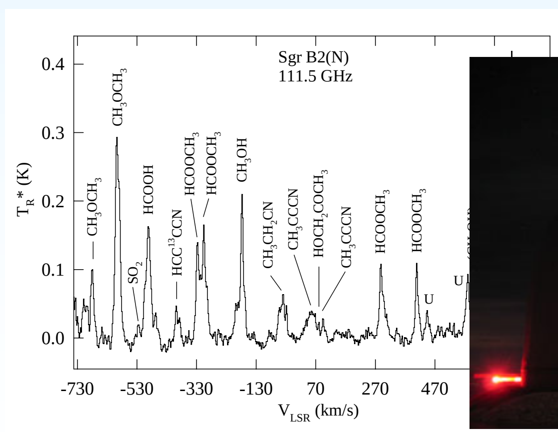
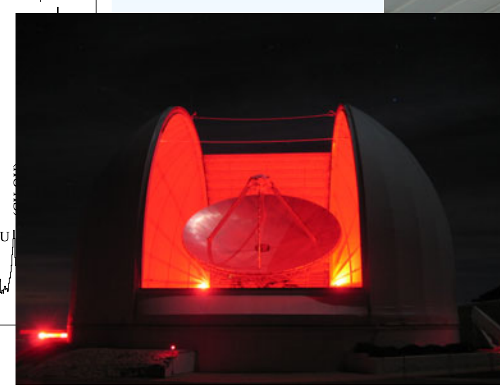
The Impact of the 12 m Telescope on Millimeter Science:
Setting the Stage for the Future

Lucy M. Ziurys and the Staff of the Arizona Radio Observatory



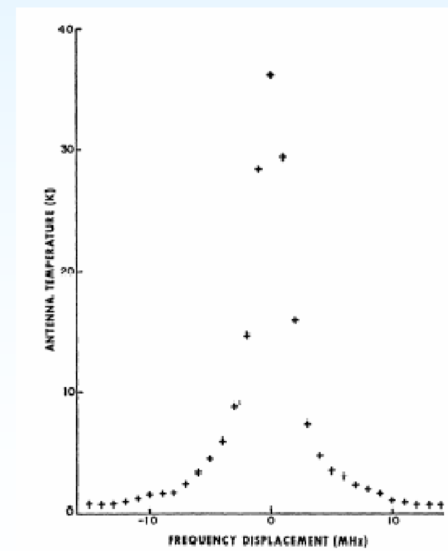


The 12 M Telescope and John Payne

- 12 m Telescope began as the 36 ft. in late 1960's
  - began as a bolometer facility (Frank Low)
  - discovery of CO in 1970 at the 36 ft.
  - emphasis shifted to spectral lines
- Upgraded to 12 m in 1984
- Remained a world class telescope for spectroscopy

John Payne played ***the major role*** in making the this telescope a renowned spectroscopic instrument in mm astronomy

CO: J= 1-0: Orion
Wilson et al 1970



Some of John's Many Contributions…

At the 36 ft….

- Upgraded ***Telescope Servo System***
  - improved performance
- Spectrometer backends: ***the Filter Banks***
  - John built the ***Multiplexer***

⇒ allowed for multiple upgrades to filter banks (2 MHz, 30 kHz filters)

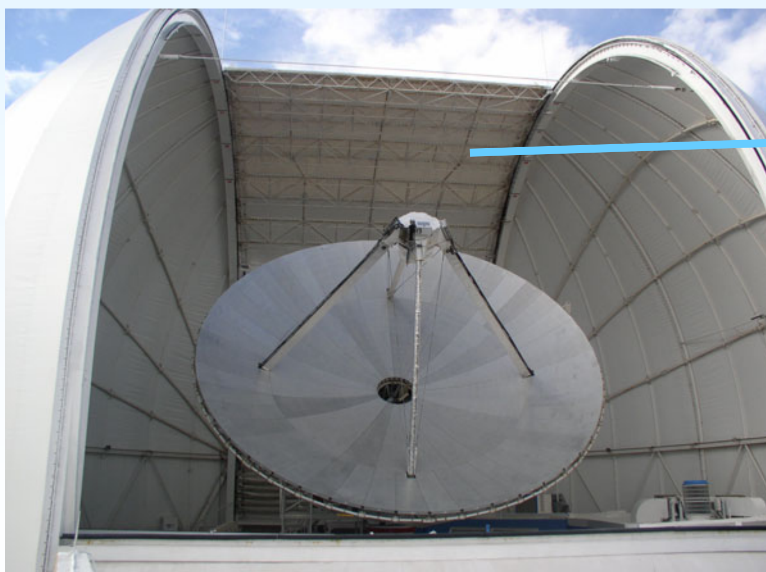
  - Also built the ***Switcher***

⇒ flexibility to easily change between various resolutions

- ***Nutating Sub-reflector***
  - one of first small, fast systems

⇒ ***Servos, multiplexer, switcher till in use today at the 12 m***

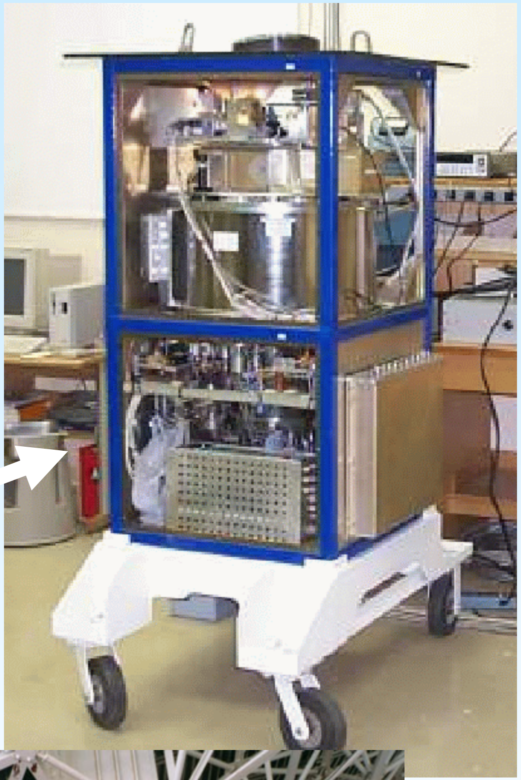
- ***Upgrade from the 36 ft. to the 12 m***
  - surface improvements needed in mid 1970's
  - Dents in the dish due to falling of feed legs
  - with John Findlay and John replaced machined ***surface with new back-up structure and panels*** (the 12 m)
- ***Holography at the 12 m*** with LES 8 satellite
  - improved overall surface accuracy (65 microns rms from > 100 microns)
  - also aided by shaped "compensating" sub-reflector



- A Huge Contribution to ***12 m receivers***
- Key to replacing old Schottky systems ***with SIS receivers*** in late 1980's
- First SIS receiver was 3 mm (WR-10)
  - fill with liquid helium
- Replaced with the J-T "Rocket" systems
  - employed closed cycle refrigerators

Receiver	Wavelength
3 mm HI	90 – 115 GHz
1 mm LOW	200 – 260 GHz
3 mm LO	65 – 90 GHz
2 mm	125 - 180 GHz
1 mm HIGH	260 -300 GHz
1 mm 8 beam	200 – 250 GHz

3 mm LO STILL unique in world



1mm LOW/
1mm HIGH

In rxr bay at 12 m

I must point out that as a mm-wave astronomer, I have had tremendous difficulty in obtaining observing time at IRAM. This appears to be a common problem for U.S. astronomers. The "open-observer" policy that NRAO has always followed apparently is not being reciprocated by IRAM. I therefore find it particularly inappropriate for the Central Development Lab to be selling any mixers to IRAM, especially since new receivers for the 12 m telescope are not being built. In fact, I am sure that both N.S.F. and Congress, which are the sources of funding for NRAO, would also question these activities. Such action by the Central Development Lab does not endear them to the U.S. mm-wave community.

In your recent letter to supporters of the 12 m telescope, you stated quite clearly that NRAO is still supporting mm-wave astronomy. I would think that the best method by which NRAO can do this is by providing the 12 meter telescope with more SIS mixers. In particular, the complete 3 mm band (70-115 GHz) needs to be covered, as well as the entire 1.2 mm band (200-300 GHz). In addition, I would strongly suggest a 2 mm receiver (120-170 GHz) be constructed. I have heard that plans have been made for a 2 mm system, but it appears to always drop from the priority list due to certain scientists within NRAO feeling the 2 mm region to be a "barren" band. Consequently, I have enclosed a spectrum at 2 mm, taken at IRAM with their SIS receiver. The spectral line confusion limit illustrated in this spectrum was reached in only a few hours integration time.

I would also like to point out that I have used SIS receivers on the CSO in October, 1989 at 1.2 and 0.8 mm both which utilized waveguide mixers. These receivers, made with lead junctions, worked tremendously well. I would rather see SIS receivers with lead junctions on the 12 meter now, rather than with niobium junctions five years from now.

If NRAO claims to be supporting a mm-wave effort, then it ought to be taking more aggressive action in this regard. Having endless discussions and expensive meetings about the proposed mm-wave array is not a particularly profitable way to accomplish this. Nor is selling SIS mixers to IRAM. Building SIS mixers for the 12 meter telescope is far more crucial. In fact, it is really what NRAO is all about.

NATIONAL RADIO ASTRONOMY OBSERVATORY

EDGEMONT ROAD CHARLOTTESVILLE, VIRGINIA 22903-2475
TELEPHONE 804 296-0211 TWX 910 997-0174 FAX 804 296-0278

January 23, 1990

Dr. Lucy Ziurys
Dept. of Chemistry
Arizona State University
Tempe, AZ 85287-1604

Dear Lucy:

I have received your letter of January 17. The current plan for 12-meter SIS receivers is to install the 220-240 GHz receivers John Payne delivered to Tucson, and then complete 70-90, 90-115, and 130-170 GHz systems. We will do this as quickly as resources allow. Despite your impatience, we will not begin to build receivers with Pb alloy junctions.

Sincerely,

Paul

P. A. Vanden Bout

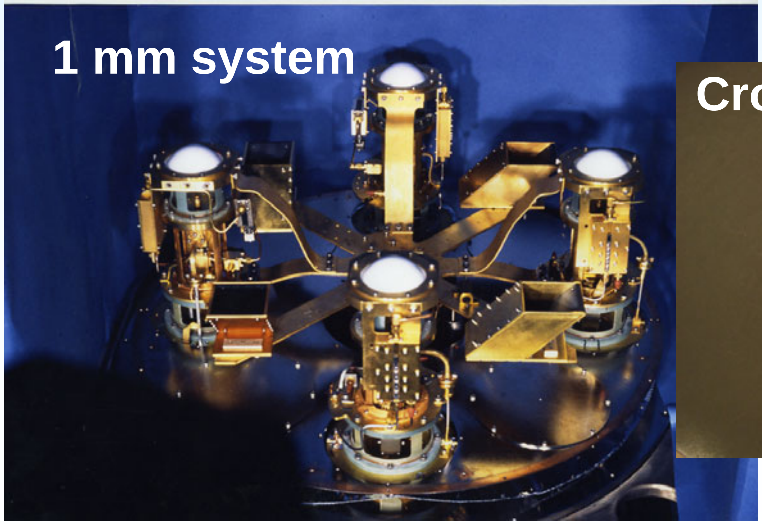
c: D. Emerson
M. Balister

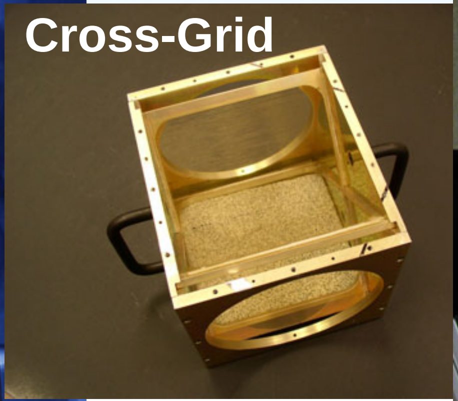
Many important innovations in the 12 m receivers

- John brought ***Joule -Thompson*** systems to 12 m

Designed mechanical infrastructure

- building ***each mixer into an insert*** (rockets)
- placing many inserts in ***one large dewar***
- spare inserts for quick replacement
  (2/3 mm dewar; 1 mm dewar)
- designed ***cross-grid*** for dual polarization
- installed ***M-P's*** for SSB operation





Led to a highly versatile, molecular-line machine

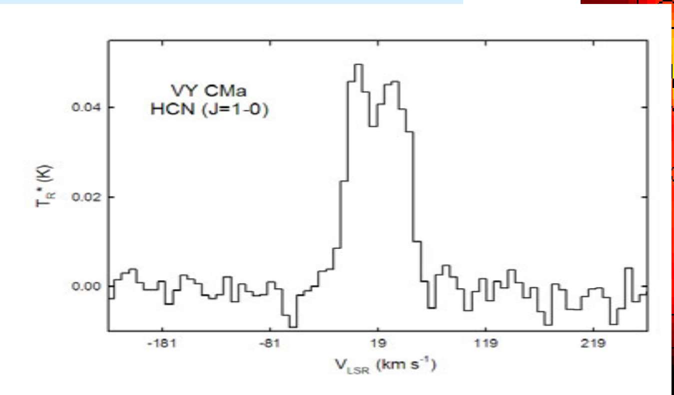
- ***Complete coverage*** of 1,2, and 3 mm windows
  - never achieved at any other telescope
- All receivers ***very sensitive*** (SIS junctions) AND STABLE
  - still competitive with the world's best
- ***Dual polarization***
  - two independent answers, besides extra integration time
- ***SINGLE-SIDEBAND***
  - Invaluable for line searches, accurate calibration
- Nice suite of ***multiple resolution backends*** (Filter banks, MAC)
- ***easy to switch*** between receivers, backends
  - moving a few cables, central selection mirror, cross-grid

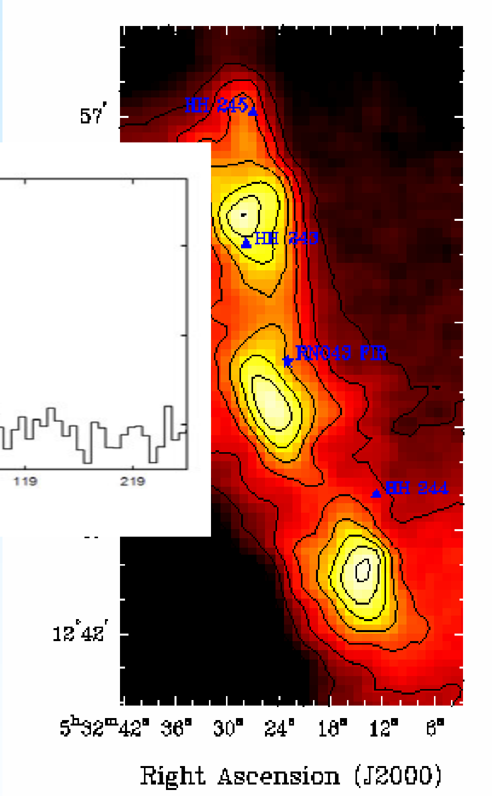
$\Rightarrow$ Coupled with a fast, efficient control system, the 12 m has been able to do great science

INTEGRATION OF THE COMPLETE SYSTEM AND ALL COMPONENTS WORKED WELL

Highlights of the 12 m Scientific Contributions

- Astrochemistry
  - Detection of many new molecules
  - 12 m created the field
- Extragalactic
  - ISM in external galaxies
  - CO at high red-shifts
- Comets and the Solar System
  - Molecule studies in comets
  - planetary atmospheres
- Star Formation
  - Outflows, disks, protostars in dense clouds
  - Cloud structure and dynamics
- Evolved Stars
  - Detection and structure of circumstellar envelopes
  - Mass loss to the ISM
- Astrobiology





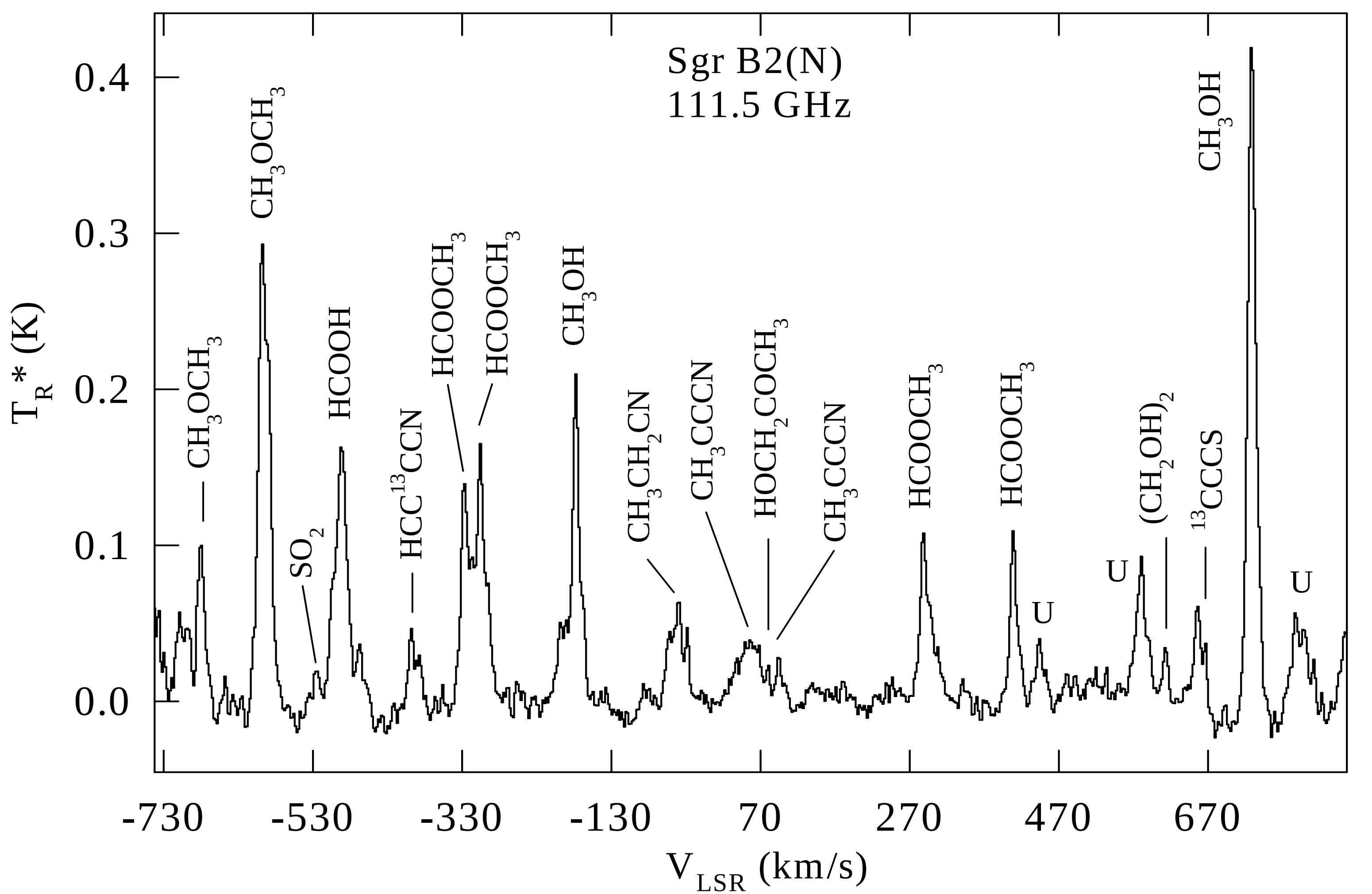
Known Interstellar Molecules

2		3		4	5	6	7	8	9	10
H_2	CH^+	H_2O	C_3	NH_3	SiH_4	CH_3OH	CH_3CHO	CH_3CO_2H	CH_3CH_2OH	
OH	CN	H_2S	HNC	H_3O^+	CH_4	NH_2CHO	CH_3NH_2	HCO_2CH_3	$(CH_3)_2O$	CH_3COCH_3
SO	CO	SO_2	HCN	H_2CO	CHOOH	CH_3CN	CH_3CCH	CH_3C_2CN	CH_3CH_2CN	$CH_3(C{\equiv}C)_2CN$
SO^+	CS	NNH^+	CH_2	H_2CS	$HC{\equiv}CCN$	CH_3NC	CH_2CHCN	C_7H	$H(C{\equiv}C)_3CN$	$(CH_2OH)_2$
SiO	C_2	HNO	NH_2	HNCO	CH_2NH	CH_3SH	$H(C{\equiv}C)_2CN$	H_2C_6	$H(C{\equiv}C)_2CH_3$	
SiS	SiC	CCS	HOC^+	HNCS	NH_2CN	C_5H	C_6H	CH_2OHCHO	C_8H	
NO	CP	NH_2	NaCN	CCCN	H_2CCO	HC_2CHO	$c\text{-}CH_2OCH_2$			**11**
NS	CO^+	H_3^+	MgNC	HCO_2^+	C_4H	$CH_2{=}CH_2$	$H_2CC(OH)H$			$H(C{\equiv}C)_4CN$
HCl	HF	NNO	AlNC	CCCH	$c\text{-}C_3H_2$	H_2C_4				**12**
NaCl	SH	HCO	SiCN	$c\text{-}C_3H$	CH_2CN	HC_3NH^+				
KCl	HD	HCO^+	SiNC	CCCO	C_5	C_5N				**13**
AlCl		OCS	H_2D^+	C_3S	SiC_4					
AlF		CCH	MgCN	HCCH	H_2C_3					$H(C{\equiv}C)_5CN$
PN		HCS^+	KCN	$HCNH^+$	HCCNC					
SiN		c-SiCC		HCCN	HNCCC					Total = 128
NH		CCO		H_2CN	H_2COH^+					
CH				$c\text{-}SiC_3$						

~100 Carbon Molecules
11 Silicon Species
9 Metal Containing Molecules

WHAT else ???

A Confusion Limited Survey of SgrB2(N)



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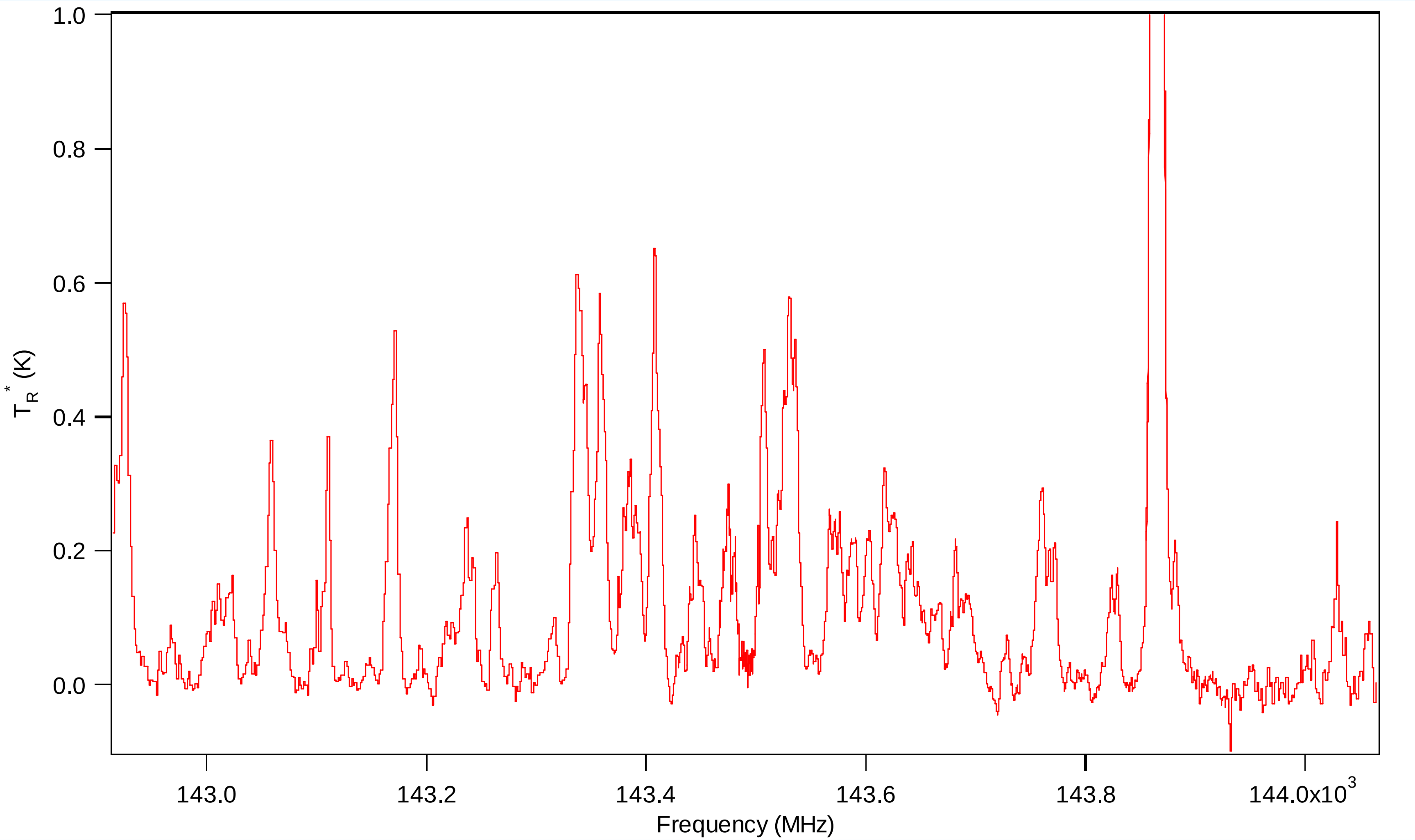


A Real Link to the Origin of Life ?

- Darwinian evolution implies ***"best" chemical solutions*** for life
- Life did not always choose the "best"
- Many alternative biochemical possibilities

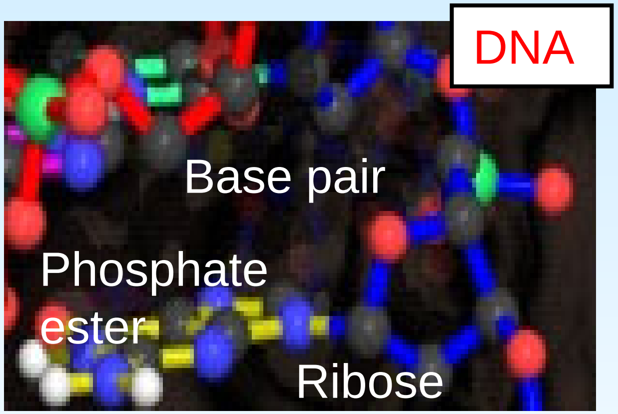
  WHY only 20 amino acids in living systems ?

  ⇒ Other amino acids work in proteins

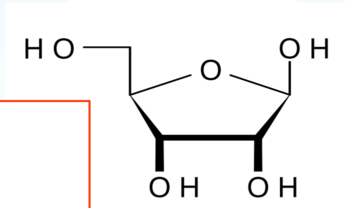
  WHY ribose and deoxyribose in DNA, ATP ?

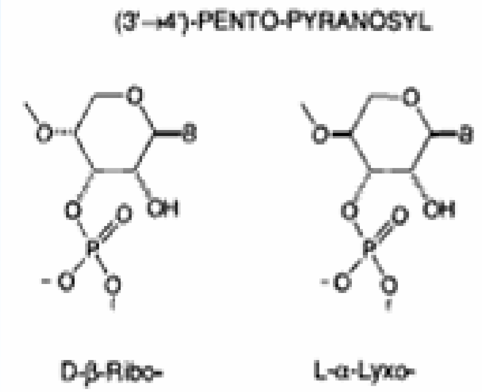
  ⇒ Why not glycerol, a hexose or a tetrose?
- Terrestrial Life did not have time to sample all chemical possibilities

- reflects what was present by chance "Synthetic Contingencies"



RIBOSE





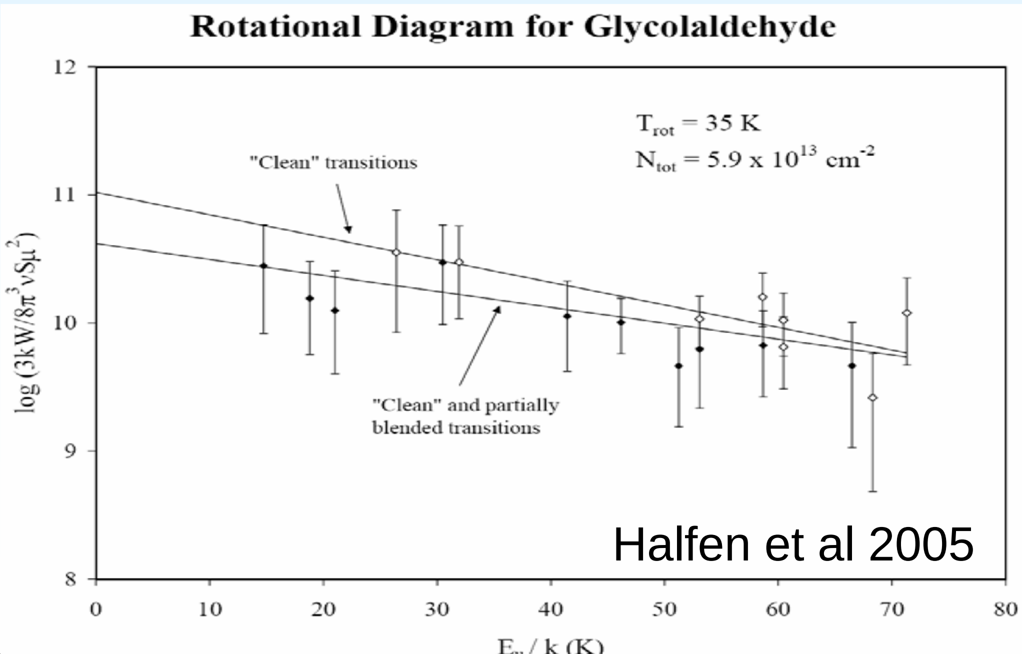
ALTERNATIVES TO RIBOSE

- Early Earth lost original carbon
- Earth constantly bombarded by organic material (comets, meteorites, dust)
- Organics came from interstellar chemistry

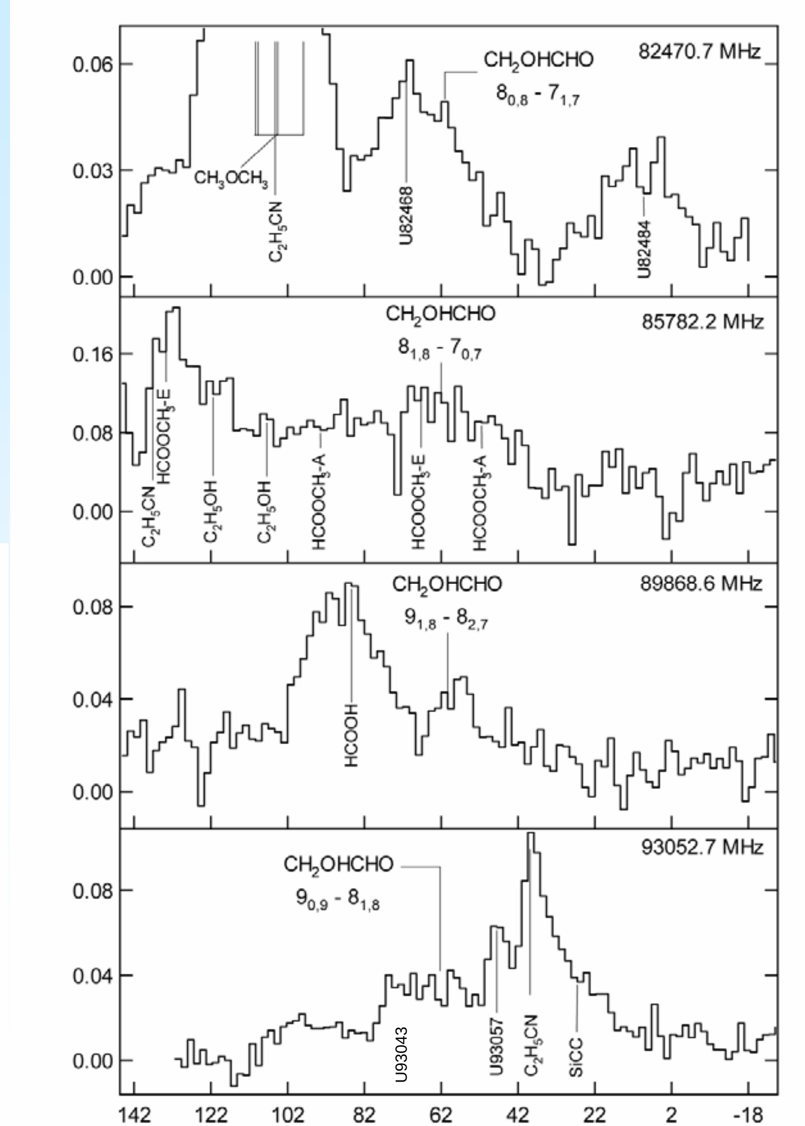
Arizona Radio Observatory

Detection of Glycolaldehyde

- Observed 40 transitions of CH_2OHCHO in range 67 – 165 GHz (12 m)
- All favorable transitions in 10-70 K range
- Accounted for all possible contaminants
  $\Rightarrow$ Modeled relative intensities
- Showed a physical connection exists



Halfen et al 2005



Arizona Radio Observatory

LAPLACE

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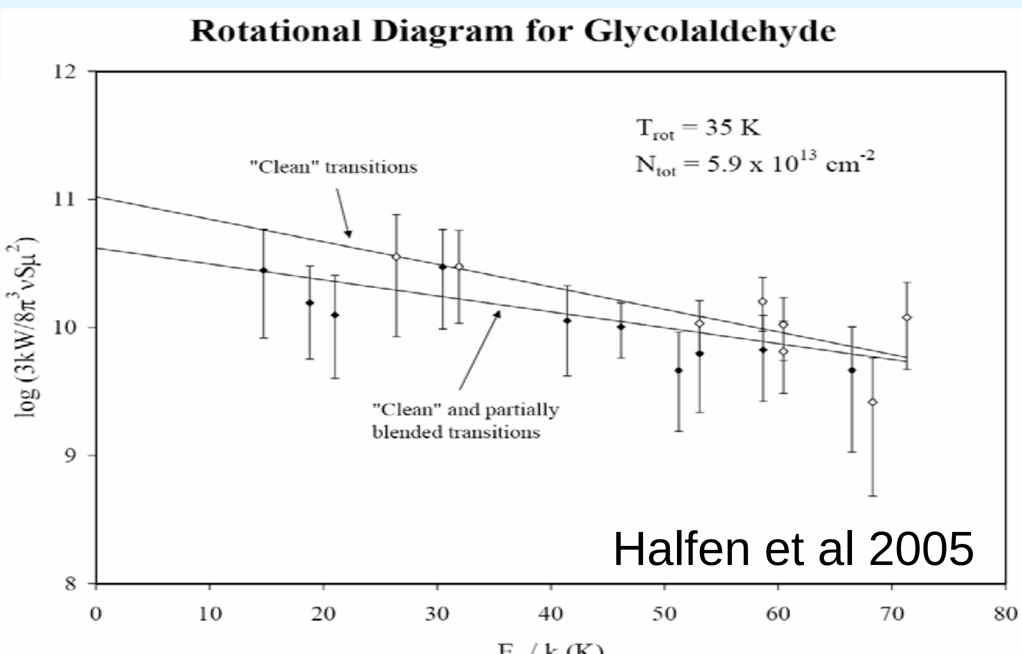

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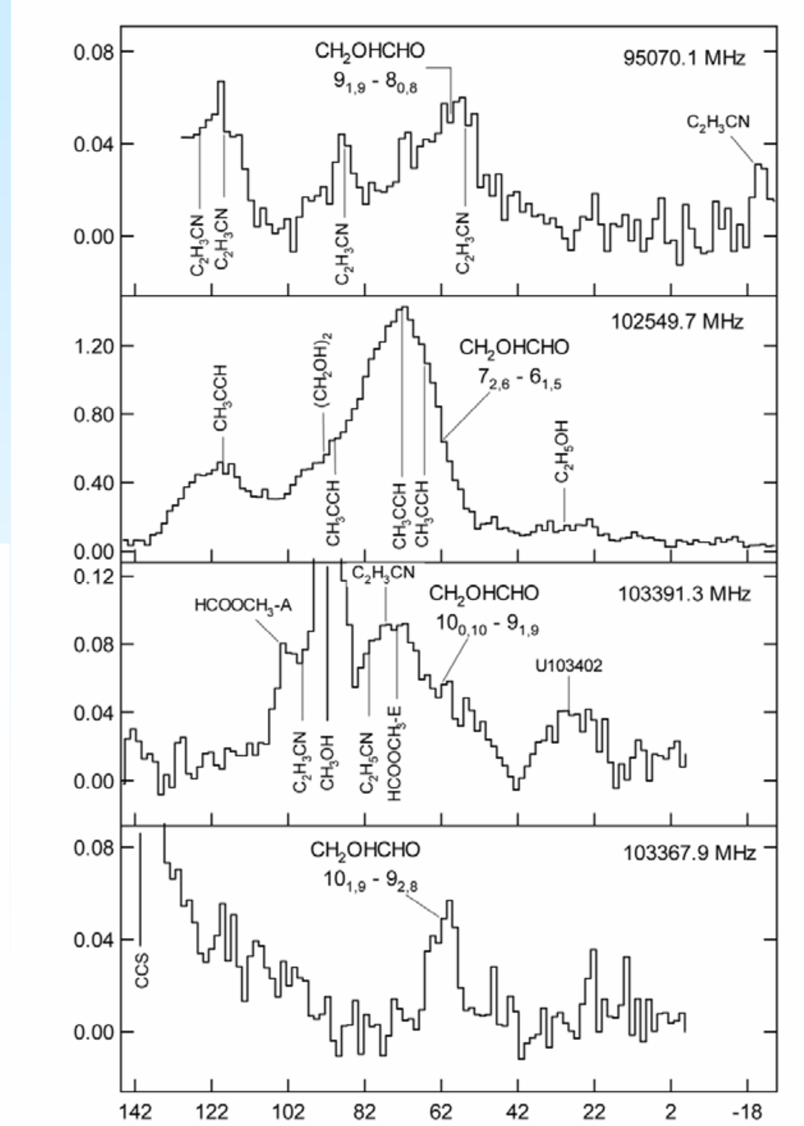

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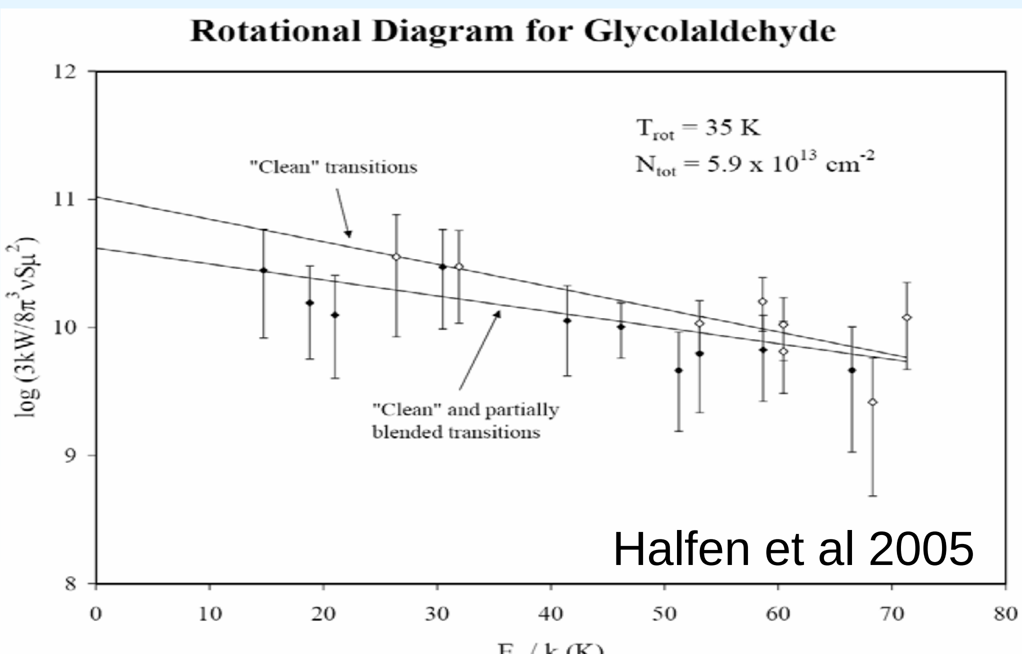
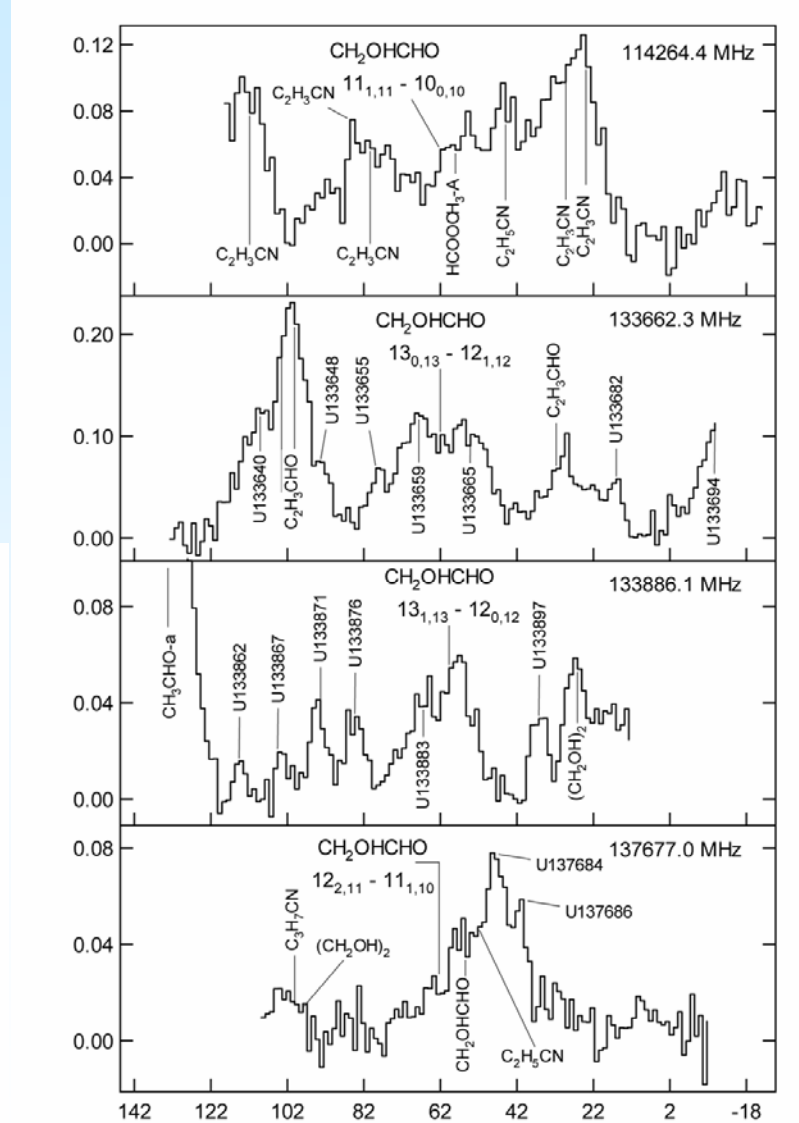


Halfen et al 2005



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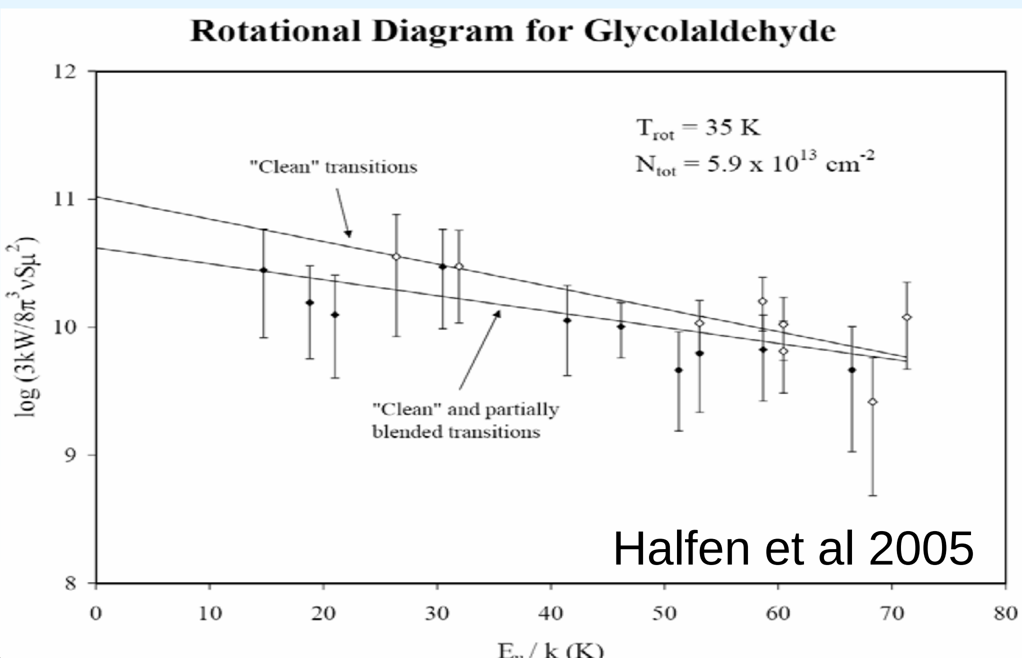

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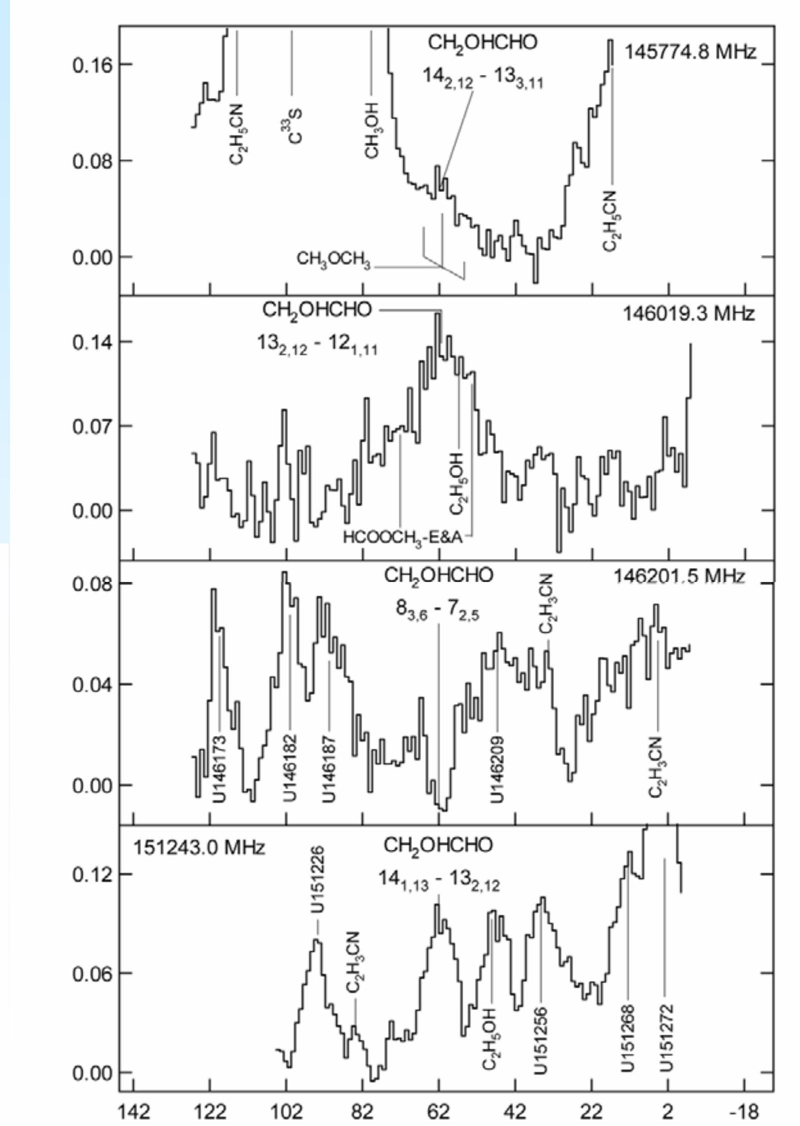
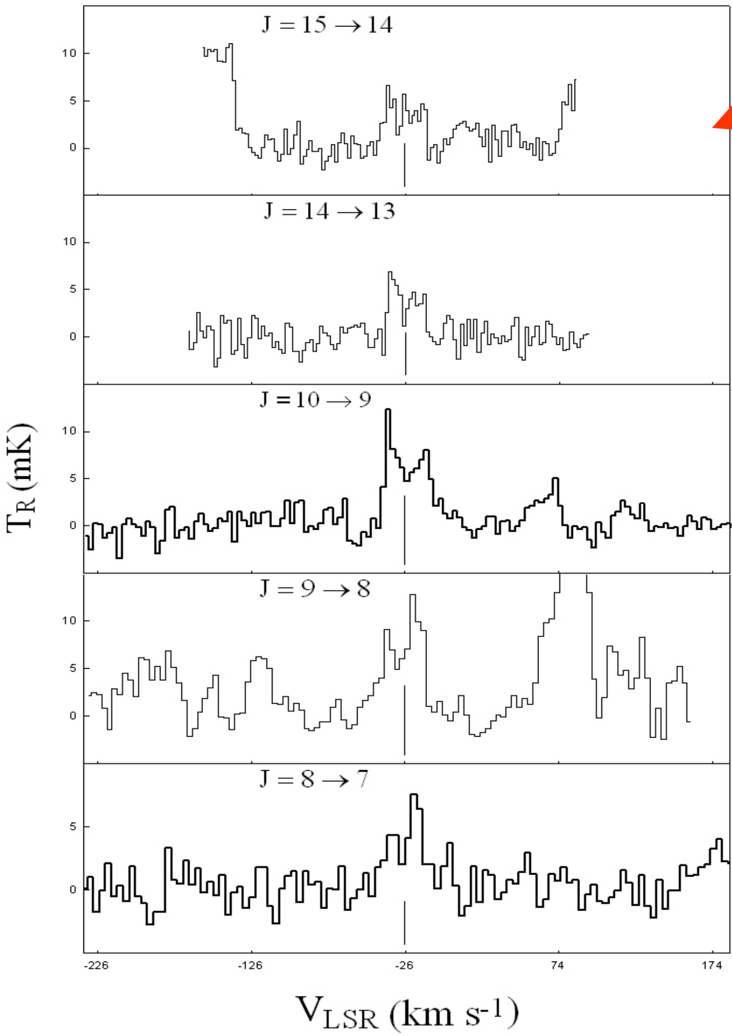


The 12 m (now ARO) remains a competitive instrument

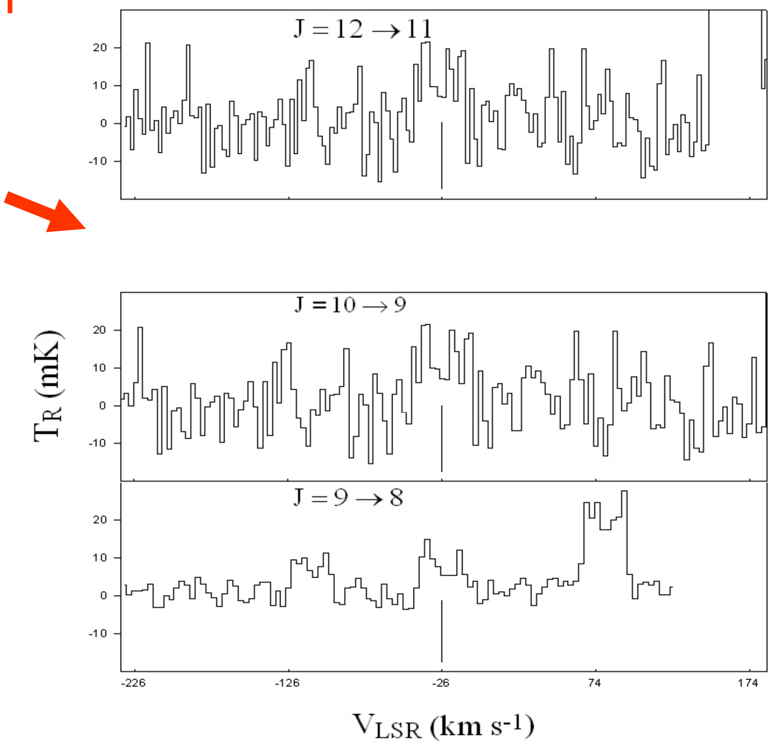
C_3O in IRC+10216

Tenenbaum et al (2006)

12 m



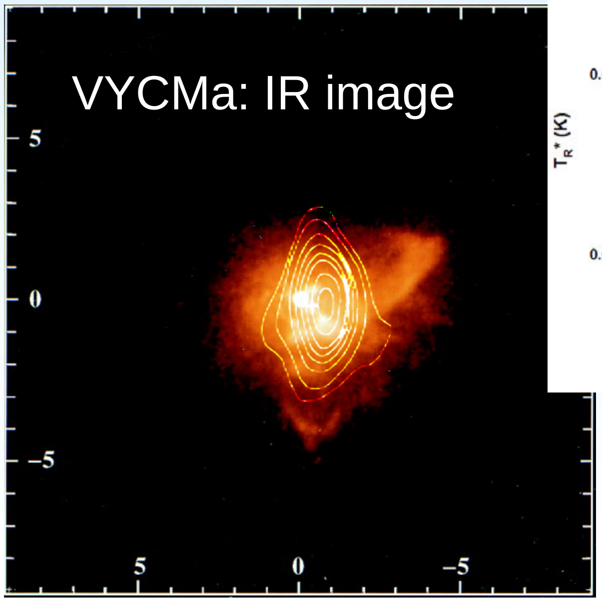
IRAM

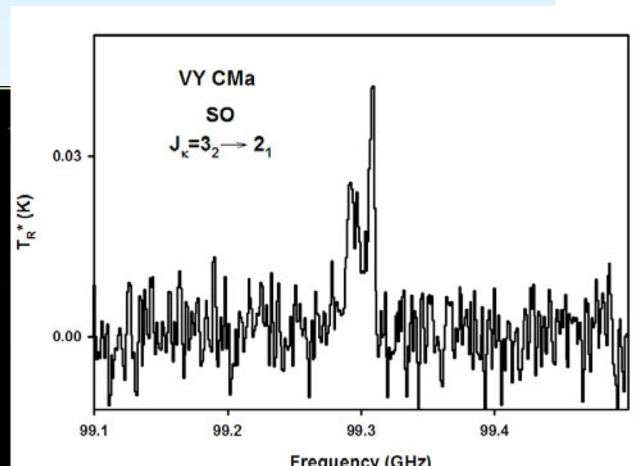


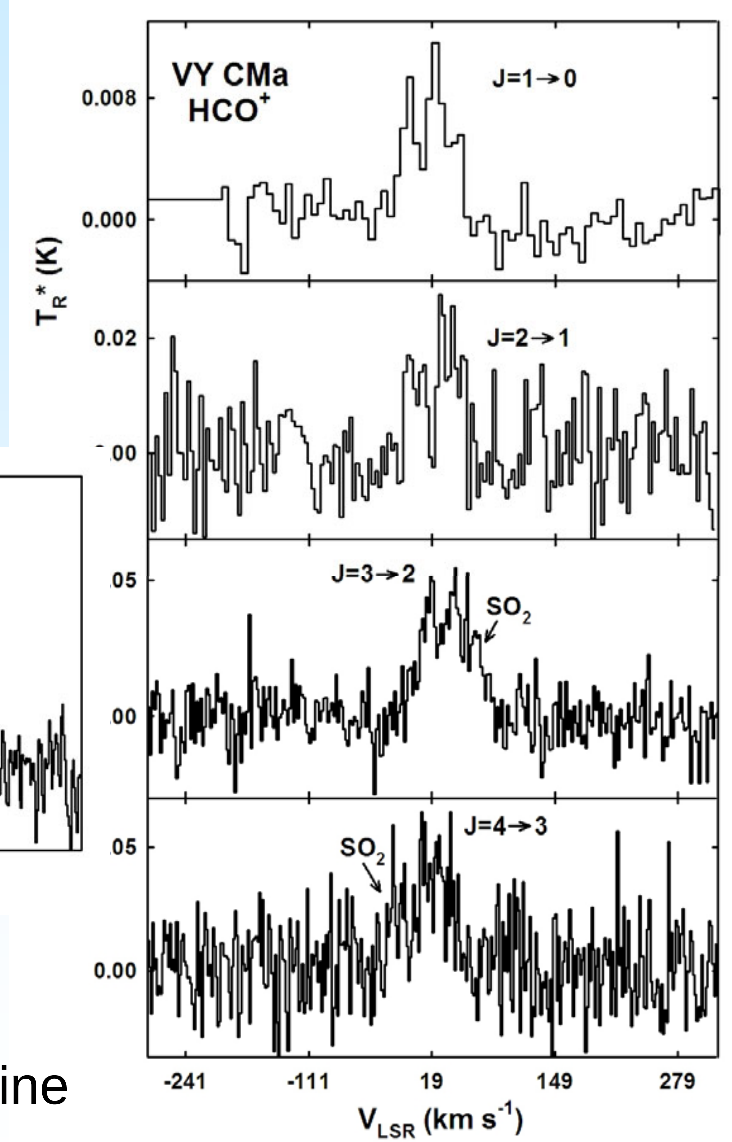
CO does not control chemistry in C-rich circumstellar shells

Studies of Oxygen-Rich Supergiant Star VY Canis Majoris

- ***First clear detection of HCO+ in a circumstellar envelope***
- ***Ions important in circumstellar chemistry***



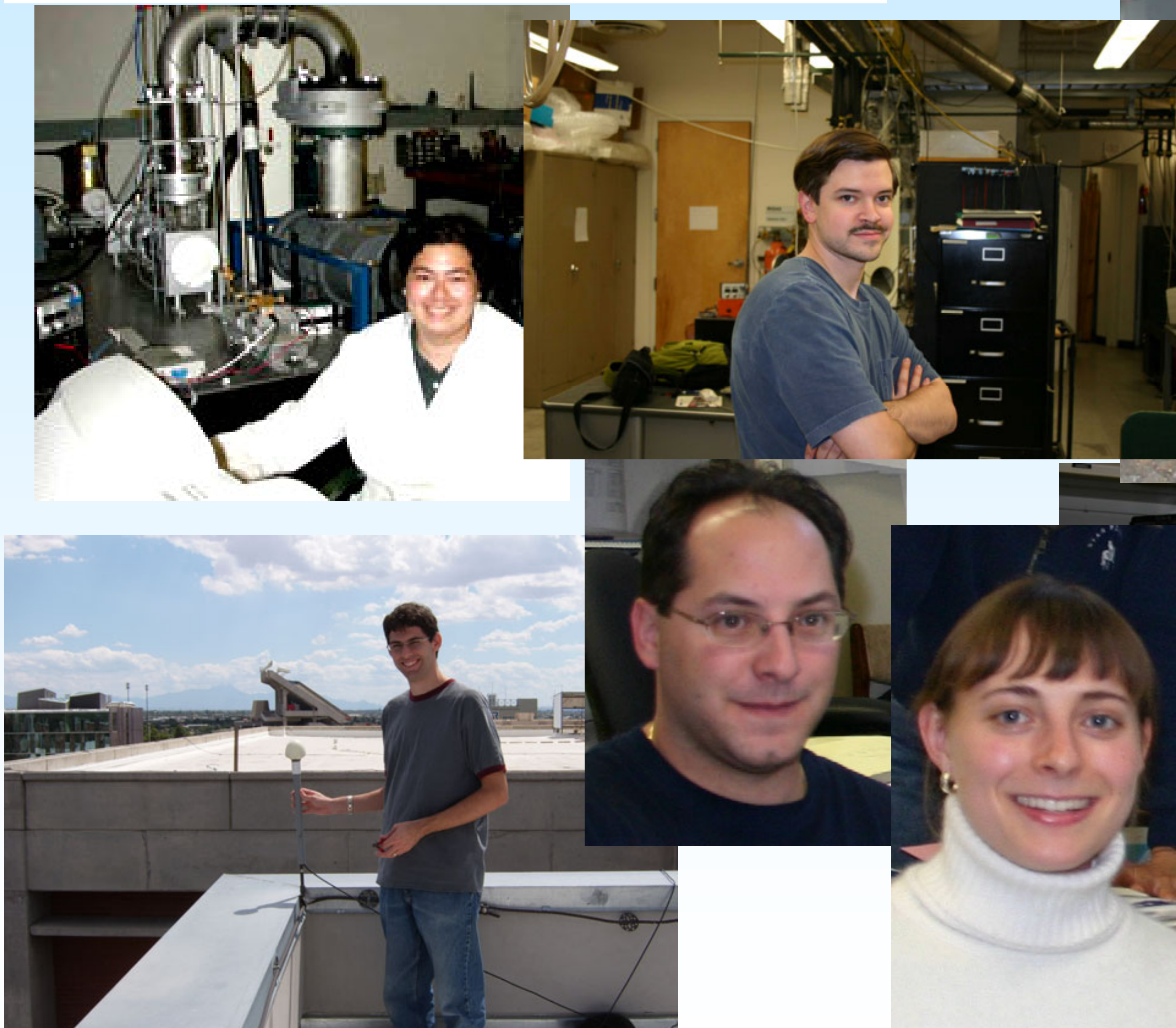




- Bipolar outflow
- 12 m/SMT baseline

Arizona Radio Observatory

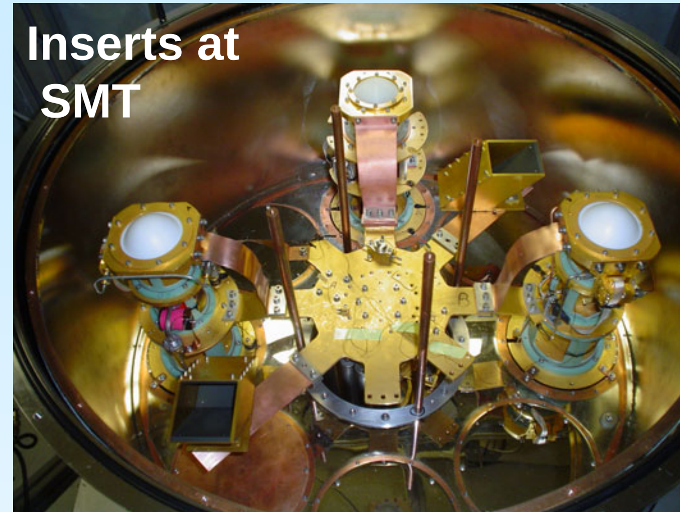
An Inspiration to Many Students….



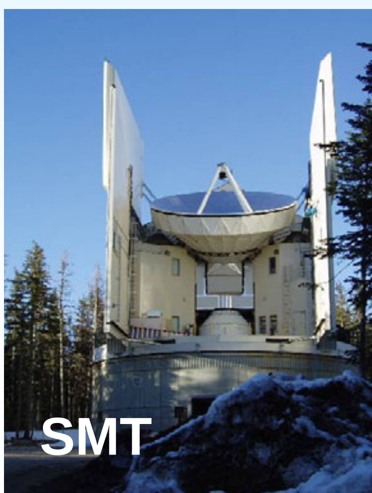
An Inspiration to Many Students….

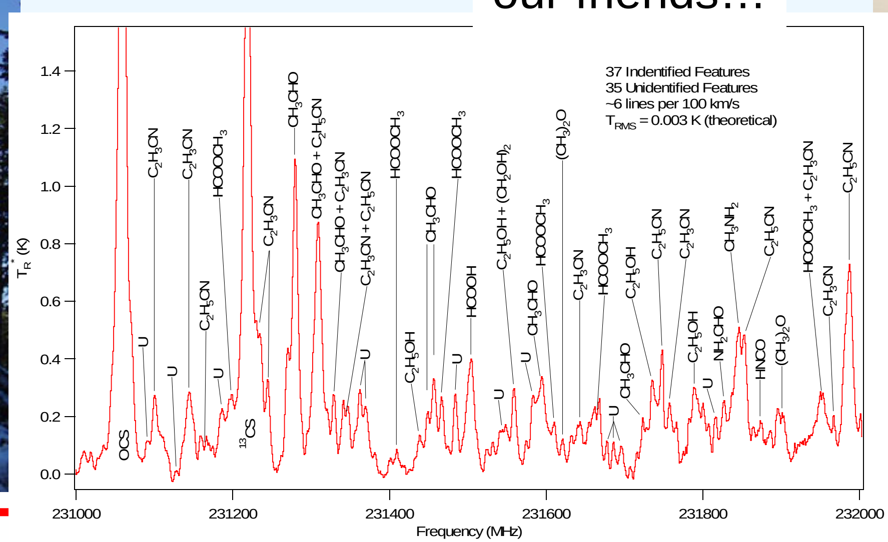
The Tradition Continues…

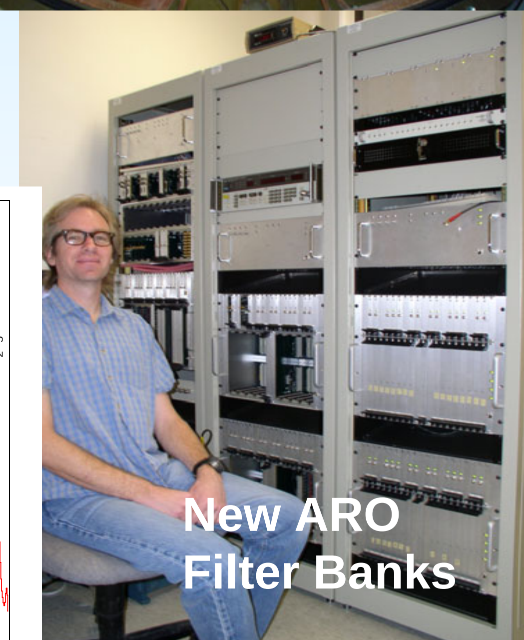
- At the Arizona Radio Observatory's SMT keep tradition handed down from John Payne
  - insert concept for receivers
  - dual polarization, SSB mixers
  - reliable backends
  - stable front-end and backends
  - ⇒ ***high quality spectroscopy***



With a little help from our friends…







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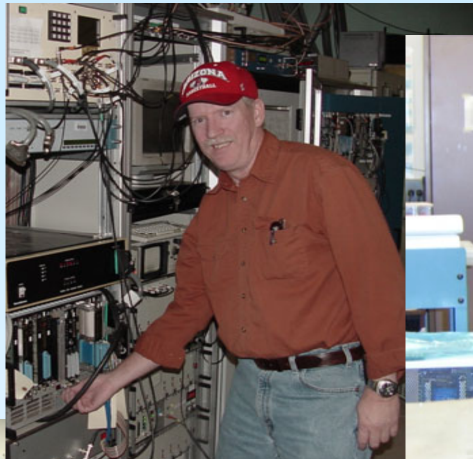



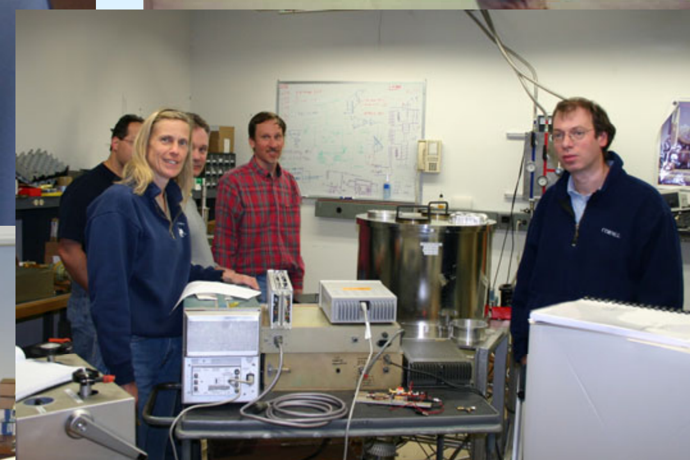

Arizona
Radio
Observatory

Thanks, John, for showing us the way….