東京大学における
突発天体の
光赤外フォローアップ体制

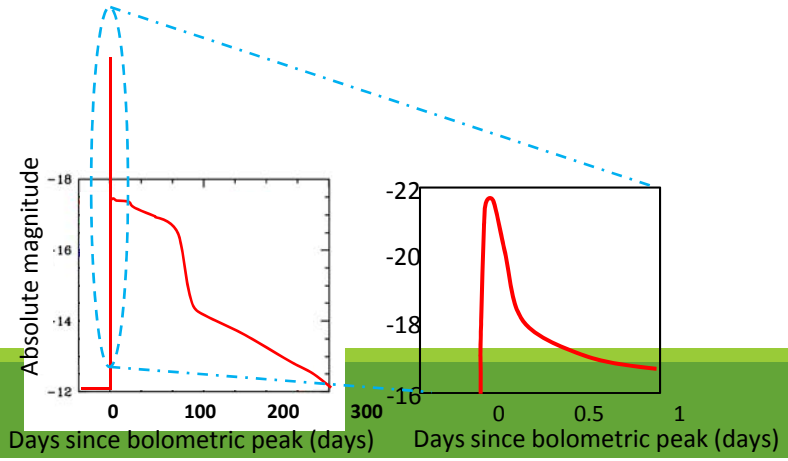
本原顕太郎、土居守、酒向重行　他

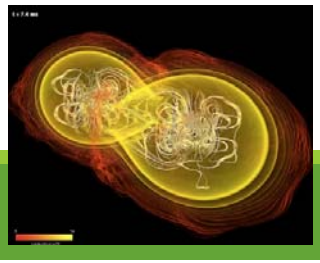
（東京大学天文学教育研究センター）

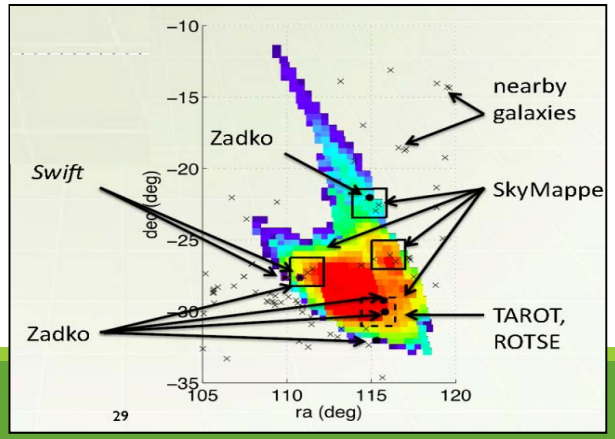
Observations of Outburst Objects by Opt/NIR

- Novae, Supernovae : Discovery and position ID in Opt/IR
- Gamma-ray bursts : Discovery in Gamma-ray, position ID in X-ray, detail observation in Opt/IR
- Counterpart objects for GW sources : Discovery in GW, position ID in Opt/IR

An outburst phenomenon requires prompt and sensitive Opt/IR observations to understand its physics, as well as the discovery and position ID.





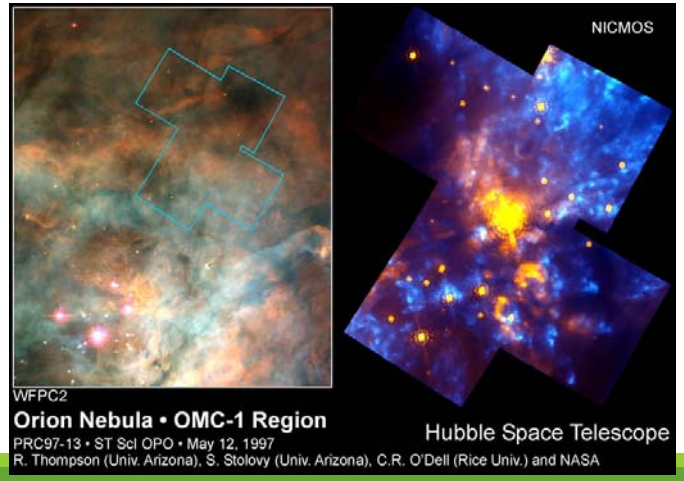


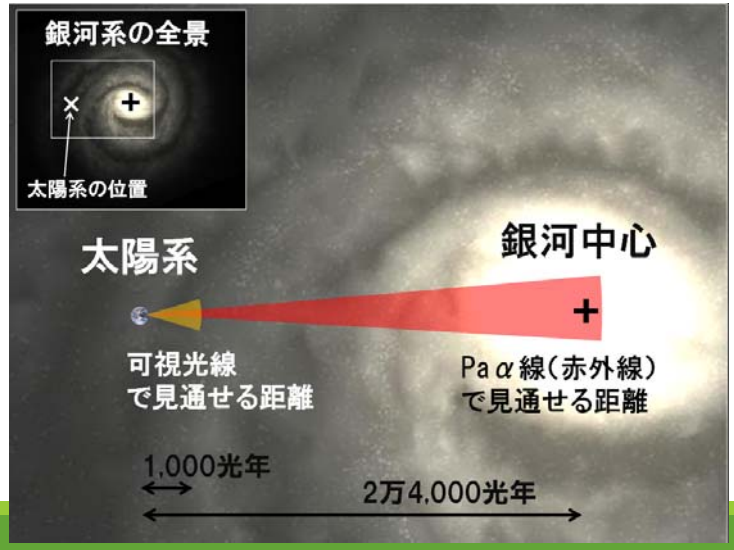
Necessity of NIR Follow-up

Barrier for Identification : Dust Obscuration

- Core collapse SNe explosion :
  - ✓ SF Region embedded in dust clouds / $A_V = 0 - 5$mag typ.
- Galactic Objects:
  - ✓ Galactic Plane, especially toward Galactic Center, is hidden by interstellar dust clouds

NIR follow-up is also necessary

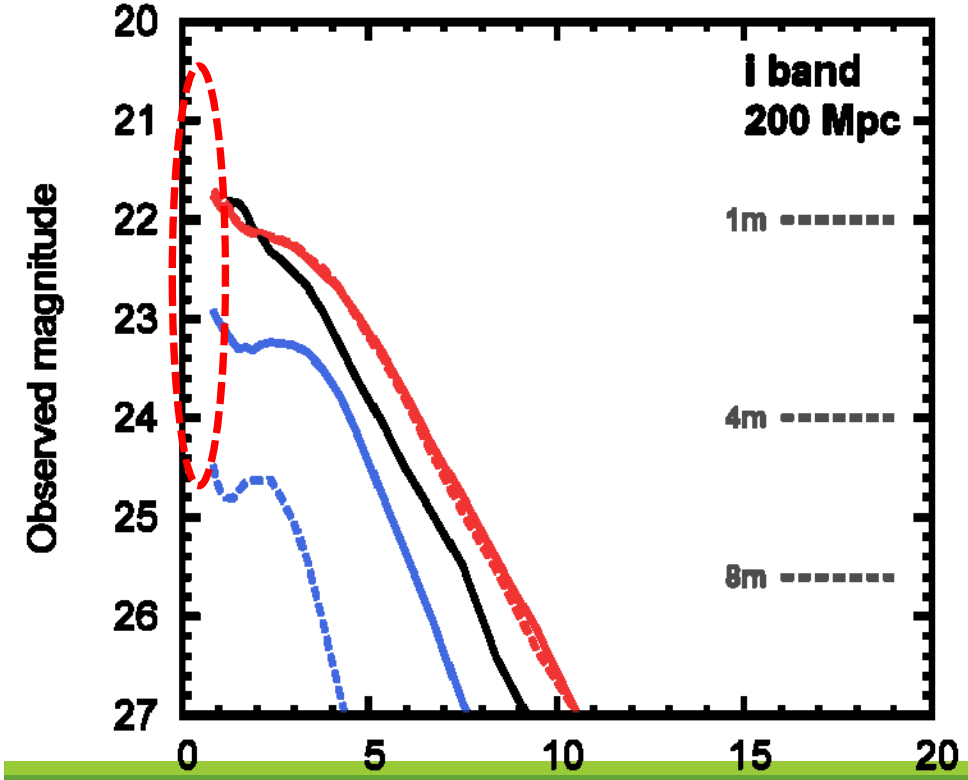


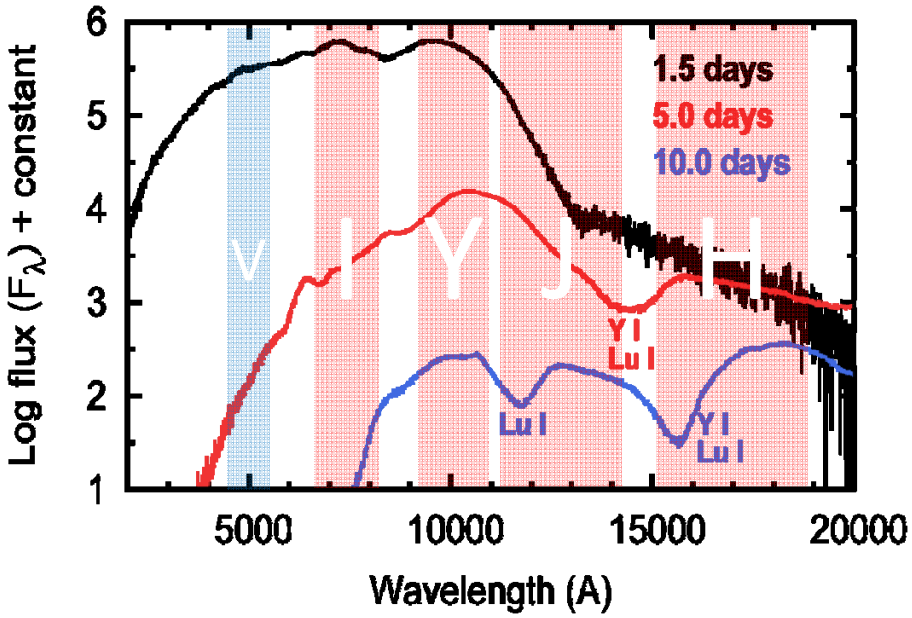


Especially for Kilonovae

SED is expected to peak @ NIR

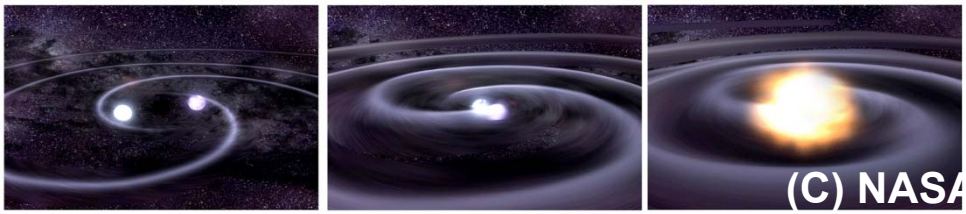
Emission from r-process elements





Tanaka & Hotokezaka 2013

Kilonovae Identification/Study Strategy : 2015



GW (e.g. KAGURA)

Optical ID @ KISO/ KWFC

Spectroscopy / IR imaging
With OISTER framework
miniTAO, Nayuta, Hiroshima…

Detailed Study with
Large Telescopes
e.g. Subaru

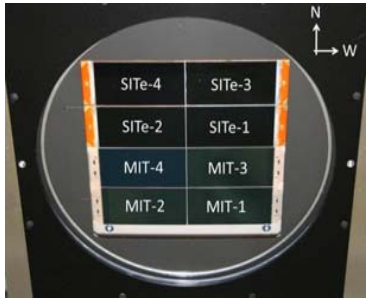
Opt/IR Facilities at IoA, Univ. Tokyo

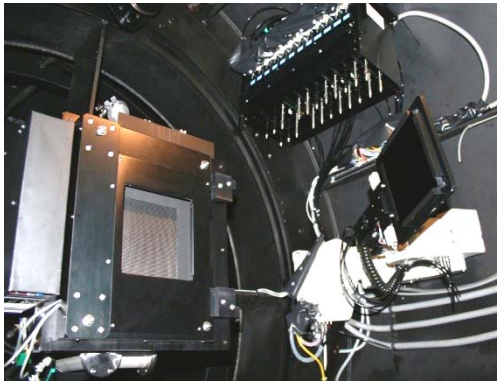
Basic Strategy :

- Optical Discovery / Identification by Kiso 1m Telescope
  - ✓Optical Wide-Field Imager
  - ✓KWFC in Operation
  - ✓Tomoe in Design Phase
- Optical/NIR Follow-up by Atacama and Other Observatories
  - ✓miniTAO 1.0m Telescope (Atacama, Chile) in Operation with ANIR for NIR imaging
  - ✓LISS optical spectrograph at Nishiharima Observatory
- Detailed study with Large telescopes
  - ✓Subaru 8.2m
  - ✓TAO 6.5m Telescope (Atacama, Chile) under construction

Kiso Observatory

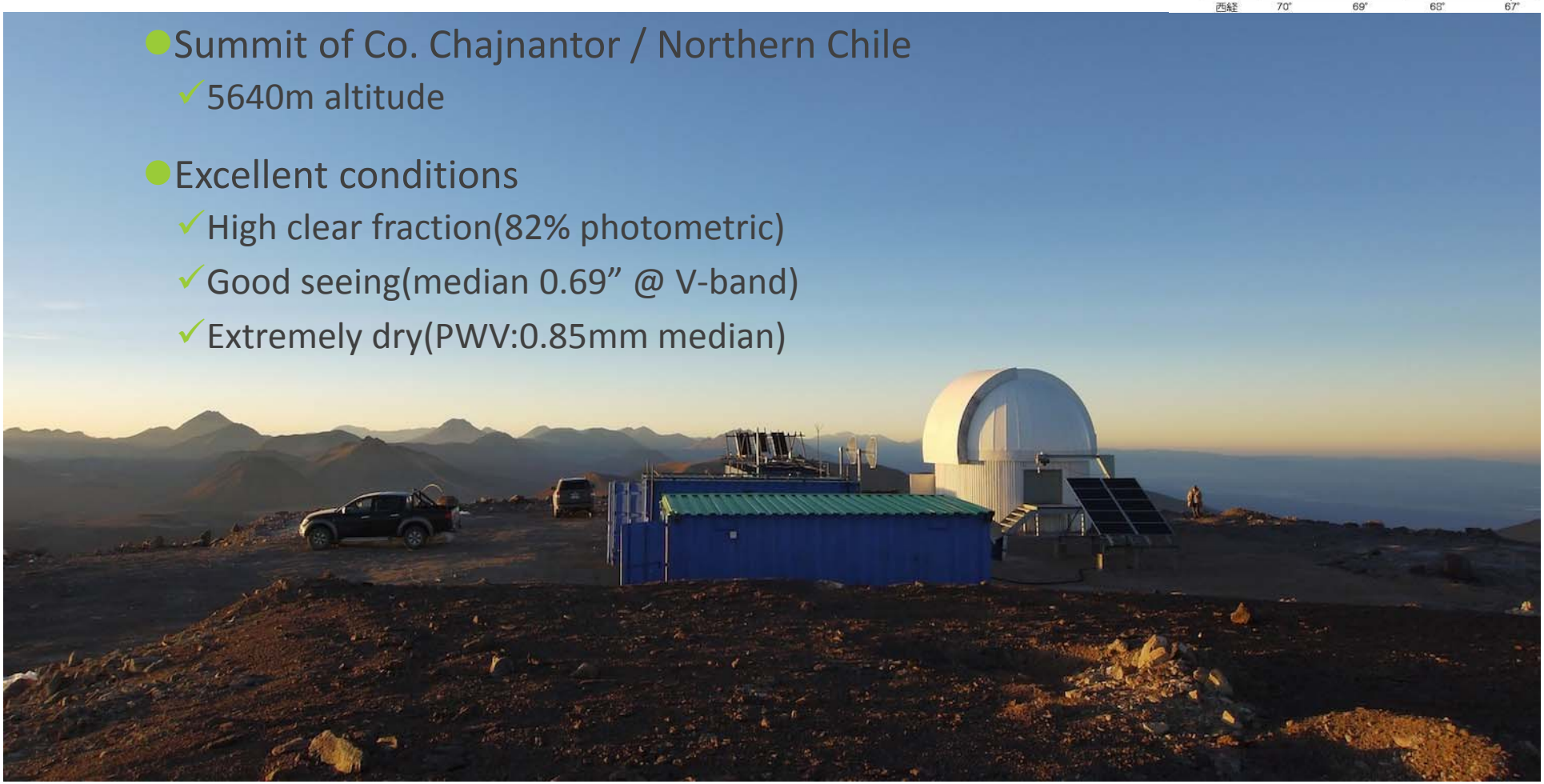
- 1.0m Schmidt Telescope at Kiso, Nagano
- Current Instrument : KWFC
  - ✓Wide-field Imager (2.2x2.2 degree FoV)
  - ✓Eight 2kx4k CCDs
  - ✓See Tanaka-san's presentation for current surveys





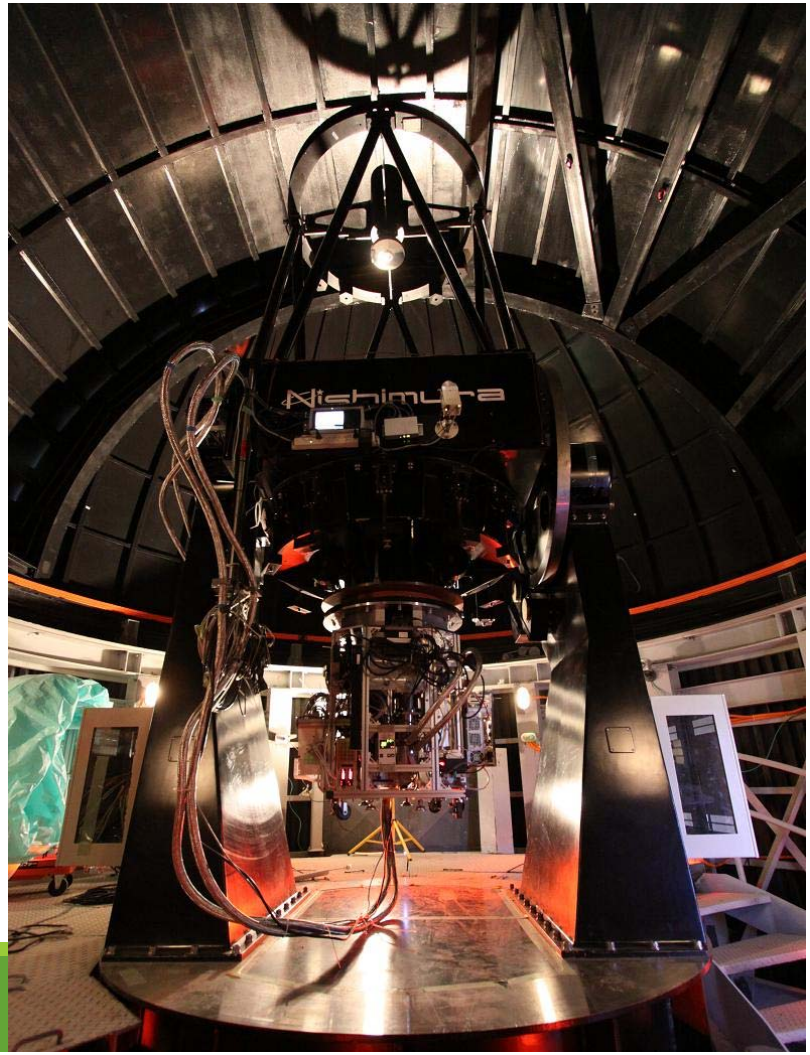
miniTAO 1m Telescope

- 1.05m Infrared Telescope
- Summit of Co. Chajnantor / Northern Chile
  - ✓5640m altitude
- Excellent conditions
  - ✓High clear fraction(82% photometric)
  - ✓Good seeing(median 0.69” @ V-band)
  - ✓Extremely dry(PWV:0.85mm median)



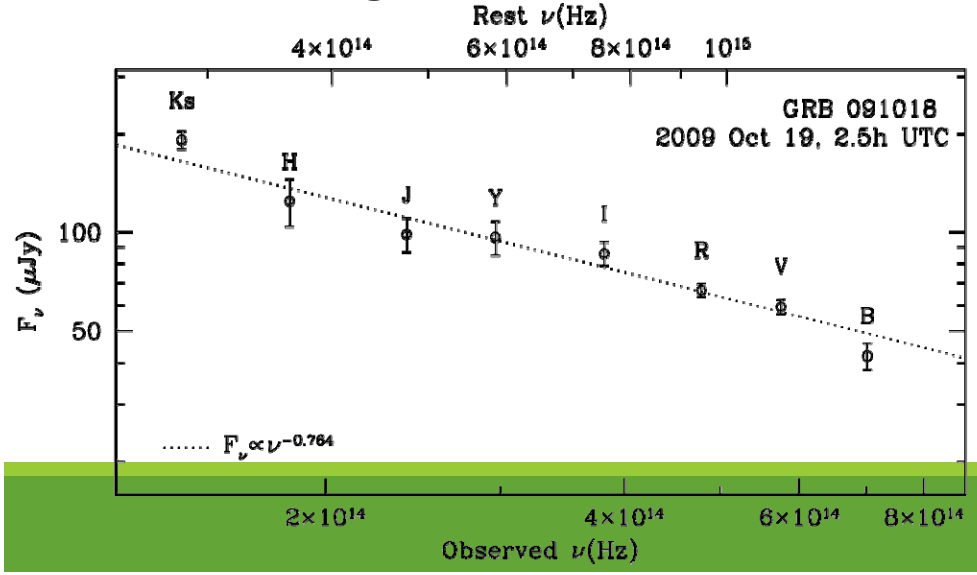
ANIR : NIR Camera for miniTAO

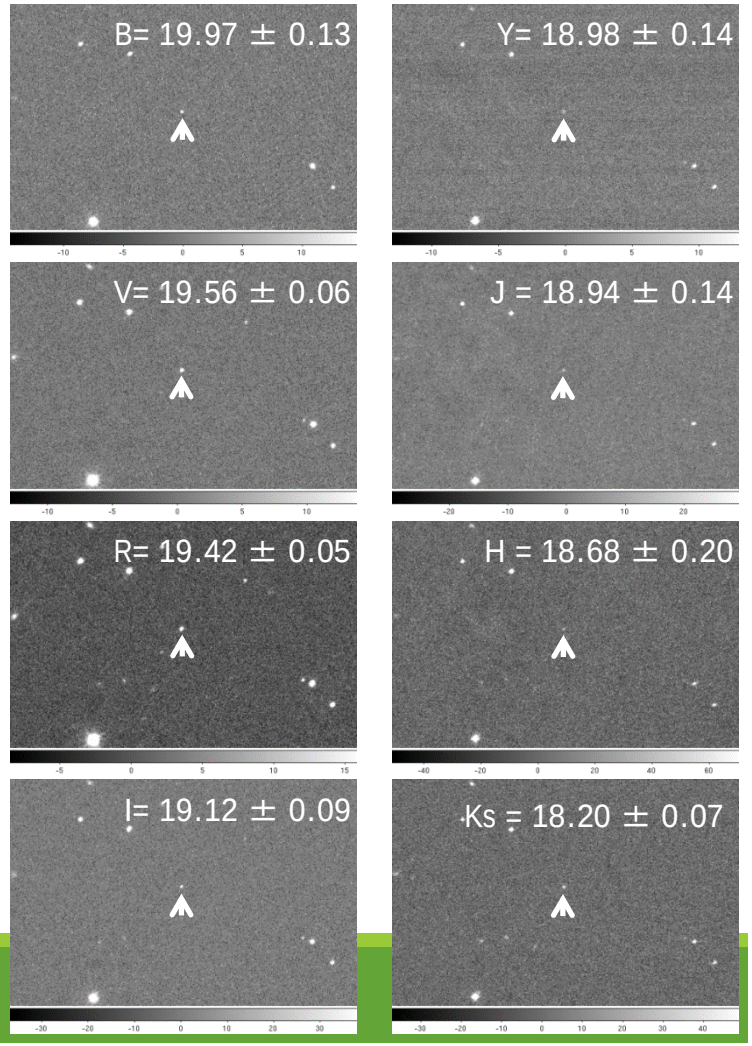
- 5x5 arcmin^2 FoV
- 0.9-2.5 μm Imaging : Y, J, H, Ks and NBFs
- Simultaneous optical observation possible : B, V, R, I and slitless grism ($\lambda/\Delta\lambda$~10)
- Remotely Operated from Base Facility @ San Pedro de Atacama, 2500m



An Example of GRB follow-up

- GRB091018
  - ✓z=0.971 burst
  - ✓~5min exposure
  - ✓$\sim\nu^{-0.76}$ power law SED
- Comparable or higher sensitivity than GROND, thanks to the good seeing
  - ✓Seeing < 1arcsec even at an elevation of 20deg





Current Status of miniTAO/ANIR

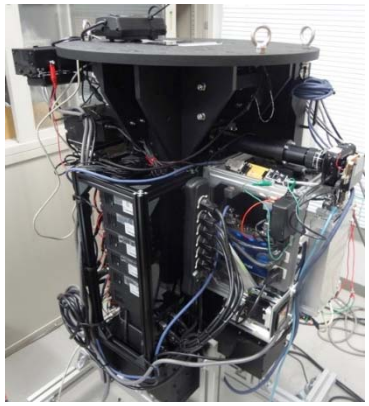
- ~FY2013 : operated only a limited period : ~30nights per year
- FY2014 : operation suspended due to shortage in resouces
- FY2015 : operation will be resumed

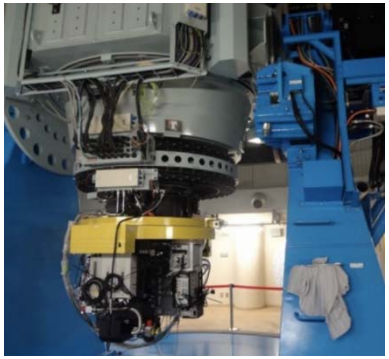
If you are interested in observing at miniTAO/ANIR, please let us know!

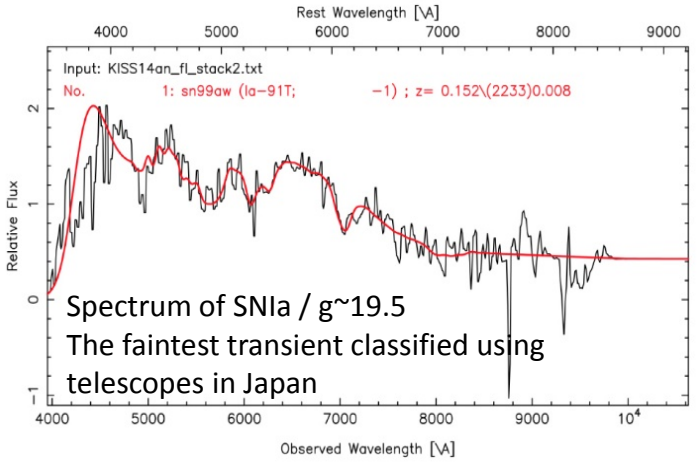
LISS : Line Imager and Slit Spectrograph

High sensitivity optical spectrograph, installed on Nayuta 2m telescope (Hashiba+14)

- ✓ Very low resolution grism (λ/Δλ~100)
- ✓ Hamamatsu high depletion CCD







Spectrum of SNIa / g~19.5
The faintest transient classified using telescopes in Japan

Currently, the most sensitive optical spectrograph in Japan

Available as a PI instrument at Nishiharima Observatory

OISTER:
Follow-up Framework in Japan

Optical and Infrared Synergetic Telescopes for Education and Research

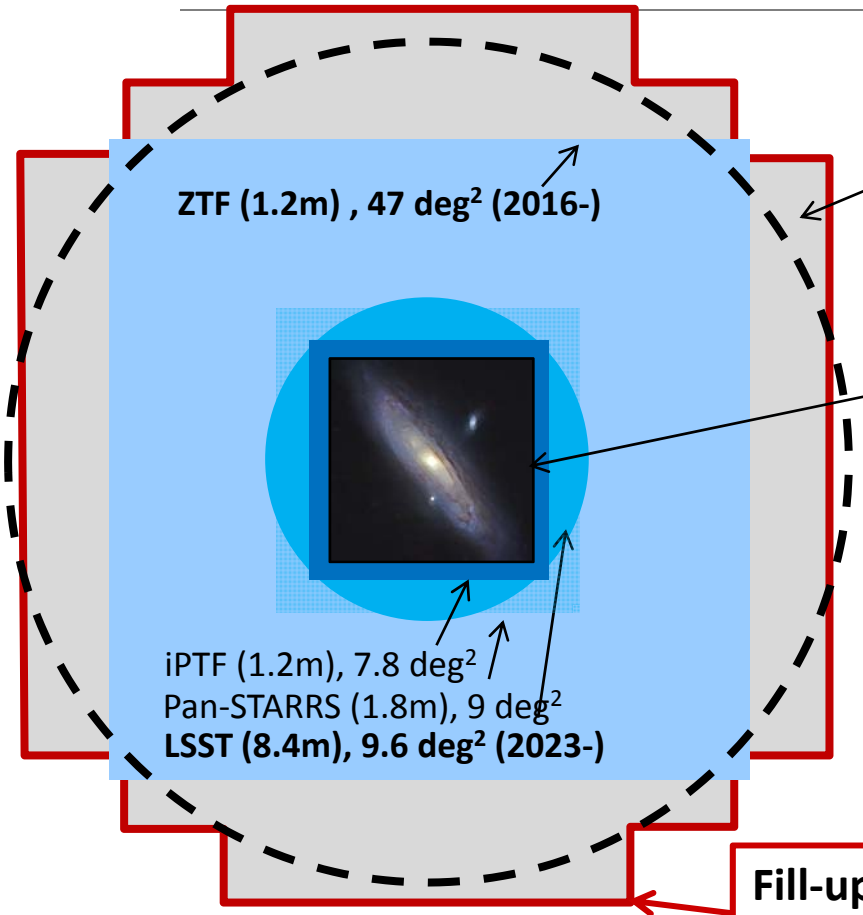
- Collaboration Small to Medium size telescopes mainly in Japan

	機関	サイト	望遠鏡
主体機関	北海道大学	名寄(北海道)	1.6 m ピリカ
(10機関)	埼玉大学	埼玉	0.55 m
	東京大学	木曽(長野)	1.05 m 木曽シュミット
		アタカマ(チリ)	1.04 m miniTAO
	東京工業大学	明野(山梨)	0.5 m MITSuME
	名古屋大学	サザーランド(南ア)	1.4 m IRSF
	京都大学	京都	0.4 m
	兵庫県立大学	西はりま (兵庫)	2.0 m なゆた
	国立天文台	岡山	1.88 m
			0.5m MITSuME
	広島大学	東広島	1.5 m かなた
	鹿児島大学	入来 (鹿児島)	1.0 m
	国立天文台	石垣島 (沖縄)	
協力機関	群馬県	ぐんま天文台	1.5m
(3機関)	京都産業大学	神山 (京都)	1.3m 荒木
	日本スペースガード協会	美星 (岡山)	1.0m

Future Plan

- Tomoe : Upgrade of Kiso 1m Schimidt Telescope
- TAO 6.5m : New 6.5m Infrared Telescope at Co. Chajnantor

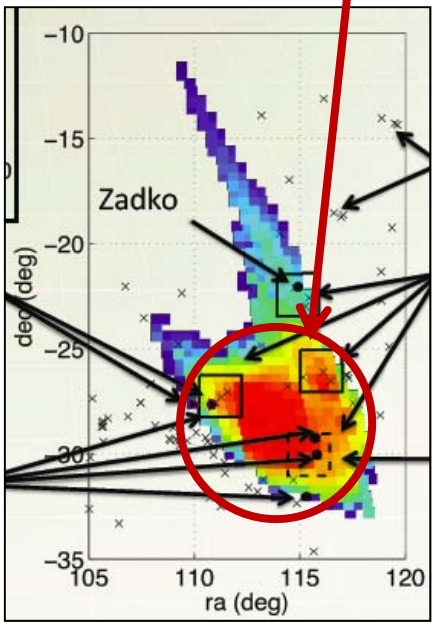
Tomoe : Next Generation WFC at Kiso Observatory



FoV of Kiso
Schmidt Telescope
ϕ 9 deg

KWFC/Kiso
4.8 deg², CCD

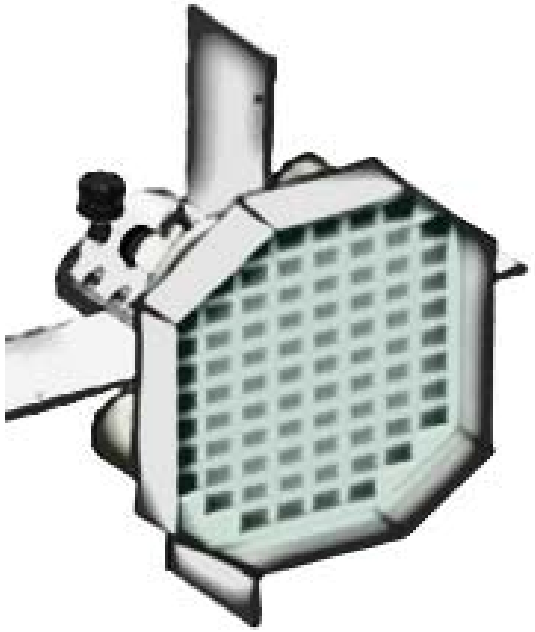
F.O.V
ϕ 9deg



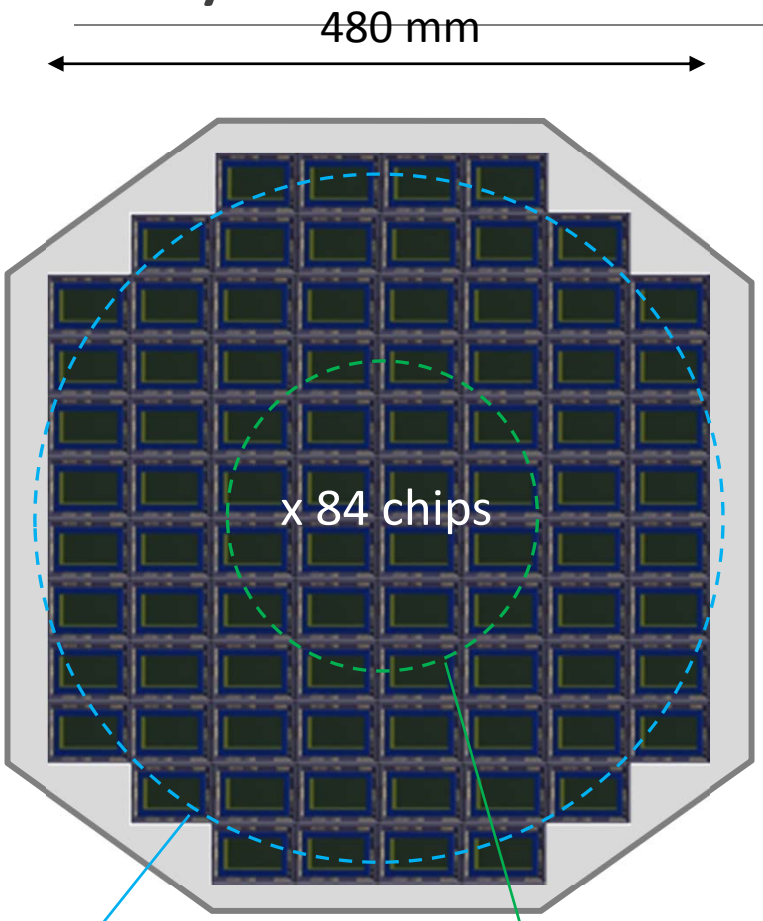
Fill-up 20 deg² of ϕ 9 deg, with CMOS sensors

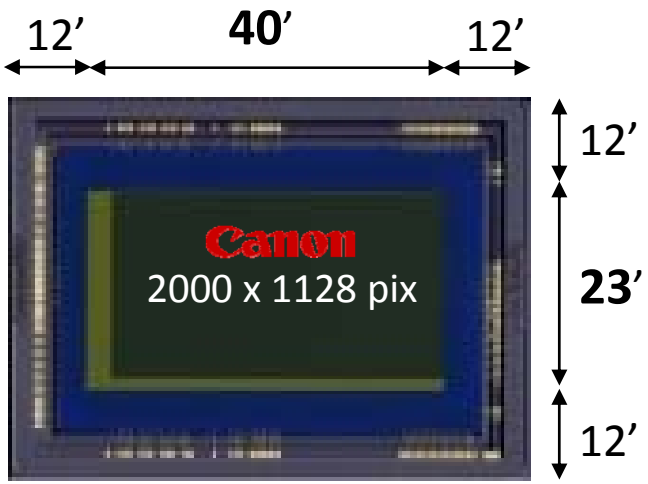
Specifications of Tomoe

- Telescope: Kiso 105 cm Schmidt
- Field of view : 20 deg^2 in ϕ 9 deg
- Sensor: 1k x 2k CMOS sensor at ambient temperature
- # of CMOS: 84
- Pixel scale : 1.2 arcsec/pix
- Frame rate : 2 frames/sec (max)
- Filter : SDSS-g+r, SDSS-g, SDSS-r , be exchanged manually



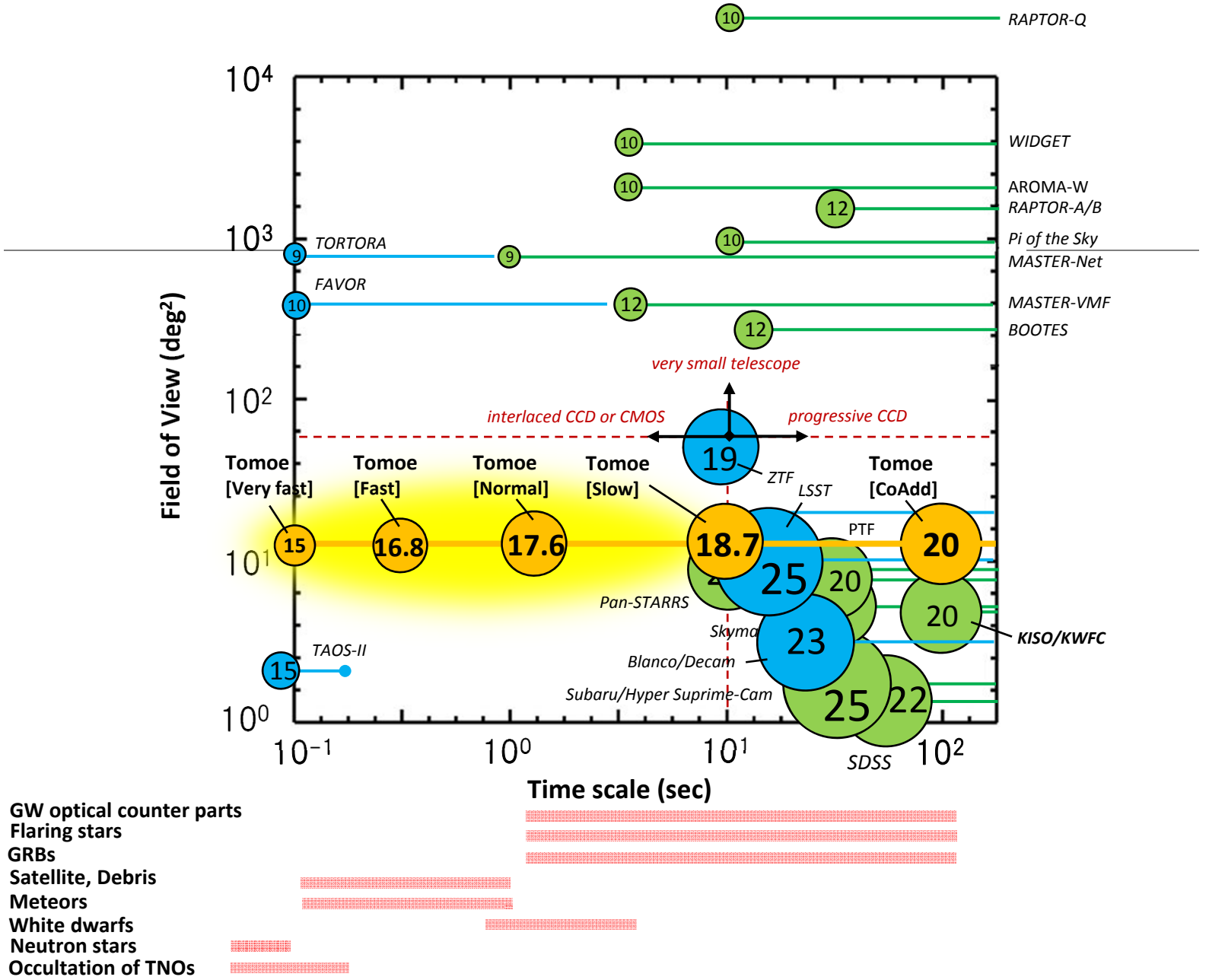
Layout of Tomoe's Focal Plane





35mm Full HD CMOS sensor
sensor / package area = 0.3

- ✓ Total sky coverage 20 deg^2
- ✓ Total 190 Mpixels
- ✓ 760 MB/exposure
- ✓ Driven at Room Temperature

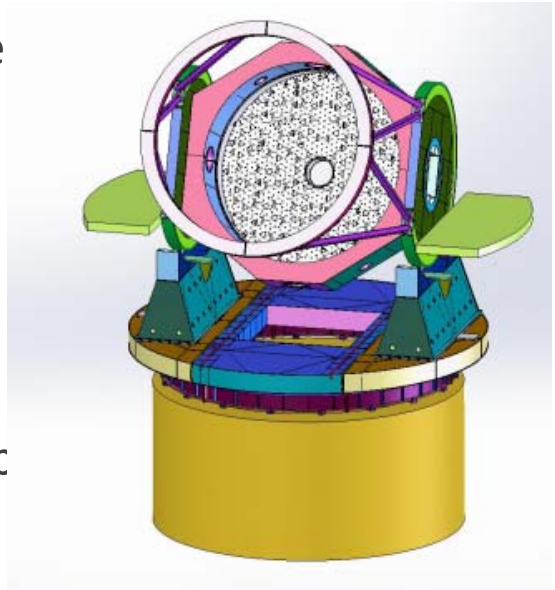


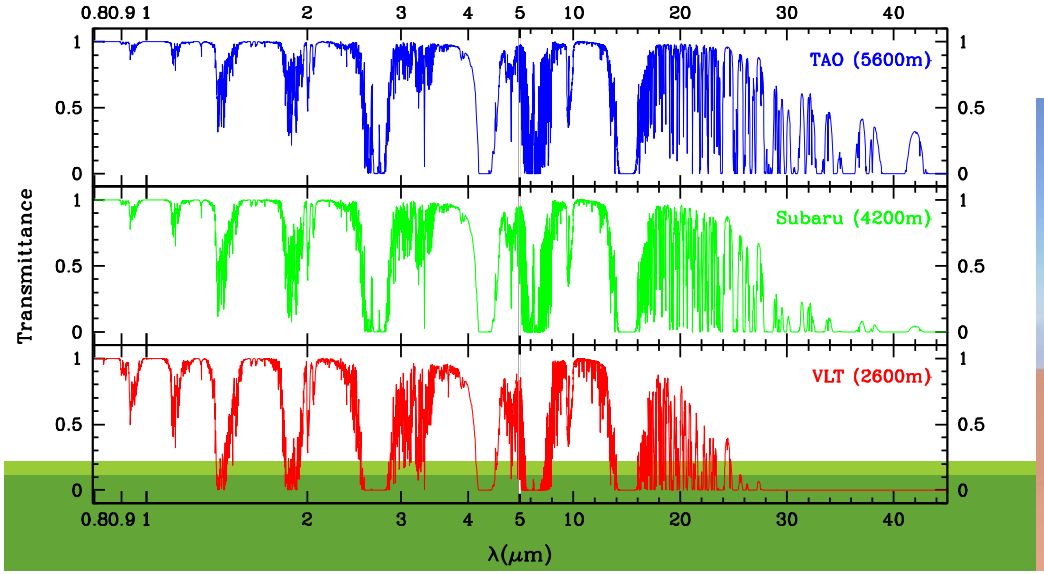
Numbers in the circles indicate limiting magnitudes.

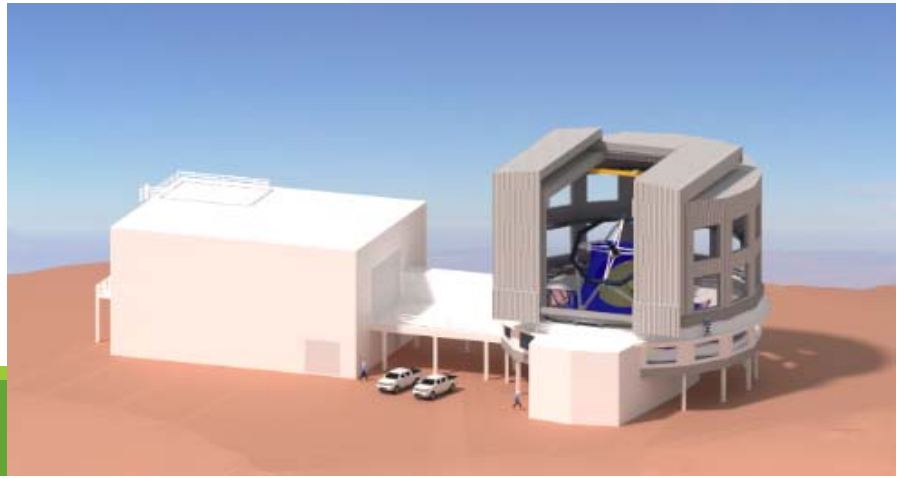
TAO 6.5m Telescope

To construct a 6.5m infrared-optimized telescope at the summit of Co. Chajnantor, next to miniTAO

- Design Based on Magellan 6.5m Telescopes
- Utilize the excellent condition of Co. Chajnantor
  - ✓Clear fraction, seeing, IR transparency ….
- University-owned telescope ; flexible operation possib





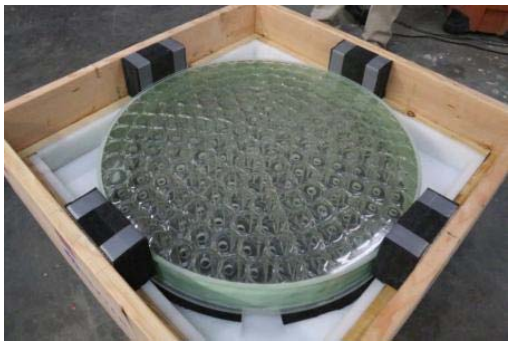


Current Status of Construction

- Major components now under construction
  - ✓Primary, secondary, and tertiary mirrors
  - ✓Telescope structure
  - ✓Upper dome structure
  - ✓Instruments ….
  - ✓Fabrication of parts completed by the end of FY2014

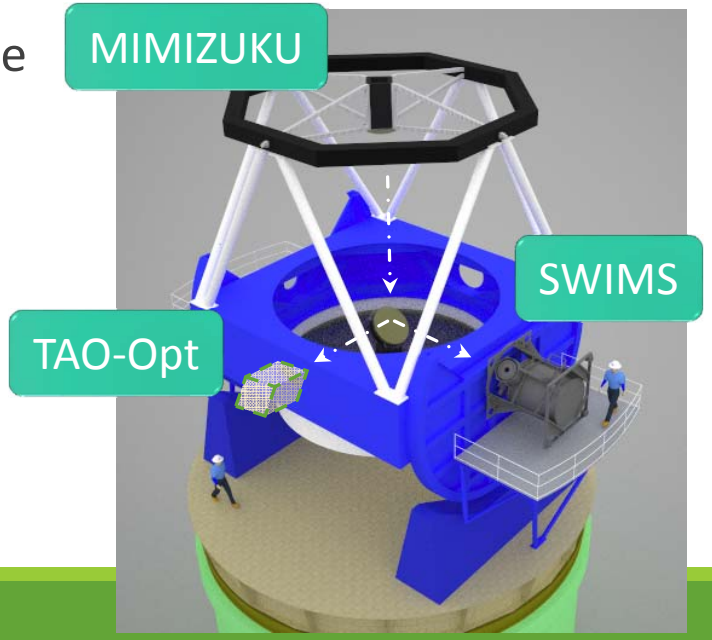
TAO 6.5-m mirror on LOG during front surface generating.

TAO 6.5-m mirror with front surface generated with 100 mesh metal bond cup wheel.

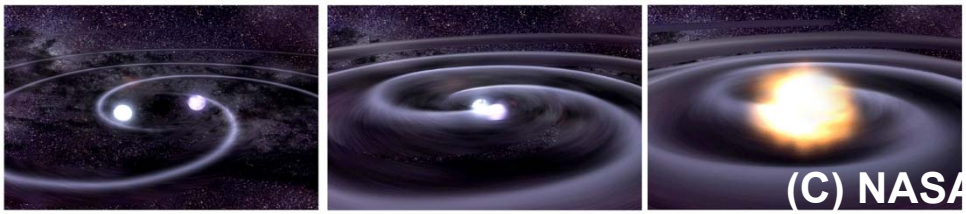


Instruments for TAO

- Two Instruments under development
  - ✓SWIMS : NIR (0.9-2.5μm) MOS Spectrograph with 9.6 arcmin FoV
  - ✓MIMIZUKU : MIR (2-38μm) Imager/Spectrograph
  - ⇒Best infrared-wavelength coverage among ground-based telescope
- U-band optimized optical spectrograph under consideration
- Quick switching between instruments be done by rotating tertiary mirror



Kilonovae Identification/Study Strategy : Update

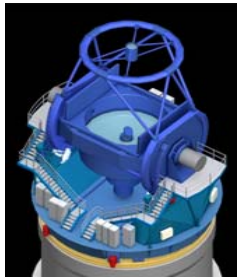


GW (e.g. KAGURA)

Optical ID @ KISO/ Tomo-e

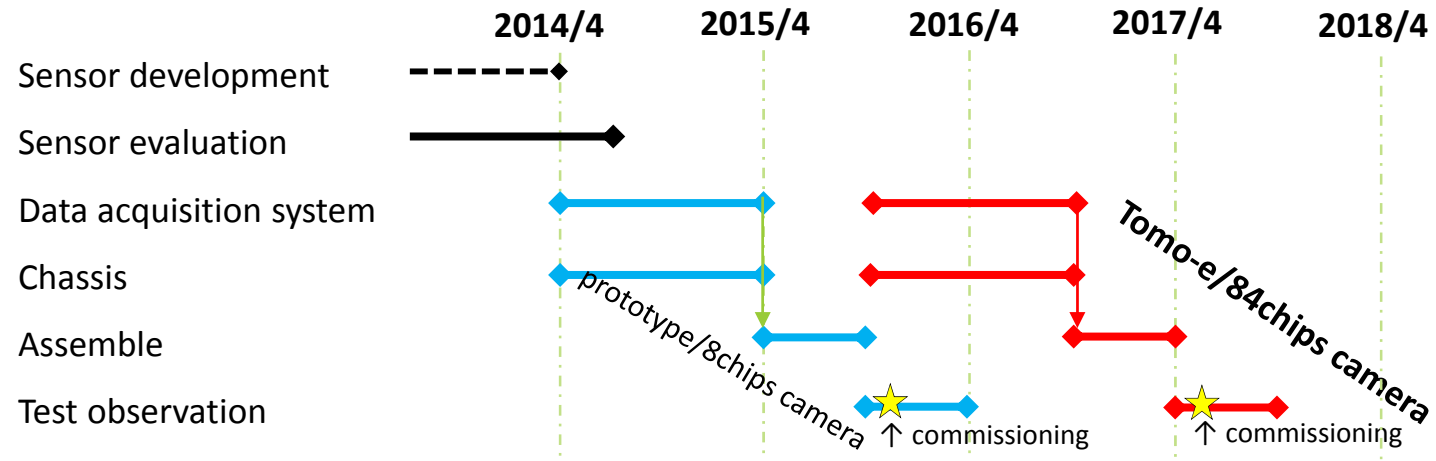
Spectroscopy / IR imaging
With OISTER framework
miniTAO, Nayuta, Hiroshima…

Detailed Study with Large Telescopes
e.g. Subaru, TAO



Schedule

Tomoe



TAO6.5m

FY2017 : Engineering First Light

FY2018 : Science First Light with SWIMS

Summary

- IoA, University of Tokyo has been developing a follow-up framework of outburst objects, consisting of
  - ✓KWFC / KISO 1m telescope
  - ✓ANIR / miniTAO 1m @ Chile
  - ✓LISS / Nayuta 2m

  within the network of OISTER framework.

- Also, we have been developing a new instrument / facilities
  - ✓Tomoe at Kiso 1m telescope, coveing 9deg FoV
  - ✓TAO 6.5m telescope optimized for infrared observations

  Both expected to be commissioned at 2017-2018.