Dense Gas in the LMC and the Circumstellar Shell of R Scl

Tony Wong, ATNF
Millimetre Workshop
21 Nov 2002

With: John Whiteoak, Maria Hunt, Michael Lindqvist, Hans Olofsson
1. Dense Gas in the LMC

• At a distance of ~50 kpc (1” = 0.25 pc), the LMC is the nearest actively star-forming galaxy.

• Low metallicity (~0.25 Z⊙) ⇒ less dust ⇒ very different interstellar environment!

• Due to strong FUV field, most molecular gas will be in photon-dominated regions (PDRs).

• **Initial target:** N113 cloud, observed with SEST by Chin et al. (1997).

• **The Future:** Take advantage of CO survey at 160” resolution conducted with 4m NANTEN telescope (N. Mizuno et al.)

• Follow up with SEST, Mopra, and ATCA.
HCO$^+$/ HCN in N113

- **SEST 58” beam**
- $T_{mb}(\text{HCO}^+) \approx 0.6$ K
- Flux $\approx 15$ Jy

Chin et al. 1997

Fukui et al. 2001
Massive Star Formation in N113

NANTEN CO contours over Hα image from Kennicutt
First ATCA Observations

- 9 Jul 2001, single baseline
- Additional observations on 10 Jul and with 3-element system on 4 and 8 Oct.
- No $T_{\text{sys}}$ or flux calibration – assumed fluxes for calibrators.
Emission is Heavily Resolved

Baseline (m)

2001 Jul & Oct Data
FWHM = 7.6 ± 0.9 arcsec

UV Distance (k\lambda)
2002 Observations

XX,YY, τ−10B1 min, B=2−3, T=17:46:04

90m

XX,YY, τ−10B1 min, B=2−4, T=17:46:04

135m

XX,YY, τ−10B1 min, B=3−4, T=17:46:04

45m

Baseline (m)

2002 Sep Data
FWHM = 5.2 ± 0.6 arcsec

UV Distance (kλ)
Integrated Spectrum
Conclusions for N113 core

- Deconvolved FWHM $\approx 1.5$ pc $\Rightarrow R \sim 1$ pc.
- Line width $\Delta v \sim 5$ km s$^{-1}$.
- For a virialized cloud, ignoring optical depth effects, $M \approx 200(R_{pc})(\Delta v_{km/s})^2 \approx 5000$ M$_{\odot}$.
- For constant density, $n_H \sim 5 \times 10^4$ cm$^{-3}$.
- Peak flux $\sim 2$ Jy, only $\sim 13\%$ of SEST flux.
- Most of the HCO$^+$ is probably in relatively diffuse gas associated with the PDR.
- HCO$^+$ enhanced due to high C$^+$ abundance (Graedel et al. 1982).
2. Circumstellar Envelopes

- In late AGB evolution, a slow wind produces a circumstellar envelope (CSE) of gas & dust.

- Strong variations in mass-loss rate (He shell flashes?) can lead to a detached shell of molecular gas (Olofsson et al. 1990).

U Cam (CO)
Lindqvist et al. (1999)
Circumstellar Shell Around R Scl

- **R Sculptoris** has been inferred from SEST CO (3-2) observations to have a detached shell (Olofsson et al. 1996).

- However, the data had insufficient resolution (16") to determine the mass loss rate or shell thickness.
ATCA Observations

![Graphs showing velocity distributions for different frequencies.

138m, 413m, 275m frequencies are displayed for each graph.

Dates: 02OCT15 and 02OCT18.

750A label is present in the top right corner of each graph.

Graphs show amplitude against velocity (radio LSR) in km/s.]
No shell emission (3σ = 75 mJy)
Peak flux $\sim 1.3 \text{ Jy}$
Central source is resolved

source FWHM $\approx 1''$ (400 AU)
Not decorrelation!
Not decorrelation!
Conclusions for R Scl

• HCN (1-0) emission has been resolved with a deconvolved FWHM ≈ 1” (400 AU).

• Peak flux ~ 1.3 Jy, virtually all of SEST flux (0.05 K x 25 Jy/K). S/N ratio of ~40.

• No evidence for emission from the R ≈ 10” shell inferred from CO data, or R ≈ 20” shell seen in scattered light (Gonzalez Delgado et al. 2001).

• HCN is probably emitted from present mass-loss envelope. Dissociation of HCN ⇒ CN probably leads to low HCN abundance in the CO shell.

• Would be interesting to image the CN line at 113.3 GHz, as well as CO and/or 13CO.
Current System (2001 Sep)

- **3 antennas** (CA02, CA03, CA04) with dual polarisation receivers.
- 2 observing bands: **84.9-87.3** and **88.5-91.3 GHz**. Module swap at antenna required to change bands.
- Up to **128 MHz** bandwidth in each of 2 frequencies.
- Minimum baseline **30m**.
- Both N-S and E-W configurations possible (since 2002 Aug).
3mm Receiver System

- At present, the tuning range is limited since we are using a fixed frequency LO at 80.5055 GHz.

- The sky frequency range is 84.9-87.3 GHz using the C-band filter module or 88.5-91.3 GHz using the X-band module.
At present, the tuning range is limited since we are using a fixed frequency LO at 80.5055 GHz.

The sky frequency range is 84.9-87.3 GHz using the C-band filter module or 88.5-91.3 GHz using the X-band module.
Improvements in 2003

• Currently, C and X modules must be swapped manually to switch from one band to the other.

• **May**: 3 antennas with prototype systems (CA02, CA03, CA04) get new down-conversion systems, eliminating need to swap modules.

• Allows one to quickly switch to **86 GHz SiO masers** for pointing, even when observing at **89-91 GHz**.

• **Will NOT** permit simultaneous observations at 86 and 90 GHz.

• **September**: 4th antenna (CA01) may be equipped with “production” 3mm receiver, but frequency range not compatible with CA02/3/4.
Priorities for Testing

- **Pointing errors**: there appears to be a systematic offset in antenna pointing between 9, 20, and 86 GHz (M. Kesteven).
- Working on freq-dependent pointing model.
- **Phase errors**: phase jumps when changing sources, seems to be mostly (or to mimic) a baseline error.
- May need a freq-dependent baseline model – but errors appear to also vary in time!
- Still more to be done…
## Baseline errors 2002

in mm, CA03 as reference

<table>
<thead>
<tr>
<th></th>
<th>$\Delta X_2$</th>
<th>$\Delta Y_2$</th>
<th>$\Delta Z_2$</th>
<th>$\Delta X_4$</th>
<th>$\Delta Y_4$</th>
<th>$\Delta Z_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>EW214</td>
<td>1.14</td>
<td>0.03</td>
<td>-1.68</td>
<td>-0.75</td>
<td>2.01</td>
<td>-2.37</td>
</tr>
<tr>
<td>750B</td>
<td>0.81</td>
<td>0.18</td>
<td>0.93</td>
<td>-1.8</td>
<td>2.67</td>
<td>0.78</td>
</tr>
<tr>
<td>H75</td>
<td>-1.83</td>
<td>-3.96</td>
<td>2.73</td>
<td>-8.58</td>
<td>-10.38</td>
<td>6.33</td>
</tr>
<tr>
<td>EW367</td>
<td>-0.39</td>
<td>1.11</td>
<td>0.63</td>
<td>12.06</td>
<td>2.46</td>
<td>-11.13</td>
</tr>
<tr>
<td>H168</td>
<td>2.01</td>
<td>0.60</td>
<td>-1.11</td>
<td>-2.82</td>
<td>1.83</td>
<td>0.06</td>
</tr>
<tr>
<td>750A</td>
<td>0.96</td>
<td>0.36</td>
<td>0.03</td>
<td>-0.99</td>
<td>-0.60</td>
<td>1.14</td>
</tr>
</tbody>
</table>
Planned configurations

- 2002 May term: EW214, EW367, 750C, 1.5C
- Proposal deadline: 15 February!

EW214_{123} + EW367_{123}
7.1" x 3.6" at \( \delta = -45^\circ \)
Suggested Projects

• Quasar absorption lines: can calibrate out most phase errors, u-v coverage unimportant.

• Compact emission sources unresolved with SEST: can expect good S/N.

• Ratios of 2 lines that can be observed simultaneously: less reliant on matched uv coverage.

• Low dec (<–45°) sources: less shadowing in compact arrays

• Anything that looked good today!
Questions to Consider

1. Does the Australian user community accept the new timeline for the 3mm upgrade?
2. Does it have a choice?
3. Are there mechanisms in place to ensure that goals and deadlines are meaningful?
4. Does ATNF have its priorities straight?
5. Are we sufficiently involving the engineers in the scientific program?
6. Should the ATNF Steering Committee be asked to take action?