# Site tests for CLEAR by solar scintillometry

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## Abstract

We briefly describe the ongoing site survey for the NSO CLEAR project which aims to put a large-aperture solar telescope at a superior location. The initial results indicate that lake sites are far better than mountain sites, at least in the US.

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## 1 Introduction: the CLEAR project

The NSO/NOAO CLEAR project is an ongoing feasibility study for a large-aperture (4 m) multi-purpose solar telescope that will combine high angular resolution with full infrared access and with coronagraphic capability. It should resolve the tiny fluxtubes in the photosphere (0.1 arcsec diameter), permit usage of the Zeeman diagnostics at 2.5 $\mu$m and 11 $\mu$m, and enable measurement of coronal magnetic fields with 1 Gauss sensitivity.

The current CLEAR concept (Fig. 1) consists of a Gregorian optical scheme with a thin off-axis parabolic primary. The latter is superpolished to 0.3 nm rms quality and is supported actively. The prime focus sits besides the incoming beam and has a cooled field stop. The telescope structure is not evacuated but is enclosed by an independently supported shroud. Temperature control inhibits mirror seeing and other local heating. Air flow regulation is used to avoid internal turbulence and dust. A 20-Zernike adaptive optics system is foreseen to produce diffraction-limited imaging at 1.6 $\mu$m. Extensive post-focus instrumentation will find place in a variety of foci.

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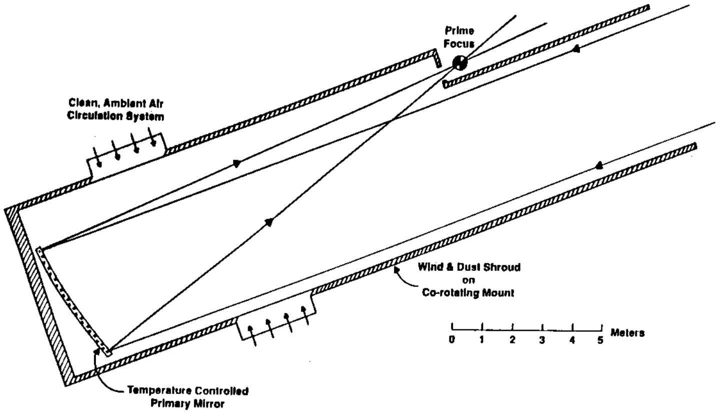


Fig. 1. CLEAR schematic. More details at URL http://www.nso.noao.edu.

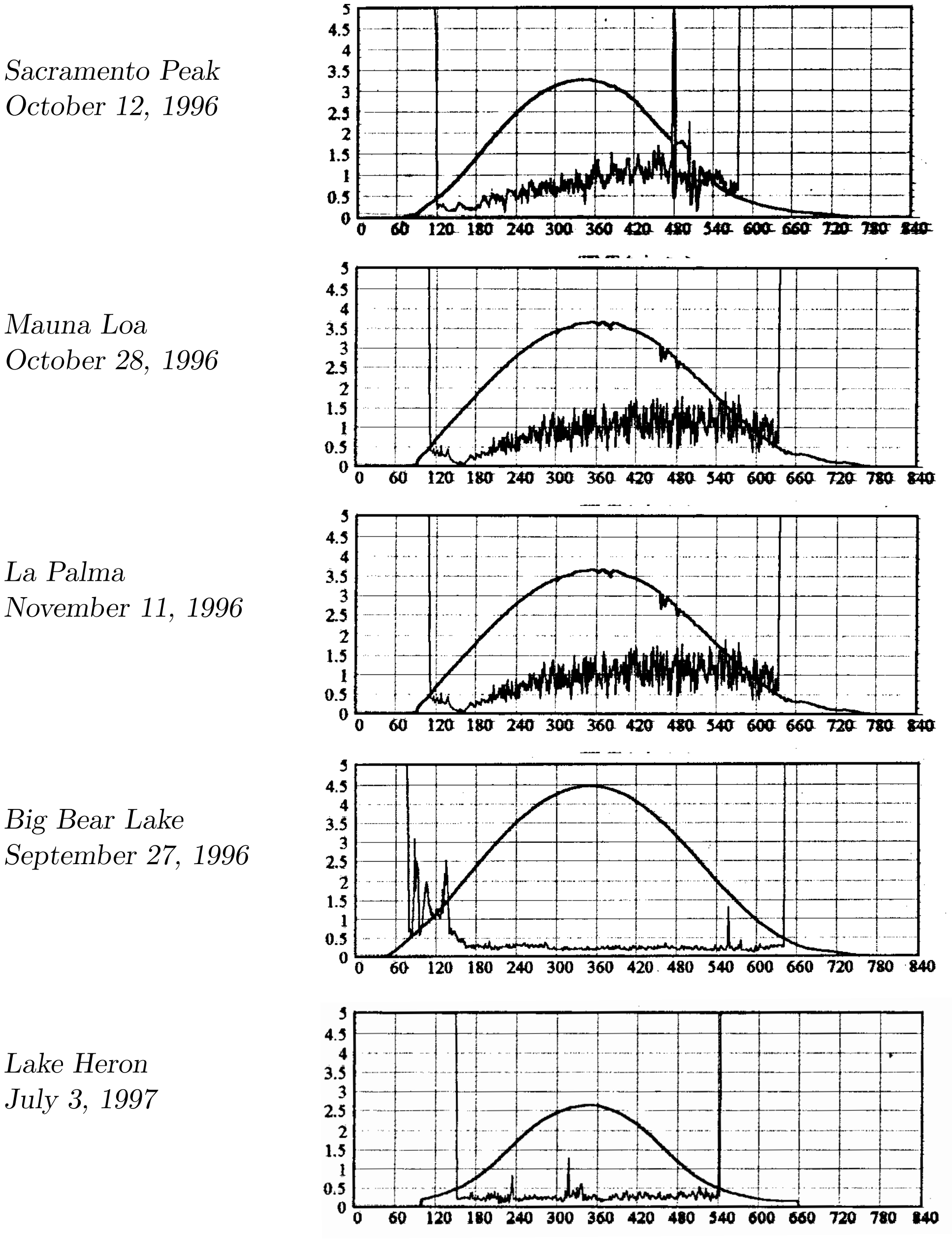
## 2 Survey method: scintillometry

The CLEAR site survey employs Seykora scintillometers (see [1] [2] [3] [4]). Each consists of a 1 $\mathrm{cm}^2$ photodiode mounted on an 11 m high mast and monitors sky irradiance in a 220 nm band centered at $\lambda = 510$ nm. The diode orientation is fixed, pointing to the celestial equator 20 degrees east of South. The irradiance signal is split with an analog circuit between the slowly varying solar illumination and the faster variations in the $0.3 - 1200$ Hz frequency band. The relative rms intensity variation $\sigma_I \equiv \mathrm{rms}\,(\Delta I/I)$ in the latter measures solar scintillation whenever the Sun is in the sky. This signal is digitized every 10 s during 14 hours per day.

Tests at the NSO/Sacramento Peak VTT have demonstrated that this irradiance variance correlates well with the granular contrast and with the image motion measured by granulation tracking. Thus, this simple gadget provides a direct proxy for the seeing disturbances that affect high-resolution imaging. Further analysis, given in [4], shows that the scintillometry signal predominantly measures low-altitude seeing, *i.e.,* the contribution by the boundary layer which for daytime solar observing is often dominated by turbulence due to ground heating. The reason for this selectivity is that the Sun is an extended object. The cone of rays from the detector to the solar disk spreads over tens of meters in the tropopause, so that the optical turbulence is averaged over larger area at greater altitude. The forthcoming Mark II scintillometers will use a spaced row of multiple Seykora detectors. Their individual cones will overlap at larger altitude, so that summation adds their signals constructively and gives larger weight to larger height.

## 3 Survey results: lakes versus mountains

Routine scintillometry measurements were started in October 1996 at Mauna Loa (3400 m), Big Bear (2070 m), Sacramento Peak (2800 m) and La Palma (the LEST site; 2350 m). Unfortunately, the latter mast did not survive one of the harsh icing and storm combinations which make the RdlM Observatory an inclement winter location; the La Palma data cover less than three months. Additional campaigns were started in the summer of 1997 at islands in Lake Heron (2150 m, northern New Mexico) and Elephant Butte Reservoir (1350 m, southern New Mexico) because the Big Bear measurements indicated good performance of lake sites, a conclusion that indeed led Leighton and coworkers to establish their observatory within Big Bear Lake [5].



*Sacramento Peak*
*October 12, 1996*

*Mauna Loa*
*October 28, 1996*

*La Palma*
*November 11, 1996*

*Big Bear Lake*
*September 27, 1996*

*Lake Heron*
*July 3, 1997*

Fig. 2. Results from the best days so far at five different sites. Abscissae: time in minutes. Smooth curves: low-frequency signal measuring solar illumination. The few dips are due to clouds. Jagged curves: scintillometer signals on a scale where unity corresponds to 1 arcsec seeing at Sacramento Peak.

Figure 2 illustrates that the scintillometry survey confirms Leighton's conclusion. Each panel shows the best day sofar at the specified site. Each curve is characteristic also for other days at each site. The smooth curves describe the low-frequency solar illumination, peaking before noon because the detector orientation favors the early-morning hours. The noisy curves are the scintillation component, plotted on a scale for which unity corresponds to about 1 arcsec seeing at Sacramento Peak. A calibration into Fried parameter $r_0$ values is given in [4].

The three mountain sites show similar behavior: good initial conditions are followed by deterioration. The latter increases steadily at Sacramento Peak and Mauna Loa and is attributed to solar ground heating and increased boundary layer turbulence.

The Big Bear curve starts with erroneous high values due to the shimmering reflection of the early morning sun on the lake surface. These are absent in newer data employing a horizontal shade below the detector. Later in the day, the Big Bear signal remains below 0.5 units without any hint of steady increase. The same pattern is seen for the Lake Heron signal.

Figure 3 summarizes the initial survey results in the form of median monthly values. These curves confirm the pattern that the lake sites perform significantly better than the mountain sites.

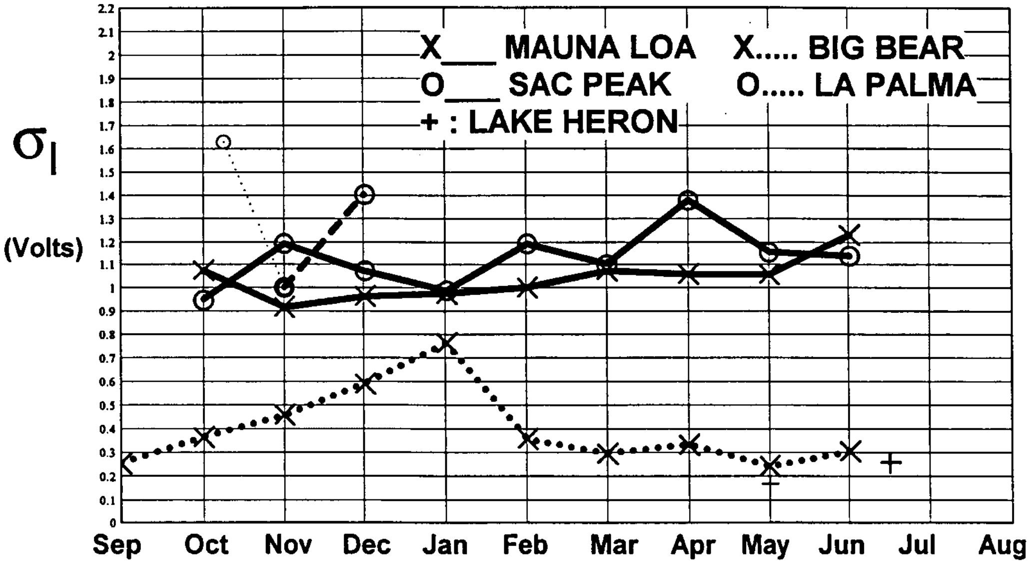


Fig. 3. Monthly median scintillation values per site. Only fully clear days are taken into account; some values are therefore based on small data sets. The initial La Palma measurements (dotted) had the detector still on the ground.

## 4 Discussion

The final proof is in the pudding, in the form of sharp long-duration image sequences. Sofar, the best have come from La Palma. Comparison of scintillometry outside and within the Big Bear dome indicates that Big Bear may gain considerably by eliminating disturbances within the dome.

It is a pity that the La Palma mast did not survive the harsh La Palma winter since the RdlM site may differ in character from the US mountain sites. The experience at the Swedish Vacuum Solar Telescope is that the best seeing, such as during the 11-hour high-quality sequence collected by [6], occurs when the trade wind is from the North and has $5 - 10$ m/s strength, strong enough to counteract the buildup of boundary-layer turbulence by solar heating that seems to affect the US mountain sites in the course of the day. The occurrence of this favorable wind pattern may be significantly less frequent than the occurrence of low boundary-layer turbulence at the US lake sites. However, the latter sites may be more often affected by jet-stream disturbances in the upper atmosphere. Planned scintillometry measurements at the Dutch Open Telescope on La Palma and at the German Vacuum Tower Telescope at Izaña and future Mark II scintillometry in the US may elucidate such differences.

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## References

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