Status of the Lulin 2 m Telescope

W. P. Chen

National Central University

The 5th EACOA Meeting 2011 Nov 07 @ Kyoto

… in boxes in Hsinchu since March 2010


TAOS D
EPA LABS
TAOS C
T2M
LELIS
SLT(0.4m)
TAOS B
LOT(1M)
TAOS A
NCKU ELF

Panoramic Survey Telescope And Rapid Response System

Pan-STARRS
PS1 Science Consortium

泛星

PS1 consortium members

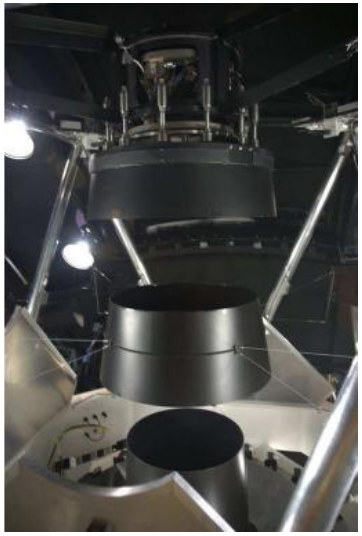
University of Hawai'i · UH Institute for Astronomy · Max Planck Institute for Extraterrestrial Physics (MPE) · Max Planck Institute for Astronomy · Johns Hopkins University Department of Physics and Astronomy · Harvard-Smithsonian Center for Astrophysics · Queen's University Belfast · University of Edinburgh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

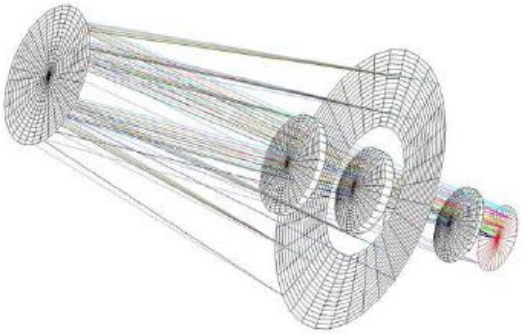
- To patrol the entire observable sky (3π) several times a month
- An array of 4 telescopes, located in Hawaii, each of D=1.8 m, equipped with a 1.4 gigapixel camera of an Orthogonal Transfer Array CCD detector (= 40 cm square focal plane)
  ➔ 7 square-degree FOV with 0.26" pixels
- Detection of moving,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

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

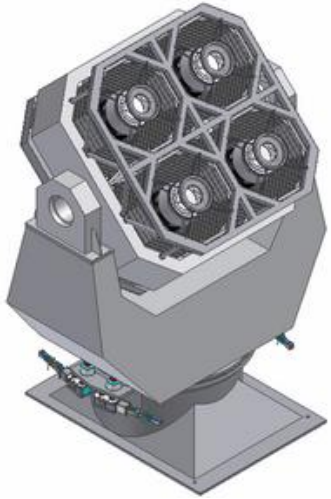
Wide-Field Optics

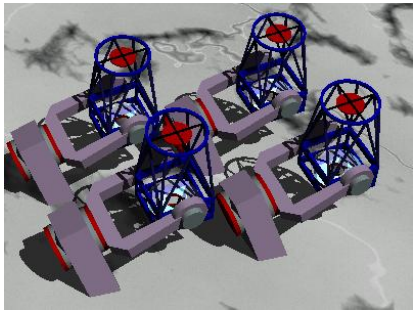
PS1 - Prototype

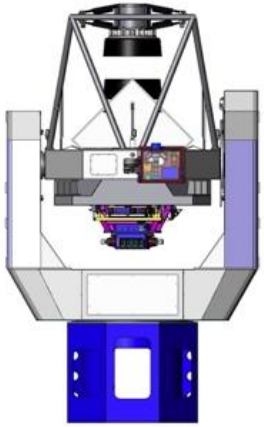




PS4







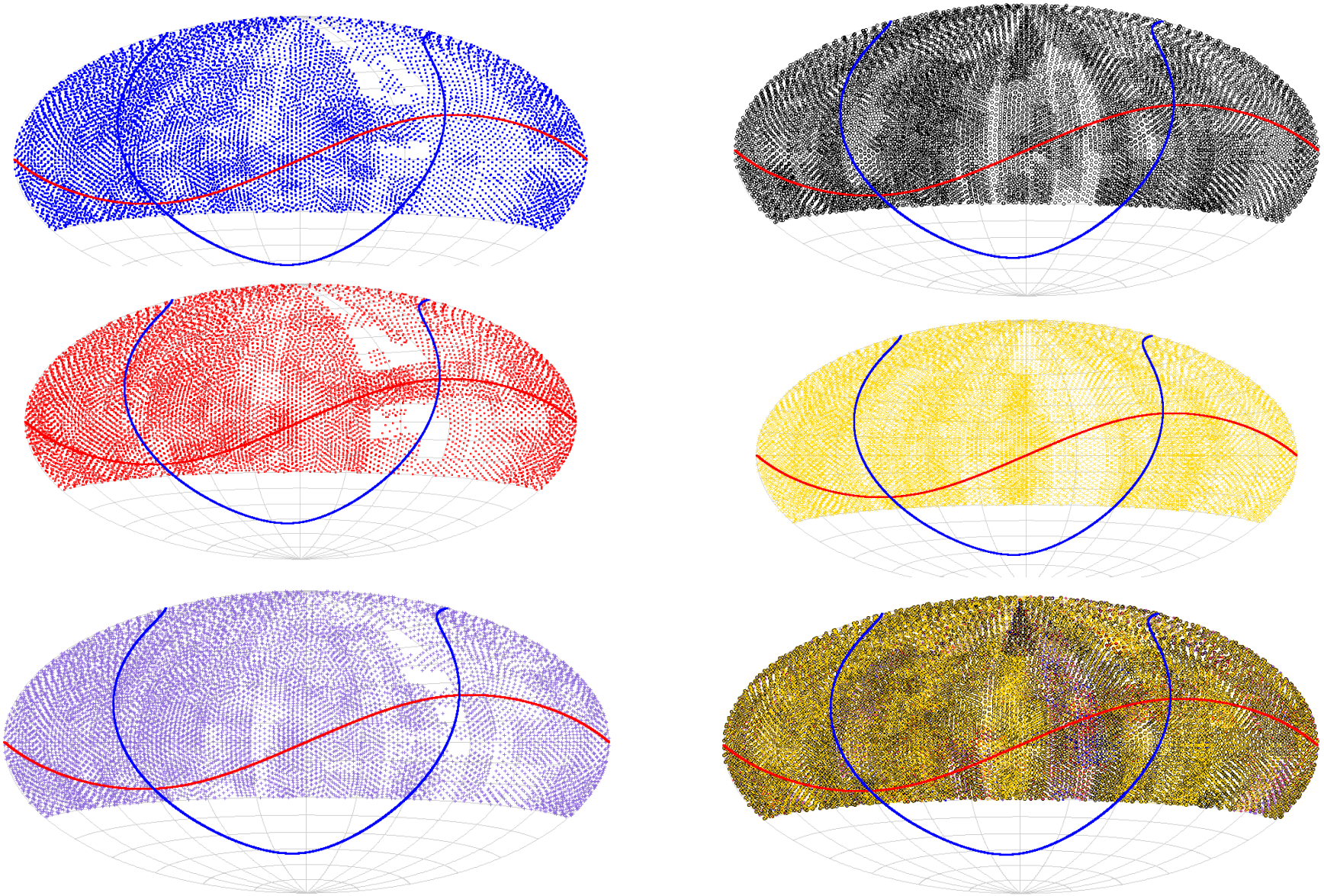
PS1– Haleakala, Maui

PS4– Mauna Kea, Hawaii

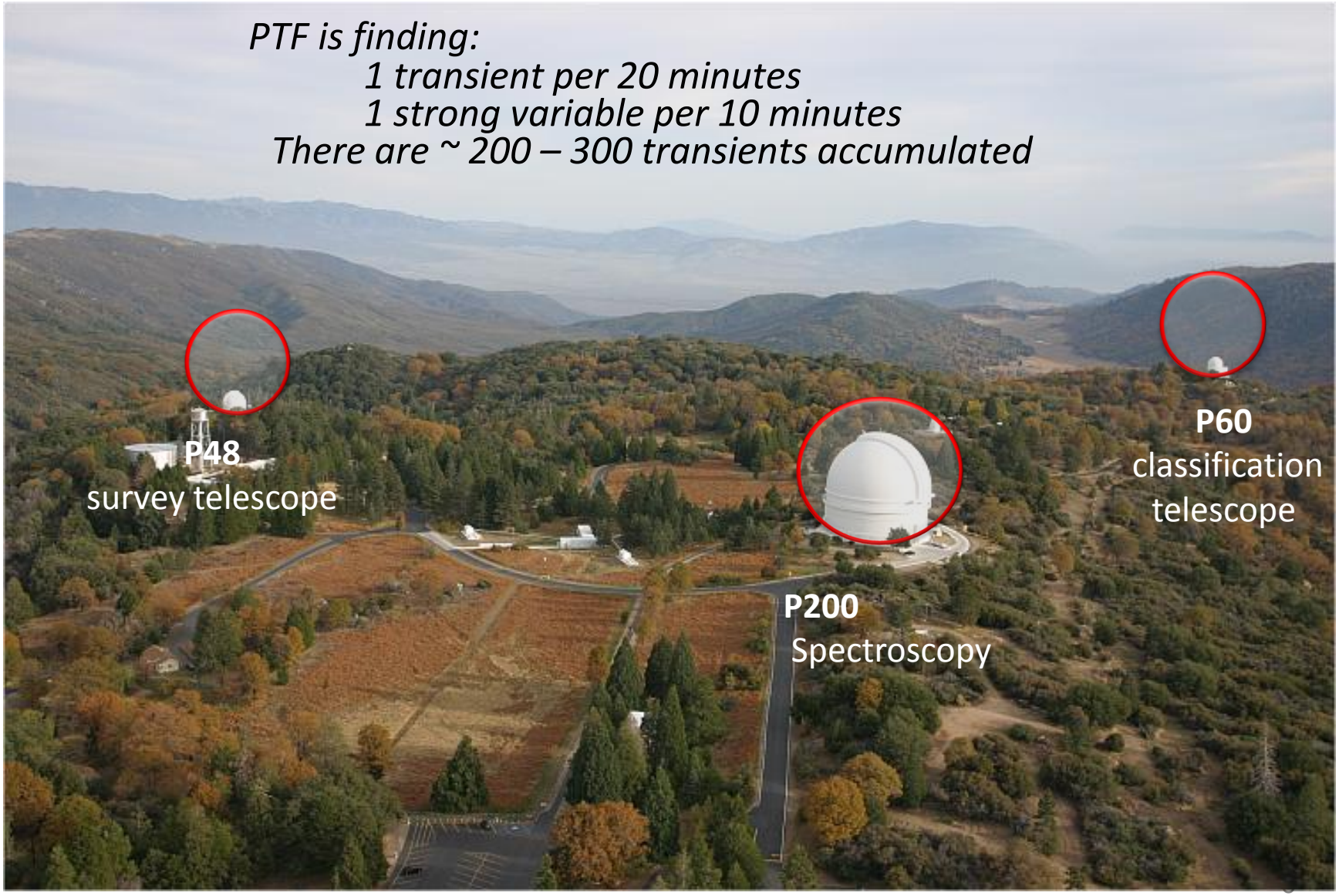
Status of the PS1 System

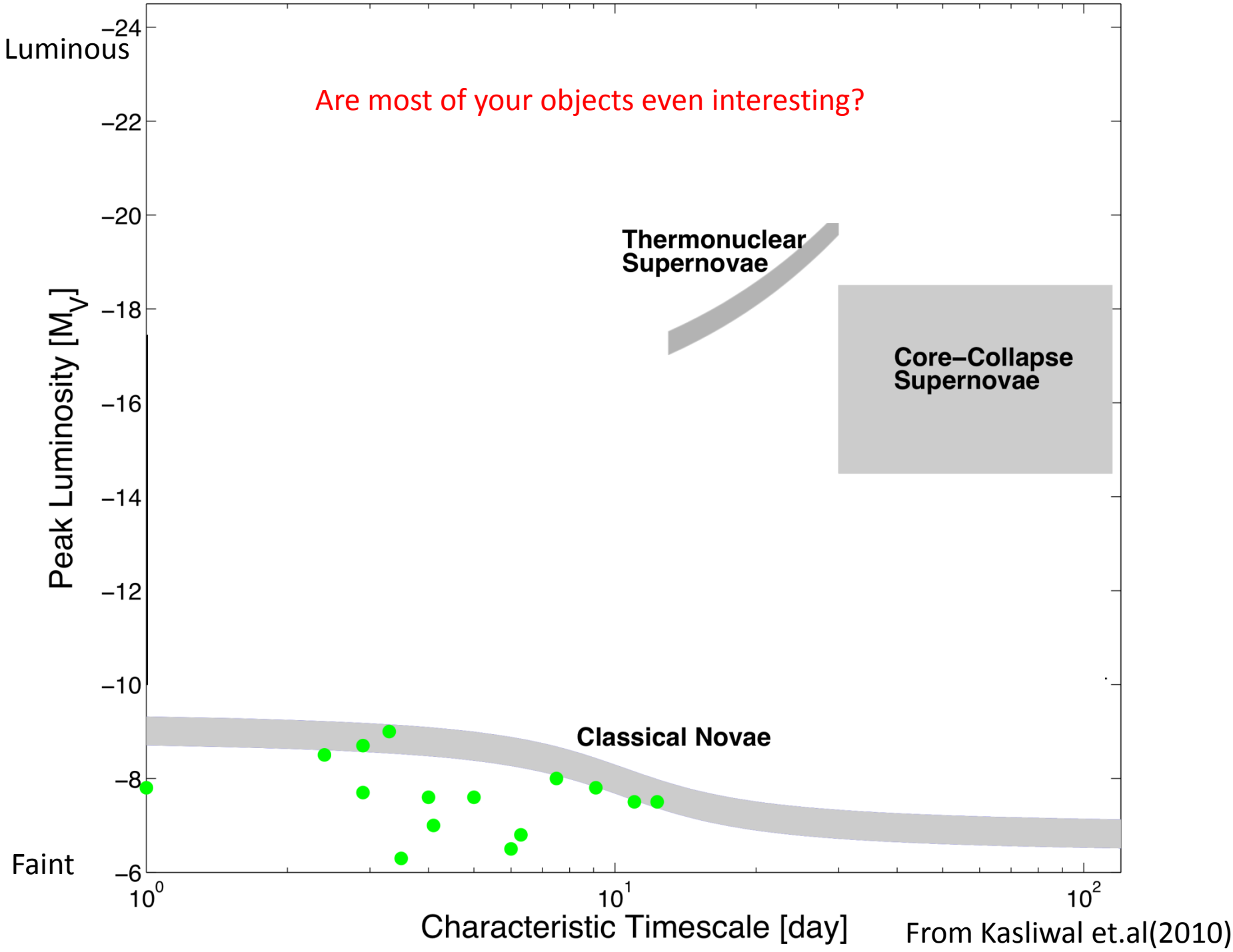
- Science Consortium operational starting 1 Jan 2009
- Commissioning starting mid-March 2009
- **Full survey started May 2010**, for duration of 3 years
- Different data release policy (immediate, 1 year, > 3 year)
- The Taiwan team has joined, in addition to science verification, in the SW pipeline developments, data quality assessment, the *Image Processing Pipeline*, the *Moving Object Processing System*, and *Published Science Processing Subsystem*, etc.
- Heavy involvements in solar-system science (Trojans, TNOs); fast turn-around follow-up observations of PS1 NEOs, and comets; lowest-mass members in star clusters; stellar variability, and large-scale structure

PS1 at 500 days: g,r,i,z,y, band sky coverage and stack

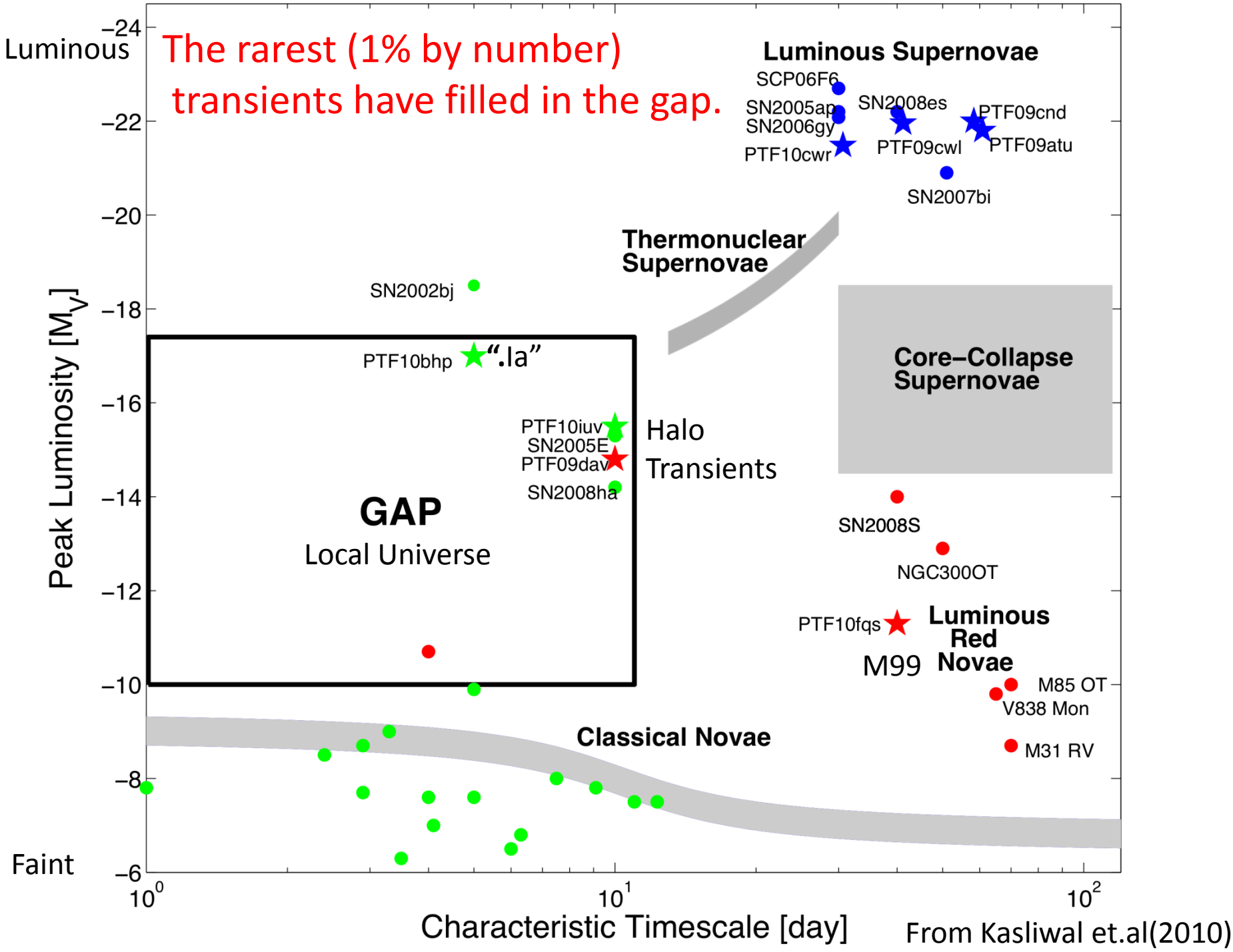


Palomar Transit Factory





From Kasliwal et.al(2010)


The rarest (1% by number) transients have filled in the gap.
Luminous
Faint
Luminous Supernovae
SCP06F6
SN2005ap
SN2006gy
SN2008es
PTF09cnd
PTF10cwr
PTF09cwl
PTF09atu
SN2007bi
Thermonuclear Supernovae
SN2002bj
PTF10bhp
".Ia"
Core–Collapse Supernovae
PTF10iuv
SN2005E
PTF09dav
SN2008ha
Halo Transients
GAP
Local Universe
SN2008S
NGC300OT
PTF10fqs
Luminous Red Novae
M99
M85 OT
V838 Mon
M31 RV
Classical Novae
Peak Luminosity [M_V]
−24
−22
−20
−18
−16
−14
−12
−10
−8
−6
10^0
10^1
10^2
Characteristic Timescale [day]
From Kasliwal et.al(2010)

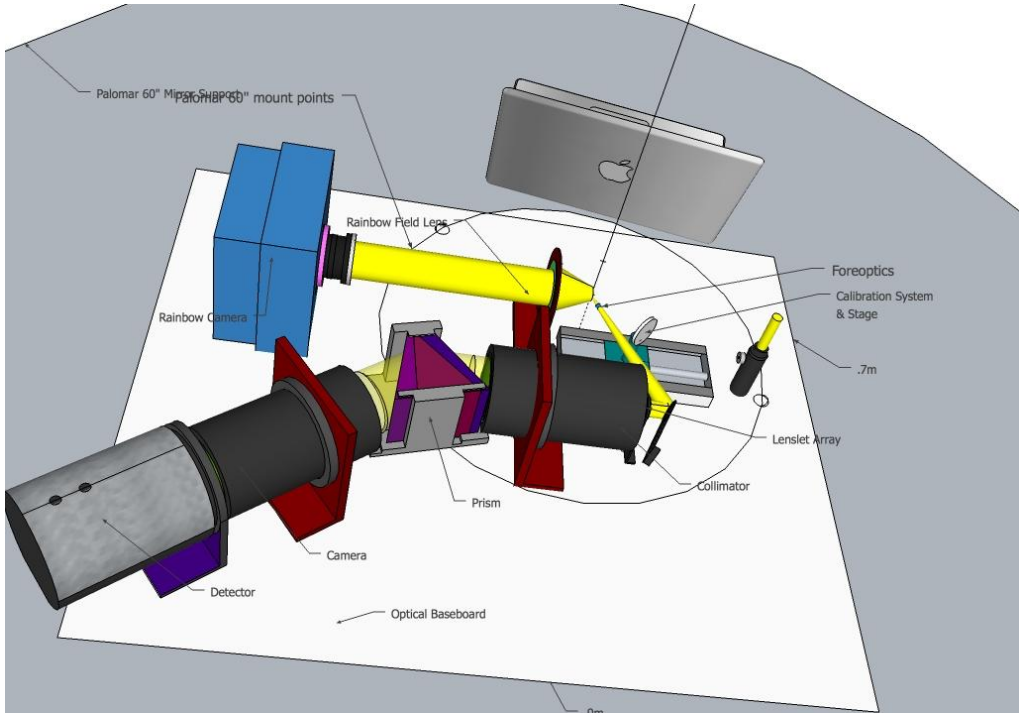
NCU-CalTech Collaboration

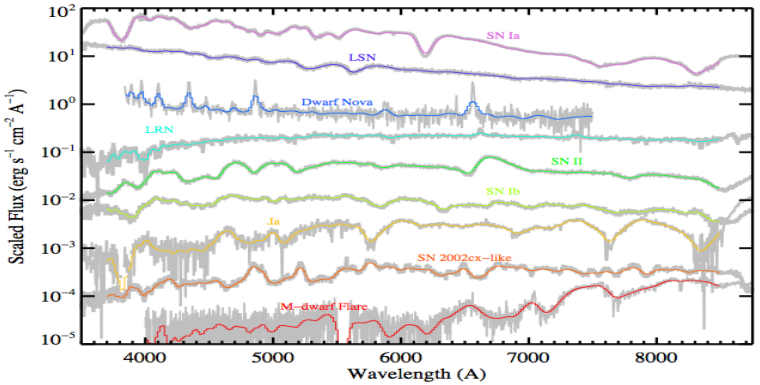
- PTF science

  solar-system objects; stellar activity; variable stars, cosmological transients, etc.

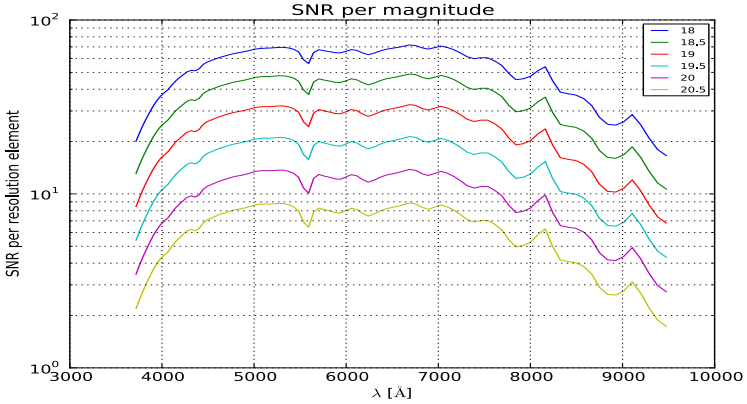
- Development of SED machines; partnered with *Instrument Technology Research Center* (*ITRC*) in Taiwan; NCU responsible for SEDM software and analysis pipelines
- Possibilities with PTF II or other big-telescope projects
- To bootstrap Taiwanese OIR astronomy (the *TANGO* program)

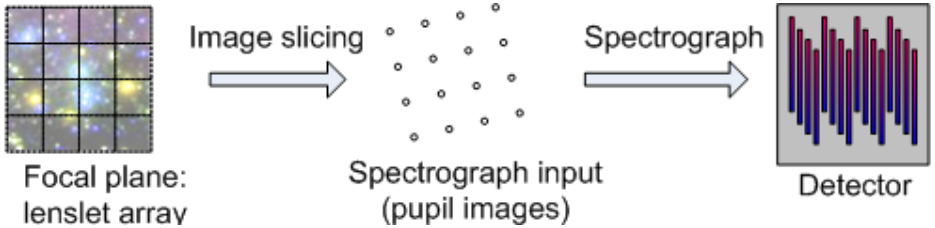
The SED Machine

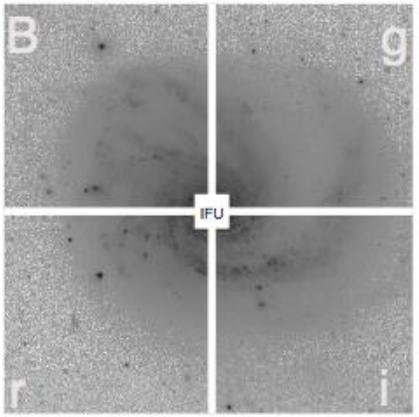




R~100 sufficient for classification



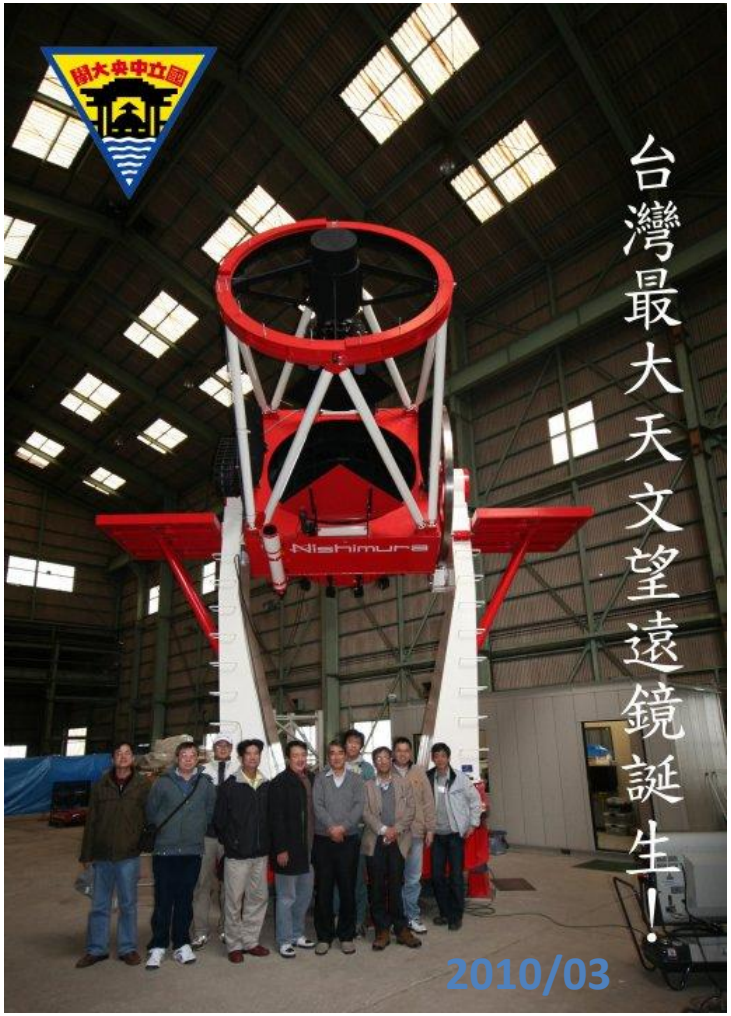




A large FOV IFU and a “rainbow” camera set for efficient calibration

Status of the Lulin 2 m Telescope

- PS1 and PTF will find many peculiar objects/phenomena, and Lulin will follow them up timely
  - ➔ ***Secure the discoveries***
- Equipped with niche instruments, the Lulin 2 m will be very competitive scientifically
- Telescope is already, stored in a warehouse in Taiwan
- …the site is not; recently cleared the environmental impact study.
- Funding request being resubmitted

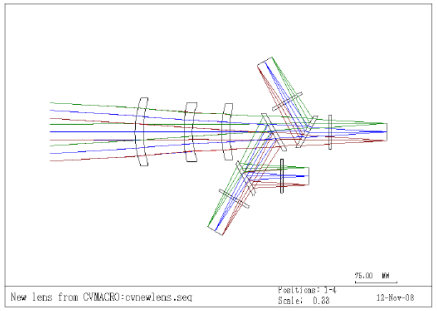


Made by Nishimura

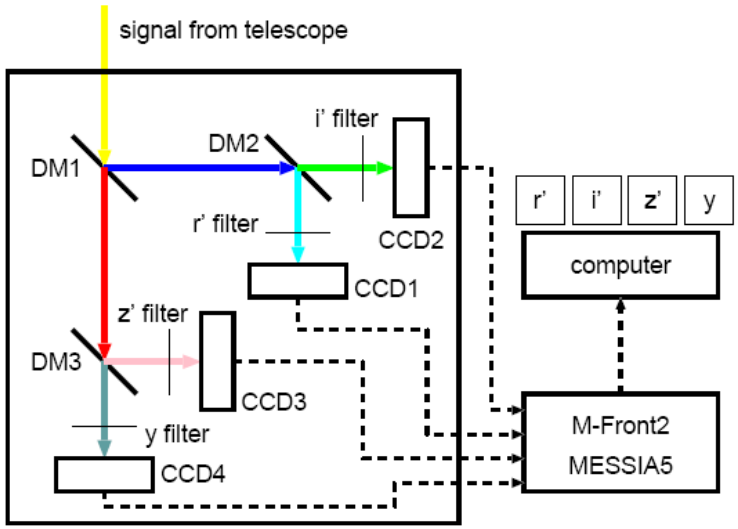
First-Light Instrument

- **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 a varying sky**

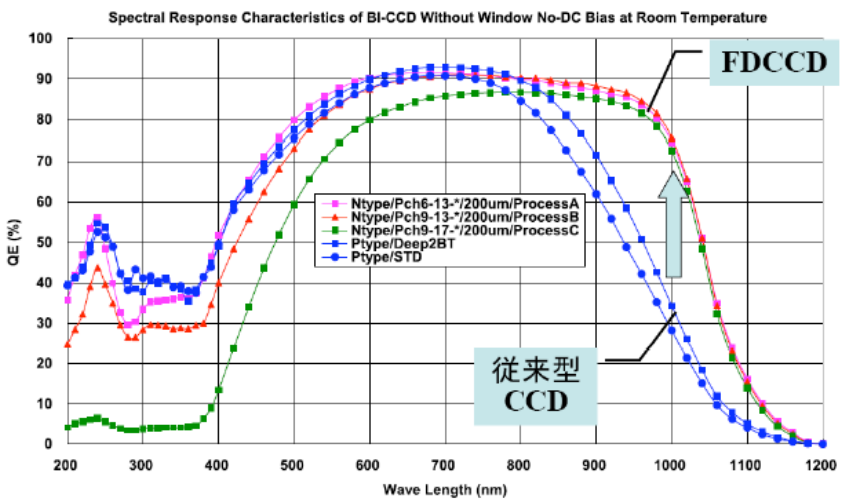
Optical Design



Conceptual Design of the Instrument

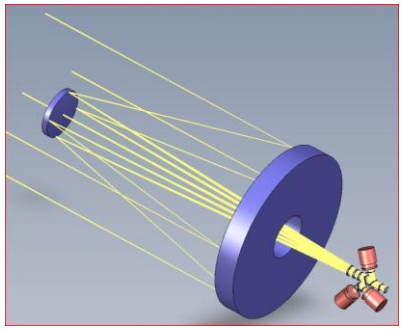


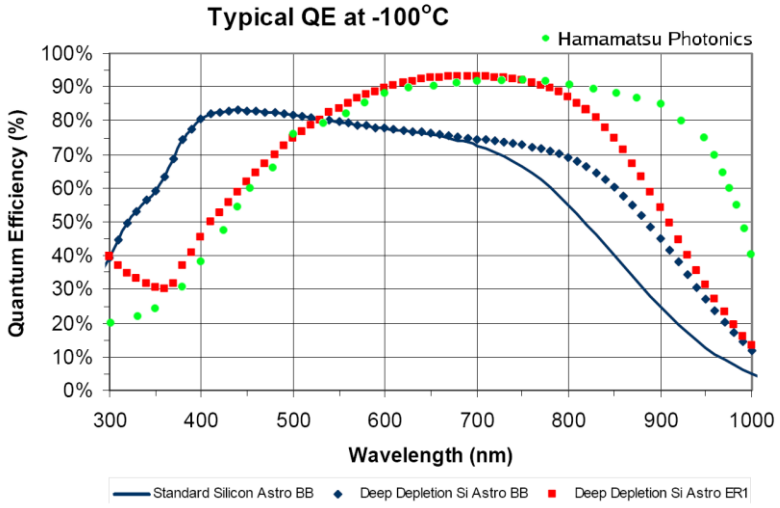
Fully depleted CCD

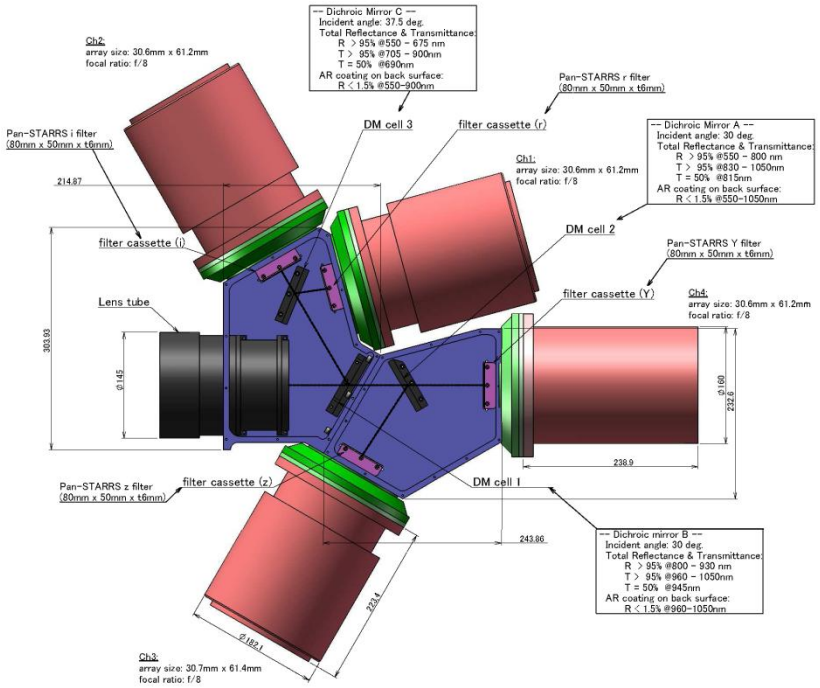


NCU/Lulin simultaneous 4-color imager

needs a telescope to adapt to …

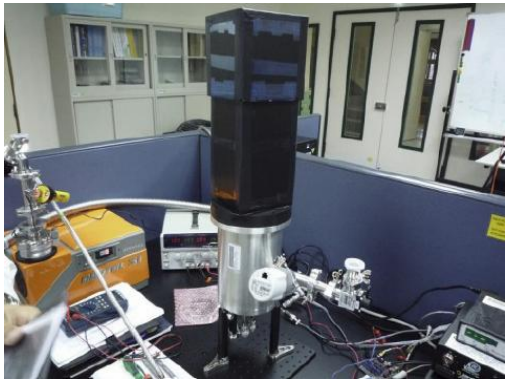




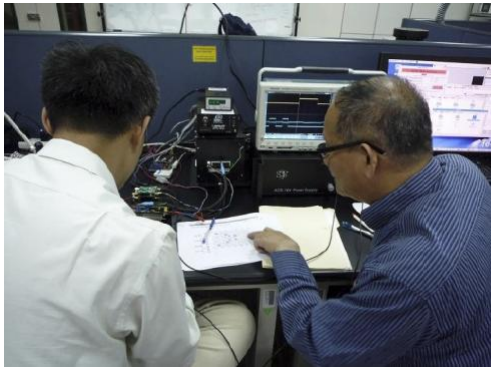


NCUcam-1 First-Light Image
Central Part of Emission Nebula M8 (Lagoon Nebula)

Instrument: Lulin 1-m Telescope + NCUcam-1
Filters: PS1 r' (60 sec × 8), i' (60 sec × 8), z' (90 sec × 8)
Field-of-view: 26.4 arcmin × 13.2 arcmin
Date/Time: 14:53:42 – 15:37:02 on 06 July 2011 (UT)
Observers: Kinoshita Daisuke, Wu Ching-Huang, Chen Tse-Chuan, Shen Pei-Hsien, Huang Ru-Huei

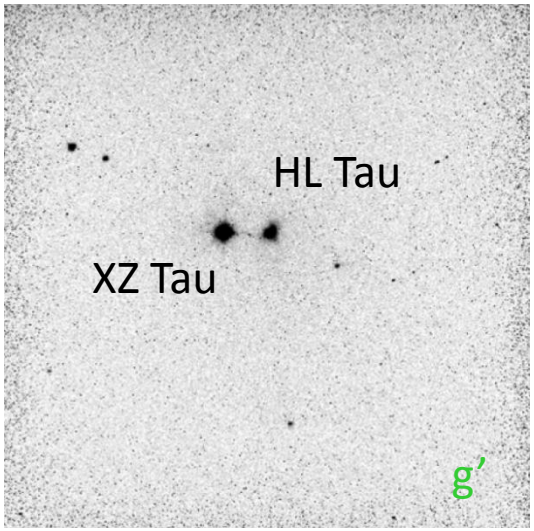


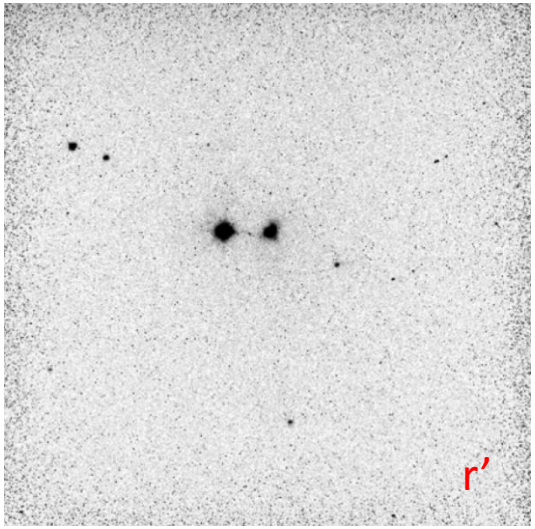
NCUIA Instrument Lab

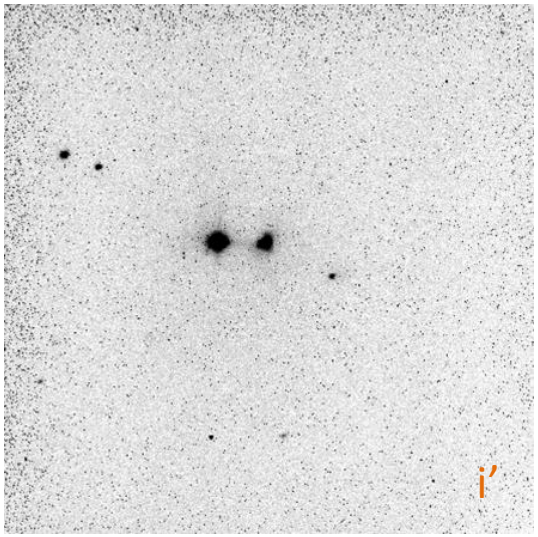


Prof. IKEDA Yuji, Kyoto Sangyo U (opt. design of 4-color imager)
Prof. KAWABATA Koji, Hiroshima U (advises on CCD imager dev.)
Prof. YOSHIDA Michitoshi, Hiroshima U (advises on CCD imager dev.)
Prof. YANAGISAWA Kenshi, OAO/NAOJ (advises on simultaneous imager dev.)
Prof. SAKO Takashi, STE Lab. Nagoya U (advises on CCD imager dev.)
Prof. SATO Shuji, Nagoya U (general advises on inst. dev.)
Mr. KAWAI Toshihide, Nagoya U (advises on materials, machining, etc.)
Prof. MIYATA Takashi, U of Tokyo (advises on CCD imager dev.)
Prof. SAKO Shigeyuki, U of Tokyo (advises on CCD imager dev.)
Prof. MINEZAKI Takeo, U of Tokyo (advises on CCD imager dev.)
Mr. ZENNO Takahiro, Nagoya U (advises on control software dev.)
Prof. TAKATA Masayuki, U of Electro-Communications (simultaneous control of multiple cameras)
Prof. WEI Ming-Zhi, UCSC (Ucam controler)

Triple-ranged simultaneous 3-color Polarimeter





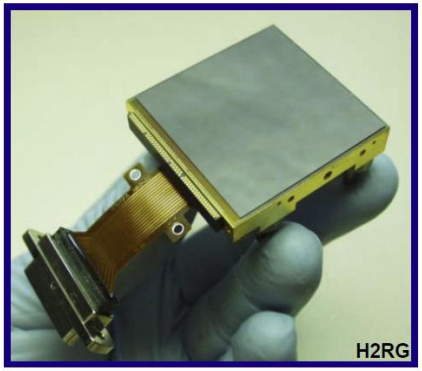


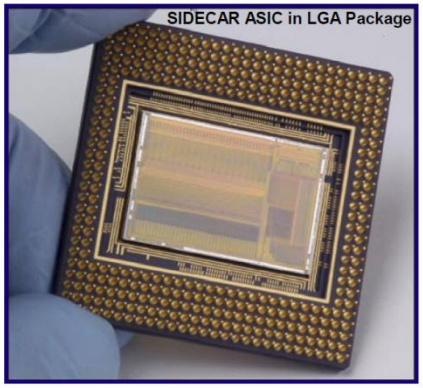
TRIPOL images taken with the LOT in August 2011

HL Tau (B=16.02, K=7.41)		
	Polarization	Pol Angle
g'	15.01 +/- 0.62	84 +/- 01
r'	14.17 +/- 0.23	87 +/- 01
i'	14.19 +/- 0.25	-88 +/- 0.0
XZ Tau (B=10.4, K=7.29)		
g'	1.48 +/- 0.18	-77 +/- 03
r'	1.29 +/- 0.11	-65 +/- 02
i'	1.51 +/- 0.10	-75 +/- 01

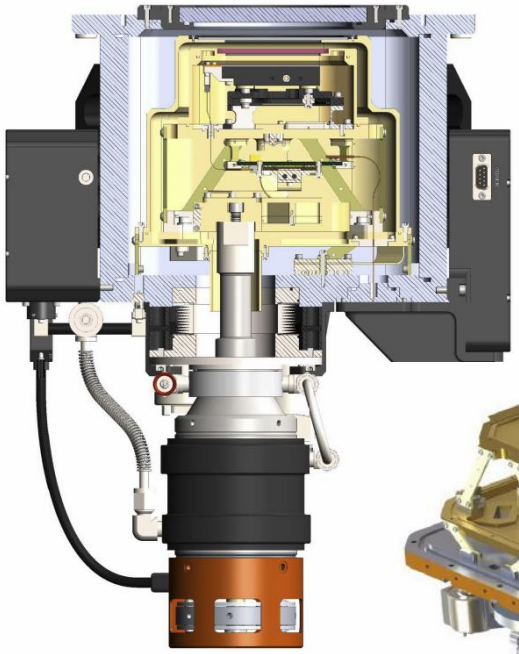
Developed by S. Sato

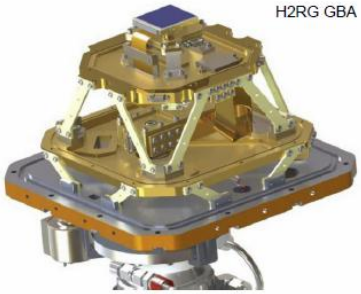
NCU/Lulin NIR Camera

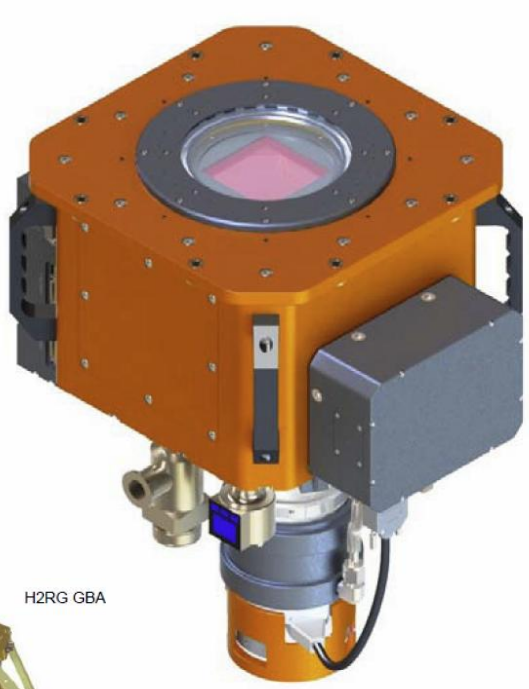




- Hawaii-2 RG 2048 x 2048 pixels
- 18 µm pixels
- JHKs filters
- LOT FOV= 15.8’
- Expected delivery end of 2012
- To be adapted to the 2 m later







Conclusions

- The Lulin 2 m telescope, though with a tough start, will be stalled in a few years.
- Meanwhile, our participation in PS1, PTF, etc, will continue to produce good science, particularly in time-domain phenomena. PS1TW has been a key member in the inner solar system discoveries.
- We are building up OIR instrumentation capability.
- We are keen to collaborate on mid- to large-sized telescopes.