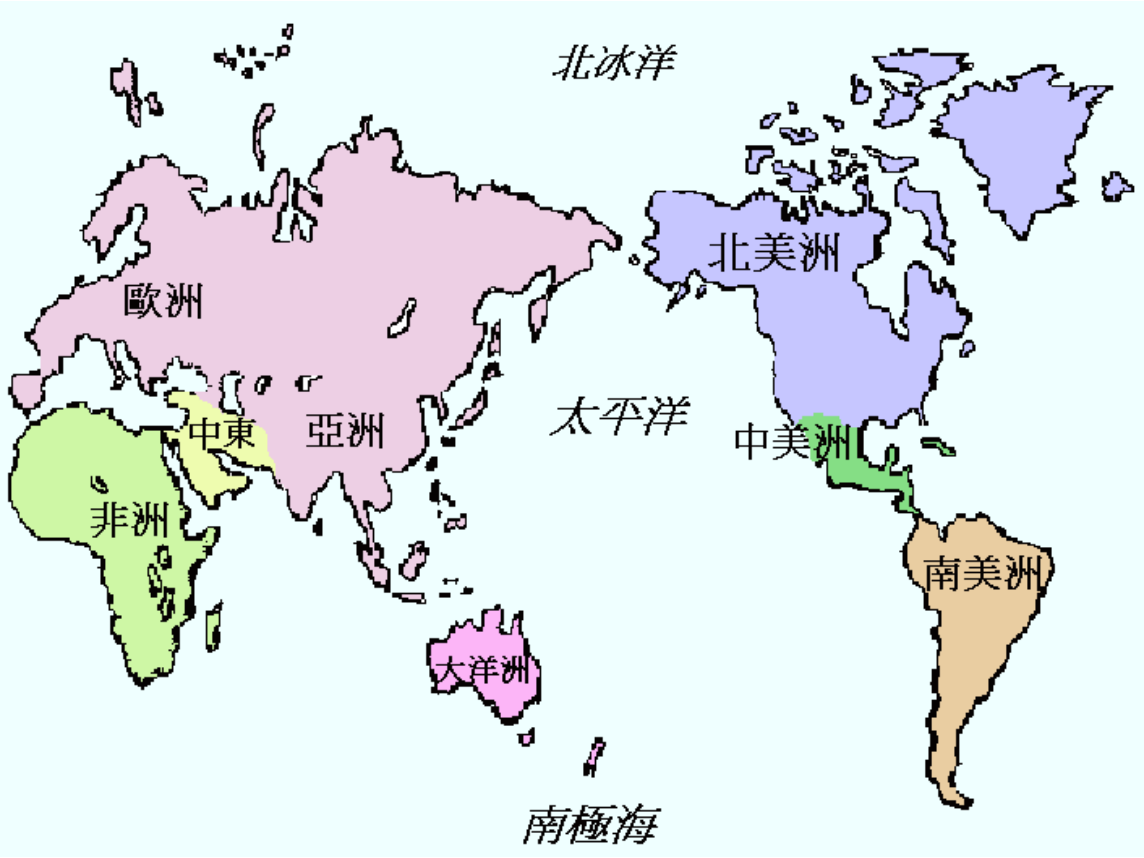
Cosmic Variability Study in Taiwan

Wen-Ping Chen

Institute of Astronomy
National Central University, Taiwan

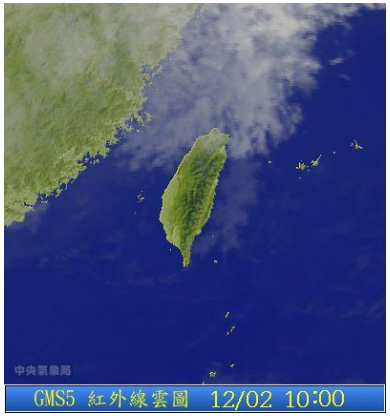
2010 November 16@Jena/YETI

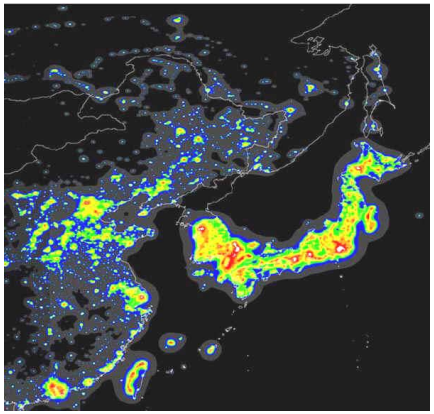


Advantages in Taiwan：

- Many high mountains
- Western Pacific longitude
- Low latitude

➔ variability studies





Lulin Observatory
鹿林天文台

Altitude 2862 m; often above the inversion layer

… seen from Yusan (Jade Mt) 玉山 4000-m

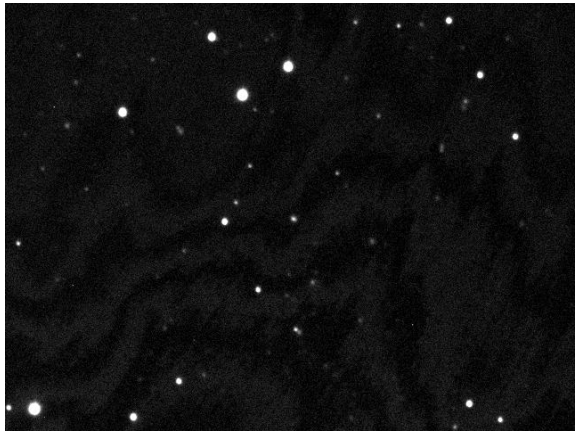
Scientific Activities at Lulin

- **Time Variability**
  - Part of global network
  - Mass data processing
  - Data mining
- **TAOS** (Taiwan, USA, Korea)
- **LELIS** (NCU)
- **Taiwan Oscillation Network** (NTHU)
- **Sprite** (NCKU)
- **Taiwan Earth-Shine Network** (NTHU)
- **Atmospheric Experiments**

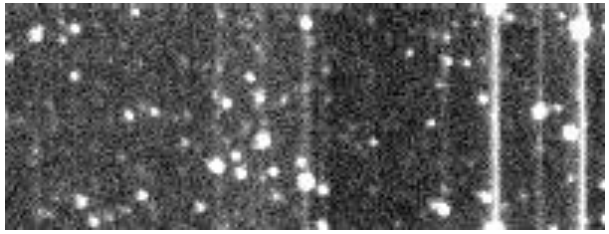
NCU/Lulin Observatory from Yusan North Peak

So far, discoveries of
10+ supernovae,
800+ asteroids, 1 comet,
variable stars …

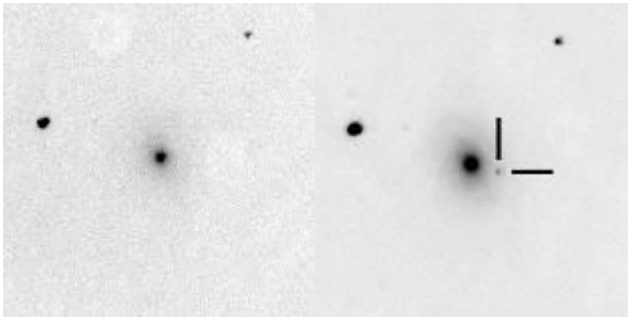

TAOS D
EPA LABS
TAOS C
T2M
LELIS
SLT(0.4 m)
TAOS B
LOT(1 m)
TAOS A
NCKU ELF
Graduate Institute of Astronomy, NCU
國立中央大學天文研究所



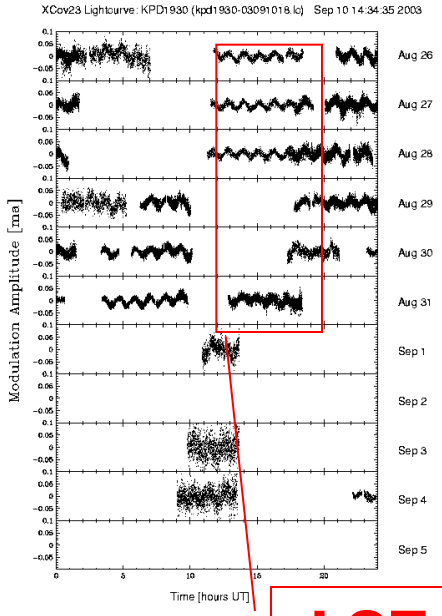
Discovery images of Comet Lulin



Stellar occultation by an asteroid observed at Lulin

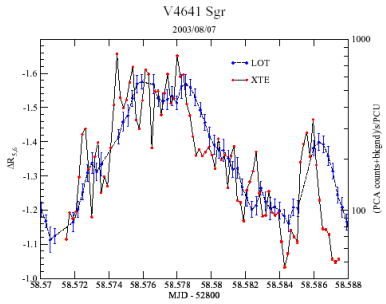


One of the supernovae found at Lulin



LOT

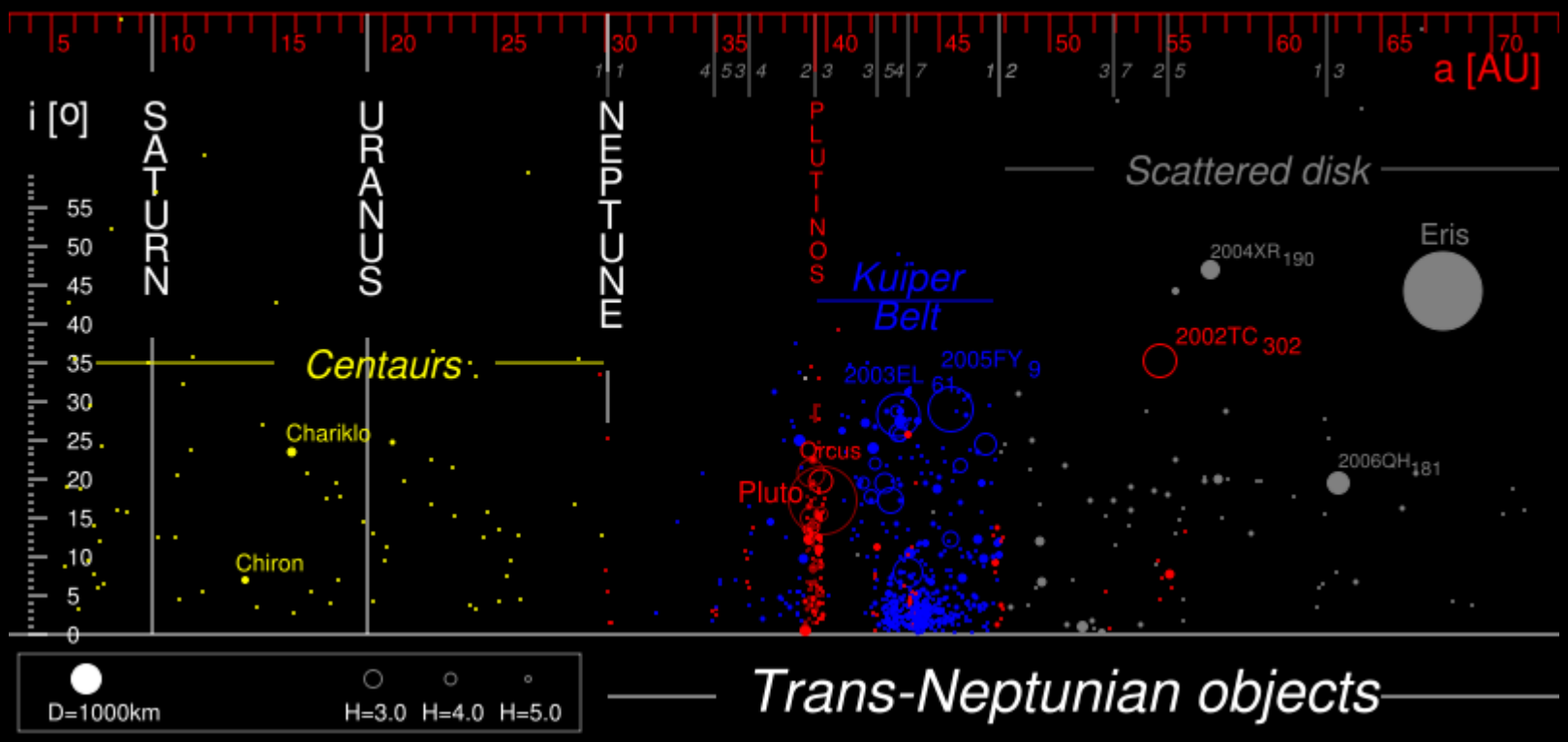
Astereoseismology



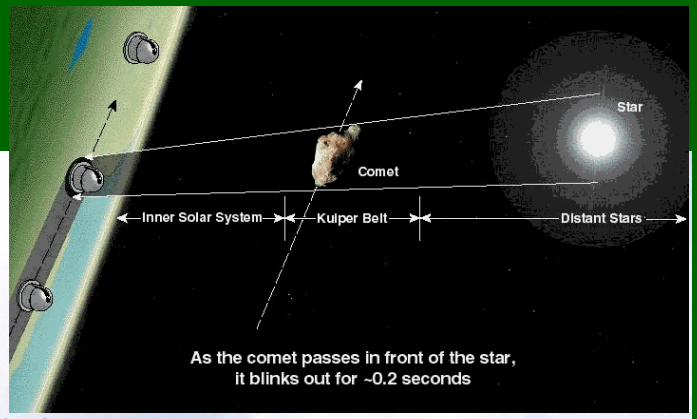
Lulin in sync with a space telescope

Dynamical classes for the Kuiper-Belt Objects (KBOs) or Trans-Neptunian Objects (TNOs)

Classical, Scattered, and Resonant



TAOS Telescopes



Lulin Observatory
altitude=2862 m

With a special data acquisition and a non-parametric statistical analysis scheme

100 GB/night

C

D

B

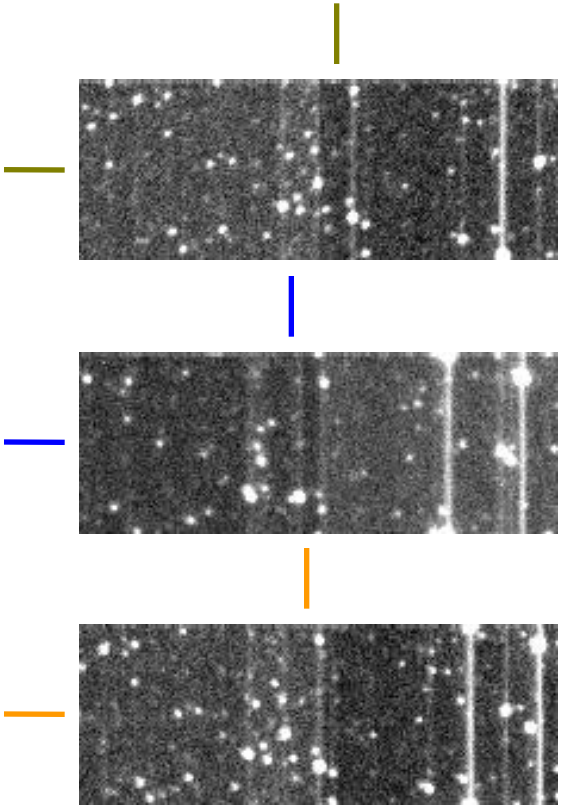
A

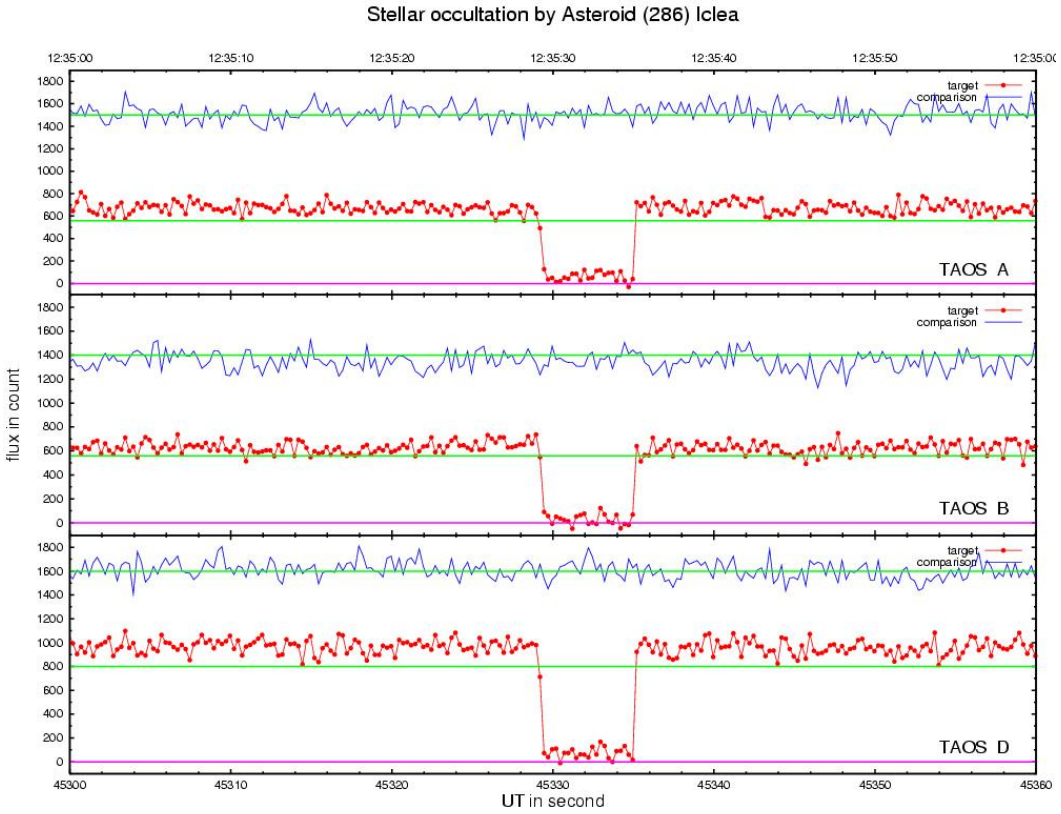
Project Overview

- Census of the small objects in the solar-system family
- An array of wide-field telescopes (D=50 cm, f/1.9, FOV=3 sq. deg) to monitor brightness changes of ~1,000 stars at 5 Hz rate
- Looking for a 'blink' of starlight (occultation) when an object (> 2 km) moves in front of a distant star
  Frequency of events ➔ population of "interveners"
- Data rate a few 100 GB per night; only "interesting" data downloaded via the dedicated E1 connection
- Real-time data analysis (light curves, statistics)
- Requiring coincidence detection of the same event by all telescopes to guard against false positive

TEST DRIVE

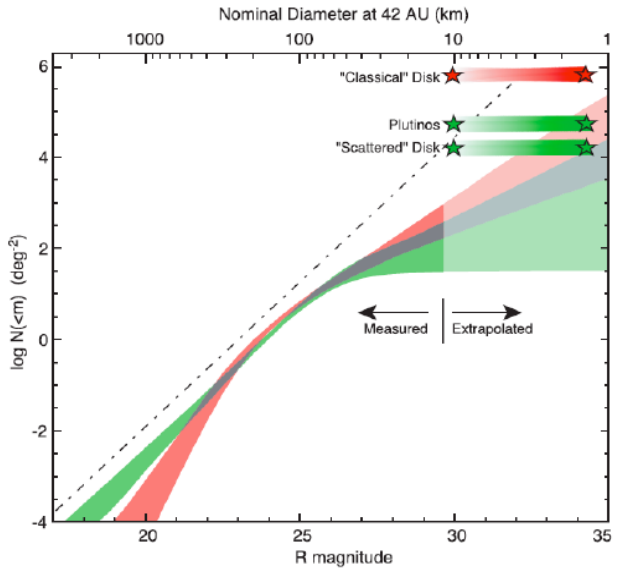
2006 Feb 06 three TAOS telescopes detected a suspected occultation of TYC 076200961 (m_V ~ 11.83) by **(286) Iclea** (m_V ~ 14.0 mag, D ~ 97 km)



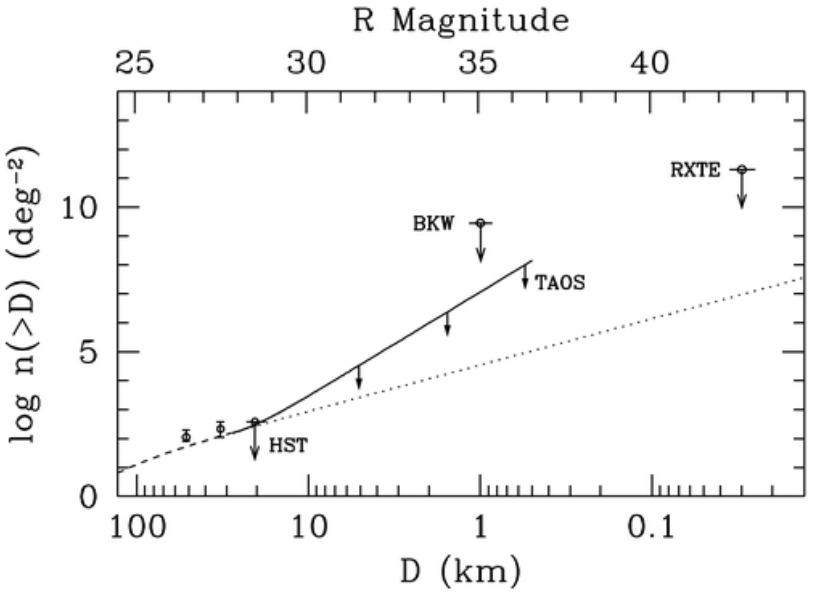


TAOS Results

- 2005-2009 several billion photometric measurements have been collected
- No event was detected, setting a stringent upper limit to the KBO population.
- Stellar variability on timescales from < 1 s to months
- Mass data processing



Bernstein & Trilling (2004)



Zhang et al. (2009)

Panoramic Survey Telescope And Rapid Response System

Pan-STARRS
PS1 Science Consortium

泛星

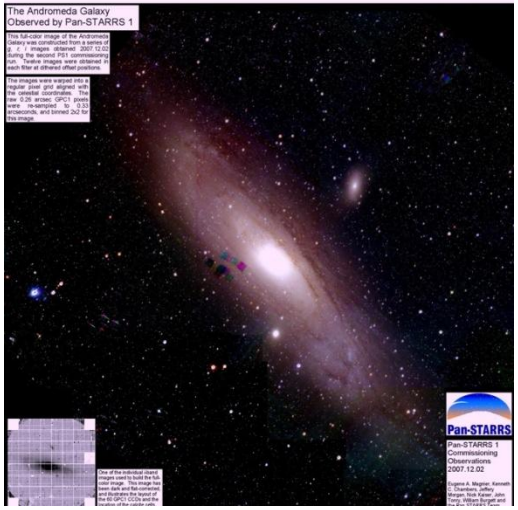
PS1 consortium members

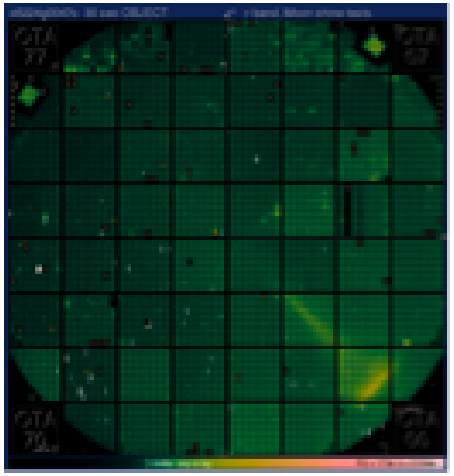
University of Hawai'i; UH Institute for Astronomy; Max Planck Institute for Extraterrestrial Physics; Max Planck Institute for Astronomy; Johns Hopkins University, Department of Physics and Astronomy; Harvard-Smithsonian Center for Astrophysics; Queen's University, Belfast; University of Edinburgh; Durham University, Institute for Computational Cosmology; National Central University, Taiwan; Las Cumbres Observatory Global Telescope Network

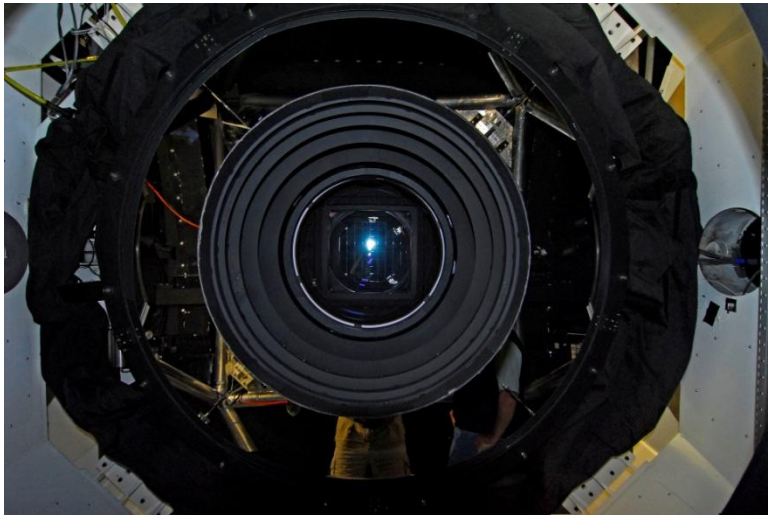
- To patrol the entire observable sky (3π) several times a month
- An array of 4 telescopes, located in Hawaii, each of D=1.8 m, equipped with a 1.4 gigapixel camera of an Orthogonal Transfer Array CCD detector (= 40 cm square focal plane)
  ➔ 7 square-degree FOV with 0.26" pixels
- Detection of moving, transient, and variable celestial objects down to very faint limits
- Very deep cumulative sky images

- Wide-Field Imaging
- Short Duty Cycle
- Efficient Operations

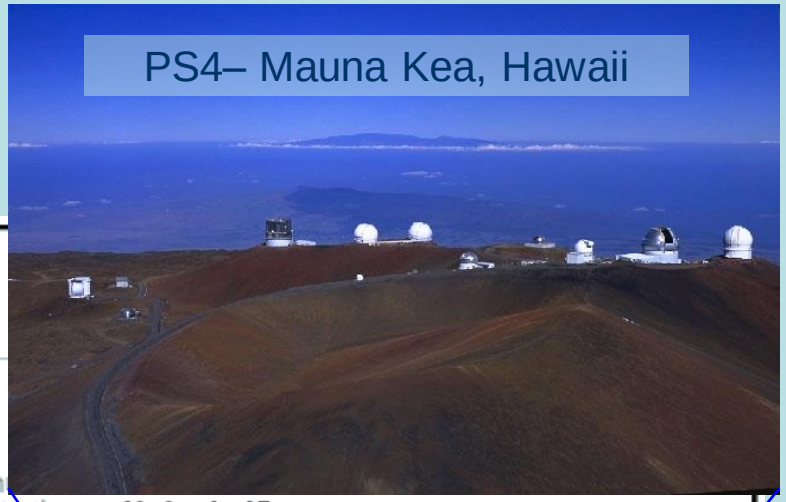
Wide-Field Optics



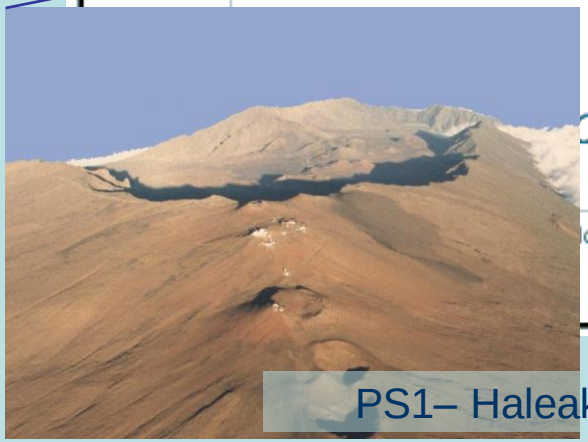




Hawaii, USA

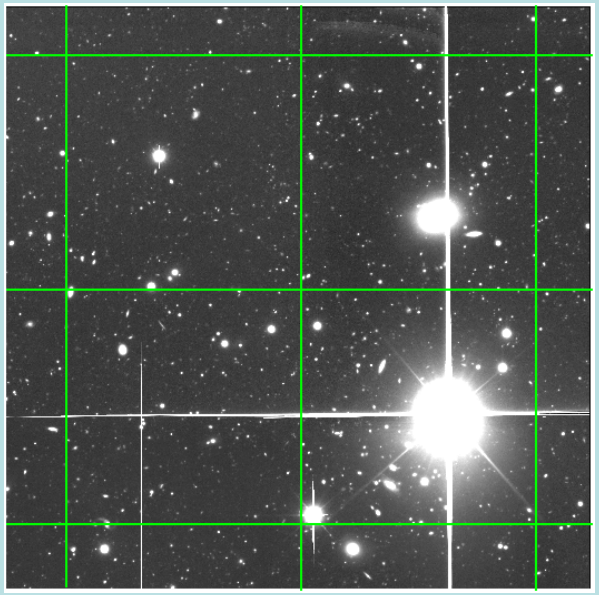

PS4– Mauna Kea, Hawaii

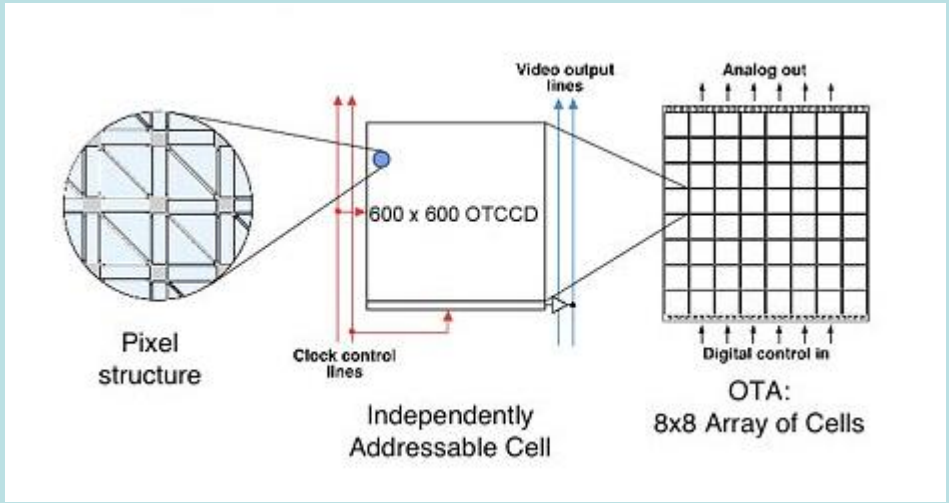
Institute for Astronomy
University of Hawai'i at Mānoa
22 N
NI'IHAU
KAUA'I
O'AHU
Honolulu International Airport
Waikiki
Honolulu
Kaua'i County
City and County of Honolulu
MOLOKA'I
LĀNA'I
KAHO'OLAWE
MAUI
Haleakalā Observatory
Mauna Kea Observatories
Astronomers' Mid-level Facility & Visitor Information Station
Maui County
20 N
Institute for Astronomy
University of Hawai'i at Hilo
Kona
Hilo
Mauna Loa
Hilo International Airport
HAWAI'I
156 W



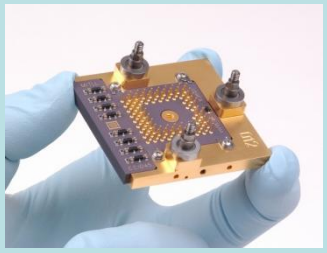
PS1– Haleakala, Maui

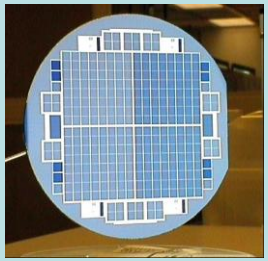
Detector Technology

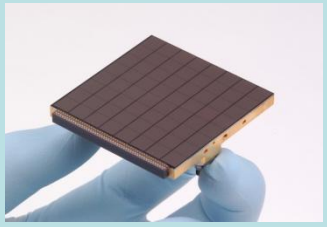


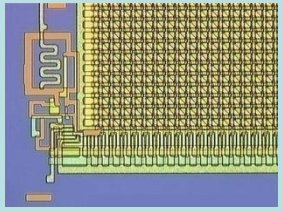


MIT Lincoln Laboratory





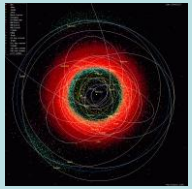


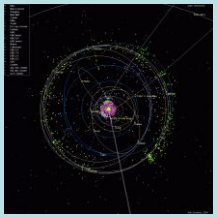


Independently addressable orthogonal transfer CCDs (cells)

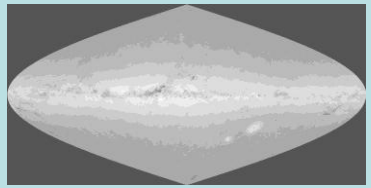
- Reducing cost by increasing yield
- Fast readout: Gigapixels in 2 s
- On-Chip guiding
- Minimizing effects of bright stars
- Compensating for image motion
- 1.4 giga pixels **Several TBs/night**

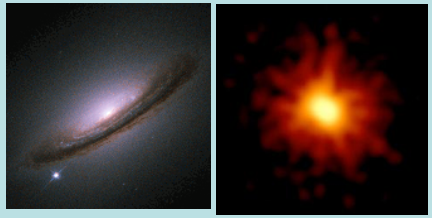
PS1 Key Projects

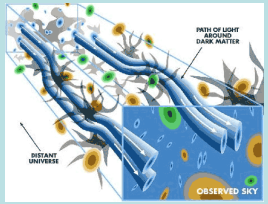




1. *Inner solar system*
2. *Outer solar system*
3. *Low-mass stars, brown dwarfs and young stars*
4. *Exoplanets by stellar transit surveys*
5. *Milky Way structure and Local Group*
6. *M31*
7. *Massive stars and supernova progenitors*
8. *Cosmology with variable stars and explosive transients*
9. *Galaxies*
10. *AGNs and high redshift quasars*
11. *Cosmological lensing*
12. *Large scale structure*







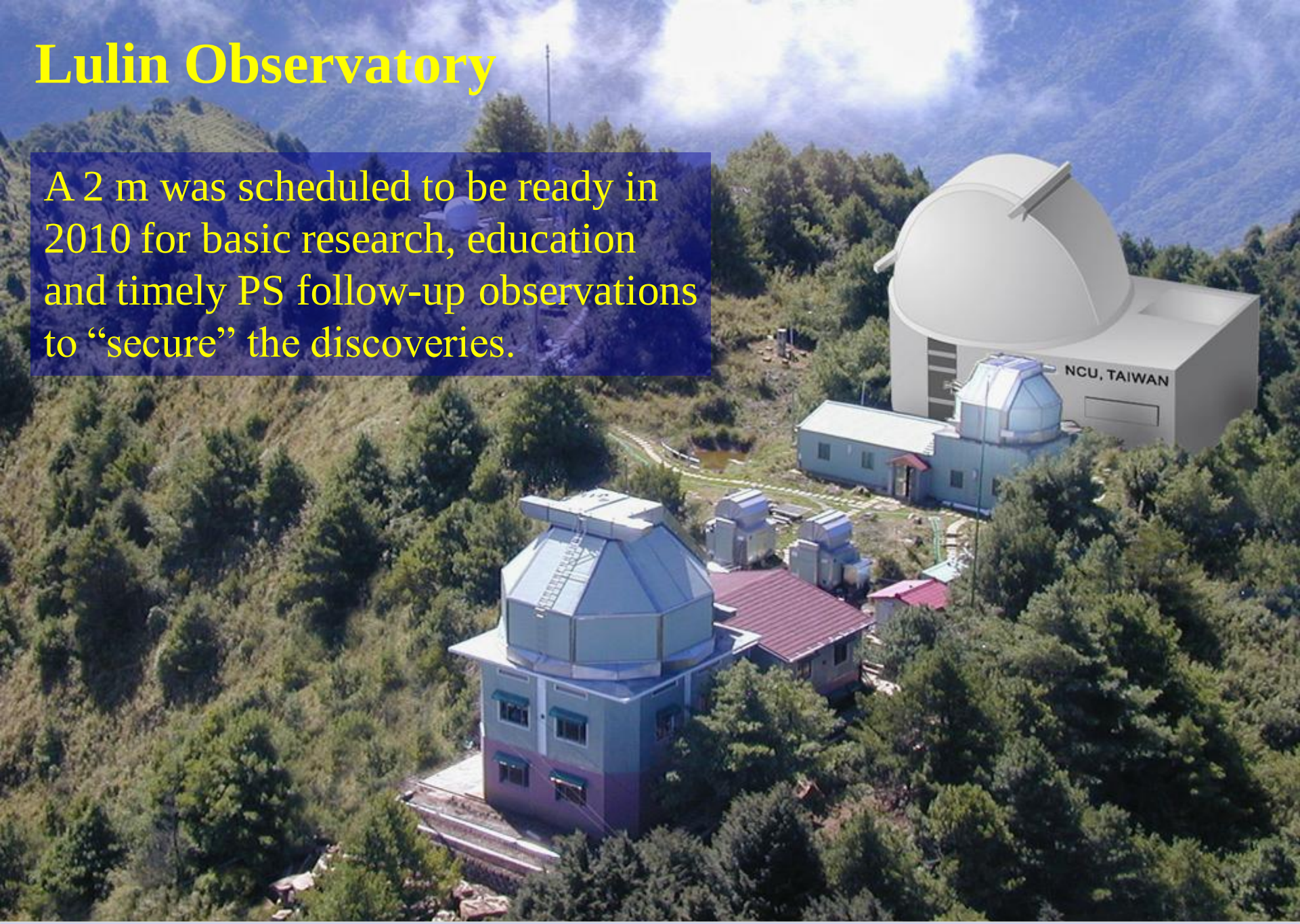
Status of the PS1 System

- Tests runs in 2008/9
- Science Consortium operational starting 1 Jan 2009
- Commissioning starting mid-March 2009
- **Full survey started May 2010**, for duration of 3 years
- Different data release policy (immediate, 1 year, > 3 year)
- The Taiwan team has joined, in addition to science verification, in the SW pipeline developments, data quality assessment, the *Image Processing Pipeline*, the *Moving Object Processing System*, and *Published Science Processing Subsystem*, etc.
- A solar-system alert server/client set up between NCU and Hawaii; an *in situ* pc cluster node

PS1 will find many peculiar phenomena …

Lulin Observatory

A 2 m was scheduled to be ready in 2010 for basic research, education and timely PS follow-up observations to “secure” the discoveries.

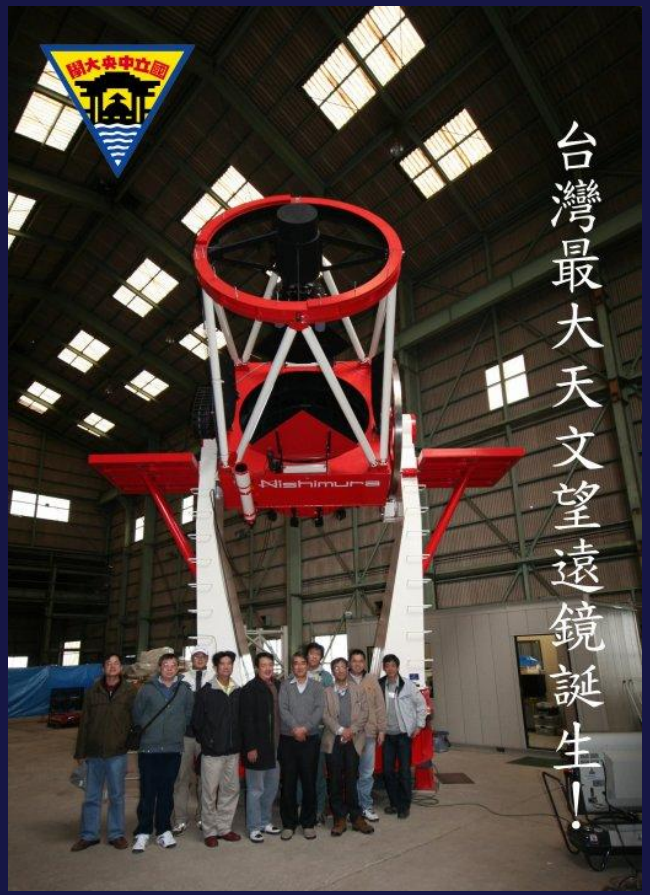


The Lulin 2 m Telescope

- PS1 will find many peculiar objects/phenomena, and Lulin will follow them up in the first opportunity

➔ ***Secure the discoveries***

- Equipped with niche instruments, the Lulin 2 m will be very competitive scientifically
- Telescope already in Taiwan
- But the site is not, currently clearing the environmental impact assessment …
- Ready in 2-3 years?

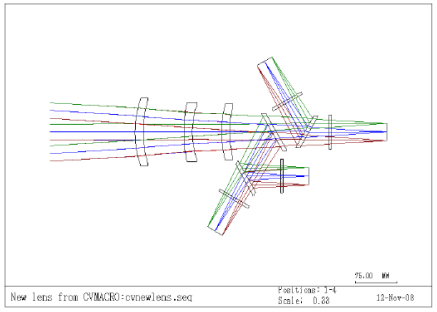


2010/03

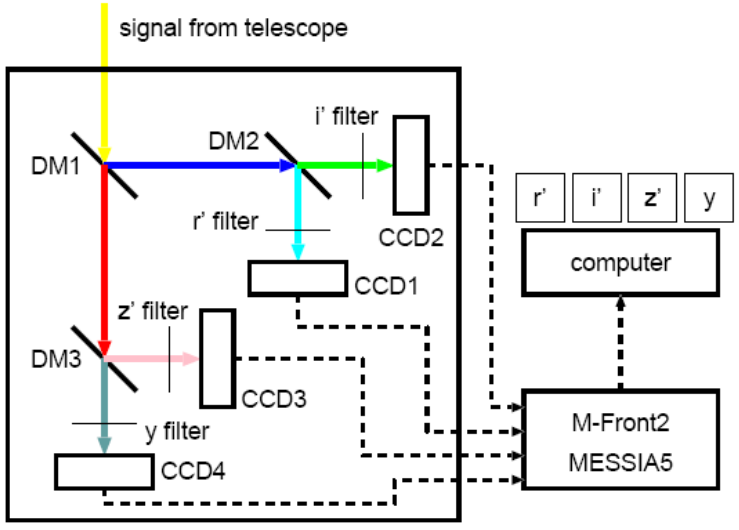
First-Light Instrument 2008~10

- **Four-Color Simultaneous Imager**
  - ✓ Deep- and fully-depleted CCDs
  - ✓ r, i, z, y bands
  - ➔ **Simultaneous colors up to 1 micron, suitable for variability study against sky**

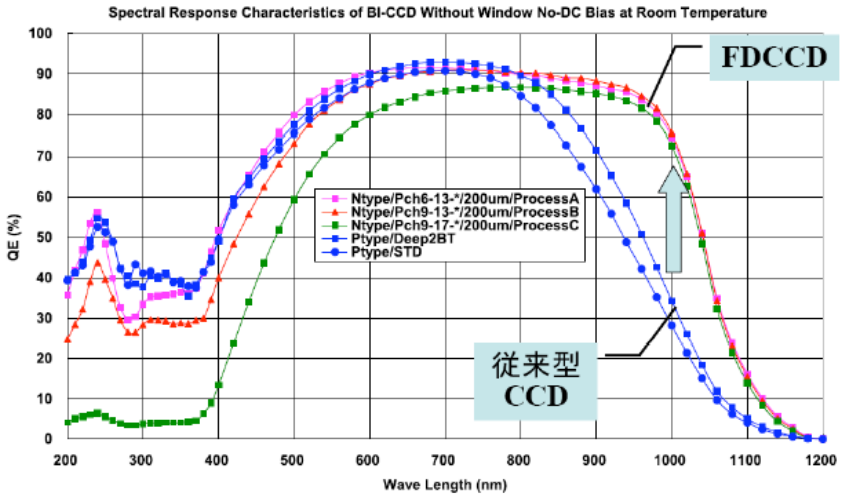
Optical Design



Conceptual Design of the Instrument



Fully depleted CCD

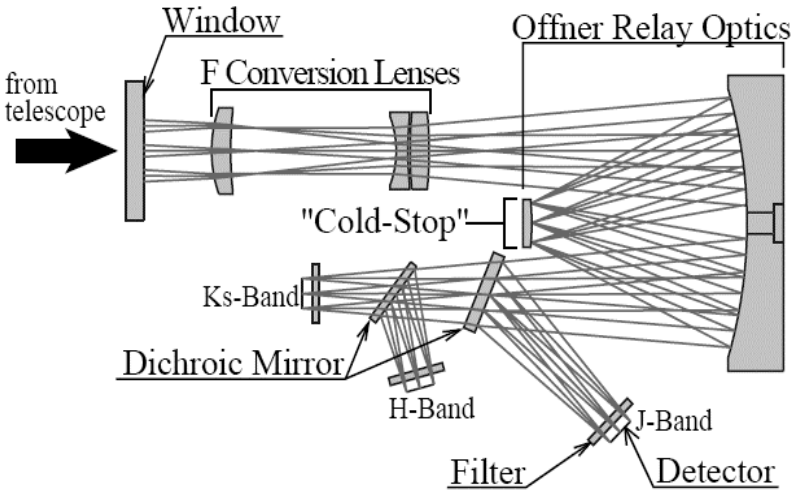


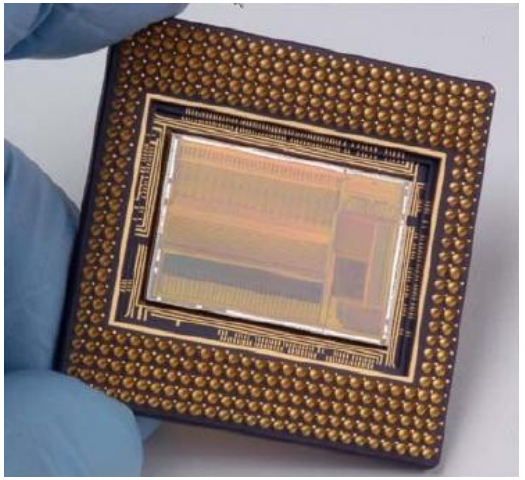
Next-Generation Instrument > 2011?

A JHKs **simultaneous** imager with **polarizers** 2K x 2 K x 18 micron chips JHKs to 19-20 mag (10 sigma) in 15 min integrations

Teledyne HAWAII-2RG

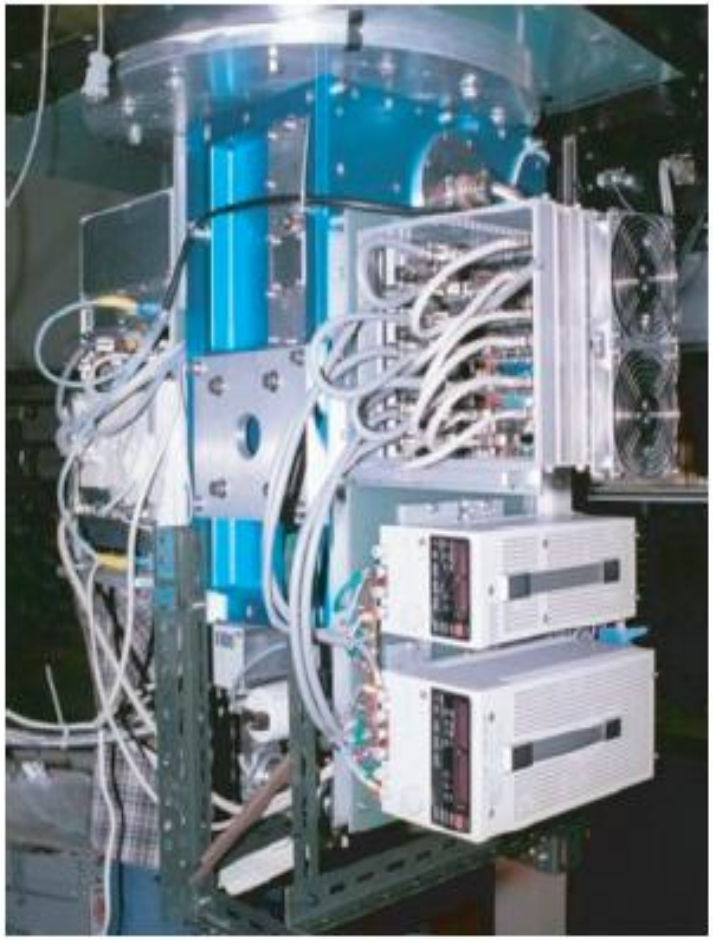
High-dispersion spectrograph; UltraPhot

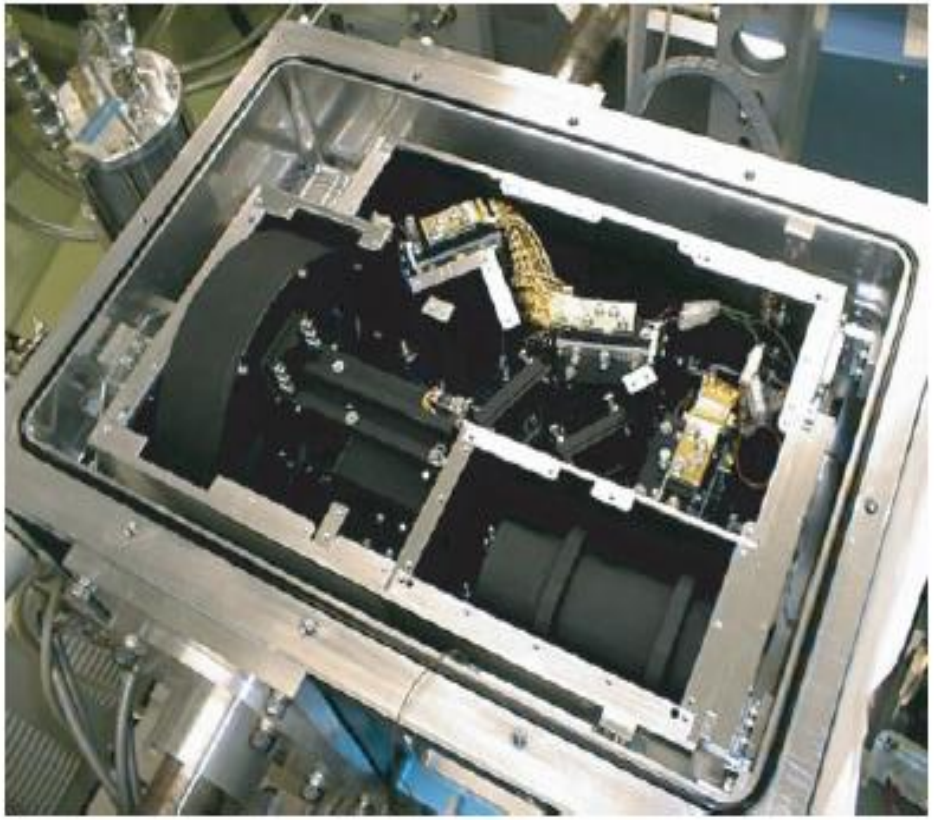




Teledyne SIDECAR/ASIC

SIRIUS (IR Camera) + Polarizer





Lulin telescopes in Taiwan, 1 m, 0.4 m, NCU operated, proposal competition; access, inc. ToO, straightforward

Tenagra telescopes, mainly 0.8 m, in southern Arizona, whole night every other night, until June 2011

Community in Taiwan has access to CFHT (5-10 nights per semester); to Subaru (instruments)

SMA, AMiBA, ALMA, Pan-STARRS, PTF

Conclusions

- OIR astronomy in Taiwan has seen time domain as the next frontier in observational astronomy.
- We joined international projects such as TAOS, Pan-STARRS, PTF, etc. and global campaigns such as the WET, GASP.
- We have developed the capability of mass data processing, analysis tools (HHT), and access to a variety of small telescopes, e.g., in Taiwan, Arizona, and to team up with observatories in other longitudes.
- We have a lot to contribute to YETI.