**Scientific Justification**

A number of studies of molecular hydrogen and its excitation in galaxies have been made over the last decade (e.g. Joseph et al. 1984; Puxley, Hawarden & Mountain 1988, 1990; Moorwood & Oliva 1990; Kawara & Taniguchi 1993; van der Werf et al. 1993). Early indications from low spatial and spectral resolution H$_2$ line ratios that the gas was always shock excited were challenged by parallel theoretical developments showing that in dense, warm photo-dissociation regions heated by UV-photons the low-lying (and brightest) transitions could be thermalised. Moreover, Puxley et al. (1990) argued that given the observed Br-γ recombination line emission, the copious non-ionizing UV photons would be expected to produce substantial H$_2$ emission when absorbed by molecular gas. Indeed, the different dependences of H and H$_2$ emission on incident UV flux provided a diagnostic of the relative spatial distributions of exciting stars and gas. Despite these arguments, however, it remains widespread in the current literature that H$_2$ in galaxies is shock excited (by supernova remnants and stellar outflows), although these studies are invariably without detection or reliable analysis of the critical higher level line fluxes.

One of the principal difficulties in determining accurate fluxes for H$_2$ lines above the lowest $v$=1-0 transitions is the strength of the underlying stellar continuum and the presence of metal absorption features in the cool stellar atmospheres. Even with very high S/N data, local variations in stellar population and element abundance produces systematic features after subtraction of empirical or theoretical stellar templates. This restricts the detectability in galaxies with strong continua to transitions brighter than those required to definitively determine the H$_2$ excitation.

The wider astrophysical context for studying H$_2$ emission from galaxies is in understanding the interaction between massive stars and their environment (e.g. the relative importance of the excitation mechanisms, the effect of the formation of massive star clusters on the local ISM and its feedback into the star-formation process), the distribution of stars and interstellar material and the subsequent evolution of the starburst. Paradoxically, within our own galaxy it can be difficult to establish, say, the H and H$_2$ emission and excitation mechanisms for a single star-forming complex. For example, although the peak H$_2$ flux from shocks is 100 times that from the diffuse component in Orion, only by integrating over a $7 \times 9$ arcmin$^2$ region is it revealed that the shocked and UV-excited luminosities are equal (Burton & Puxley 1990; Usuda et al. 1996). Observation of a galaxy provides such a census of the entire emission in a single measurement.

During an IR spectroscopic study of several Wolf-Rayet galaxies, four lines of H$_2$ were serendipitously detected in the nearby dwarf galaxy NGC5253 (Lumsden, Puxley & Doherty 1994): 1-0 S(1), 1-0 S(0) and marginally 3-2 S(3) and 2-1 S(1). This observation represented the first suggestive evidence for the dominance of UV-photon excitation of H$_2$ in at least some galaxies, now strongly supported by the spectrum of NGC5461 in M101 (Fig. 1).

The NGC5253 and NGC5461 observations raise several interesting questions: Is UV-excitation of H$_2$ actually a general phenomenon in galaxies? What are the relative fractions of UV- and thermally-excited gas? What does the UV-excited component and hydrogen recombination line emission imply about the physical relationship of sources in the emitting region e.g. are they consistent with the models described by Puxley, Hawarden & Mountain (1988, 1990)?

To address these questions we require measurements of the H$_2$ line excitations sufficient to determine the contributions from UV irradiated low and high density gas, and from shocks. We propose observations of weak continuum, dwarf galaxies. All have been detected in the 1-0 S(1) H$_2$ transition (Doherty, Puxley, Lumsden & Doyon 1995). The weakness of the continua provides two benefits (i) a relatively large H$_2$-to-continuum ratio and (ii) weak underlying stellar absorption features.
Figure 1: Spectrum of NGC5461 from Puxley et al. (2000).
Experimental Design

Images with NIRI f/6 camera are requested of four weak-continuum, blue compact dwarf galaxies (NGC5253, Haro2, Haro3, IIZw40). The giant HII region NGC5461 (in M101) previously observed provides a 'bridge' between studies of the starburst nuclei of galaxies and Orion-like complexes in our own Galaxy.
Technical Description

The expected continuum flux density in NGC5253 is $0.5 \times 10^{-15} \text{ W/m}^2/\mu\text{m} (K \sim 14.7)$ assuming approximately uniform surface brightness in scaling from our previous $3\times3$ arcsec$^2$ measurement.

Similar previous observations of the rest of the sample gives expected continuum flux densities of $0.5 - 2 \times 10^{-15} \text{ W/m}^2/\mu\text{m} (K \sim 13.3-14.8)$ and 1-0 S(1) line/continuum ratios of $0.5 - 1.0$. The galaxies with weaker continua have larger line/continuum ratios and thus we expect similar integration times.

The total request to observe the four targets, allowing 1 hour per target for calibration and acquisition, and 75% efficiency on long integrations is 15 hours.
**Band 3 Plan**

If we are allocated time in Band 3 we will either require twice the time allocation to observe all the targets or we will only observe the brightest half of the sample and double the integration time per object.

**Classical Backup Program**

**Justify Target Duplications**

**Publications**


**Use of Other Facilities or Resources**

**Previous Use of Gemini**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Allocation</th>
<th>% Useful</th>
<th>Status of previous data</th>
</tr>
</thead>
<tbody>
<tr>
<td>UKIRT97A</td>
<td>2 nights</td>
<td>100%</td>
<td>Data shown in text, paper in preparation.</td>
</tr>
<tr>
<td>GN-2009B-Q-13</td>
<td>12 hours</td>
<td>80%</td>
<td>Reductions in progress</td>
</tr>
</tbody>
</table>

**ITC Examples**
Gemini Integration Time Calculator
NIRI version 4.2

Click here for help with the results page.
software aperture diameter = 1.12 arcsec
enclosed pixels = 74.31

derived image size (FWHM) for a point source = 0.70 arcsec.

Contributions to total noise (e-) in aperture (per exposure):
Source noise = 311.26
Background noise = 812.44
Dark current noise = 47.21
Readout noise = 103.44

Total noise per exposure = 877.42
Total signal per exposure = 96883.19

Intermediate S/N for one exposure = 110.41

S/N for the whole observation = 360.70 (including sky subtraction)

Requested total integration time = 2400.00 secs, of which 2400.00 secs is on source.

Observation is background noise limited.

The peak pixel signal + background is 10215. This is 5% of the full well depth of 200000.

Input Parameters:
Instrument: NIRI

Source spatial profile, brightness, and spectral distribution:
The extended source is an emission line, at a wavelength of 2.2000 microns, and with a width of 100.00 km/s.
It's total flux is 5.0E-19 watts_flux on a flat continuum of flux density 1.0E-16 watts_fd_wavelength.

Instrument configuration:
Optical Components:
- Filter: H210S1
- Fixed Optics
- Camera: f6
- Detector - 1024x1024-pixel ALADDIN InSb array
• Read Mode: lowNoise
• Detector Bias: lowWell

Pixel Size: 0.116

Telescope configuration:
• silver mirror coating.
• side looking port.
• wavefront sensor: pwfs

Observing Conditions:
• Image Quality: 70.00%
• Sky Transparency (cloud cover): 50.00%
• Sky transparency (water vapour): 80.00%
• Sky background: 80.00%
• Airmass: 1.50
Frequency of occurrence of these conditions: 22.40%

Calculation and analysis methods:
• mode: imaging
• Calculation of S/N ratio with 20 exposures of 120.00 secs, and 100.00 % of them were on source.
• Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.
Gemini Integration Time Calculator
NIRI version 4.2

[Click here for help with the results page.]
software aperture extent along slit = 2.12 arcsec
derived image size (FWHM) for a point source = 0.70 arcsec

Requested total integration time = 2400.00 secs, of which 2400.00 secs is on source.

Signal and SQRT(Background) in software aperture of 18.0 pixels

[Click here for ASCII signal spectrum.]
[Click here for ASCII background spectrum.]
Intermediate Single Exp and Final S/N

![Intermediate Single Exp and Final S/N Graph](image)

**Input Parameters:**

**Instrument:** NIRI

Source spatial profile, brightness, and spectral distribution:
The extended source is an emission line, at a wavelength of 2.2000 microns, and with a width of 100.00 km/s.

It's total flux is 5.0E-19 watts_flux on a flat continuum of flux density 1.0E-16 watts_fd_wavelength.

**Instrument configuration:**

**Optical Components:**
- Filter: K
- Fixed Optics
- Grism Optics: K-grism
- Camera: f6
- Detector - 1024x1024-pixel ALADDIN InSb array
- Focal Plane Mask: 4-pix-center
- Read Mode: lowNoise
- Detector Bias: lowWell

Pixel Size: 0.116

Telescope configuration:
- silver mirror coating.
- side looking port.
- wavefront sensor: pwfs

Observing Conditions:
- Image Quality: 70.00%
- Sky Transparency (cloud cover): 50.00%
- Sky transparency (water vapour): 80.00%
- Sky background: 80.00%
- Airmass: 1.50
Frequency of occurrence of these conditions: 22.40%

Calculation and analysis methods:
- mode: spectroscopy
- Calculation of S/N ratio with 20 exposures of 120.00 secs, and 100.00 % of them were on source.
- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.

Output:
- Spectra autoscaled.