., Zari, E., Covey, K., et al. 2023b, ApJS, 266, 10.

Kwan, J., & Fischer, W. 2011, MNRAS, 411, 2383.

Experimental Design *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification?*

We have a target of 23 sources - all in the Orion nebula region that were found to be emission sources but non-yso candidates (Kounkel etal. 2023). We are planning to get high resolution spectrum of these sources so that we can calculate veiling and other properties of these sources to compare them with YSO candidate. These properties include specifically the temperature and surface density of the disk. To compare the spectral width with a model, it's very important that we have a high resolution spectra. We are planning to use IGRINS-2, available at both Gemini North and Gemini South, for its capability in high resolution. Another important reason is that IGRINS-2 will cover the spectral region that we are targeting for. We are also planning to target for a $10 \sim 13$ magnitude limit as that will give us the best YSO spectrum considering lower exposure time based on the region (Orion nebula) that we are targeting for.

The H-band (1.49-1.80 micrometers) and K-band (1.96-2.46 micrometers) wavelength range of IGRINS-2 are ideal for studying YSOs. These bands are less affected by interstellar dust extinction, allowing us to observe regions obscured in optical wavelengths. These bands also include key spectral lines and features relevant to YSOs, such as molecular hydrogen emission, CO overtone bands, and Brackett series lines, which are essential for studying accretion processes, disk properties, and outflows.

A high spectral resolution like IGRINS-2 ($R \approx 4000$) will enable us to resolve fine spectral details, crucial for accurately measuring line profiles, velocities, and widths. This can provide insights into the kinematics of accretion disks and outflows. High resolution will also help in calculating the most accurate veiling which is vital for studying the environments around YSOs.

Also, the adequate spectral sampling in IGRINS-2 ensure that each spectral feature is well-represented across several pixels, enhancing the quality of the spectral data and allowing for precise measurements.

The Gemini telescopes' locations are advantageous for observing Orion, given the position of Orion near the celestial equator. This setup will allow a detailed spectral analysis of the YSOs, enhancing our understanding of their accretion processes and disk properties. We don't necessarily need to use both these telescopes as Orion is located near the Celestial equator and any of these telescope can be used for the observation.

The target YSOs are within the magnitude range suitable for IGRINS-2, with coordinates based on (Kounkel et al., 2023). The coordinate that we are targeting for all 23 sources is given in Table 1. The J, H, and K band magnitudes are also given in the same table. These magnitudes were collected in the last time these objects were studied (Kounkel et al, 2023).

No.	**RA (J2000)**	**DEC (J2000)**	**J Magnitude**	**H Magnitude**	**K Magnitude**
1	81.67344	-0.68123	12.358	11.642	11.379
2	82.83596	-0.82218	12.133	11.221	10.55
3	83.0266	-1.18337	11.78	11.026	10.449
4	83.46863	-1.2674	12.849	12.135	11.86
5	83.74821	-0.31663	12.424	11.647	11.302
6	82.74104	-0.67716	12.441	11.556	11.086
7	83.3738	-1.17832	12.526	11.758	11.454
8	84.31109	-1.03071	12.602	12.029	11.708
9	82.30297	-0.17189	12.649	11.93	11.74
10	82.63803	-2.35194	13.081	12.497	12.171
11	80.48922	0.19505	12.67	11.672	10.917
12	82.69984	-1.45327	13.881	13.252	13.026
13	83.29713	-0.62808	13.148	12.495	12.147
14	83.25821	-0.34984	11.989	11.115	10.551
15	81.12437	0.39607	12.704	12.016	11.73
16	81.2036	0.53855	12.602	11.78	11.145
17	83.60988	-0.56424	12.804	12.139	11.88
18	82.52106	-2.25645	11.92	11.267	11.044
19	81.43542	-1.32287	12.539	11.867	11.603
20	82.33883	-0.47665	12.786	12.152	11.893
21	82.50549	-0.34623	12.323	11.681	11.256
22	83.41696	-1.58486	13.57	12.822	12.586
23	84.44592	-0.35335	11.846	11.042	10.553

Table 1: Coordinates and magnitudes of targeting 23 sources.

Technical Justification *Describe the observations to be made during this observing run. Justify the specific telescope, the exposure times, and the constraints requested (seeing, cloud cover, sky brightness, and, if appropriate, water vapor). If applying for instruments on both Gemini North and South, state the time request for each site. If a Band 3 allocation is acceptable, give the Band 3 time requested from each partner.*

The technical approach draws inspiration from high-resolution studies focusing on a specific region. IGRINS-2, with its high spectral resolution, is ideal for this study. The exposure time will be calculated to achieve an optimal signal-to-noise ratio, allowing for precise veiling measurements.

Exposure time calculation:

We're aiming for a signal to noise ratio of 50 $\sim$ 100 as that would be the best to compare it with the existing model to get the veiling and other main properties like . We are also targeting for a K magnitude of 13 based on the values in the Table 1. Based on these information and the configurations for IGRINS -2, we need a total exposure time of $\sim$ 10400 s or $\sim$ 2.89 hours for a signal to noise ratio of $\sim$ 100 (the best that we need). But we can reduce the signal to noise to 83 to reduce the total exposure time to $\sim$ 7200 s or $\sim$ 2 hours as that would be sufficient for our study. The spectrum can be collected targeting the coordinate region given in the Table 1.