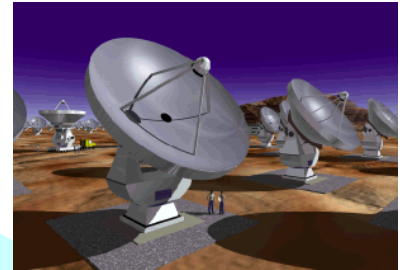


# Interstellar Weeds



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# Reported Interstellar and Circumstellar Molecules

N=2	N=2	N=3	N=3	N=4	N = 5	N = 6	N = 7	N = 8	N = 9	N = 10
H <sub>2</sub>	AlCl	H <sub>3</sub> <sup>+</sup>	HDO	NH <sub>3</sub>	CH <sub>4</sub>	CH <sub>3</sub> OH	CH <sub>3</sub> NH <sub>2</sub>	HCOOCH <sub>3</sub>	(CH <sub>3</sub> ) <sub>2</sub> O	(CH <sub>3</sub> ) <sub>2</sub> CO
CH	PN	CH <sub>2</sub>	OCS	H <sub>3</sub> O <sup>+</sup>	SiH <sub>4</sub>	CH <sub>3</sub> SH	CH <sub>3</sub> CCH	CH <sub>3</sub> C <sub>2</sub> CN	C <sub>2</sub> H <sub>5</sub> OH	CH <sub>3</sub> C <sub>4</sub> CN
CH <sup>+</sup>	SiN	NH <sub>2</sub>	MgCN	H <sub>2</sub> CO	CH <sub>2</sub> NH	C <sub>2</sub> H <sub>4</sub>	CH <sub>3</sub> CHO	C <sub>6</sub> H <sub>2</sub>	C <sub>2</sub> H <sub>5</sub> CN	?glycine?
NH	SiO	H <sub>2</sub> O	MgNC	H <sub>2</sub> CS	H <sub>2</sub> C <sub>3</sub>	CH <sub>3</sub> CN	<sup>c-</sup> CH <sub>2</sub> OCH <sub>2</sub>	C <sub>7</sub> H	CH <sub>3</sub> C <sub>4</sub> H	CH <sub>3</sub> CH <sub>2</sub> CHO
OH	SiS	H <sub>2</sub> S	NaCN	<i>l</i> -C <sub>3</sub> H	<i>l</i> -C <sub>3</sub> H <sub>2</sub>	CH <sub>3</sub> NC	CH <sub>2</sub> CHCN	HOCH <sub>2</sub> CHO	C <sub>8</sub> H	(CH <sub>2</sub> OH) <sub>2</sub>
HF	CO <sup>+</sup>	C <sub>2</sub> H	SO <sub>2</sub>	<i>c</i> -C <sub>3</sub> H	<i>c</i> -C <sub>3</sub> H <sub>2</sub>	H <sub>2</sub> CCHO	HC <sub>4</sub> CN	CH <sub>3</sub> COOH	HC <sub>6</sub> CN	
C <sub>2</sub>	SO <sup>+</sup>	HCN	N <sub>2</sub> O	HCCH	H <sub>2</sub> CCN	NH <sub>2</sub> CHO	C <sub>6</sub> H	H <sub>2</sub> CCCHCN	CH <sub>3</sub> CONH <sub>2</sub>	
CN	PO	HNC	SiCN	HCNH <sup>+</sup>	H <sub>2</sub> NCN	HC <sub>3</sub> NH <sup>+</sup>	H <sub>2</sub> CCHOH	H <sub>2</sub> C <sub>6</sub>		
CO	SH	HCO	CO <sub>2</sub>	H <sub>2</sub> CN	CH <sub>2</sub> CO	H <sub>2</sub> C <sub>4</sub>		CH <sub>2</sub> CHCHO		N = 11
CS	AlF	HCO <sup>+</sup>	<i>c</i> -SiC <sub>2</sub>	<i>c</i> -C <sub>3</sub> H	HCOOH	C <sub>5</sub> H				HC <sub>8</sub> CN
CP	FeO	HOC <sup>+</sup>	SiNC	HCCN	C <sub>4</sub> H	C <sub>5</sub> N				
NO	SiC	HN <sub>2</sub> <sup>+</sup>	AINC	HNCO	HC <sub>2</sub> CN	C <sub>5</sub> O				N = 12
NS	CF <sup>+</sup>	HNO		HOCO <sup>+</sup>	HC <sub>2</sub> NC	C <sub>5</sub> S				C <sub>6</sub> H <sub>6</sub>
SO	? N <sub>2</sub> ?	HCS <sup>+</sup>		HNCS	C <sub>4</sub> Si					
HCl		C <sub>3</sub>		C <sub>2</sub> CN	C <sub>5</sub>	C <sub>6</sub> H <sup>-</sup>				N = 13
NaCl		C <sub>2</sub> O		C <sub>3</sub> O	C <sub>4</sub> N					HC <sub>10</sub> CN
KCl		C <sub>2</sub> S		C <sub>3</sub> S	H <sub>2</sub> COH <sup>+</sup>					
				SiC <sub>3</sub>						

# What are interstellar weeds?

- Abundant ( $10^{-7}$  w.r.t.  $H_2$ )
- Dense rotational emission spectra
- Normally associated with hot cores (100-300 K) and “saturated” organics
- Either heavy and/or associated with internal degrees of freedom such as torsion
- Low-lying vibrational states
- Spectra particularly difficult to predict

# Why Weeds are Important

- A) good probes of  $n$  and  $T$  over wide ranges, and of hot core extent
- B) make observing lesser abundant species difficult if not impossible
- C) poorly understood chemistry of formation which, if understood, would tell us about the history of cores
- D) pre-biotic

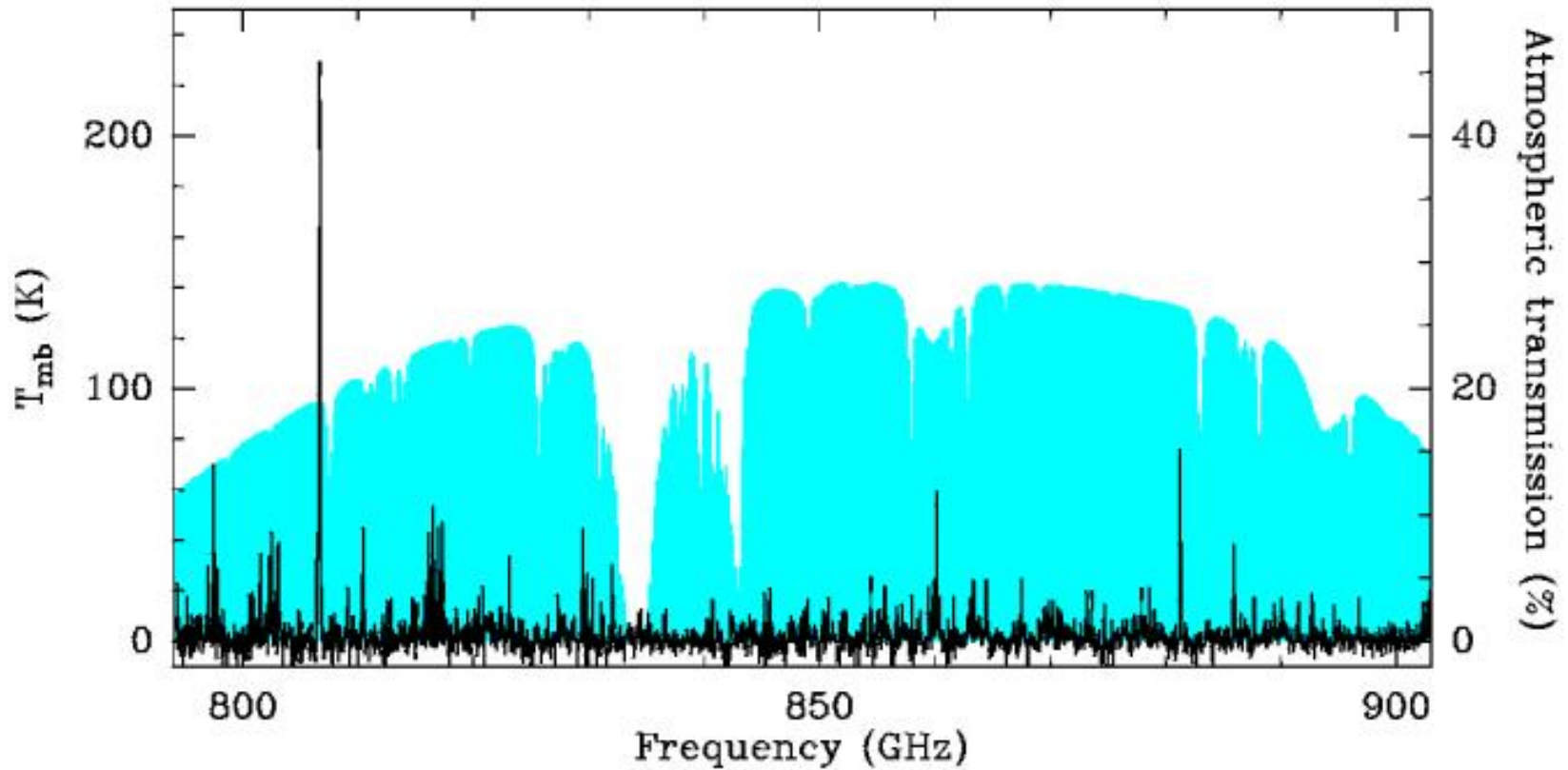
# Some Major Weeds (2002, NIST)

- $\text{CH}_3\text{OH}$  (1050)
- $\text{HCOOCH}_3$  (900)
- $\text{CH}_3\text{OCH}_3$  (961)
- $\text{CH}_3\text{CH}_2\text{CN}$  (507)
- $\text{SO}_2$  (340)
- $\text{CH}_3$  internal rotation
- $\text{CH}_3$  internal rotation
- Double internal rot.
- Heavy
- heavy

100 MHz/line through 700000 MHz

Half width = 10 – 30 MHz

# Ori KL Survey (CSO; Comito)



# Some Lab Work

- Methyl formate: Oesterling et al. 1999, up to 700 GHz
- Dimethyl ether: Groner et al. 1998, up to 600 GHz
- Methanol: Belov et al. 1995, up to 1.2THz ( $v=0,1,2$ )
- Propionitrile: Pearson et al. 1994, up to 460 GHz

# Newer Lab Work

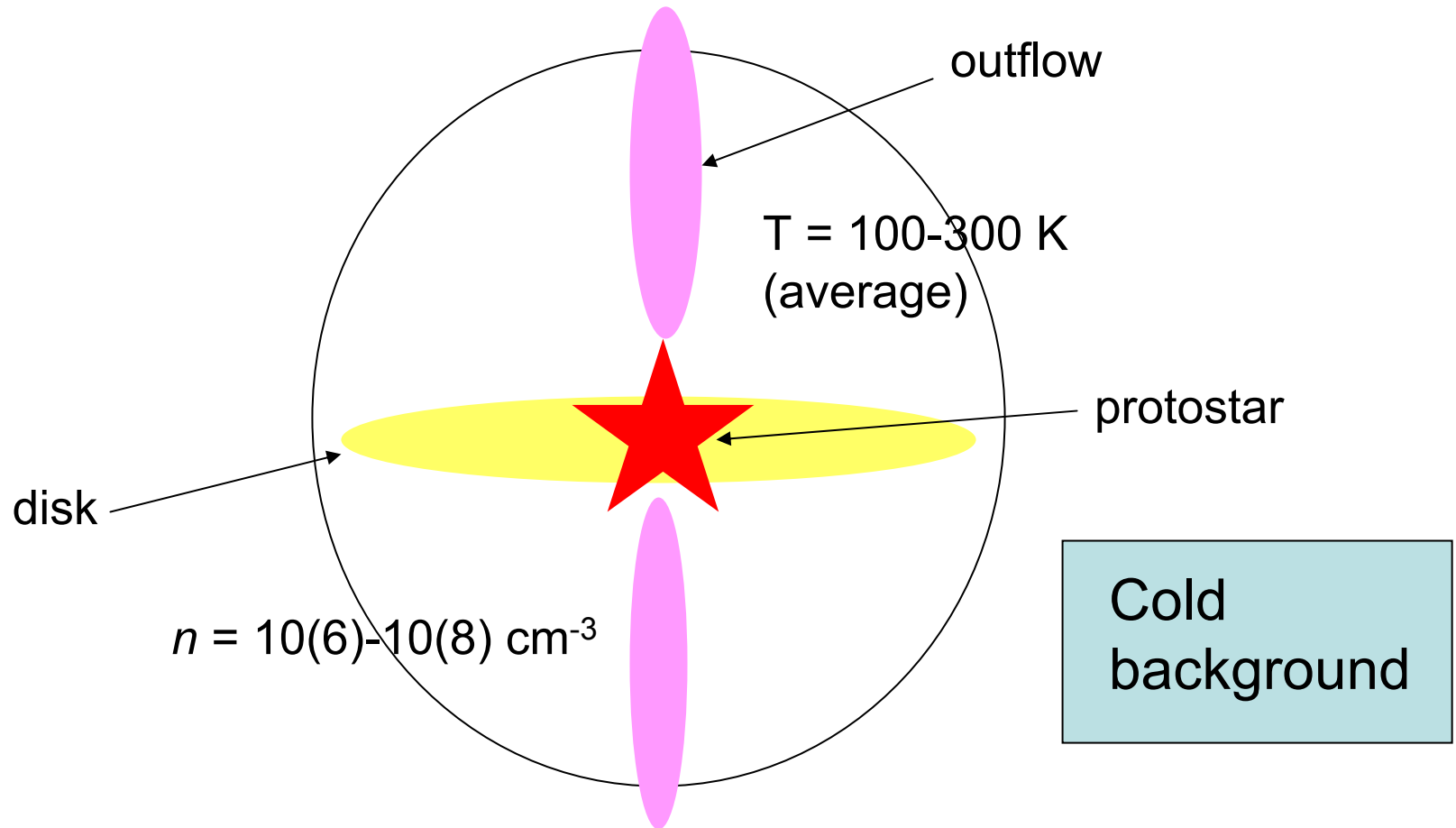
- Methanol:  $v=0$  &  $v=3$  “over 1 THz of frequency measured spectra”; Braakman et al., Pearson et al. (OSU Symp.)
- Methyl formate:  $v=1$ ; Ogata et al. 2004
- Methyl formate ( $C^{13}$ ): Willaert et al. 2006; us

# Weeds in Catalogues

- Methanol (up to 1.00 THz; Cologne; work at higher frequencies)
- Methyl formate (up to 1.67 THz; JPL, but far from accurate)
- Dimethyl ether (up to 2.17 THz, JPL, but predictions far from accurate)
- Ethyl cyanide (up to 3.39 THz; JPL, but far from accurate)

Isotopologues and excited states less well known typically.

# Hot Core/Corino Environment

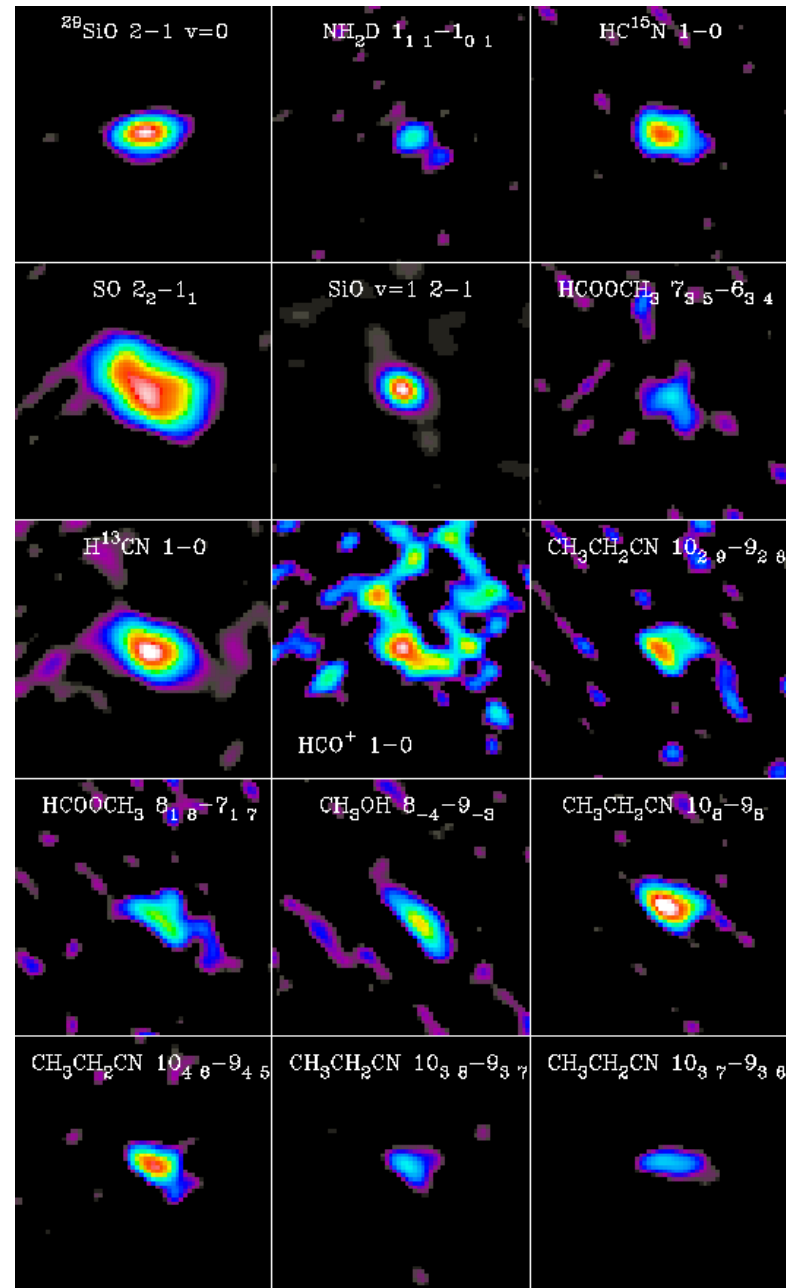


# OMC: KL

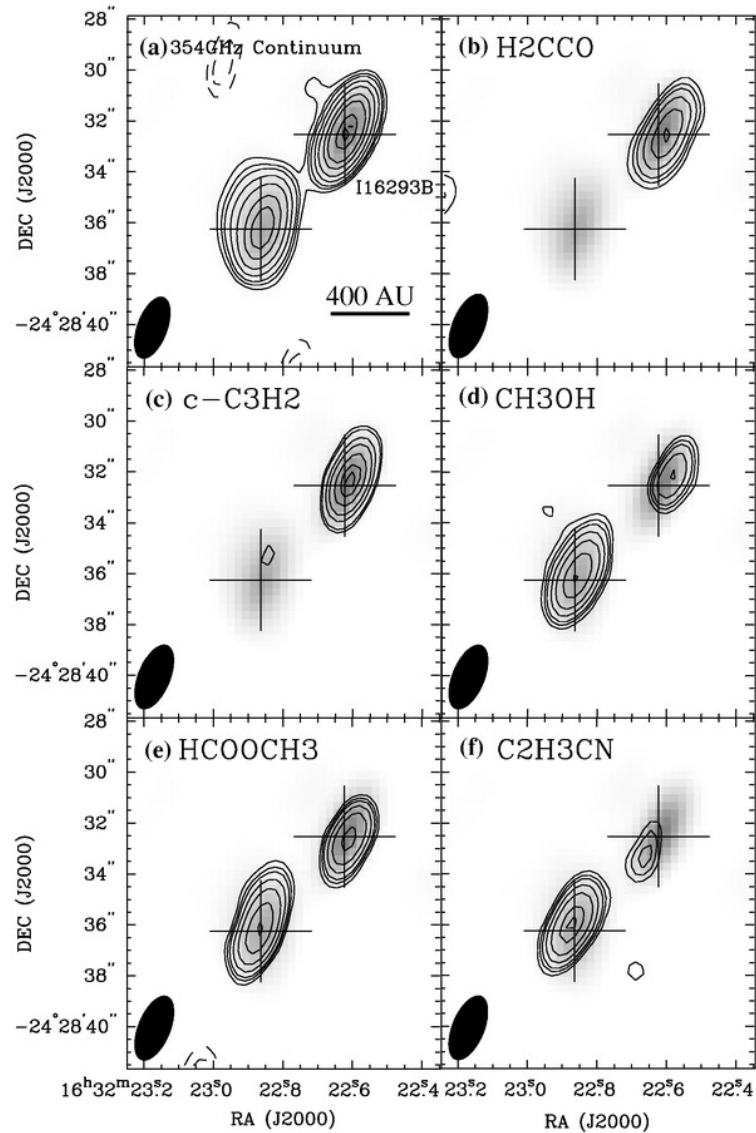
## HOT CORES

Molecular inventory contains gaseous saturated (H-rich) “normal” organic molecules, not detected in colder regions. Ice mantles no longer exist.

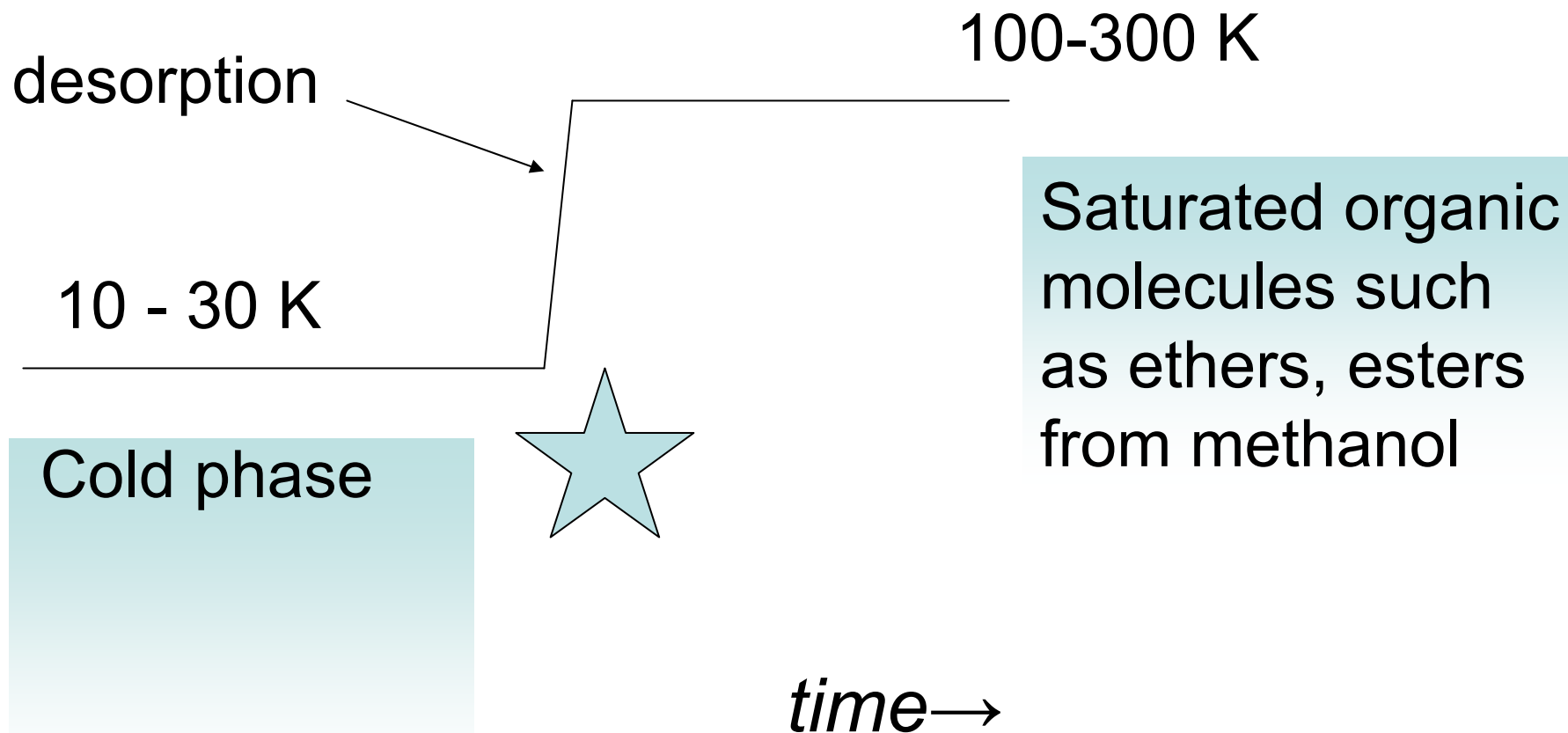
Two sources: hot core & compact ridge



# SMA – IRAS 16293-2422

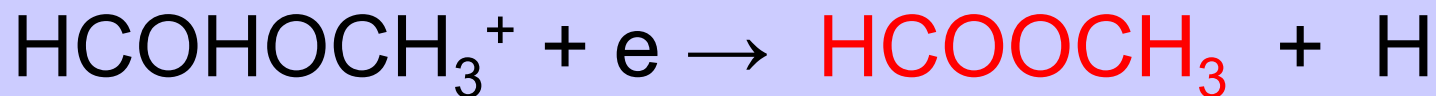
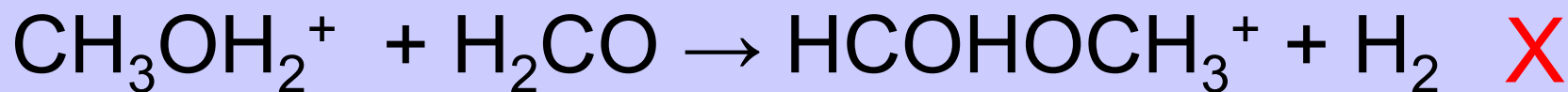
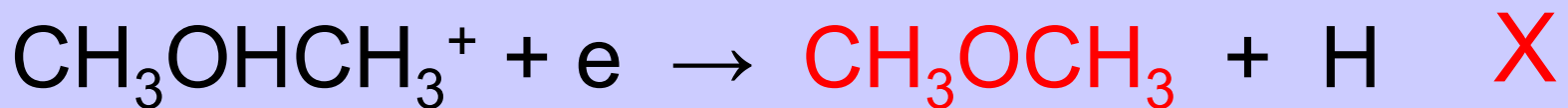
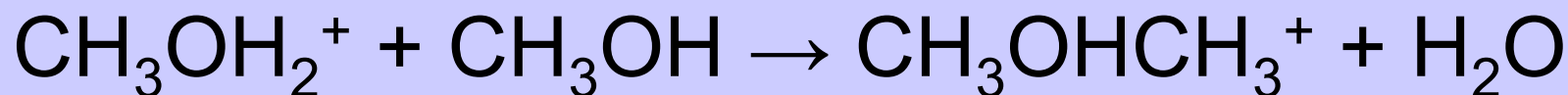


# Hot Core Chemistry: Classical View

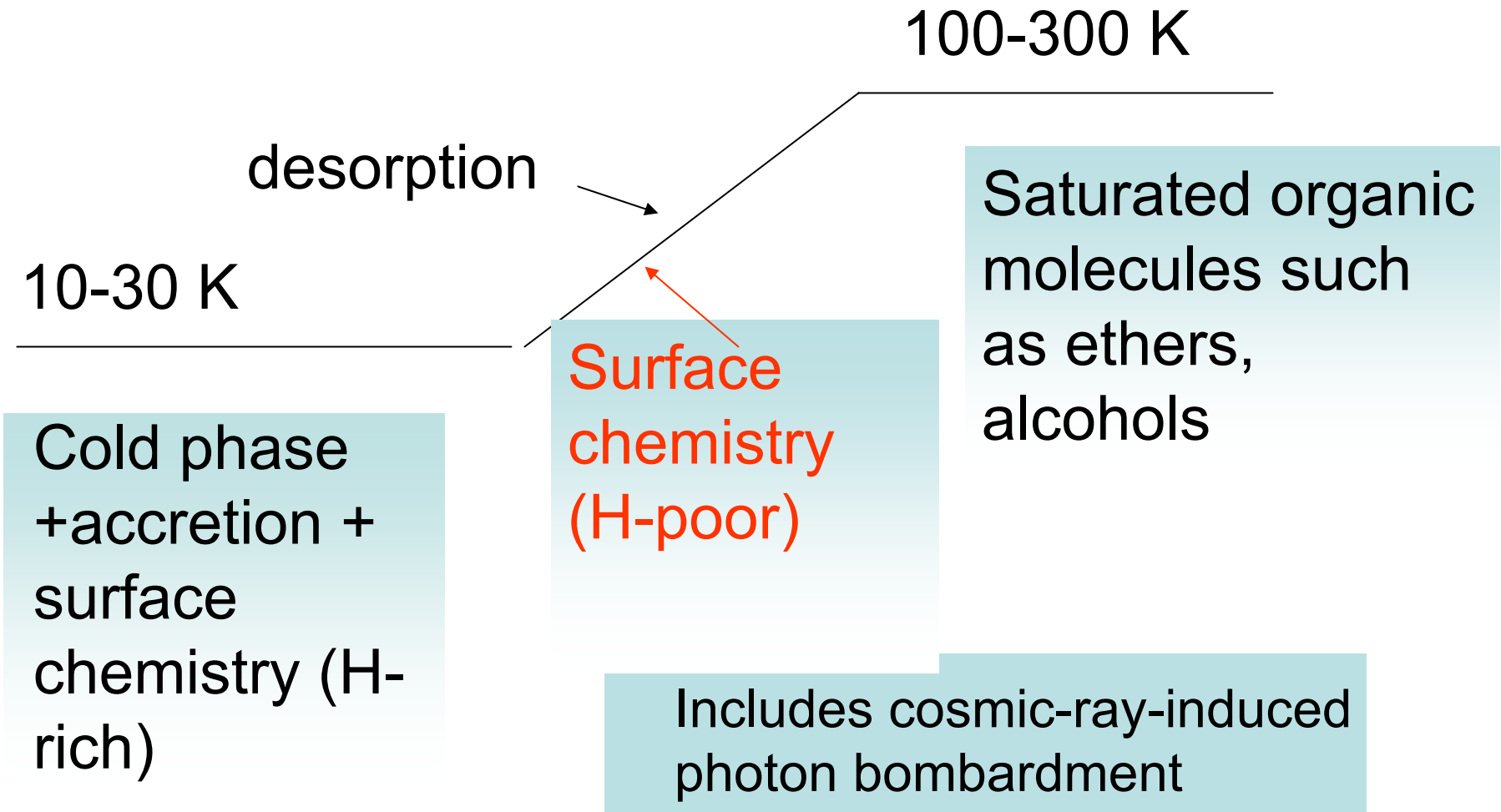


Millar, Tielens, Blake, Charnley, Herbst, Caselli, Walmsley

# Formation of Methyl Formate and Dimethyl Ether



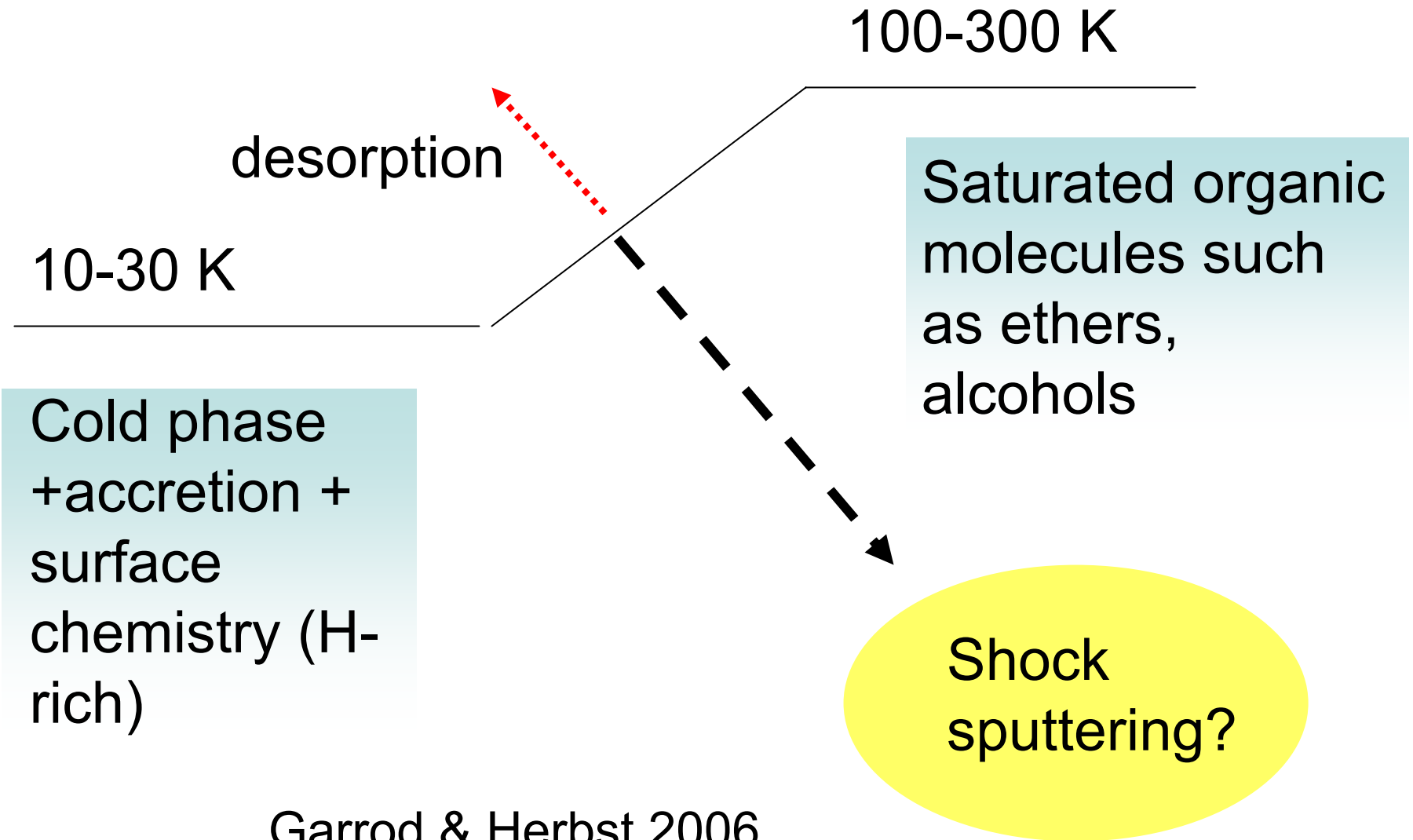
# Hot Core Chemistry: A New Phase?



# Galactic Center

- **GBT studies** on new molecules towards SgrB2(N): **often cold** and sometimes in absorption (Hollis et al.; Lovas et al.)
- **IRAM studies** of weeds shows them to be all over the place in 40 different sources, perhaps caused by shock sputtering off of mantles (Requena-Torres et al. 2006). The sources have lower densities than standard hot cores, but are **lukewarm**.

# Hot Core Chemistry: A New Phase?



# Summary

- Weeds are both useful and annoying.
- They are useful as probes of physical conditions in hot cores and signposts of their chemical histories...
- Isotopologues and excited vibrational state spectra must also be considered.
- They are annoying because they tend to block the detection of other species, so it would be nice to be able to remove them from the detected spectra.....