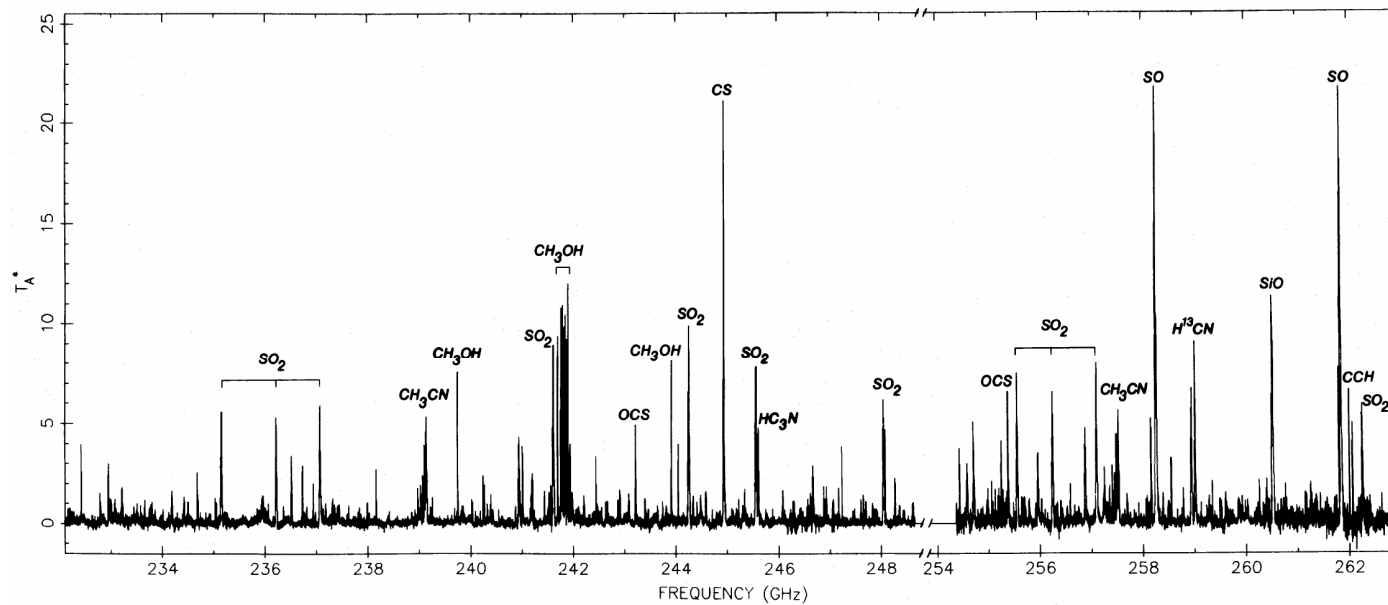
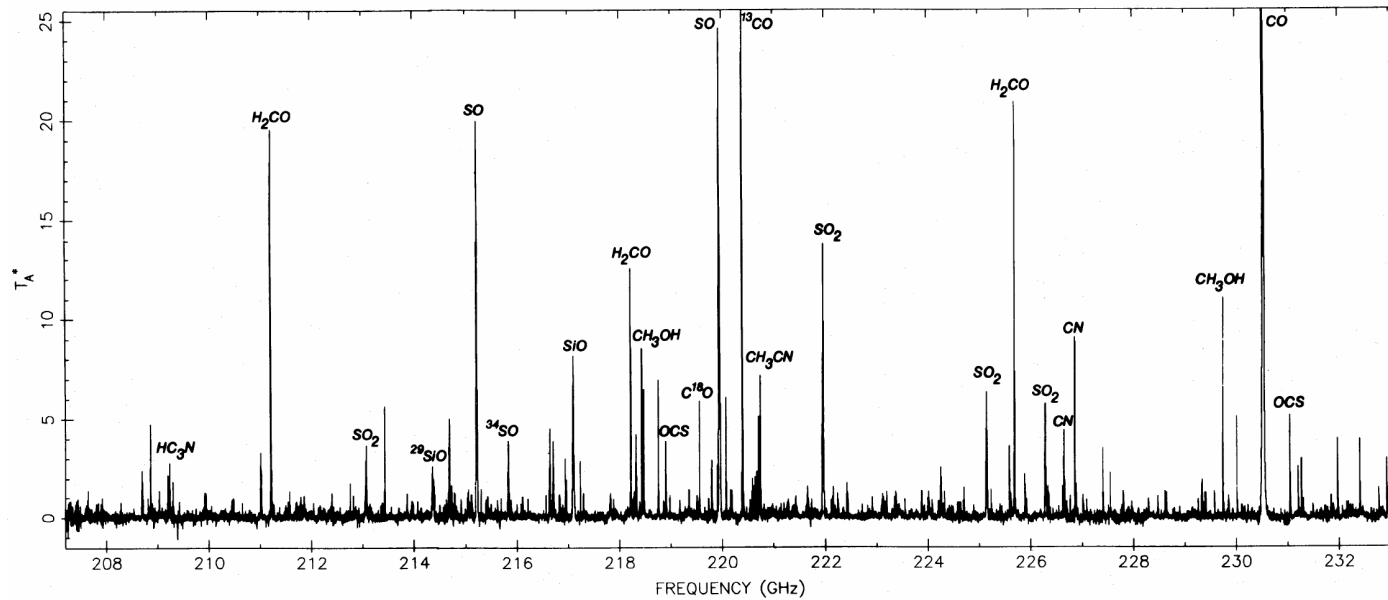


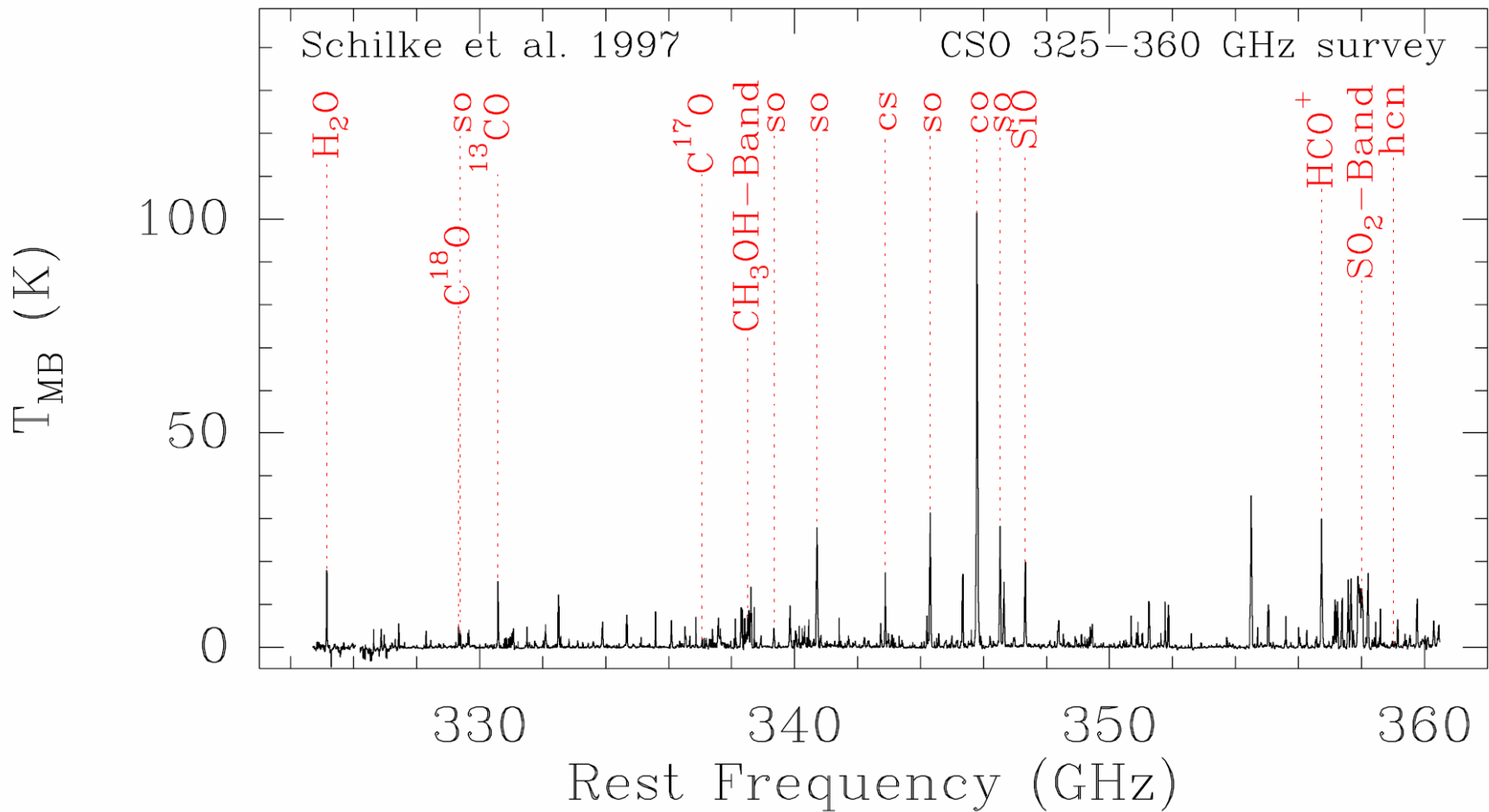
# THE PROBLEM

- For many sources line confusion will prevent secure identification of either weak or inaccurately determined spectral features
- Early surveys found thousand of lines—line forest
- Examples: CSO Blake, Groesbeck, Schilke and Comito
- DSB with sideband deconvolution (Clean or MEM)

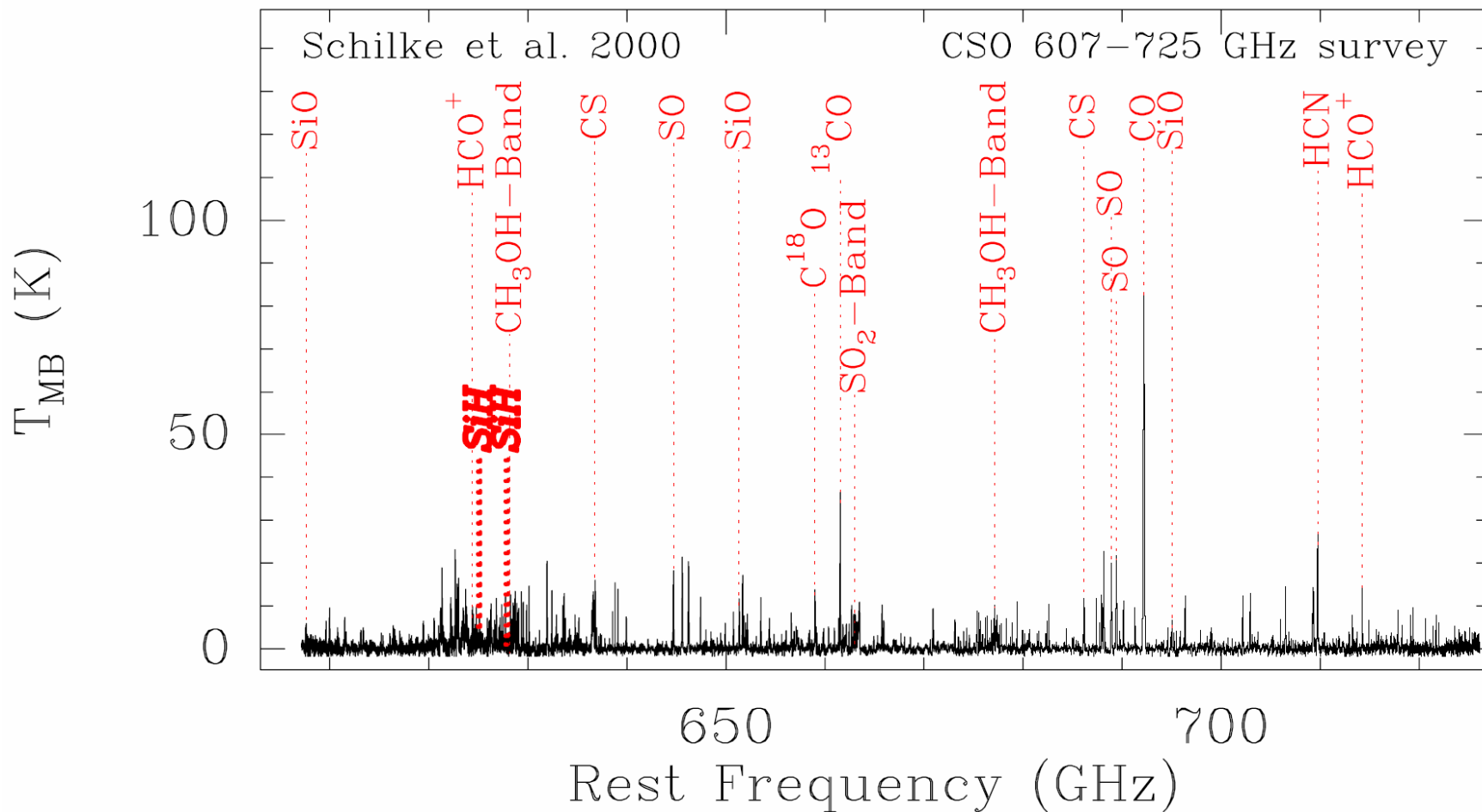


*OVRO surveys of Orion KL (Sutton et al. 1985; Blake et al. 1986)*

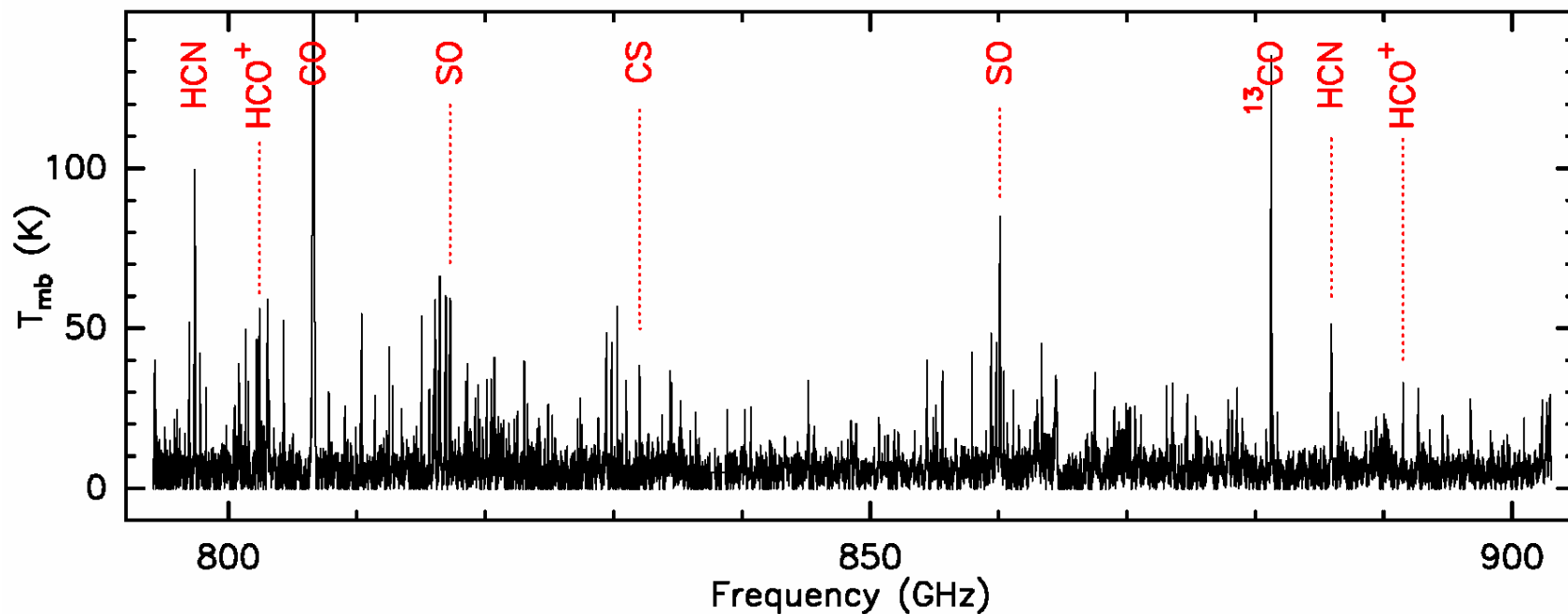
*Laboratory Spectroscopy Workshop, Pasadena, October 19-20, 2006*



**CSO 345 GHz survey of Orion KL (Grosbeck 1994; Schilke et al. 1997)**



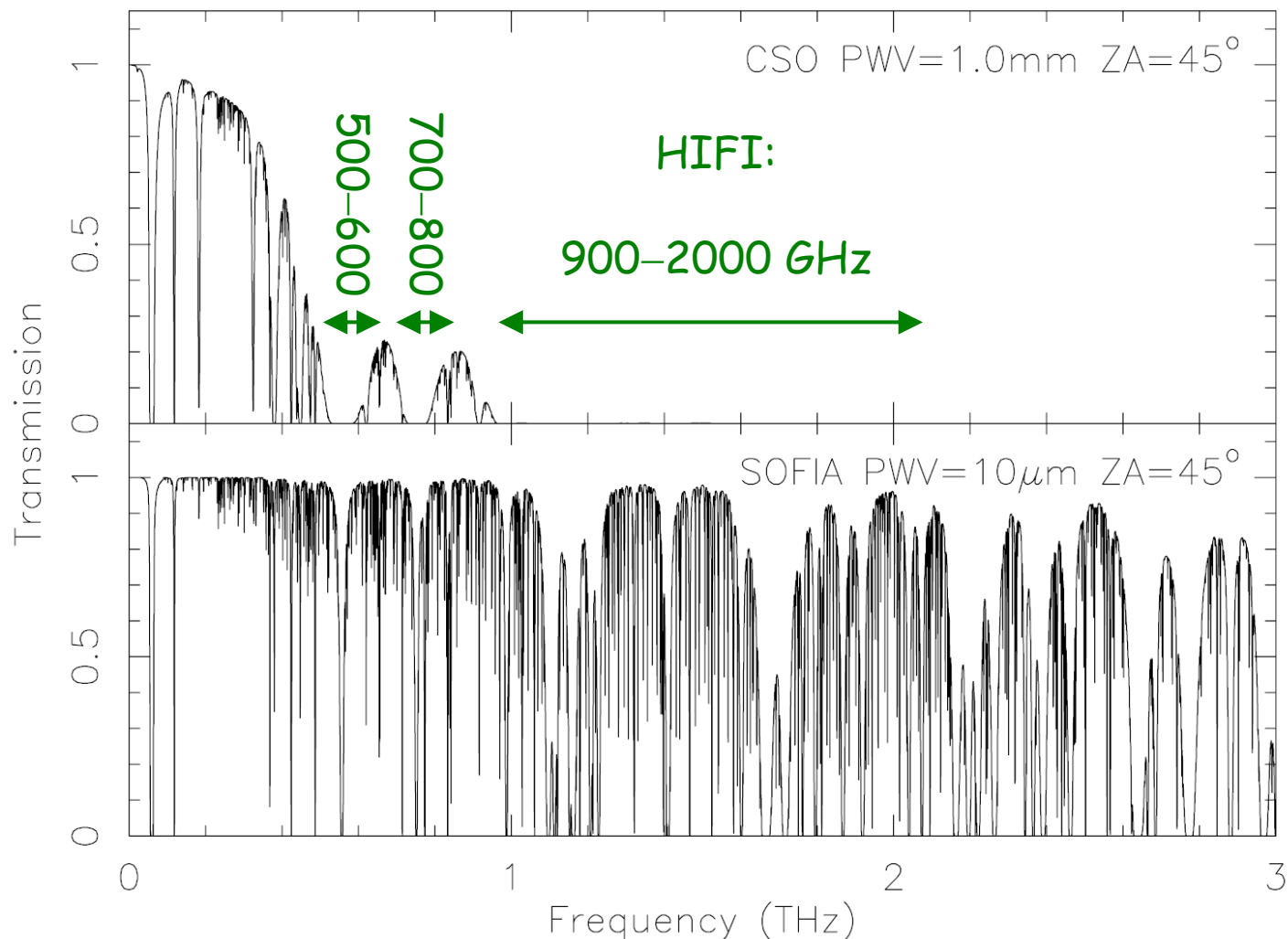
*CSO 650 GHz survey of Orion KL (Schilke et al. 2000)*



*CSO 850 GHz survey of Orion KL (Comito et al. 2005)*

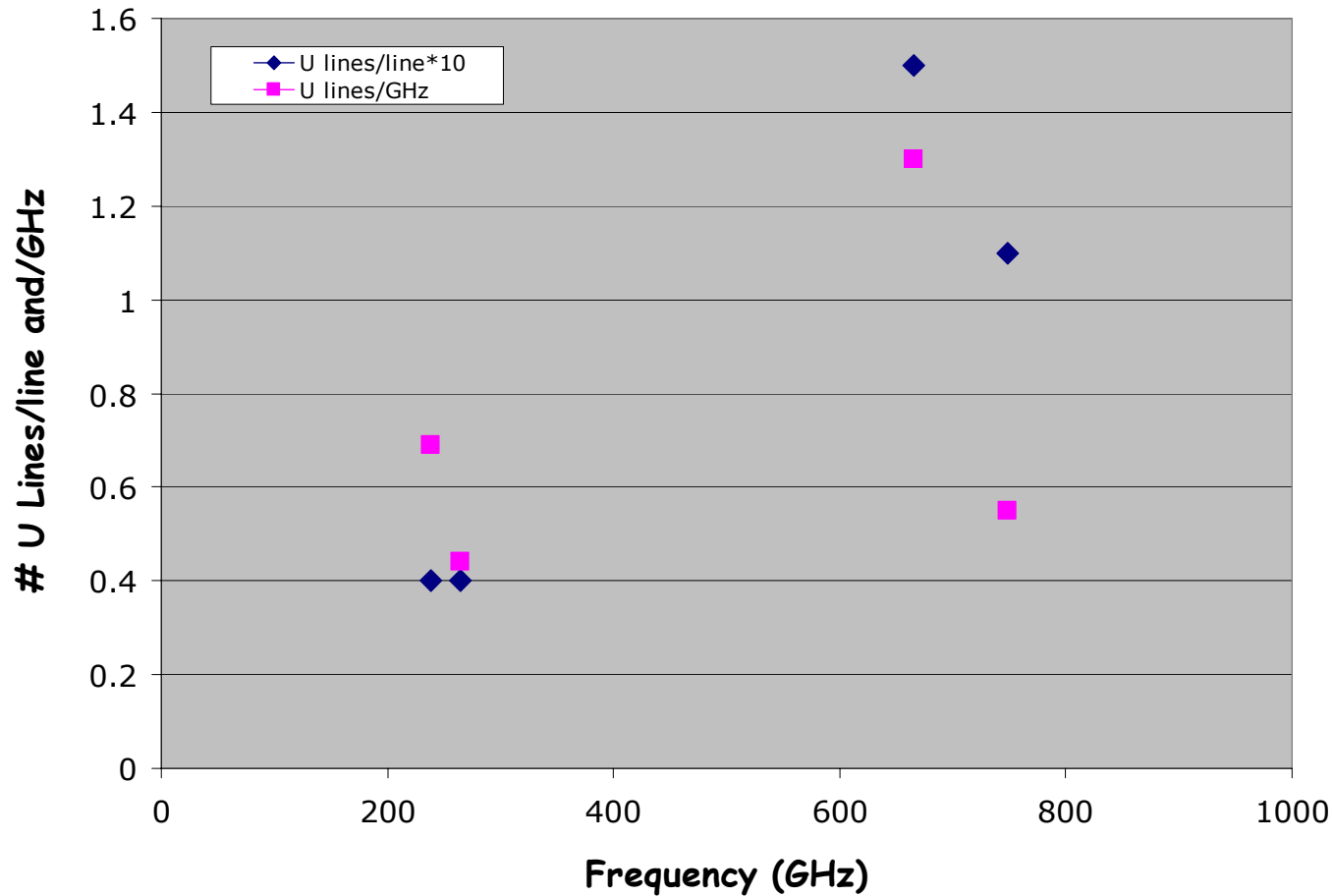
*Laboratory Spectroscopy Workshop, Pasadena, October 19-20, 2006*

# Atmospheric Transmission for CSO and SOFIA



- HIFI concentrates on frequencies inaccessible from the ground—new frequency ranges

## U Lines/line or /GHz

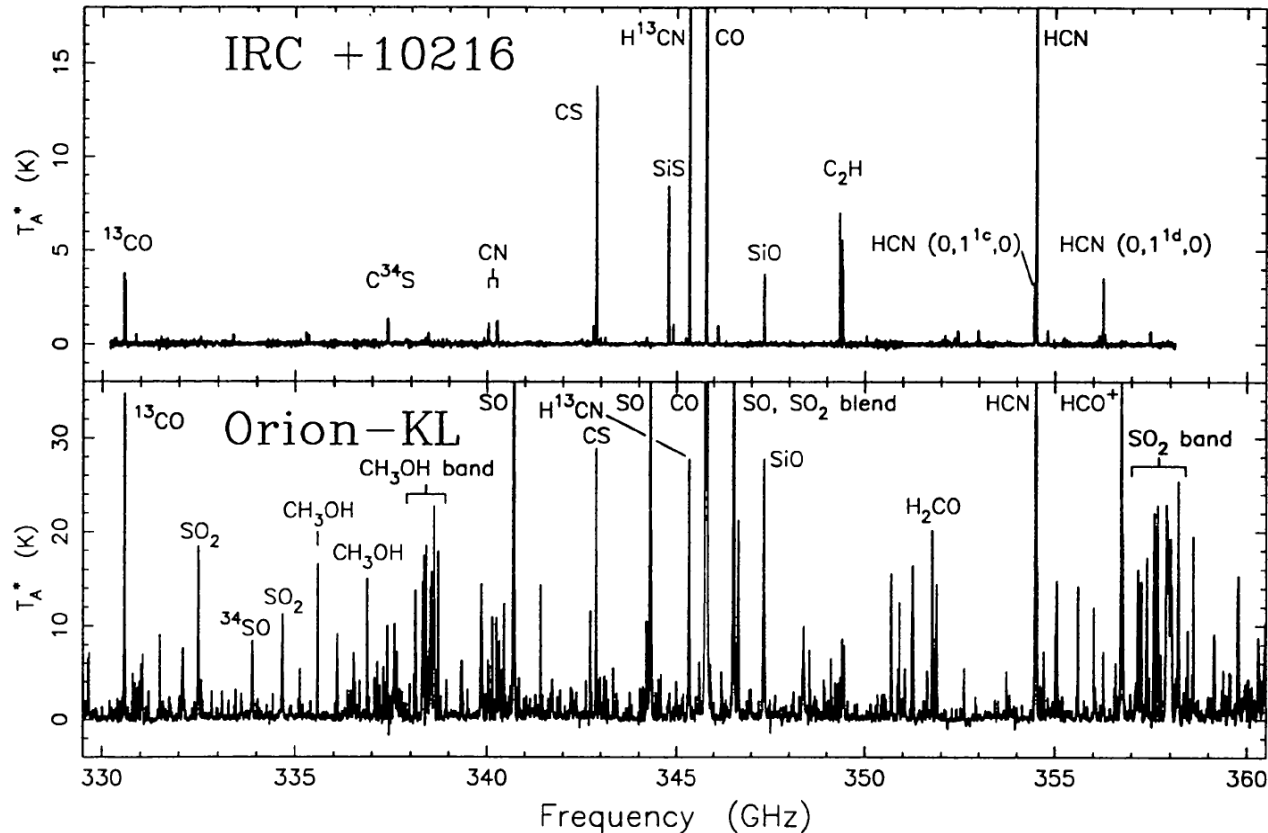


- Line IDs?
  - Below 500 GHz—OK due to available lab spectroscopy
  - Above 500 GHz—many “U” lines

# Extrapolation Errors

- Difficult to predict high frequencies from low frequencies
- Even in the simplest case, a linear molecule
$$E(J+1)-E(J)=2BJ-4DJ^3+\dots$$
  - Measured to 10 kHz, gives an error at  $J=20$  of about 10 MHz
- Complicated molecules are in even worse shape—e.g. methanol—we even may not know the correct Hamiltonian

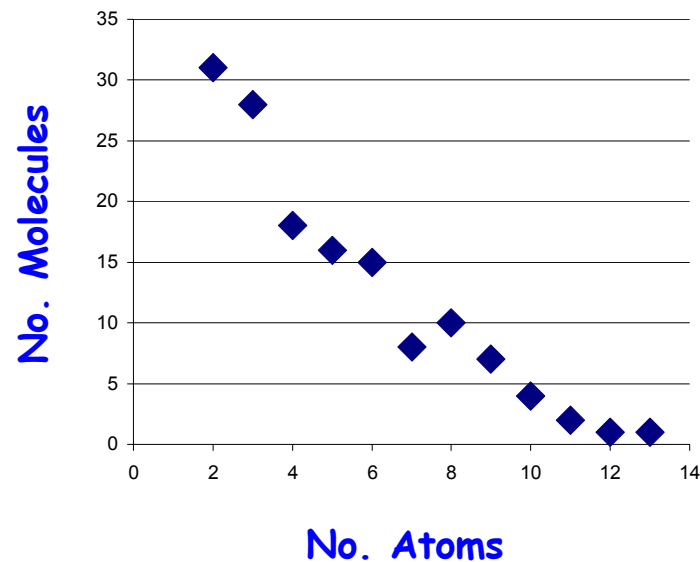
**ALMA** will have the problem of much higher sensitivity in the well studied frequency ranges, possibly seeing exotic transitions, but also susceptible to confusion from "Weeds"



Note: Absorption spectroscopy is much less likely to suffer from confusion because the absorbing material is cold, so "Weeds" are not excited and only light molecules can absorb

# A Categorization of Known ISM Molecules

- To date 141 known—listed by atom number
- List of Weeds: labeled
  - A—accurate to 2 THz
  - B—accurate to 1 THz
  - C—accurate to 500 GHz
  - D—optical/IR only
  - E—microwave only
- Extra designation:
  - X—thought to be a problem



# Interstellar Molecules

141 as of April 2006

Red Lettering => IR or UV Detections | Colored Background ==> Isomers

## Molecules with 2 atoms

H <sub>2</sub>	hydrogen molecule	CO	carbon monoxide
CSi	carbon monosilicide	CP	carbon monophosphide
CS	carbon monosulfide	NO	nitric oxide
NS	nitrogen monosulfide	SO	sulfur monoxide
HCl	hydrogen chloride	NaCl	sodium chloride
KCl	potassium chloride	AlCl	aluminum monochloride
AlF	aluminum monofluoride	PN	phosphorus mononitride
SiN	silicon mononitride	SiO	silicon monoxide
SiS	silicon monosulfide	NH	imidyl radical
OH	hydroxyl radical	C <sub>2</sub>	diatomic carbon
CN	cyanide radical	HF	hydrogen fluoride
CO <sup>+</sup>	carbon monoxide ion	SO <sup>+</sup>	sulfur monoxide ion
CH	methylidyne	CH <sup>+</sup>	methyliumylidene
SH	mercapto radical	LiH	lithium hydride
FeO	iron oxide	N <sub>2</sub>	diatomic nitrogen
CF <sup>+</sup>	fluoromethylidinium ion		

## Molecules with 3 atoms

H <sub>2</sub> O	water *	H <sub>2</sub> S	hydrogen sulfide *
HCN	hydrogen cyanide	HNC	hydrogen isocyanide
CO <sub>2</sub>	carbon dioxide *	SO <sub>2</sub>	sulfur dioxide
MgCN	magnesium cyanide	MgNC	magnesium isocyanide
NaCN	sodium cyanide	N <sub>2</sub> O	nitrous oxide
NH <sub>2</sub>	amidyl radical *	OCS	carbonyl sulfide *
HCO	formyl radical	C <sub>3</sub>	triatomic carbon *
C <sub>2</sub> H	ethynyl radical *	HCO <sup>+</sup>	formyl ion
HOC <sup>+</sup>	hydroxymethylidyne	N <sub>2</sub> H <sup>+</sup>	hydrodinitrogen ion *
HNO	nitrosyl hydride	HCS <sup>+</sup>	thiooxomethylum
H <sub>3</sub> <sup>+</sup>	hydrogen ion *	C <sub>2</sub> O	ketenylidene *
C <sub>2</sub> S	thiooxyethynylidene	SiC <sub>2</sub>	silicon dicarbide
AlNC	aluminum isocyanide	CH <sub>2</sub>	methylene *
SiCN	silicon monocyanide	SiNC	silicon isocyanide

Molecules with 4 atoms			
NH <sub>3</sub>	ammonia *	H <sub>2</sub> CO	formaldehyde
H <sub>2</sub> CS	thioformaldehyde	C <sub>2</sub> H <sub>2</sub>	acetylene
HNCO	isocyanic acid	HNCS	thioisocyanic acid
H <sub>3</sub> O <sup>+</sup>	hydronium ion *	HOCO <sup>+</sup>	protonated carbon dioxide
C <sub>3</sub> S	1,2-propadienyldiene, 3-thioxo	H <sub>2</sub> CN	methylene amidogen
c-C <sub>3</sub> H	cyclopropenylidyne	l-C <sub>3</sub> H	2-propynylidyne
HCCN	cyanomethylene	C <sub>3</sub> O	tricarbon monoxide
C <sub>2</sub> CN	cyanoethynyl	SiC <sub>3</sub>	Rhomboidal SiC <sub>3</sub>
HCNH <sup>+</sup>	iminomethylum	CH <sub>3</sub>	methyl radical *
Molecules with 5 atoms			
CH <sub>4</sub>	methane *	SiH <sub>4</sub>	silane *
CH <sub>2</sub> NH	methyleneimine	NH <sub>2</sub> CN	cyanamide
CH <sub>2</sub> CO	ketene	HCOOH	formic acid
HC <sub>3</sub> N	cyanoacetylene	HC <sub>2</sub> NC	isocyanoacetylene
c-C <sub>3</sub> H <sub>2</sub>	cyclopropenylidene	l-C <sub>3</sub> H <sub>2</sub>	propenylidene
CH <sub>2</sub> CN	cyanomethyl radical	C <sub>4</sub> H	1,3-butadiynyl radical
C <sub>4</sub> Si	silicon tetracarbide	C <sub>5</sub>	pentacarbon molecule
HNC <sub>3</sub>	1,2-propadienyldiene, -3-imino	H <sub>2</sub> COH <sup>+</sup>	protonated formaldehyde
Molecules with 6 atoms			
CH <sub>3</sub> OH	methanol *	CH <sub>3</sub> SH	methanethiol *
H <sub>2</sub> CCH <sub>2</sub>	ethylene	HCCCCH	diacetylene
CH <sub>3</sub> CN	methyl cyanide	CH <sub>3</sub> NC	methylisocyanide
HCONH <sub>2</sub>	formamide	HC <sub>2</sub> CHO	propynal
C <sub>5</sub> H	2,4-pentadiynylidyne	HC <sub>3</sub> NH <sup>+</sup>	protonated 2-propynenitrile
C <sub>5</sub> N	1,3-butadiynylum, 4-cyano	H <sub>2</sub> CCCC	butatrienylidene
HC <sub>4</sub> N	3-cyano 2-propynylidene	c-H <sub>2</sub> C <sub>3</sub> O **	cyclopropenone
CH <sub>2</sub> CNH **	ketenimine		

Molecules with 7 atoms			
CH <sub>3</sub> CCH	methyl acetylene	CH <sub>3</sub> CHO	acetaldehyde
CH <sub>3</sub> NH <sub>2</sub>	methylamine *	CH <sub>2</sub> CHCN	vinyl cyanide
HC <sub>5</sub> N	cyanobutadiyne	C <sub>6</sub> H	1,3,5-hexatriynl
c-C <sub>2</sub> H <sub>4</sub> O	ethylene oxide	CH <sub>2</sub> CHOH	vinyl alcohol
Molecules with 8 atoms			
CH <sub>3</sub> COOH	acetic acid	CH <sub>3</sub> OCHO	methyl formate
CH <sub>3</sub> C <sub>3</sub> N	methylcyanoacetylene	CH <sub>2</sub> (OH)CHO	glycolaldehyde
H <sub>2</sub> C <sub>6</sub>	hexapentaenyldiene	HC <sub>6</sub> H	triacetylene
C <sub>2</sub> H <sub>6</sub>	ethane	C <sub>7</sub> H	2,4,6-heptatriynylidyne
CH <sub>2</sub> CHCHO **	propenal	CH <sub>2</sub> CCHCN **	cyanoallene
Molecules with 9 atoms			
(CH <sub>3</sub> ) <sub>2</sub> O	dimethyl ether	CH <sub>3</sub> CH <sub>2</sub> OH	ethanol
CH <sub>3</sub> CH <sub>2</sub> CN	ethyl cyanide	CH <sub>3</sub> C <sub>4</sub> H	methylbutadiyne
HC <sub>7</sub> N	cyanohexatriyne	C <sub>8</sub> H	1,3,5,7-octateraynyl
CH <sub>3</sub> CONH <sub>2</sub> **	acetamide		
Molecules with 10 atoms			
(CH <sub>3</sub> ) <sub>2</sub> CO	acetone	HOCH <sub>2</sub> CH <sub>2</sub> OH	ethylene glycol
CH <sub>3</sub> CH <sub>2</sub> CHO **	propanal	CH <sub>3</sub> C <sub>5</sub> N **	methylcyano diacetylene
Molecules with 11 atoms			
HC <sub>9</sub> N	cyanooctatetrayne	CH <sub>3</sub> C <sub>6</sub> H **	methyltriacetylene
Molecules with 12 atoms			
C <sub>6</sub> H <sub>6</sub>	benzene		
Molecules with 13 atoms			
HC <sub>11</sub> N	cyanodecapentayne		

# THE SOLUTION—Panel Output

- International capability:
  - Labs
  - Facilities
  - Frequency ranges
  - List of weeds—prioritized
  - List of labs/tasks
  - Lab upgrades
  - Formatting of catalogs
  - ID software
  - Source models
  - White paper