# CRIRES Science Verification Proposal

## Molecular Hydrogen in 30Dor

| Investigators | Institute | EMAIL |
|---|---|---|
| Jorge Melnick | ESO | jmelnick@eso.org |
| Roland Gredel | MPIA | gredel@mpia.de |

**Abstract:**
We propose to use 5 hours in total of CRIRES SV to detect pure rotational emission lines of $H_2$ in 30Dor. The observations will help to constrain models of X-ray excitation of $H_2$, which may be of help to interpret the $H_2$ emission in active galaxies.

**Scientific Case:**

The giant star-forming region 30Dor in the LMC is characterised by large wind-driven bubbles filled with hot plasma (Townsley et al. 2006). The plasma, at temperatures of a few million degrees, emits soft X-rays (peak at 1 keV) which penetrate surrounding molecular material. Thus, 30Dor serves as an ideal testbed to study the effects of molecular gas exposed to X-rays.

In X-ray dominated regions (XDRs), energetic secondary electrons produced by X-ray ionisation of $H_2$ collisionally excite electronic states of $H_2$, apart from dissociating and ionising $H_2$. The electron impact excitation follows different selection rules than fluorescent excitation and therefore the emerging UV- and IR spectrum of $H_2$ shows distinct spectral features, compared to fluorescent excitation, or excitation in fast shocks (Gredel & Dalgarno 1995, Tiné, Lepp, Gredel, & Dalgarno 1997). For instance, direct electron impact excitation of rotational levels in v=1 and v=2 in the $X^1\Sigma_g^+$ electronic groundstate affect the population distribution and lead to a suppression of the (2,1) S(3) line, compared to (1,0) S(1) (e.g. Table 4 of Gredel & Dalgarno 1995).

It is important to note that according to the present models, the effects of X-ray illuminated gas are only seen at values of $\zeta/n_{\mathrm{H}} < 10^{-15}$ cm$^{-3}$ s$^{-1}$, where $\zeta$ is the ionisation rate and $n_{\mathrm{H}}$ is the particle density (Tiné et al. 1997). In 30Dor, this is estimated to occur on spatial scales of a few arcsec. The reason is that in the denser molecular gas thermal collisions dominate the $H_2$ excitation. This issue is, possibly, one of the reasons why efforts to detect X-ray excitation in active galactic nuclear have, so far, not been successful (e.g. Davies et al. 2006).

**Required observing time**

| Target | RA | DEC | Wavelength Band | Magnitude | DIT | NDIT |
|---|---|---|---|---|---|---|
| P409 Knot 3 | 05 38 34 | -69 06 06 | 2.121 | | 60 | 10 |
| P409 Knot 3 | 05 38 34 | -69 06 06 | 2.073 | | 60 | 10 |
| P409 Knot 3 | 05 38 34 | -69 06 06 | 3.235 | | 60 | 10 |
| P409 Knot 3 | 05 38 34 | -69 06 06 | 3.99 | | 60 | 10 |
| P1222 | 05 38 45 | -69 05 18 | 2.121 | | 60 | 10 |
| P1222 | 05 38 45 | -69 05 18 | 2.073 | | 60 | 10 |
| P1222 | 05 38 45 | -69 05 18 | 3.235 | | 60 | 10 |
| P1222 | 05 38 45 | -69 05 18 | 3.99 | | 60 | 10 |

Here we propose high spatial- and spectral-resolution observations of two bright $H_2$ knots in 30Dor in order to detect the XDR that forms between the hot plasma and the molecular gas. The diagnostic lines are (1,0) S(1) (2.122 $\mu$m), (2,1) S(3) (2.073 $\mu$m), (1,0) O(5) (3.235 $\mu$m), and (0,0) S(12) (3.99 $\mu$m). The observation of the pure rotational (0,0) S(12) line will, in the future, be complemented by VISIR observations of the pure rotational (0,0) S(1) (17.03 $\mu$m), (0,0) S(2) (12.28 $\mu$m), (0,0) S(3) (9.66 $\mu$m), and (0,0) S(4) (8.02 $\mu$m) lines, which provide extremely useful insights to the excitation scenario which is at work (e.g. Flower et al. 2003, their Fig. 6).

We will observe two $H_2$ knots (near sources P409 and P1222)) close to R136 in the four lines given above, and obtain long-slit traces which cover part of the hot gas as well. The high spectral resolution will provide enough kinematical information to determine whether the $H_2$ emission arises from cold clumps embedded in the HII region, or from the placental molecular cloud from where the R136 cluster has formed. The high spatial resolution of $0.''2$ will allow to probe the HII-HI-$H_2$ interface of the XDR. The $H_2$ emission in 30Dor is about two orders of magnitude fainter than in Orion (e.g. Rubio et al. 1998). We expect line fluxes of the order of 2 x 10(-18) W m(-2) for the K-band lines, which are detected with a S/N of 50 in 10 min of integration time each. The L-band lines are about a factor of 3-5 weaker than (1,0) S(1) according to the predictions from Gredel & Dalgarno 1995. They are detected with a S/N of 10 in 1 hour of integration time. Two knots are thus observed in a total of 5 hours.