Estimating the gas density of the Orion nebula

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The Orion nebula is divided into two main regions: the large fan-shape object, and the bubble next to it. The second object is a Strömgren sphere (a sphere of ionized hydrogen).

Can we estimate the average density of M42 using the approximation of the density of the Strömgren sphere?

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Measuring density via extinction

To calculate the density of M42, we look for an increase in density in the line of sight from Earth to the nebula. Higher frequency light gets refracted and absorbed more in interstellar gas than that of lower frequencies. We looked at the difference in magnitude of the stars marked in figure 1 in the B and V filter. With the formula below, *'reddening'* can be calculated: [1]

$$E_{B-V} = (B - V) - (B - V)_0$$

The reddening is directly related to the column density of the line of sight, which with known limits in distance can be used to calculate the average density of an area.

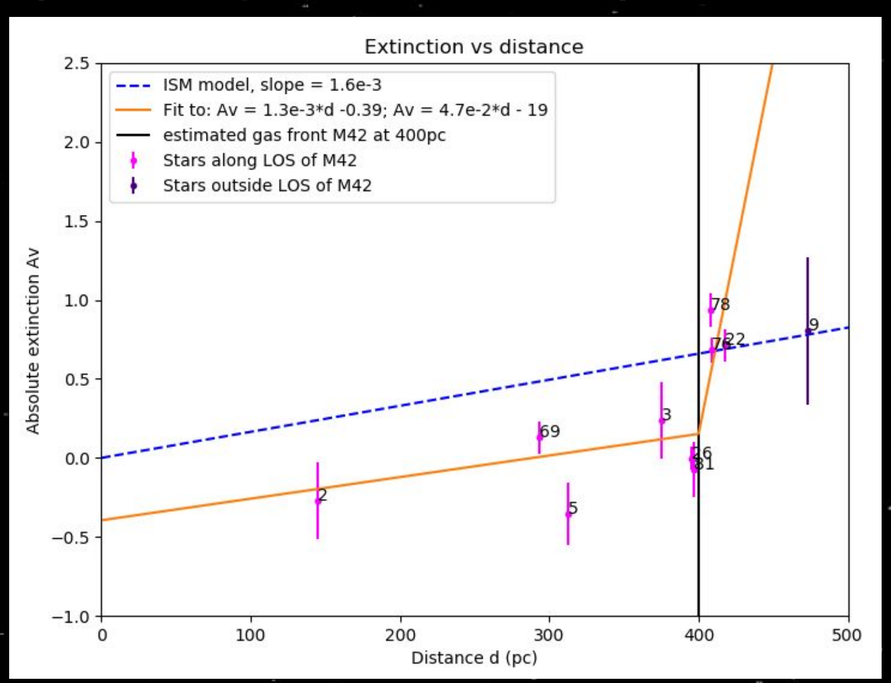

Fig. 2 Fit to the measured absolute extinction versus distance in orange. In blue the predicted extinction for the ISM model, with gas density of 1.0 cm-3. In black the estimated distance to the nebula. Note that the data and fit show negative extinction values, which should not be possible.

Density of the Strömgren sphere in M42

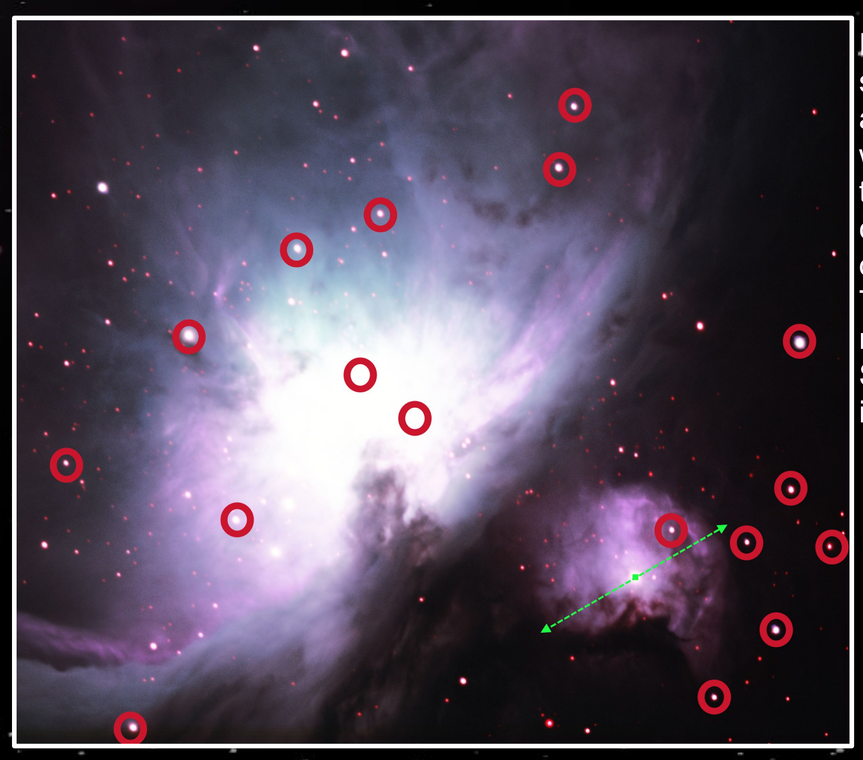

Fig.1 Colored photo of M42, shot in (R,V,B,I,SII) 30 x 60s, and (OIII,Hα) 15 x 60s, shot with the RCOS 20" telescope, and the FLI camera (with a field of view of 0.5 degrees). The stars in our sample are marked in red. The Strömgren sphere diameter in green.

$$Q_* = \int_{0.3e-9}^{9.6e-9} \frac{L_\lambda}{E_f} d\lambda \approx \int r_r dV$$

Amount of ionising photons emitted per second.

Strömgren radius, estimated from HII data

$$R_s = \left(\frac{3Q_*}{4\pi\alpha_H n^2}\right)^{\frac{1}{3}}$$

Constant pertaining to the recombination rate r_r of hydrogen, $r_r = \alpha_H n^2$

Particle density of ionised hydrogen, the objective of this research

An estimate of the Strömgren radius of star HD37061 (spectral class O9V) was made from figure 2. The integral for Q_* starts at 3 nm to prevent zero division; 3 nm< does not contribute significantly to Q_*. Then, using a number of assumptions about the gas and its ionisation, a particle density n of ~ 6.9e2 cm⁻³ ± 2.2e1 was found, a factor 2 off from Simón-Diaz et al.[2] See table 1 for the values used.[3]

	Value	Error		Value	Error
T_{eff}	30000 K *	500	α_H	2.6e-19 m³ s⁻¹	2.0e-20
L_*	30000 $L_\odot$*	500	Q_*	1.1e48 photons s⁻¹	5.5e39
λ_{ion}	9.6e-19 m	-	R_S	1.3e16 m	2.7e14

Table 1 * Estimated from spectral type.

Results & Discussion

- Strömgren density: 6.9e2 cm⁻³ ± 2.2e1
- ISM density estimate: 0.83 cm⁻³
- M42 density estimate: 2.9e1 cm⁻³

No error on the ISM and M42 density estimates could be obtained due to too little usable stars. The ISM density estimate agrees with the model value. The estimate for M42 is on the low side for nebulae and an order of ten smaller than the density derived from the Strömgren sphere. The derived extinction values
should not be negative. Causes for this could be one or more erroneous measurements, faulty data, or an overlooked systematic error. Furthermore, our sample size was more limited than hoped due to largely unusable data. Overexposed stars and stars that were not within one sigma of the Simbad data were excluded from the research. The low density estimate of M42 could be explained in part by the fact that the sample is primarily located at the front edge of the nebula.[4]

Conclusion

We conclude that the measured gas density of M42 via extinction differs by a factor 23 from the Strömgren gas density. However, considering the limited amount of data for the extinction map, the research question cannot be answered with certainty. Future research should aim to include more stars at a greater variety of distances, as well as determine exact values for the assumptions on the Strömgren sphere where possible.

References:
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