An interferometric line survey of IRC+10216 in the 345 GHz band

Nimesh A. Patel
Submillimeter Array
Harvard-Smithsonian Center for Astrophysics

Laboratory Astrophysics Symposium, CfA, 20 September 2010

Collaborators:
Ken Young, Patrick Thaddeus, Robert Wilson, Karl Menten, Mark Reid, Carl Gottlieb, Michael McCarthy, Jinhua He, Sandra Brünken, Dinh-van-Trung, Eric Keto & Jose Cernicharo
Figure 1: The life cycle of the interstellar medium and its relationship to planets and solar systems, as traced by molecular material.

Ziurys et al. 2010, Astro2010 Science White Paper
IRC+10216 (CW Leo)

- Nearest and brightest Carbon-rich AGB star (distance: ~150 pc)
- Mass loss rate = several x 10^{-5} Msun/yr

Some of these features can be better seen in Fig. 4 where we plot representative radial strips (20° wide) through the shells. The uncertainty in the intensities is small (3–5\%\) so most of the structure seen is real. The two plots at the top of Fig. 4 are adjacent strips (to the NW) and it can be seen that they exhibit quite similar, though not identical, features. The next two strips point to the NE and SW in opposite directions and have essentially no correlated features. The structure in the strip at P.A.=214° shows a particularly clear shell profile: from 30′′ to 42′′ the intensity is nearly constant, it then rises to a limb brightened peak, and falls abruptly to the outside by a factor of nearly two in <∼2′′. Note that when all sectors are averaged, the shells are not seen.

The spacing of the shells does not obviously show a regular spatial pattern, but the typical radial separation is ∼5′′–20′′ which corresponds to a time interval of 200–800 yr. From consideration of a simple model of limb brightened shells, as in Mauron (1997) but modified for external, optically thin illumination, the density contrast between the shells and intershell regions is inferred to be quite large, up to a factor of 10.

3.5. Relation of the dust shells to the gas

The relation of the dust shells to the distribution of gas in the envelope is of interest because in AGB envelopes the dust and gas are not completely coupled. The dust is expected to drift through the gas, in the case of IRC+10216, at a speed of ∼2 km s^{-1} (Kwan & Hill 1977). In a homogeneous envelope, this relative motion has no major effect on the structure, but in a multiple shell envelope, this might not be the case.
### Published line surveys of IRC+10216

<table>
<thead>
<tr>
<th>Line survey</th>
<th>Frequency range (GHz)</th>
<th>No. of lines</th>
<th>FWHM beam (&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onsala 20m</td>
<td>72.2 - 91.1</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>Johansson et al. (1985)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JCMT 15m</td>
<td>222.4 - 267.9</td>
<td>46</td>
<td>20</td>
</tr>
<tr>
<td>Avery et al. (1992)</td>
<td>339.0 - 364.6</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>CSO 10.4m</td>
<td>330.2 - 358.1</td>
<td>56</td>
<td>21</td>
</tr>
<tr>
<td>Groesbeck et al. (1994)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nobeyama 45m</td>
<td>28.0 - 50.0</td>
<td>188</td>
<td>42</td>
</tr>
<tr>
<td>Kawaguchi et al. (1995)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRAM 30m</td>
<td>129.0 - 172.5</td>
<td>380</td>
<td>16</td>
</tr>
<tr>
<td>Cernicharo et al. (2000)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMT (ARO) 10m</td>
<td>131.2 - 160.3</td>
<td>377</td>
<td>51</td>
</tr>
<tr>
<td>He et al. (2008)</td>
<td>219.5 - 267.5</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Herschel HIFI (3.5m)</td>
<td>554.5 - 636.5</td>
<td>130</td>
<td>36</td>
</tr>
<tr>
<td>Cernicharo et al. (2010: arXiv:1008.1199)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Molecules in IRC+10216 (67)

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Molecule</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-3}$</td>
<td>CO</td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td></td>
</tr>
<tr>
<td>$10^{-5}$</td>
<td></td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td></td>
</tr>
<tr>
<td>$10^{-7}$</td>
<td></td>
</tr>
<tr>
<td>$10^{-8}$</td>
<td></td>
</tr>
<tr>
<td>$10^{-9}$</td>
<td></td>
</tr>
<tr>
<td>$10^{-10}$</td>
<td></td>
</tr>
</tbody>
</table>

- **CO**: detected only in IR
- **C**: detected in SMA survey
- **C$_2$H$_2$**: mapped by PdBI
- **SiH$_4$**, **NH$_3$**: recently reported new detections

- **C$_2$H**: detected only in IR
- **C$_4$H**: detected in SMA survey
- **C$_5$**: mapped by PdBI
- **C$_6$H**: recently reported new detections
- **C$_7$**: detected only in IR
- **C$_8$H**: detected in SMA survey

- **SiH$_4$**: detected only in IR
- **NH$_3$**: detected in SMA survey
- **C$_2$H$_2$**: mapped by PdBI
- **C$_4$H**: recently reported new detections
- **C$_5$**: detected only in IR
- **C$_6$H**: detected in SMA survey
- **C$_7$**: mapped by PdBI
- **C$_8$H**: recently reported new detections
SMA characteristics

http://sma1.sma.hawaii.edu

8 antennas of 6 m diameter, located near the summit of Mauna Kea, (4145 m)

24 pads in four rings of baseline lengths 8 - 508 m

Receivers:

177-256 GHz
256-360 GHz
320-420 GHz
420-520 GHz (future)
600-720 GHz
780-920 GHz (future)

Correlator:

4 GHz bandwidth per sideband (separation: 12 GHz)

Polarization capability in all frequency bands
SMA in subcompact configuration

Baselines: 9.5-25m
angular resolution: \(~3''\) at 345 GHz

Elevation limit: 31.3 deg on three of the antennas to avoid antenna collisions
RMS Noise = 25-300 mJy/beam
Spectra over 2”x2” region
SiS v=2 J=17–16 in IRC+10\degree\textit{216} (305.513 GHz)
SiC$_2$ 13(8,5)−12(8,4) in IRC+10\textdegree216 (305.197 GHz)
CH$_3$CN

SMA+CSO  $v_8=1$
March 2010  18(8)-17(8)
331.536 GHz
SiCC
$v_3=1$
$15_{9.6}^{14}_{9.5}$
342.293 GHz

SMA+CSO
March 2010
NaCl(27–26) in IRC+10°216 (350.969 GHz)
HCN(4–3) ν3=1 in IRC+10°216 (352.088 GHz)
Distribution of expansion velocities

He et al. (2008)
New population of narrow lines
Distribution of expansion velocities of U-lines

(most U-lines are narrow)
Expansion velocity profile


Decin et al., 2010, Nature, 467, 64
440 lines detected toward IRC+10216

• ~200 new detections, most of them narrow lines ($V_{\text{exp}} < 7$ km s$^{-1}$)

• ~213 lines as yet unidentified

Many narrow lines are identified as vibrationally excited rotational transitions in species such as SiCC, SiS, CH$_3$CN, HC$_3$N, CS and CO (Patel et al. 2009)

Spatial distribution of emission from narrow lines is very compact: ~0.2” => we are probing the region of dust formation and rapid acceleration

Images and calibrated visibility data-sets of full survey will be made publicly available on acceptance of ApJSS paper.

Recently completed SMA line-surveys: VY CMa, IK Tau (O-rich AGB stars; PI: Ken Young)