

# New Laboratory Measurements of Rhomboidal $c\text{-SiC}_3$

Carl A. Gottlieb and Patrick Thaddeus

Harvard-Smithsonian Center for Astrophysics  
and  
School of Engineering and Applied Sciences  
Harvard University, Cambridge MA

# SMA line survey of IRC+10216 in the 345 GHz band

**Nimesh Patel**

Submillimeter Array  
Harvard-Smithsonian Center for Astrophysics

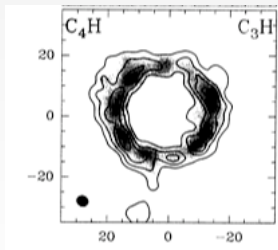
## Collaborators:

Ken Young, Patrick Thaddeus, Robert Wilson, Mark Reid, Eric Keto (CfA)  
Michael McCarthy, Carl Gottlieb, Sandra Brünken (CfA, Harvard Spectroscopy lab)  
Karl Menten (MPIFR, Bonn), Jinhua He (Yunnan Observatory), Dinh-van-Trung (ASIAA)



# SMA Survey

- Frequency range : 295 – 355 GHz
- Field of view :  $\sim 30$  arcsec
- Synthesized beam :  $3'' \times 2''$   
[ $1'' = 2 \times 10^{15}$  cm]
- Exploring inner envelope :  $T = (100 - 1000)$  K  
 $10^{14} - 10^{15}$  cm [  $R_{\star} = 7 \times 10^{13}$  cm ]
- Outer shell :  
 $4 \times 10^{16} - 10^{17}$  cm (20 – 50)''



*Lucas and Guélin (1999)*

- **Results :**

- ~400 lines detected

- ~70 lines unidentified

- ~100 narrow lines [ $V_{\text{exp}} < 7 \text{ km s}^{-1}$ ]

- **Vibrationally Excited States :**

- Stretching modes ( $E/k \leq 3700 \text{ K}$ )

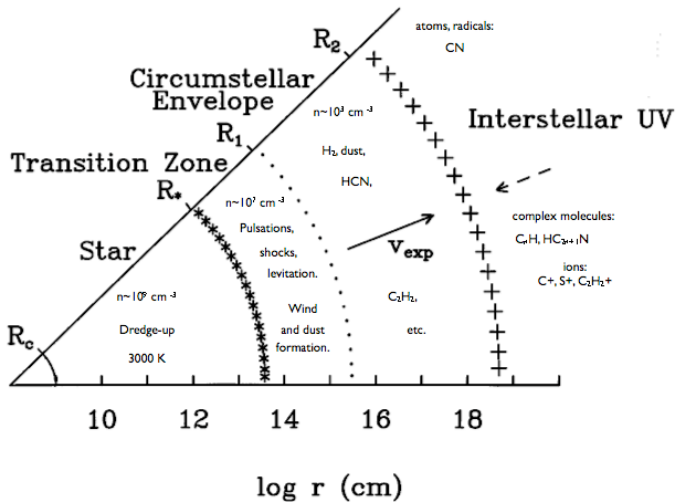
- CS ( $\nu = 2$ ) and CO ( $\nu = 1$ )

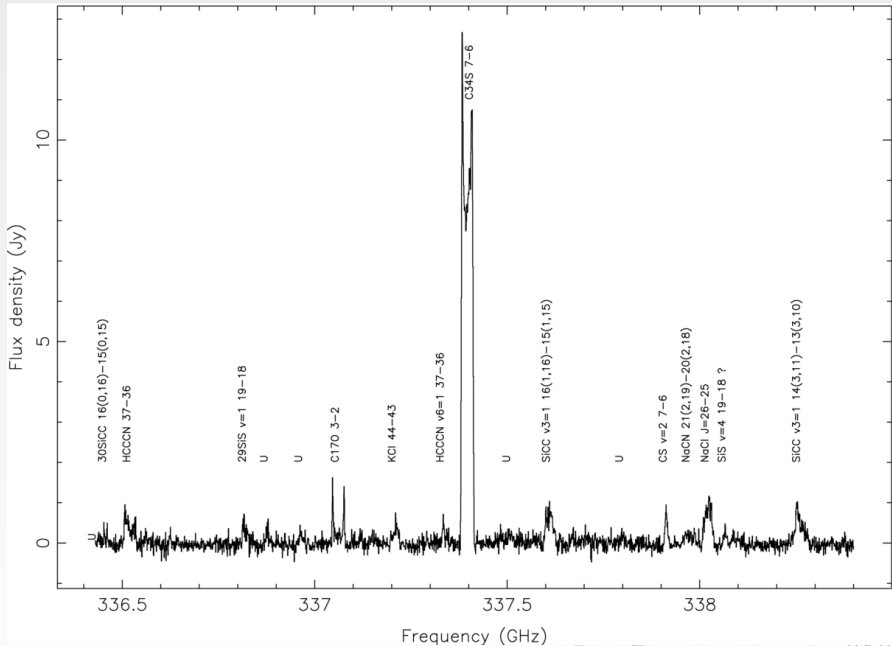
- Bending modes ( $E/k \leq 800 \text{ K}$ )

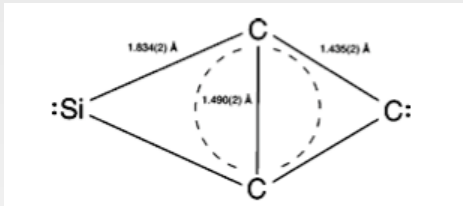
- HCCCN and SiCC ( $\nu_3 = 1, 2$ )

[1] N.A. Patel, K.H. Young, S. Brünken, R.W. Wilson, P. Thaddeus, K.M. Menten, M. Reid, M.C. McCarthy, Dinh-V Trung, C.A. Gottlieb, and A. Hedden, *Astrophys. Journ.* **692**, 1205 (2009).

[2] N.A. Patel *et al.*, in preparation.







- **1999 :**

46 transitions with  $\nu \leq 286$  GHz

$J \leq 26$  and  $K_a \leq 6$

$\Delta_K = 0.0$  (**constrained**)

- **Present :**

c-SiC<sub>3</sub> in SMA spectral line survey?

**How accurate are frequencies in CDMS catalog?**

A. J. Apponi, M. C. McCarthy, C. A. Gottlieb, and P. Thaddeus, *Journ. Chem. Phys.* **111**, 3911 (1999).

# New Laboratory Measurements of c-SiC<sub>3</sub>

- Frequency range : 315 – 438 GHz
- $J \leq 40$  and  $K_a \leq 20$
- 50 transitions with  $E/k \leq 825$  K
- Total : 96 transitions [Old + New]
- RMS : 38 kHz with 12 constants
- $\Delta_K$  determined ( $r_{ij} = -0.69$ )



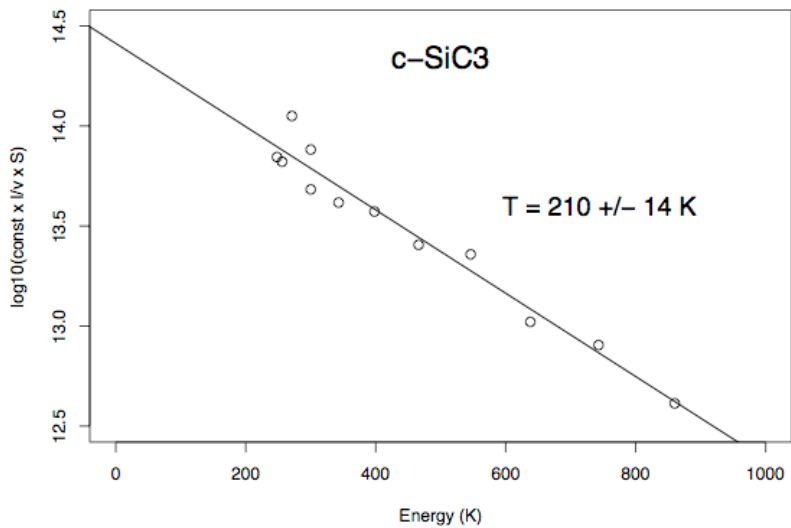
# New Measurements vs. CDMS

$K_a$	Transition	This work	CDMS	$\Delta$ (MHz)
<b>0</b>	$30_{0,30} - 29_{0,29}$	328,519.91(1)	328,520.5 (1)	<b>0.6</b>
<b>0</b>	$40_{0,40} - 39_{0,39}$	436,056.72(5)	436,064.8(17)	<b>8</b>
<b>12</b>	$37_{12} - 36_{12}$	432,585.45(3)	432,620.3(17)	<b>35</b>
<b>20</b>	$30_{20} - 29_{20}$	350,021.77(3)	350,505. (21)	<b>483</b>

Constant	Laboratory	
	This work	AMGT <sup>a</sup>
Rotational constants:		
$A$	37950.65(12)	37943.76(51)
$B$	6282.9550(6)	6282.904(4)
$C$	5386.8181(6)	5386.868(4)
Quartic centrifugal distortion constants:		
$10^3 \times \Delta_J$	1.6808(6)	1.667(4)
$10^3 \times \Delta_{JK}$	7.86(1)	8.55(12)
$\Delta_K$	0.249(8)	<b>0.0<sup>b</sup></b>
$10^3 \times \delta_J$	0.2698(1)	0.229(5)
$10^3 \delta_K$	11.45(8)	10.3(5)
Sextic centrifugal distortion constants:		
$10^9 \times \Phi_J$	1.3(3)	-20(5)
$10^6 \times \Phi_{JK}$	-0.091(7)	-1.88(25)
$10^6 \times \Phi_{KJ}$	...	61.0(64)
$10^3 \times \Phi_K$	0.24(2)	...
$10^6 \times \phi_J$	...	-0.026(3)
$10^6 \times \phi_{JK}$	0.08(4)	-2.7(5)

<sup>a</sup>A. J. Apponi, M. C. McCarthy, C. A. Gottlieb, and P. Thaddeus, *J. Chem. Phys.* **111**, 3911 (1999).

<sup>b</sup>Constrained to zero because of high correlation with  $A$  rotational constant, versus  $r_{i,j} = -0.693$  (This work).



# Conclusions

- Frequency range : 315 – 438 GHz
- $J \leq 40$  and  $K_a \leq 20$
- 50 transitions with  $E/k \leq 825$  K
- Total : 96 transitions [Old + New]
- RMS : 38 kHz with 12 constants
- $\Delta_K$  determined
- Calculated frequencies accurate to  $\sim 3$  MHz ( $1 \text{ km s}^{-1}$ )  
at 1000 GHz.