太陽観測におけるシーイング評価
Evaluation of the Seeing for Solar Observations

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1. Introduction
2. Solar Observations and the Seeing
3. Prospects for Solar Observations in Antarctica

1. Introduction

Collaboration with Night-Astronomy People

- We are greatly interested in the seeing condition at Dome Fuji etc.
- The Sun is a possible light source in summertime
  - Evaluation of the seeing condition at Dome Fuji etc. with the Sun
- Collaboration for a seeing monitor/imaging instrument for the solar observation

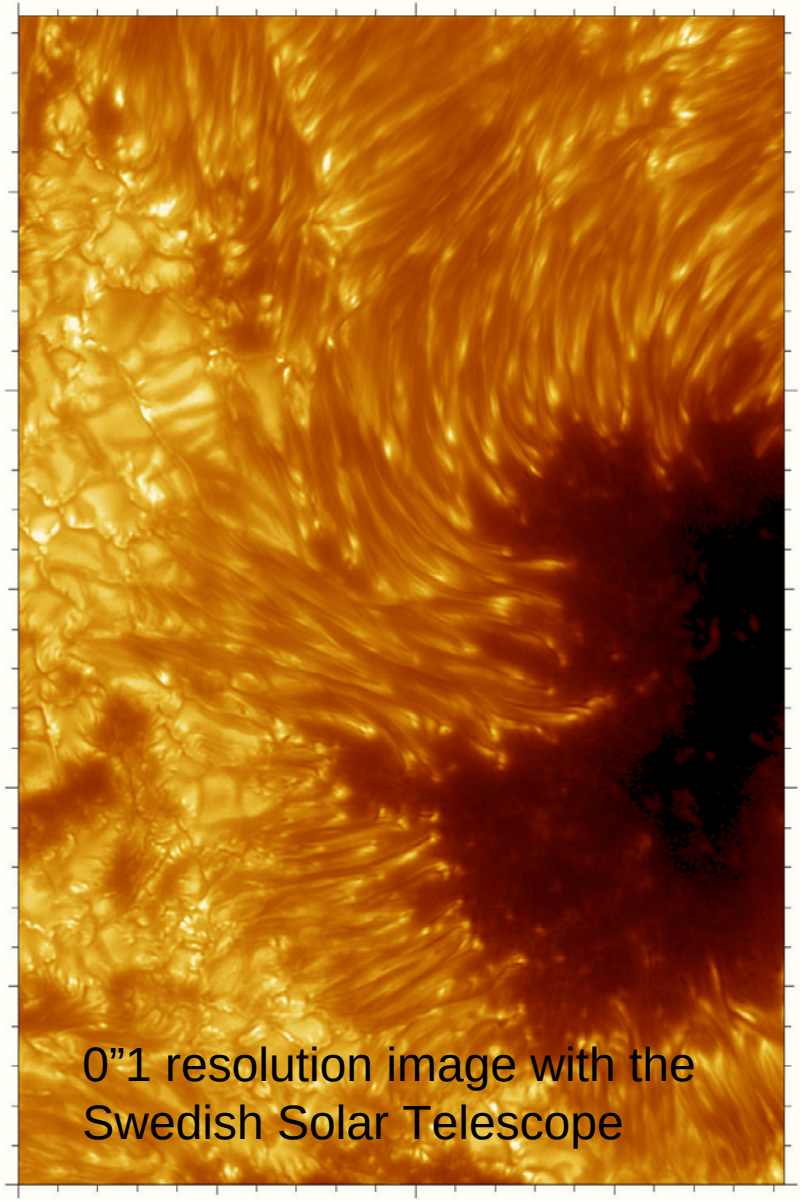
1. Introduction

Solar Observations and Antarctica

- Long, continuous sunshine
  - Seismology observations were attempted at the South Pole in 1970s-80s, but much attention has not been paid (e.g. Harvey 1989)
    - Weather condition was not very good
    - Seeing has not been considered to be very good
- Dome-C results (Lawrence et al. 2004)
  - *Excellent seeing*, good weather condition
  - Low scattered light
  - Low temperature, low water vapor pressure
- → attracting solar observers' attention

2. Solar Observations and the Seeing

- Spatial resolution 0.”1 has been quested for long time
- Late 1990s - Adaptive optics became in operation
  - Now 0.”1 resolution is available with a 1m telescope
- 2006- Hinode SOT realized 0”.2 resolution from space
- In future: stable high resolution/comparable resolution in IR
  - Bigger telescopes, diffraction limited, are required (at ground base)



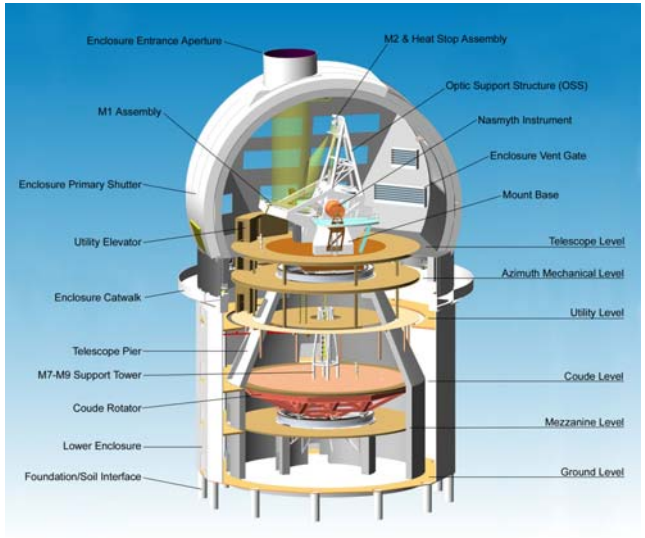
0”1 resolution image with the Swedish Solar Telescope

2. Solar Observations and the Seeing

How to evaluate the seeing for solar observations?

- Direct imaging
- With seeing measuring instruments
  - Combining S-DIMM (Solar Differential Image Motion Monitor) and SHABAR (SHAdow-BAnd Ranger)

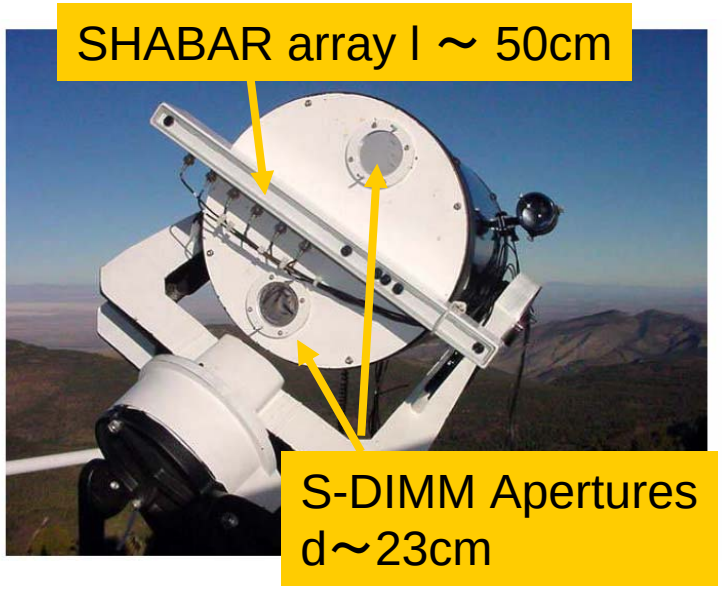
• Site tests for a 4-m telescope project, Advanced Technology Solar Telescope (ATST), were carried out extensively



2. Solar Observations and the Seeing

ATST Site Survey

- Seeing was measured with S-DIMM+SHABAR system
- Major solar observation sites were covered
  - 6 sites including Haleakala (Maui), La Palma(Canaries), Big Bear(California), ...

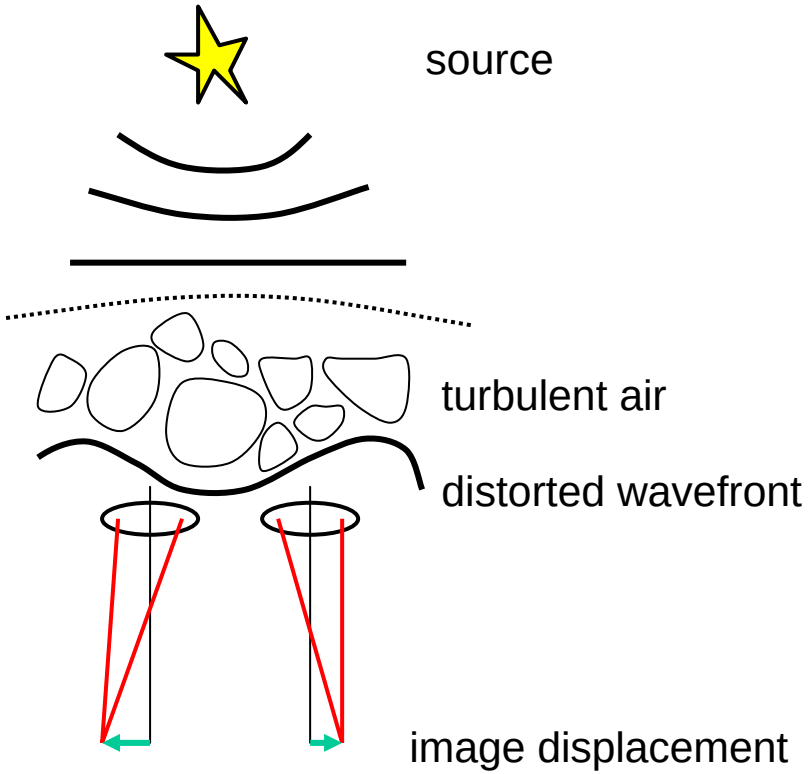


Big Bear(old photo)

(ATST Report #0021)

DIMM (Differential Image Motion Monitor)

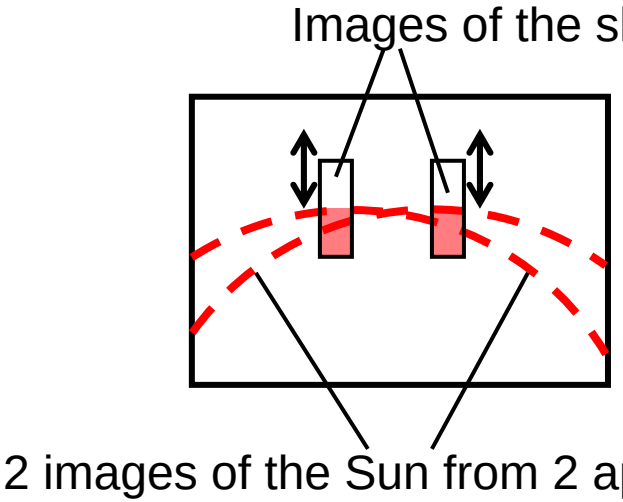
- Fried parameter (a measure of the seeing) is derived from differential image motions



2. Solar Observations and the Seeing

Solar DIMM

- The Sun is not a point source - the solar limb is used to measure image motions
  - 1-dimensional motions



2 solar images on a detector

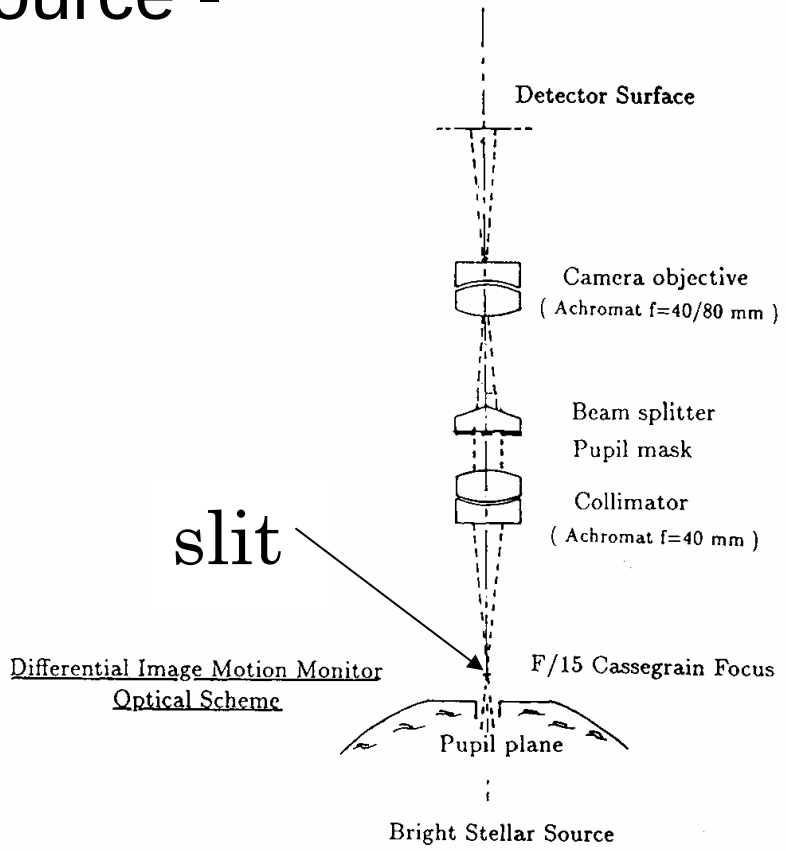
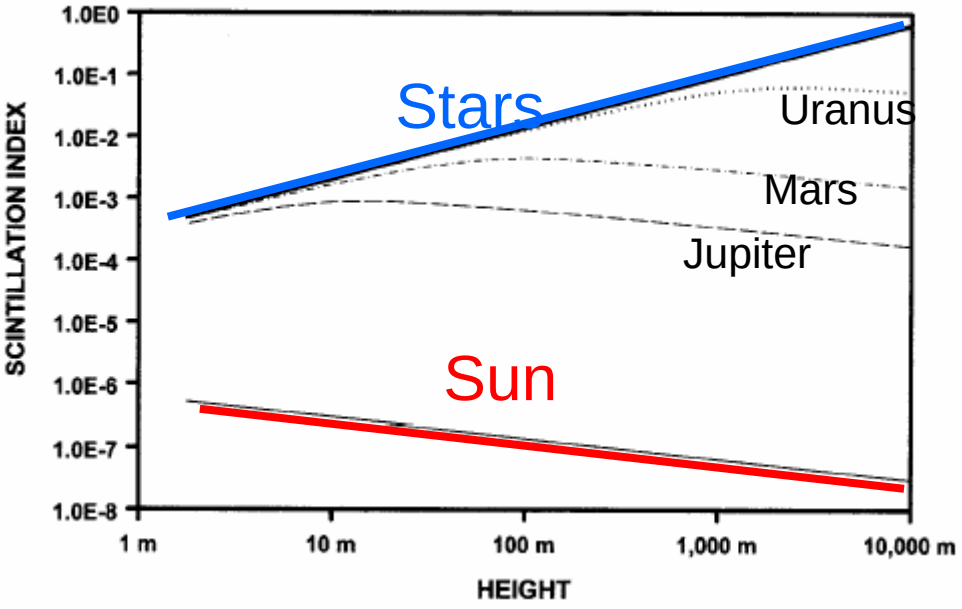


Fig. 2. Optical pupil imaging system

(Sarazin & Roddier, 1990)

SHABAR (SHAdow-BAnd Ranger) : Scintillation of the Sun and Stars

- σ_I^2 stars: $1 \sim 10^{-3}$ the Sun: $10^{-6} \sim 10^{-8}$
  - Fried parameter and scintillation: anti-correlation



Scintillation of the Sun and Stars

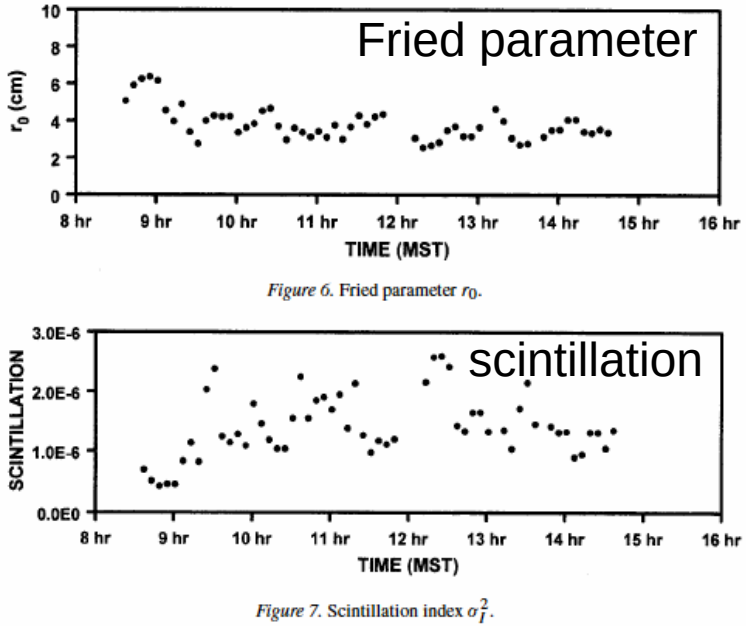


Figure 6. Fried parameter r_0.

Figure 7. Scintillation index σ_I^2.

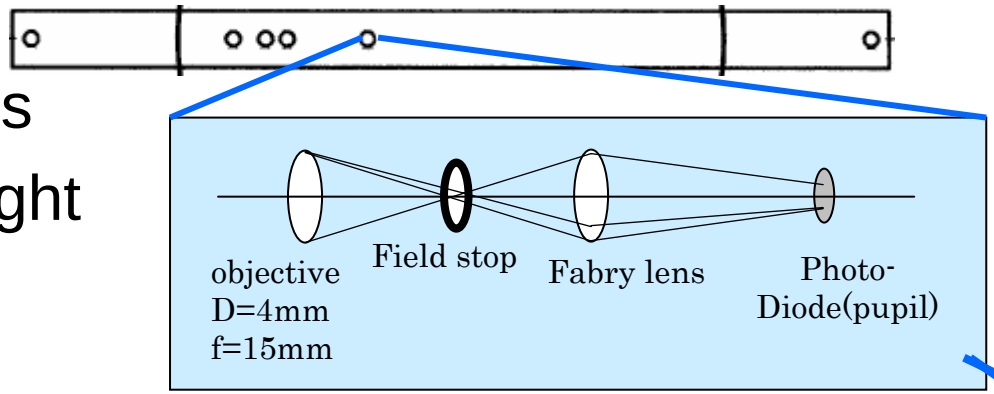
Fried parameter and scintillation

Beckers 2001

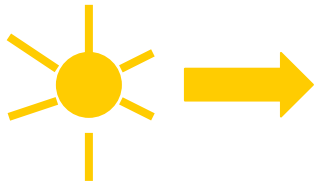
2. Solar Observations and the Seeing

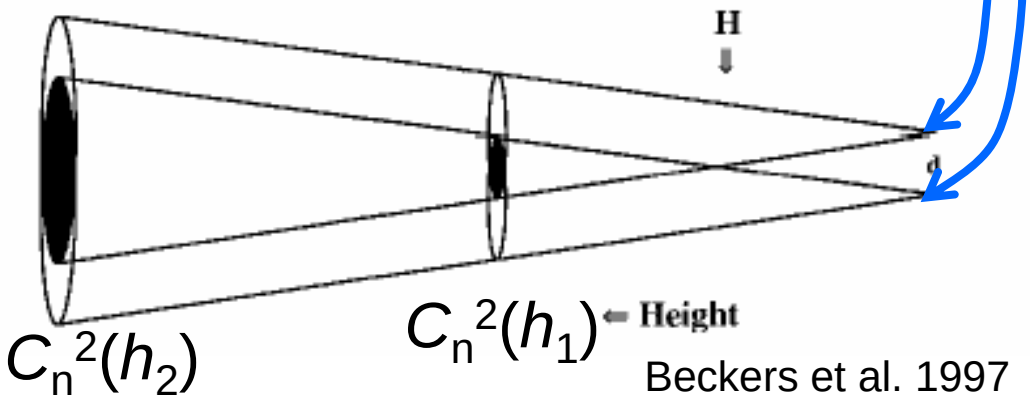
SHABAR

- Measuring the brightness of the Sun with a detector array
  - Very simple optics
    - The Sun is bright
  - 0.1～1200Hz



- Correlation between the scintillations shows $C_n^2(h)$ distribution

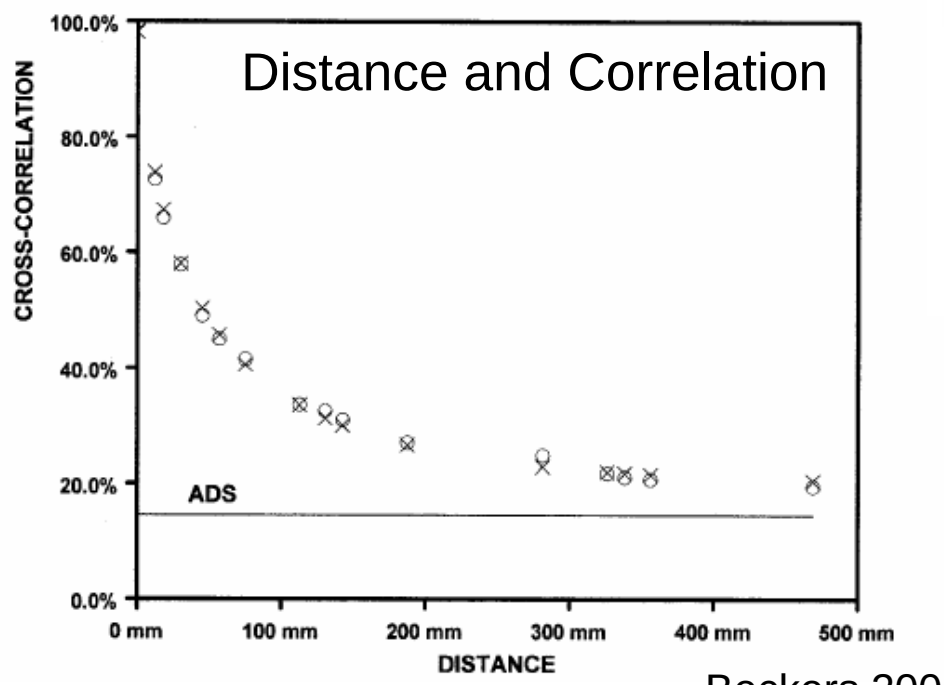


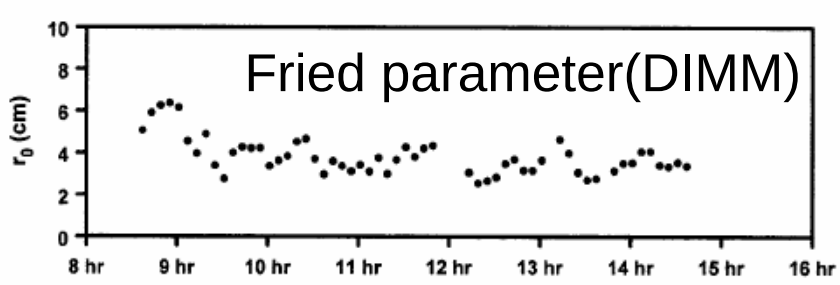


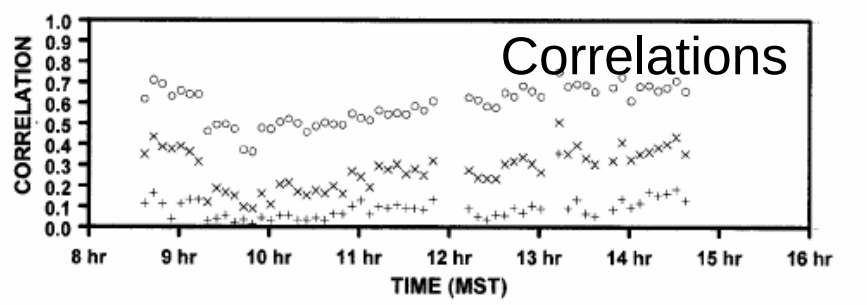
Beckers et al. 1997

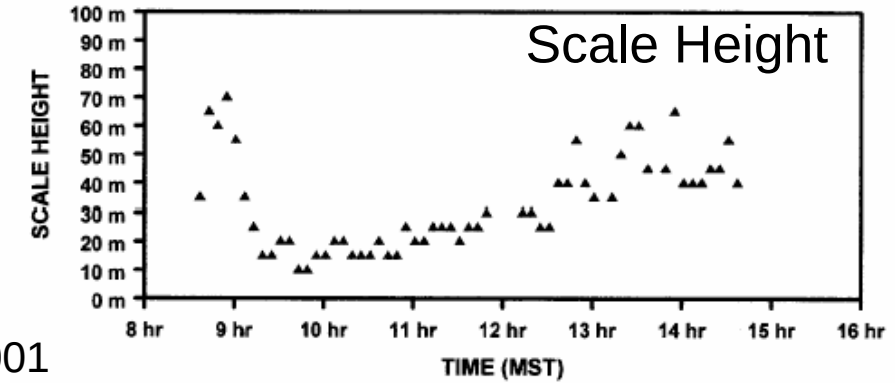
SHABAR

- An example of measurements
  - Combined with results from S-DIMM
  - height distribution of the atmospheric turbulence





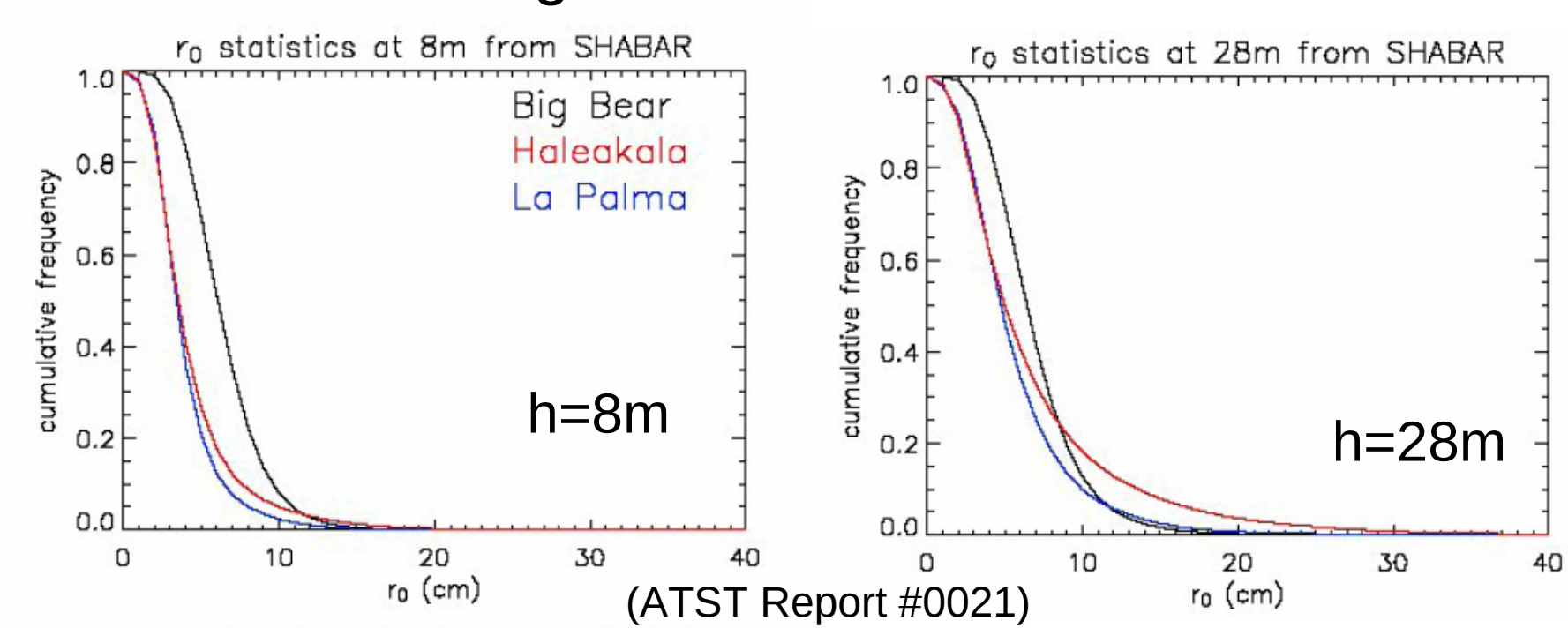




Beckers 2001

Seeing of the Best Solar Observing Sites

- Results from ATST site survey
  - Fried parameter r_0> 10cm: 10-20% of the observing time

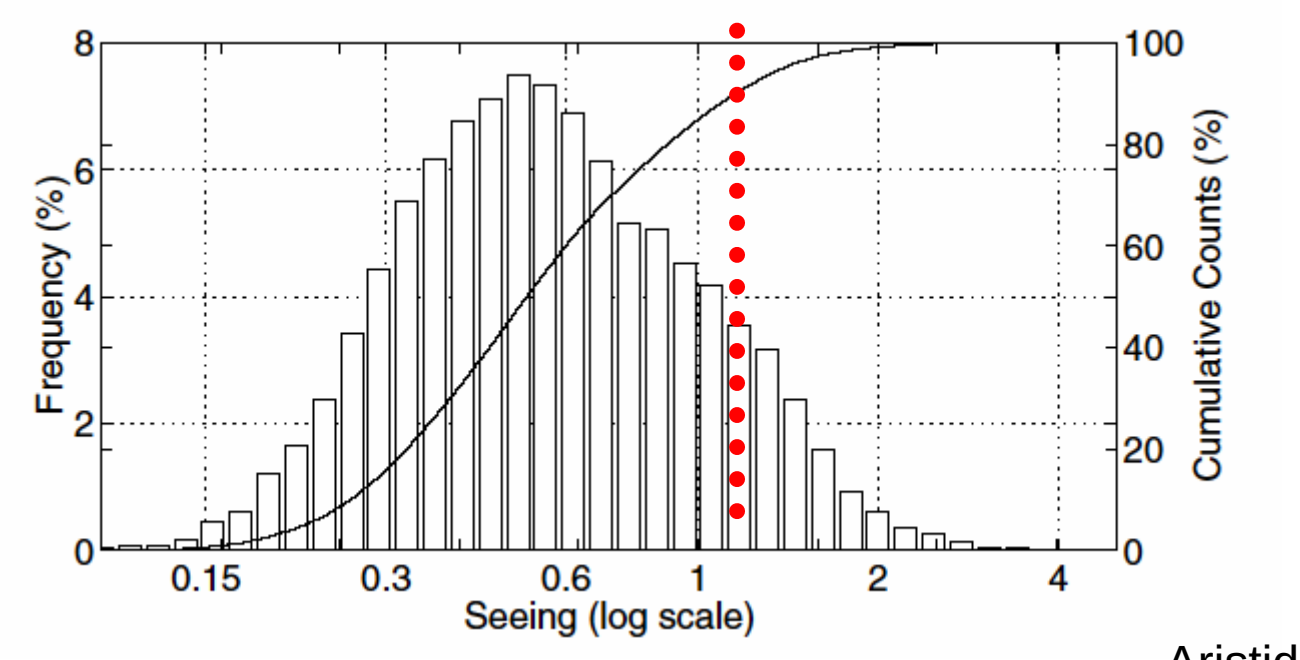


(ATST Report #0021)

2. Solar Observations and the Seeing

Seeing at Dome-C

- r_0> 10cm: 80% or more
  - Note: non-solar measurements, zenith
  - The seeing at Dome-C enables us to obtain diffraction-limited images without AOs??



Aristidi et al.(2005)

3. Prospects for Solar Observations in Antarctica

- 1. Evaluation of the seeing
  - Anyhow, activity will start in summertime
  - Seeing monitor instruments and/or simple imagings
- 2. Scientific Observations
- 3. Future Prospects

3. Prospects for Solar Observations in Antarctica

Evaluation of the Seeing at Dome Fuji etc. with the Sun

- S-DIMM/SHABAR
  - Our own seeing monitor: now constructing
    - For the room temperature, of course
- Imaging
  - Quality of usual white-light/G-band images are a good indicator of the seeing
  - Which telescope?

3. Prospects for Solar Observations in Antarctica

Scientific Observations with a moderate size telescope

- Diffraction limited imaging observations with a moderate size telescope (30～50cm) are still strongly required
  - Flares, prominences, polarizations, ...
- Can a simple telescope achieve the diffraction limit?
  - A candidate: open telescope
    - Non-vacuum telescope, which realizes diffraction limited image quality

3. Prospects for Solar Observations in Antarctica

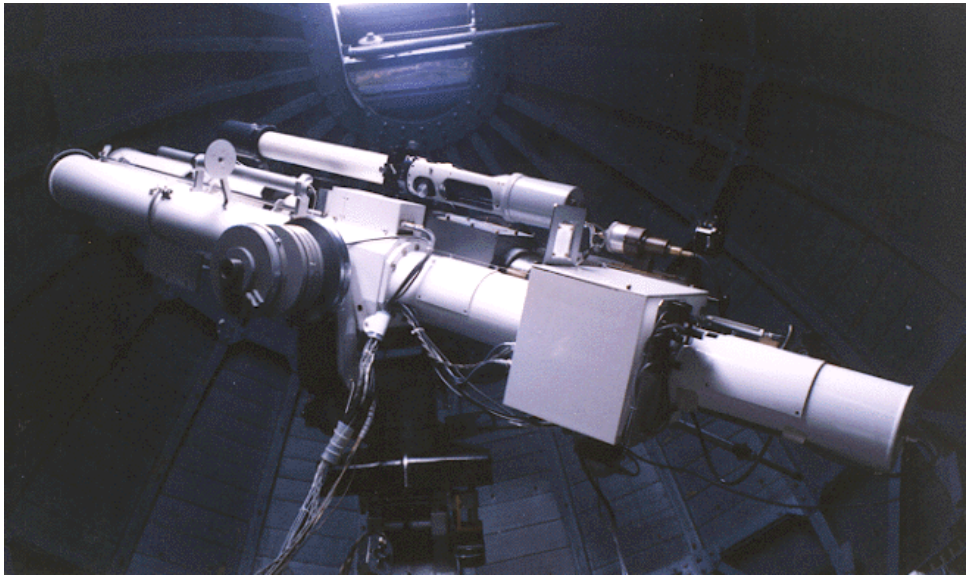
Open Telescope

- Dutch Open Telescope
  - 45cm, La Palma, 1997～
  - The first successfully operated Open Telescope
  - Without any active wind control
  - Structures and the secondary are cooled
  - Diffraction limit without AO
  - Imaging only
- A hint for solar telescopes at Antarctica

3. Prospects for Solar Observations in Antarctica

Scientific Observations with a Coronagraph

- Long lasting coronal sky (at Dome C)
  - A small coronagraph will produce high S/N images and Dopplergrams
- Coronagraph site after Norikura's shutdown?



A 10cm coronagraph of Norikura Solar Observatory, NAOJ

3. Prospects for Solar Observations in Antarctica

Future Prospects

- Not only the next generation visible-light solar telescope, but also a large aperture IR/Coronal telescope
- IR/Corona requires
  - a large aperture (>2m)
    - Difficult targets for space telescopes
  - Excellent seeing
    - Difficult targets for AO
  - low scattered light
  - low temperature, low water vapor pressure

- Coronal Magnetic field observations will become possible