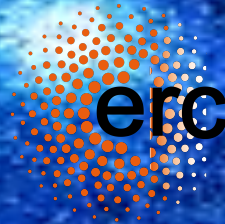


# Surprises from *Herschel* and ALMA on the chemistry of envelopes around evolved stars (the case of IRC+10216)

Marcelino Agúndez

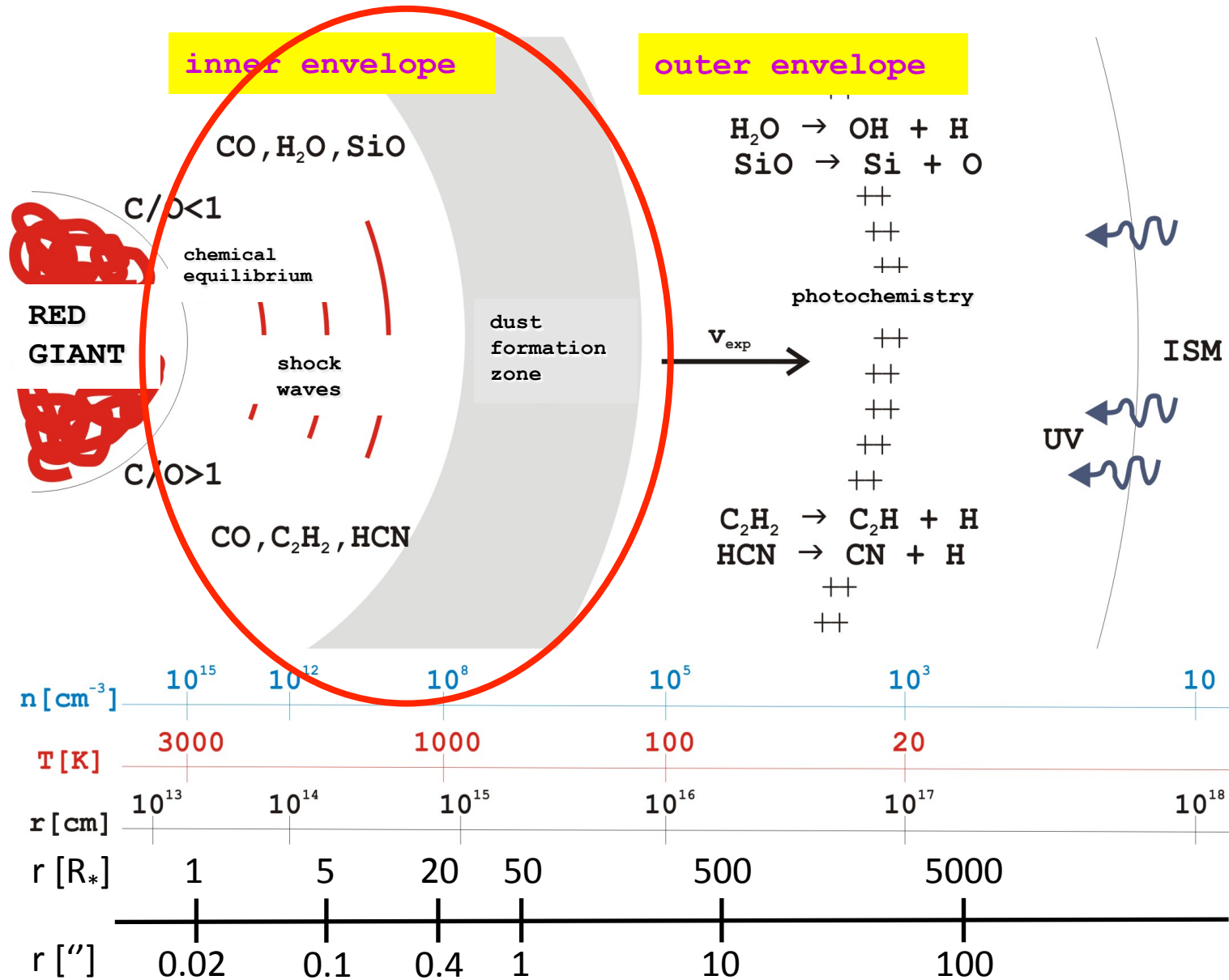
Instituto de Ciencia de Materiales de Madrid (ICMM), CSIC, Spain



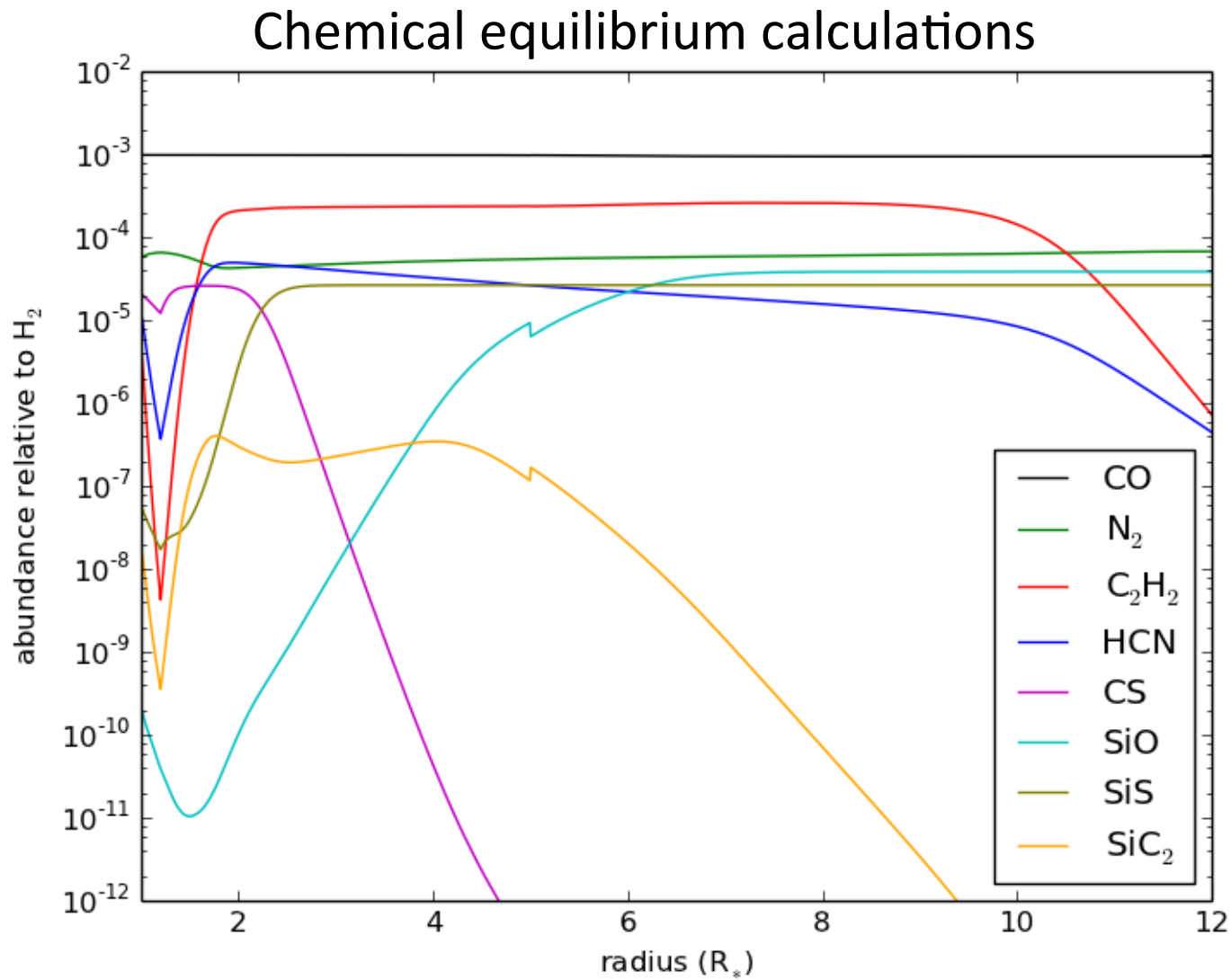
ALMA/*Herschel* Archival workshop ESO Garching, April 15-17, 2015

- 1.- Standard view of the chemistry in IRC+10216
- 2.- *Herschel* surprises: detection of hydrides
- 3.- ALMA surprises: observations of CH<sub>3</sub>CN

# 1.- Standard view of the chemistry in IRC+10216



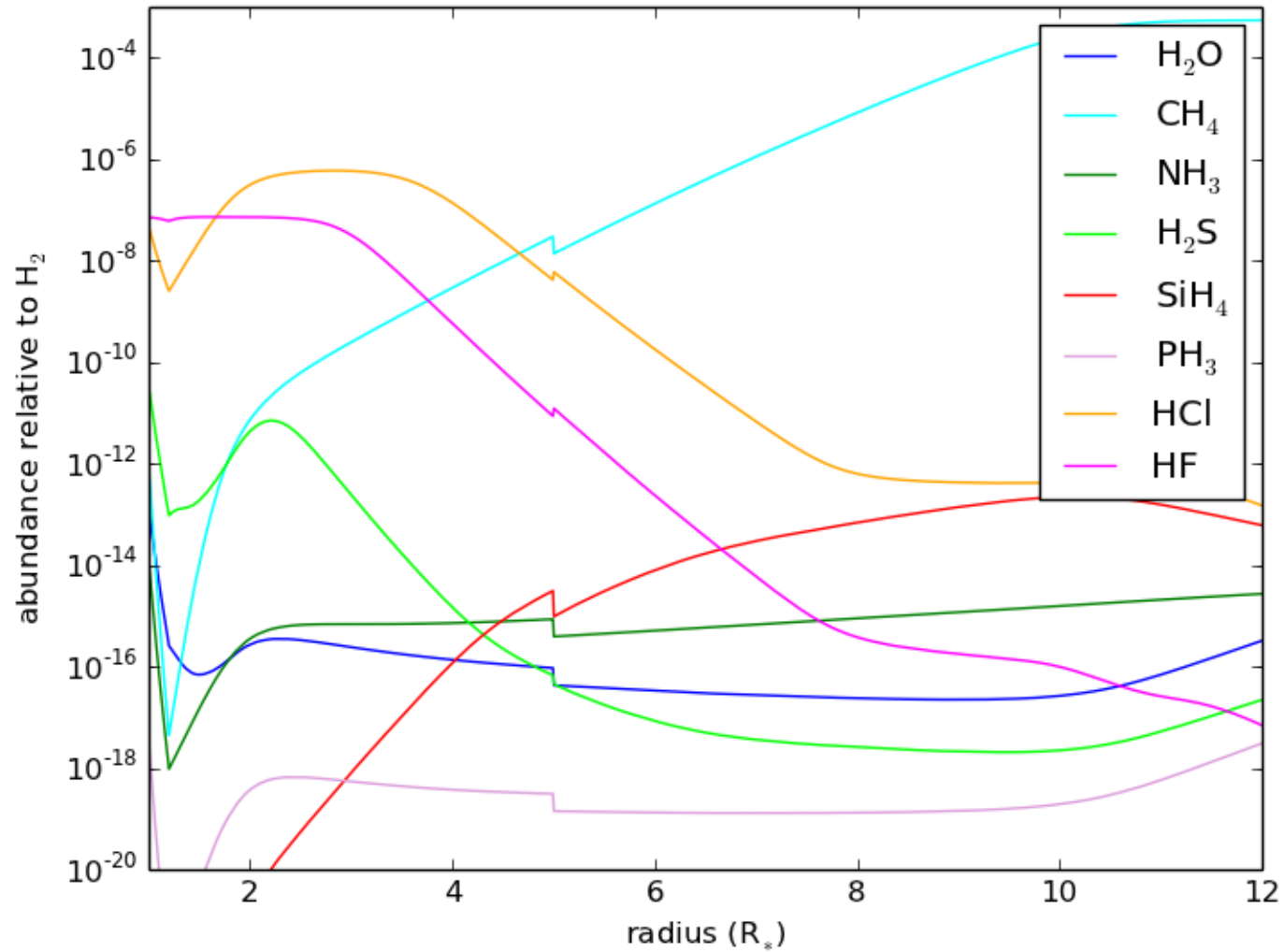
# 1.- Standard view of the chemistry in IRC+10216



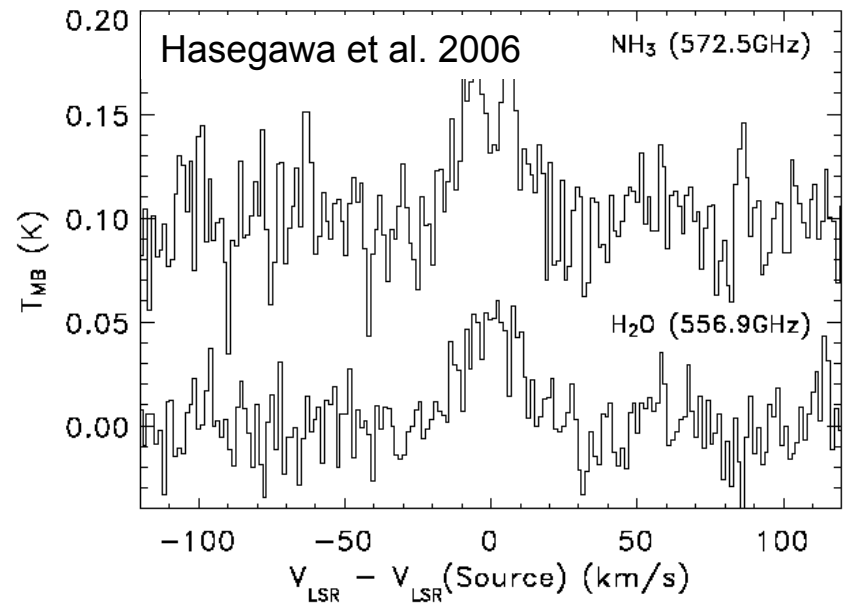
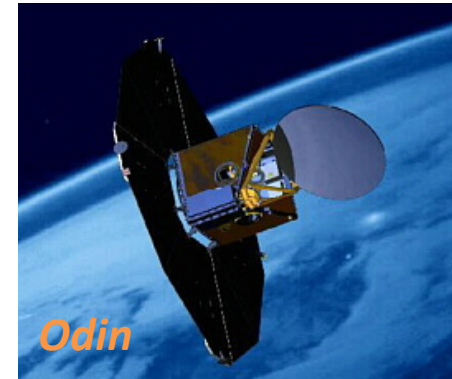
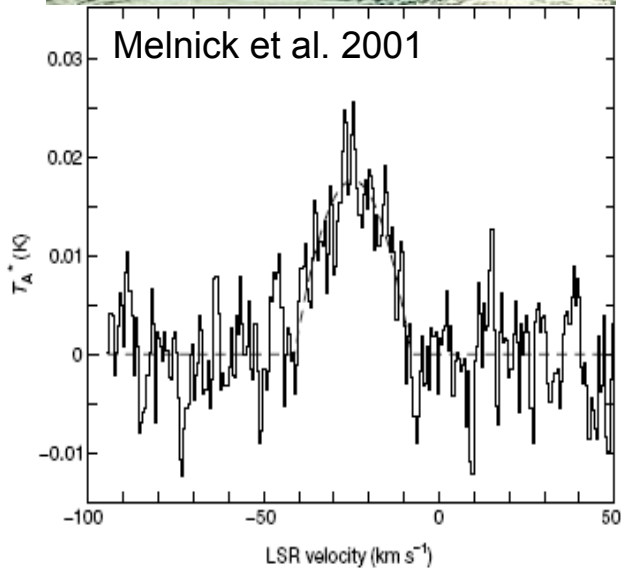


## 2.- *Herschel* surprises: detection of hydrides

### Chemical equilibrium calculations



## 2.- *Herschel* surprises: detection of hydrides H<sub>2</sub>O

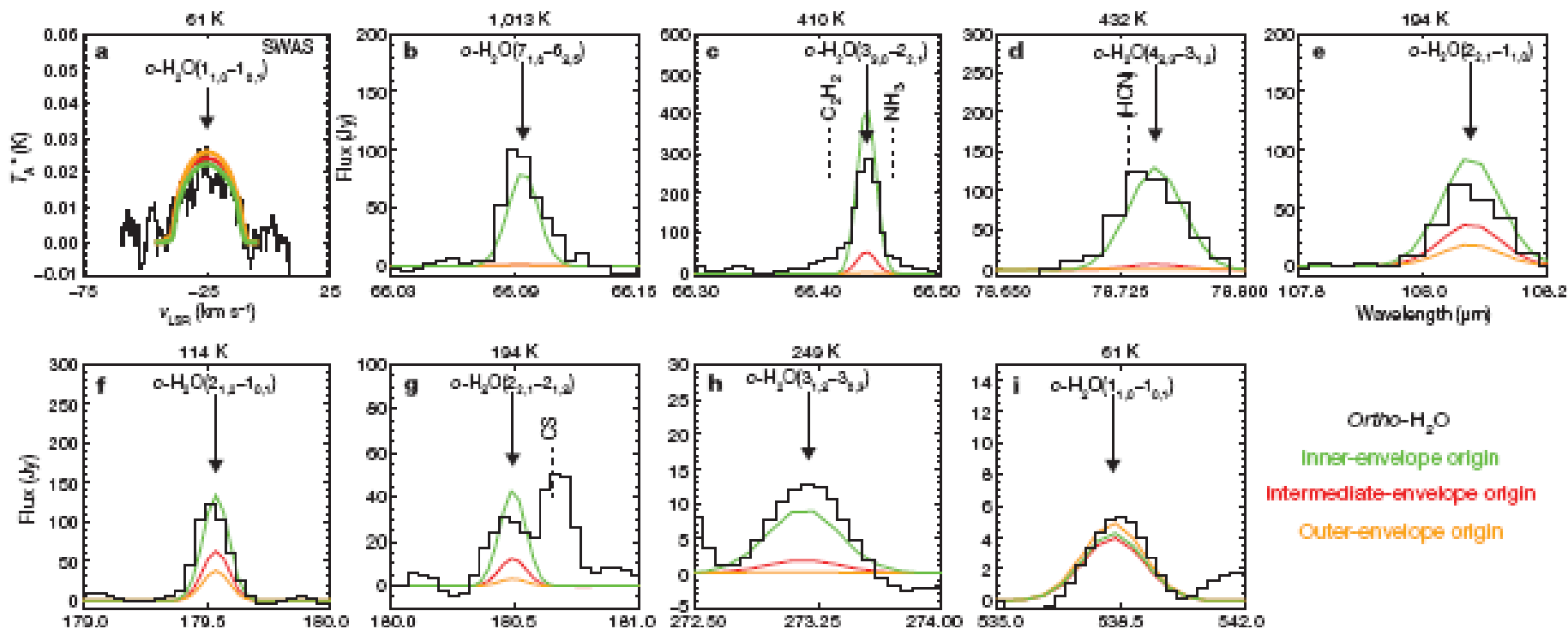


Detection of H<sub>2</sub>O 1<sub>1,0</sub>-1<sub>0,1</sub> at 556.936 GHz ( $E_{up} = 26.7$  K)

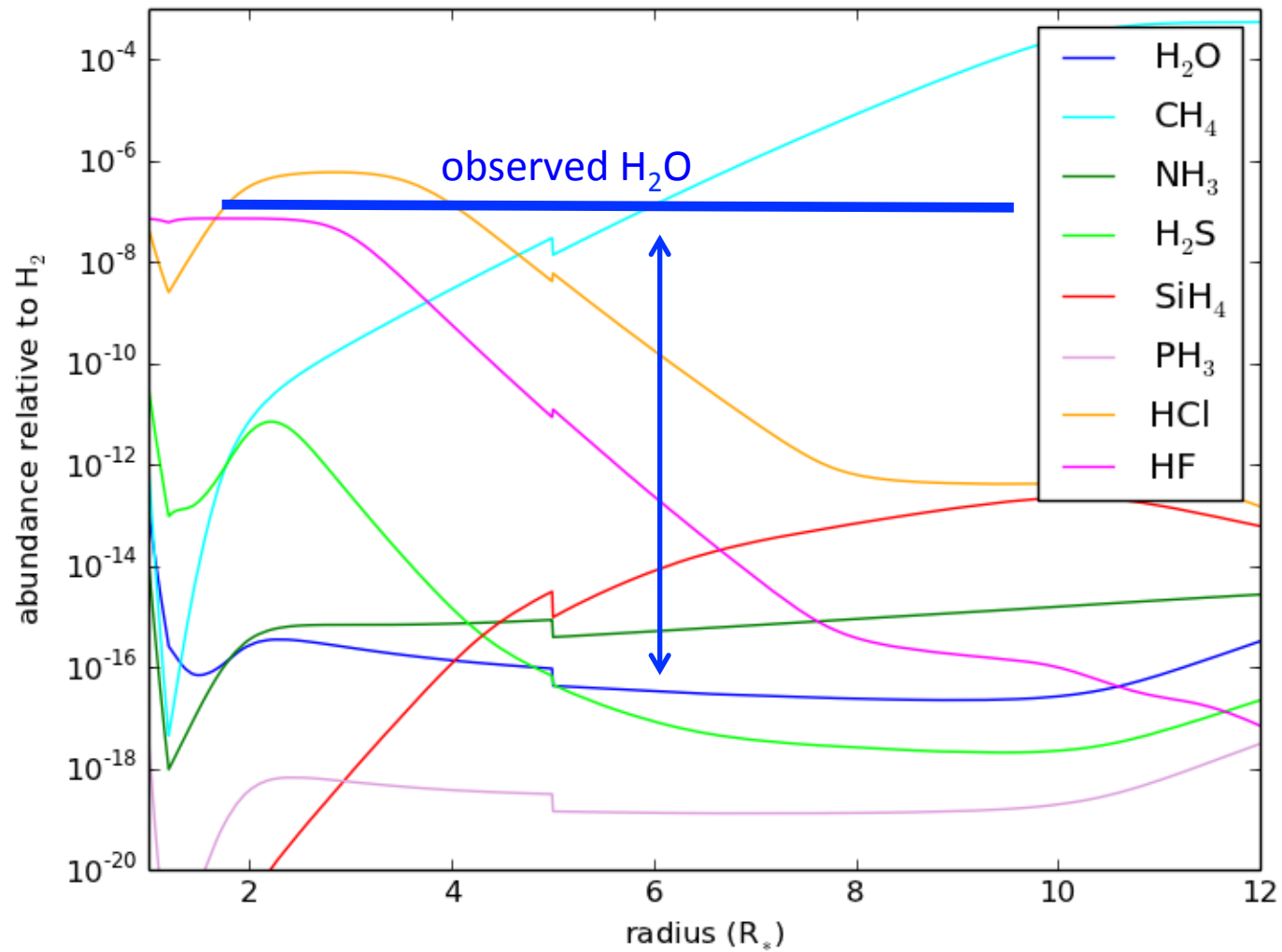
## LETTERS

## Warm water vapour in the sooty outflow from a luminous carbon star

L. Decin<sup>1,2</sup>, M. Agúndez<sup>3,7</sup>, M. J. Barlow<sup>4</sup>, F. Daniel<sup>3</sup>, J. Cernicharo<sup>3</sup>, R. Lombaert<sup>1</sup>, E. De Beck<sup>1</sup>, P. Royer<sup>1</sup>, B. Vandenbussche<sup>1</sup>, R. Wesson<sup>4</sup>, E. T. Polehampton<sup>5,6</sup>, J. A. D. L. Blommaert<sup>1</sup>, W. De Meester<sup>1</sup>, K. Exter<sup>1</sup>, H. Feuchtgruber<sup>8</sup>, W. K. Gear<sup>9</sup>, H. L. Gomez<sup>9</sup>, M. A. T. Groenewegen<sup>10</sup>, M. Guélin<sup>16</sup>, P. C. Hargrave<sup>9</sup>, R. Huygen<sup>1</sup>, P. Imhof<sup>11</sup>, R. J. Ivison<sup>12</sup>, C. Jean<sup>1</sup>, C. Kahane<sup>17</sup>, F. Kerschbaum<sup>14</sup>, S. J. Leeks<sup>5</sup>, T. Lim<sup>5</sup>, M. Matsuura<sup>4,15</sup>, G. Olofsson<sup>13</sup>, T. Posch<sup>14</sup>, S. Regibo<sup>1</sup>, G. Savini<sup>4</sup>, B. Sibthorpe<sup>12</sup>, B. M. Swinyard<sup>5</sup>, J. A. Yates<sup>4</sup> & C. Waelkens<sup>1</sup>



## 2.- *Herschel* surprises: detection of hydrides H<sub>2</sub>O





## 2.- *Herschel* surprises: detection of hydrides $\text{PH}_3$

### CONFIRMATION OF CIRCUMSTELLAR PHOSPHINE

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<sup>1</sup> Instituto de Ciencia de Materiales de Madrid, CSIC, C/ Sor Juana Inés de la Cruz 3, E-28049 Cantoblanco, Spain

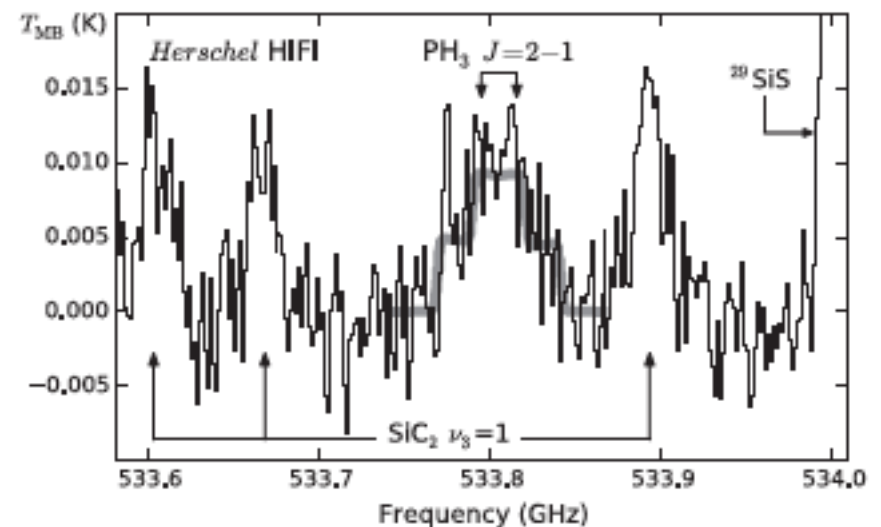
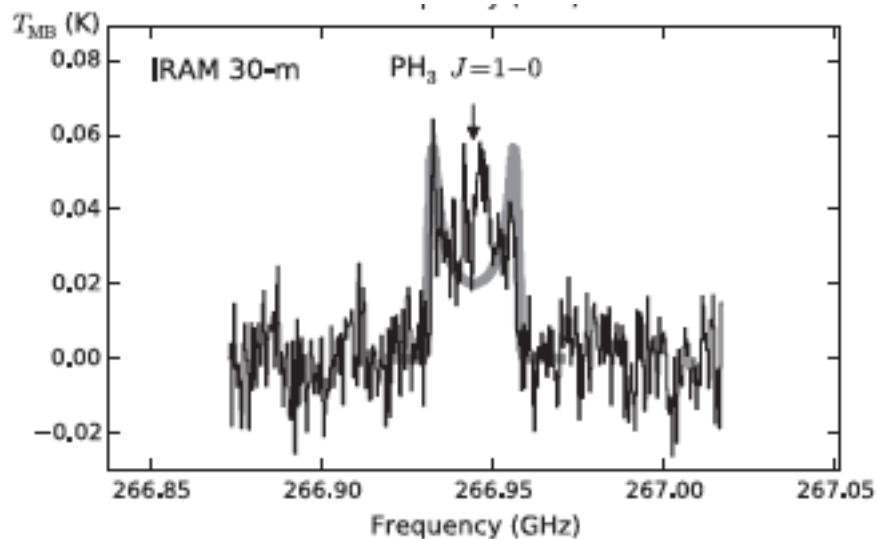
<sup>2</sup> Sterrenkundig Instituut Anton Pannekoek, University of Amsterdam, Science Park 904, NL-1098 Amsterdam, The Netherlands

<sup>3</sup> Instituut voor Sterrenkunde, Katholieke Universiteit Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

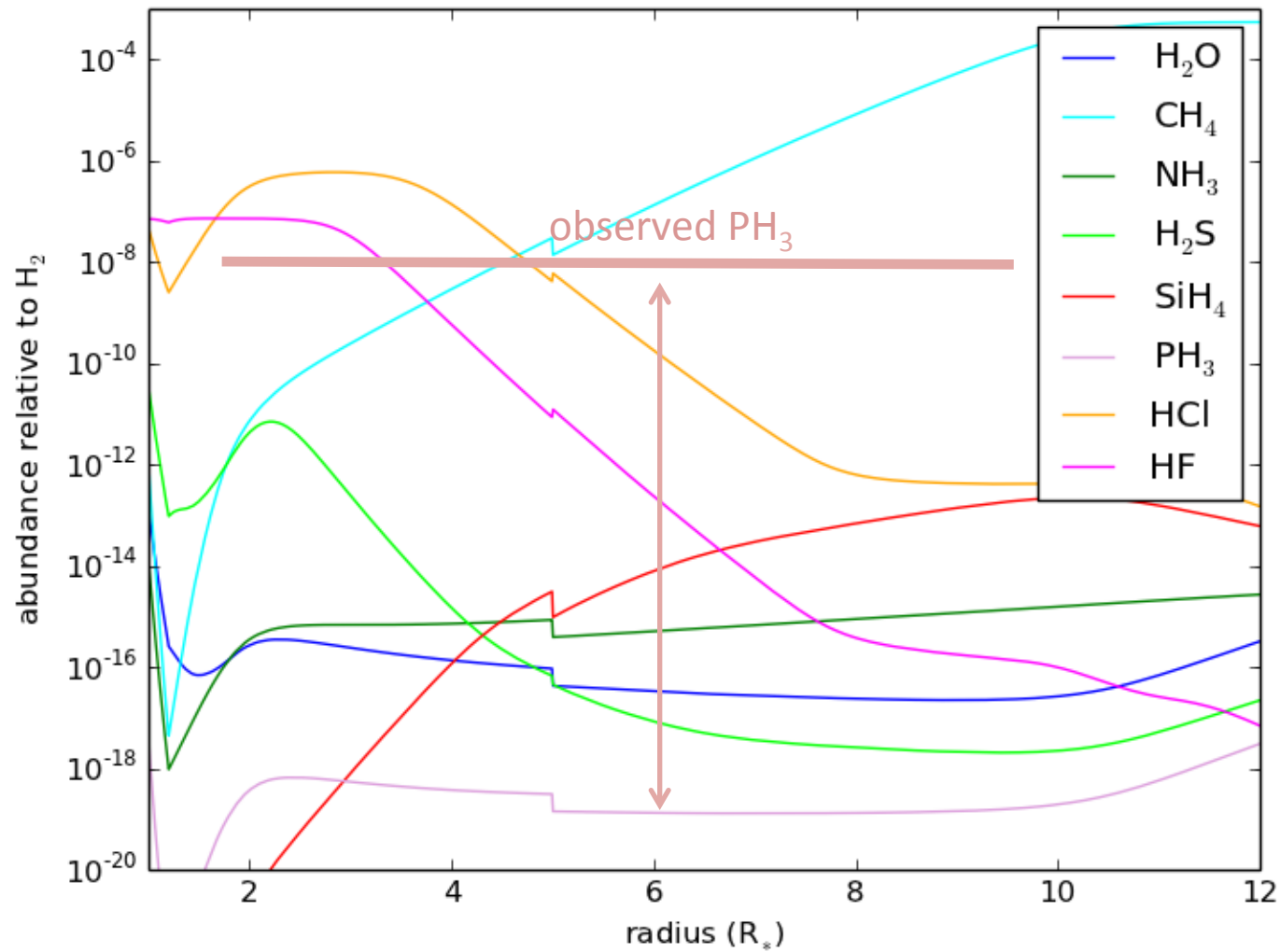
<sup>4</sup> LERMA, Observatoire de Paris, 61 Av. de l'Observatoire, F-75014 Paris, France

<sup>5</sup> European Space Astronomy Centre, Urb. Villafranca del Castillo, P.O. Box 50727, E-28080 Madrid, Spain

Received 2014 June 16; accepted 2014 July 3; published 2014 July 16

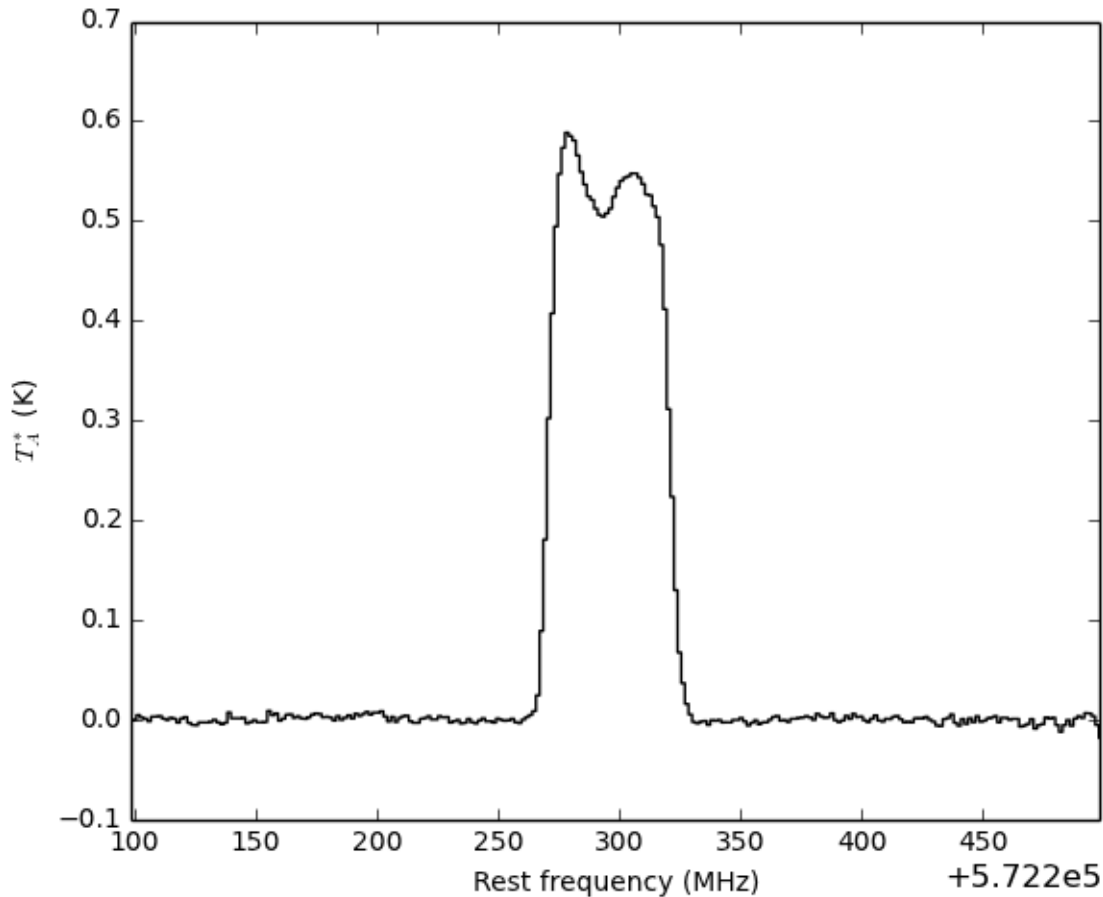


## 2.- *Herschel* surprises: detection of hydrides $\text{PH}_3$



## 2.- *Herschel* surprises: detection of hydrides $\text{NH}_3$

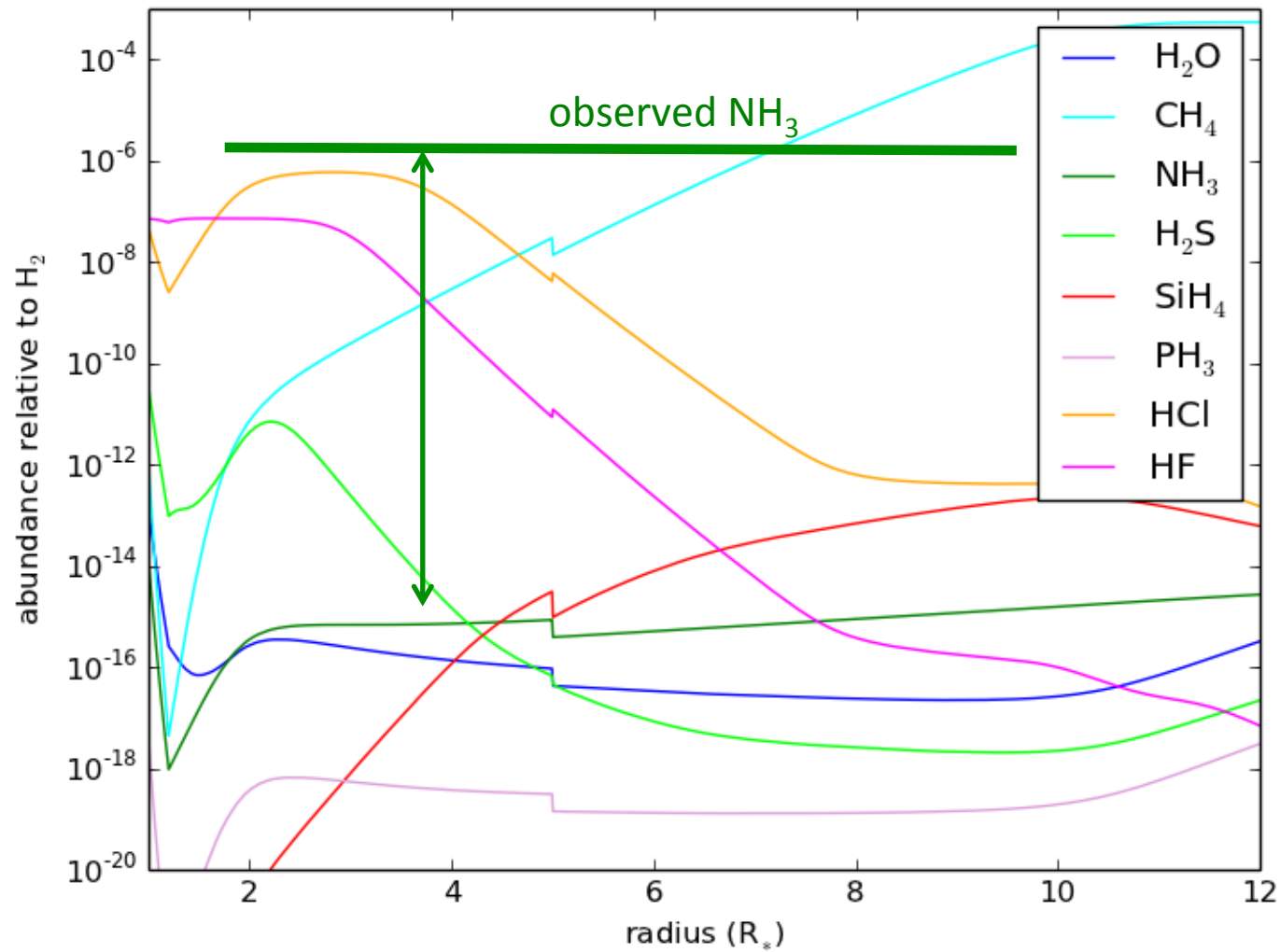
$\text{NH}_3$   $1_0-0_0$  line observed in IRC+10216 by HIFI



Line previously observed by *Odin*  
(Hasegawa et al 2006)

And ro-vibrational absorption  
lines of  $\text{NH}_3$  observed in the IR  
(Keady & Ridgway 1993)

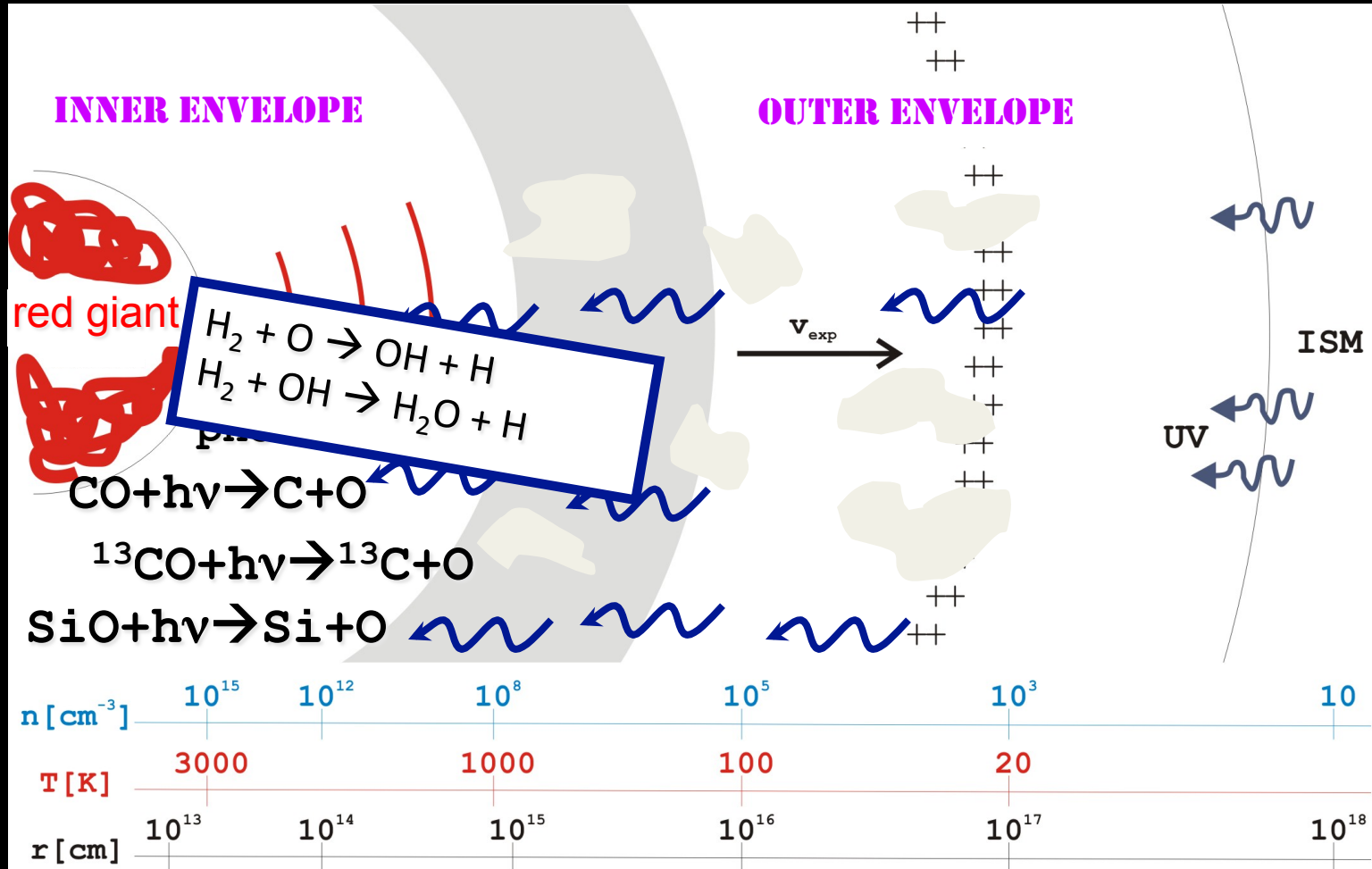
## 2.- *Herschel* surprises: detection of hydrides PH<sub>3</sub>





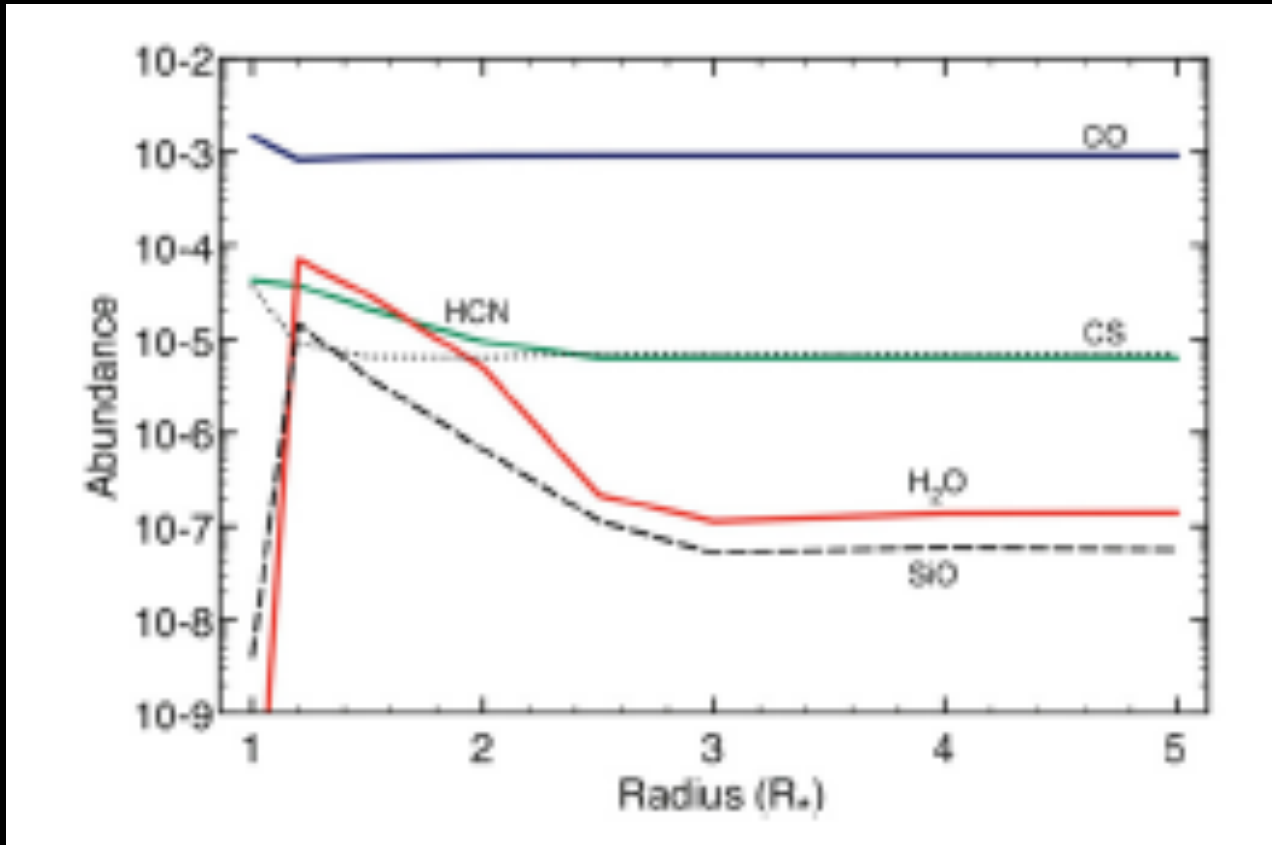
## 2.- Why these so big differences ?

photochemistry in inner layers due to a clumpy envelope

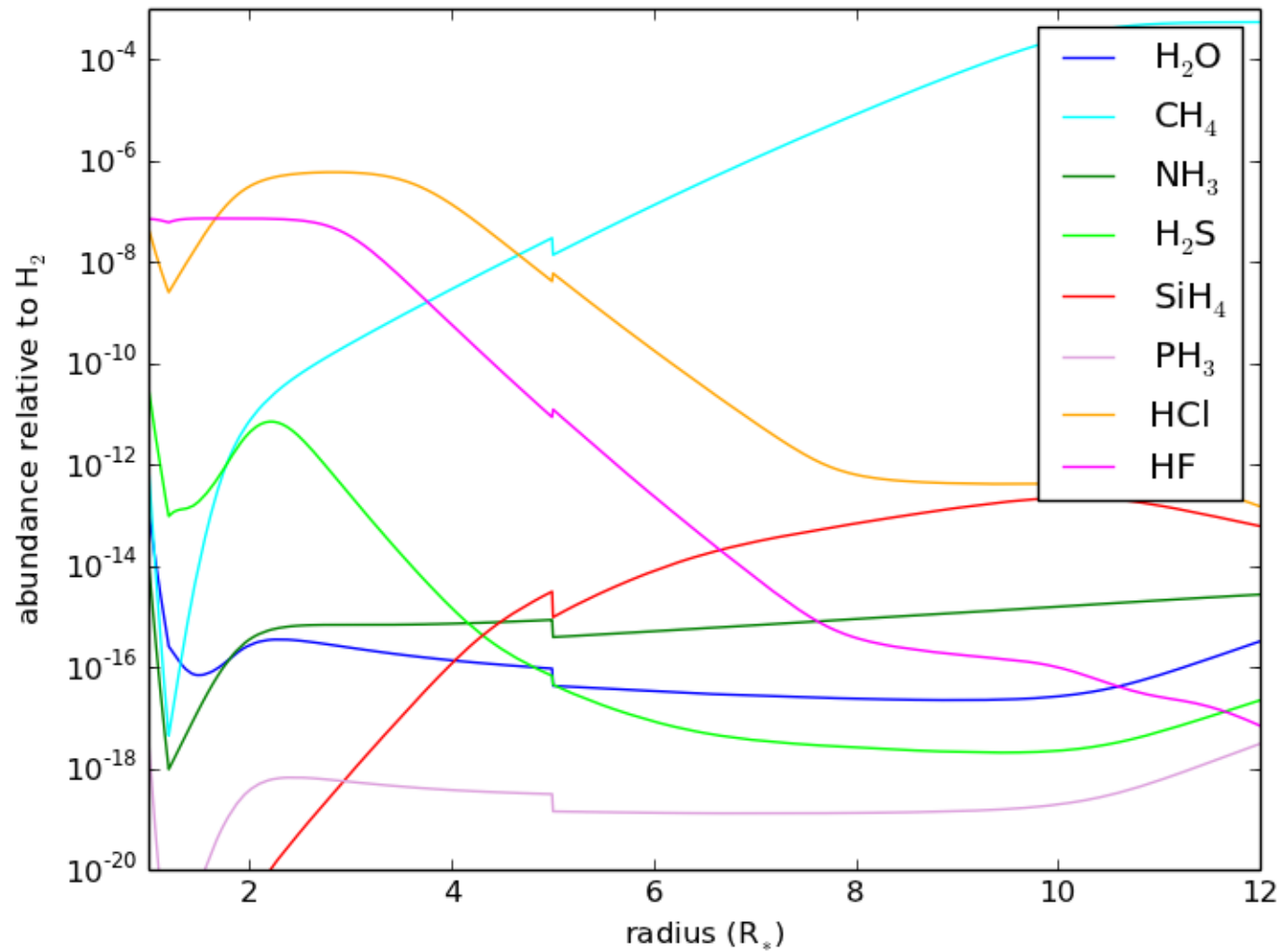


## 2.- Why these so big differences ?

### shocks-driven chemistry



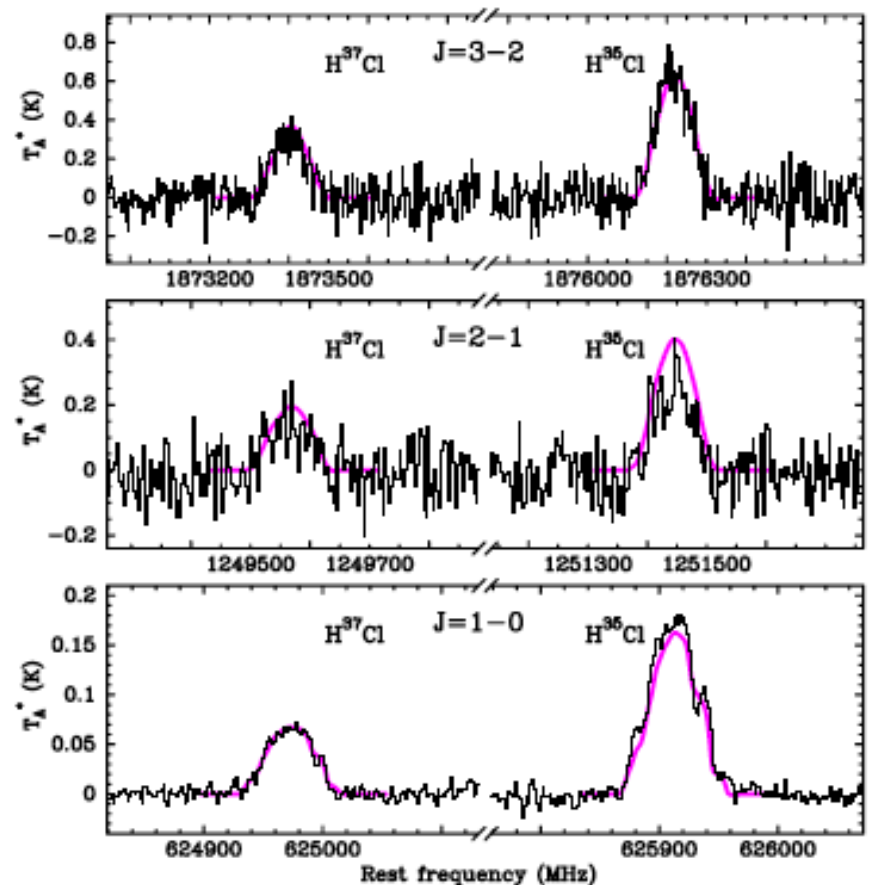
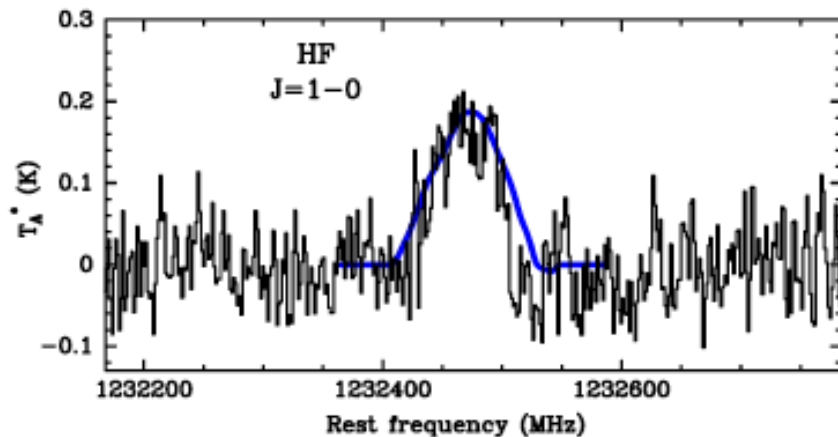
## 2.- Hydrides HCl and HF



## 2.- Hydrides HCl and HF

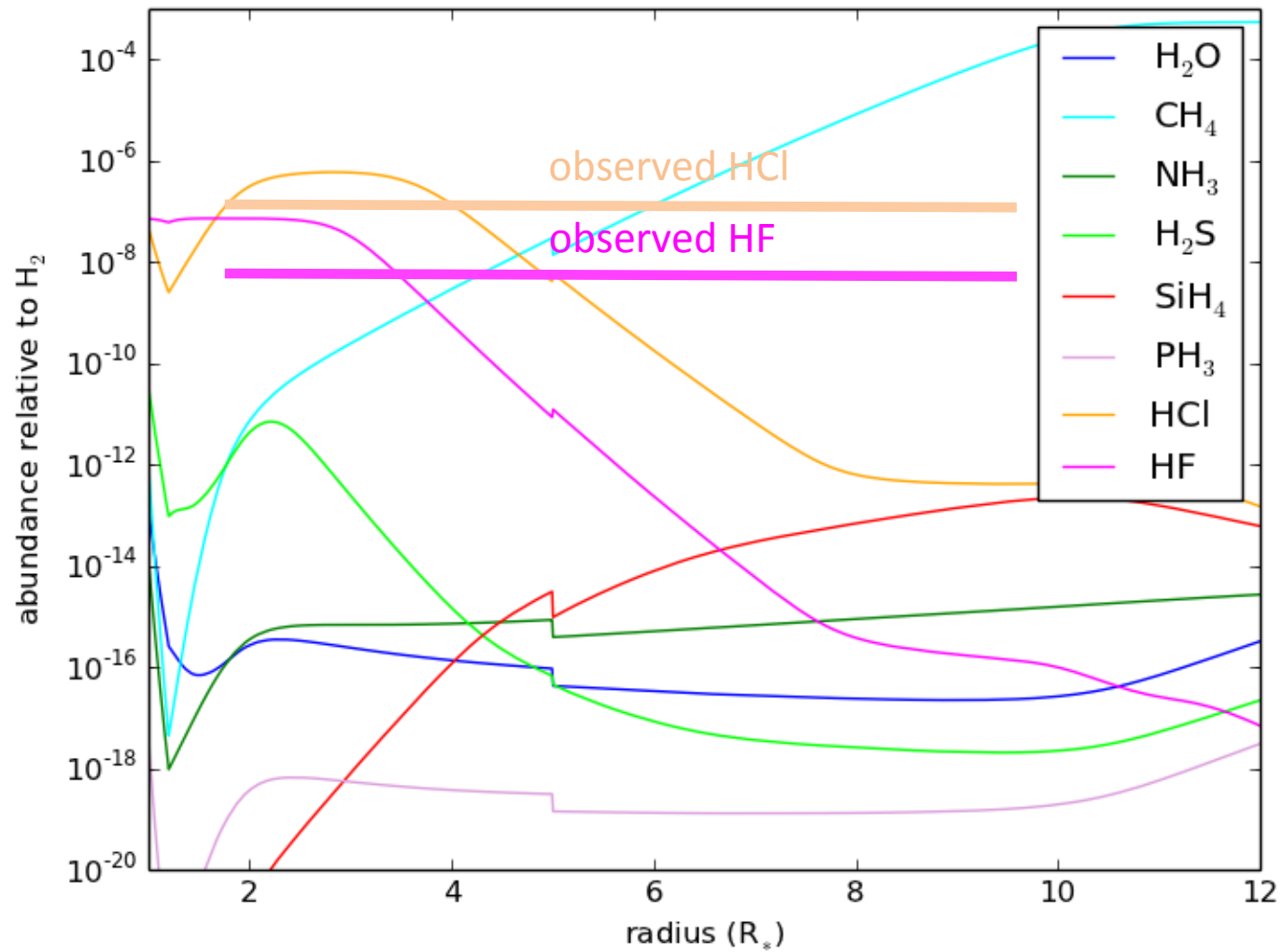
### HIFI<sup>★</sup> detection of hydrogen fluoride in the carbon star envelope IRC +10216

M. Agúndez<sup>1</sup>, J. Cernicharo<sup>2</sup>, L. B. F. M. Waters<sup>3,4</sup>, L. Decin<sup>4,5</sup>, P. Encrenaz<sup>6</sup>, D. Neufeld<sup>7</sup>, D. Teyssier<sup>8</sup>, and F. Daniel<sup>2</sup>





## 2.- Hydrides HCl and HF



# 1.- ALMA surprises: observations of CH<sub>3</sub>CN

THE PECULIAR DISTRIBUTION OF CH<sub>3</sub>CN IN IRC +10216 SEEN BY ALMA

M. AGÚNDEZ<sup>1</sup>, J. CERNICHARO<sup>1</sup>, G. QUINTANA-LACACI<sup>1</sup>, L. VELILLA-PRieto<sup>1</sup>, A. CASTRO-CARRIZO<sup>2</sup>, N. MARCELINO<sup>3</sup>,  
AND M. GUÉLIN<sup>2</sup>

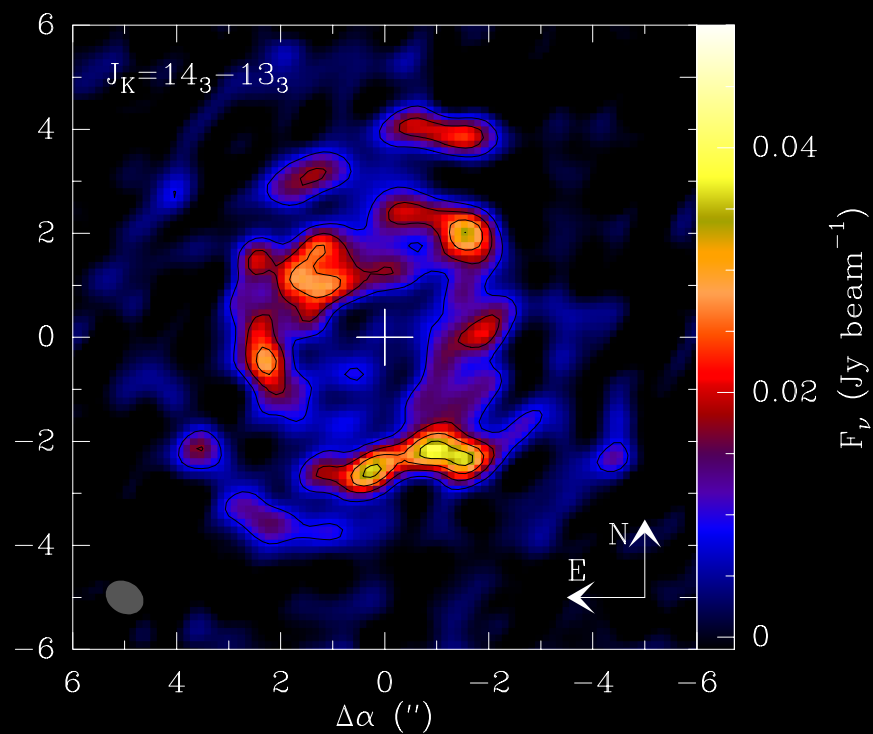
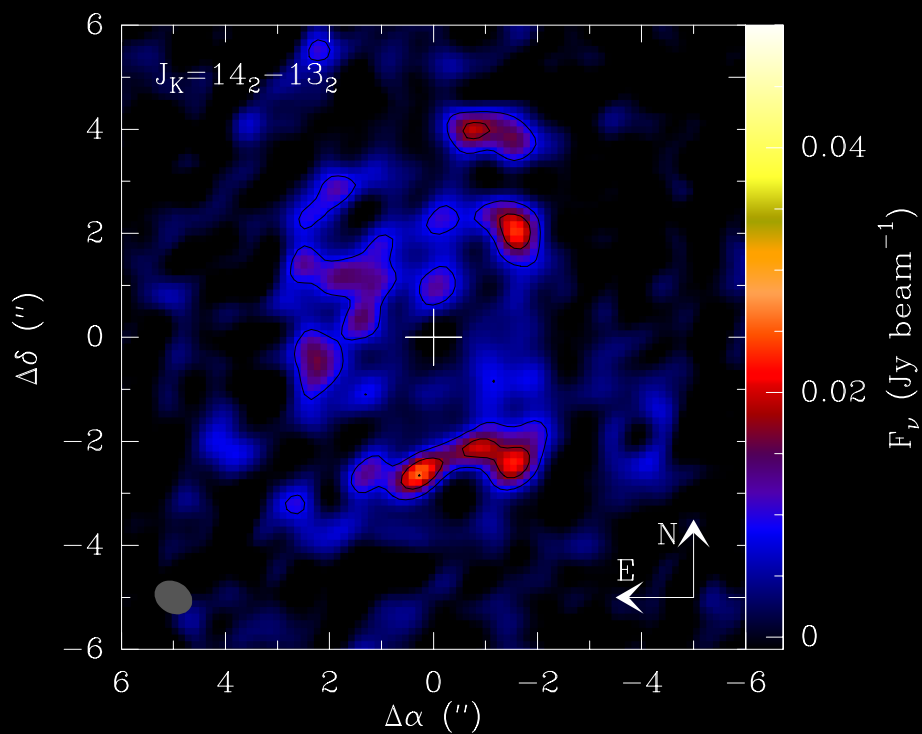
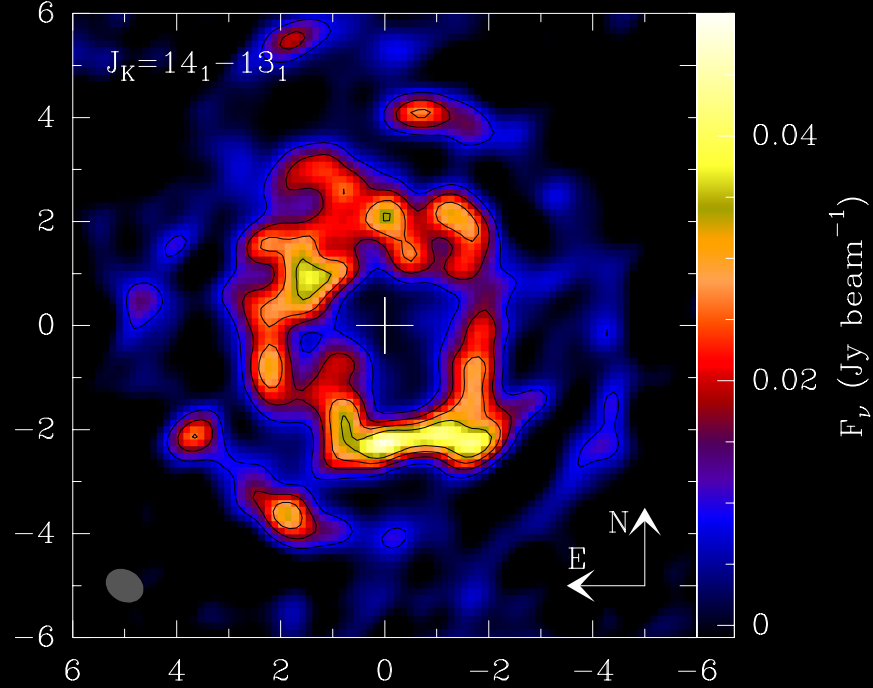
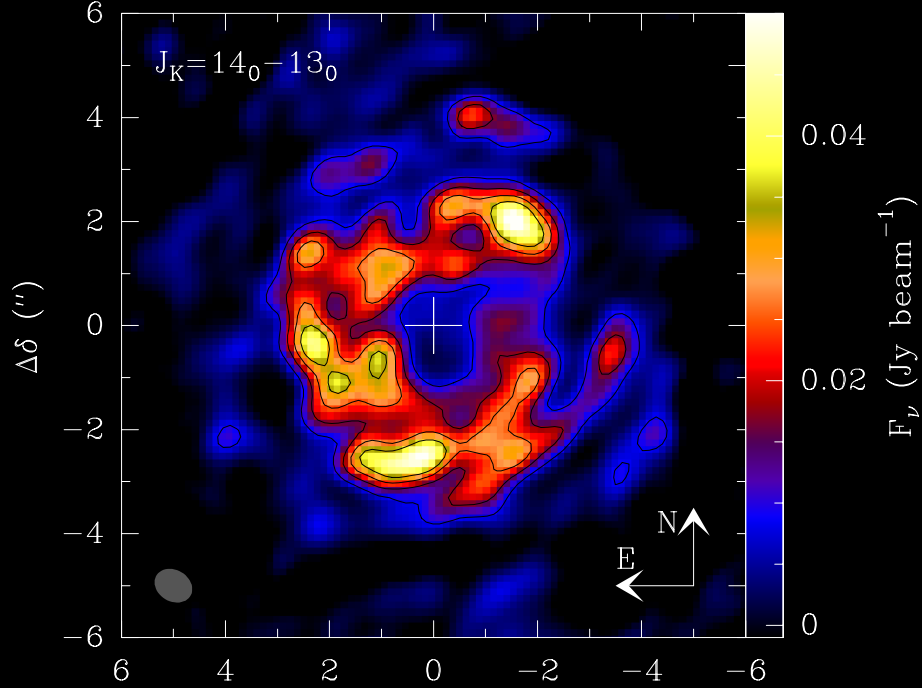
submitted to A&A Letters

ALMA Cycle 0

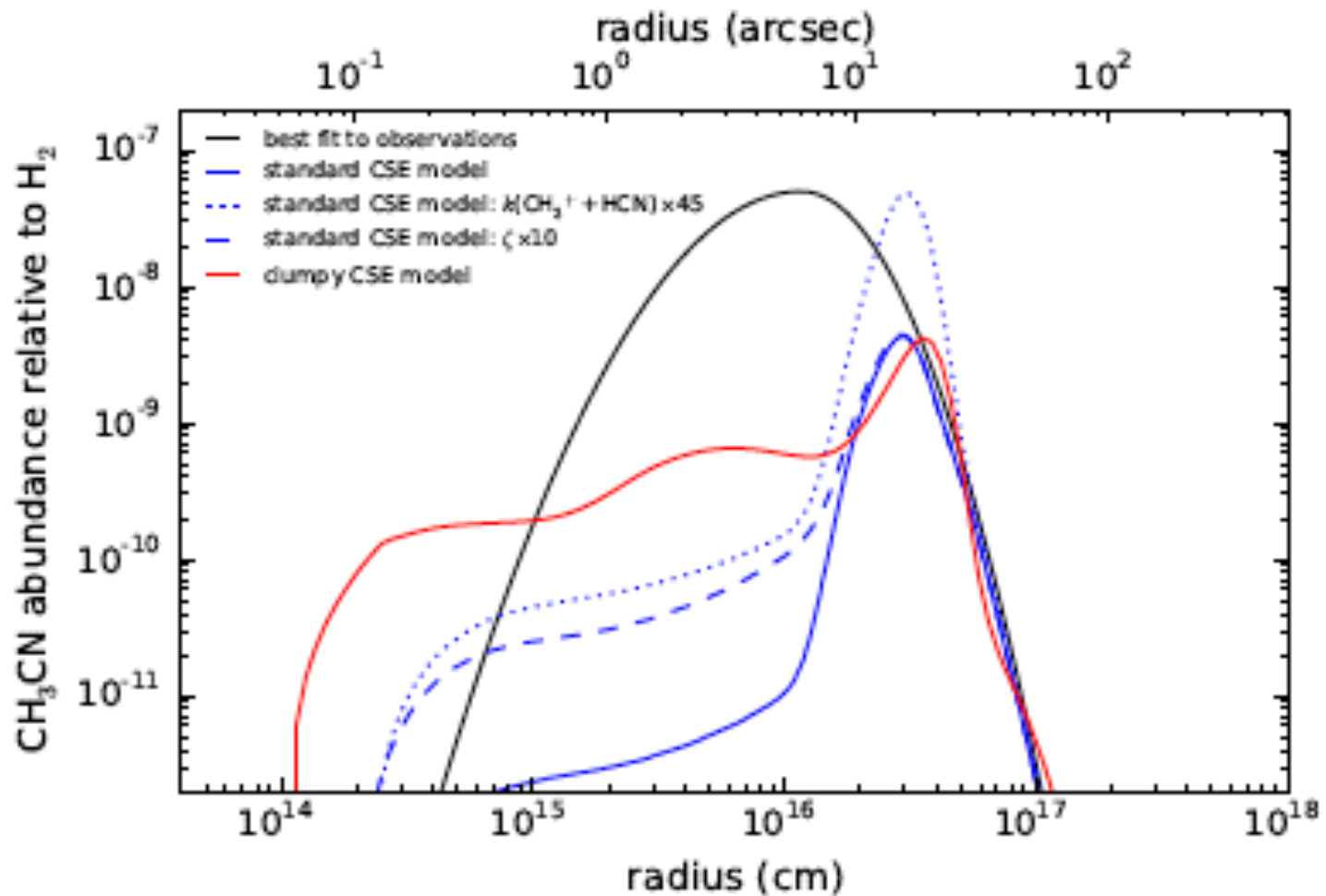
Band 6 (257.5 GHz)

angular resolution = 0.76''×0.60''

rms = 3.4 mJy beam<sup>-1</sup> per 0.5 MHz channel



# 1.- ALMA surprises: observations of CH<sub>3</sub>CN





## Conclusions on the chemistry in the inner layers of IRC+10216:

### *Herschel*

- Many hydrides ( $\text{H}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{PH}_3$ ) much more abundant than expected

### ALMA

- Molecules such as  $\text{CH}_3\text{CN}$  is formed at much inner regions than expected

Chemical processes in the inner layers still need to be understood:

- Dust formation
- Shocks
- Photochemistry