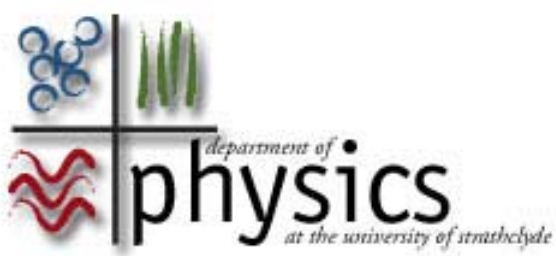
"The Origins of the Molecular Building Blocks of Life"

Helen Jane Fraser

Department of Physics
University of Strathclyde



Astrobiologists ask…

Whether there is life elsewhere in our universe…

(by concentrating (right now) on finding suitable habitable zones, exoplanets, prebiotic molecules & using solar system as lab)

"m

ents the COSMIC ABUNDANCE of each element

Back to cold dark space....

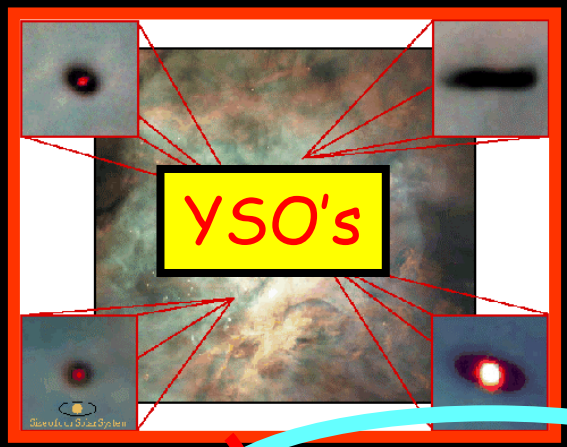
Star Formation

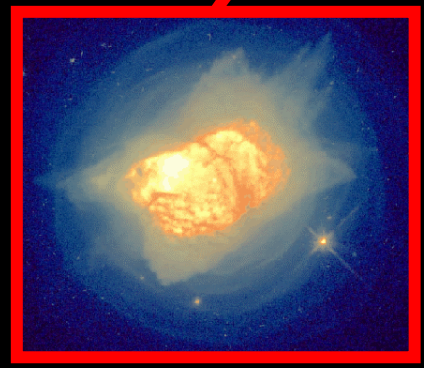
Planet Formation

Refuelling the Interstellar medium.

ISM

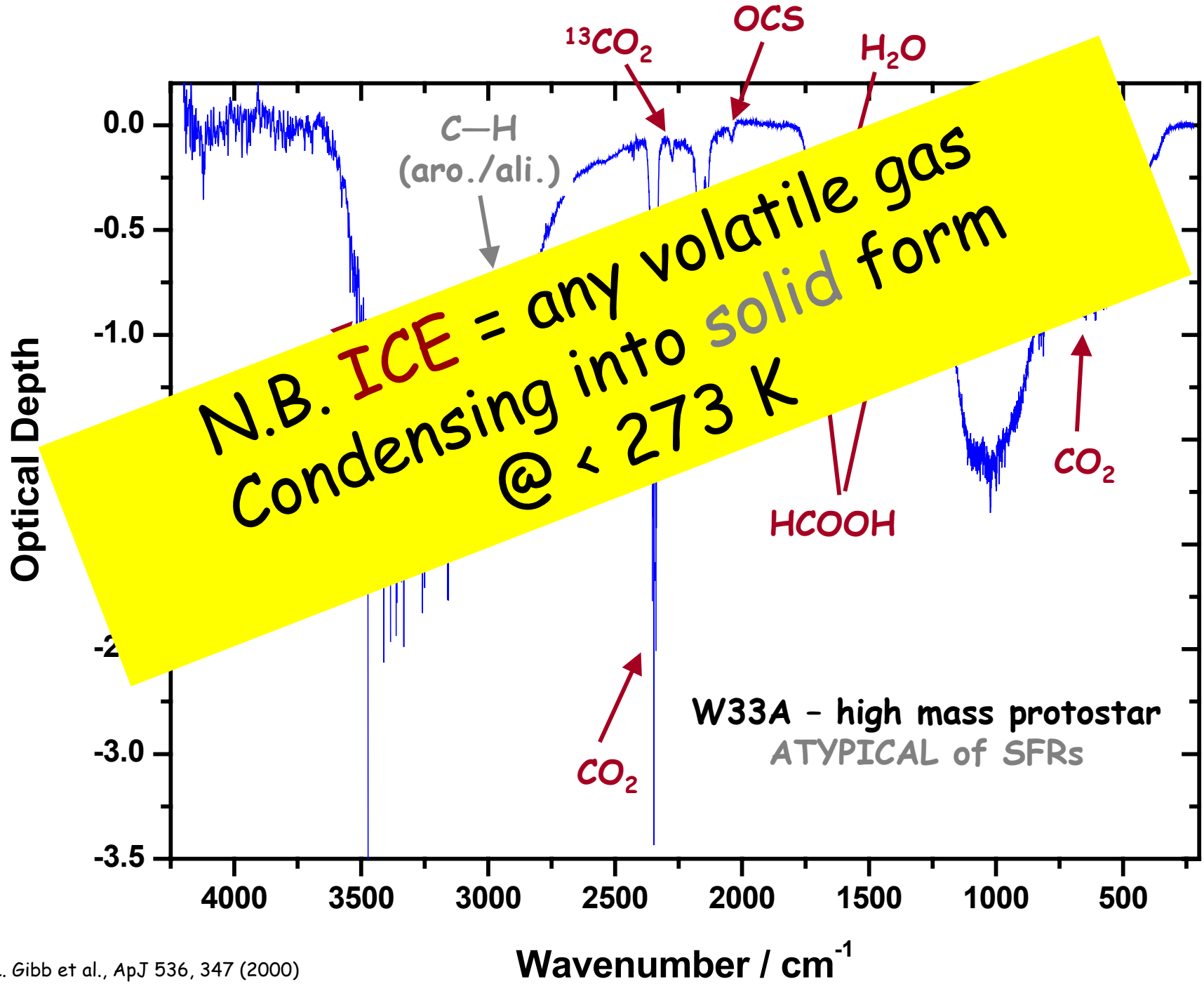
= 99% by mass GAS
(H / H_2 / He)
& 1 % DUST
(Si / C / Mg, Fe, Al, Na, K)





Formation of life

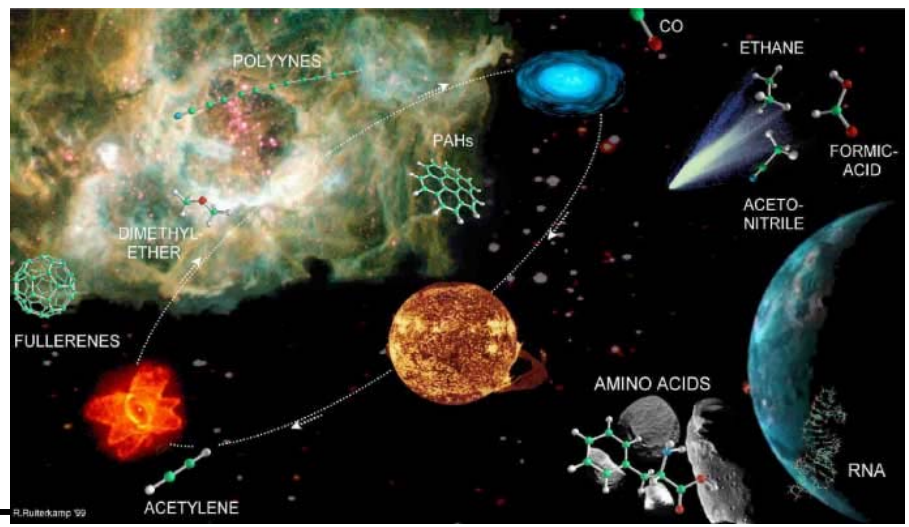
Star Death



E.L. Gibb et al., ApJ 536, 347 (2000)

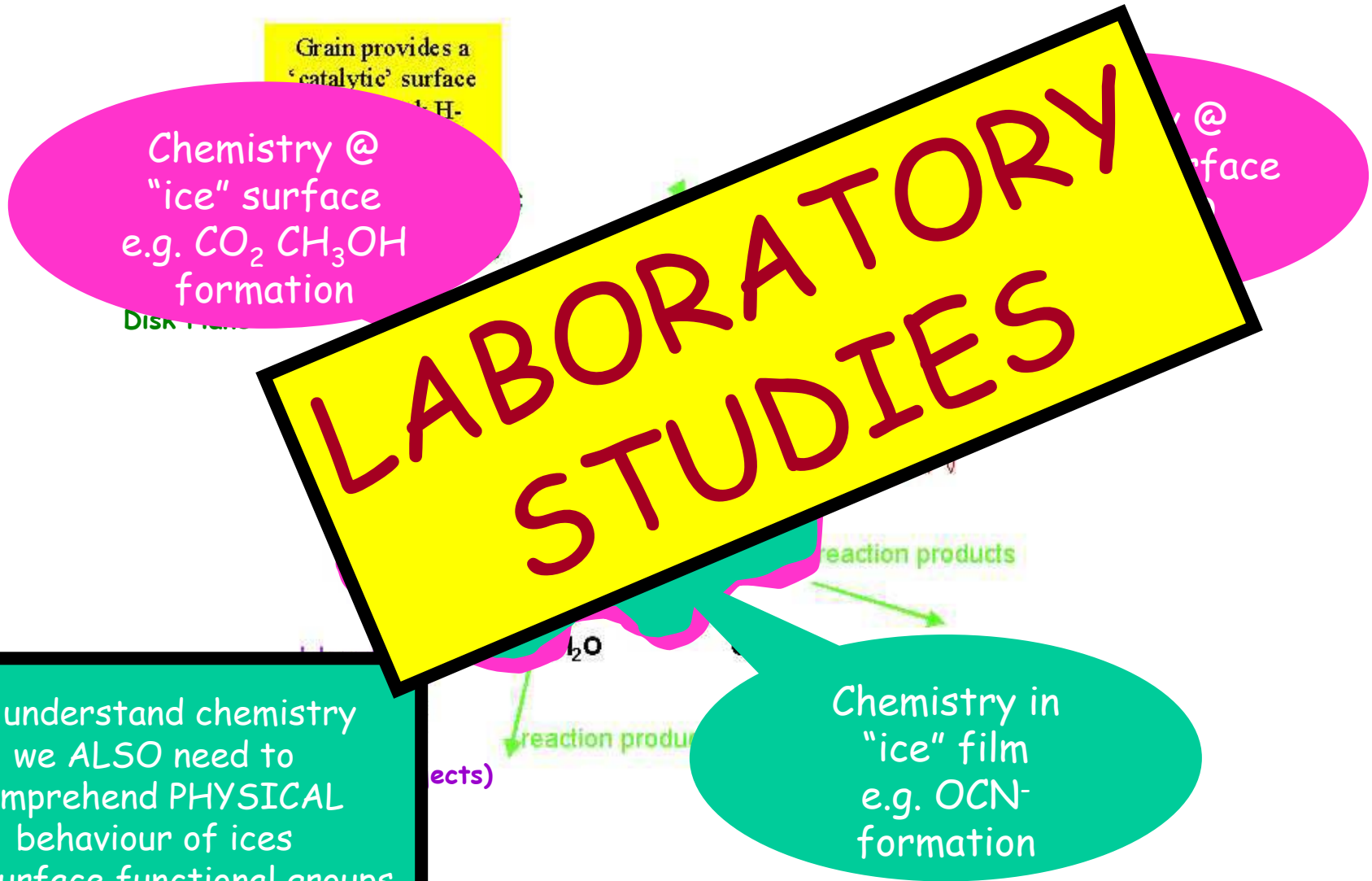
2	3	4	5	6	7	8	9+
H_2	C_3	c-C_3H	C_5	C_5H	C_6H	CH_3C_3N	CH_3C_4H
AlF	C_2H	l-C_3H	C_4H	l-H_2C_4	CH_2CHCN	$HCOOCH_3$	CH_3CH_2CN
AlCl	C_2O	C_3N	C_4Si	C_2H_4	CH_3C_2H	CH_3COOH	$(CH_3)_2O$
C_2	C_2S	C_3O	l-C_3H_2	CH_3CN	HC_5N	C_7H	CH_3CH_2OH
CH	CH_2	C_3S	c-C_3H_2	CH_3NC	$HCOCH_3$	CH_2OHCHO	HC_7N C_8H
CH^+	HCN	C_2H_2	CH_2CN	CH_3OH	NH_2CH_3		CH_3C_5N
CN	HCO	CH_2D^+	CH_4	CH_3SH	c-C_2H_4O		$(CH_3)_2CO$
CO	HCO^+	HCCN	HC_3N	HC_3NH^+	CH_2CHOH		NH_2CH_2COO
CO^+	HCS^+	$HCNH^+$	HC_2NC	HC_2CHO			H? HC_9N
CP	HOC^+	HNCO	HCOOH	NH_2CHO			$HC_{11}N$
CSi	H_2O	HNCS	H_2CHN	C_5N			
HCl	H_2S	$HOCO^+$	H_2C_2O				
KCl	HNC	H_2CO	H_2NCN				
NH	HNO	H_2CN	HNC_3				
NO	MgCN	H_2CS	SiH_4				
NS	MgNC	H_3O^+	H_2COH^+				
NaCl	N_2H^+	NH_3					
OH	N_2O	SiC_3					
PN	NaCN						
SO	OCS						
SO^+	SO_2						
SiN	c-SiC_2						
SiO	CO_2						

List of Detected Cosmic Molecules in Interstellar and Circumstellar Environments.



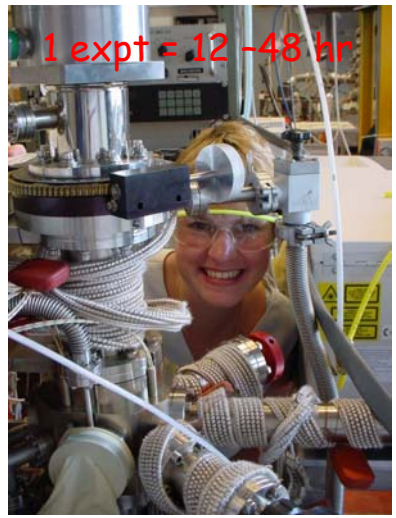
Fraser et. al. A&G, 43, no. 2, 2.10 (2002)

Solid-State Chemistry of Star-Forming Regions



Fraser, Collings & McCoustra, Rev. Sci. Inst. 73, no.5, 2161 (2002)

Solid-State Astrochemistry



Astronomy

small grains

P < 10^{-10} – 10^{-15} mbar
(dominated by H_2 then CO)

T_{grain} = 10 – 300 K

T_{gas} = 10 – 1000 K

1 Lyman α / Lyman-Werner band UV photon per 10^6 years per grain

1 atom / molecule – grain collision per 10^4 years

1 X-Ray / CR 'direct hit' per 10^5 years

Surface Science

To date = flat surfaces

P < 10^{-10} mbar
(also dominated by H_2 then CO)

T_{grain} = 10 – 450 K

T_{gas} = 100 - 300 K

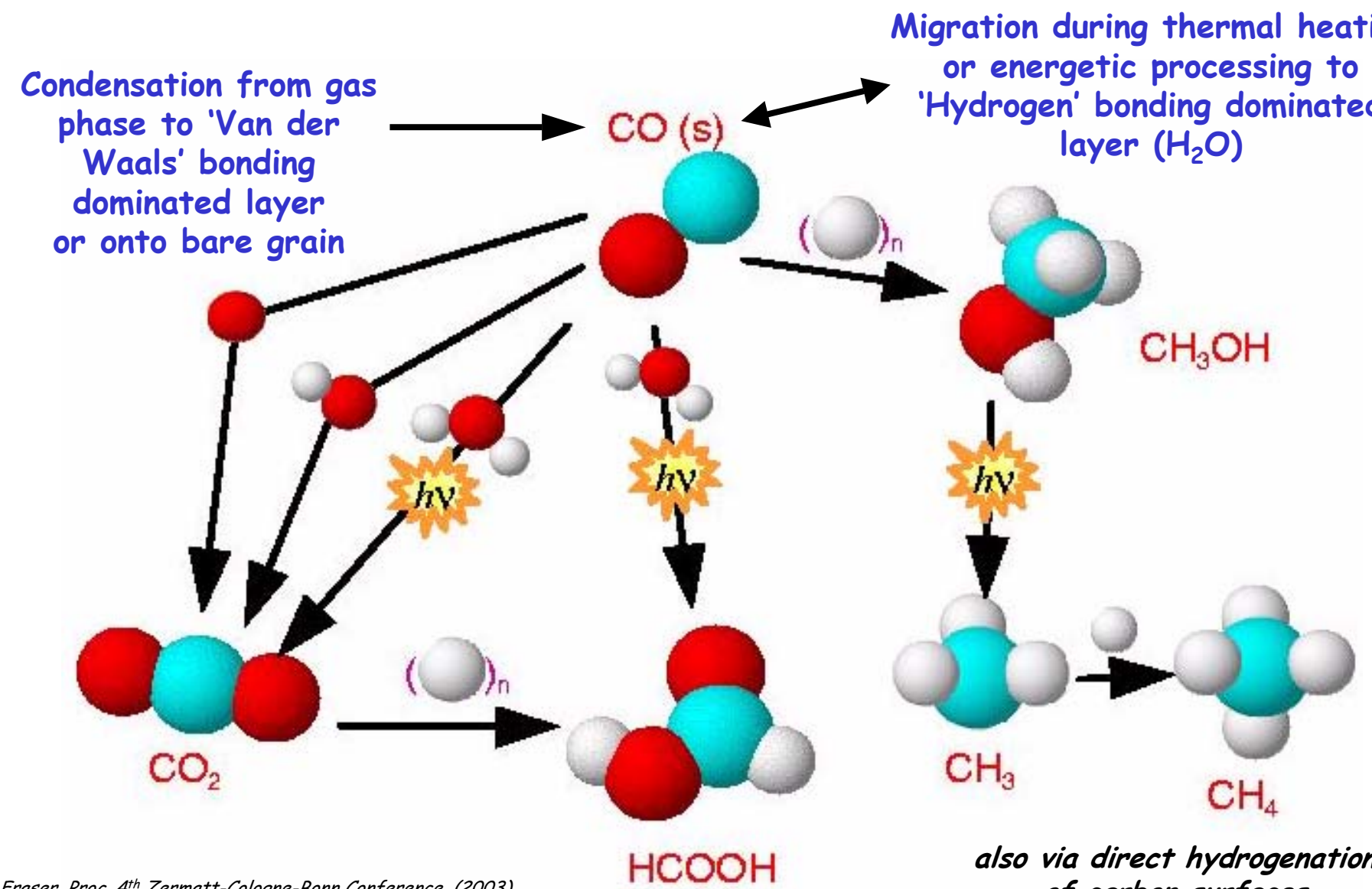
1 Lyman α / Lyman-Werner band UV photon per molecule per second!! (≈ 5 sec ≅ ISM)

@ 1 L (Langmuir) dose = 10^{15} molec cm^{-2} s^{-1}

1 X-Ray / CR …. ✘

Fraser, Collings & McCoustra, Rev. Sci. Inst. 73, no.5, 2161 (2002); Fraser & Van Dishoeck, ASR, 33, 14 (2004)

Postulated Chemistry of Solid CO in SFRs



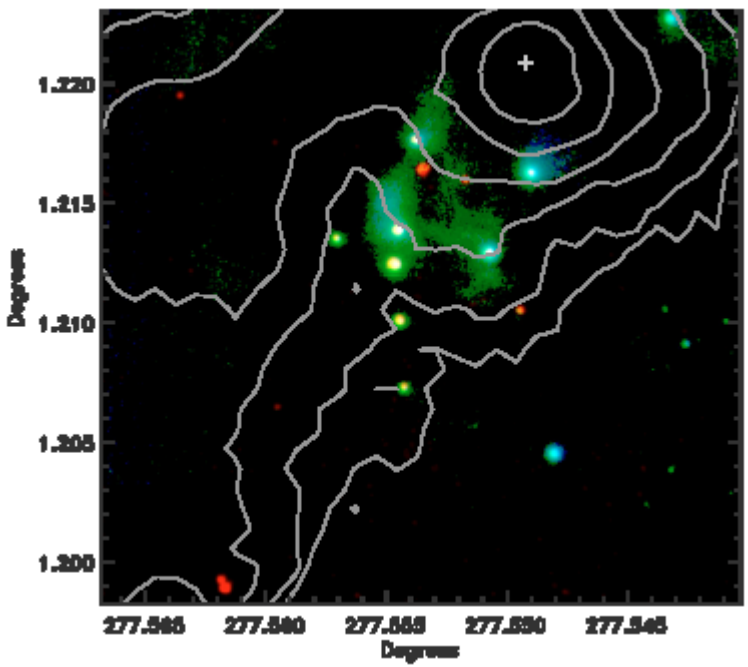
also via direct hydrogenation of carbon surfaces

Fraser, Proc. 4th Zermatt-Cologne-Bonn Conference, (2003)
Fraser, Proc. Chem-03, Cairo, Egypt, (2004)

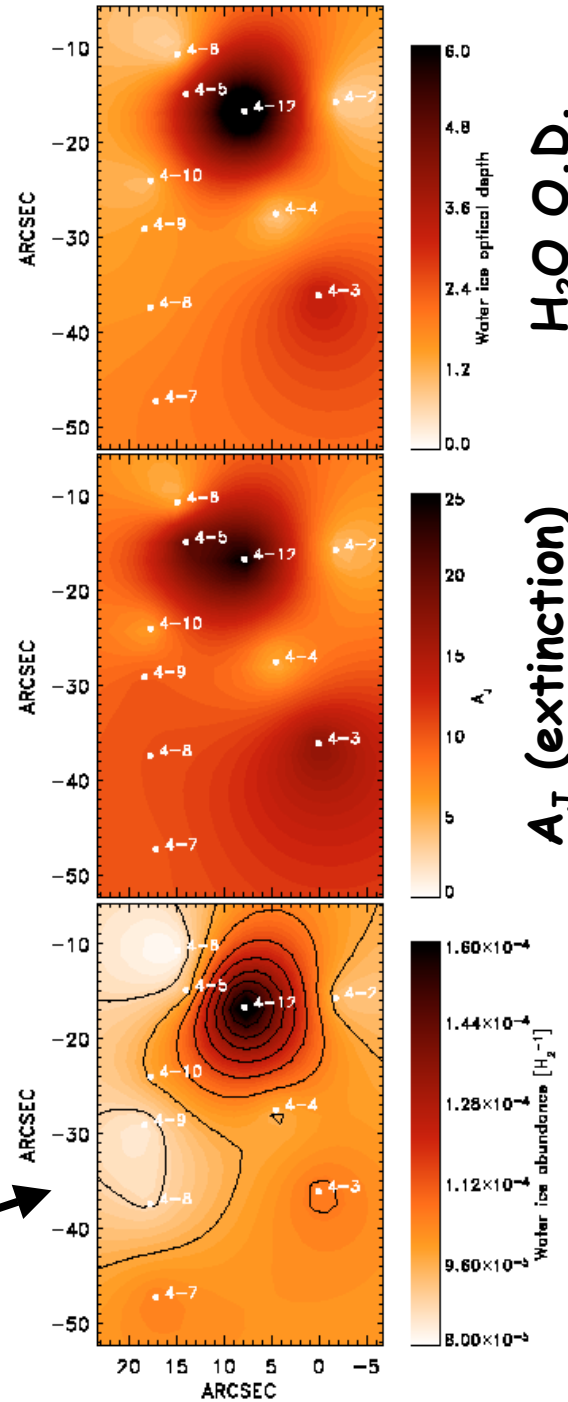
Mapping Ices Towards SVS 4 - H_2O ice mapping

N.B. proposed observational programmes on ESO VLT / SPITZER to continue mapping especially H_2O / and CO (H_2O-rich and pure) and CO_2 on SAME lines of sight

such work equally conducted in collab. CfA (Harvard) / Caltech (Keck) / JPL (Spitzer)



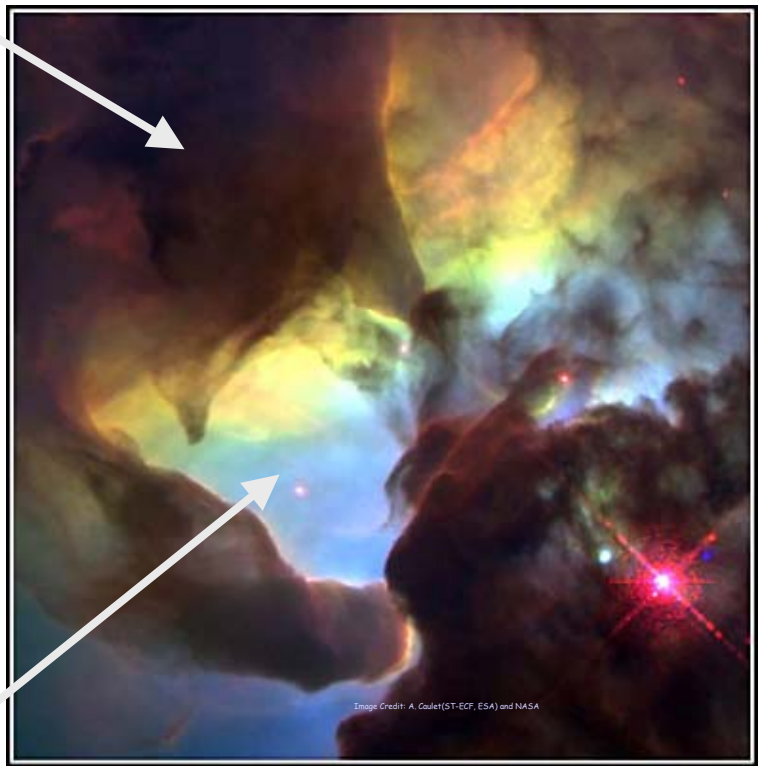
vs.. $[H_2]$ i.e. measure of formation efficiency



Pontoppidan et al, 2004, A&A, 426, 925

H_2O Formation - What precisely am I going to do?

H_2O (s) = most abundant 'ice'
porous & amorphous

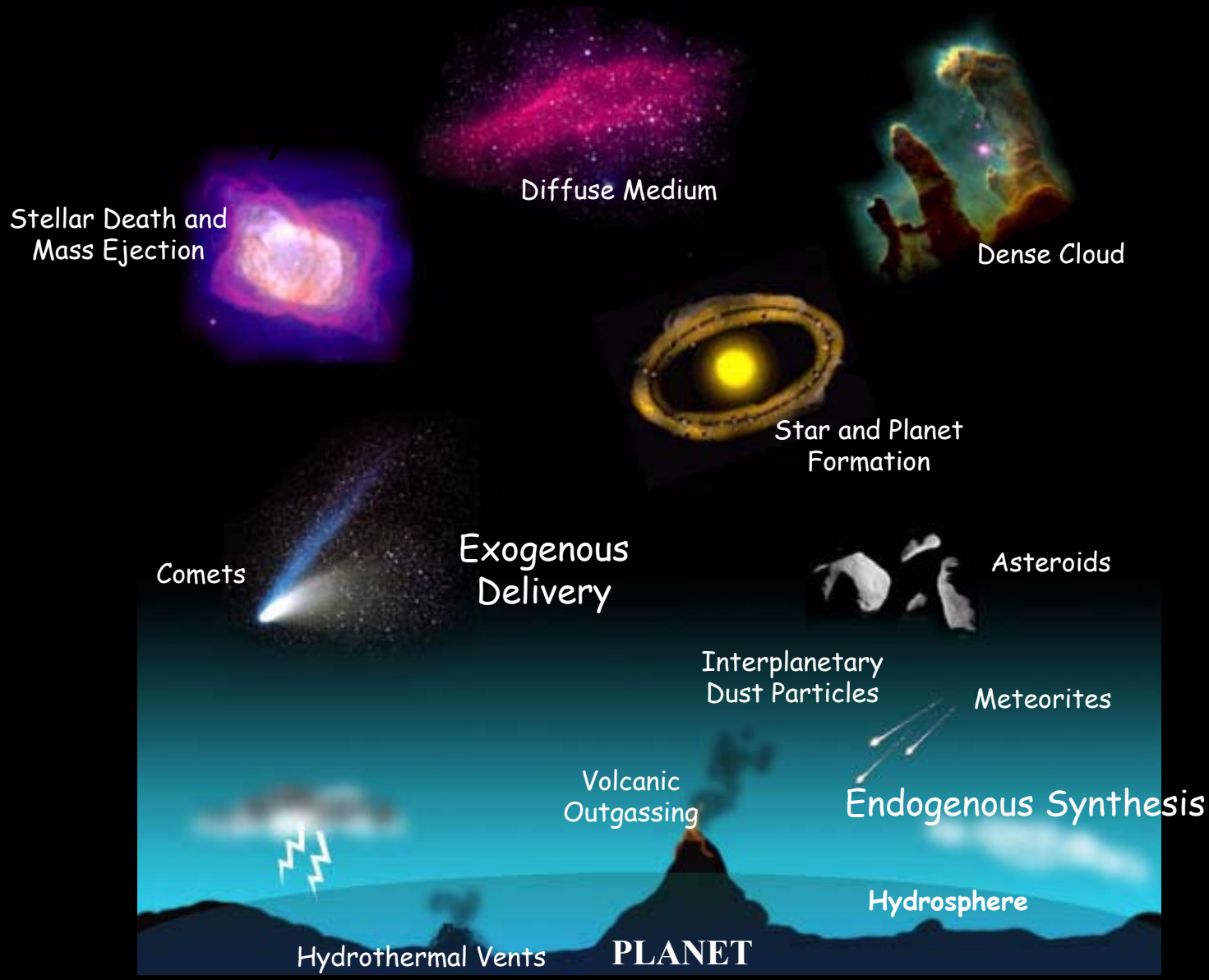


NO H_2O (g)

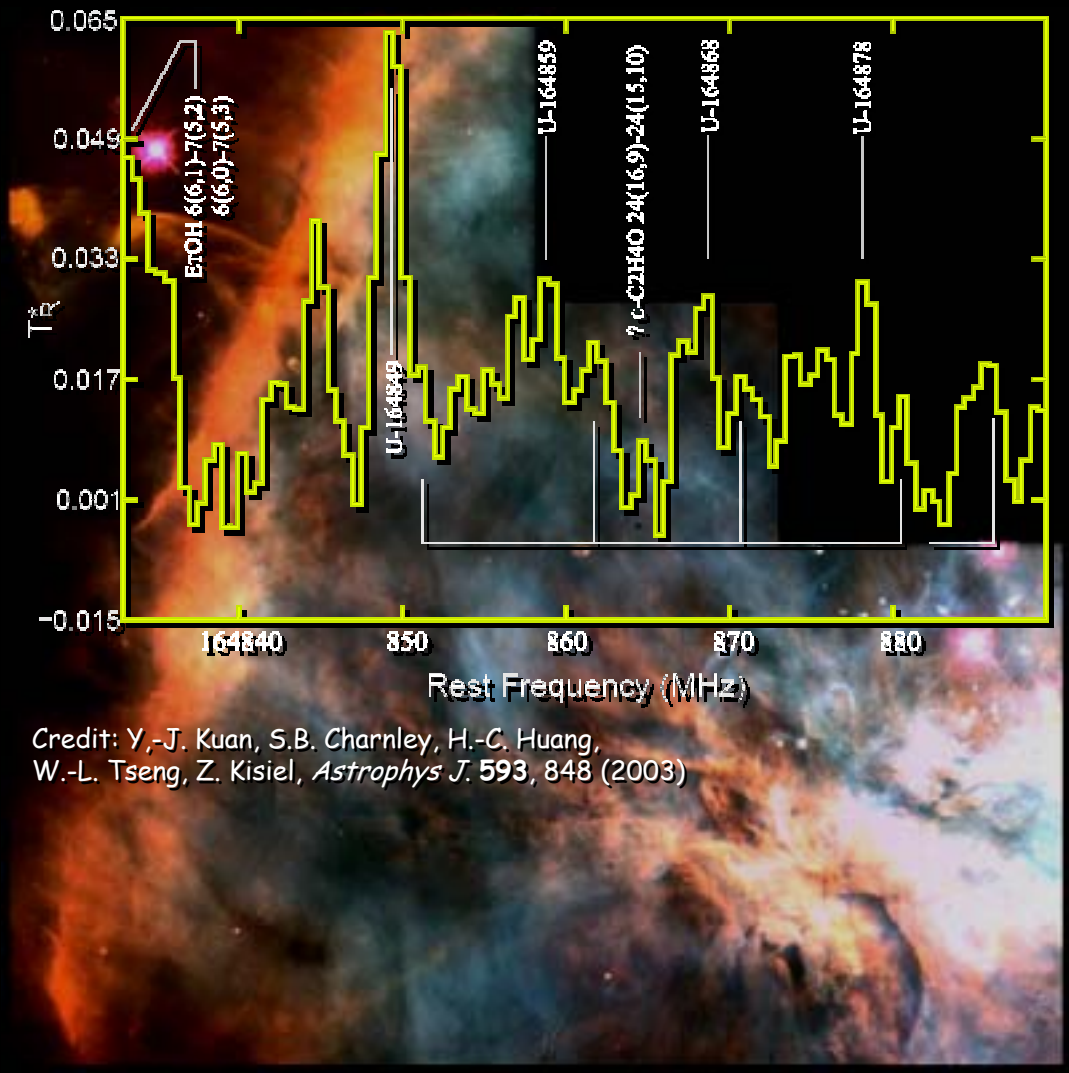
NO H_2O (s)

$\therefore$ H_2O formed on grains

So, do we make the building blocks of life in space… and then transport them to planets?



Complex molecules such as amino acids (the building blocks of life), have also been found in space



Credit: Y.-J. Kuan, S.B. Charnley, H.-C. Huang, W.-L. Tseng, Z. Kisiel, *Astrophys J.* **593**, 848 (2003)

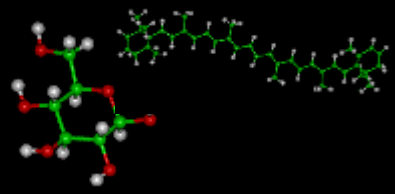
glycine in Orion!

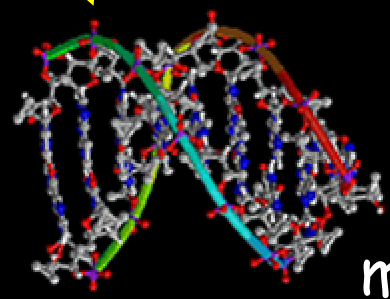
Credit: C.R. O'Dell/Rice University, NASA.

These complex molecules are important for forming the molecules of Life…

Simple Molecules

Complex Molecules & Polymers



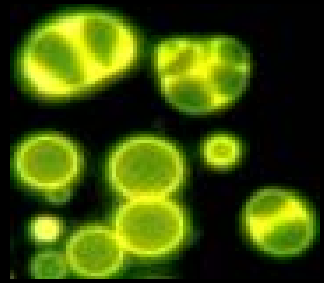


DNA

The molecule of Life

Cell Membranes

Protocells



?

LIFE

Acknowledgements

Prof. E.F. van Dishoeck
Prof. Stephan Schlemmer

Prof. G.J. Kroes
Dr. Ayman Al- Halabi

Dr. Klaus Pontoppidan

Fleur van Broekhuizen
Suzanne Bisschop

Wassim Alsindi
Irene Groot
Karin Oberg

Ewie de Kuyper & all the technical staff at UL

Prof. A Kleyn
Dr. Mischa Bonn

Prof. Pascale Ehrenfreund

Dr. M.R.S. McCoustra
Dr. M. P. Collings
John Dever

Prof. D.A.Williams

Prof. X. Tielens

& the VLT ISAAC large programme 'TEAM'!!

& members of THEORETICAL / SURFCAT LIC research groups

& members of the ESA IMPF/ ICAPS teams and ICES TT