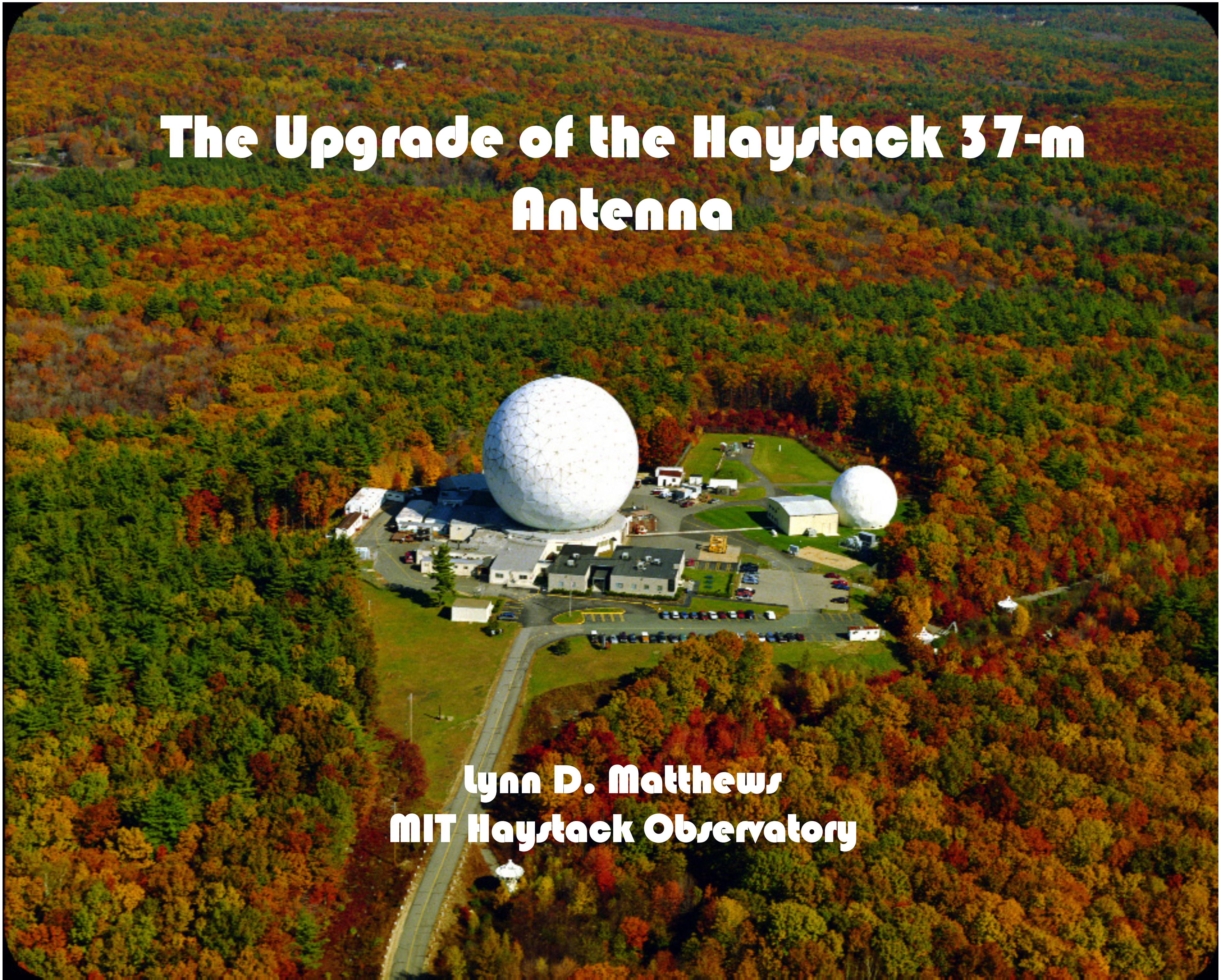
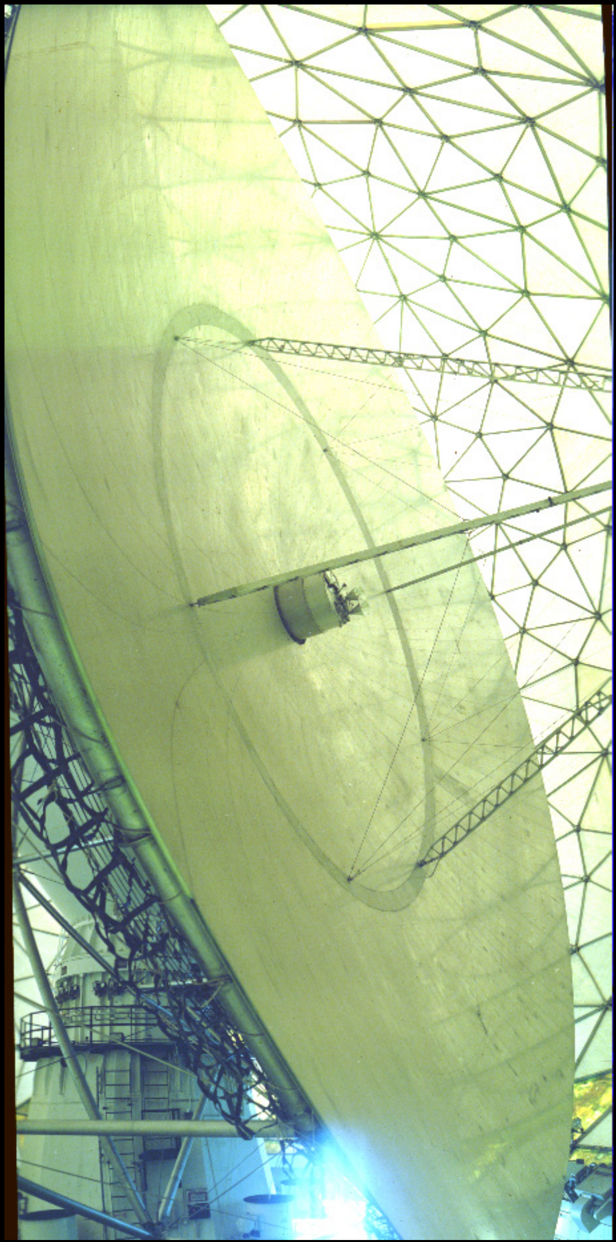
The Upgrade of the Haystack 37-m Antenna



Lynn D. Matthews
MIT Haystack Observatory



Two views of the 37-m Telescope

A Brief History of the Haystack 37-m Antenna

1964: "Haystack Microwave Research Facility" completed in Tyngsborough, MA; supported by US Air Force

Characteristics: radome-enclosed 120-ft (36.6-m) parabola; alt-az mount; Cassegrain focus; solid aluminum panel surface

Initial operating frequencies: 8-10 GHz ; 8 GHz radar

July 1970: Operations shifted to university consortium (NEROC)
HMRF ➔ Haystack Observatory

January 1971: Phil begins part of his PhD thesis work at Haystack ("*Microwave Observations of Molecular Spectral Lines in Galactic Clouds*")

Haystack Observatory c. 1968

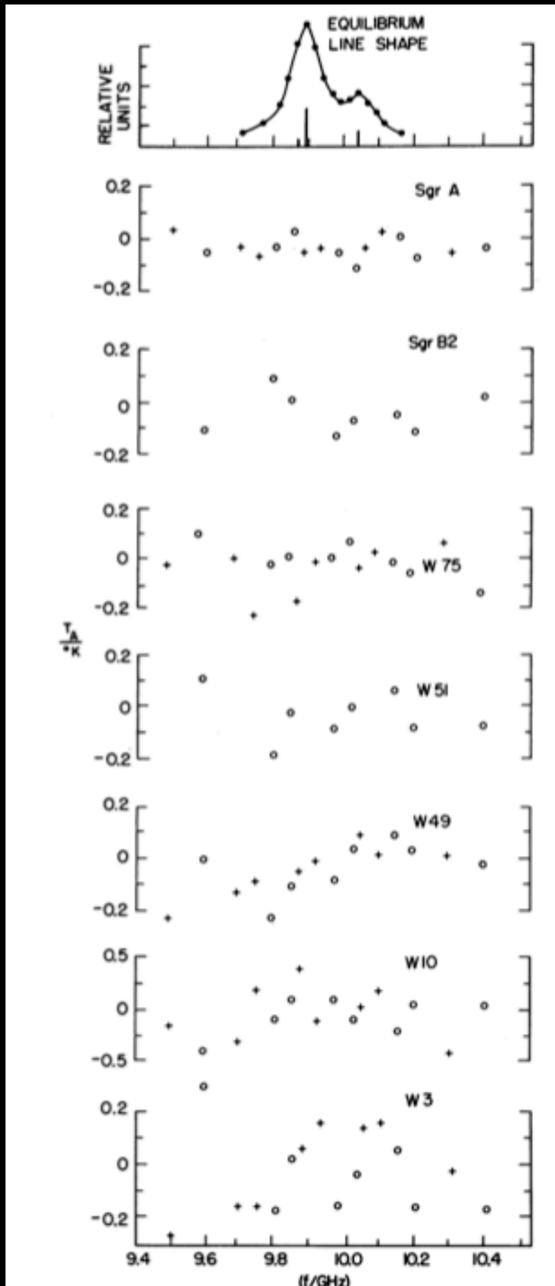
Haystack Control Room, late 1960 s

Al
Barrett

Phil
Myers

Phil and PhD thesis advisor, Al Barrett
MIT, June 1987

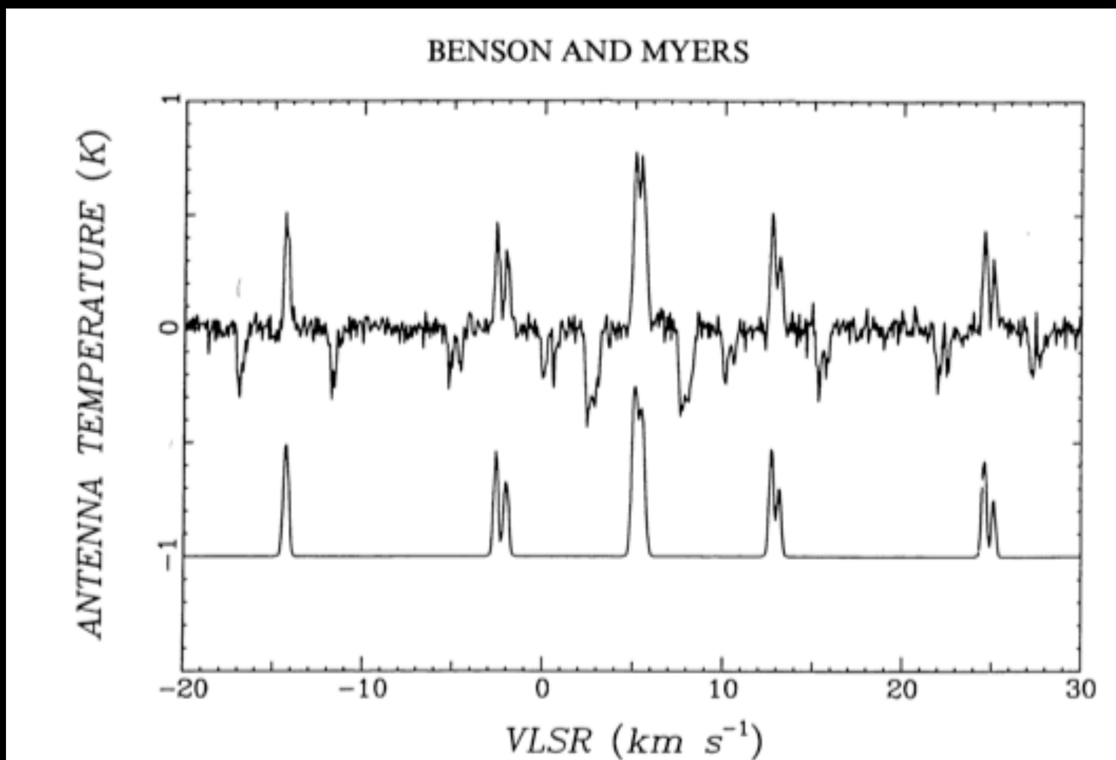
Examples of science done by Phil & collaborators using the Haystack 37-m Antenna



Search for $2^2P_{3/2}$–$2^2S_{1/2}$ fine structure transition of H in HII regions

Myers & Barrett 1972

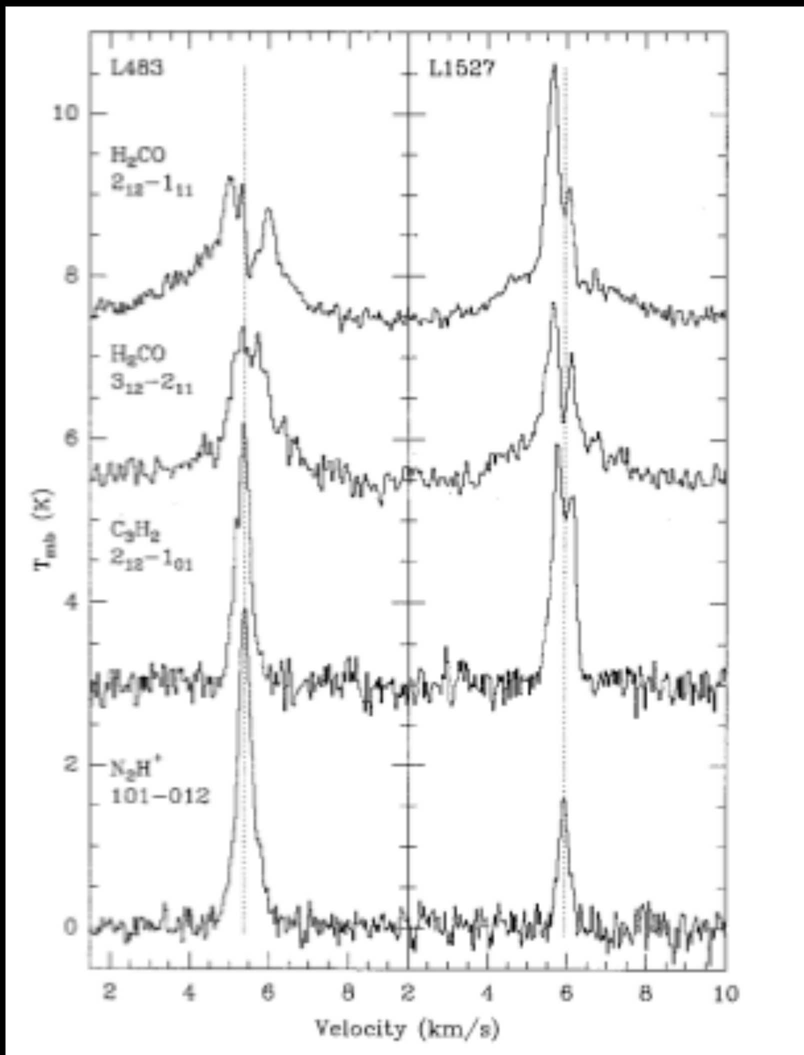
Examples of science done by Phil & collaborators using the Haystack 37-m Antenna (cont.)



NH_3 surveys of dense cores

Myers & Benson 1983; Benson & Myers 1989

Examples of science done by Phil and collaborators using the Haystack 37-m Antenna (cont.)

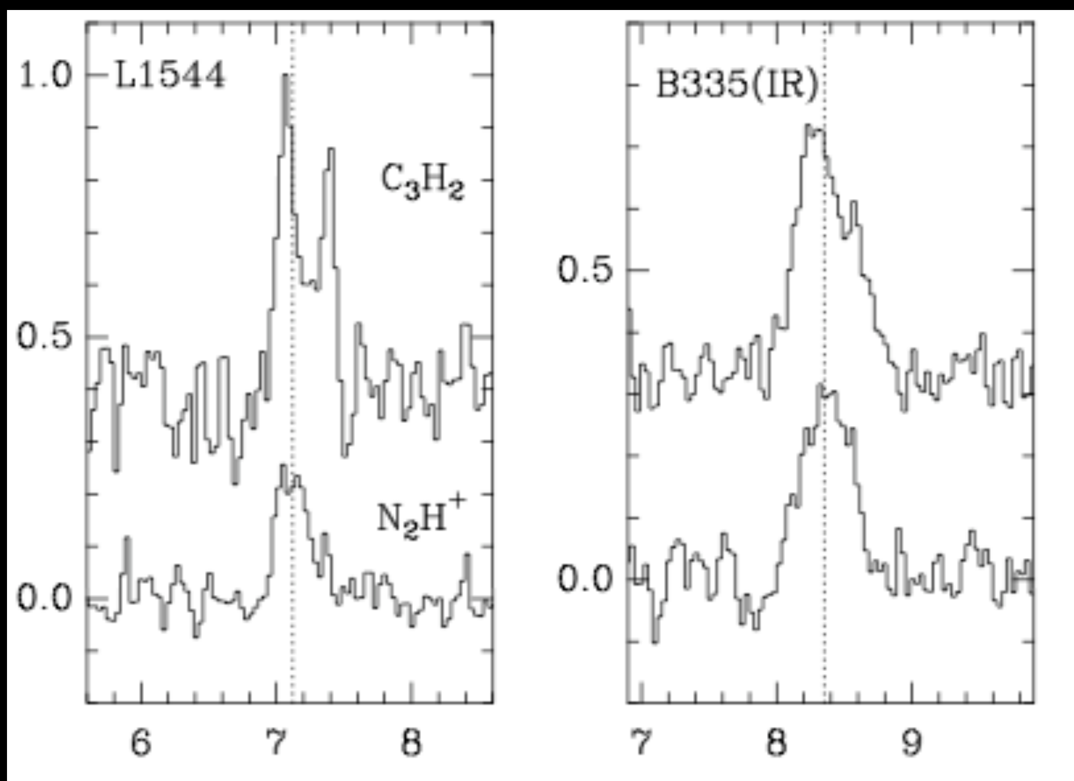


Discovery of infall signatures in dense cores containing embedded protostars through observations of N_2H^+, C_3H_2, H_2CO

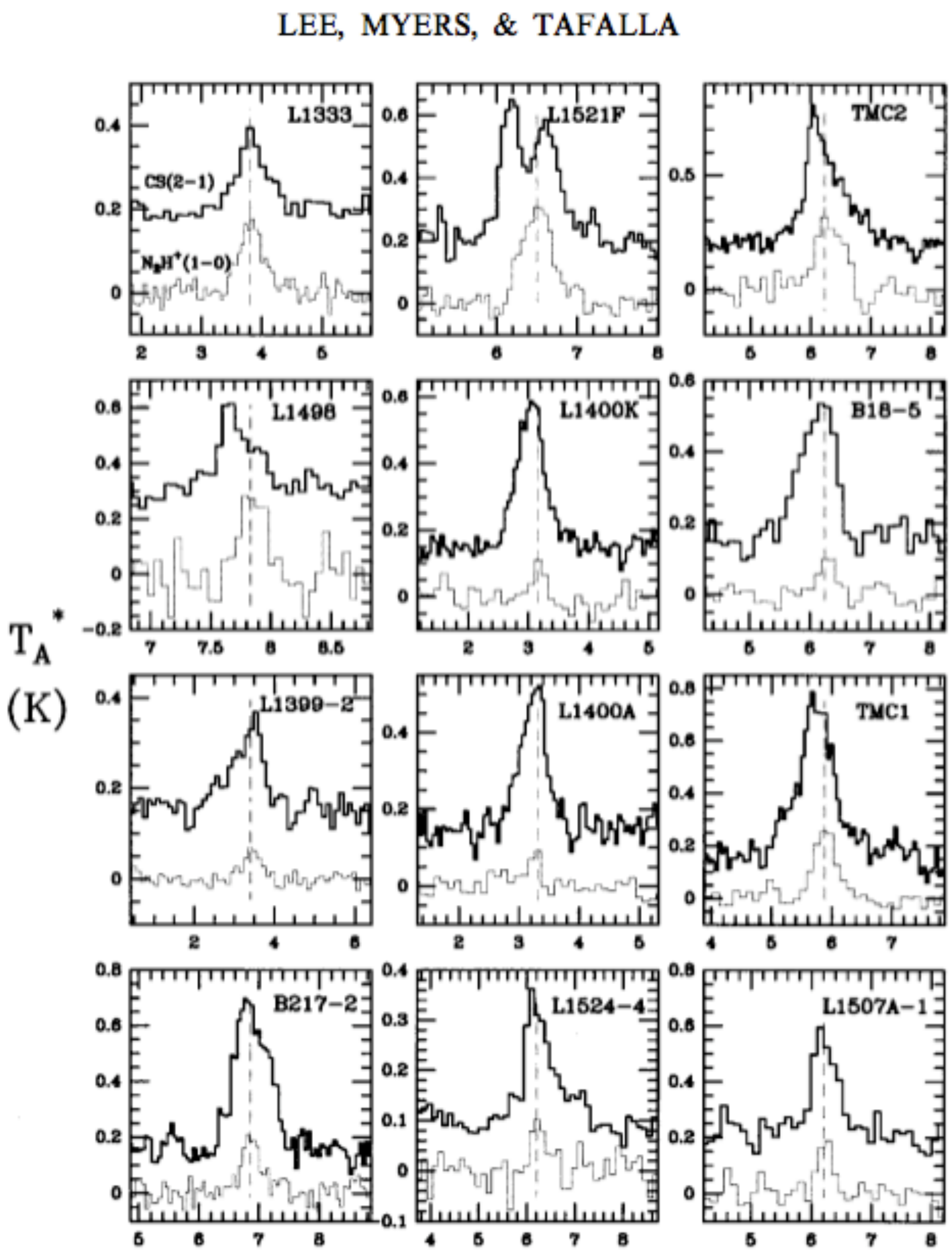
Myers et al. 1995

Examples of science done by Phil & collaborators using the Haystack 37-m Antenna (cont.)

First simultaneous survey of neutrals (C_3H_2, CCS) and ions (N_2H^+) in dense cores



Benson, Caselli, & Myers 1998



Examples of science done by Phil & collaborators using the Haystack 37-m Antenna (cont.)

Survey of infall motions of 220 starless cores via CS & N_2H^+

Lee, Myers, & Tafalla 1999

Previous Upgrades of the Haystack 37-m Antenna

"λ7-mm upgrade'' (1986-1989):

- replacement of radome membrane
- implementation of active thermal control of critical substructure elements
- adjustment of surface panels to 500 μm rms

"λ3-mm upgrade" (1991-1993):

- installation of deformable subreflector
- enhanced thermal control of surface
- improved radome heating and circulation

Limitations of Existing 37-m Antenna:

- Gravitational deformations of primary and differential thermal expansion of telescope components limit high-frequency performance:

  - Aperture efficiency @115 GHz only ~13%
  - No operational capabilities at higher frequencies

- Inability to rapidly switch between radar/radio astronomy boxes limits scheduling flexibility

Moreover:

- NSF support for Haystack as user facility ceased in May 1998

- Control of telescope passed back to Air Force in June 2005

- Radiometers were removed and 37-m education programs ceased in January 2007

A New Life for the 37-m Antenna:

However...
Needs of Air Force (e.g., characterizing microsatellites) has motivated development of new wideband 95 GHz radar system.

And...
The existing system cannot support such a capability

➔ A *new Haystack 37-m upgrade program is currently underway*

(funded jointly by Air Force and Defense Advanced Research Projects Agency and executed by MIT Lincoln Lab).

And...
Funds to re-establish ***radio science capabilities*** on new 37-m now committed by Lincoln Lab.

Ongoing Upgrade of Haystack 37-m Antenna

Plan: replacement of radome membrane and entire elevation structure supported by existing yoke and tower:

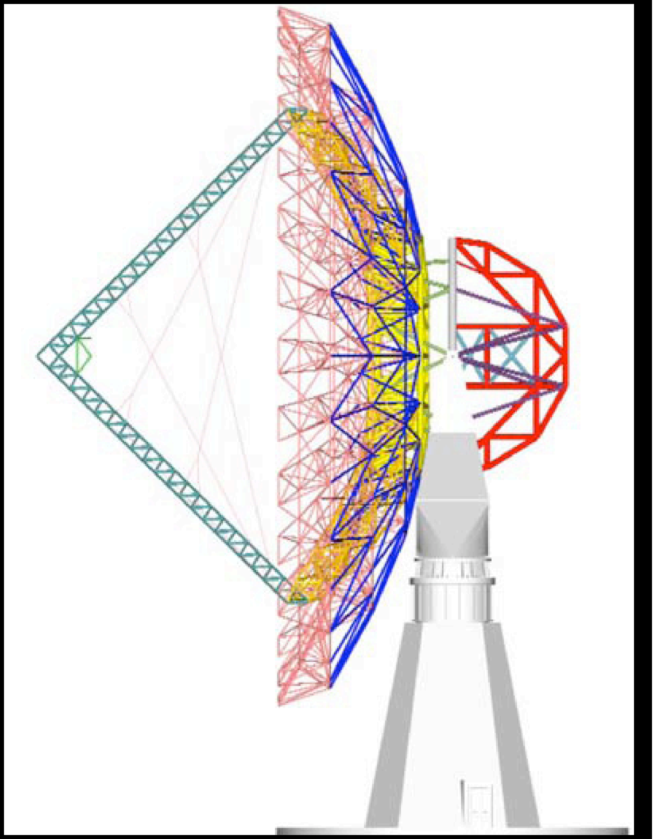
- Reflector panels
- Subreflector
- Reflector back structure
- Transition structure (drive arcs and elevation bearings)
- Drive and control systems
- Equipment box (for radar receivers and radiometers)

(Existing hydrostatic azimuth bearing will be retained).

37-m tower and yoke, c. 1962

Specifications:

- 37-m diameter dish with aluminum panel surface; improved thermal properties
- 100 micron rms surface accuracy (~ 3× improvement)
- ~40-50% aperture efficiency at 100 GHz (inclusive of radome losses)
- New 3-ply radome membrane (improved hydrophobicity; similar transmissivity)



37-m Upgrade Timeline:

April 2010: operations with current dish cease

March 2011: new dish in place; begin initial verifications

April 2011: acceptance tests; characterization of radiometer performance

Late 2011: possible early science opportunities?

September 2012: fully operation system

Some recent milestones:

- Back structure completed
- Cast aluminum subreflector complete
- Control system being tested
- Azimuth gear fabricated
- Panel manufacturing complete

Radio Astronomy with the Upgraded 37-m

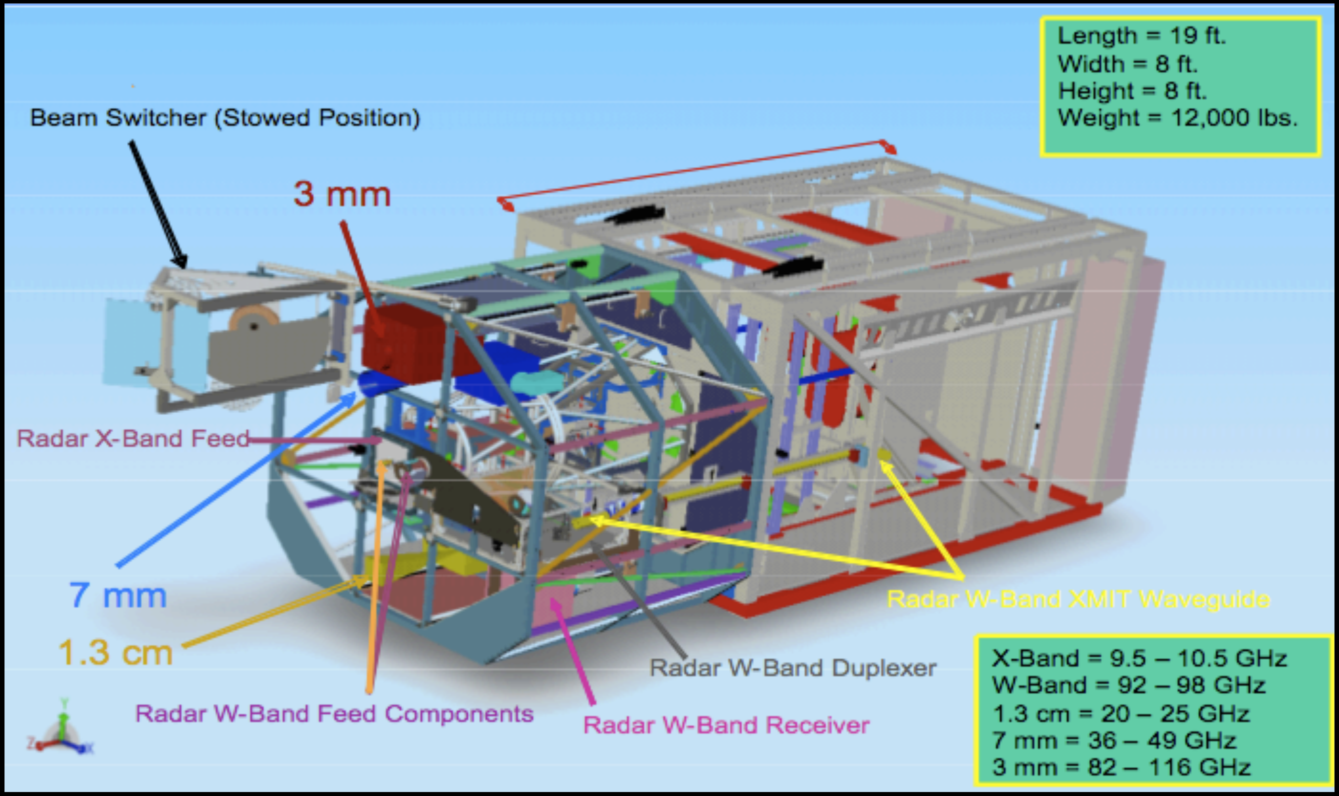
- Expected ~30% of telescope time will be available for science
- Radio astronomy feeds will be offset from center axis and subreflector tilted to provide alignment➔ rapid switching (~5 minutes) between radar receivers and radiometers will be possible

Radio Astronomy with the Upgraded 37-m (cont.)

Initially 3 radio astronomy receivers available:

1.3 cm/36-49 GHz (Q-band): 1 GHz BW, T_{sys}~120 K (above atmos.)
7 mm/20-25 GHz (K-band): 1 GHz BW, T_{sys}~120-200 K
3mm/86-116 GHz (W-band): T_{sys}~200-500 K

(new W-band radiometer with HEMT amplifiers will replace old system with SIS mixers)



New RF Box for radar and radio astronomy systems

Radio Astronomy with the Upgraded 37-m (cont.)

Existing digital autocorrelator will be re-installed:

- 4096 lags, 4 independent modules
- Bandwidth: 0.65 to 160 MHz
- Channel spacing $\Delta\nu$: 0.16 to 312 kHz

New wideband digital spectrometer being built (some details not yet finalized):

- up to 15 GHz bandwidth

- (Very) large number of spectral channels

- 3 pairs of independent dual polarization hardware channels (providing ability to observe multiple spectral lines simultaneously)

What capabilities would make the 37-m most useful to the science community?

(Caveat: there is no funding yet!)

- Additional frequency bands?

(Radome transparency window exists at 230 GHz freq.; ~10 nights/yr with opacities ~0.3)

- VLBI capabilities? Which bands? 22 GHz? 43 GHz? 230 GHz?

- Focal plane array?

- Unique scientific niches?—e.g.,

- Long-term monitoring programs?
- Rapid response science?
- Key project opportunities?
- Student training opportunities?

- Other??

Additional thoughts or comments?

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