Small-Telescope Astronomy on Global Scales
ASP Conference Series, Vol. 246, 2001
W.P. Chen, C. Lemme, B. Paczyński

The NCU Lu-Lin Observatory

Wean-Shun Tsay, Alfred Bing-Chih Chen[1], Kuang-Hsiang Chang and Huan-Hsin Li

Institute of Astronomy, National Central University, Chung-Li 32054, Taiwan

Abstract. The NCU (National Central University) Lu-Lin observatory is located at Mt. Front Lu-Lin, 120°52′25"E and 23°28′07" N, a 2862-m peak in the Yu-Shan National Park. The construction of Lu-Lin observatory was finished on January 14, 1999. The initial assessment of Lu-Lin site started in 1989, after which a three-year project was founded by the National Science Council (NSC) to support a modern seeing monitoring program. The average seeing at Lu-Lin is about 1.39 arc-second with an average of 200 clear nights annually. The sky background is 20.72 mag/arcsec^2 in V band and 21.22 mag/arcsec^2 in B band.

The Lu-Lin observatory is for both research and education. A home-made 76-cm Super Light Telescope (SLT) and four TAOS 50-cm robotic telescopes for a survey on Kuiper Belt Objects will be the two major research facilities. The pilot program for SLT consists of observations of time-varying astrophysical phenomena. The TAOS #1 telescope was installed at Lu-Lin in March 2000. A 90 KW/240 VAC power line and a water pipe system have been pulled to the site in early 2001. A wireless Network system through A-Li Shan has been operating at Lu-Lin observatory while a faster wireless Network system with 11.5 Mbit/sec bandwidth is under consideration and may be available in the near future for remote observing.

1. Introduction

We started the first site survey for a modern observatory in Taiwan in 1989. The original plan was to move the NCU 24" telescope from the campus to a suitable site in the central high mountain range of Taiwan. Weather station data and infrared satellite cloud cover data for Taiwan were studied to identify potential sites (Table 1) for further investigation.

Mt. Front Lulin (Figure 1), due to its flat summit and relatively easy access, was eventually selected and a three-year seeing study followed. Lu-Lin, located within the vast region of the Yu-Shan (Mt. Jade) National Park and Forest Reserves, at an elevation of 2862 m, is a five-hour drive from the NCU campus.

[1]Current Address: Department of Physics, National Cheng-Kung University, Tainan 70101, Taiwan

https://doi.org/10.1017/S0252921100079124 Published online by Cambridge University Press

Mt. Front Lu-Lin	2862 m	Mt. Lu-Lin	2860 m
Mt. Stone-Water	2770 m	Mt. Ali	2406 m
Mt. Small Snow site #1	2550 m	Mt. Small Snow site #2	2990 m
Mt. Pear	2600 m	Mt. Ho-Huan	3400 m

Table 1. Potential Sites for Taiwan optical telescopes

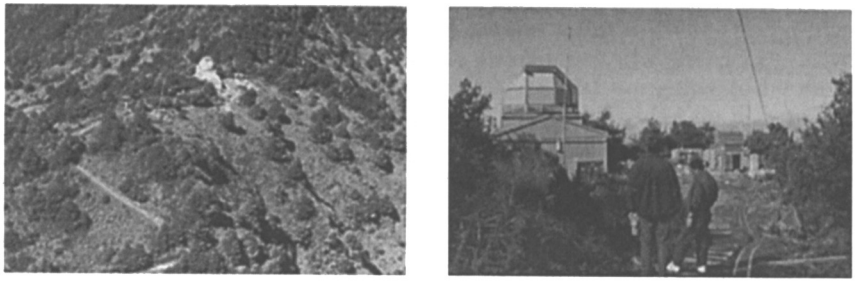


Figure 1. **Left**: A bird's-eye view of the Lu-Lin summit. A trail is visible to the lower left.
Right: A close-up view of the 6m dome that houses the SLT. The small enclosure to the central right houses one of the TAOS telescopes.

2. Seeing Study

The visible seeing α is defined as

$$\alpha = 2 \times 10^5 \cdot (\lambda / r_0)$$

where α is in arc-seconds, λ in μm , and r_0 in units of cm is called the Fried parameter (Fried 1965, 1966), defined as the coherence radius of the wavefront distorted by the turbulent atmosphere. The Fried parameter, r_0, is thus a function of the turbulence, the refractive index, the wavelength of the transmitted light, and the air-mass above the telescope. Typically, at a reasonably good site, α is about one arc-second or less.

Seeing is considered as the utmost important factor for most observations (Woolf 1982). For direct imaging, spectroscopy, photometry, and interferometric observations, seeing determines the spatial resolution, limiting magnitude and instrument speed. There are many methods to estimate the seeing such as direct visual estimates, star trailing, high-speed photoelectric image scanning, monitoring of differential image motion and image profile width, speckle interferometry plus pupil imaging, and shearing interferometry (Ardeberg 1987).

For the Lu-Lin site survey, we designed a portable optical seeing monitor with a Celestron C-14 mounted on a Takashi NJP equatorial mount and a high-sensitivity CCD TV-camera (Philips Amprex NXA 1031/01) as detector (Figure 2, right). This seeing monitor recorded real-time images of stars whose profiles were then analyzed by an IBM-AT/compatible clone equipped with a video digitizer board at a rate of $\sim$ 1/30 sec. After a three-year seeing study at Lu-Lin, we found the average seeing to be about 1.39 $\pm$ 0.34 arc-second, based on 757 CCD observations of 682 single star and 75 binary-star measurements

https://doi.org/10.1017/S0252921100079124 Published online by Cambridge University Press

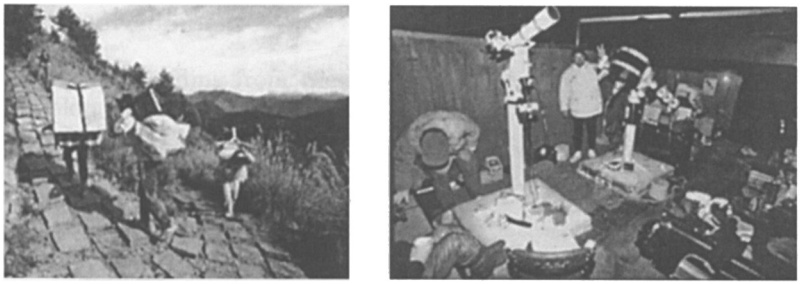


Figure 2. Parts were carried up by manpower to the summit (left) to set up the seeing monitoring station (right).

(Figure 3). The annual number of clear nights at Lu-Lin is about 200. The sky background is 20.72 mag/arcsec^2 in V band and 21.22 mag/arcsec^2 in B band.

3. Site Development

Negotiations with the Yu-Shan National Park, the Ministry of the Interiors and the Taiwan Forest Bureau took about one year for the permission to construct a site survey station within 100 square meters on the summit. Since there was no road access to the site, all the construction material for the site survey station and the instruments had to be carried up by manpower from the base of the mountain to the summit (Figure 2, left). The observing station was built in 1991. Power supply for all equipments relied solely on generators.

After the site survey was completed in 1993, we proposed that the Lu-Lin site be developed to host a medium size 2-m telescope. More land was contracted for from various authorities, expanding the area to its present 300 square meters.

Until late 1997, the development of Lu-Lin observatory had been supported by NSC funds. A 6-m dome was built for a homemade 76 cm reflector. The construction of the dome was finished on January 14, 1999. Discussions with the electrical power company followed. A 3.3 km underground electrical power line to the foot of Lu-Lin in the national park area was built in 2000. Another electrical power line extending from the foot to the summit of Lu-Lin was installed in early 2001 as part of the Ministry of Education's Research Excellency project. The first TAOS telescope was installed at Lu-Lin in March 2000. A 90 KW/240 VAC power line and a water pipe system was pulled up in 2001. Also a wireless network system through A-Li Shan was set up, while a faster wireless network system with 11.5 Mbit/sec bandwidth is now under development.

4. Research Activity

The Lu-Lin observatory is being developed for both research and education. The homemade Super-Light Telescope (SLT, Figure 4, left), which includes a 76-cm diameter HEXTEK Honey Comb lightweight gas-fusion mirror, has seen the first light in the fall of 1999. The field of view (FOV) of a fast primary focus (f/1.8), Ritchey-Chretien focal ratio (f/9), and a plate scale of about 0.3"/10μm,

https://doi.org/10.1017/S0252921100079124 Published online by Cambridge University Press

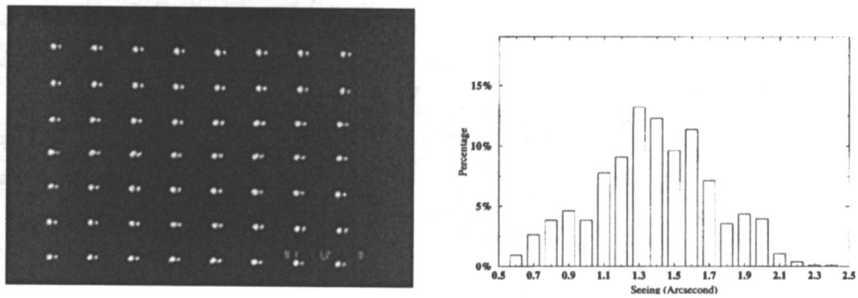


Figure 3. **Left**: Binary star - Castor - measurements.
Right: The average seeing of Lu-Lin is about 1.39 ± 0.34 arc-second.

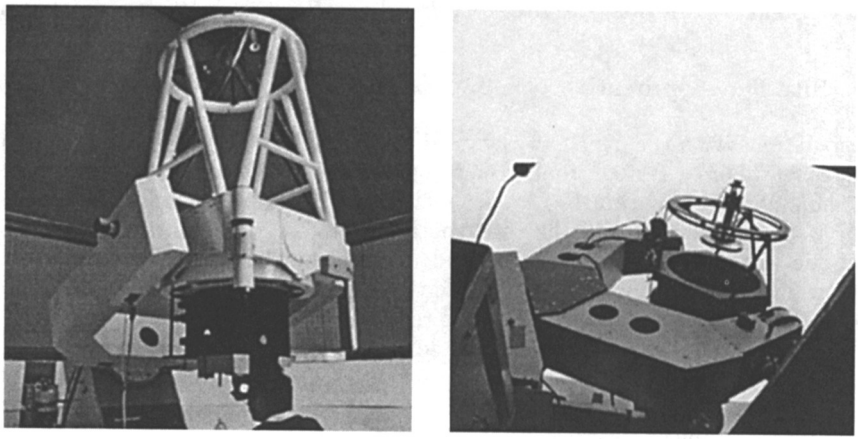


Figure 4. **Left**: The homemade 76 cm Super Light Telescope (SLT).
Right: The TAOS # 1 robotic telescope.

approaches half a degree square. In the first stage, only one quarter of the FOV will be used with an Apogee AP-8 thin CCD (1K × 1K, 24μm/pixel). A pilot program for the SLT deals with time-varying astrophysical phenomena, exploiting the unique geophysical location (time and longitudinal coverage) of Taiwan on the Western Pacific Rim.

The Taiwan-America Occultation Survey (TAOS, King 2001) is a collaborative project to conduct a census of comet nuclei in the outer solar system. The TAOS experiment consists of four 50 cm, wide field (f/1.9), robotic telescopes, each equipped with a 2K × 2K CCD camera (Figure 4, right). This experiment provides the only means to study the cometary population in the small sized end of the distribution. A great number of scientific products, notably variable stars, will also derive from the huge TAOS database.

https://doi.org/10.1017/S0252921100079124 Published online by Cambridge University Press

5. Future Development

Supported by the funding from the MoE Excellency project, we are going to further develop the facilities at the Lu-Lin observatory. This effort will focus on road construction, water and power supplies, communication links and other items necessary for the establishment and maintenance of the observatory as an inter-university astronomical facility for research and education. Members currently involved in this joint venture are the National Central University (which is operating the Lu-Lin observatory), Tsinghua University and Taiwan University. We expect that more universities will be included in this consortium in the near future. The proposed national infrastructure will promote Taiwan's role in many first-class astronomical projects, from solar system astronomy to cosmology; especially in view of its geographical position that beneficially complements the longitudinal coverage for joint international observing projects.

Acknowledgments. This work would not have been possible without the effort of a lot of people working on developing the site. We wish to thank the long-term support from the National Science Council, the Ministry of Education, the National Central University, the Yu-Shan National Park, and the Taiwan Forest Bureau. We also sincerely thank Mr. P.K. Chen for the first guided visit to the Lu-Lin site.

References

Ardeberg, A. 1987, in "*Identification, Optimization, and Protection of Optical Telescope Sites*", Proc. of an International Conf. Flagstaff, AZ

Fried, D.L. 1965, J. Opt. Soc. Am., 55, 1427

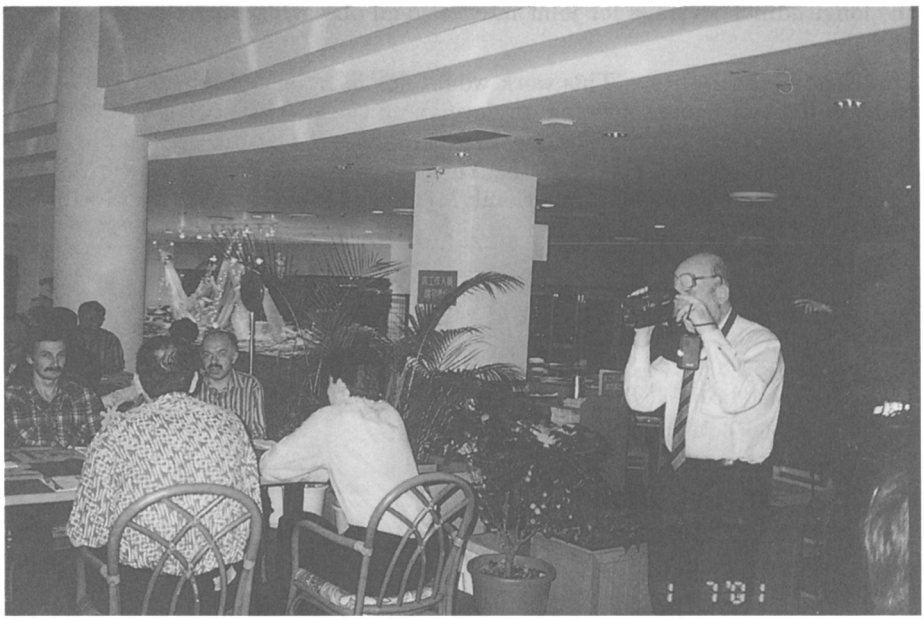
Fried, D.L. 1966, J. Opt. Soc. Am., 56, 1372

King, S.K. 2001, this volume

Tsay, W.S. et al. 1999, in "*The NCU Lu-Lin Observatory and its Future Direction*", Proceedings of Fourth East-Asian Meeting on Astronomy, 1999, p24

Woolf, N.J. 1982, ARA&A, 20, 367

https://doi.org/10.1017/S0252921100079124 Published online by Cambridge University Press



(From left, facing camera) Nesterenko, Samus, Bochkarev (taking pictures)

https://doi.org/10.1017/S0252921100079124 Published online by Cambridge University Press