

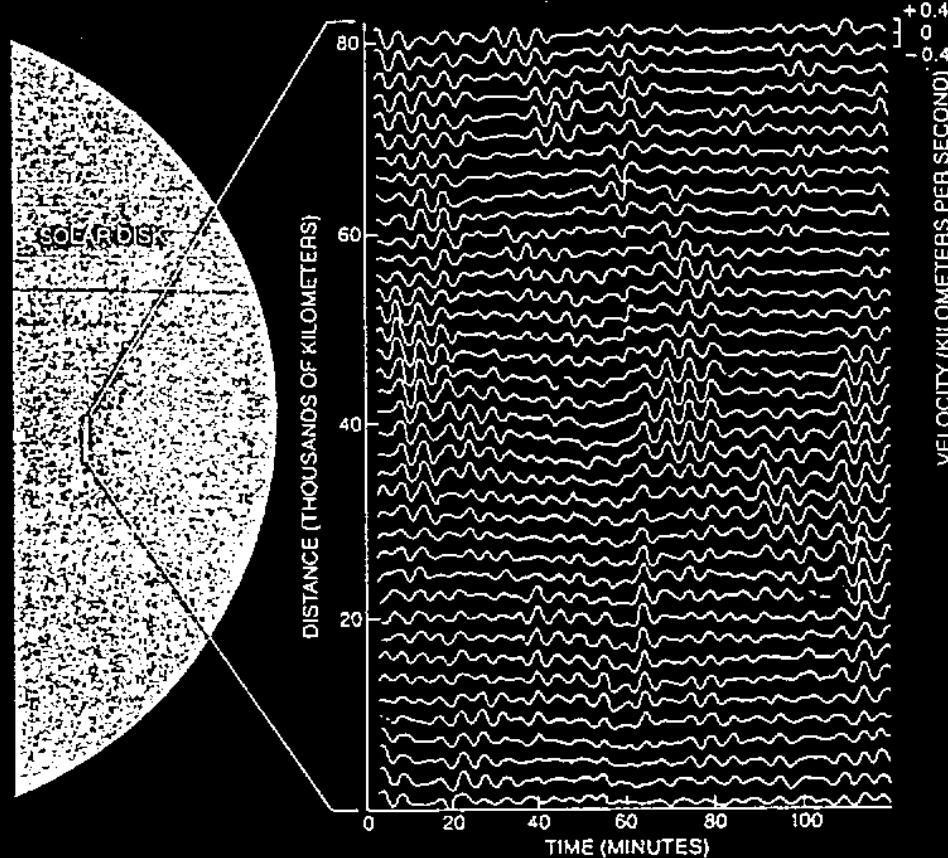
A Brief of TON (Taiwan Oscillation Network)

The Research Using 3.5" Telescopes

Ming-Tsung Sun
Chang-Gung University
&
Dean-Yi Chou
National Tsing-Hua University

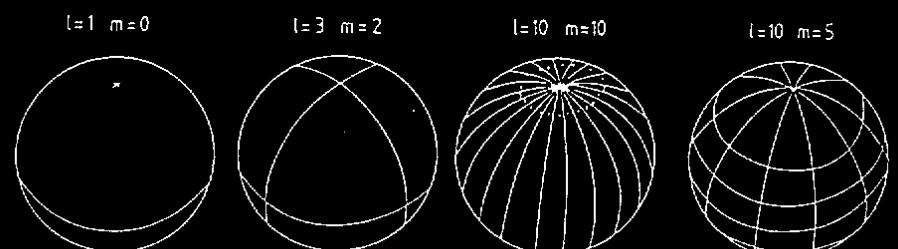
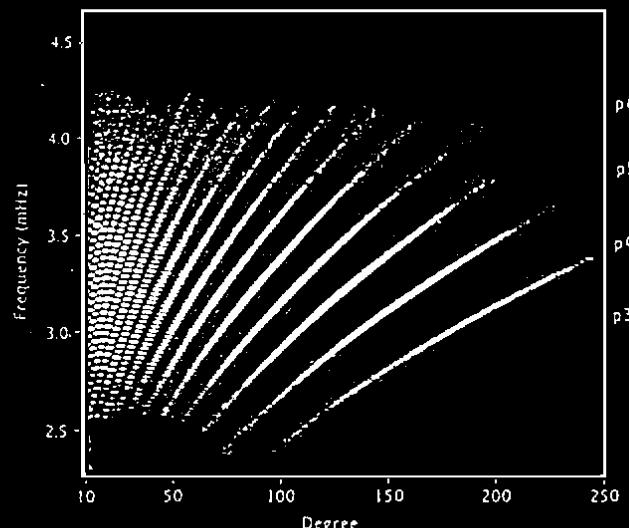
Helioseismology

Five-minute Oscillation

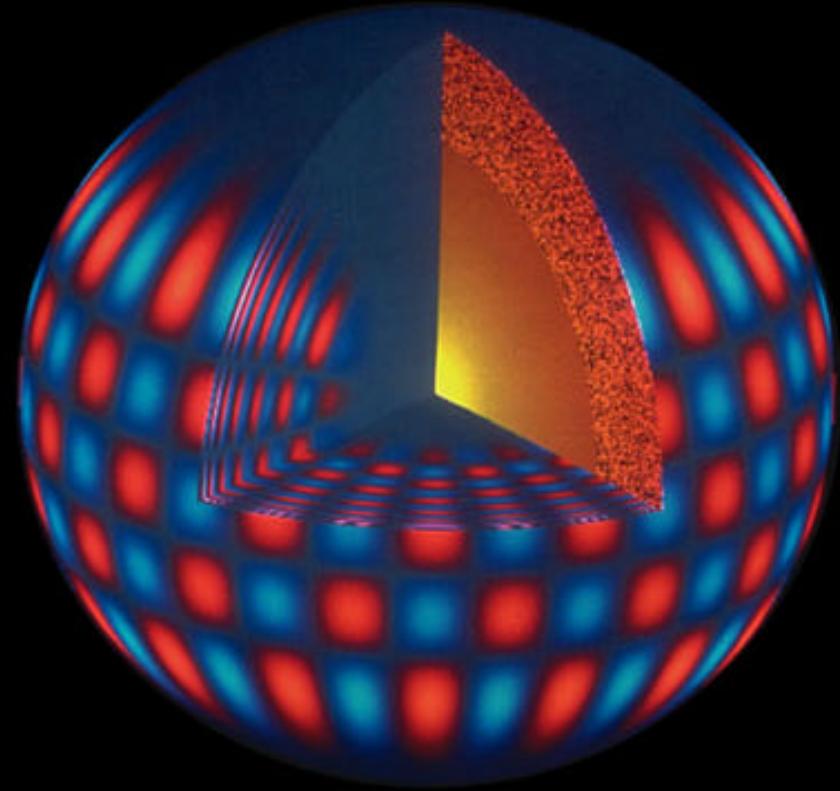


Spherical Fourier Transform:

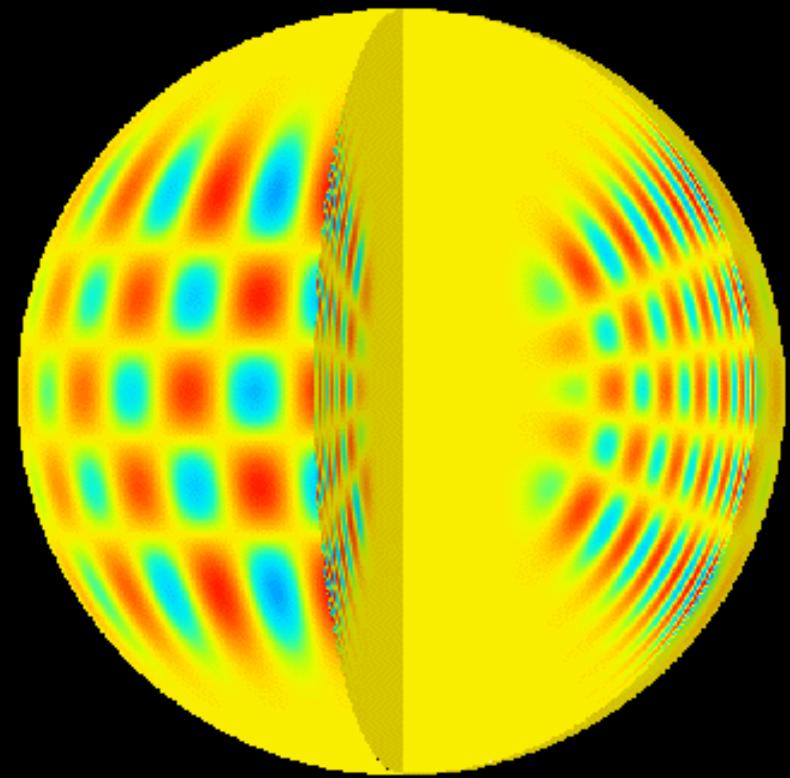
$$I(\theta, \phi, t) = \sum_{l,m,\omega} I(l, m, \omega) Y_l^m(\theta, \phi) e^{i\omega t}$$



Solar *p*-mode



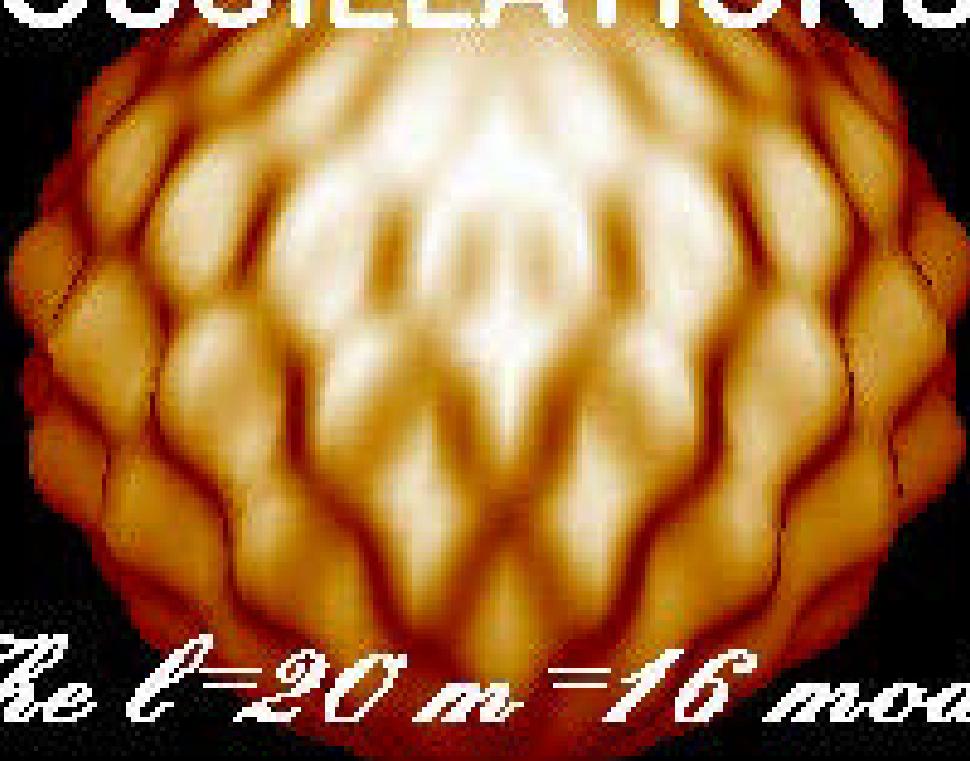
$l = 28, \ m = 24, \ n = 9$



$l = 28, \ m = 24, \ n = 10$

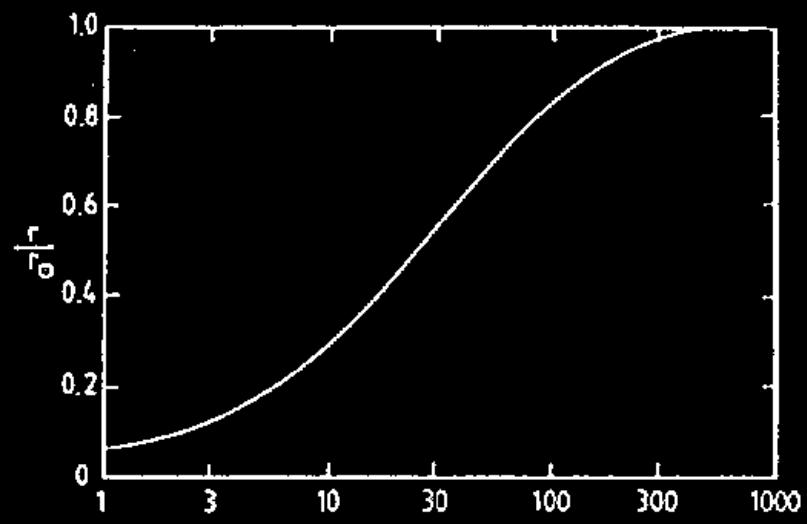
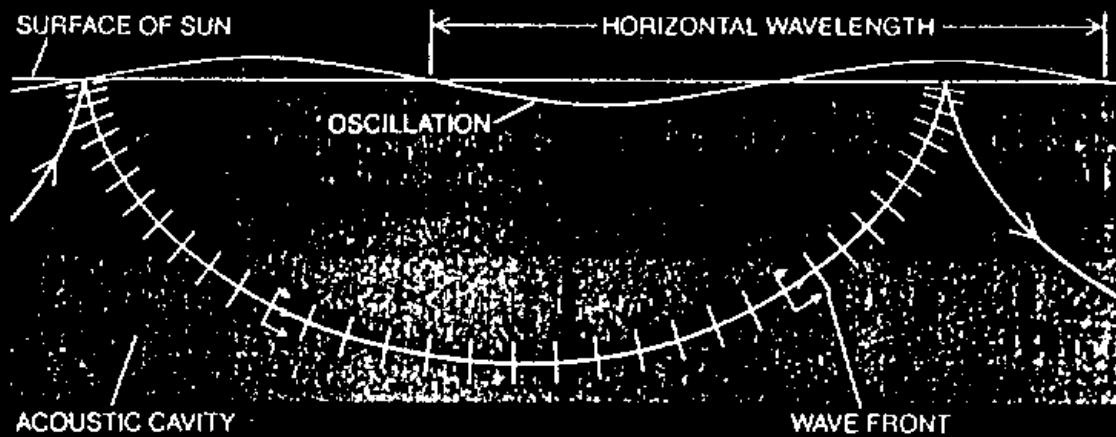
Solar p -mode – A Time Series

SOLAR OSCILLATIONS

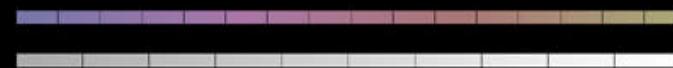
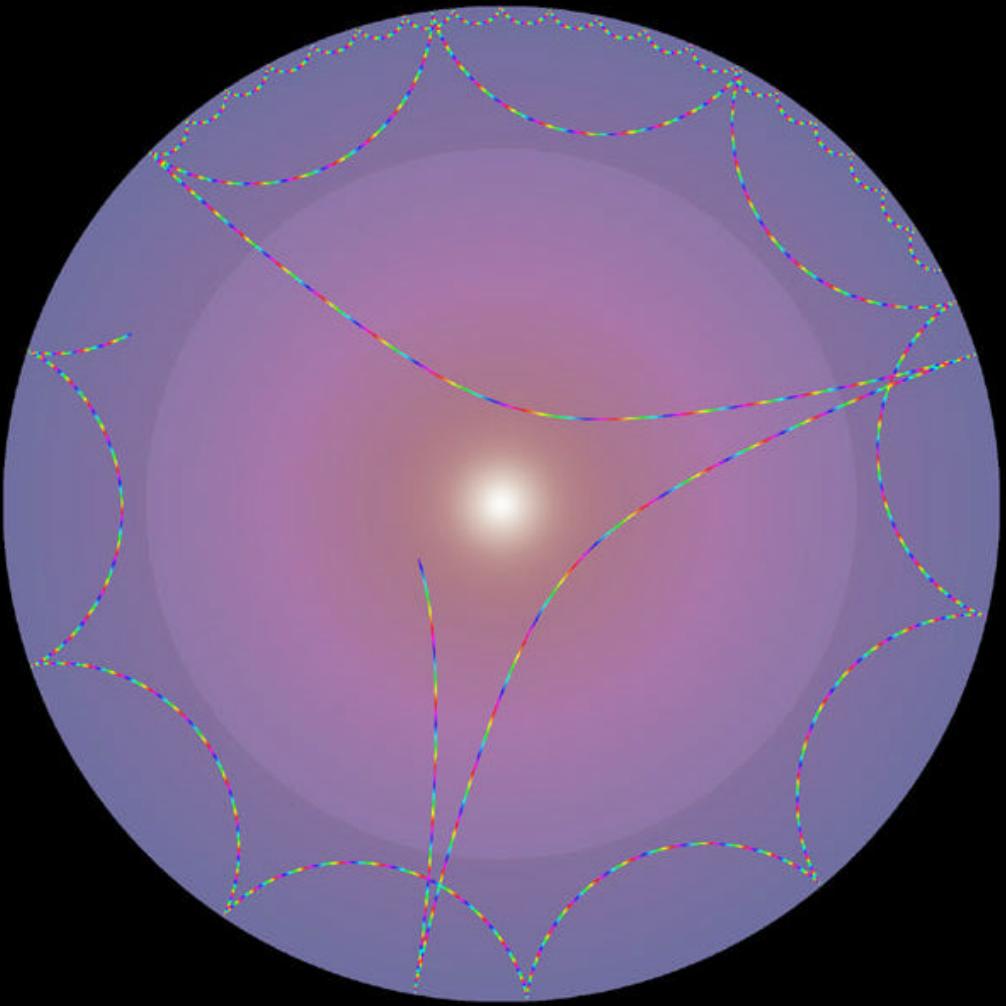
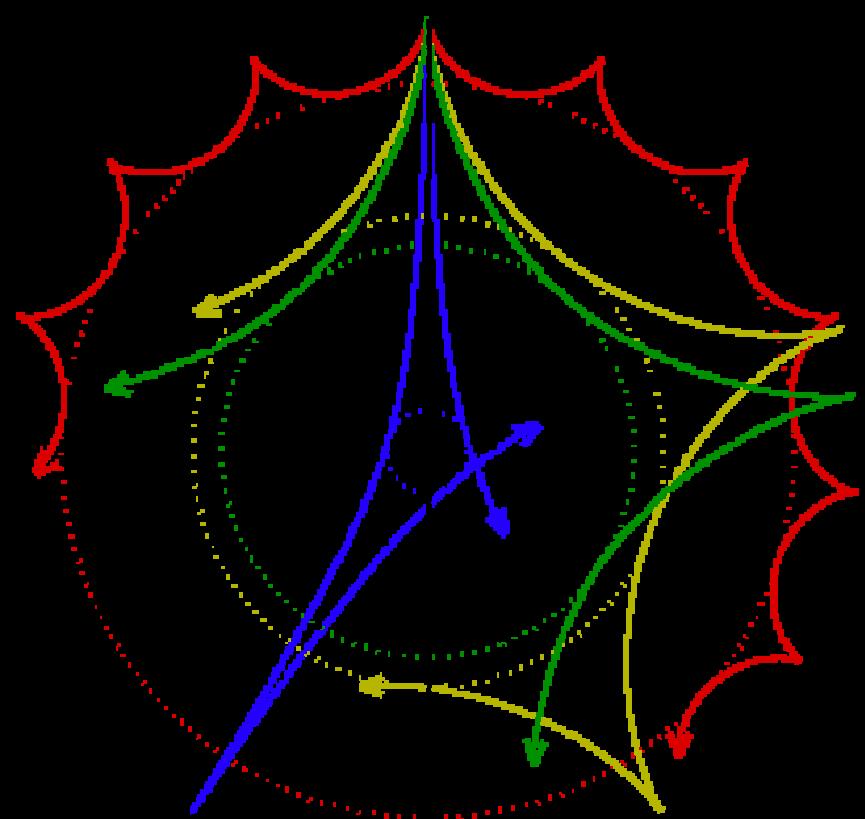


The $\ell=20 m=16$ mode

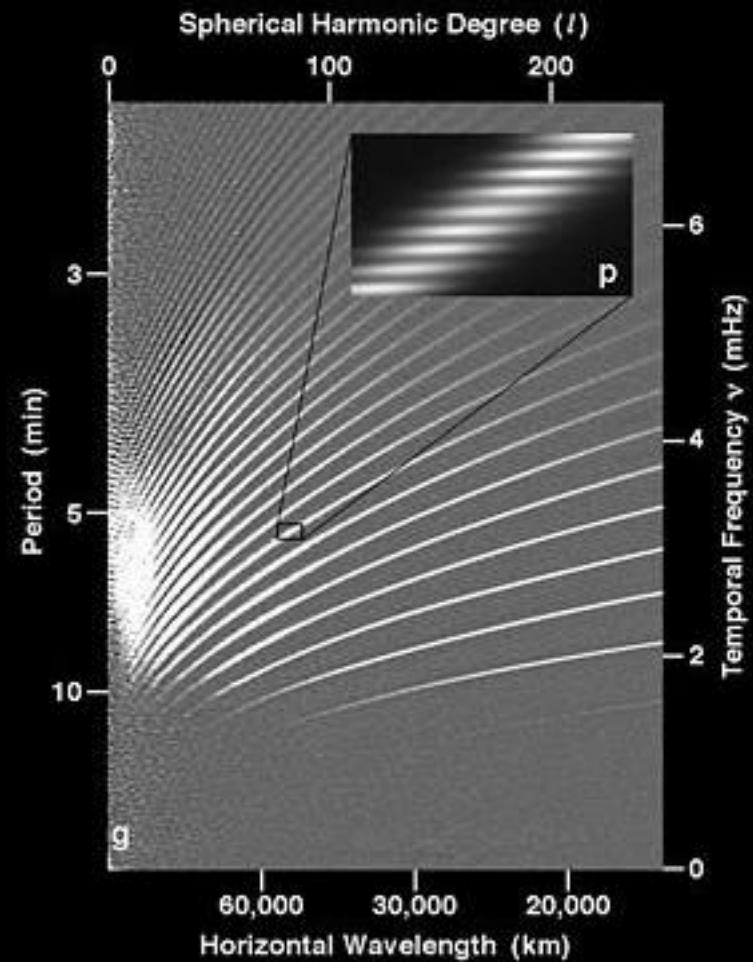
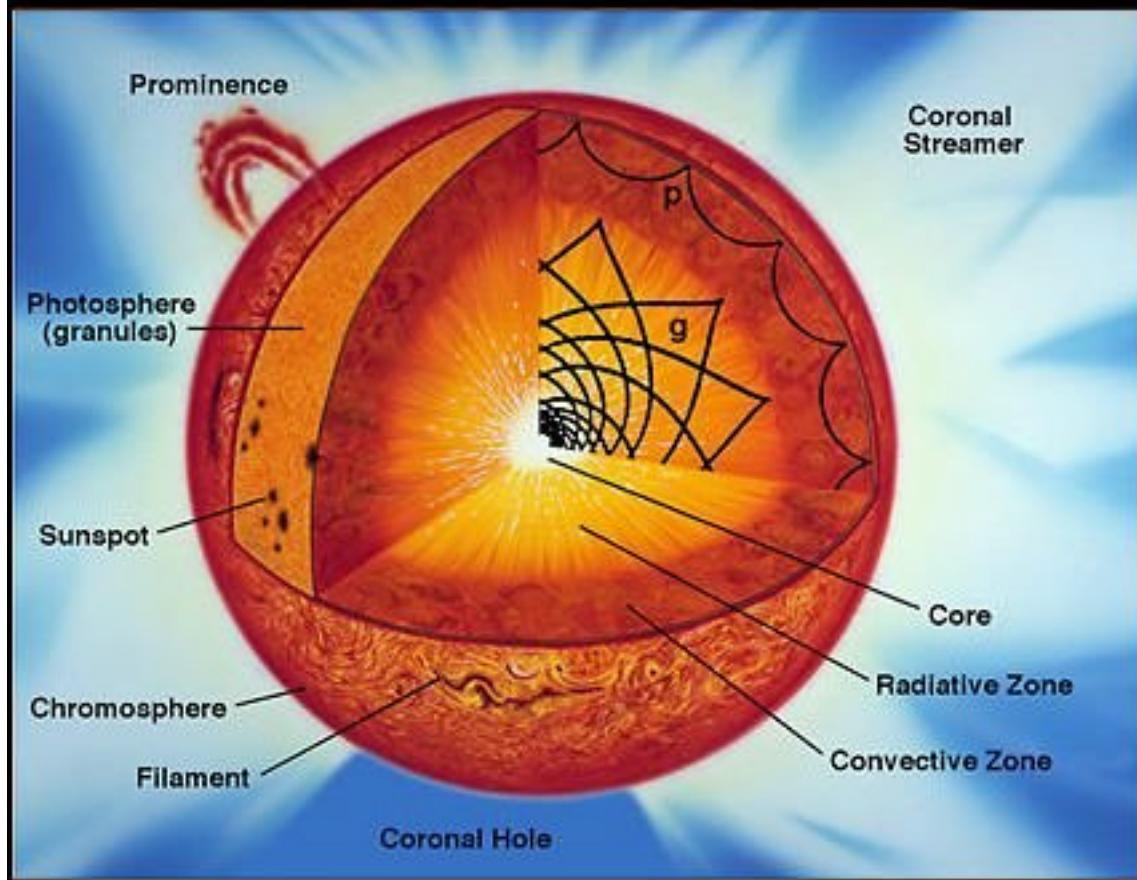
Acoustic Resonance Cavity



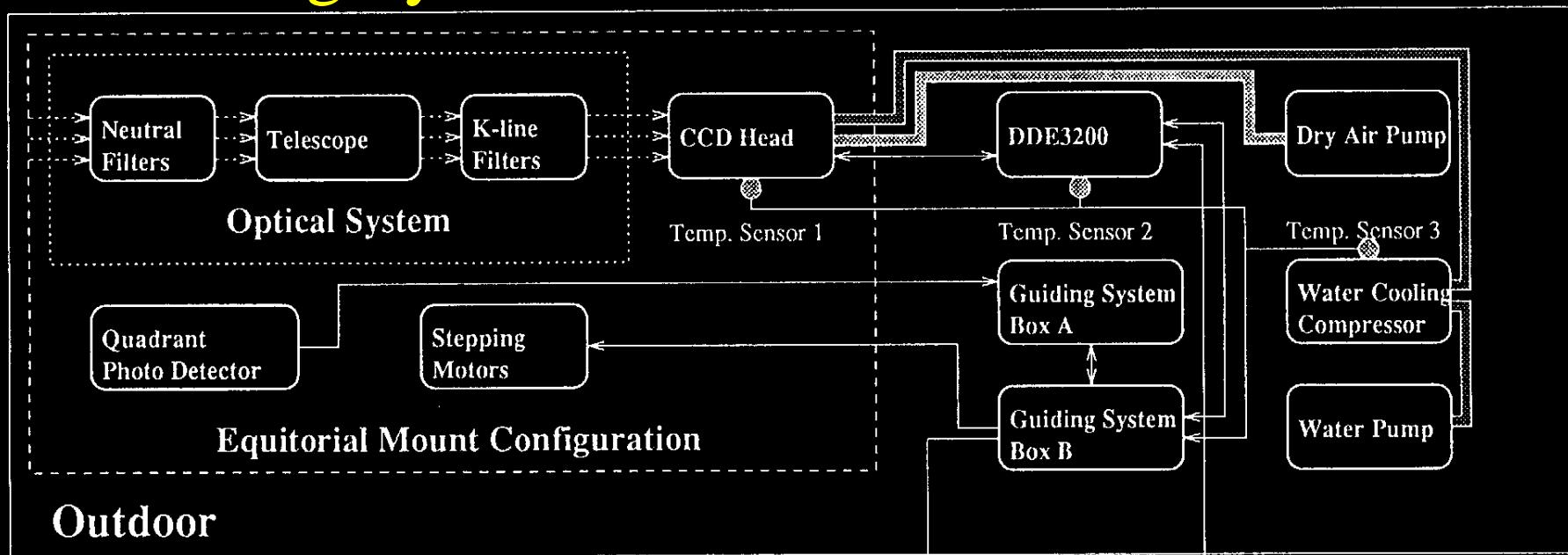
Acoustic Resonance Cavity



Dispersion Relation of Solar p -mode Waves



Observing System of Taiwan Oscillation Network



Legends

- 1-way data signal transmission
- ↔ 2-way data signal transmission
-> light beam
- ===== high pressure hose
- water hose

DOS Control System

PC-DOS

UNIX Control System

PC-UNIX

Tape Drive 1

Tape Drive 2

Display Monitor

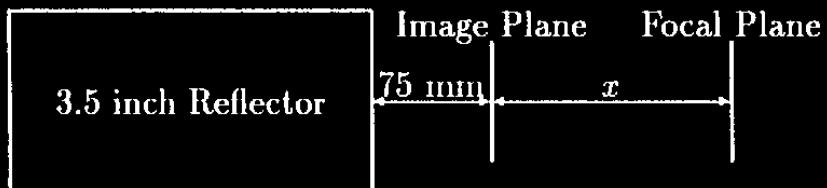
Printer

3.5" Reflector and Charged Couple Device (CCD)

Telescope

Prototype: 12.5 cm Refractor + Extender

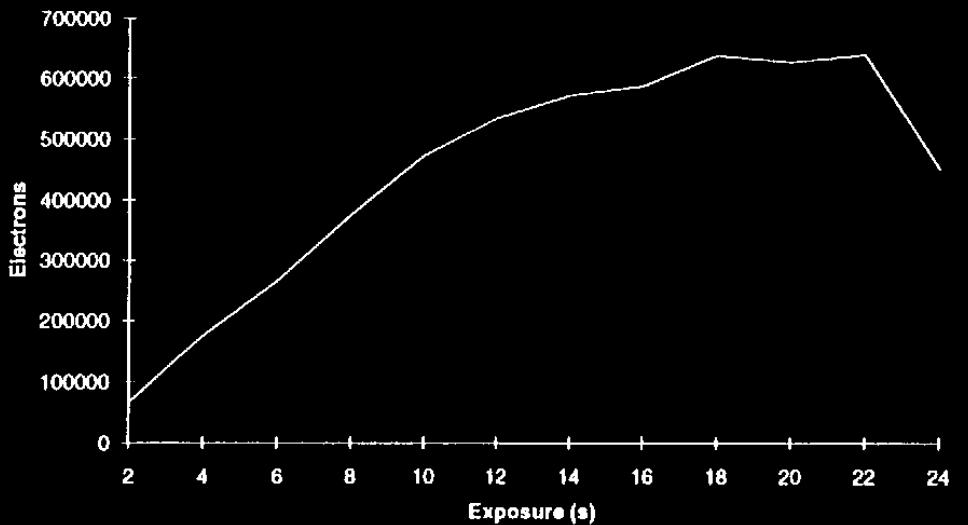
New System: 3.5 in Reflector



$$\text{EFL} = 1297.9 + 3.85x$$

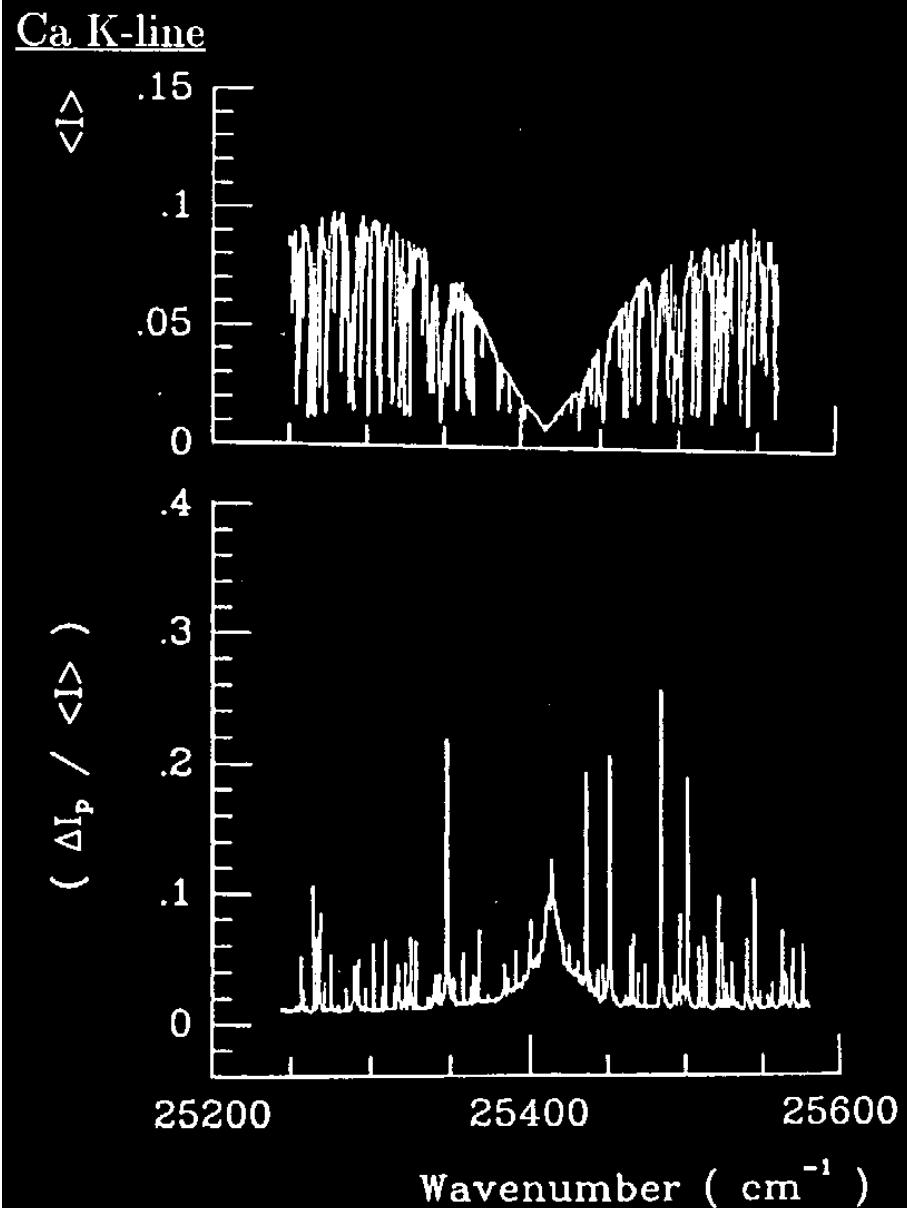
CCD

Dynamic Response:

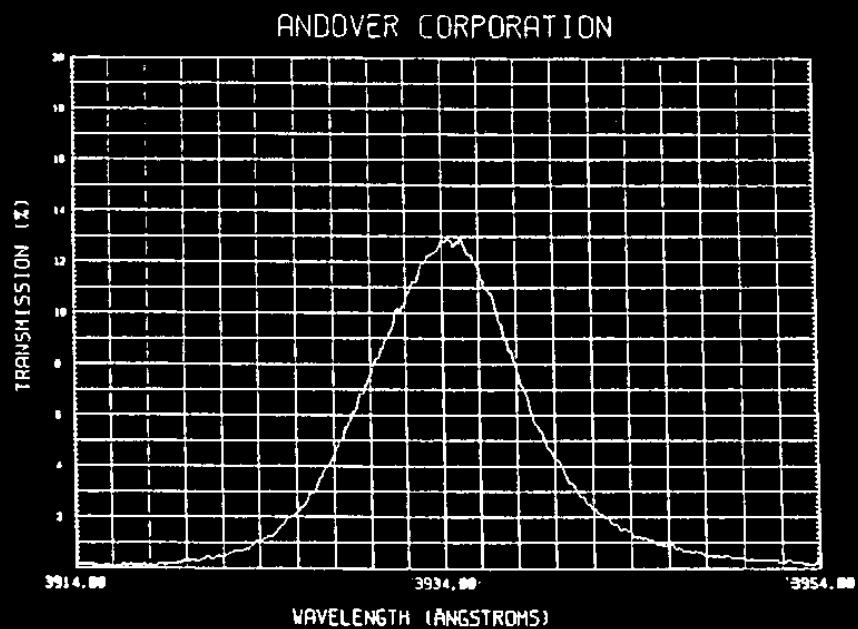


Low Noise: CCD Temp = -50 °C

K-line Filter



Transmission of Filter T_f



$$\frac{\Delta I}{\langle I \rangle} = \frac{\int \langle I \rangle \frac{\Delta I_p}{\langle I \rangle} T_f d\lambda}{\int \langle I \rangle T_f d\lambda} = 6.2\%$$

Solar K-line Image

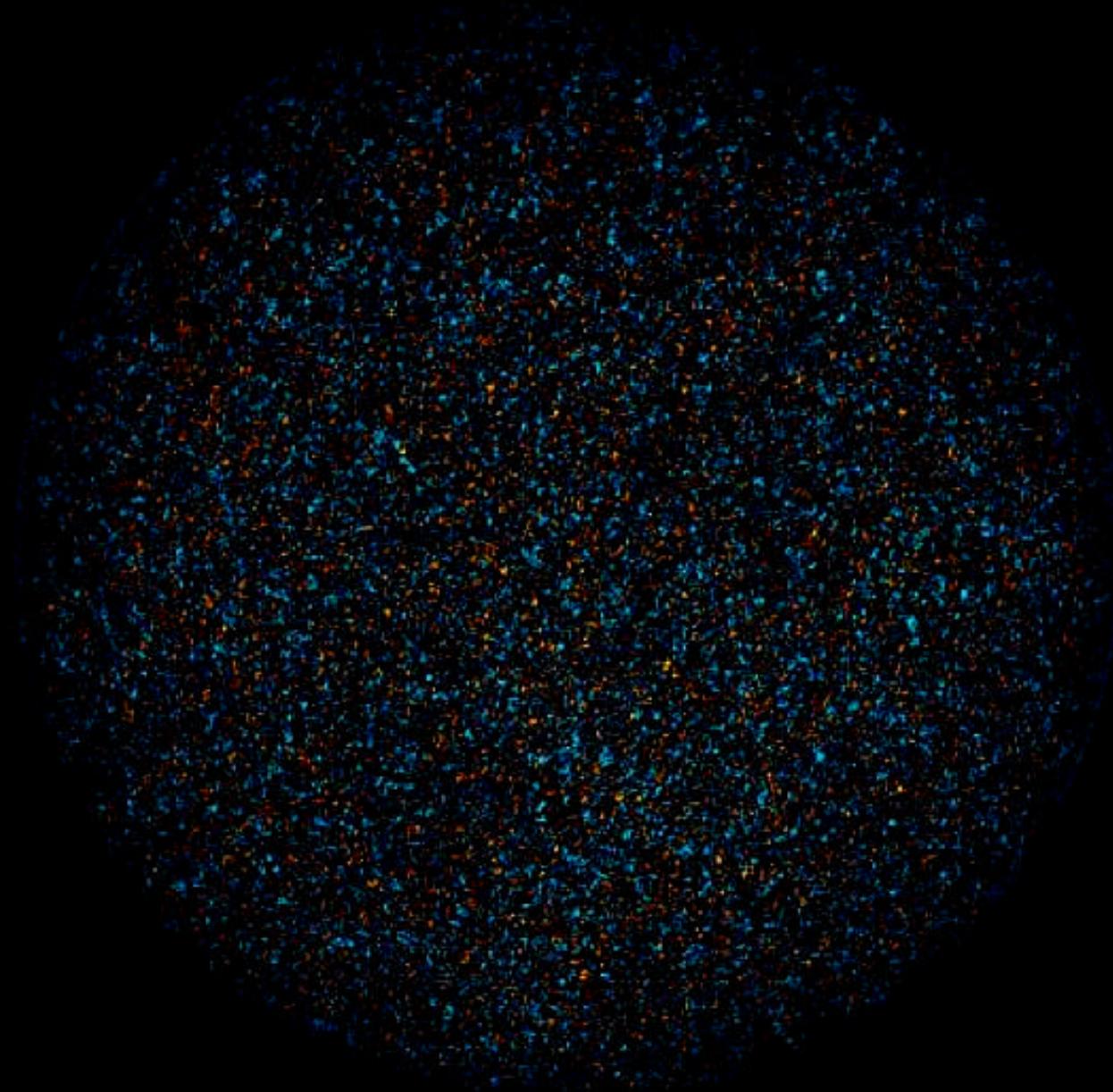
Data Specification :

- Image Size : 1051 × 1051 pixels
1000 pixels (24 mm) diameter
- File Size : 2.3 MB / image
- Sampling Rate : 1 frame / minute
- Oscillation Amplitude : 2 – 3 %

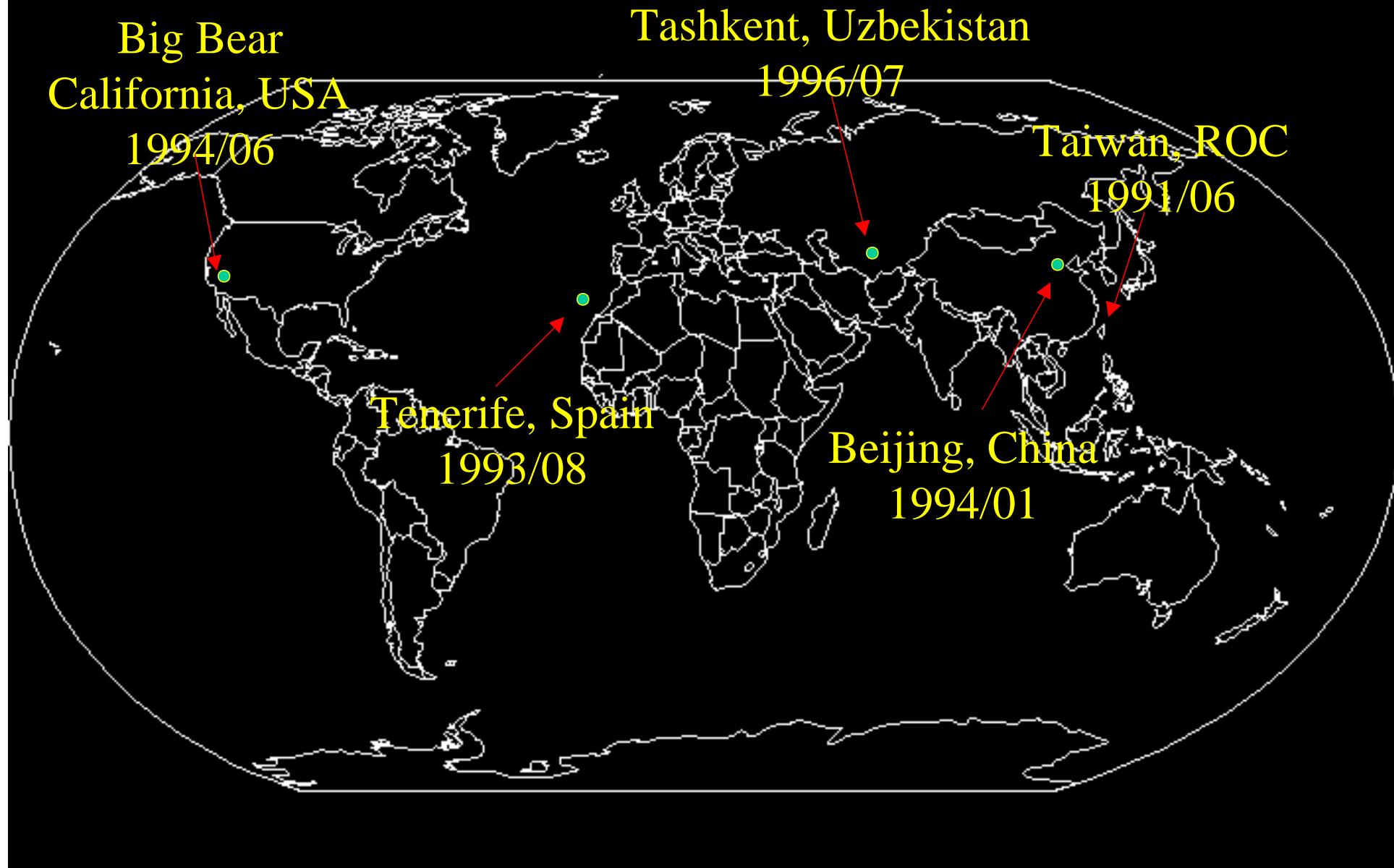
Pre-processing Procedures :

- Dark-current Removing
- Flat-field Correction
- Image Registration
- Image-size Reduction
- Brightness Normalization
- Limb-darkening Effect
- Site Connection

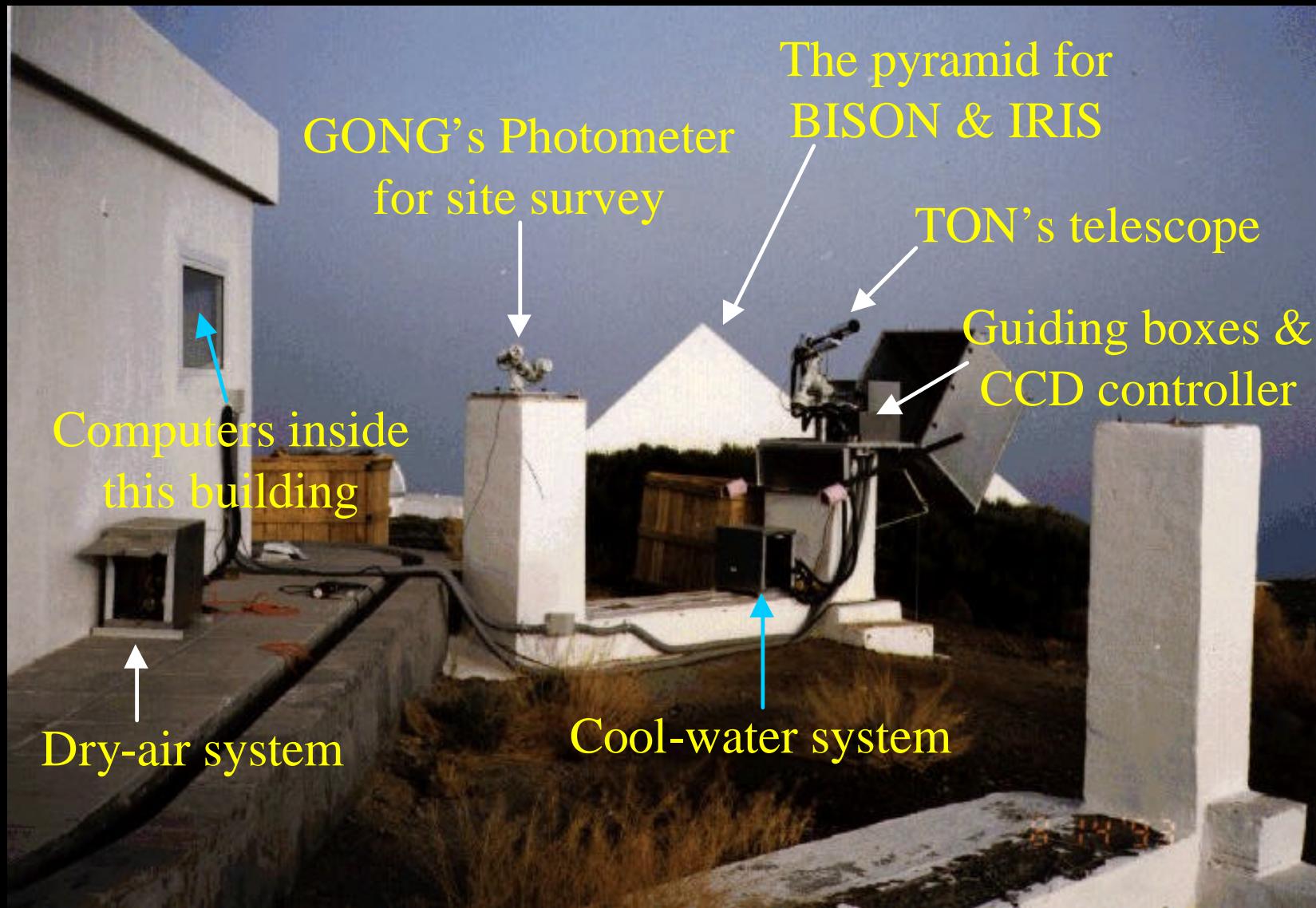
Solar Velocity Image



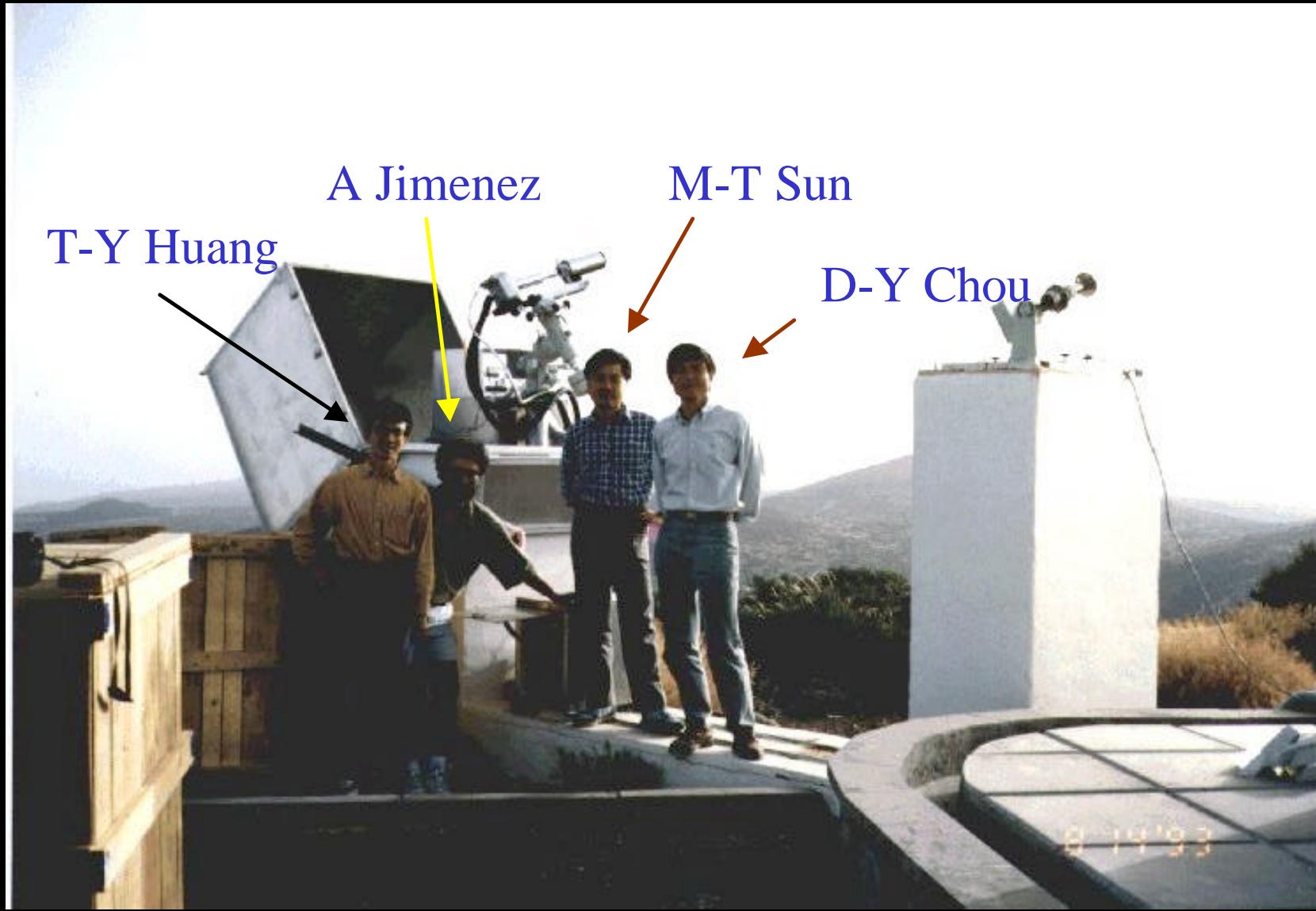
Sites of Taiwan Oscillation Network



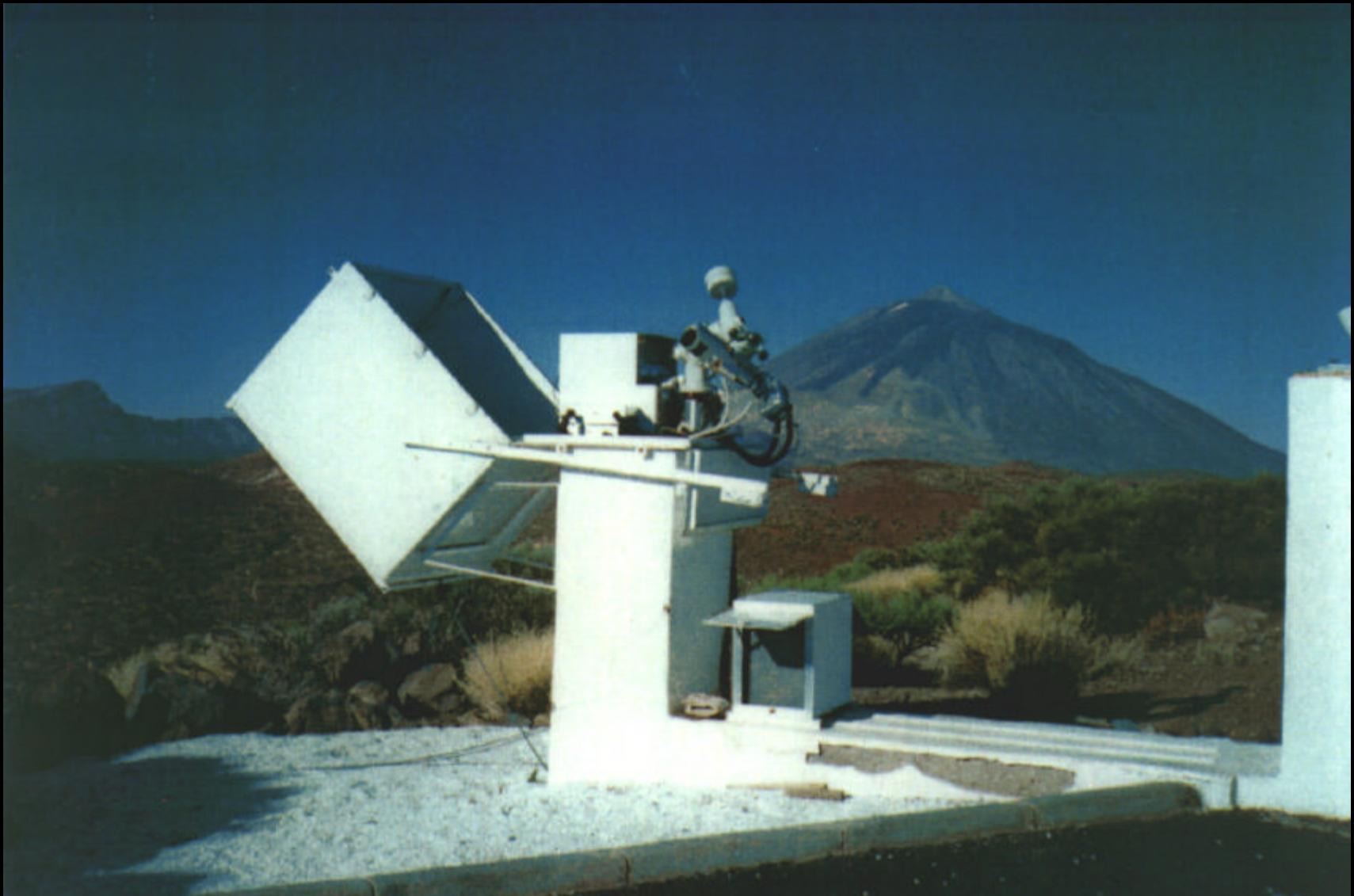
Tenerife — Observatory Initiation



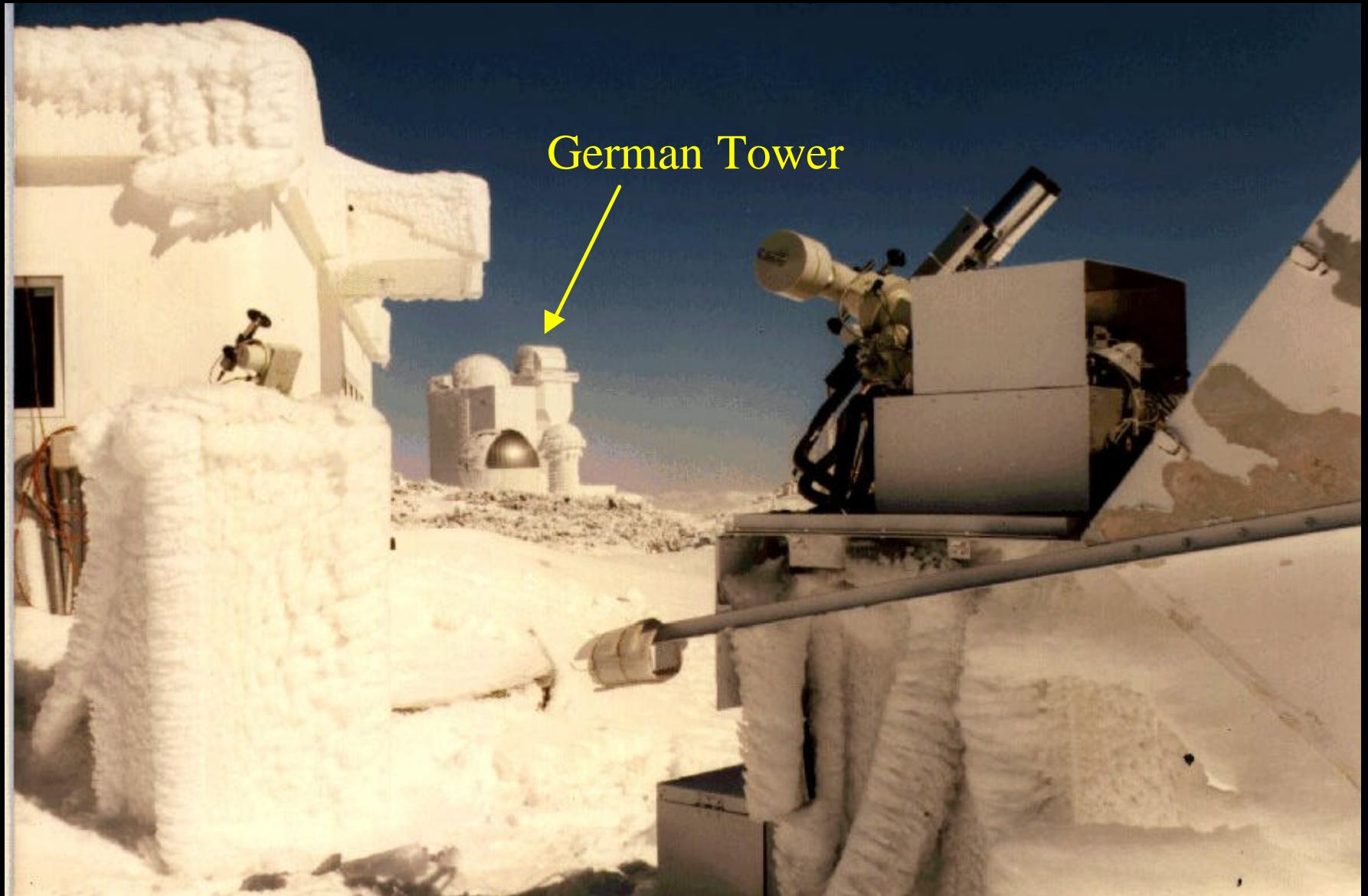
Tenerife — Project Pioneers



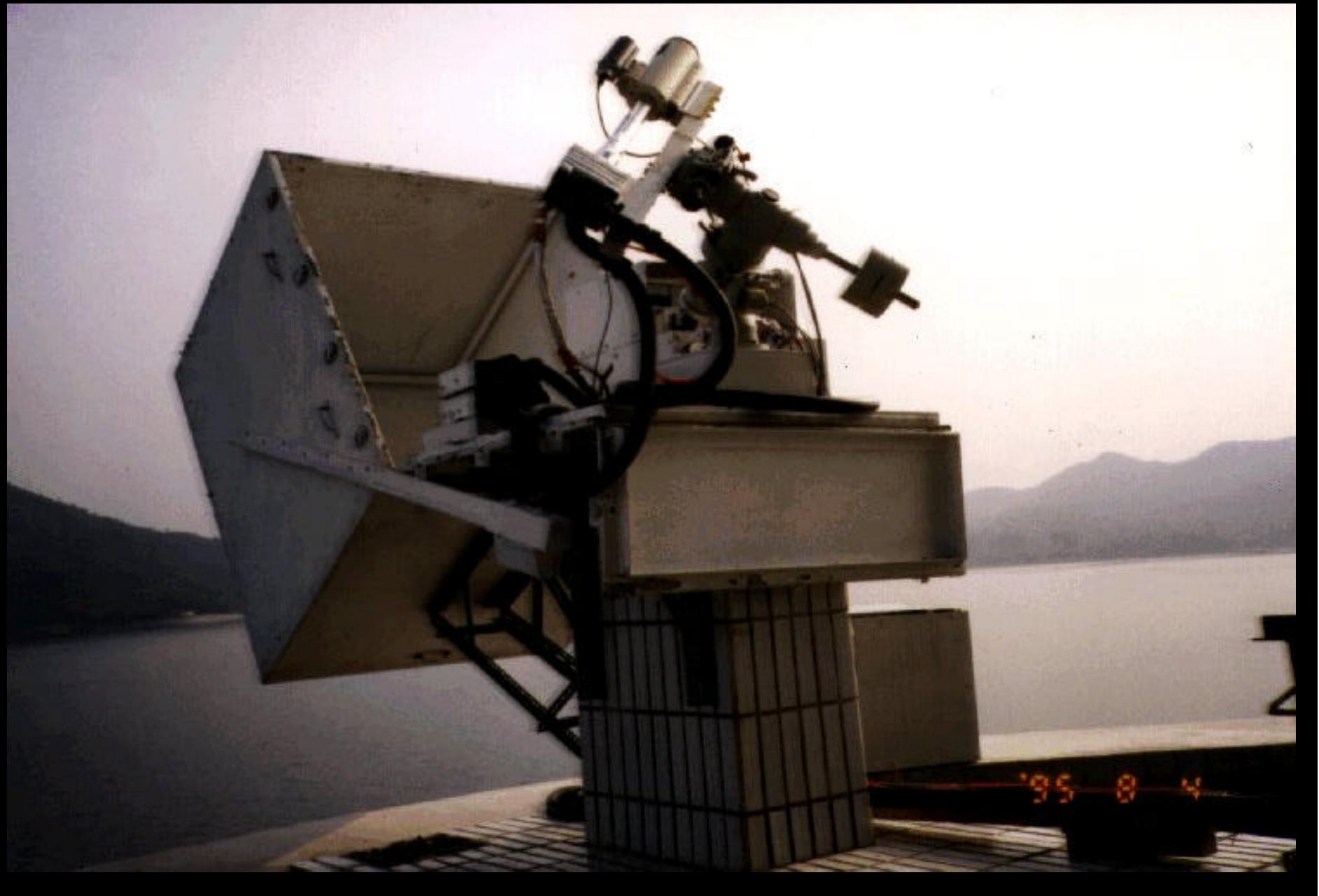
Tenerife — In the Summer



Tenerife — In the Winter



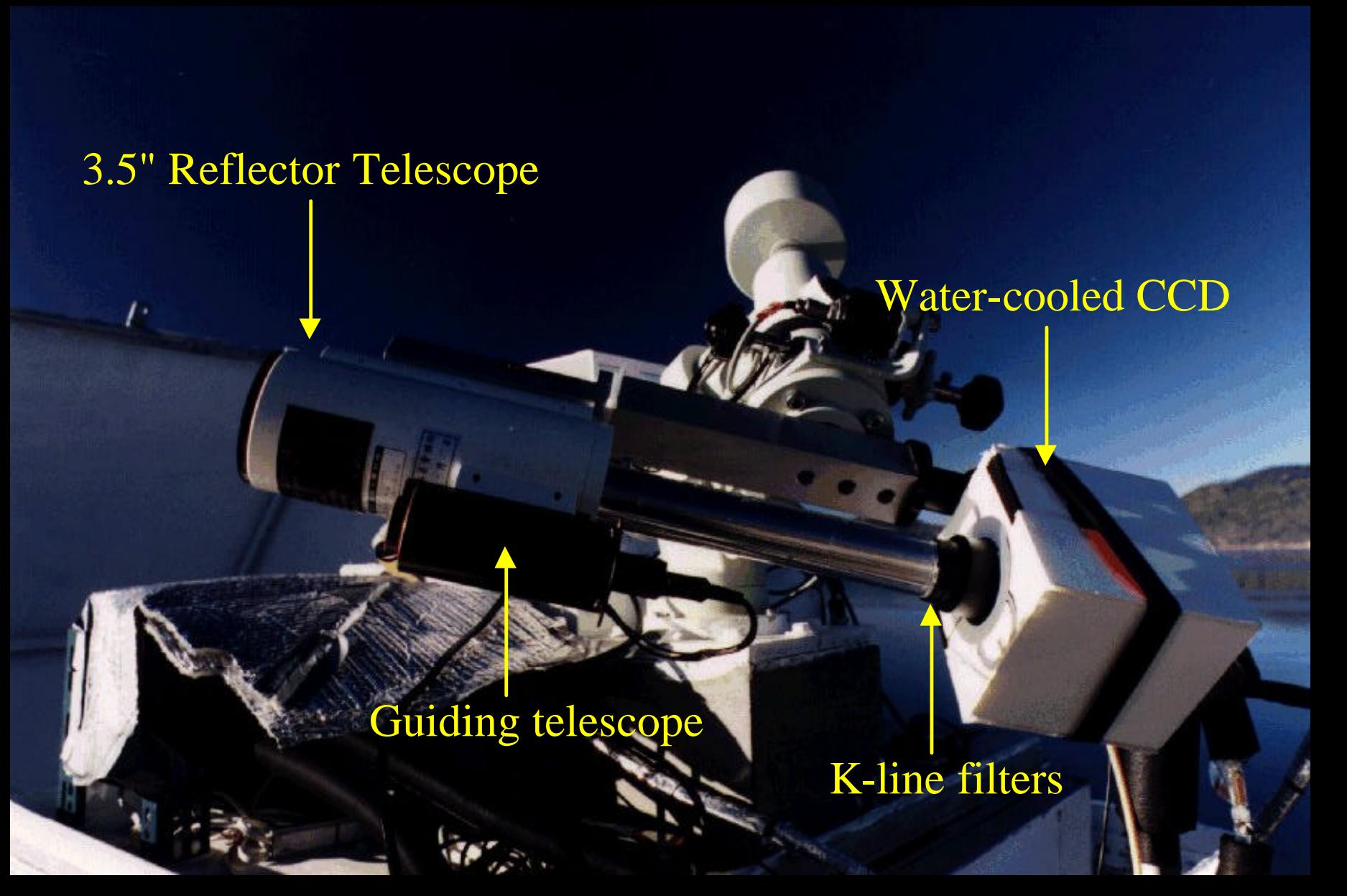
Huairou Lake, Beijing A Poetic Site



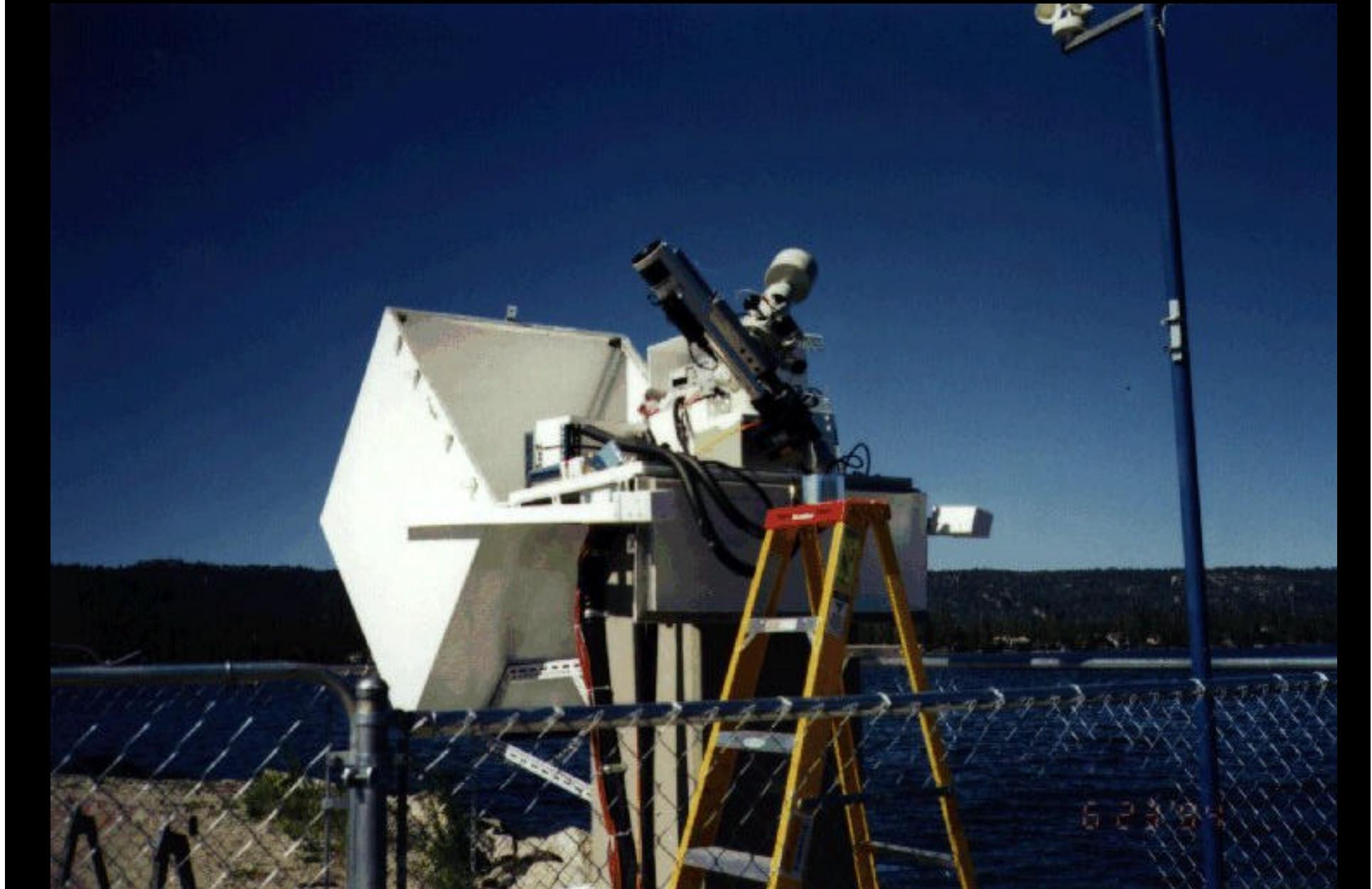
Big Bear Solar Observatory (BBSO, NJIT)



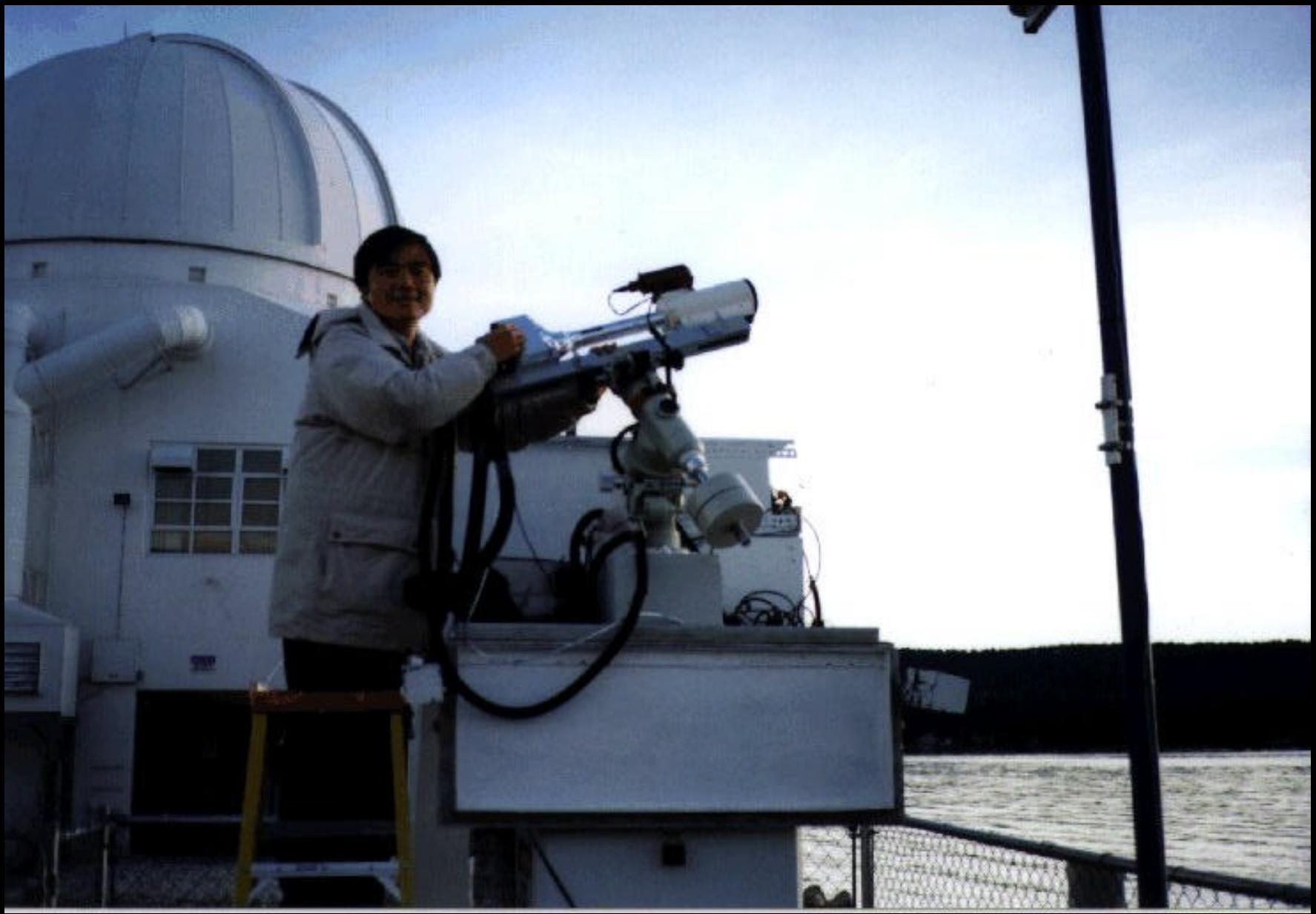
Big Bear — After Sunrise



Big Bear — In the Morning



Big Bear — After Sunset



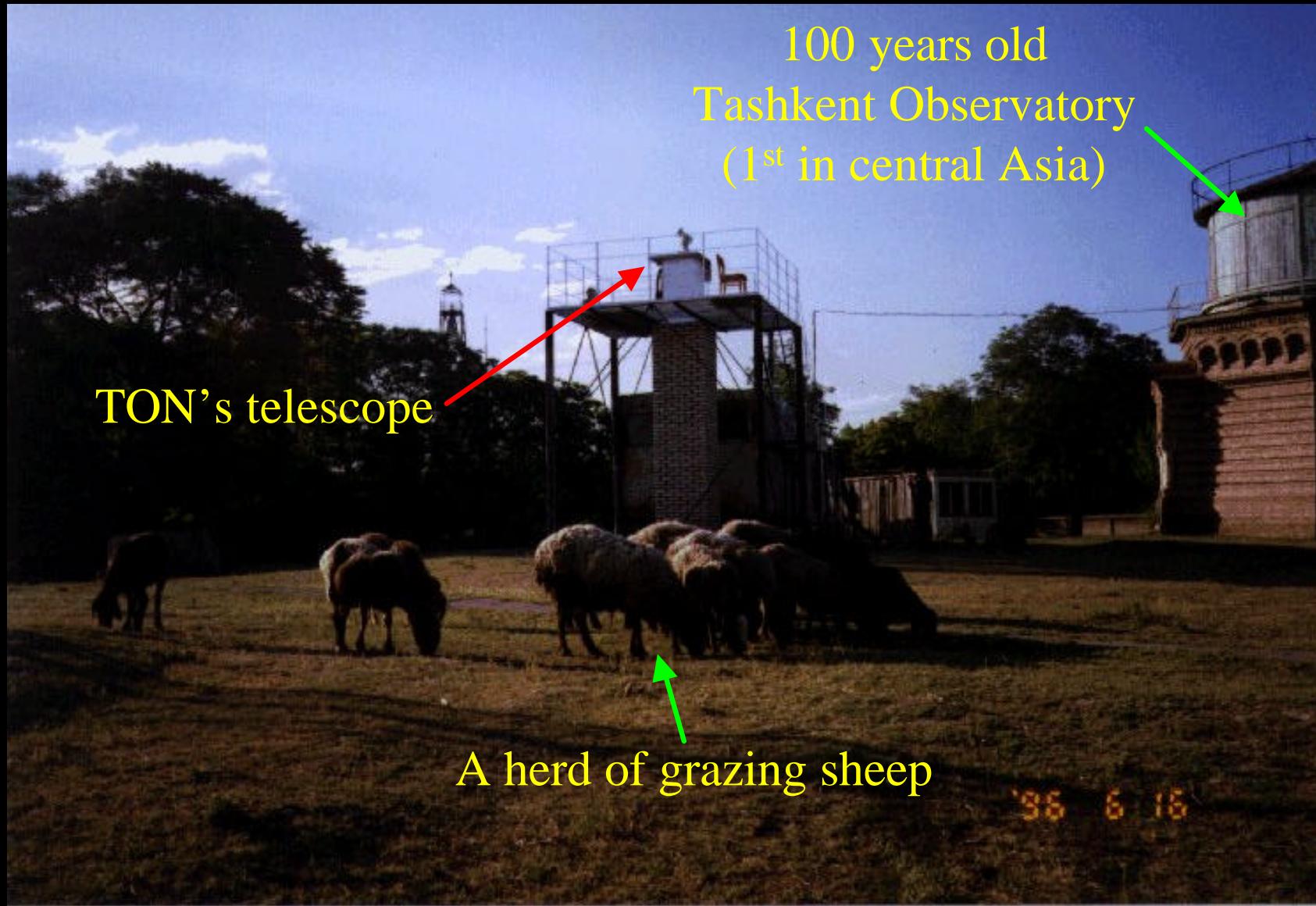
Big Bear — Indoor Instrument



Tashkent, Uzbekistan — The Installer



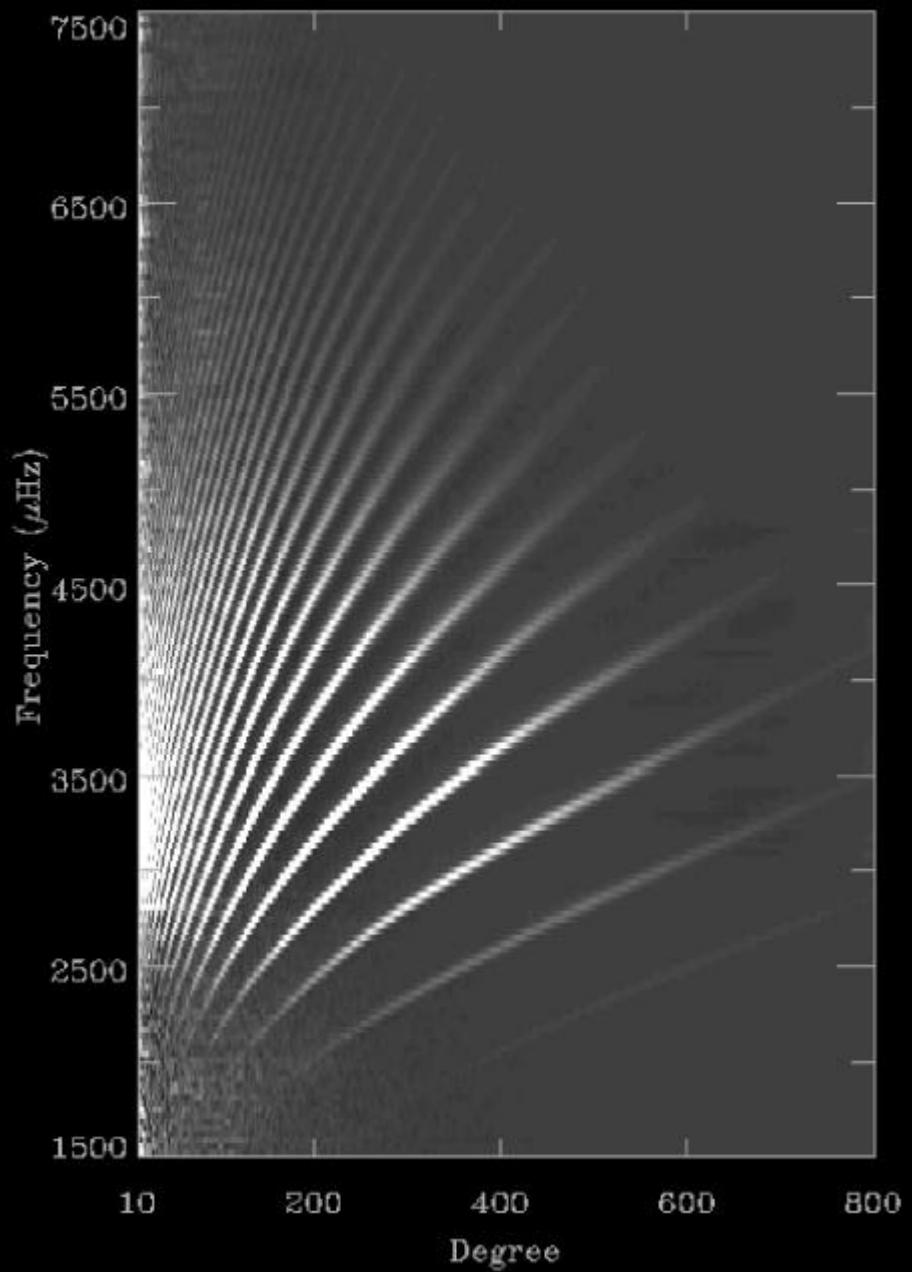
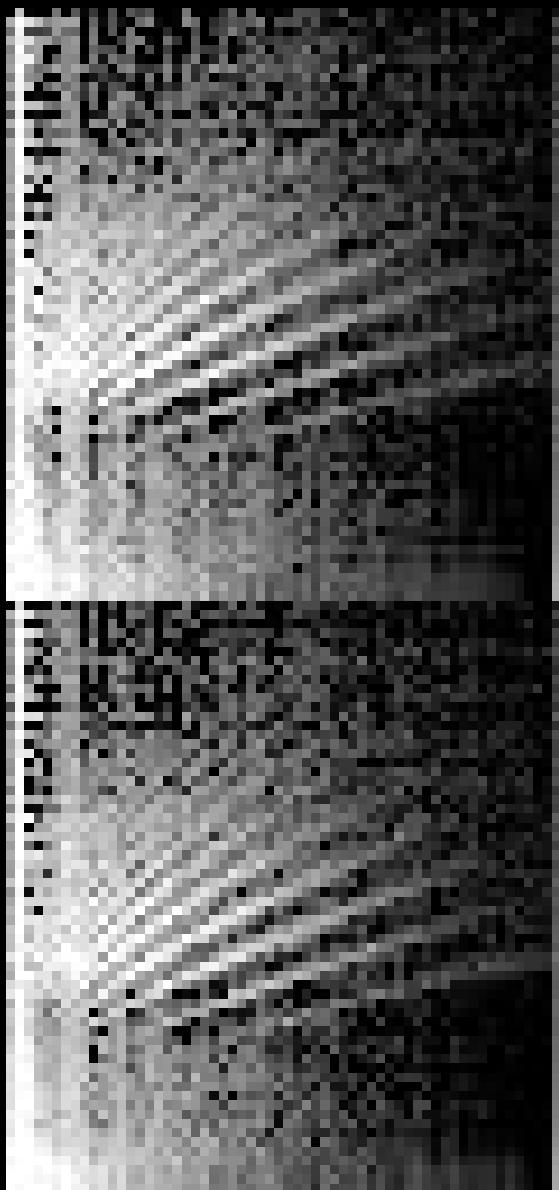
Tashkent, Uzbekistan — Sharing the Sun



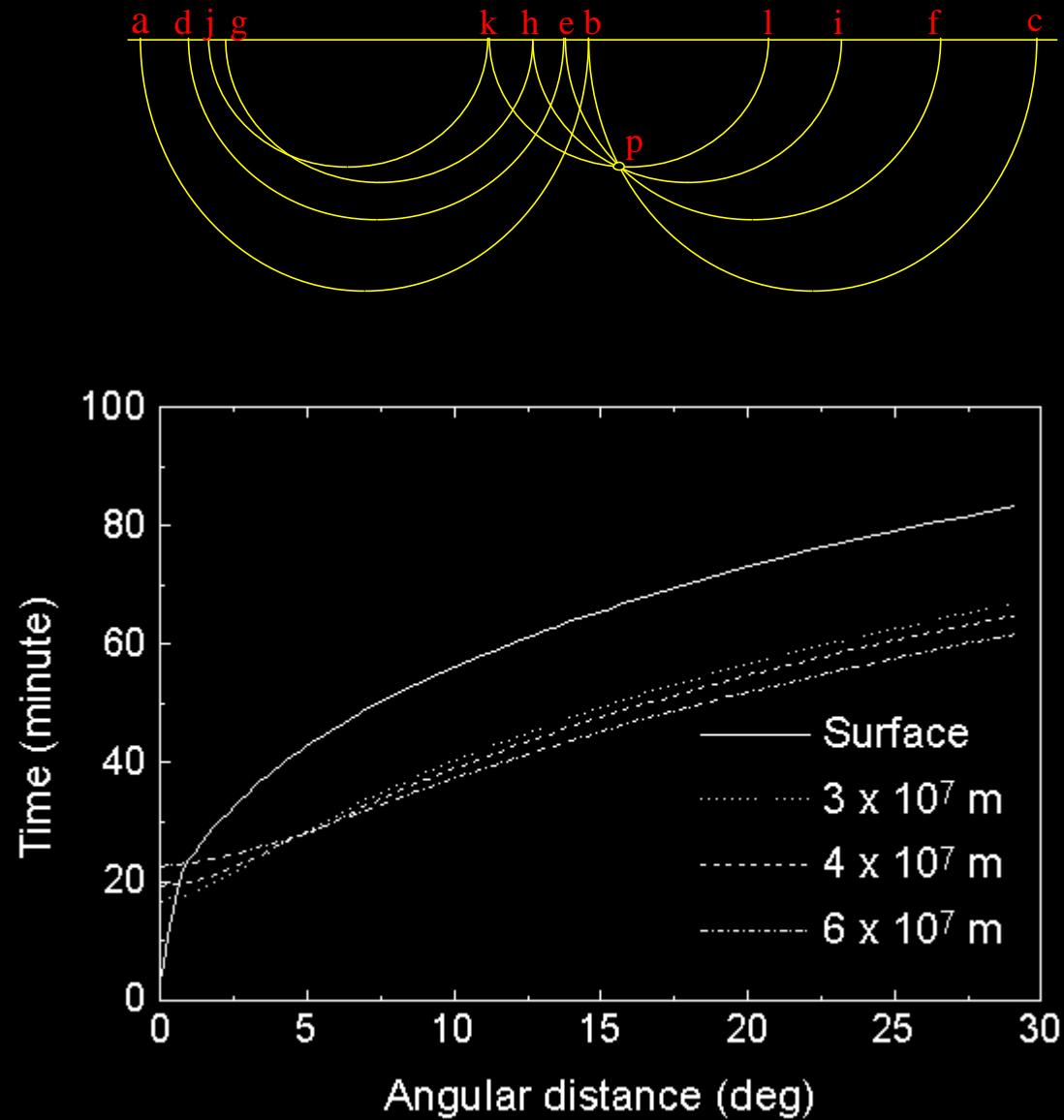
Tashkent, Uzbekistan — The Telescope



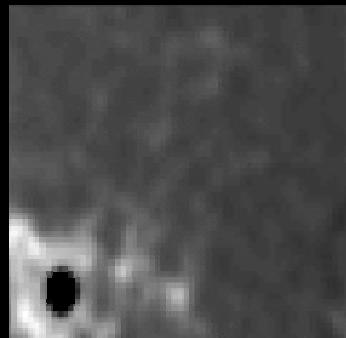
The First ℓ -Diagram



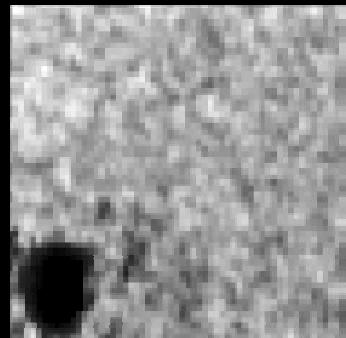
Acoustic Imaging



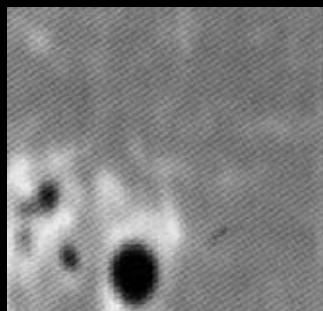
Acoustic Imaging



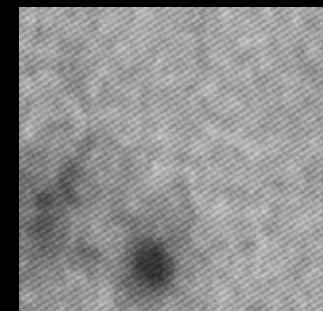
a Average Brightness



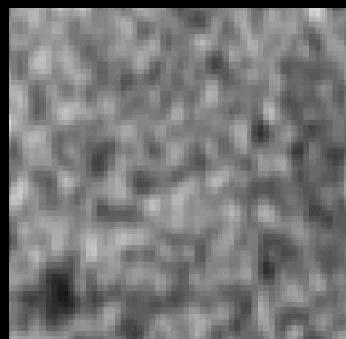
b Intensity Image



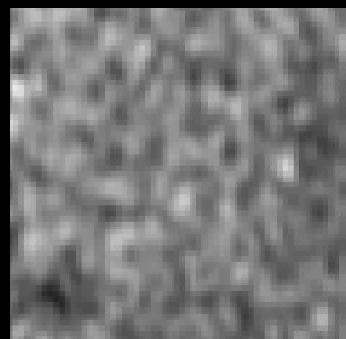
a Average Brightness



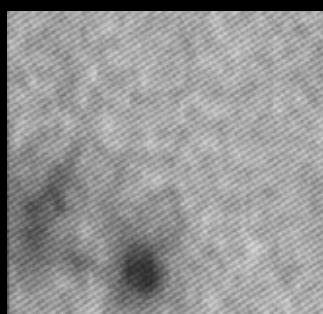
b Depth = 0 m



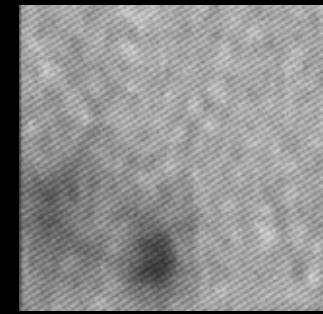
c Depth = 0 m



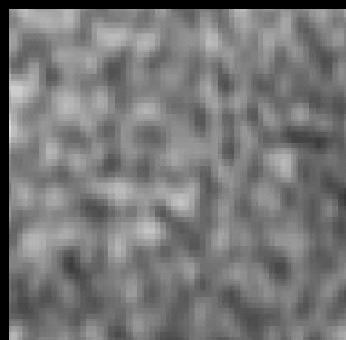
d Depth = 3×10^7 m



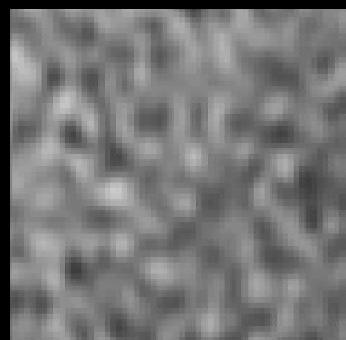
c Depth = 1×10^7 m



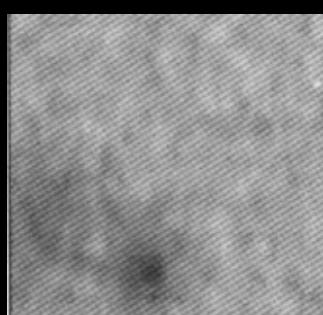
d Depth = 2×10^7 m



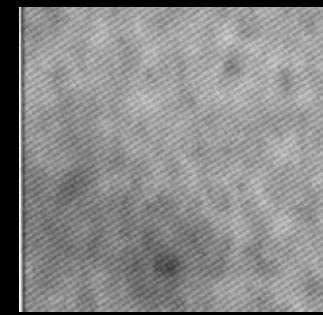
e Depth = 4×10^7 m



f Depth = 6×10^7 m

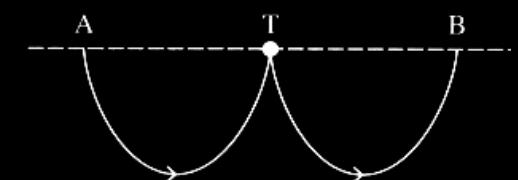
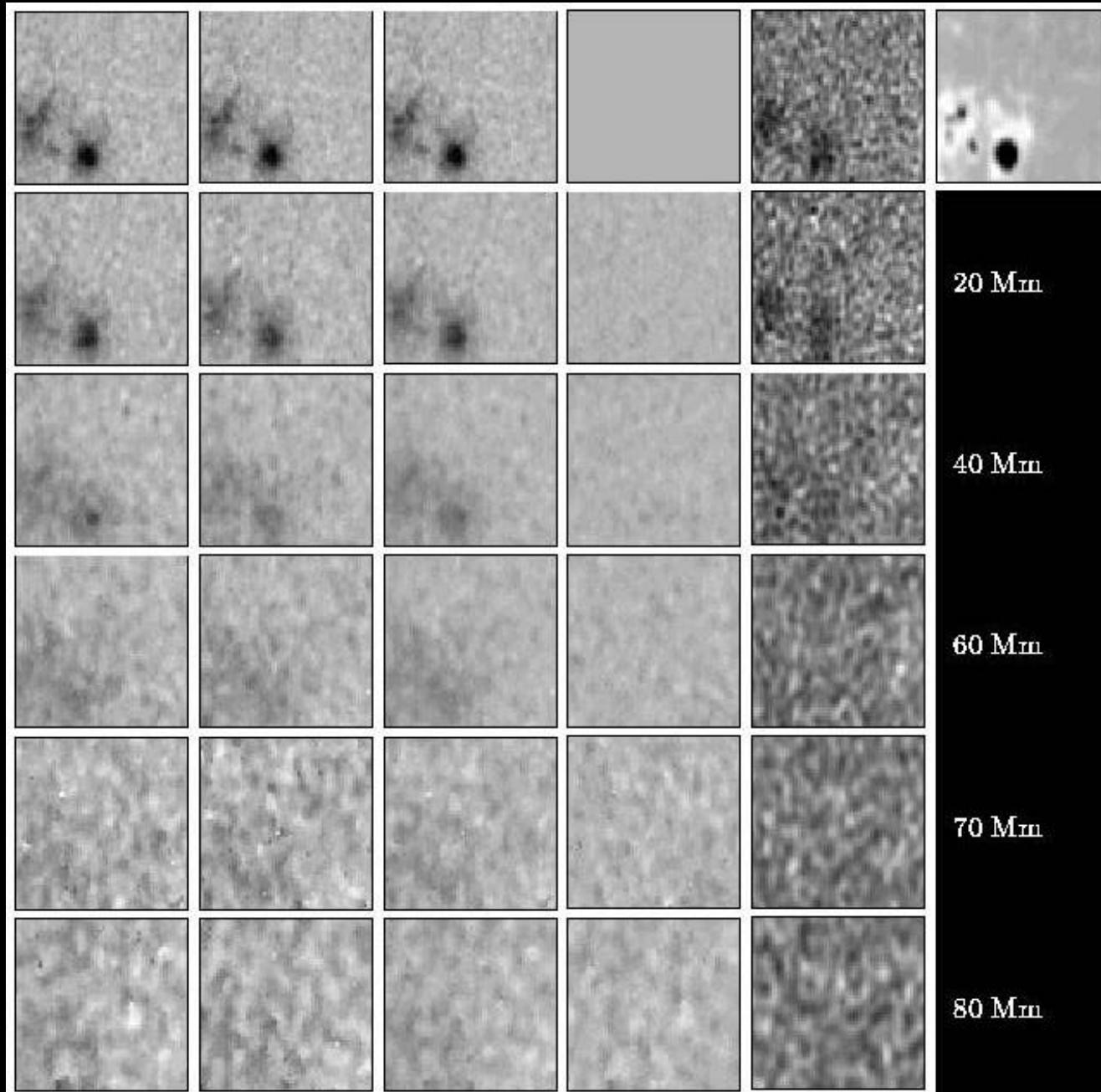


e Depth = 3×10^7 m



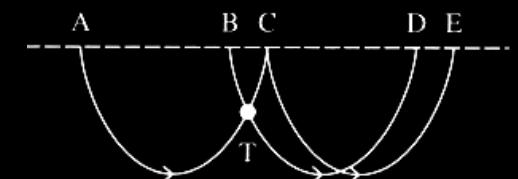
f Depth = 4×10^7 m

Acoustic Imaging – Experiments



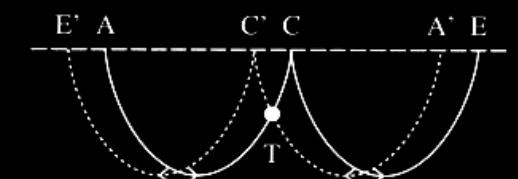
20 Mm

(a)



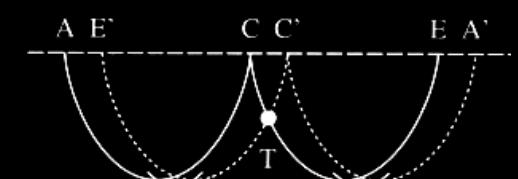
40 Mm

(b)



60 Mm

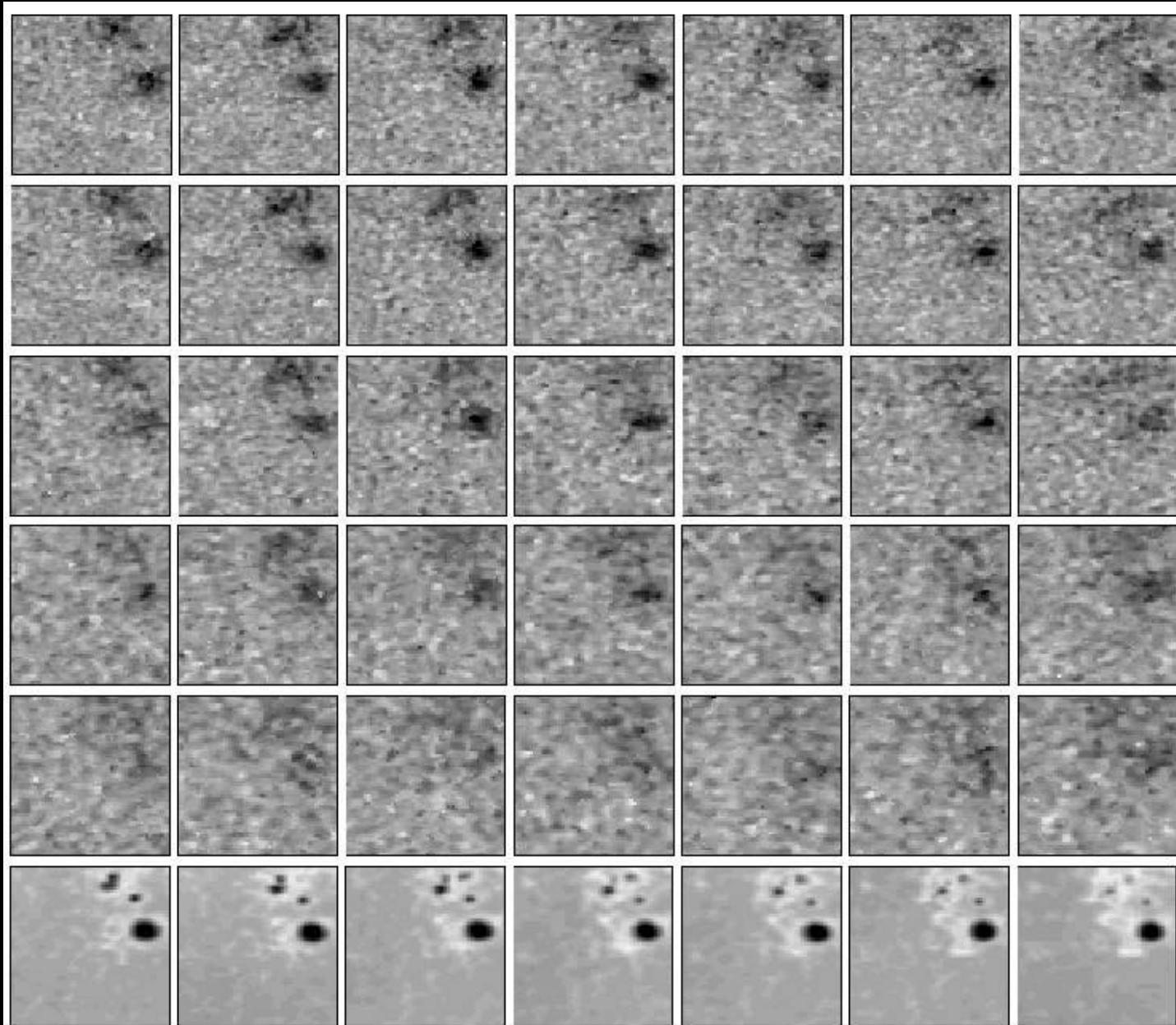
(c)



80 Mm

(d)

Acoustic Imaging – Tempo Evolution



Acoustic Imaging – Inversion Method

Model Source



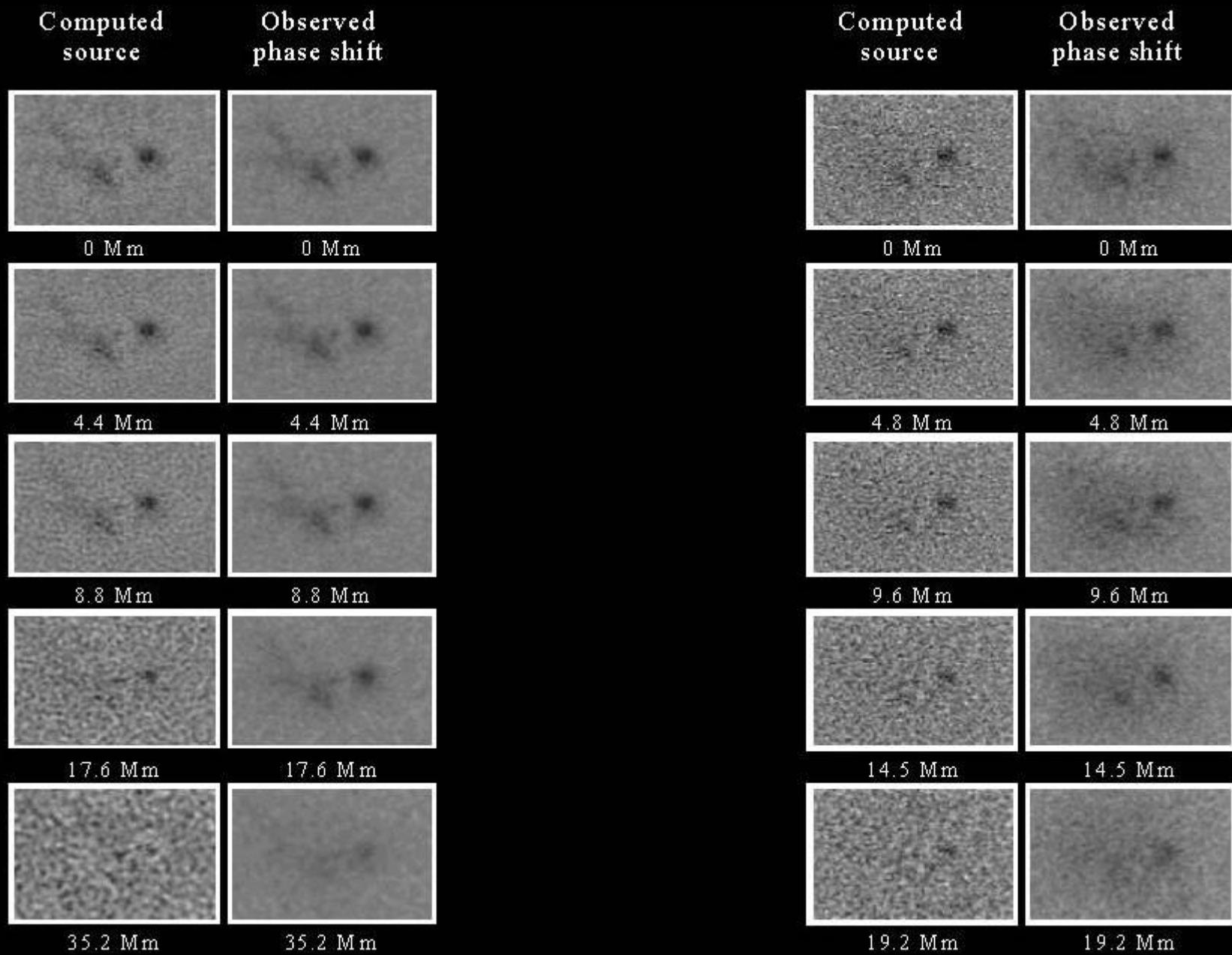
Computed Phase-shift



Estimated Source



Acoustic Imaging – Inversion Experiments



TON-related Academic Achievement

- 19 refereed papers
 - Nature 1
 - Ap. J. Letter 4
 - Ap. J. 10
 - Solar Phys. 4
- 3 invited talks
- 36 conference papers
- Initializing the Taiwan Earthshine Network project

URL: <http://ton.phys.nthu.edu.tw>