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Study of the forbidden oxygen lines in a dozen comets observed at the VLT (ESO)

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1. Introduction

Oxygen is an important element in the chemistry of the Solar System objects given its abundance and its presence in many molecules including H_2O which constitutes 80% of cometary ices. The analysis of oxygen atoms in comets can provide information not only on the comets themselves but also on our Solar System. Oxygen atoms in the coma are produced by photo-dissociation from the Solar radiation of the parent molecules coming from the sublimation of the cometary ices. These atoms have been analysed using the 3 forbidden oxygen lines observed in emission in the optical region at 5577 Å (the green line), 6300 Å and 6364 Å (the red lines) [1].

The forbidden lines are difficult to analyse because their detection requires high spectral and spatial resolutions. Their analysis is however interesting because it allows the determination of the spatial distribution and the production rate of the parent molecules, supposedly H_2O which doesn't have any feature in the optical range. But as shown by Cochran [2] [3], some issues remain about the nature of the parents of the oxygen atoms. Moreover the width of the green line was found larger than that of the red lines. One of the goals of this study is to determine the parent species that photo-dissociate to produce oxygen atoms and see how this process depends on the heliocentric distance. We present here the results of the analysis of a homogeneous set of high quality spectra of 13 different comets observed with UVES at the ESO VLT since 2002 [4] [5].

2 Observations

Our analysis is based on a sample of 13 comets of various origins (external, new, Jupiter family, Halley type). The observing material is made of 86 high signal-to-noise spectra obtained with the high resolution UVES spectrograph (Ultraviolet and Visible Echelle Spectrograph [6]) at the ESO VLT. The spectra were recorded with the same instrumental setting and reduced using the same procedure, keeping the spatial information. Final 1D spectra were extracted and flux calibrated.

3 Results

We measured both the intensity and the Full Width at Half Maximum (FWHM) of the three oxygen lines using the 1D spectra. The line widths were corrected for the instrumental broadening. The line intensities are measured to evaluate the ratio of the two red lines and the ratio of the O(^{1}S - ^{1}D) intensity (green line) to the sum of the O(^{1}D - ^{3}P) intensities (red lines). The red doublet intensity ratio has an average value of 3.11 $\pm$ 0.10 considering the whole sample. This result is in very good agreement with the theoretical value of the branching ratio of 3.096 given by quantum mechanics [7]. We obtain an average value of 0.12 $\pm$ 0.08 for the intensity of the green line over the sum of the intensities of the red lines. This result confirms that H_2O molecules are the main parent species of oxygen atoms regarding the Festou and Feldman effective excitation rates [8]. However, we noticed that the value of the latter ratio was larger than the average for C/2001 Q4 (NEAT). This comet was observed when it was at a large heliocentric distance (3.4 AU). Since the sublimation of molecules depends on the distance to the Sun, we assume that in this case, oxygen atoms could come from at least one other parent molecule. To confirm these observations, we have observed in May with the UVES spectrograph the comet C/2009 P1 Garradd at 3.2 AU from the Sun. Data are at time of writing under analysis.

Table 1 lists the average intrinsic FWHM for the 3 forbidden oxygen lines. As expected, the red line widths are equal. But, as shown in figure 1, the green line is wider than the red ones while we would expect the opposite as already shown by Cochran [2] [3]. We will present some assumptions to explain this discrepency and we will discuss the possibility of a blend of the green line with a C_2 line.

Oxygen lines (Å)	**FWHM**$_{intrinsic}$ (km s^{-1})
5577.339	4.45 ± 0.11
6300.304	2.37 ± 0.09
6363.776	2.51 ± 0.10

Table 1: The instrinsic Full Width at Half Maximum. Errors correspond to the standard deviation of the mean.

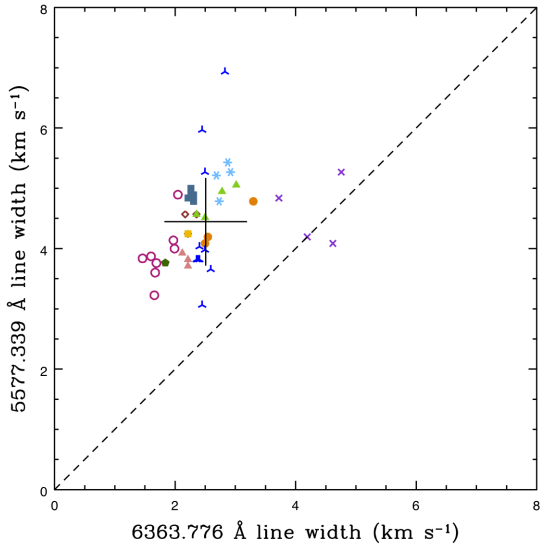

Figure 1: The green line width versus the width of one of the red doublet lines. Spectra belonging to a given comet are denoted with the same symbol.

Acknowledgements

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