SMA spectral line imaging survey at 279-355 GHz of the O-rich AGB star IK Tau

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Chemistry around AGB stars

Intro

- ~80 molecular species identified around evolved stars [mm, sub-mm, far-infrared]

~20 around O-rich AGB stars (i.e. NOT VY CMa!

→ Chemistry or observational bias?
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S1-10, D.Keller
JVLA survey of IRC+10216
Physics & chemistry around AGB stars

The gap

Inner - intermediate - outer wind

Decin, De Beck et al. (2010, A&A 516, A69)

Duari et al. (1999)
Cherchneff (2006, 2011)

See also talks by
I. Cherchneff,
D. Gobrecht,
M. Wittkowski,
Physics & chemistry around AGB stars
Spectral surveys

- Large wavelength coverage & no bias for specific molecules
  - New species - chemical inventory
  - Abundance determinations - chemical networks
  - Isotopes - stellar nucleosynthesis

→ study a few selected objects in great detail
Physics & chemistry around AGB stars
Spectral surveys

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<table>
<thead>
<tr>
<th>Classification</th>
<th>IRC +10 216</th>
<th>IK Tau</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>[pc] 130</td>
<td>250 - 265</td>
</tr>
<tr>
<td>Luminosity</td>
<td>[L_{sun}] ~ 10^4</td>
<td>~ 10^4</td>
</tr>
<tr>
<td>Mass-loss rate</td>
<td>[M_{sun}/yr] ~ 2 x 10^{-5}</td>
<td>~ 1 x 10^{-5}</td>
</tr>
<tr>
<td>Terminal wind velocity</td>
<td>[km/s] ~ 14.5</td>
<td>~ 18.5</td>
</tr>
</tbody>
</table>
SMA survey of IK Tau
Intro

- Previously: targeted line observations
  APEX, CSO, JCMT, IRAM 30m, OSO, SEST, Herschel/HIFI
  beam sizes of 10” - 45”

- Survey using Submillimeter Array (SMA)
  - Extended configuration: synthesised beam  ~ 0.80” x 0.65”  (1”~ 80R·)
  - 10 tracks of 8 GHz each, 17 Jan. - 2 Feb. 2010
  - 279 - 355 GHz
  - Telluric H$_2$O around 325 GHz
SMA survey of IK Tau
Overview

Current status

- 13 species (30 isotopologues), 3 tentative species
- ~110 identified lines, ~30 unidentified / tentatively identified features
- Dominated by SiO, SiS, and isotopologues
- Vibrational excitation: $\text{H}_2\text{O}$ ($v_2=1$), SO ($v=1$), $\text{SO}_2$ ($v_2=1$), SiO ($v=1,2,3$)

De Beck et al. (in prep.)
SMA survey of IK Tau
Chemical families: P-bearing

• First detection of PO and PN around O-rich AGB star (SMA & IRAM 30m)
  4 rotational transitions of PN
  4 rotational transitions of PO

• SMA: diametrical extent (PO, PN) ≤ 0.7” ... max. radial extent of ~40 stellar radii

• \( \frac{X(\text{PN}/\text{H}_2)}{X(\text{PO}/\text{H}_2)} = 3 \times 10^{-7} \)
  \( X(\text{PO}/\text{H}_2) = 0.5 - 6.0 \times 10^{-7} \)

PN and PO main P-carriers ... update chemical models
No PS or PH\(_3\)
SMA survey of IK Tau
Dust-related species: small oxides

- SMA survey of VY CMa: AlO, TiO, TiO$_2$

- No TiO, TiO$_2$ for IK Tau

- AlO?
  - IRAM 30m: (3-2) and (4-3)
  - SMA: (8-7) and (9-8)
  - Unresolved by SMA $\lesssim$ 0.7"
  - Trot = 500K
  - 7 km/s width

Kamiński et al. (2013, A&A 551, A113)
Kamiński et al. (2013, ApJS 209, 38)
Kamiński et al. (2013, A&A 549, A6)

De Beck et al. (in prep.)
SMA survey of IK Tau

Conclusions

SMA line imaging survey at 279 - 355 GHz

- 30 species detected (+ 3 tentatively)
- Isotopes of C, N (?), O, S, Si
- PO & PN: too high abundances \(\rightarrow\) update of chemical models needed!
- Gas-dust: tentative detection of AlO
- Asymmetry

Coming up:

- Overview paper … De Beck et al. (2014, in prep.)
- Detailed analysis (RT) of some molecules … e.g. SO, SO\(_2\)
- ALMA full science: 0.006” - 0.037” … for IK Tau this is ~ 0.5 - 3 R*!
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