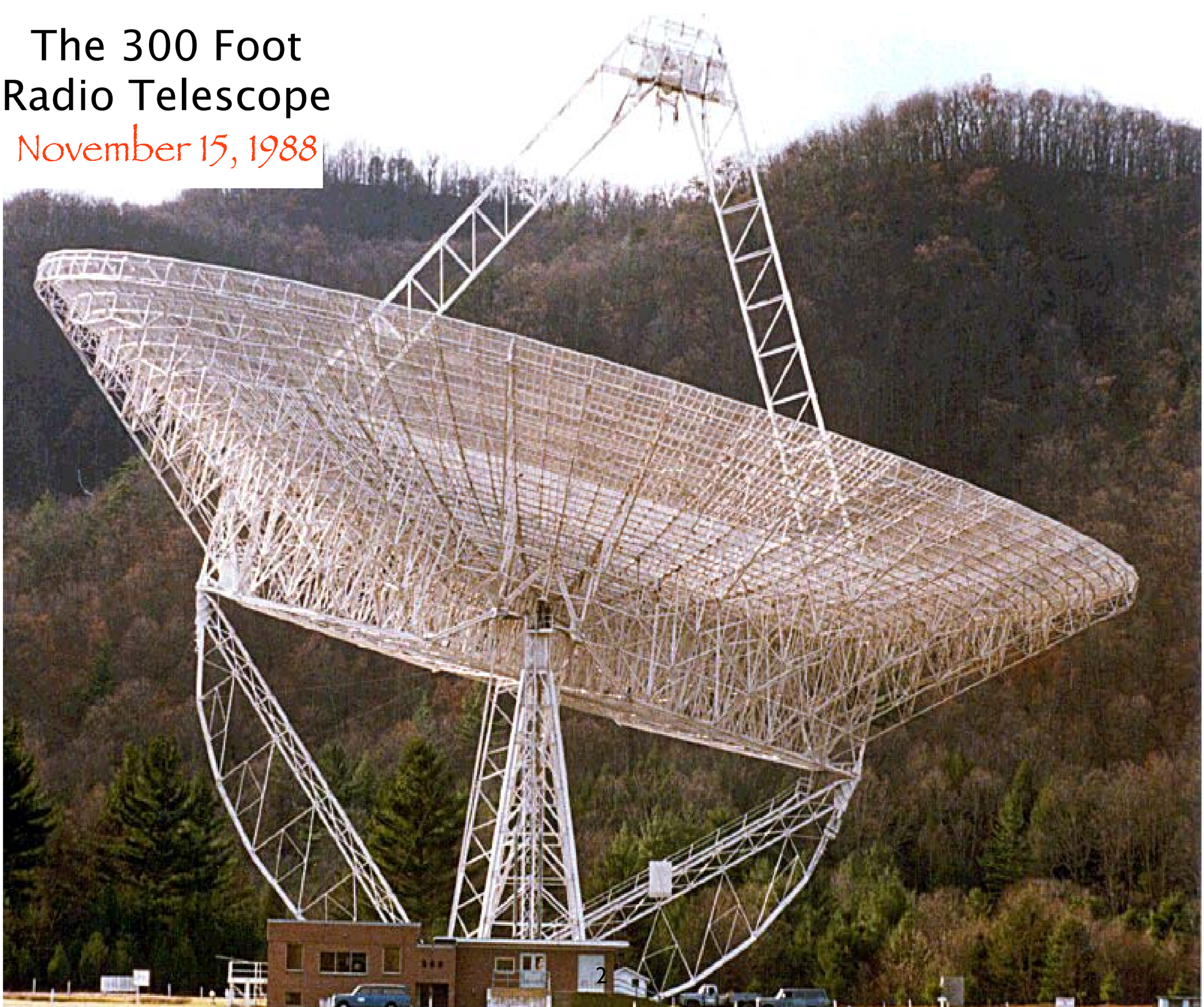
The NRAO Green Bank Telescope

Felix J. Lockman
NRAO, Green Bank

We are entering the GBT's most productive decade yet

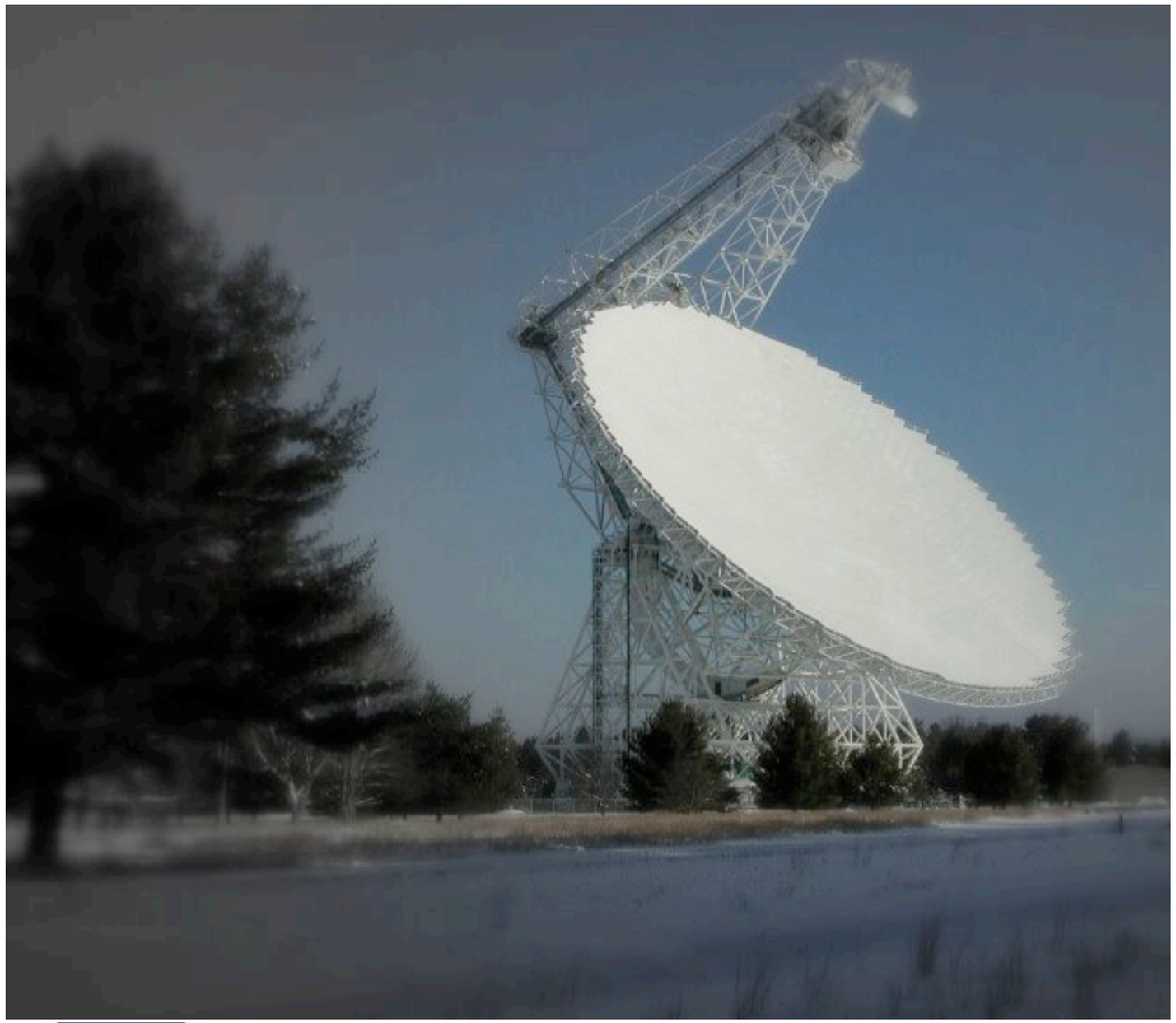
The 300 Foot Radio Telescope

November 15, 1988



November 16, 1988

The Green Bank Telescope



Large Collecting Area

Unblocked Aperture

Low sidelobes gives high dynamic range

Resistance to Interference

Excellent spectral Baselines

Excellent sensitivity to low surface brightness

Frequency coverage from 100 MHz -100GHz

Spectroscopy, Continuum, Pulsar, VLBI

>85% Sky Coverage $\delta \geq -46°$

Pointing to 1”-2” accuracy

Surface good for 3mm work

The Active Surface

2209 actuators

currently rms < 240μ at night, the goal is 210μ

GBT Status

- Surface
  - σ < 240μ at night, the goal is 210μ
- Track
  - Replaced summer 2007
- Pointing
  - 5” rms blind, ~2” offset under best conditions
- Motion and tracking
  - New digital servo
  - New turret motor allows receiver changes at any elevation
- Weather
  - Wind limit increased
  - Temperature limit lowered
  - Dynamic Scheduling ~60% of the time
- Receivers
  - 7-pixel dual polarization 18-26 GHz focal plane array
  - 2-pixel dual polarization for 68-92 GHz
- New Spectrometer

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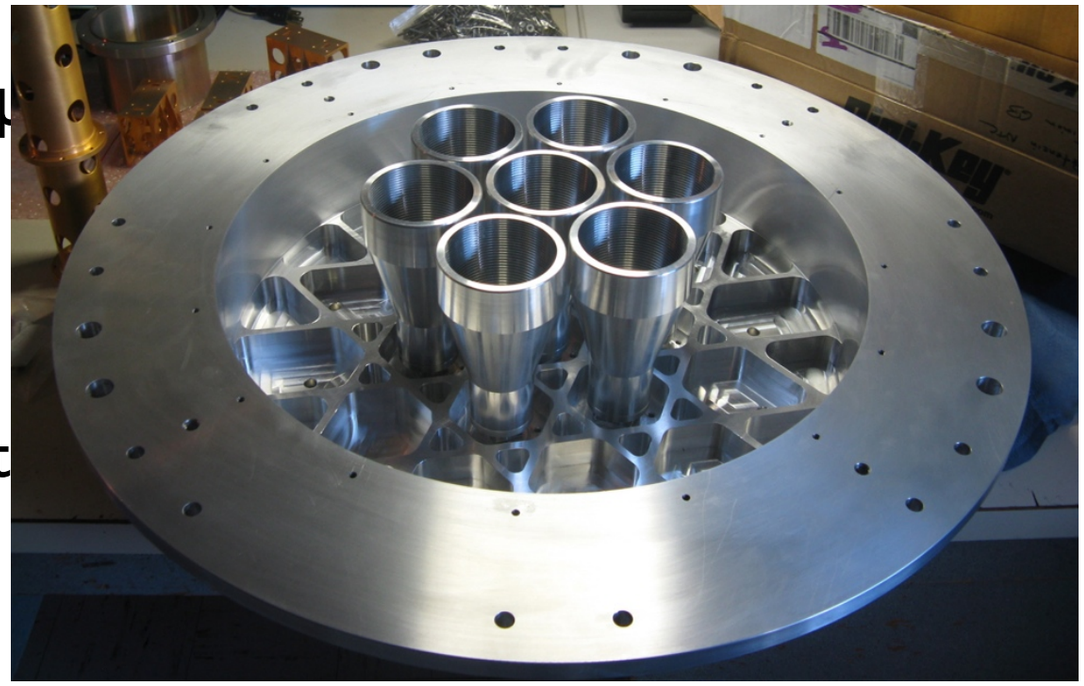

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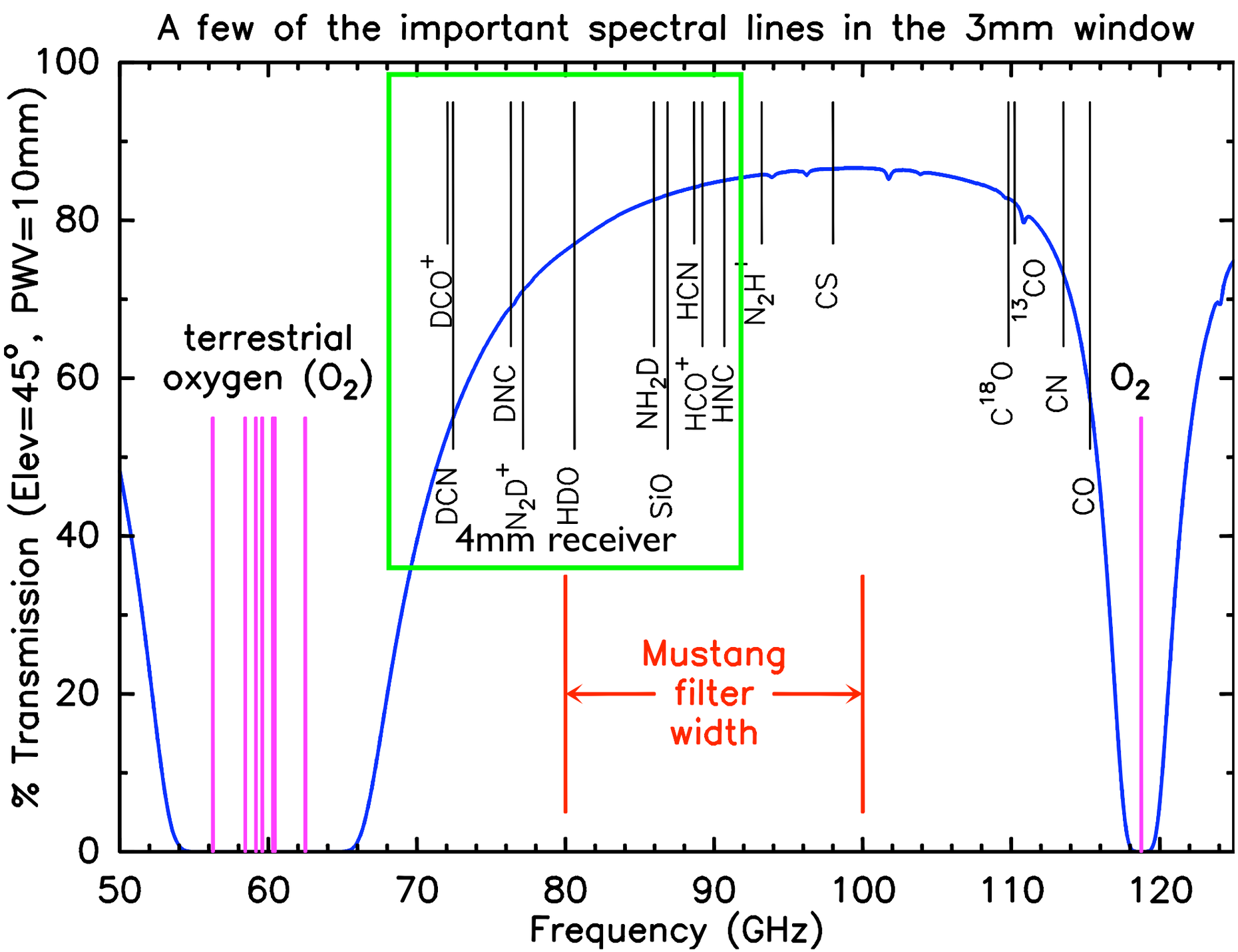
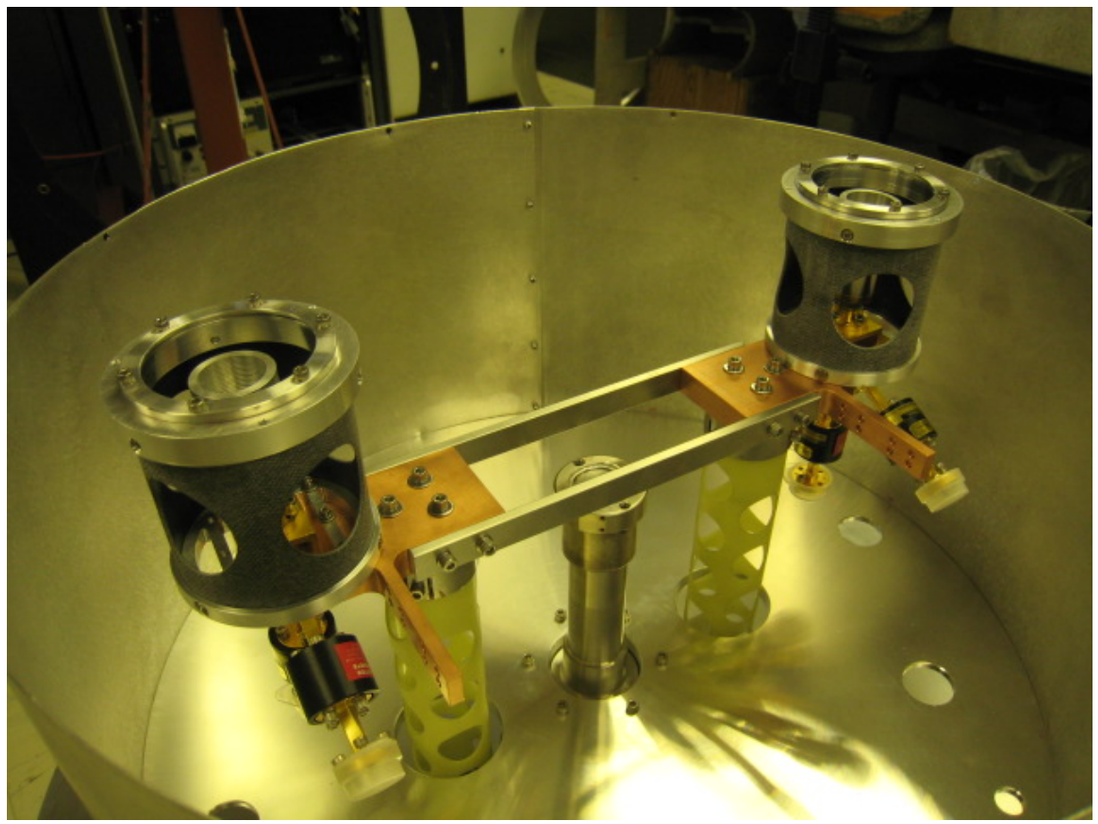
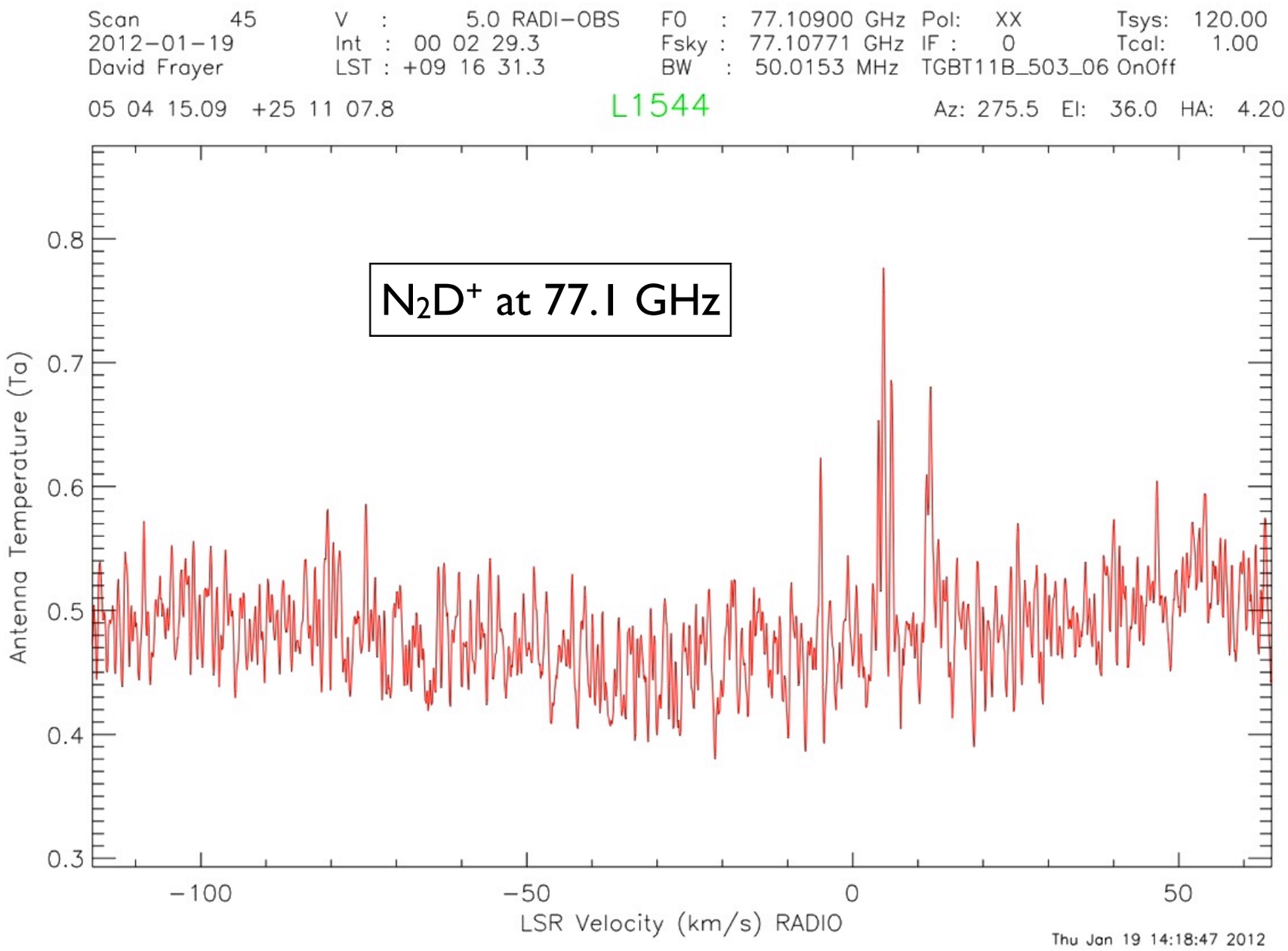

A few of the important spectral lines in the 3mm window
% Transmission (Elev=45°, PWV=10mm)
100
80
60
40
20
0
50
60
70
80
90
100
110
120
Frequency (GHz)
terrestrial oxygen (O_2)
4mm receiver
Mustang filter width
DCO+
DNC
HDO
N_2D^+
DCN
SiO
NH_2D
HCO^+
HCN
HNC
N_2H^+
CS
$C^{18}O$
^{13}CO
CN
CO
O_2

GBT 4mm Receiver Project

- Tunable frequency range: 68-92 GHz (Coverage to 93.2GHz is highly desirable.)
- HPBW 11" to 8"
- Tsys = 100 K
- Polarization: Dual linear and circular for VLB observations.
- Number of beams: Two beams each with dual polarization
- Beam separation: 4.7 arcmin
- Calibration with cold, ambient, and sky loads using optical table



First astronomical observations at 4mm Jan 19, 2011

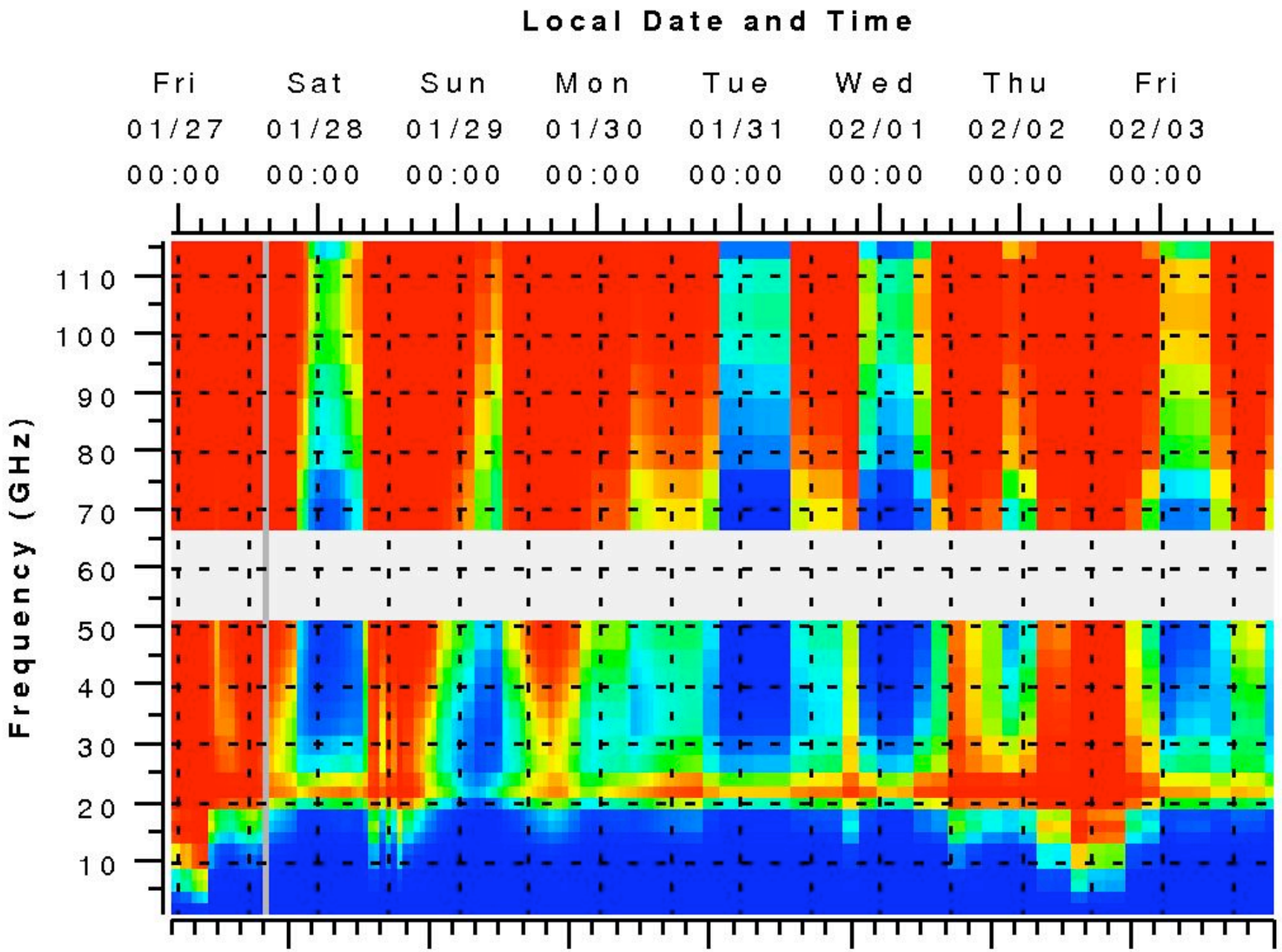


GBT Performance

Freq (GHz)	Tsys (K, za=0)	η_a %	K/Jy	SEFD (Jy)
1.2-6.0	20	70	2.0	10
10-16	25	65	1.85	15
20.0	40[a]	65	1.85	20[a]
45.0	70[a]	60	1.70	40[a]
85.0	100-125[a]	>35	1.00	100-125[a]

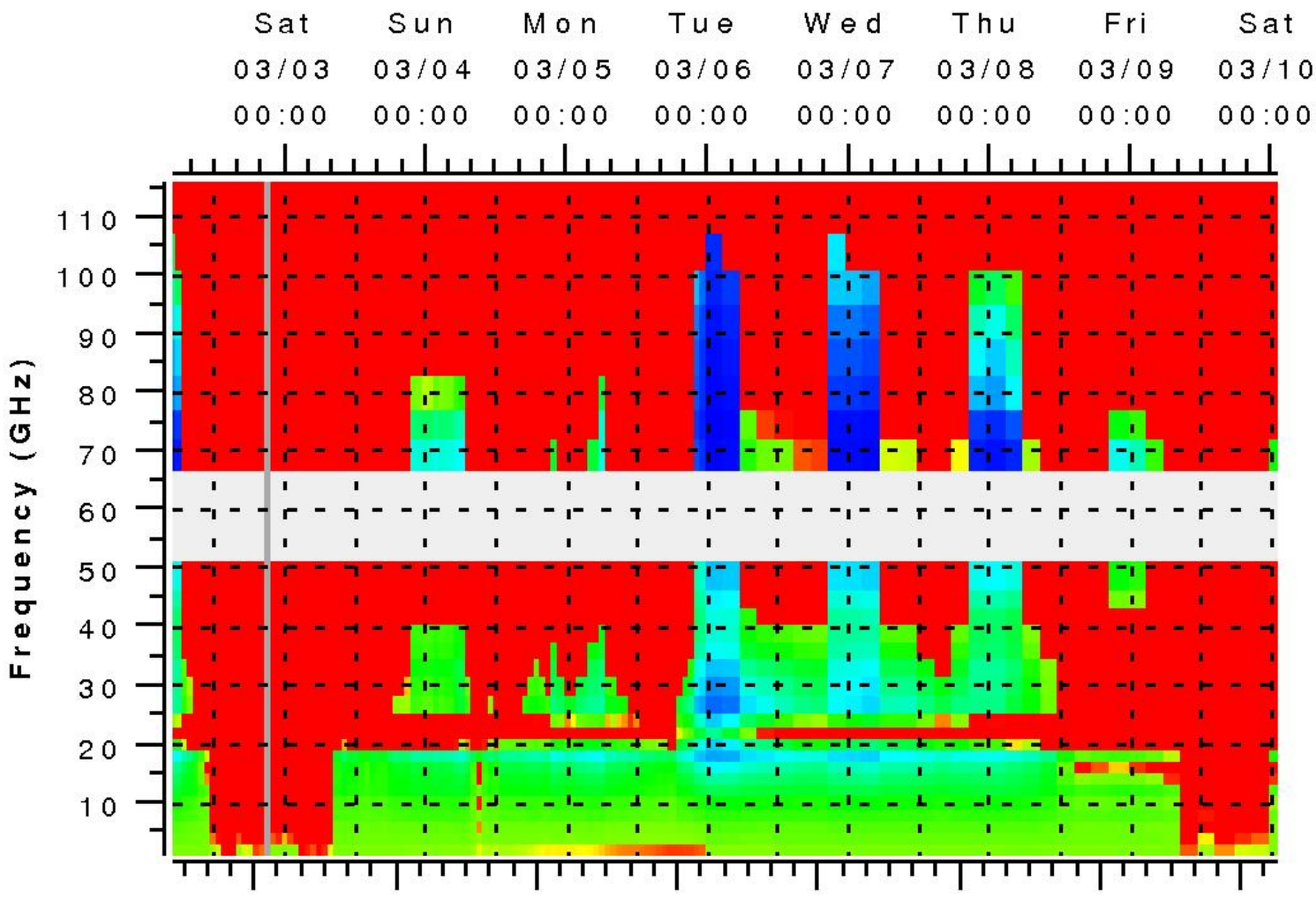
[a]) In median winter weather

Dynamic Scheduling Matches Experiments to the Weather



6500 hours a year used for astronomy

In 2010 there were 1776 hours used at frequencies above 18 GHz



Ron Maddalena, prognosticator

GBT Instrument Development Program

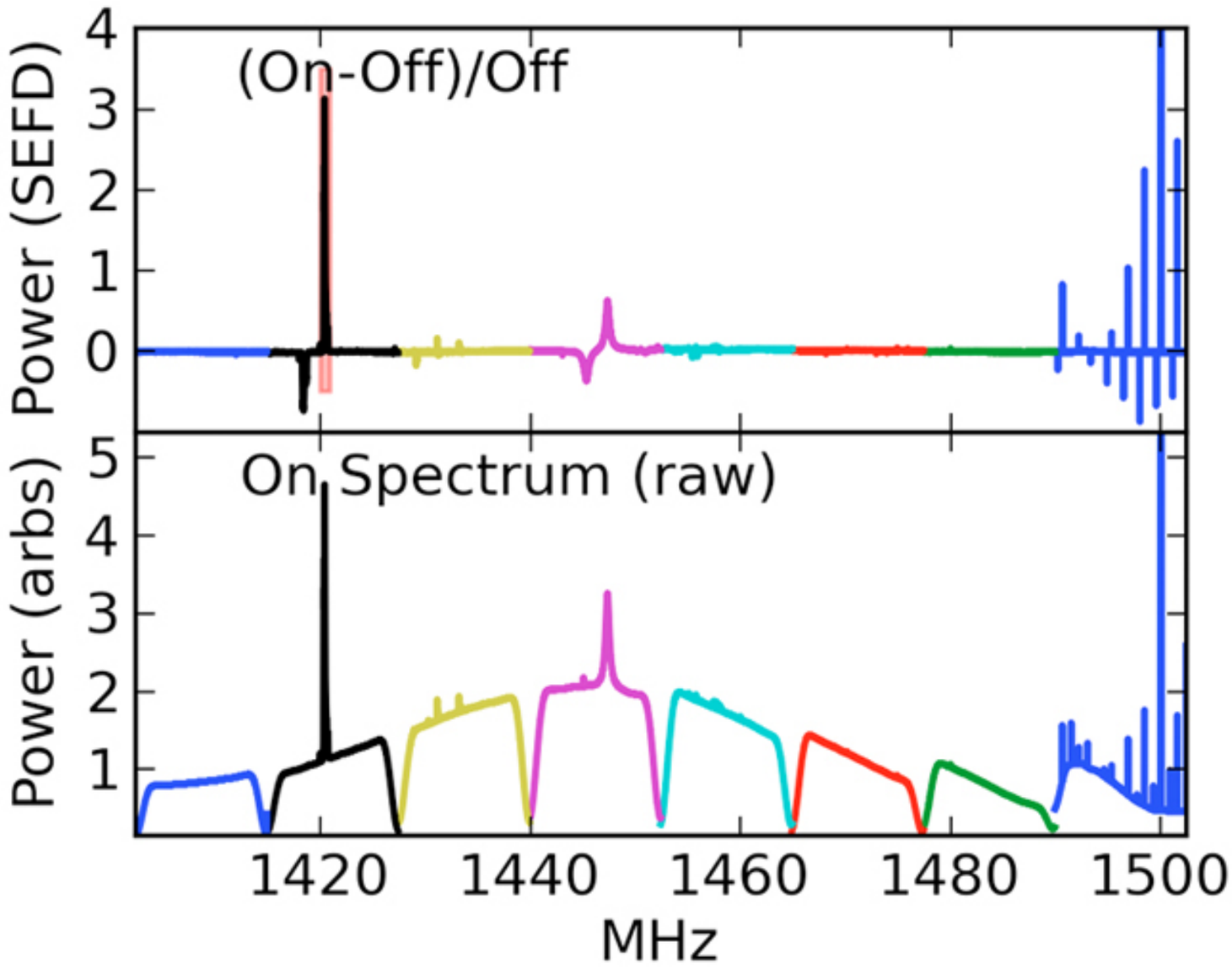
- K-band Focal Plane Array 7 pixels for 18-27 GHz
  - Completed and in regular use
- 4mm two-pixel receiver for 68-92 GHz spectroscopy
  - First observations shared risk NOW
- FPGA based spectrometer with up to 128 spectral windows
  - VEGAS testing shared risk NOW
- MUSTANG-2 bolometer array >100x faster than MUSTANG
  - Proposed but not yet funded
- W-band 100 pixel Focal Plane array 68-116 GHz (ALMA Band 3)
  - Under study but not yet funded
- Phased Array Receivers

VEGAS(pectrometer) Specifications

- Spectra can be measured from 8 dual polarized beams.
- 8-bit Analog to Digital Converters will be used.
- Digitized bandwidth : 1.5 GHz (usable bandwidth 1.25 GHz).
- Number of digitally tuned sub-bands within 1.5 GHz bandwidth : 8.
- Number of sub-bands per beam when processing signals from 8 dual polarized beams: 8
- Total bandwidth that can be processed from a dual polarized beam : 10 GHz.
- Number of sub-bands per beam when processing signals from a dual polarized beam : 64
- Maximum number of spectral channels: 32768.
- Maximum spectral dump rate : every 0.5 msec.

NRAO + CASPER (UCal Berkeley)

VEGAS TEST SPECTRUM



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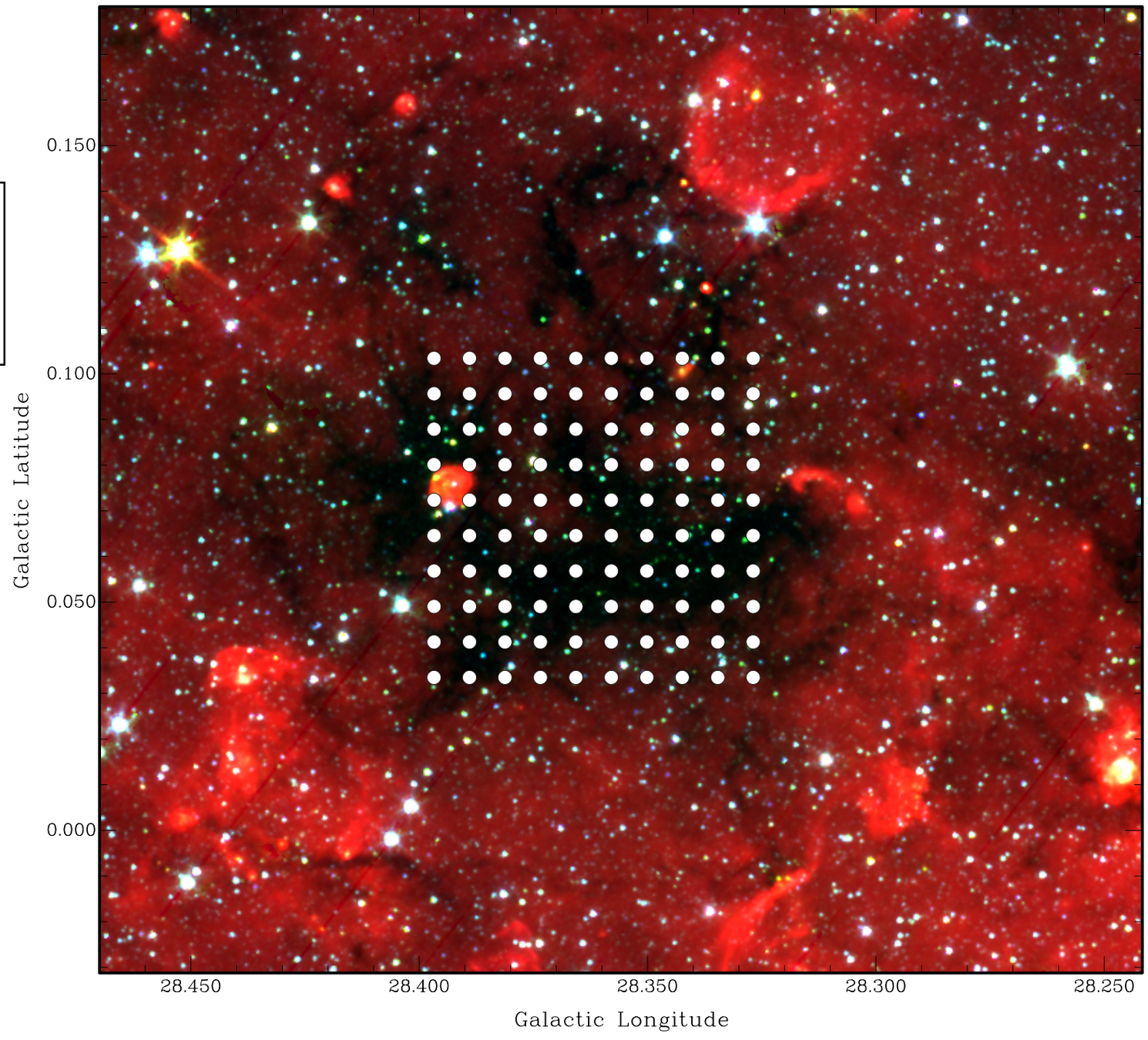
Planned 3mm Focal Plane Array

a wide field mapping complement to ALMA Band 3

GBT 3mm FPA footprint on an Infrared Dark Cloud

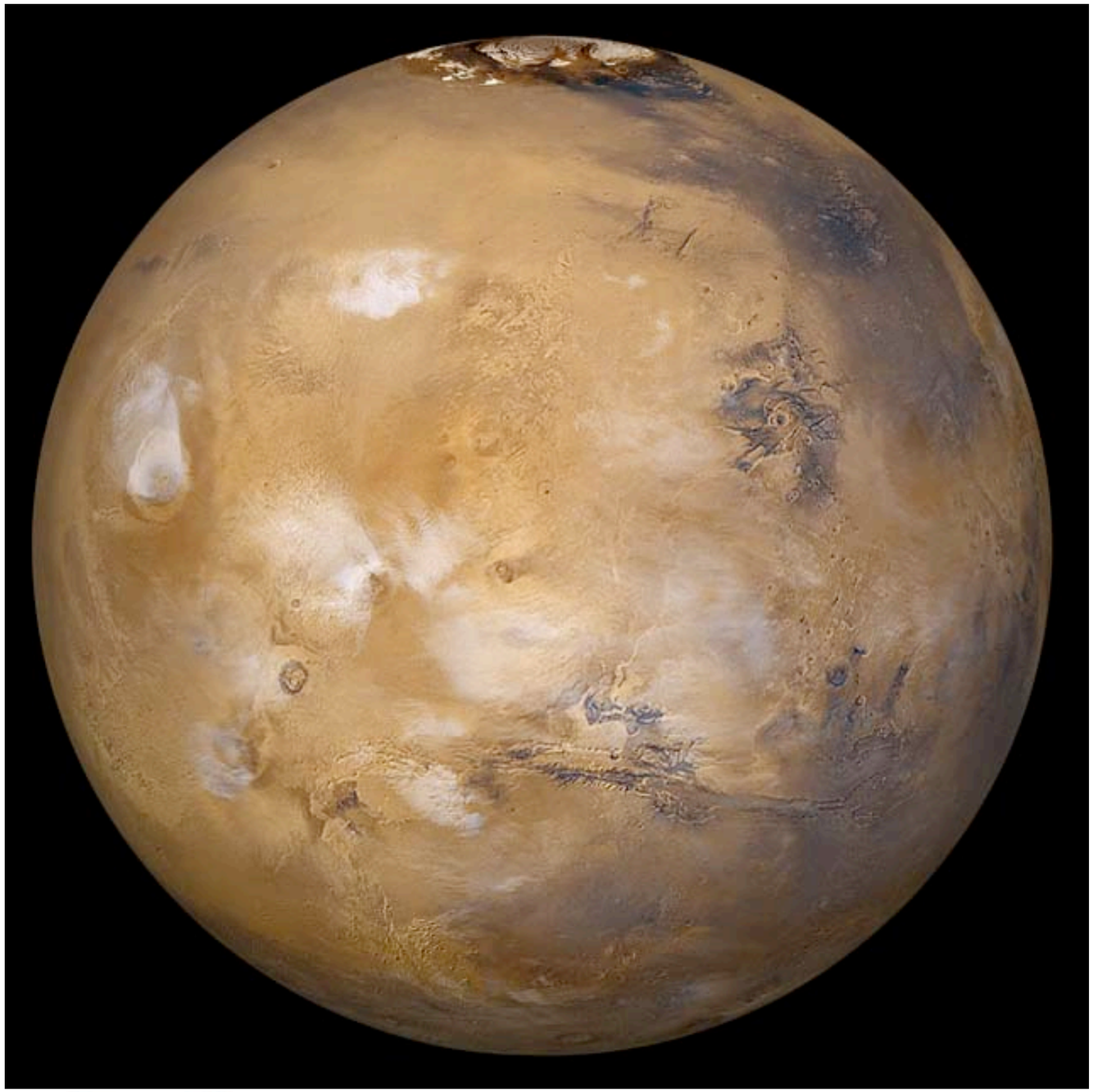


FLAG -- Focal Plane L-Band Array for the GBT

B. Jeff, K. Warnick et al (BYU)
J.R. Fisher, R. Norrod, A. Roshi (NRAO)

- 19 dual polarized elements. Cryogenic PAF system
- Tsys $\sim$ 20 K; Aperture efficiency $\sim$ 75 to 80 %
- 7 beams; spacing 0.5 FWHM to 1 FWHM
- Frequency coverage – 1300 to 1800 MHz; Backend for processing signals

Why is a planet like a disco ball?



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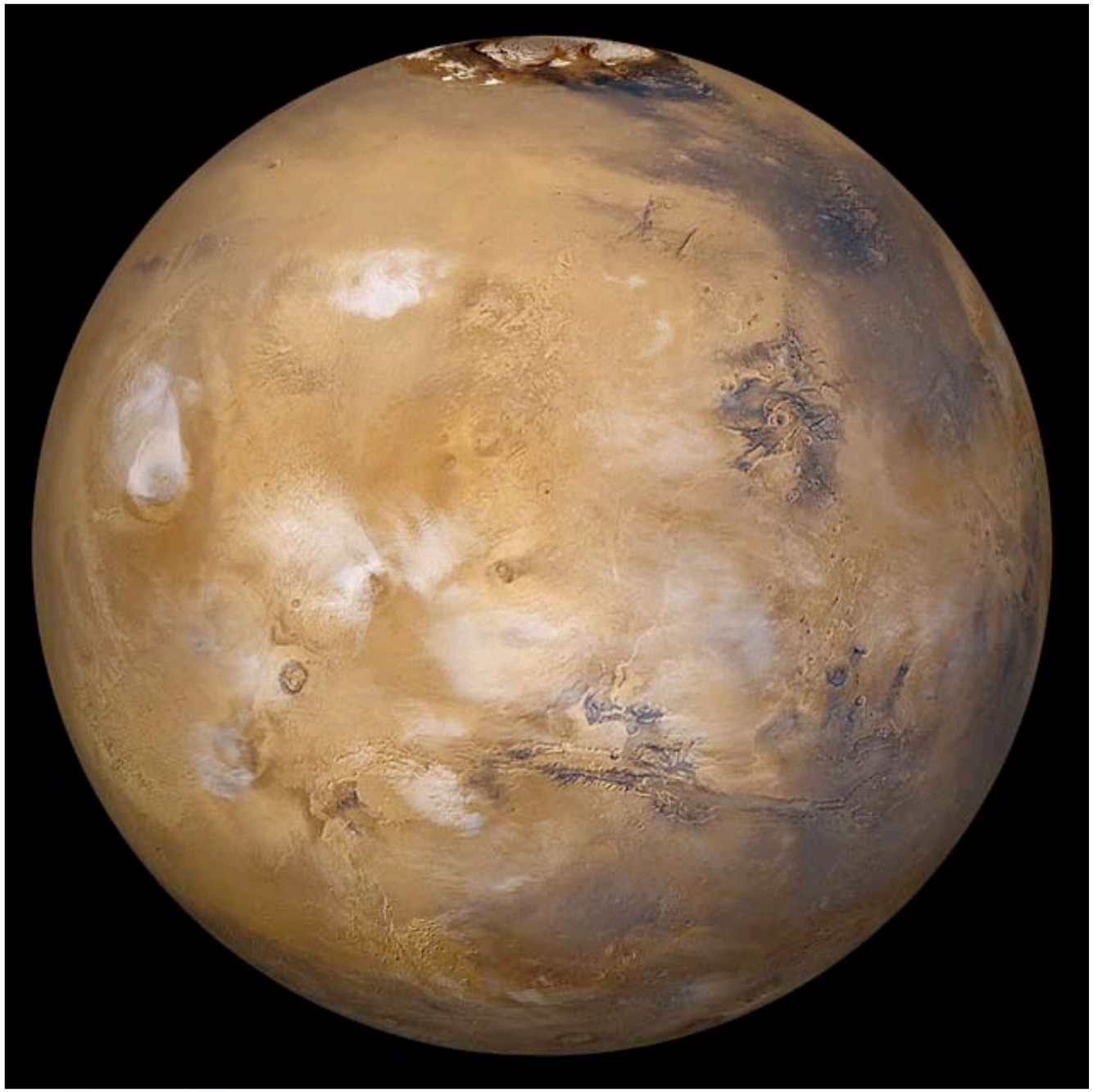
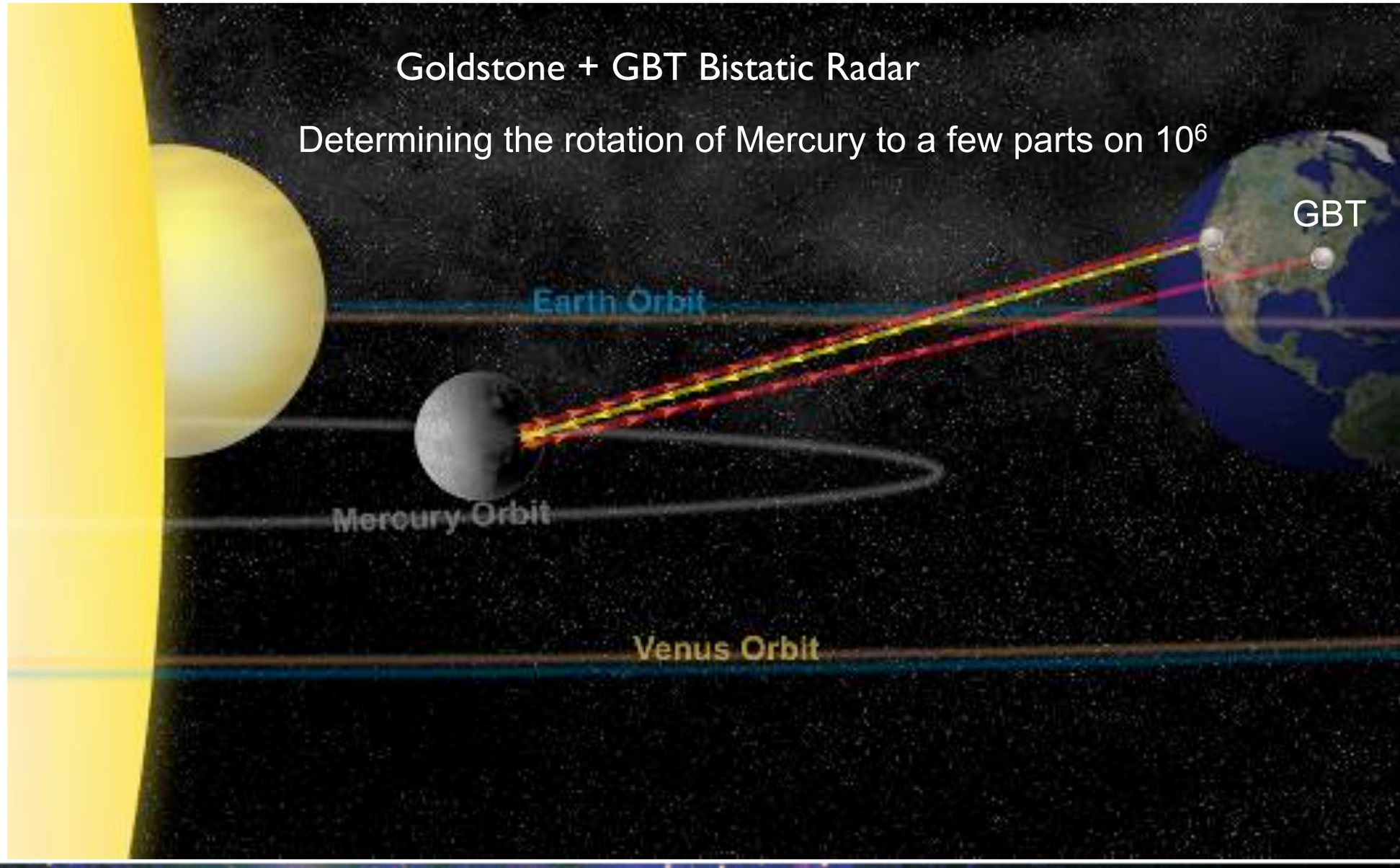
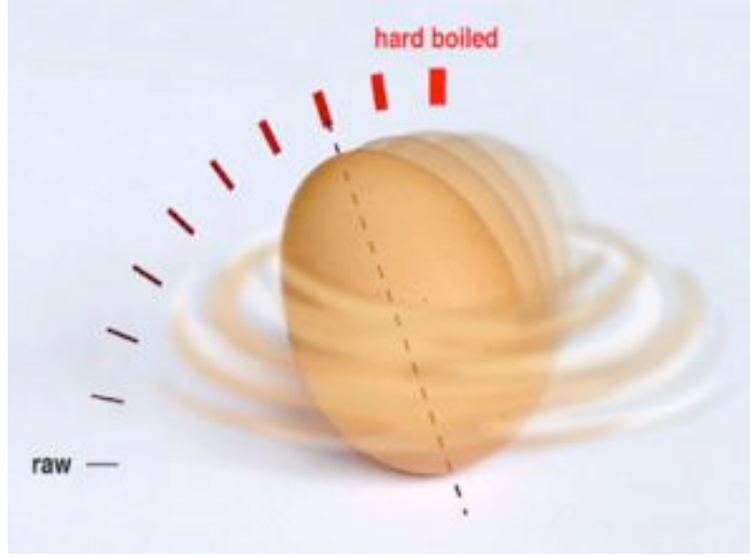
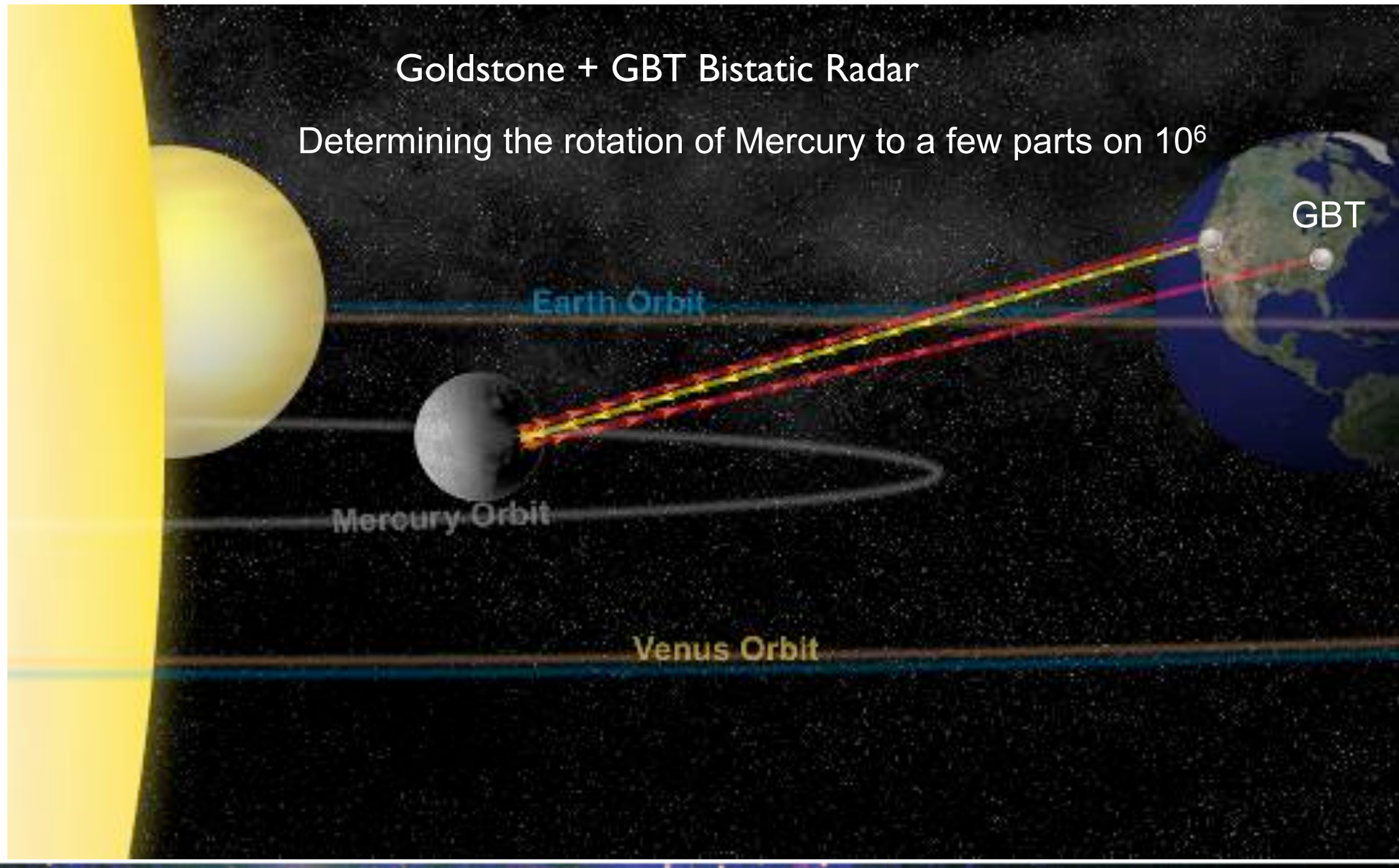


Its radar return is speckled


Goldstone + GBT Bistatic Radar
Determining the rotation of Mercury to a few parts on 10^6
GBT
Earth Orbit
Mercury Orbit
Venus Orbit

When is a planet like a raw egg?

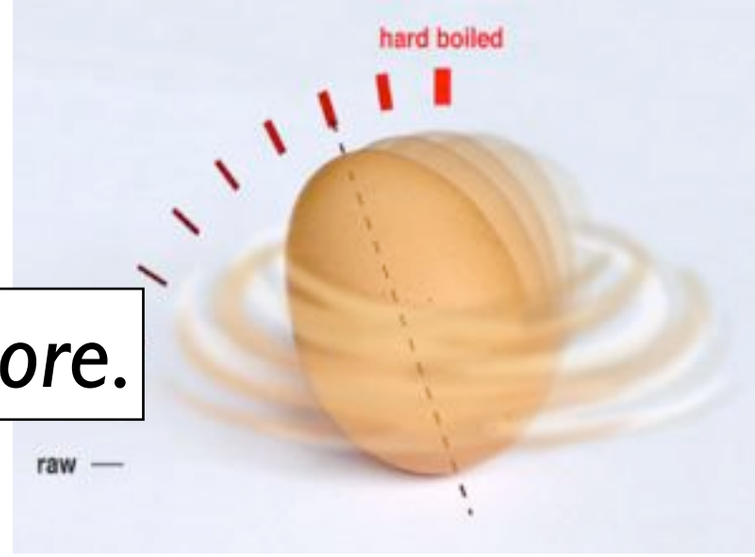


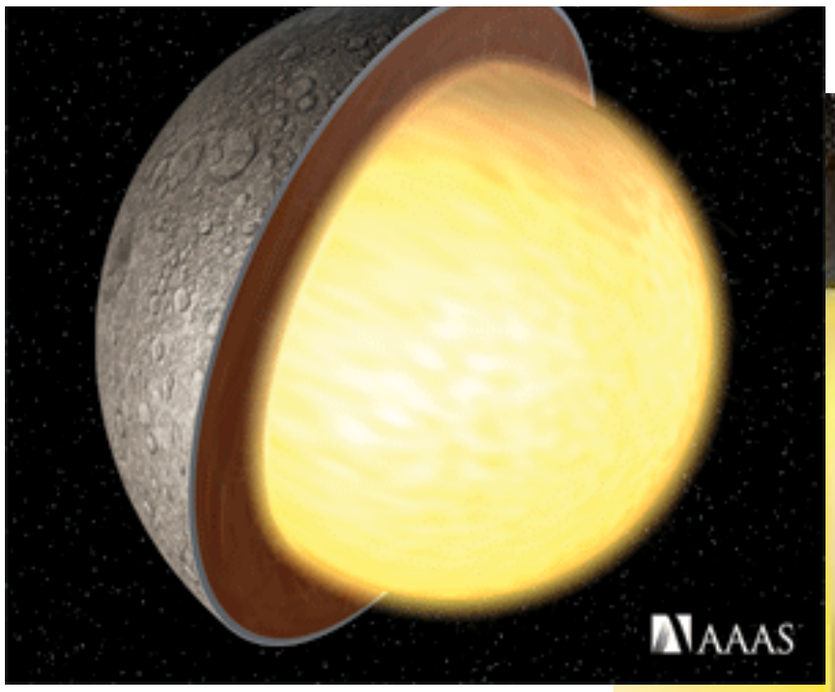


"Large Longitude Libration of Mercury Reveals a Molten Core"
Margot et al. 2007 Science

When is a planet like a raw egg?

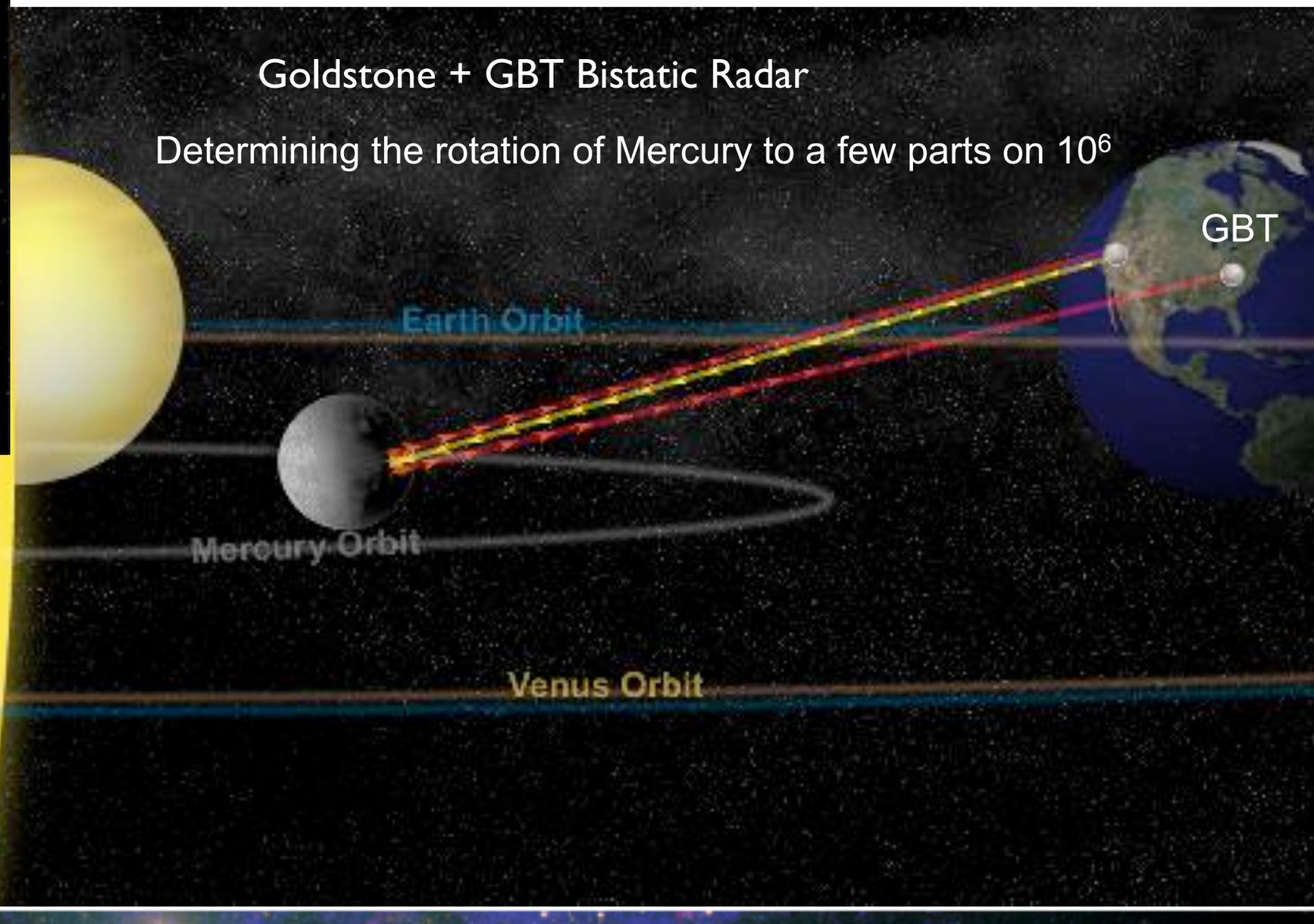
When it has a molten core.



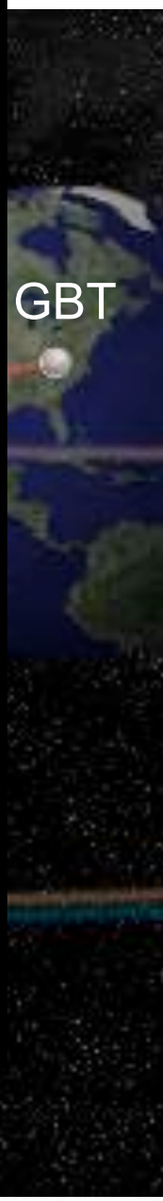


Goldstone + GBT Bistatic Radar

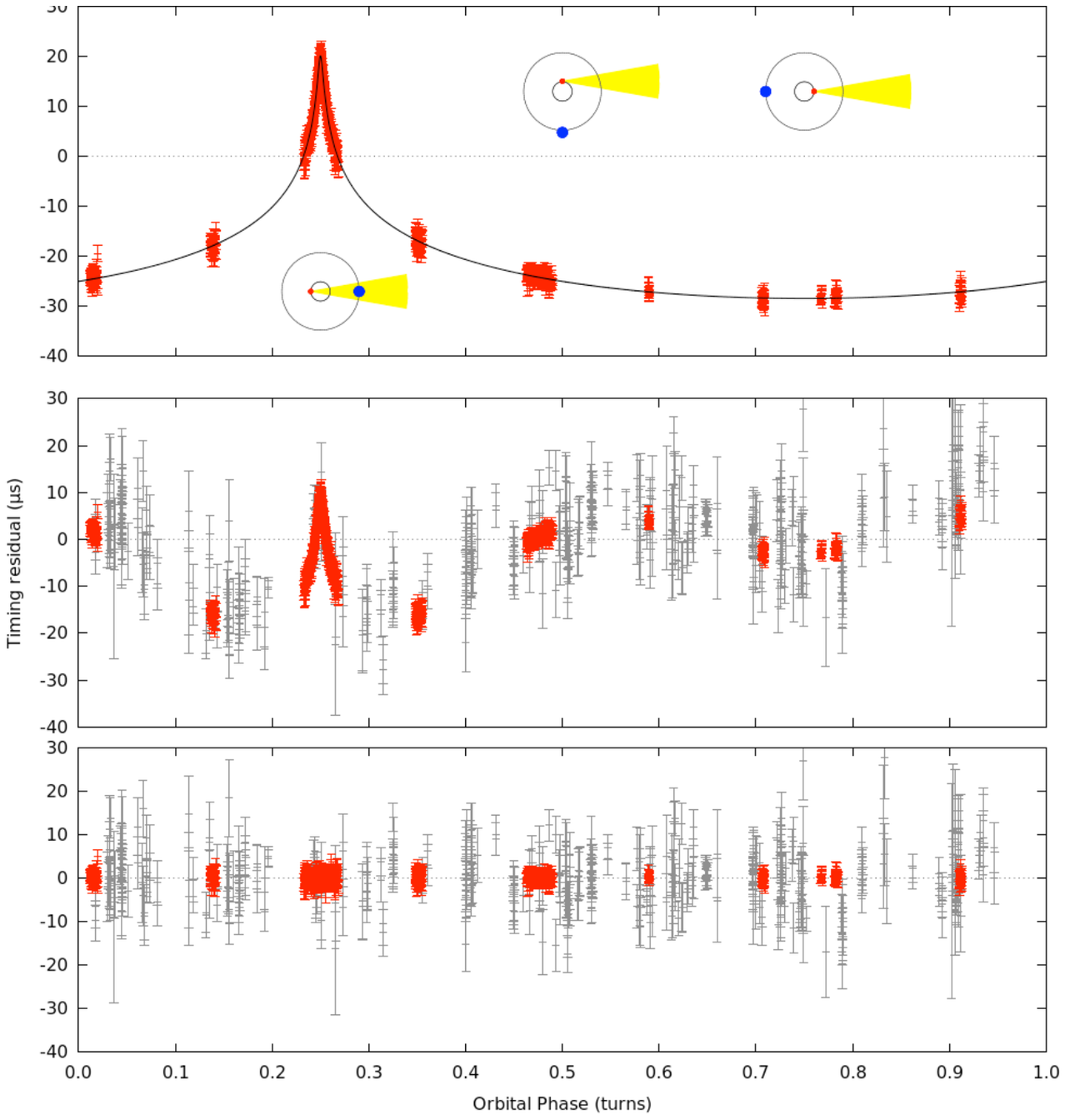
Determining the rotation of Mercury to a few parts on 10^6



Europa



GBT measurements test fundamental physics with radio pulsar J1614-2230



~1 week of GBT timing observations with coherent GUPPI

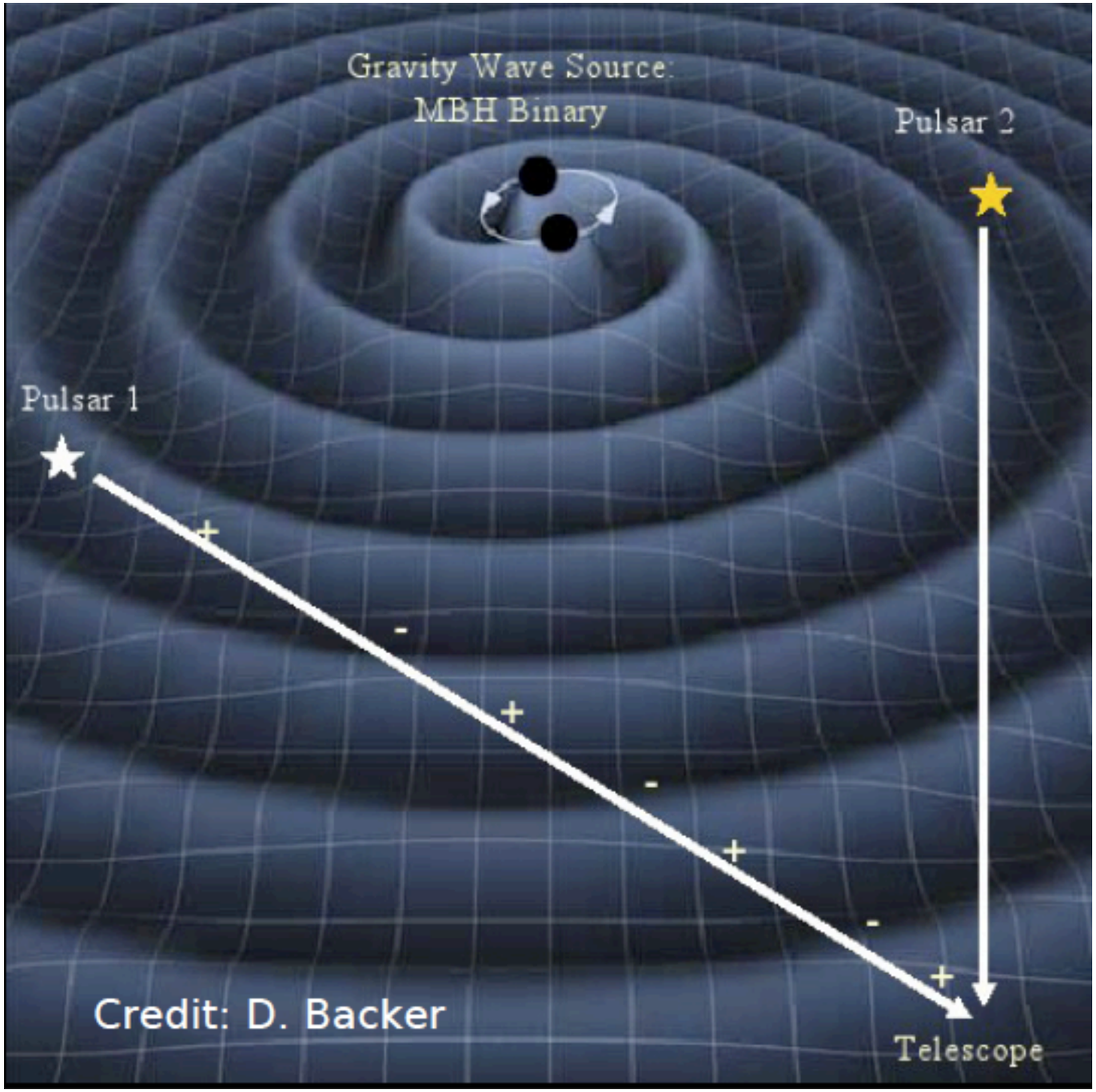
Orbital inclination = 89.17(2) deg!

Companion mass = 0.500(6) solar!

Pulsar mass = 1.97(4) solar!

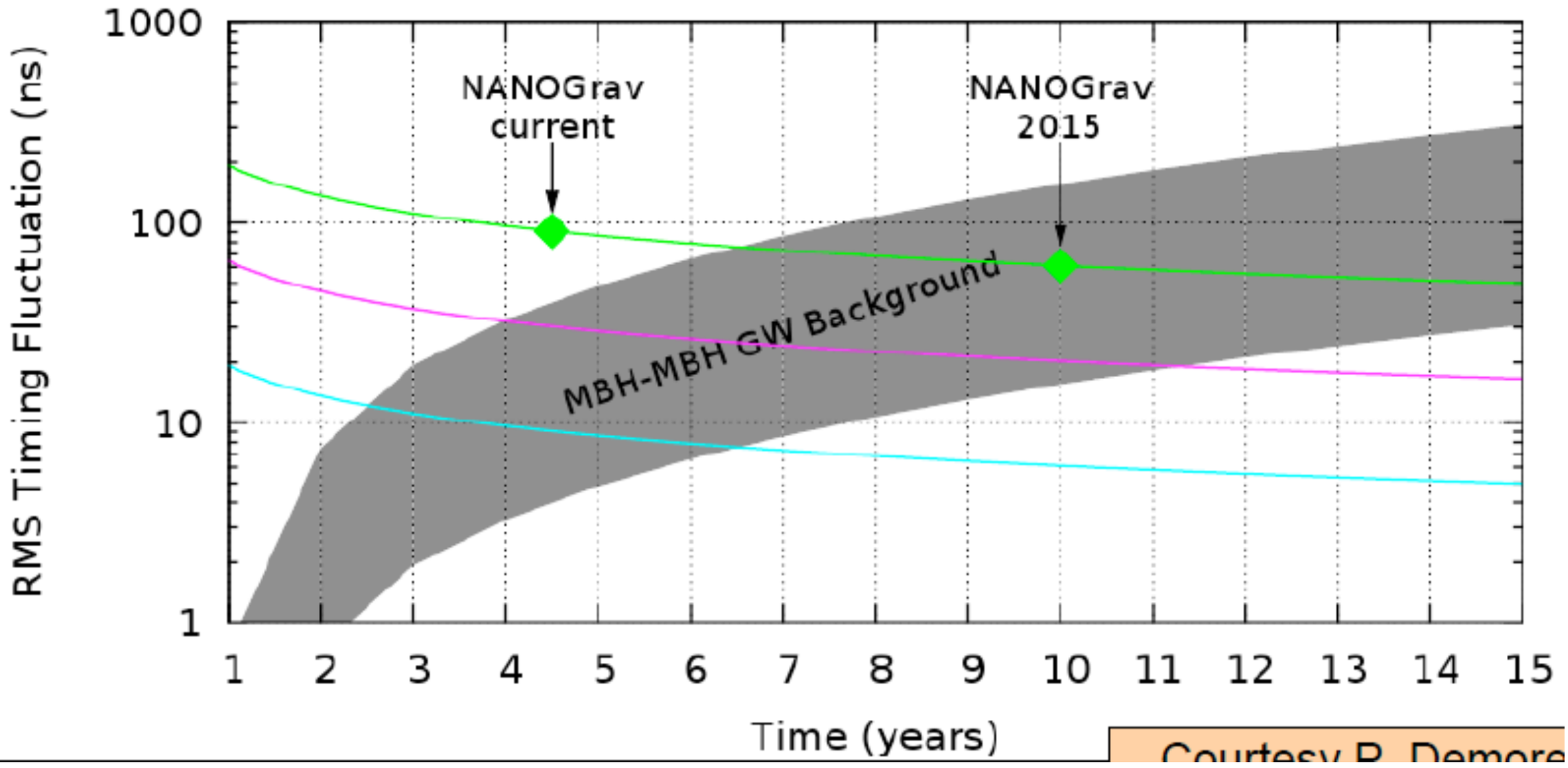
(Demorest et al. 2010)

Using pulsars to detect gravitational radiation

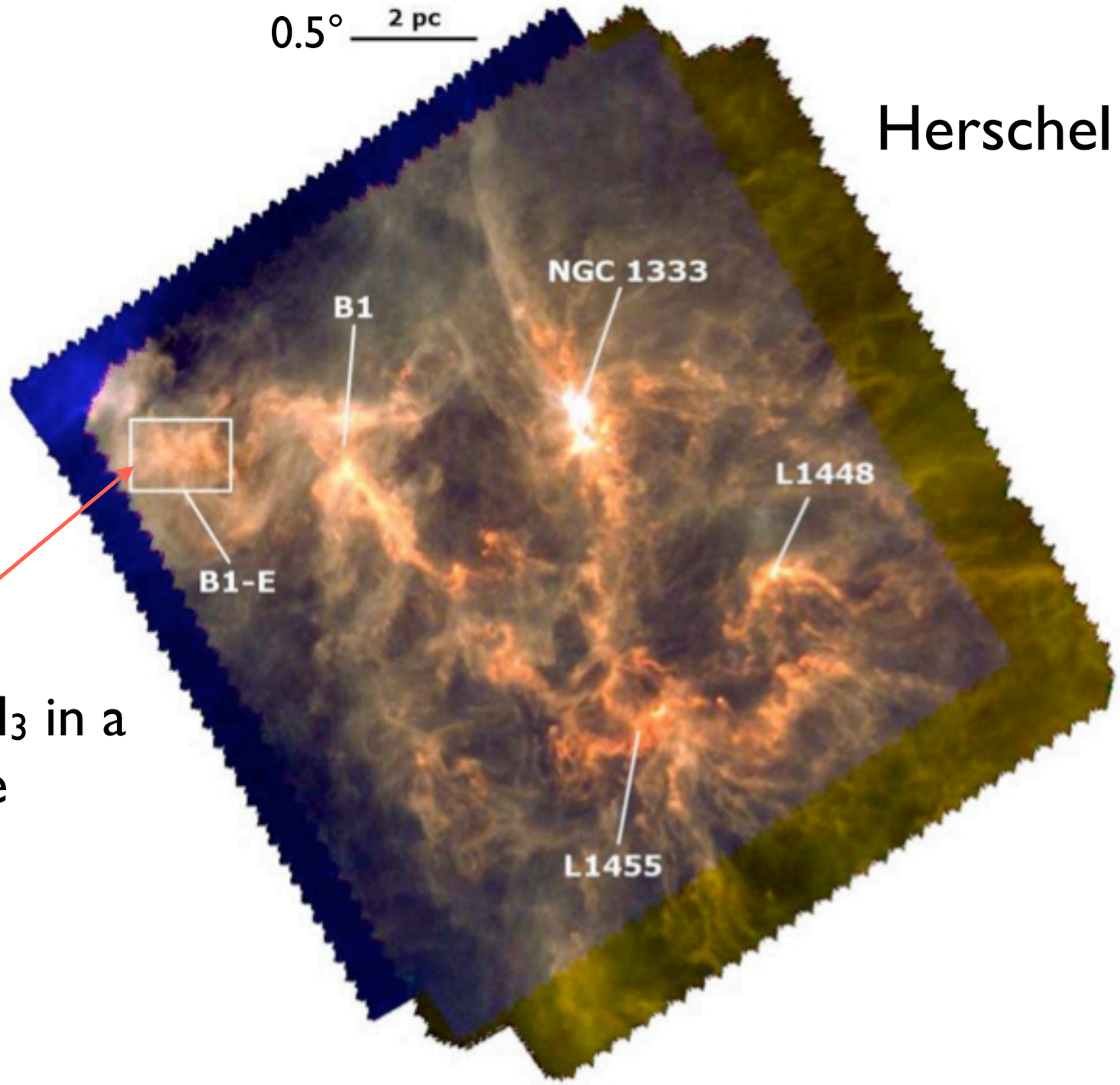


The NANOGrav Collaboration

nanograv.org



Courtesy P. Demorest

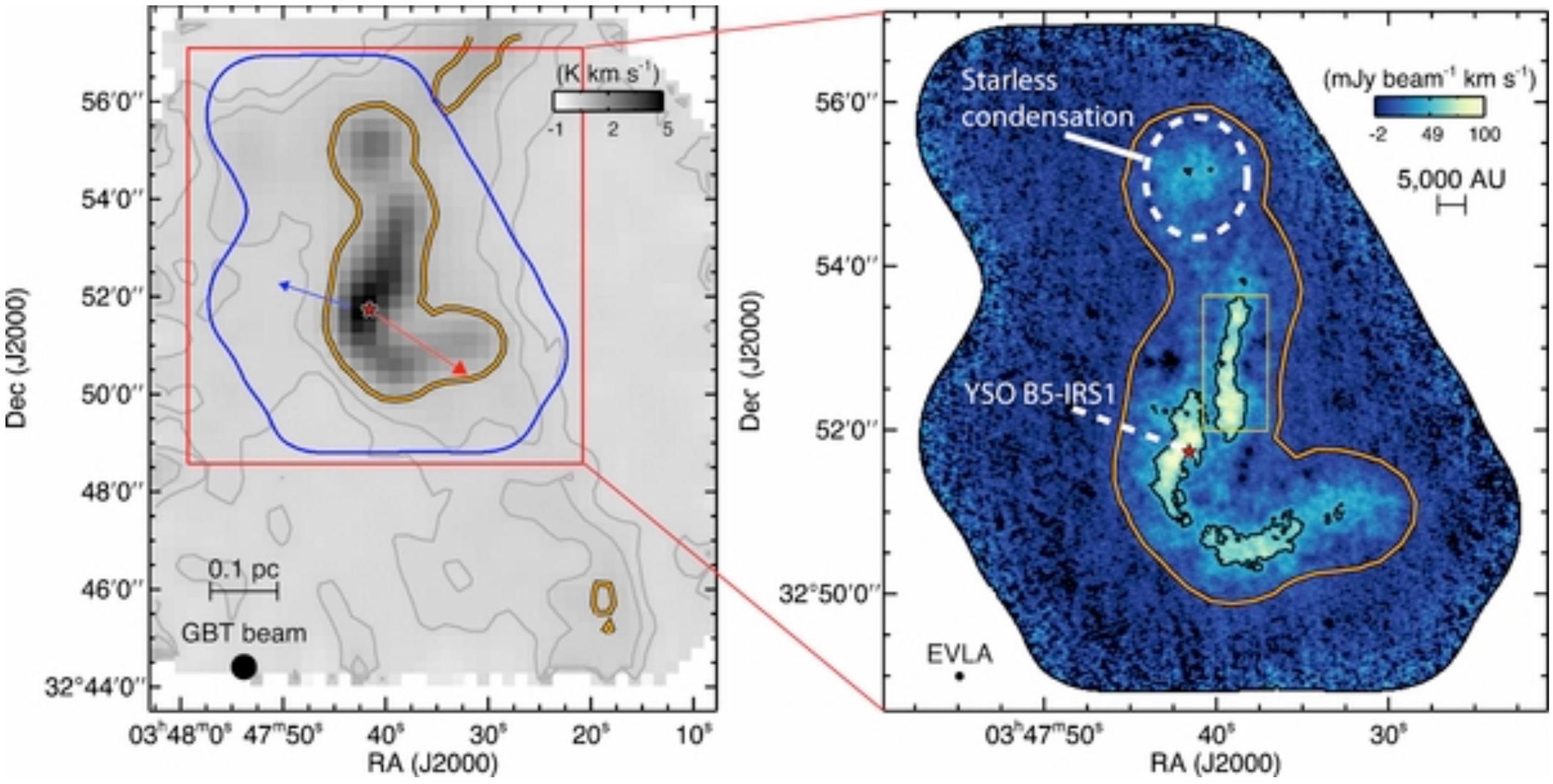


Herschel dust map

GBT study of NH_3 in a starless core

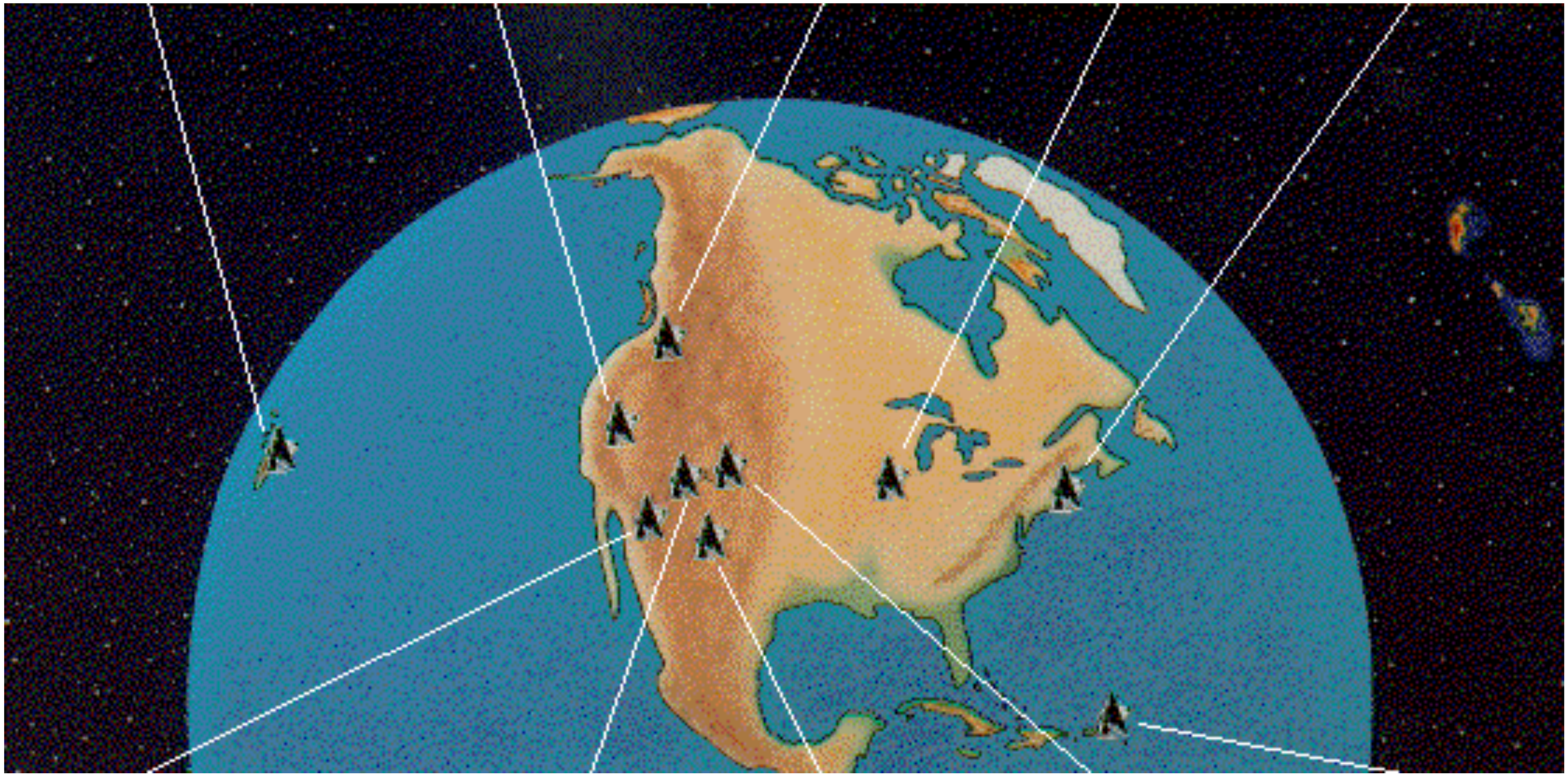
GBT map of NH_3 in a star-forming cloud

EVLA map of NH_3



Pineda et al 2011

GBT + VLBA



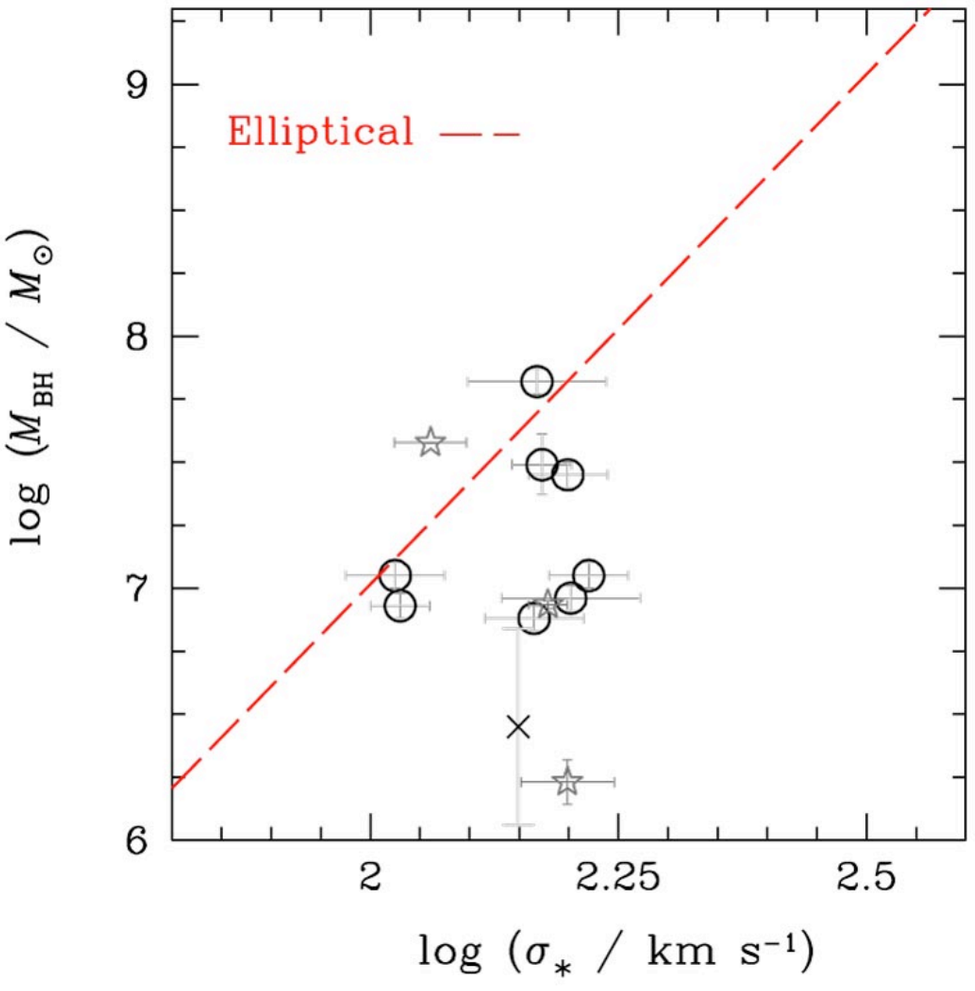
- Nuclear Black Hole Masses

GBT and HSA Measurements of Black Hole Masses

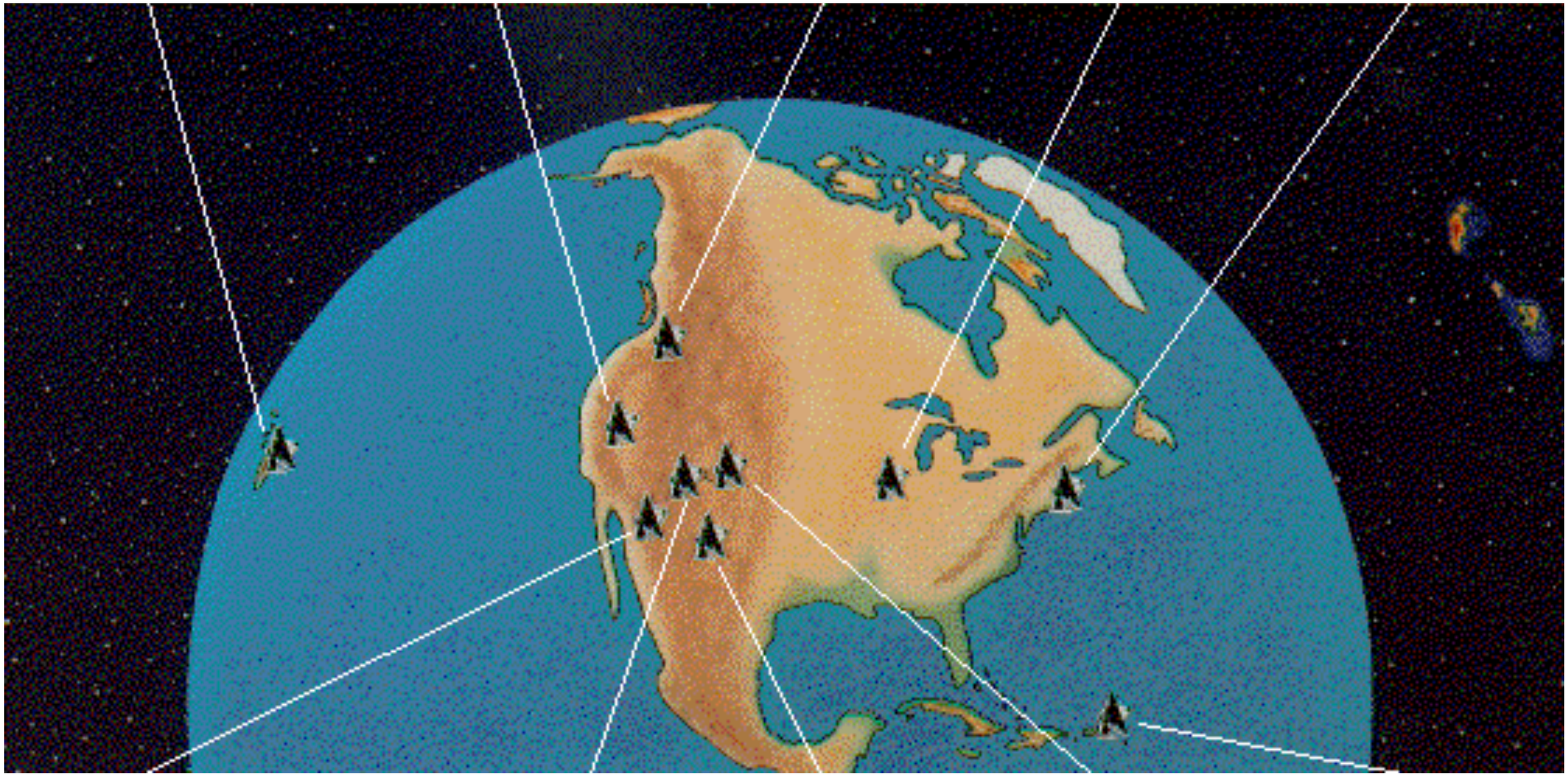
H2O masers discovered with the GBT
Nuclear disk mapped with the HSA
Black Hole masses obtained for Seyfert galaxies

SMBH masses in Seyfert galaxies lie below the "universal" line defined by SMBH's in elliptical galaxies

Kuo et al. 2011
Greene et al. 2010



GBT + VLBA



- Nuclear Black Hole Masses
- 3mm M87 Jet
- Parallax to Sgr A*

We are entering the GBT's most productive decade yet


NRAO