NOBEYAMA

Nobeyama 45-m Telescope

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Nobeyama Radio Observatory

*with support from Miyamoto and Wada

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Nobeyama Radio Observatory

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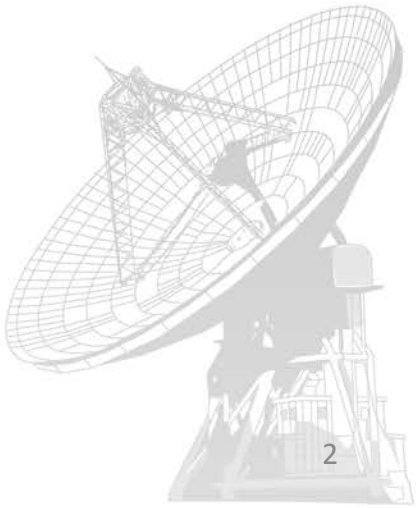
Outline

- Nobeyama 45-m Telescope
- Performance and previous Metrology
- Future Metrology System



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Nobeyama 45-m Telescope

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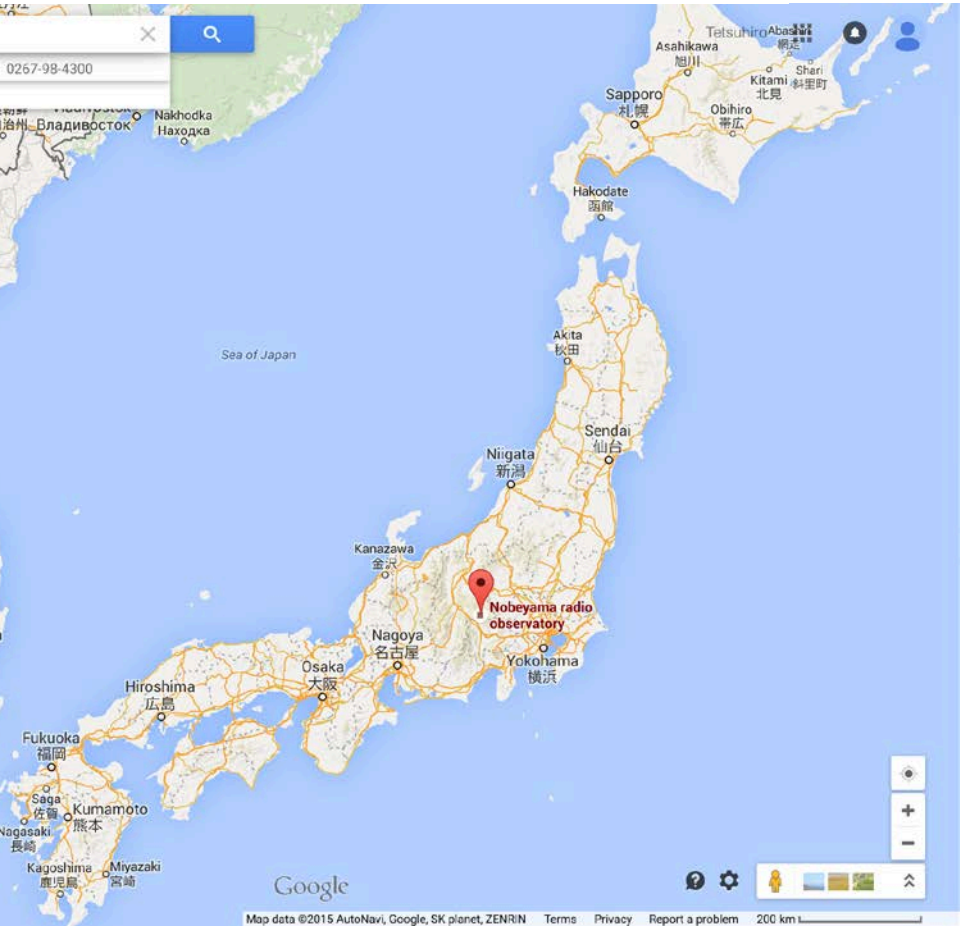
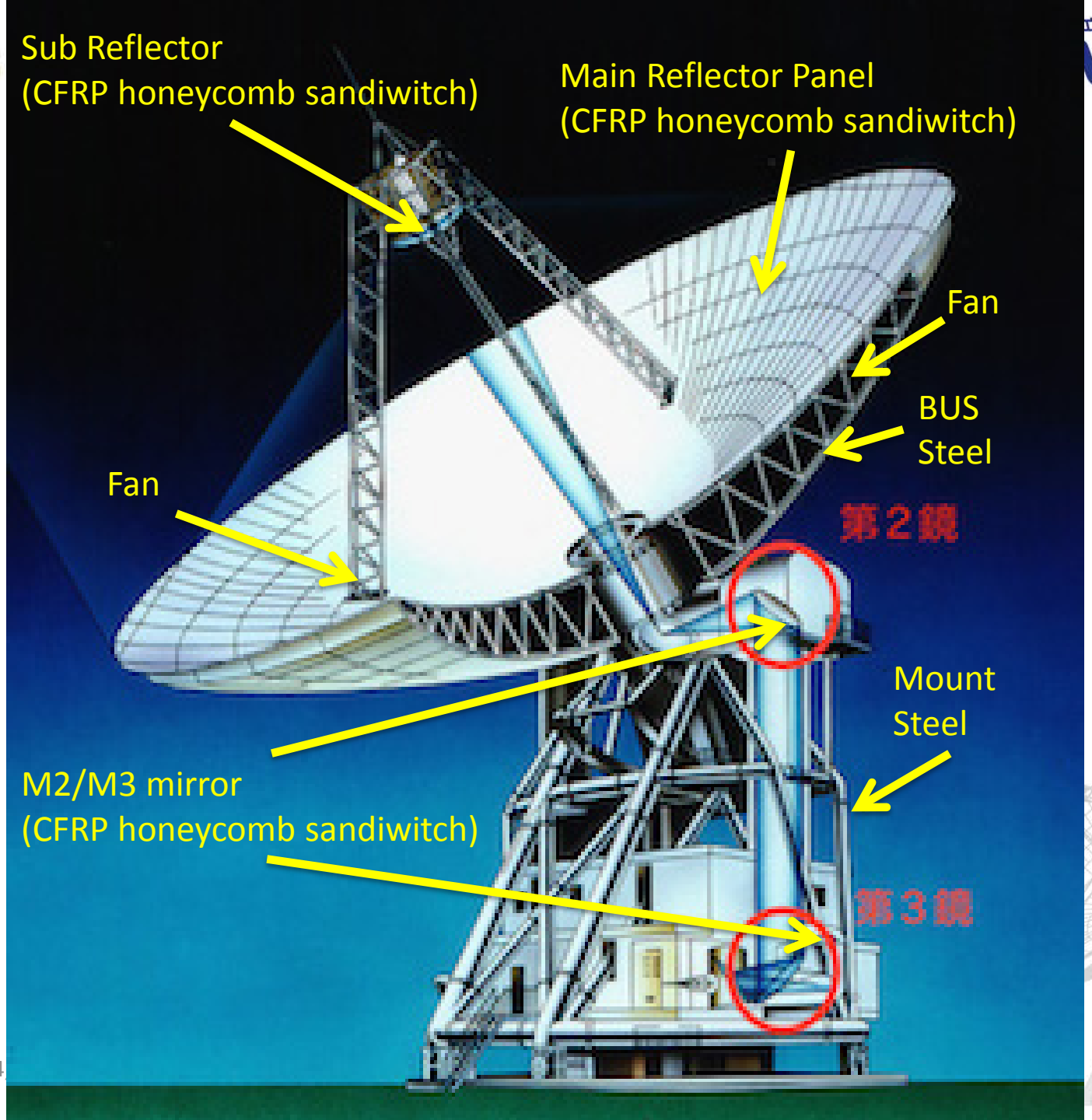
Nobeyama 45-m Telescope

Nobeyama Radio Observatory (NRO)



- 1350 m altitude
- 45m Diameter (homologous)
- Optics: Beam waveguide
  - Master Collimator
- Pointing accuracy: 2-3”
- Surface accuracy: 100 μm
- Beam size: 14” @ 115GHz
- η_A: 0.35 @ 110 GHz
- Receivers (20 – 116 GHz)
- Digital/VLBI Backend
- Open sky policy


Sub Reflector
(CFRP honeycomb sandiwitch)
Main Reflector Panel
(CFRP honeycomb sandiwitch)
Fan
BUS
Steel
Fan
第2鏡
Mount
Steel
M2/M3 mirror
(CFRP honeycomb sandiwitch)
第3鏡

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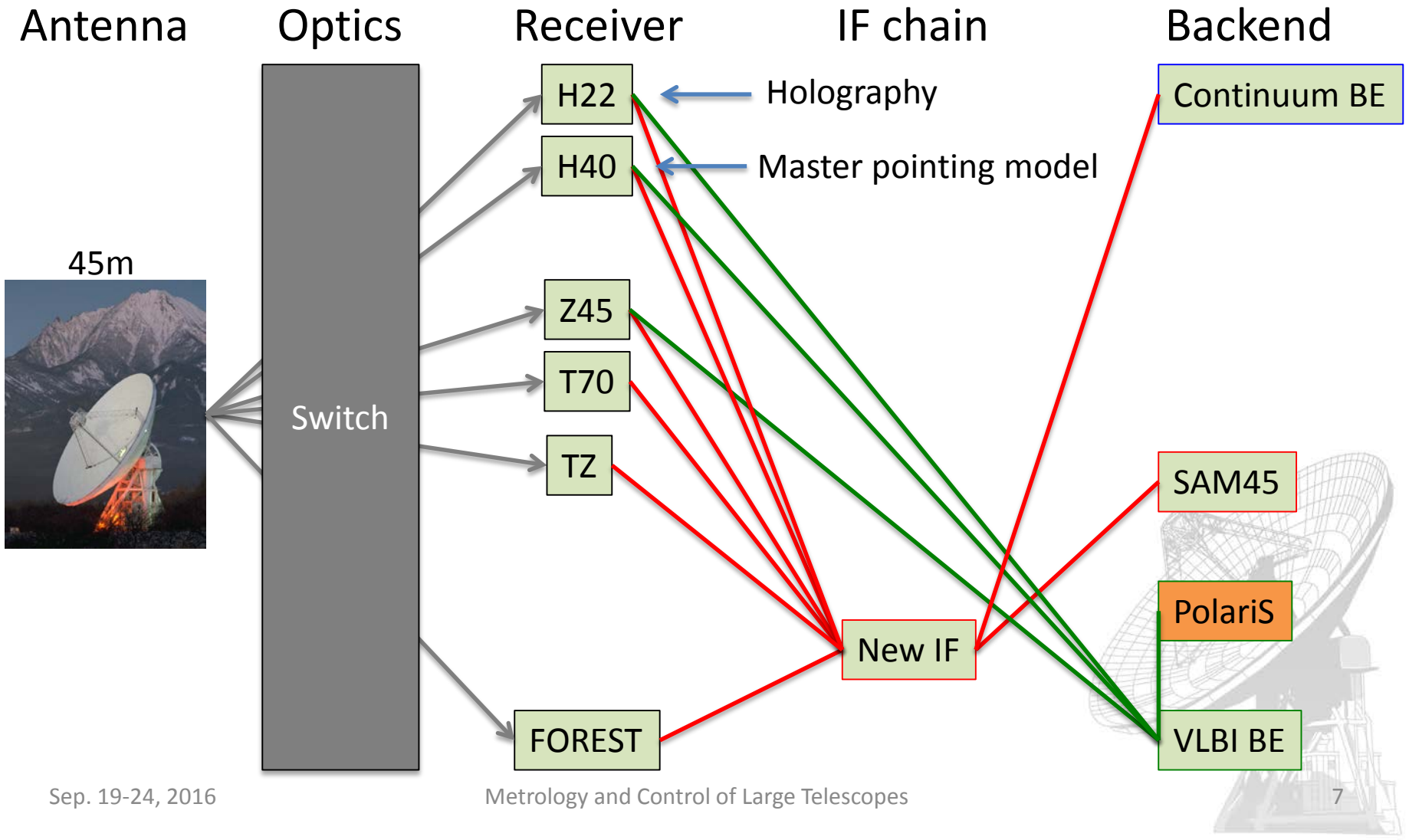
Current System

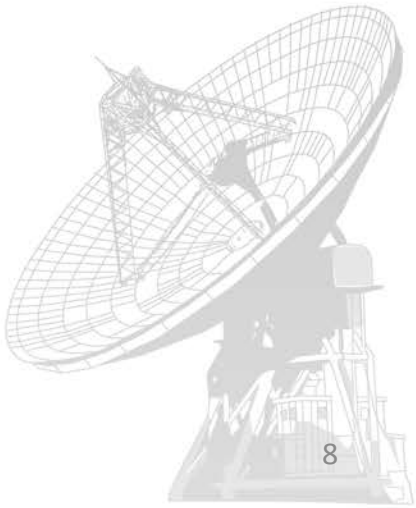
OPEN USE

Commissioning



Issues as of 2014

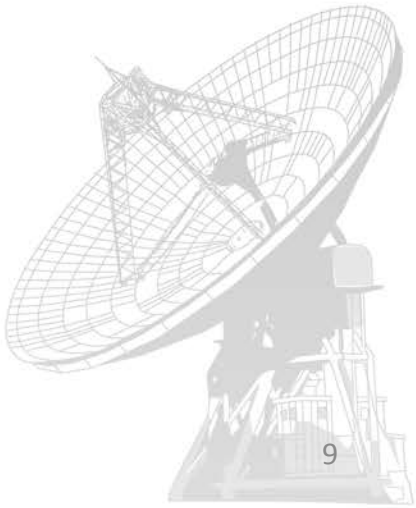
- Large surface errors: 180 μm ($\eta_{A,110\ GHz}$:0.25)
- High antenna noise temperature: 30 K
- Single pixel Rx only at 3 mm
- Rust on mount structure



Holography

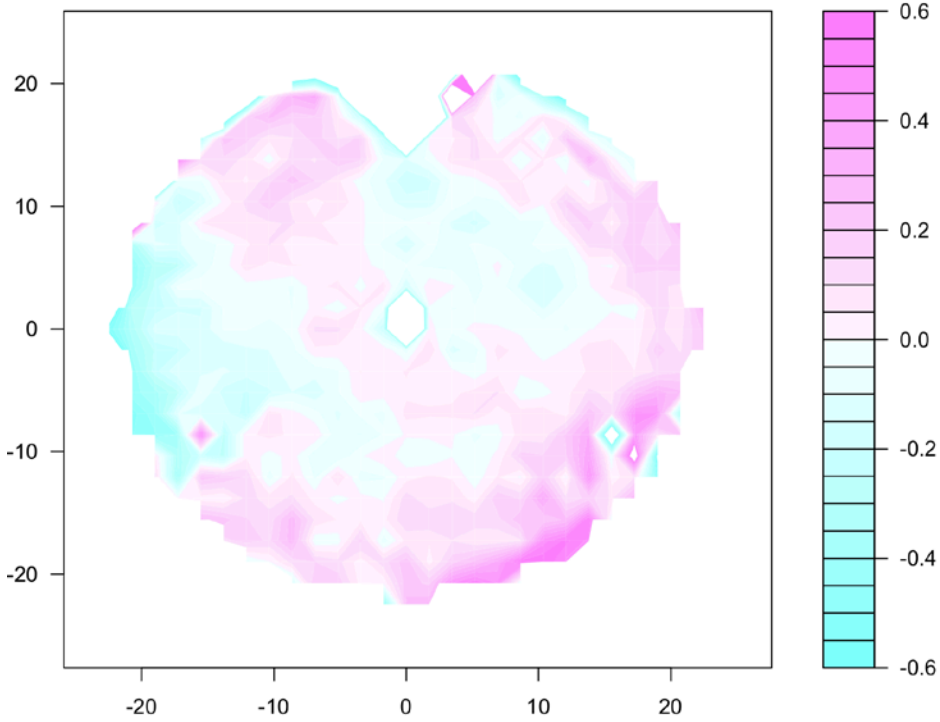
- Measurement
  - Frequency 19.45 GHz (CS satellite)
  - Rx: H22
  - Ref Ant: CS dish (1.8 m)

- Adjustment (700 panels)
  - 2015 sep-oct
  - Motorized part are broken
  - Manually adjusted

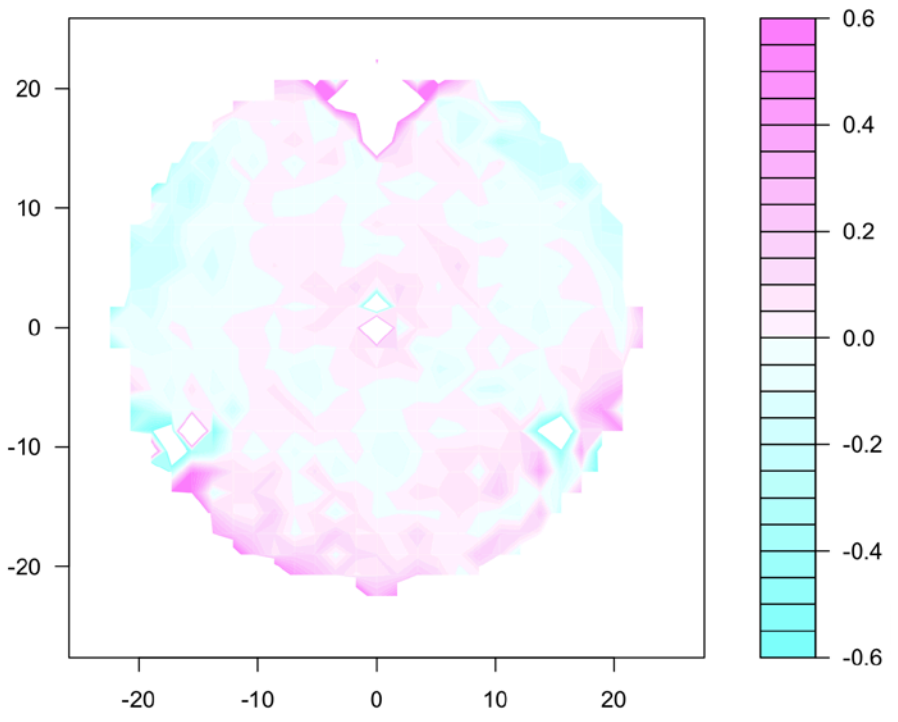


Surface Adjustment

Before (2015-06-08)



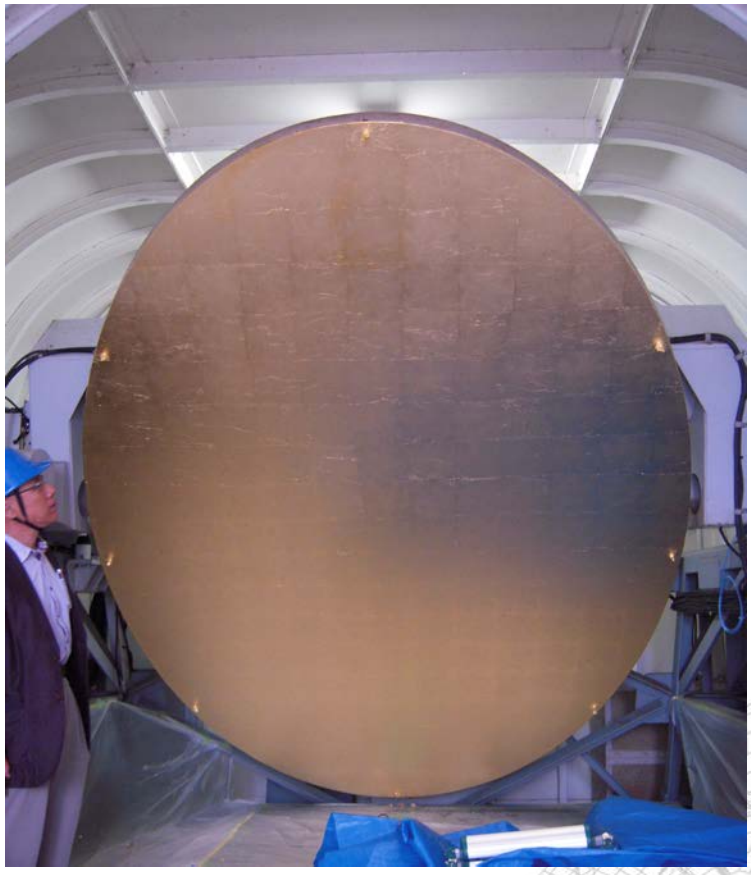
After (2015-10-05)



- K band Rx at 19.45 GHz using satellite beacon
- Include M1, M2, and beam waveguide optics
  - 180 μm rms → 100 μm rms (nominal)
    - η_A :0.25 -> 0.35 at 110 GHz

These two mirrors were degraded.

Put (Stick) metal foils to M2 and M3



- Put (Stick) metal foils to M2 and M3 (3 um thick)
- Tsys is reduced by ~ 11K @ 3mm

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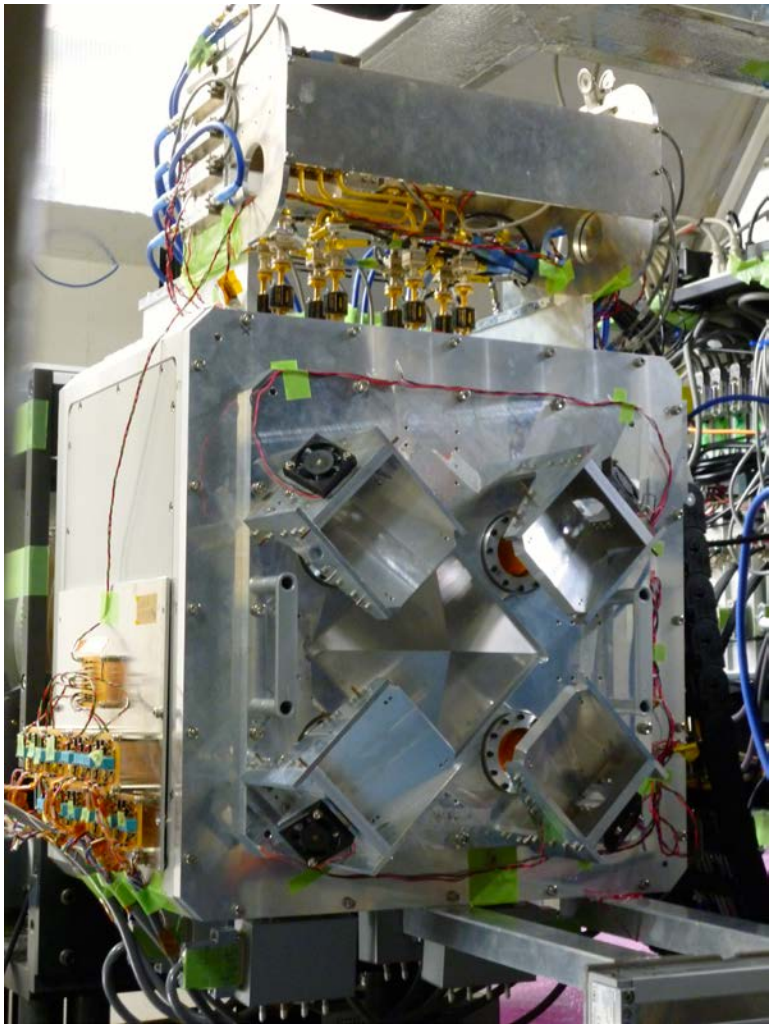
"FOREST"

FOur beam REceiver System on 45-m Telescope



- 4-beam x 2-pol.(H/V) x 2-sideband = 16 IFs
- Beam separation ~ 50"
- Beam size ~ 14" @ 115GHz
- IF: 4-12 (4-11) GHz ➔ simultaneous ^{12}CO, ^{13}CO, C^{18}O observation
- Dewar rotation system to track same sky position

(Minamidani +16 Proc. SPIE)

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Paintings

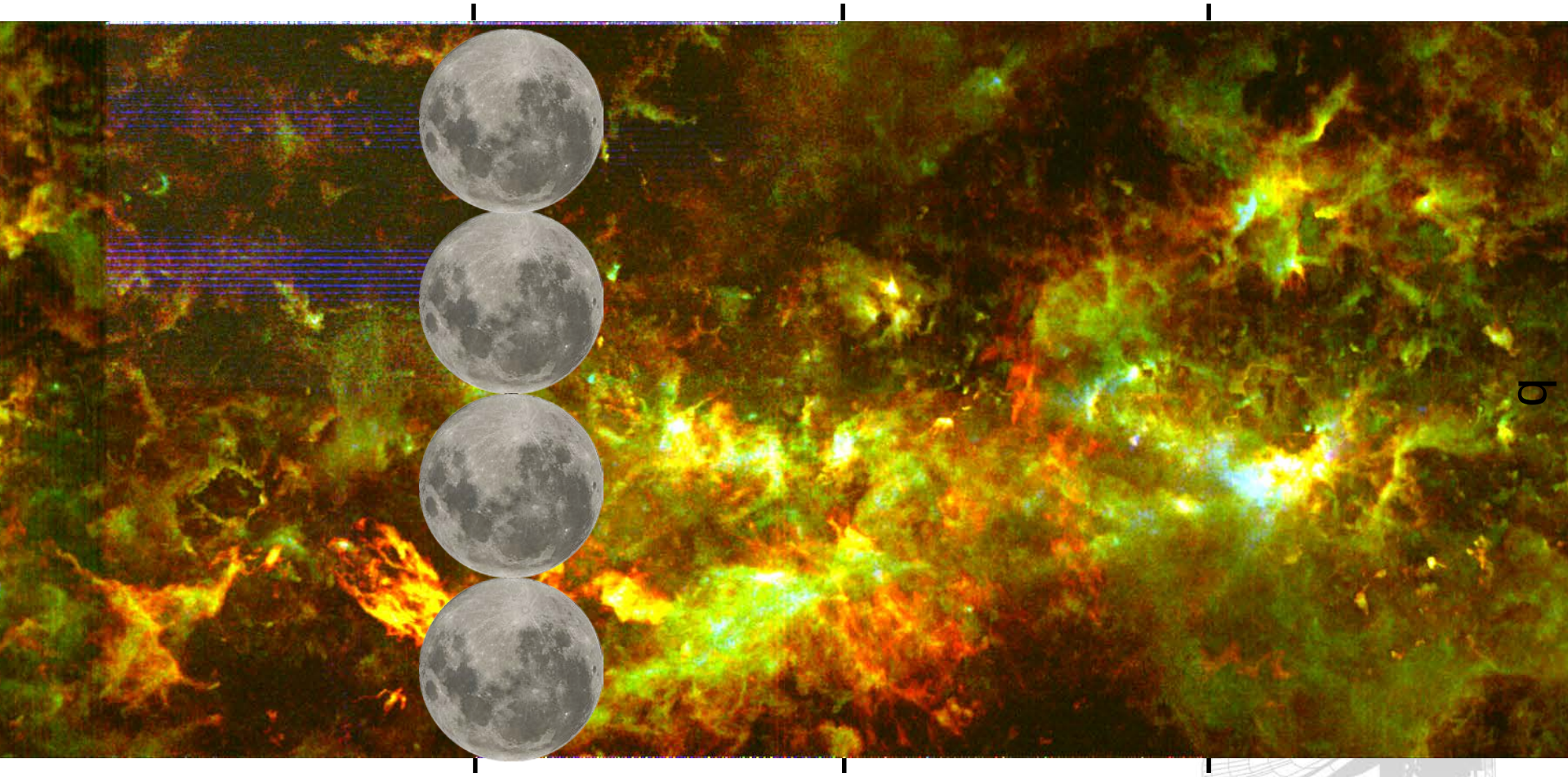
Issues

- Large surface errors: 180 μm ($\eta_{A,110\,GHz}$:0.25)
  - Improved to be 100 μm ($\eta_{A,110\,GHz}$:0.35)
- High antenna noise temperature: 30 K
  - Reduced to be 19 K (w/o atmosphere)
- Single pixel Rx only at 3 mm
  - Expanded to be 4 pixels

Overall a factor of 10 improvement in 3 mm mapping

  - Painting of mount structure

Galactic Plane Survey



Umemoto et al.

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Performance and Previous Metrology System

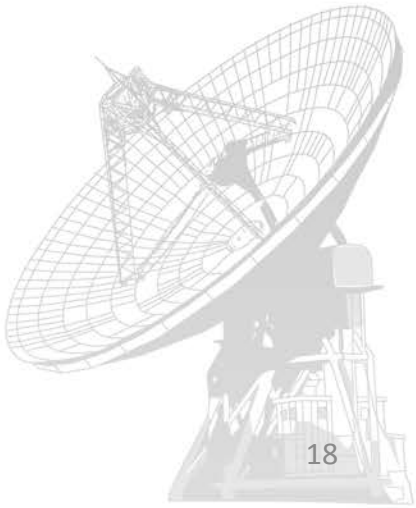
Ukita, N. 1999, Publ. Natl. Astron. dbs. Japan Vol. 5. 139 147

Kuno+ 2006, NRO Users Meeting

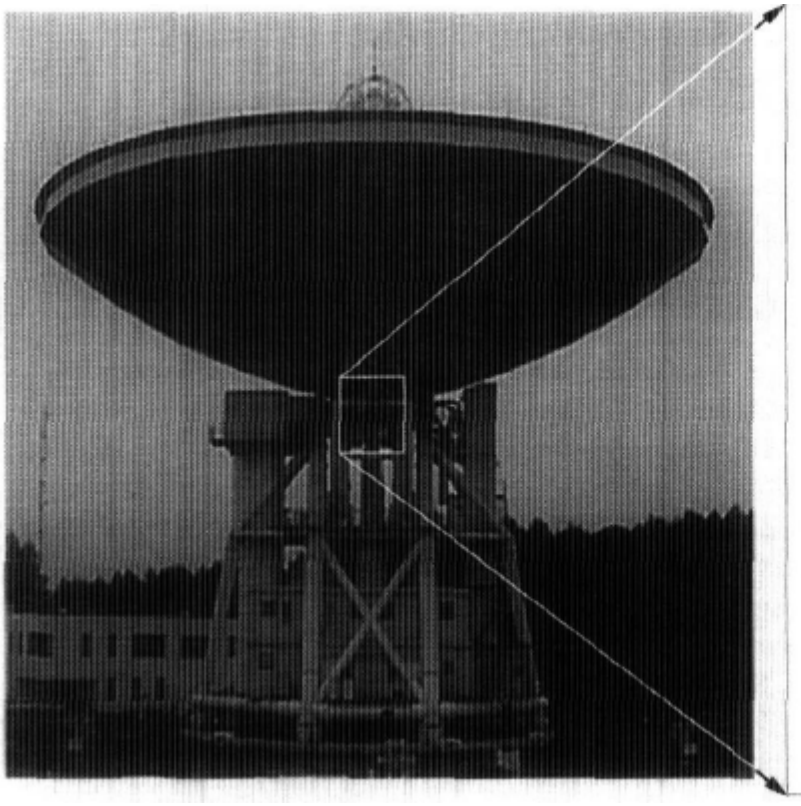
Pointing error equations

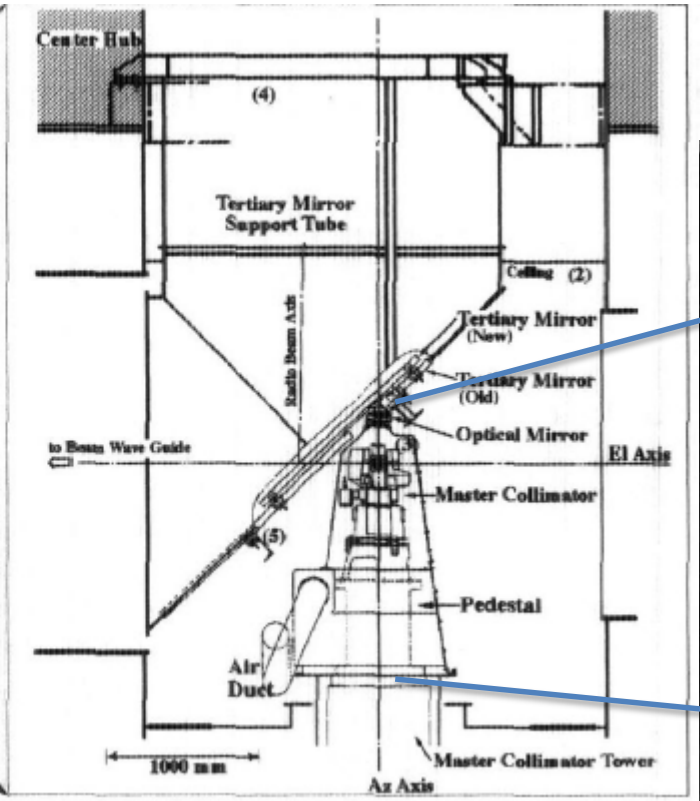
$$\sigma_{Az}^2 = \sigma^2(\mathrm{mea}) + \sigma_{Az}^2(\mathrm{irreg}) + \sigma_{Az}^2(\mathrm{thermal}) + \sigma_{Az}^2(\mathrm{Sun}) + \sigma_{Az}^2(\mathrm{wind})$$

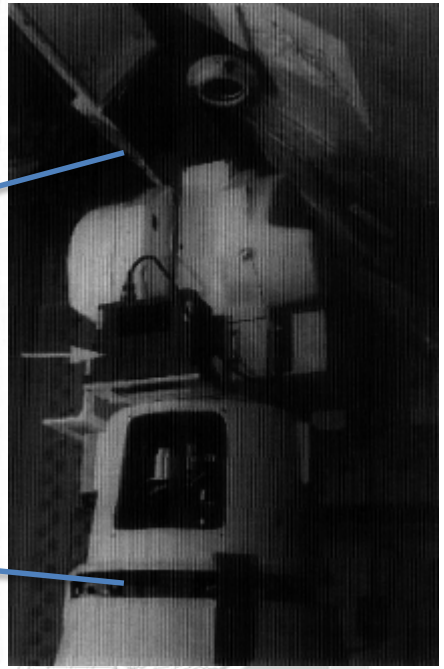
$$\sigma_{El}^2 = \sigma^2(\mathrm{mea}) + \sigma_{El}^2(\mathrm{irreg}) + \sigma_{El}^2(\mathrm{thermal}) + \sigma_{El}^2(\mathrm{Sun}) + \sigma_{El}^2(\mathrm{wind})$$



Thermal Deformation



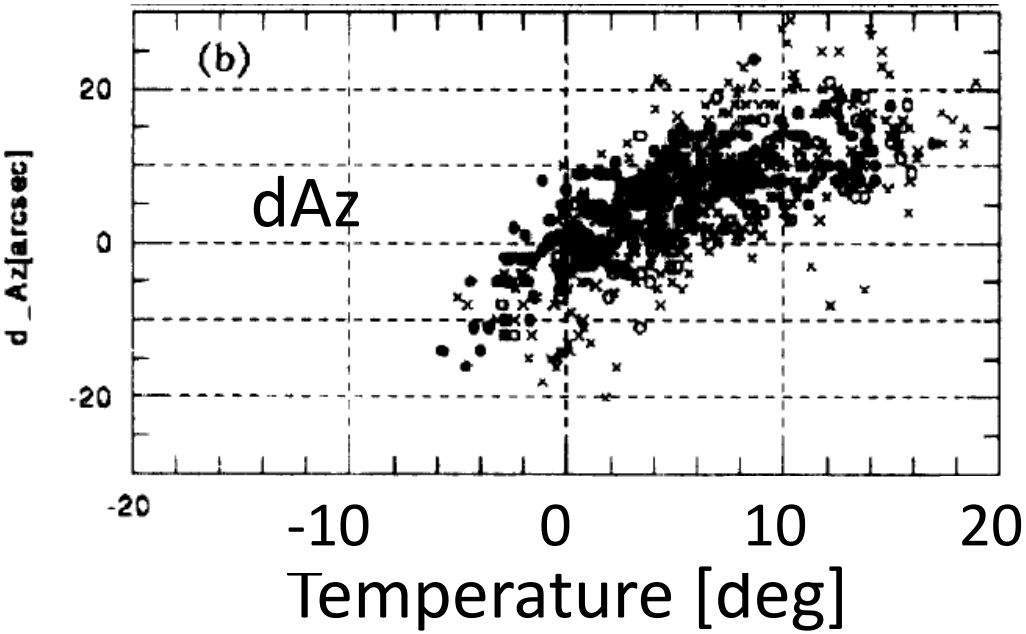


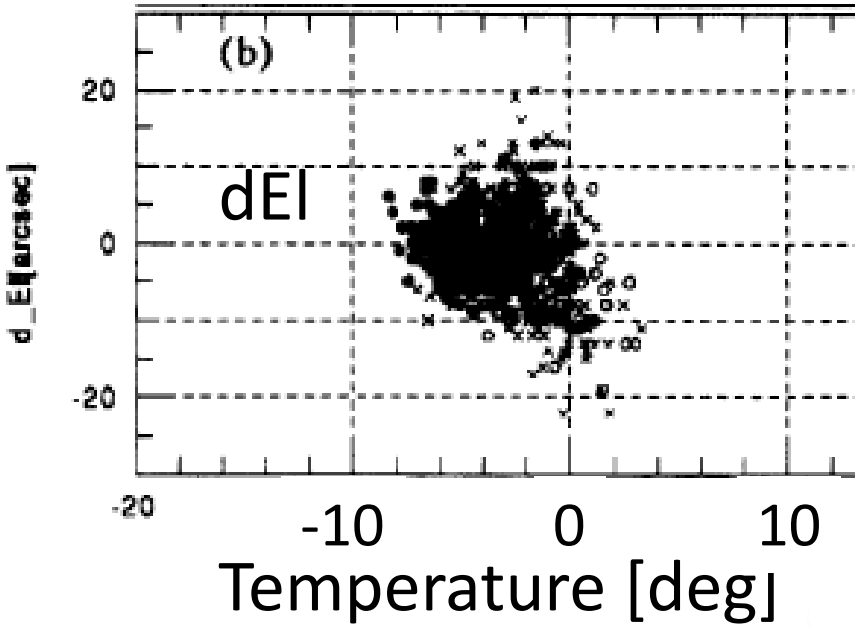


Ukita 1999

Thermal behavior

Ukita 1999



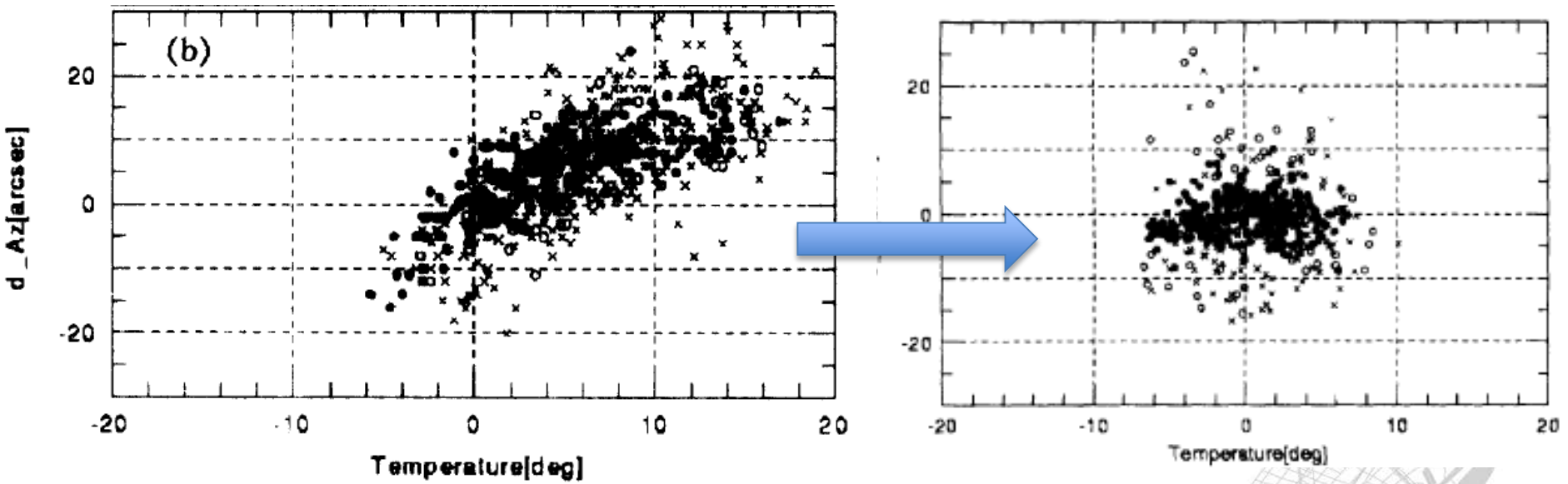


Observed pointing offsets in azimuth against the temperature at the bottom of the tertiary mirror support tube (Ts)

Thermal Metrology

- Before and After thermal metrology implemented

Ukita 1999

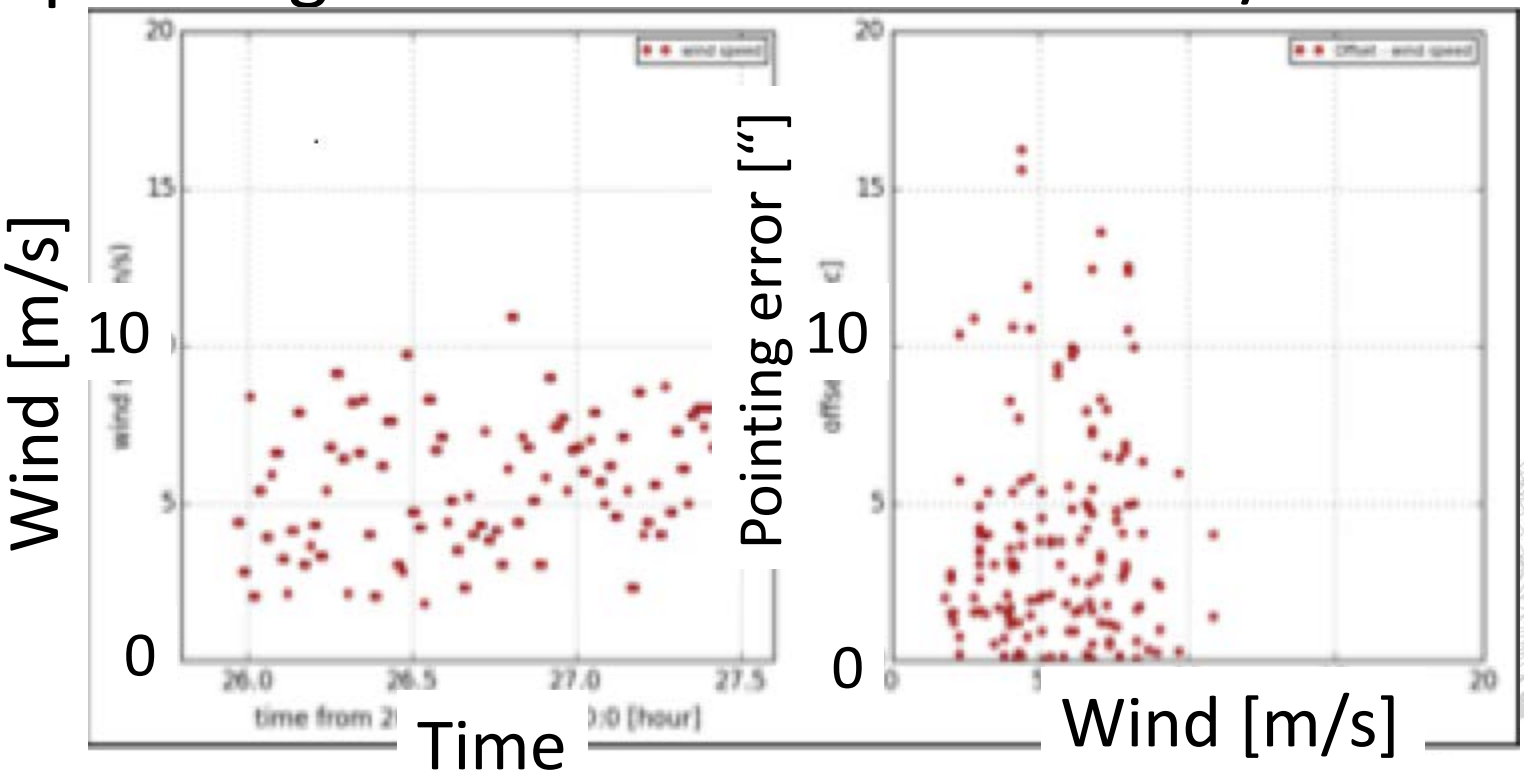


Left) Before, Right) After

But, …

Pointing under Wind

- Homology design – susceptible to wind e.g. pointing offset 0-15” under > 10 m/s wind



Wind metrology

- OPT+CCD/LED sensor experiment
  - OPT at center hub and LED at dish edge
  - Four directions
  - 0.1 sec sampling
  - 100 um or better accuracy

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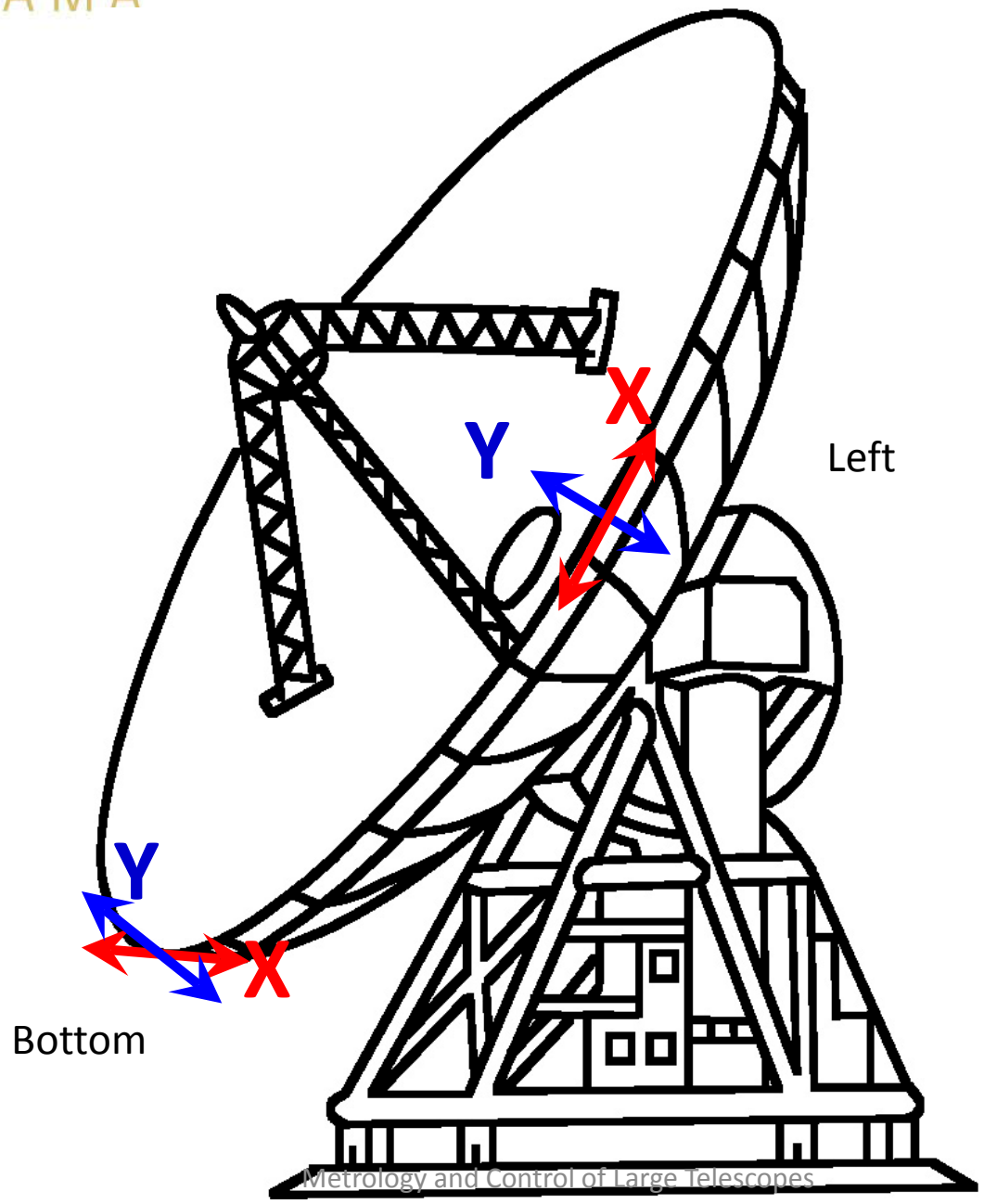
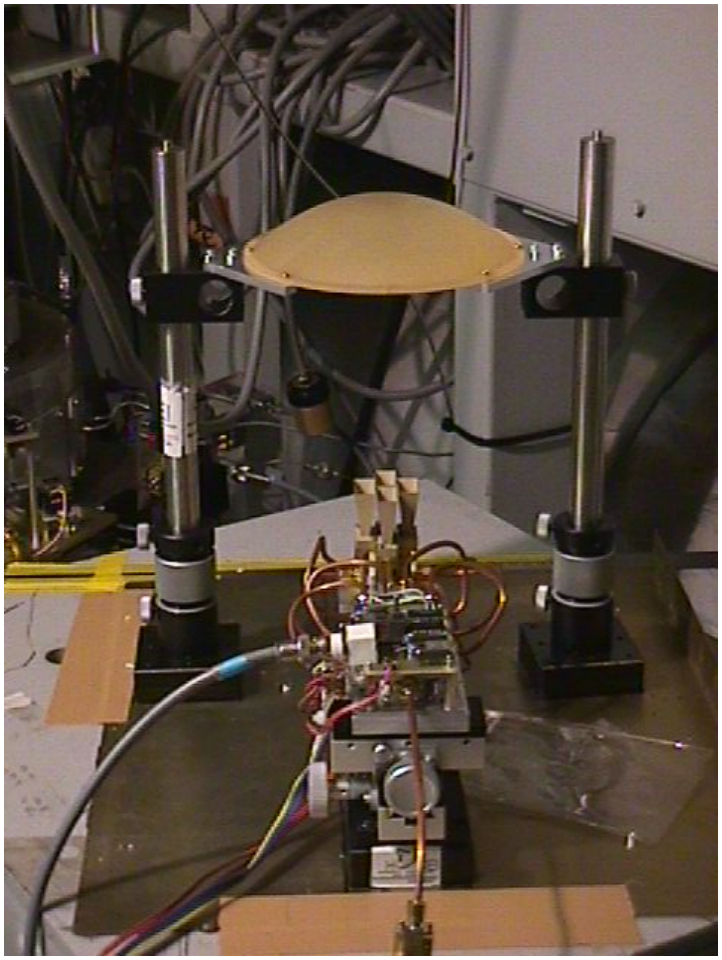
Measurement Setup

Kuno 2006

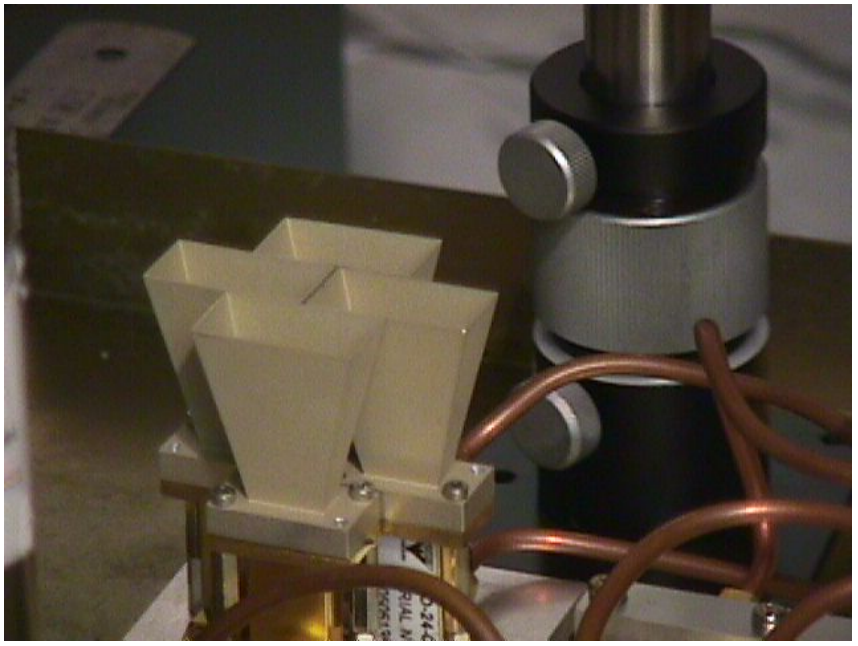

X
Y
Left
Y
X
Bottom

Four beam pointing monitor Rx



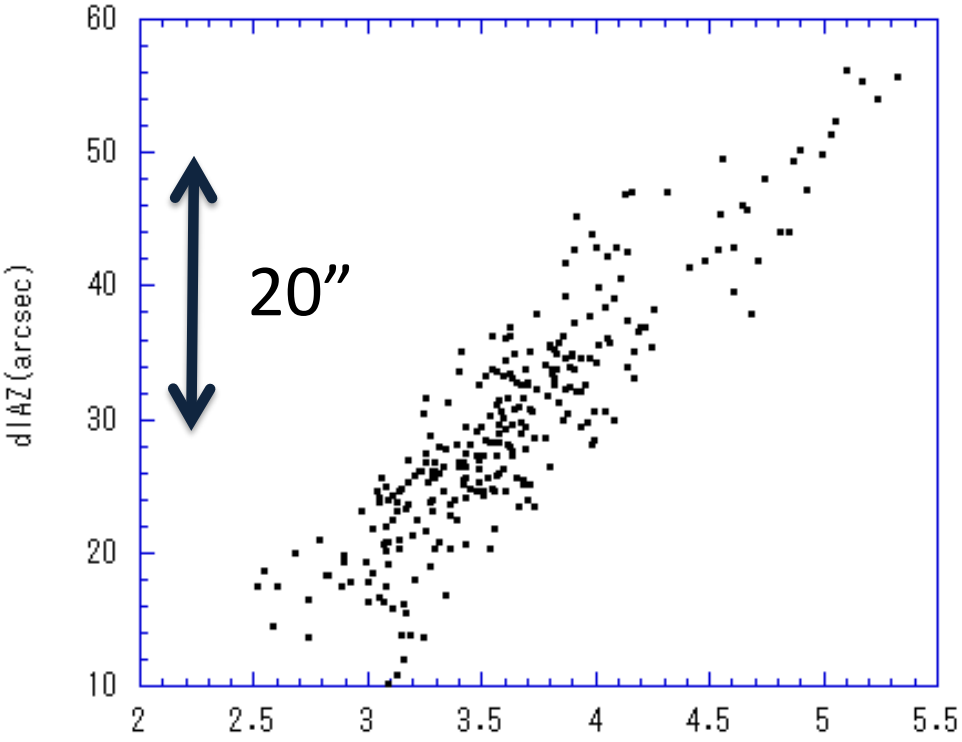
N-STAR（19.45GHz）

Kuno 2006

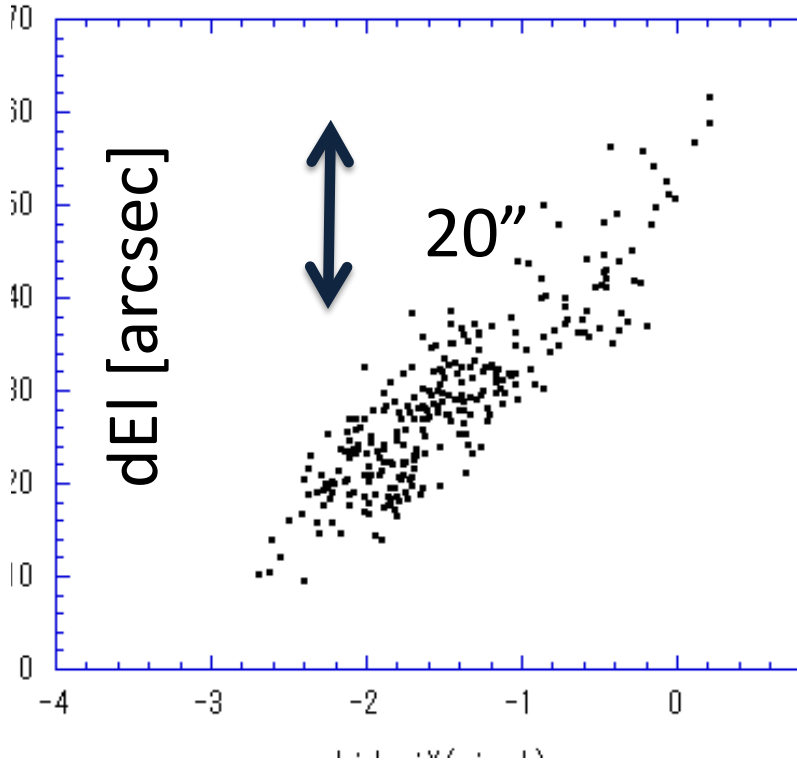


Pointing error and dish movement Azimuth/Elevation

Kuno 2006



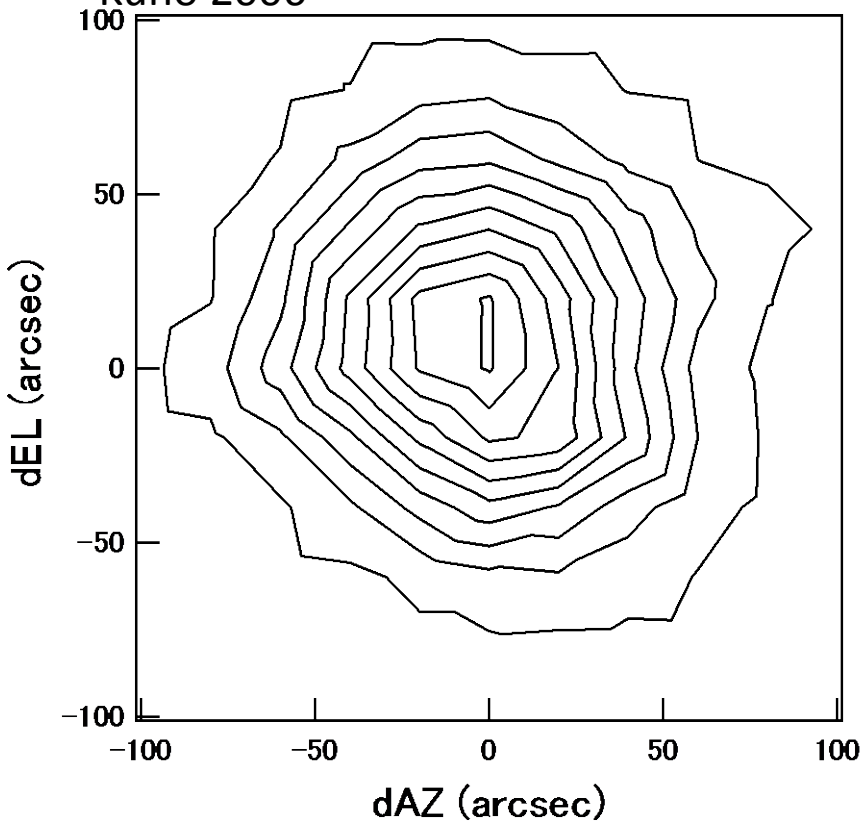
Top X [Pixel]

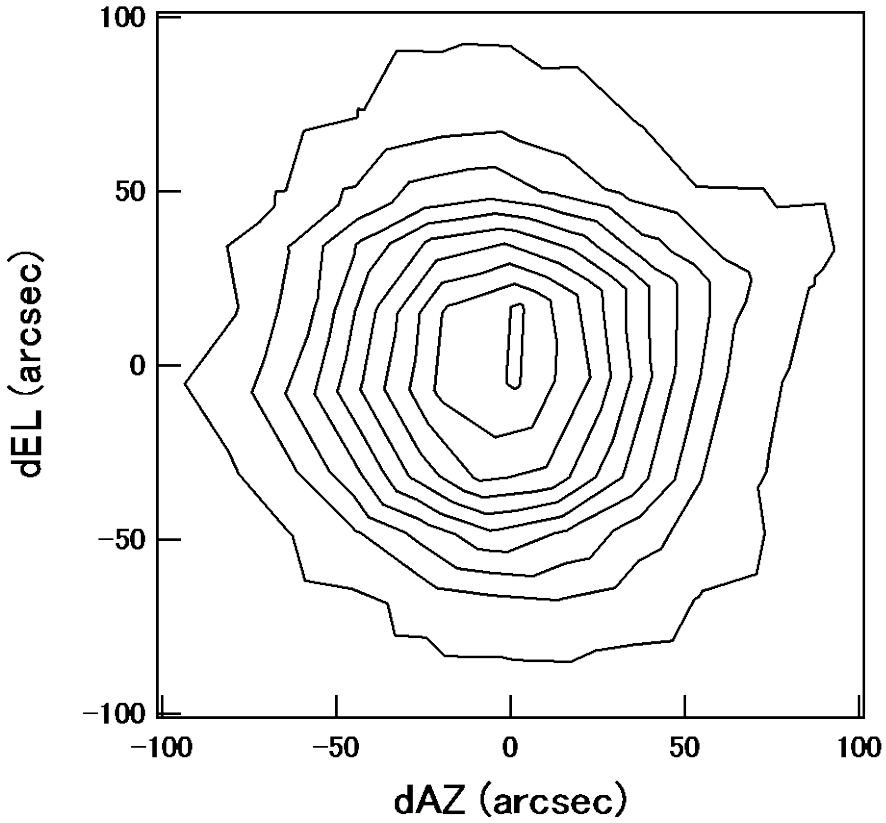


Left X [Pixel]

Beam patter @23GHz＞10m/s

Kuno 2006





Before

After offline correction

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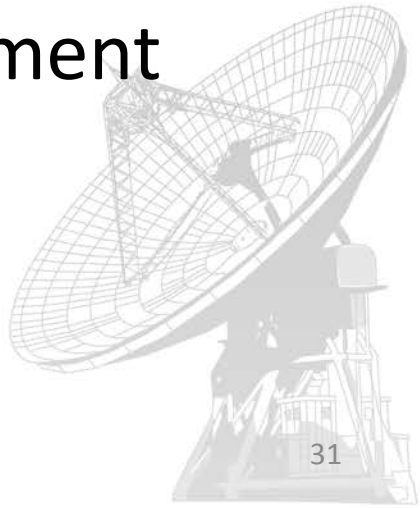
Future Metrology System

Thermal Metrology

- Re measure the correlation (update current thermal metrology)
- Temperature distribution and pointing errors (after painting)
- Solar irradiation effect
- Simultaneous Inclinometer measurement



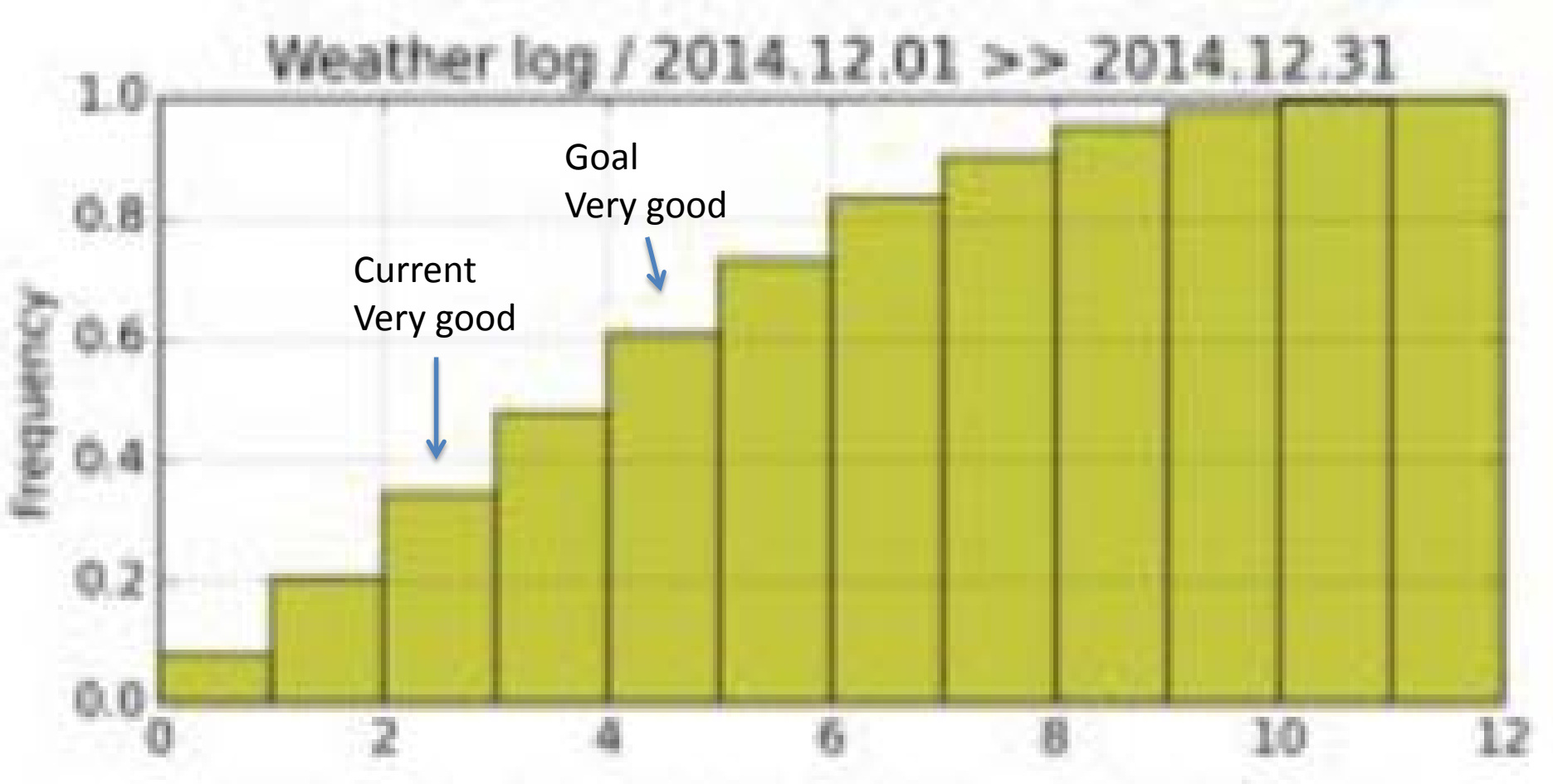
Wind Metrology

- Update the previous wind metrology system
- Set more stable LED mount structure
- Enclosure around LET to avoid unwanted sunlight
- Simplify pointing telescopes

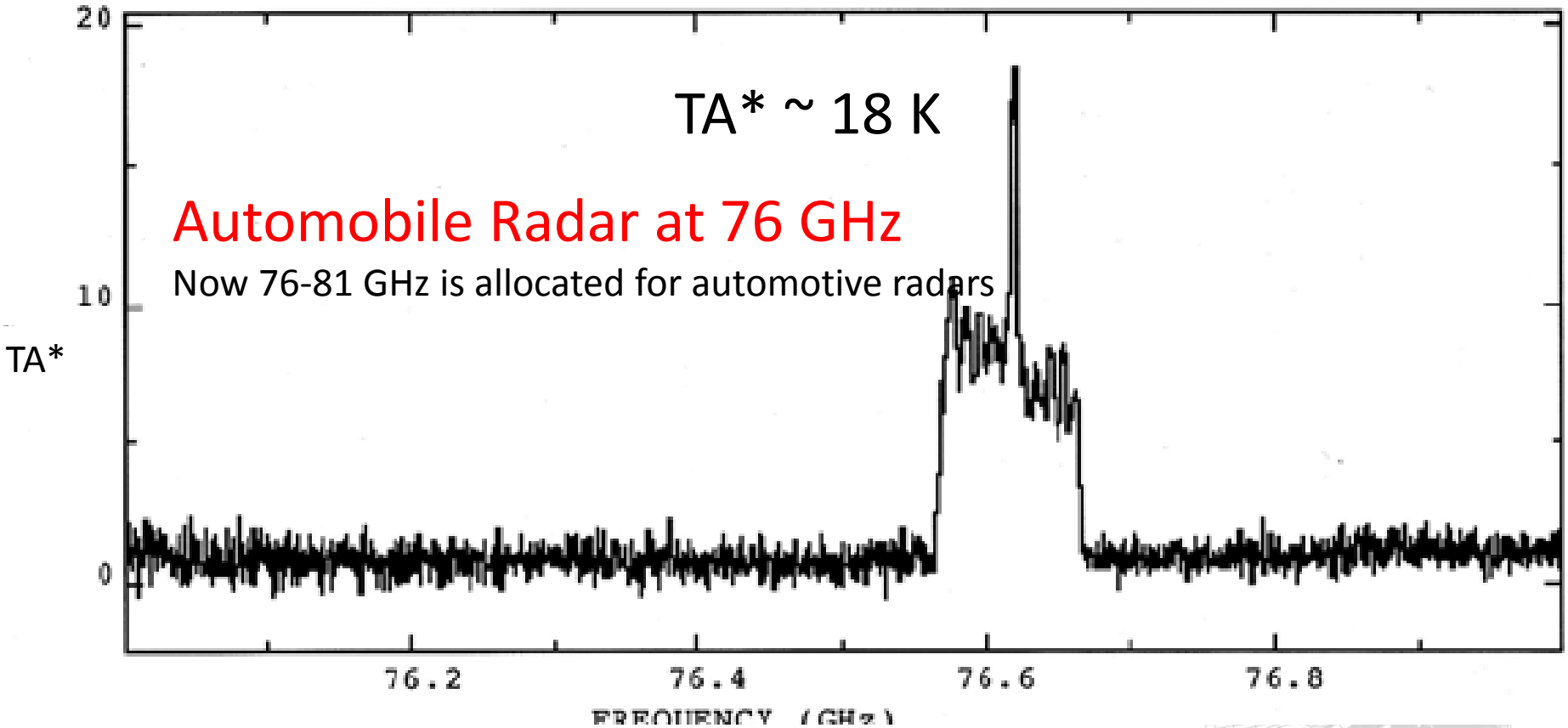
- Jupiter or Venus observations with FOREST yields accurate pointing errors in both Az/El.

Metrology goal

Push wind limit further from 3 to 5 m/s by meterology

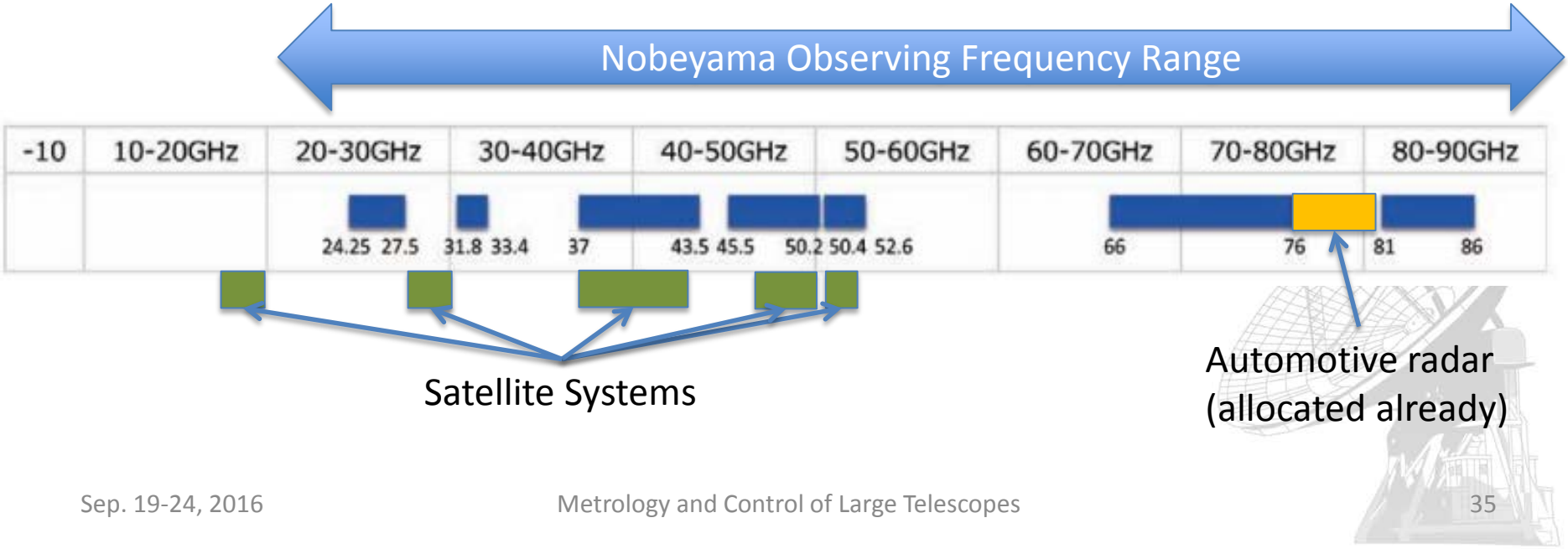


New Discovery?



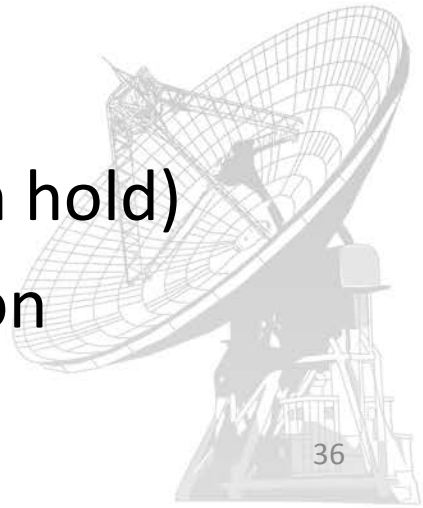
More to come in WRC-19

- Higher and higher
- IMT, Satellite, Automotive radar
- > 275 GHz application also on the table



Summary

- Nobeyama 45-m telescope (34 yrs old)
  - One of the largest single dish antennas operated at 20-116 GHz.
- Pointing behavior
  - Thermal effect
  - Wind effect
  - Current thermal metrology system
  - Experimental wind metrology system (on hold)
  - Future metrology system under discussion



And more learnt in this WS

- OOF (gravitational/thermal effect)
- Subref position monitor