Measuring the radio-frequency emission line of the Orion A H_{II} region

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Abstract

The emission spectrum from the Orion A H_{II} region is analysed. The frequencies associated with the main emission lines are calculated, and the responsible energy level transition is calculated. The associated electron temperature and turbulent velocity are calculated.

1 Introduction

The weak signal strength received in radio astronomy makes measuring radio-frequency lines difficult. One solution to this problem is analyse the Fourier transform of the autocorrelation function of the signal. The result is a power spectrum plotted against the velocity with respect to the local standard of rest, which admits investigation.

2 Theory

Spectra are observed in pairs in order to eliminate instrumental effects. These effects are due to bandpass ripple, the roll off of the filters and reflections within the receiver system(Gaylard, 2005b). One spectrum is measured by directing the spectrum at the receiver, and the other is measured with the receiver aimed elsewhere. In order to counter noise at the 2.5 cm wavelength, 4 pairs of measurements are taken, normalised and then averaged for both the on-source and off-source results. The off-source results are then subtracted from the on-source results, the difference normalised according to the off-source results and then denormalised using the on-source system temperature. This process is reflected in equation 1. This data is then baseline corrected and has gaussians fitted to it as shown in Carr (2005). The number of gaussians to be fitted depends on the number of emission lines.

When an electron jumps down an energy level, radiation is released. The Rydberg equation, equation 2, is used to calculate the frequency of the emission.

$$\text{Difference Spectrum} = \frac{(A-B)T_{sysA}}{B} \quad (1)$$

$$\nu_{ki} = Z^2 R_M(\frac{1}{i^2} - \frac{1}{k^2}) \quad (2)$$

$$R_M = \frac{R_\infty}{1 + \frac{m_e}{M}} \quad (3)$$

where i & k are energy levels, Z is the effective charge on the nucleus, m is the effective mass of the nucleus, m_e is the mass of an electron and R_∞ is the Rydberg constant.

The emissions we are most likely to detect are the α lines, which correspond to an energy level jump of n + 1 → 1

There are two emission lines in the spectrum we are looking at. If we assume we are looking for α lines, choosing a value of i in equation 2 sets the value of k. i and k must be integer values.

We discover the correct values by subtracting the calculated emission frequency from the true emission frequency and varying the i and k parameters in order to minimise this error.

We know what the correct i and k values are, so we substitute in these values and then use solver to vary these quantities in order to minimise the error. Since the initial value we select is correct, there is insignificant deviation from this point.

Once we have fitted our data, and determined ν_{ki} we can calculate the electron temperature using

$$T_e = (6985(\frac{\nu}{GHz})^{1.1}(\frac{1}{1 + \frac{N(He^+)}{N(H^+)}})(\frac{T_{ac}}{T_{al}})(\frac{\Delta v_{\frac{1}{2}}}{kms^{-1}})^{-1})^{0.87} \quad (4)$$

(5)

This quantity enables us to calculate the turbulence velocity of the source after rearranging the following equation and solving for v_t .

$$\Delta v_{\frac{1}{2}} = \sqrt{0.04576 T_e + v_t^2} \quad (6)$$

3 Procedure

The Orion A H_{II} region was studied at the 2.5 cm wavelength. Four pairs of readings were taken with the receiver directed at the source. Another four were taken with the receiver directed away from the source.

The data was processed as discussed in the theory.

4 Results

We verified that the transition we are witnessing is from energy level 82 to 81.

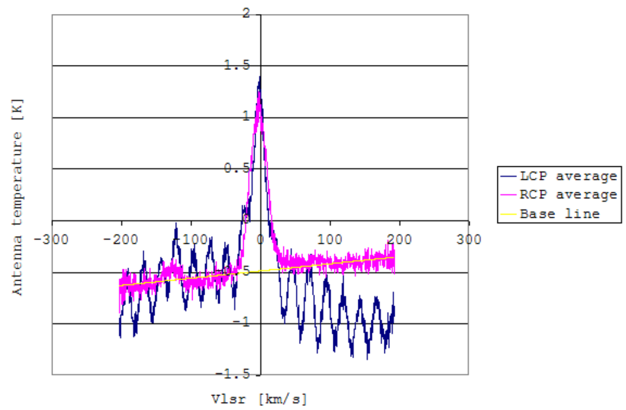

Figure 1: The original data and fitted baseline

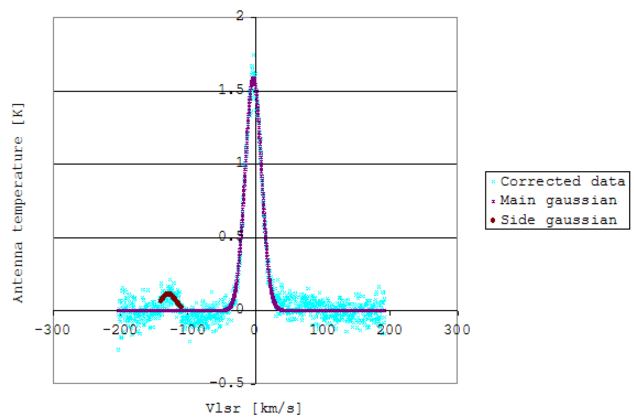

Figure 2: The corrected rcp data and fitted gaussians

	Main gaussian	Side gaussian
R_m [Hz]	3.288052E+15	3.289391E+15
ν_{ki} [Hz]	1.214866E+10	1.215361E+10

Table 1: ν_{ki} for i = 81 and k = 82

T_e [K]	9200 ± 920
v_t [km s^{-1}]	19.6 ± 1.9

Table 2: The electron temperature and turbulence velocity

5 Discussion

The erratic lcp data shown in figure 1 deviates from theoretical predictions and is probably due to a systematic error. It is therefor discarded and the investigation focuses on the rcp data.

There are two clear gaussians shown in figure 2. The large gaussian corresponds to the Hydrogen line, and the small gaussian on its lefthand side corresponds to the Helium line.

Substituting the values 82 and 81, into the equation for ν_{ki} automatically minimised the error, and subsequent searching with Solver introduced negligible deviations in these values in the 4th decimal place.

The calculated electron temperature shown in table 2 fits within the predicted temperature range of 5000 - 10000 K for H_{II} regions (Gaylard, 2005a).

6 Conclusion

The spectrum of the Orion A H_{II} region was analysed. The main emission lines had gaussians fitted to them and the source transitions were discovered to be the jump from the energy level 82 to 81. The turbulence velocity and a plausible electron temperature were calculated.

References

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