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Molecular gas dynamics in the Rosette Nebula

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Abstract. We present observations of the Rosette Nebula and its near environment in the CO 3–2 transition obtained with an angular resolution of 20″. The gas dynamics of the region are complex; we find (1) a ring of gas expanding at about 20 km s^{-1}, (2) a number of collimated outflow sources, and (3) a chain of dust clumps having a velocity gradient along its length.

Keywords. ISM: molecules, ISM: kinematics and dynamics, instrumentation: detectors

1. Observations and Data Reduction

The Rosette Nebula, at a distance of 1400 pc, is a textbook example of the interaction between OB stars and surrounding gas and dust. NGC 2244, the central star cluster, contains six O-type stars with a total luminosity of 1000 $L_\odot$.

The data were obtained in 2006 and 2007 using a completely new suite of instrumentation at the James Clerk Maxwell Telescope (JCMT), on Mauna Kea, Hawaii, following major upgrades to the telescope and its observing capabilities. HARP, a 16-receptor (square 4×4) array receiver (Smith *et al.* 2003) operating in the 325–375 GHz (850 μm) region, was used with ACSIS, the spectral line correlator backend (Hovey *et al.* 2000) and a new telescope control system (OCS; Rees *et al.* 2002). The observations were carried out by continuously recording the data while the telescope was scanned across the target field. The scan rate used was 75″ per second, with a sample rate of 10 Hz. The entire region was scanned in both RA and Declination directions, ultimately resulting in a basket-weaved image solution with a well-determined and flat baselevel. The raw spectral resolution of these data was 0.42 km s^{-1}.

Data processing employed the SMURF package (Jenness *et al.* 2008) to first convert the data to spectral cubes. The Starlink KAPPA and CCDPACK routines were then used to remove a linear baseline, transform to a regular grid and combine the data into a single cube. Of these data, only 66 spectral channels were retained, covering the velocity interval of −3 through 25 km s^{-1} appropriate for the Rosette Nebula. Subsequent smoothing of the data to an angular resolution of 20″ resulted in a data cube in which the rms noise per point was 0.3 K T_A^* (corrected antenna temperature scale).

2. Results

The CO 3–2 image of the Rosette Nebula (see Figure 1, and Dent *et al.* 2008) obtained from these data shows that molecular material extends over a substantially larger area than the optical extent of the nebula. The structural features of the CO emission fall into four main types: compact flows, clumps, smooth extended regions, and elongated structures with narrow line velocity widths.

The data reveal a ring of gas expanding at 20 km s^{-1}, and show that compact, relatively high-velocity flows tend to be associated with the known IRAS sources, of which AFGL 961 is the most well-known, correlated with young star clusters. The CO 3–2/1–0 ratios indicate excitation temperatures of about 30–60 K in these regions. In a galactic context, these are relatively low energy outflows, having little influence on the Rosette Molecular Cloud.

Clumps of gas, typically 15″ to 3′ in size, are common. We estimate that in the present work we are able to detect such objects with masses as low as perhaps 30–100 Jupiter masses. Of particular note is a chain of clumps in the north-west quadrant of the Rosette which corresponds with a group of dust globules and elephant truck structures (Gahm *et al.* 2006) seen against the nebular background. The velocity information from these and other objects suggest that these objects are part of an expanding partial ring. The expansion rate of this structure, 16 km s^{-1}, suggests a dynamical age of 0.8 Myr, as compared with a systemic age of 2–3 Myr (Balog *et al.* 2007).

Kinetic temperatures derived from the CO 1–0 and 3–2 integrated line intensities are in the range 25–45 K. The clump mass distribution is estimated to be complete to about 0.1 $M_{\odot}$. For optically thin CO emission ($A_v \leqslant 1$) we find a mass-number slope of -0.6 (i.e., $dN(m)/dM{\sim}{-1.6}$) for the clump mass range 0.1–1.0 $M_{\odot}$.

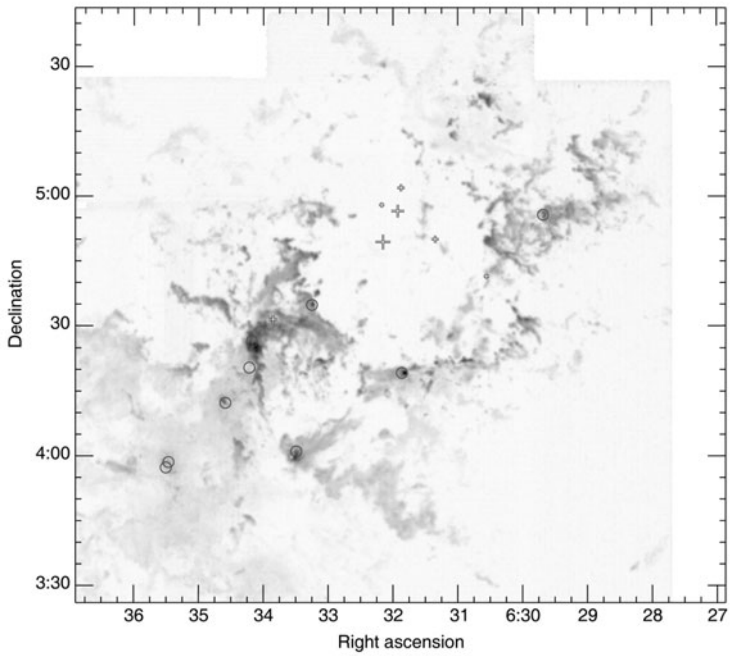

Figure 1. A molecular line image of the Rosette Nebula seen in emission from CO (3-2 transition). The image is about 2 degrees across, about twice the extent of the visible nebula. The positions of the luminous O-stars are indicated by crosses just above the centre of the image, and the circles show the locations of outflow sources.

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