

# Introduction of instruments in Gunma Astronomical Observatory and transit observation at GAO

Gunma Astronomical Observatory

<http://www.astron.pref.gunma.jp/>

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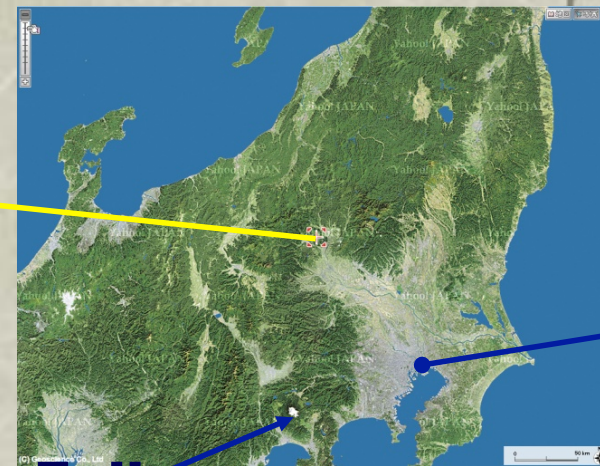
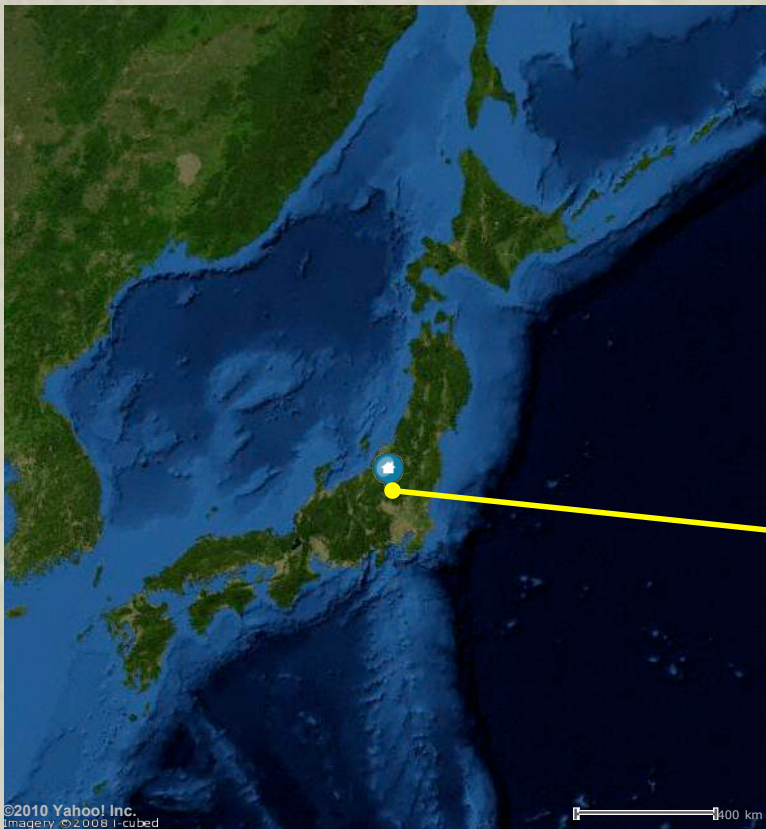
# About Gunma Astronomical Observatory

Gunma Astronomical Observatory

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Gunma Astronomical Observatory (GAO), which is located about 120 km northwest of Tokyo.

Latitude 36. 35' 37" N  
Longitude 138. 58' 35" E  
Altitude 885 m



**Mt. Fuji**

**Tokyo**

# About Gunma Astronomical Observatory

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- ❖ Established in April 1999 by Gunma prefecture local government.
- ❖ Designed for both *astronomical research* and *public use*.
- ❖ With devices and facilities for full scale observational research with **150cm reflector**.
- ❖ There are some other telescopes which is prepared for both researchers and public visitors; a **65cm reflector** on an equatorial mounting, and six **25-30cm small telescopes** in sliding roof.



# Advantages and disadvantages of GAO

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## Multi Instruments with medium size telescope

- \* large wavelength coverage from optical to NIR
- \* fairly good time resolution, little saturation
- \* quick switching of instruments (only flip 3<sup>rd</sup> mirror)
- \* cooperate with other small telescopes in GAO



## Independent management and operation (no common use observatory)

- \* time allocation for selected research (non proposal based)
- \* efficient observation matched to the occasion



## Flexibility of observing time allocation

- \* Long term : Variable targets
- \* Flexibility : Transient targets



## Weather conditions

- \* Typical seeing  $\leq 2''$ , few photometric nights / month



## Public organization (weekend star watching for amateurs)

# 150cm Reflector

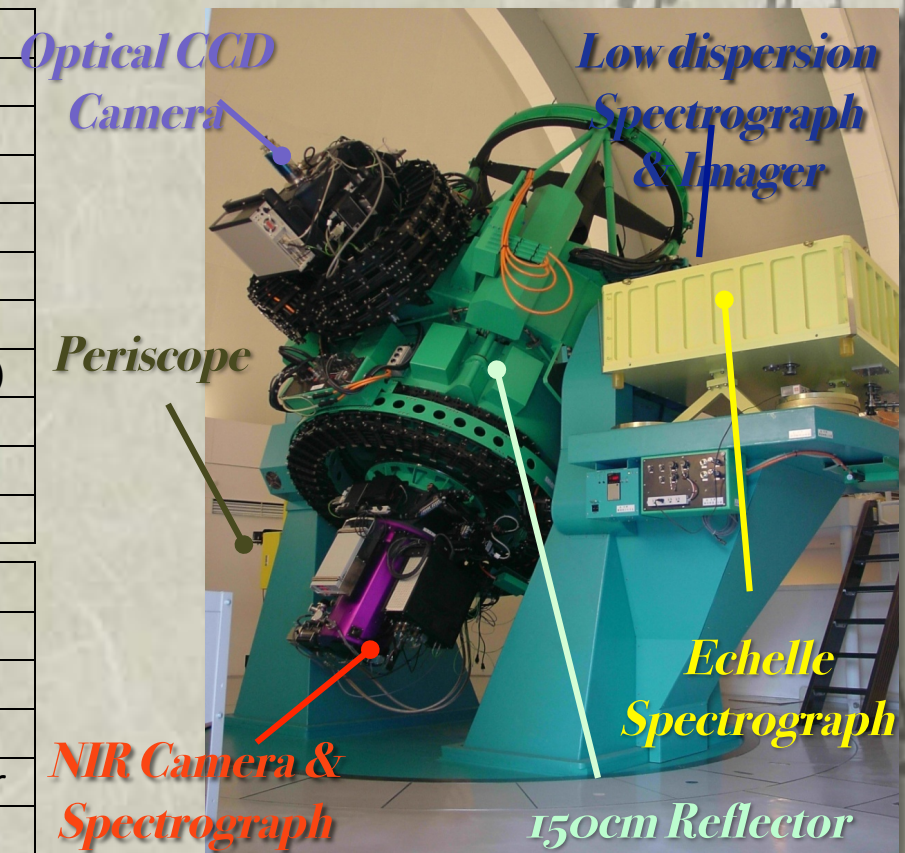
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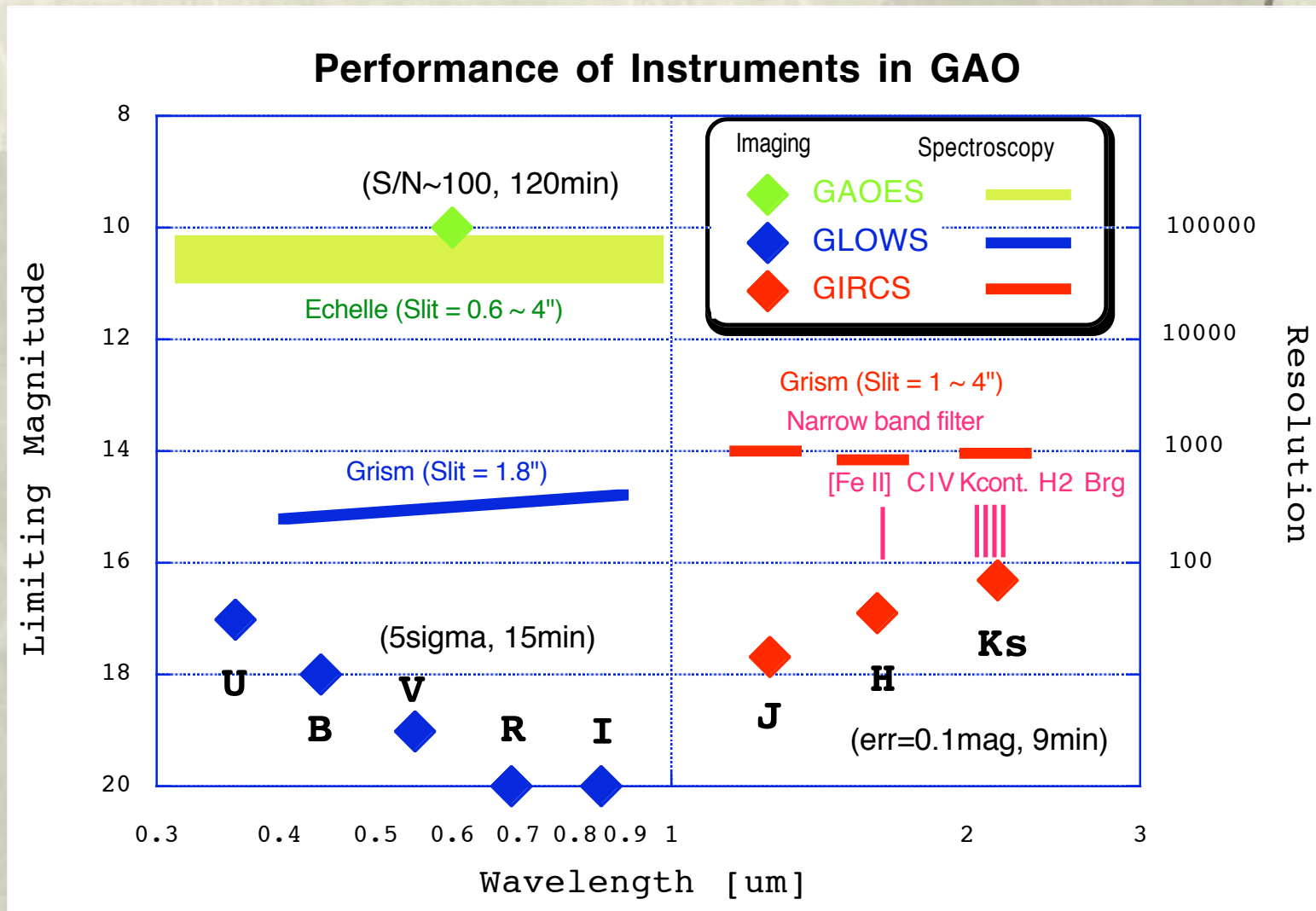
Five focus are fully used. There are **4 scientific instruments**, which are used various observations not only nominal observation programs but also follow-up and campaign observations.

Optics	Ritchey-Chretien
Diameter of primary mirror	160 cm
Effective diameter	150 cm
Focal length	1830 cm (F/12.2)
Haltman constant	0.3 arcsec
Mounting	Altazimuth
Pointing accuracy	3.0 arcsec (rms)
Tracking accuracy	0.7 arcsec (rms) (15 min)
Diameter of dome	11 m
Establish	March 1999
Manufacturer	Mitsubishi Electronics

Coverage	Optical~NIR (0.38 – 2.35 $\mu\text{m}$ )
Nasmyth 1	Echelle spectrograph
Nasmyth 2	Periscope
Bent-cassegrain 1	LN2 cooled CCD Camera
Bent-cassegrain 2	Low dispersion spectrograph & Imager
Cassegrain	NIR camera & spectrograph



# Performances of each instrument with 150cm



# Features of each instrument and Project Observations & Collaborations

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## GAOES

### Wide spectral coverage, Quick read-out Echelle

- ❖ Evolution of carbon stars in AGB
- ❖ Stellar Metallicity in globular clusters
- ❖ High dispersion spectroscopy of eclipsing binaries
- ❖ Mass loss of cool giants

## GIRCS

### Imaging & Spectroscopic capability in NIR

- ❖ IMF of HII regions
- ❖ Search for WR stars in massive starforming regions
- ❖ Monitoring of SNe in starburst galaxies
- ❖ Spectral library of Mira variable

## GLOWS

### Optical Imaging & Spectroscopic capability

- ❖ Transient observation of GRBs
- ❖ Early phase spectroscopy of SNe and Novae
- ❖ Spectroscopy of dwarf Novas
- ❖ Spectroscopy of planets and dwarf planets
- ❖ Spectral library of Cepheids
- ❖ YETI/TTV

## Campaign

- ❖ ASCA
- ❖ SUZAKU
- ❖ AKARI
- ❖ MAXI

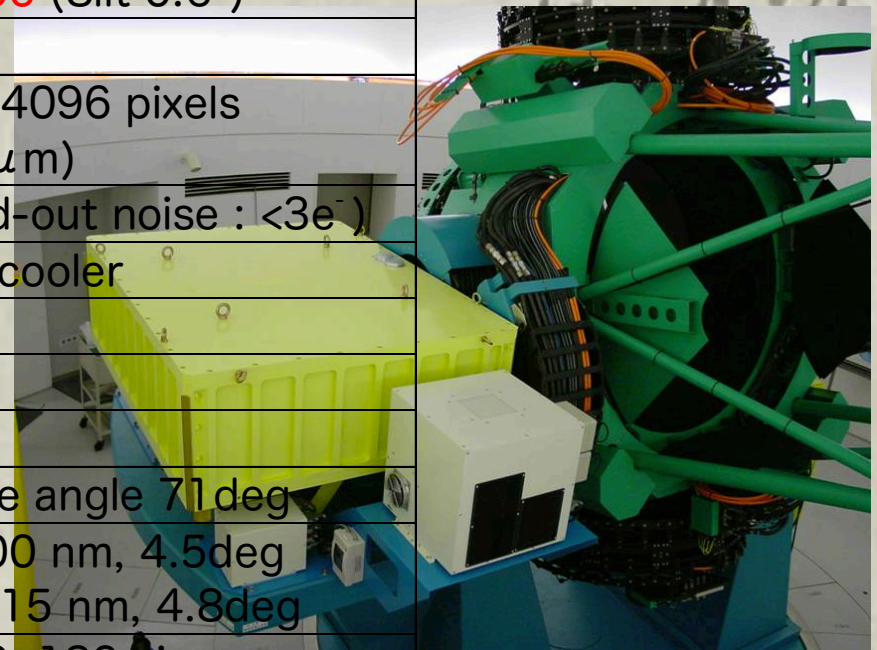
# Gunma Astronomical Observatory Echelle Spectrograph (GAOES)

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GAOES is a high resolution spectrograph on a Nasmyth focus of the 150cm reflector. It provides an optical spectrum of a spectral resolution up to 100,000.

Coverage	360–1000 nm
Spectral resolution	75,000 (Slit 1.0"), <b>100,000</b> (Slit 0.6")
Slit length	8.0" (720 $\mu\text{m}$ )
Detector	e2V CCD44-82 2048 $\times$ 4096 pixels (pixel size : 15 $\mu\text{m}$ $\times$ 15 $\mu\text{m}$ )
Read-out	MFront2 + Messia-V (read-out noise : $<3e^-$ )
Cooler	He circulating mechanical cooler
Type	Semi-Littrow
Collimeter	Lens system
Camera optics	Lens system
Echelle grating	R = 2.8, 31.6 gr/mm, blaze angle 71deg
Cross disperser	(red) 250 gr/mm, blaze 600 nm, 4.5deg (blue) 400 gr/mm, blaze 415 nm, 4.8deg
Limiting magnitude	<b>10 mag</b> ( $\sim 600\text{nm}$ ) S/N $\sim 50$ , 120min
Manufacturer	Genesia corporation



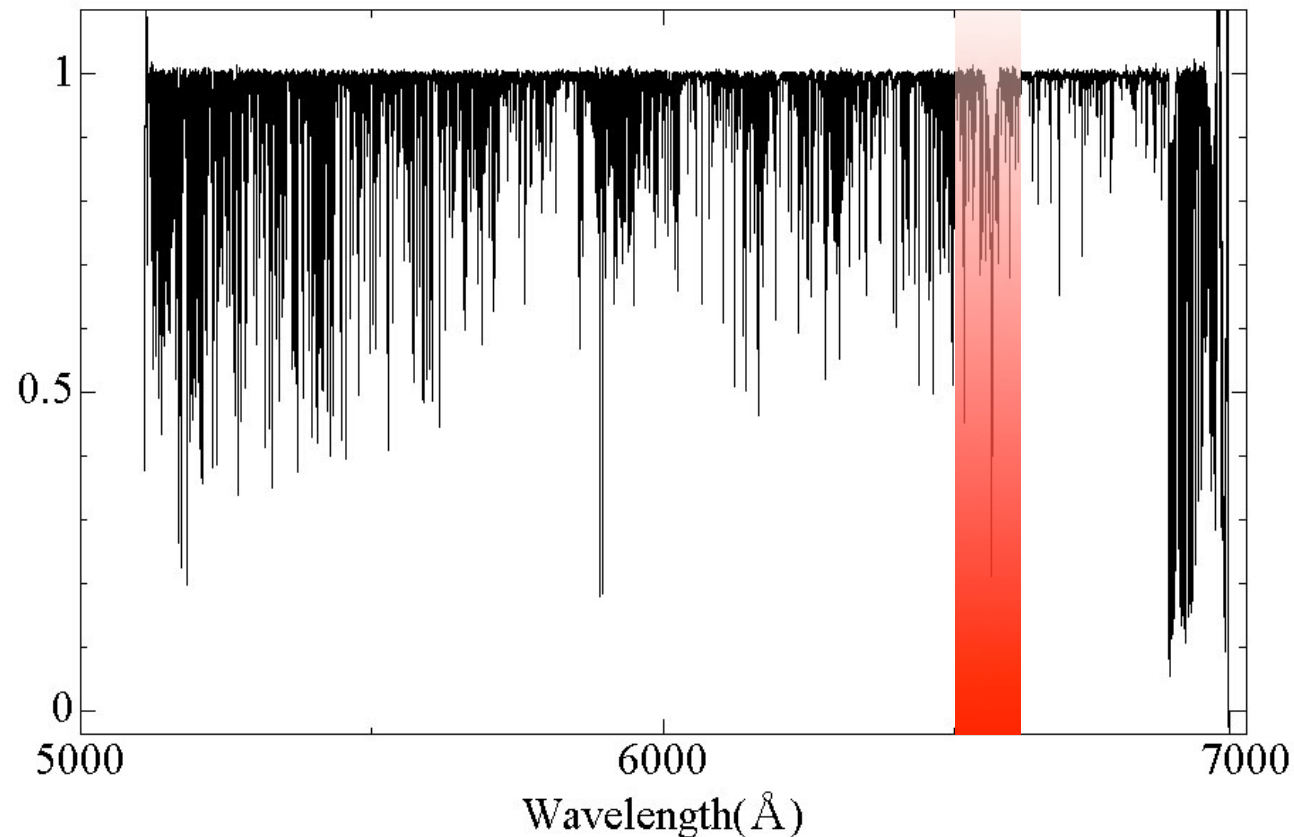


# Gunma Astronomical Observatory Echelle Spectrograph (GAOES)

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## High resolution spectrum of Stars $\alpha$ CMi



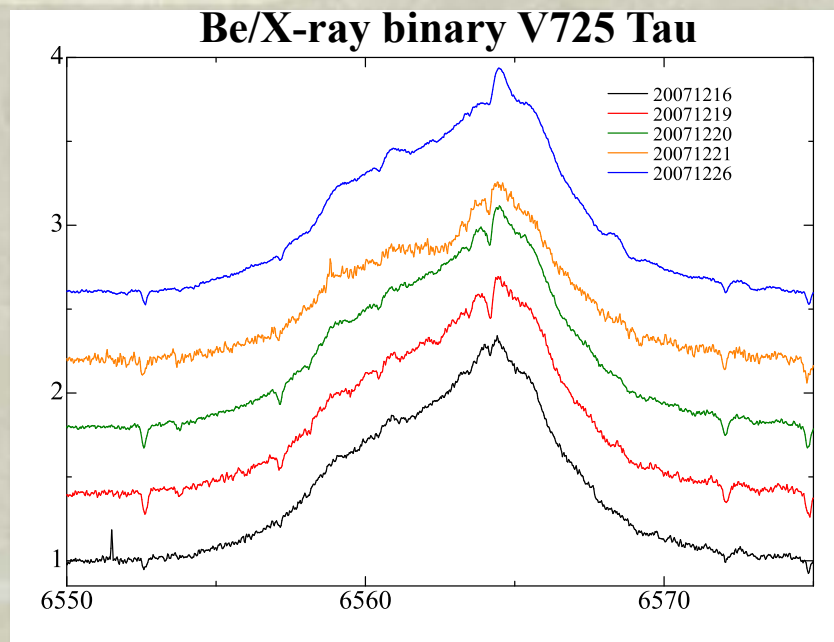
GAOES has highly spectral performance compared with similar instruments in the world.

# Gunma Astronomical Observatory Echelle Spectrograph (GAOES)

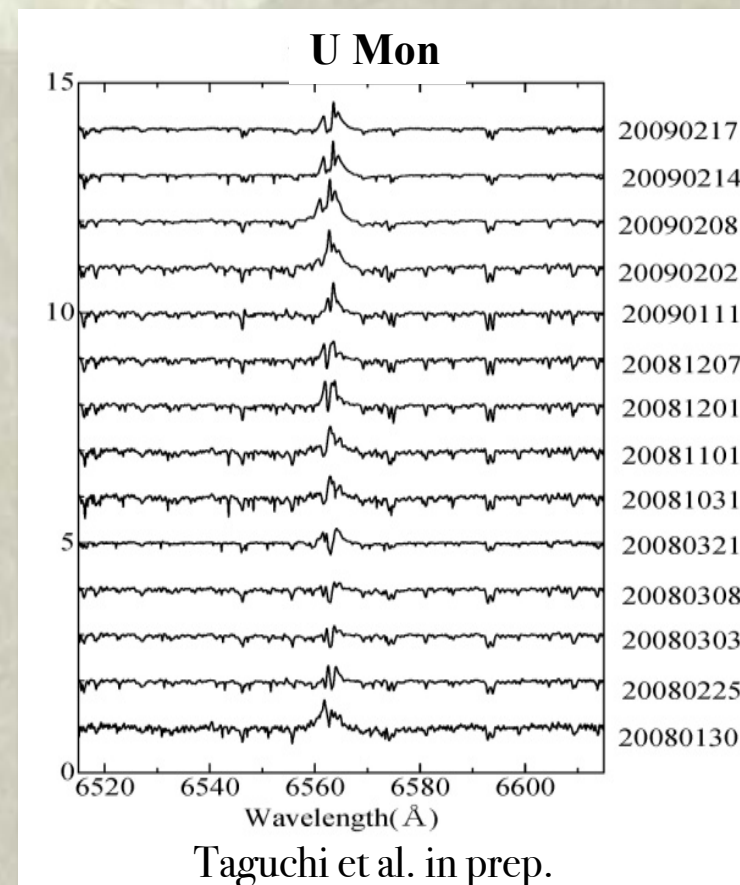
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## Long Term Variability



Moritani et al. 2010



Taguchi et al. in prep.

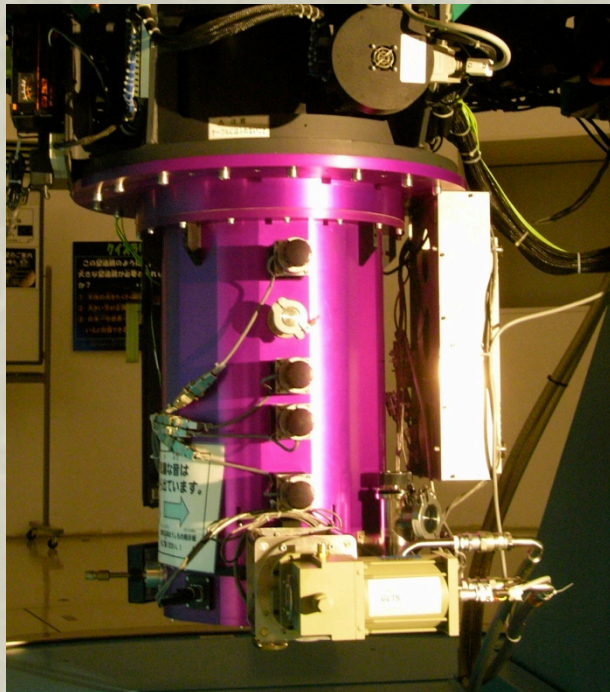
A continuous and uniform observational condition to cover a long period is needed to discuss physics of an object like the variable star.

# Gunma InfraRed Camera & Spectrograph (GIRCS)

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GIRCS is an infrared camera at the Cassegrain focus for wavelength from 1.0-2.4 micron, covering a field of 6.8 square arcminutes. It has also spectroscopic capability using grism.



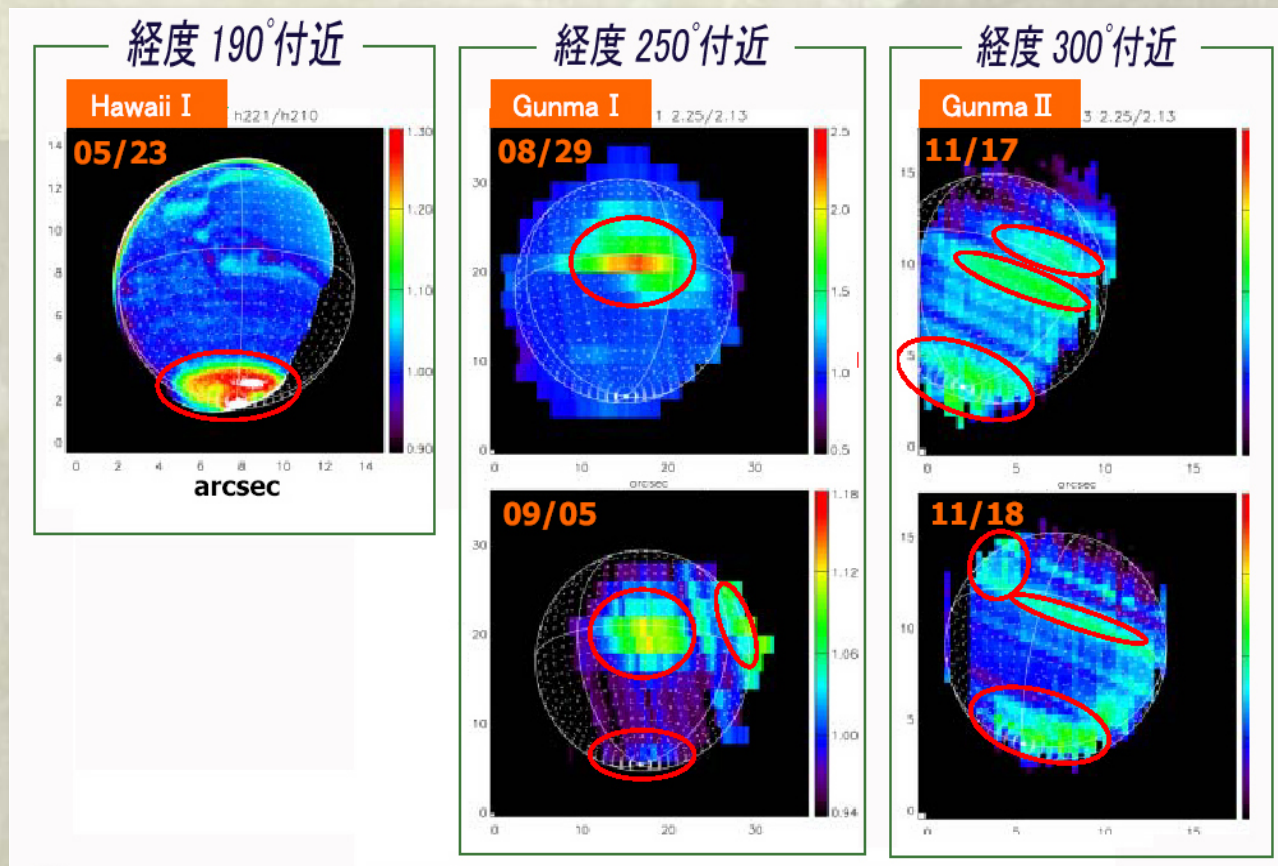
Detector	<b>HAWAII</b> (HgCdTe 1024 X 1024) 0.4" / pixel → FOV: 6.8'
Imaging	<b>10 filter</b> positions Wide-band <i>J, H, K, Ks</i> Narrow-band [Fe II] (1.644 μm) CIV (2.07 μm) H2 1-0 S(1) (2.122 μm) Br γ (2.166 μm) K-cont. (2.144 μm)
Spectroscopy	<b>6 grism</b> positions <i>J</i> (1.114 - 1.397 μm) <i>R</i> ~ 1000 <i>H</i> (1.439 - 1.794 μm) <i>R</i> ~ 900 <i>K</i> (1.959 - 2.397 μm) <i>R</i> ~ 1000 Slit : 1", 2", 4"
Manufacturer	Infrared Laboratories Inc.

# Gunma InfraRed Camera & Spectrograph (GIRCS)

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## Planets



Mars image which were derived by GIRCS. These images show the spatial distribution of H<sub>2</sub>O ice. (Sakanoi et al. 2005)

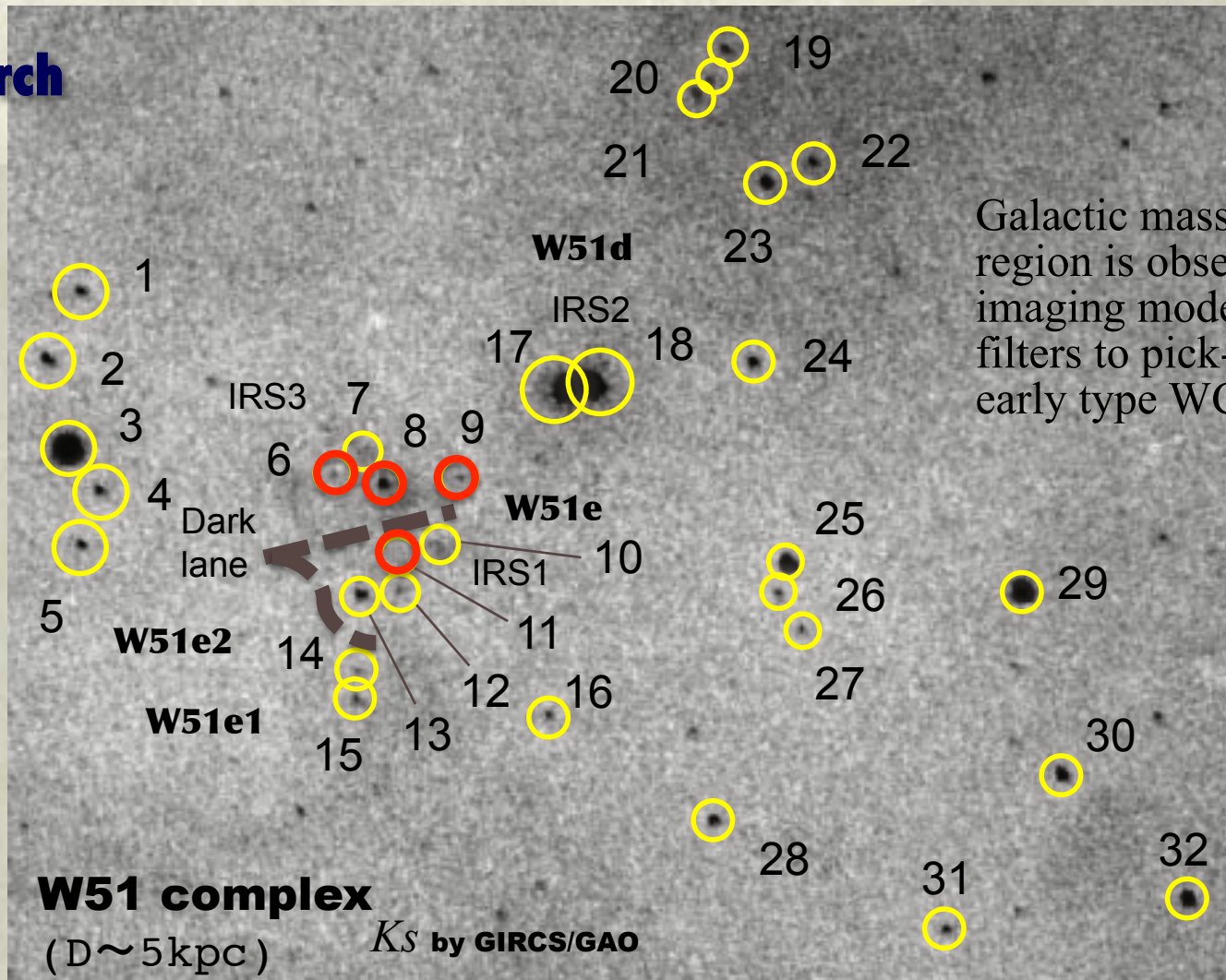
# Gunma InfraRed Camera & Spectrograph (GIRCS)

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## WR search

60"



Galactic massive starforming region is observed using imaging mode with **Ks** & **CIV** filters to pick-up embedded early type WC Wolf-Rayet star.

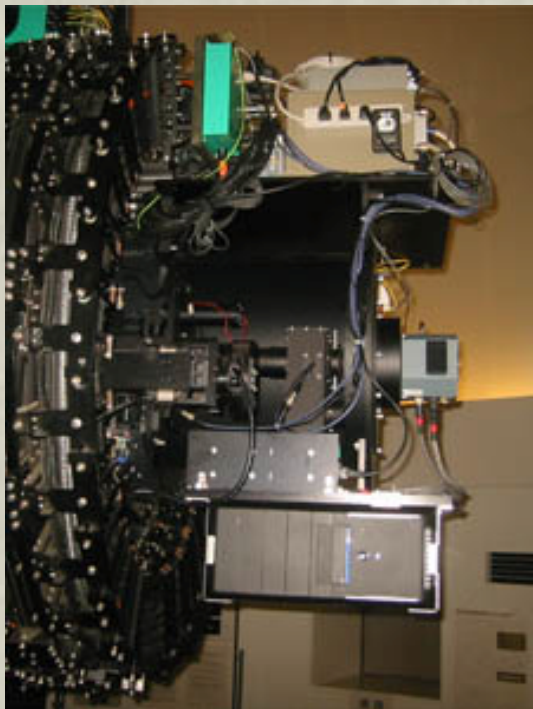
**W51 complex**  
( $D \sim 5 \text{ kpc}$ )  $K_s$  by GIRCS/GAO

# Gunma LOW-resolution Spectrograph & imager (GLOWS)

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There is low resolution spectrograph GLOWS at the bent-Cassegrain focus. It is often used for the identification of newly discovered targets such as SNe.



Detector	Andor DW432 (e2v CCD55-30 Back-illumination 1250 X 1152 ) 0."6 / pixel → FOV: 10'
Coverage	400 ~ 780 nm
Imaging	4 filter positions (+ hole) : <i>B, V, R, I</i>
Disperser	Grism
Resolution	400 ~ 500
Slit	40" (length) 、 1.8" (width)
Cooler	3 stage Pertier
Comparison	Fe, Ar, Ne in HCT
Manufacturer	Genisia corporation

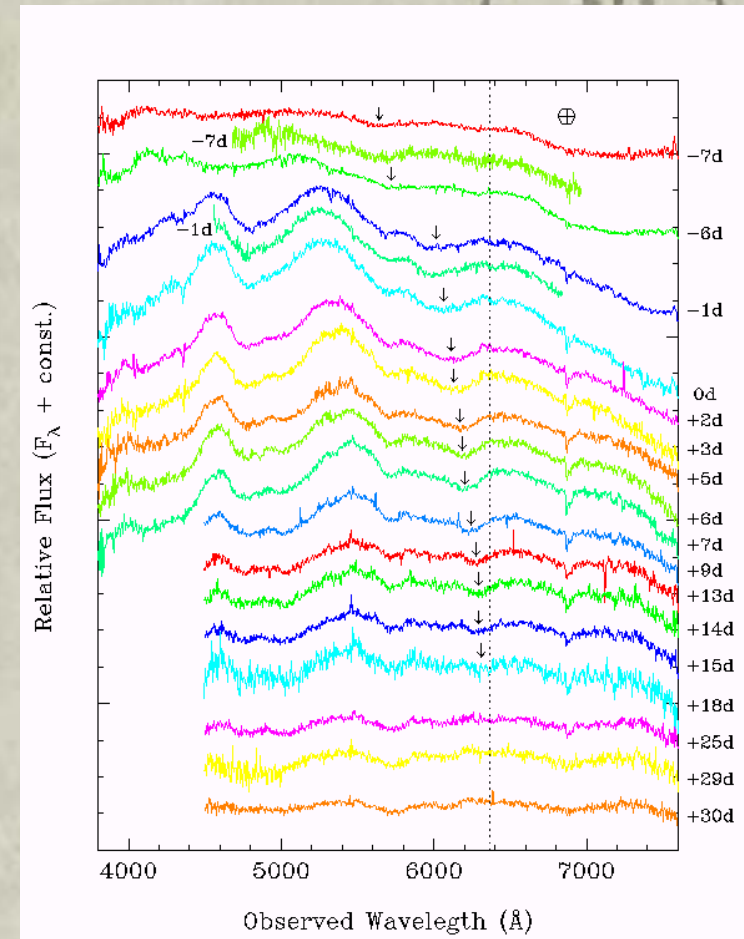
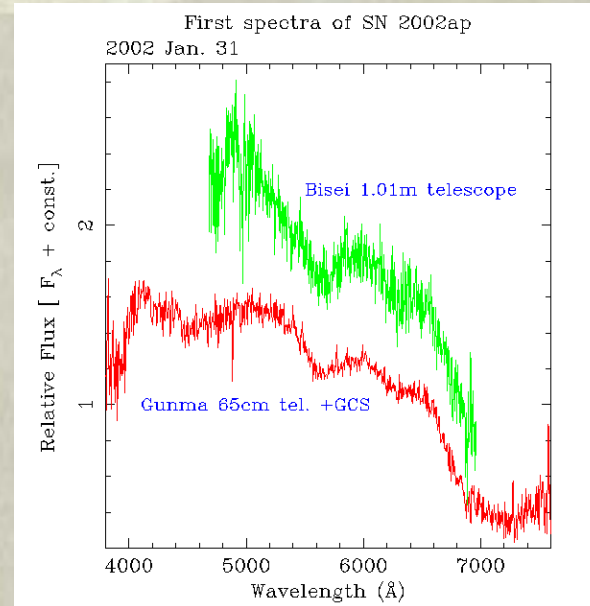
# Gunma LOW-resolution Spectrograph & imager (GLOWS)

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## Super Novae

### Ex : SN2002ap



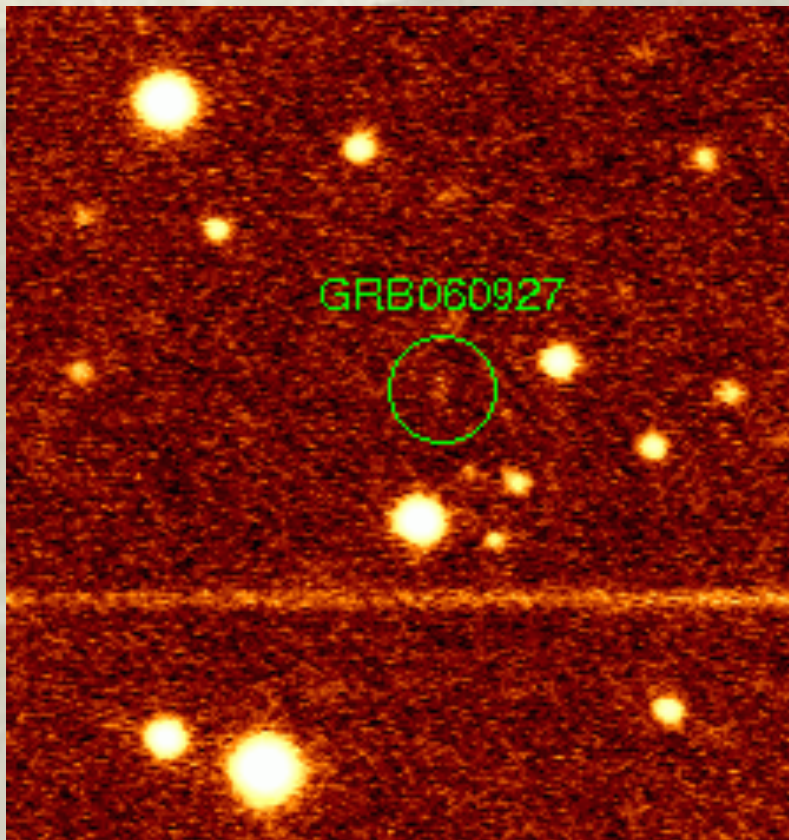
The overall features resemble that of the peculiar type-Ib/c supernova (or “hypernova”) 1997ef, but SN 2002ap is much bluer. (IAUC7811, Kinugasa et al. 2002)

# Gunma LOW-resolution Spectrograph & imager (GLOWS)

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## Gamma Ray Burst



### GRB060927

- Observation on 37 min. after the burst
- $R \sim 20.3$  mag.
- $Z \sim 5.47$  !!

As for the observation of GRB, the promptness is very important. In GAO, the flexibility of the observation is made use of, and a lot of observation of GRB are done.



# YETI & TTV Observation @ GAO

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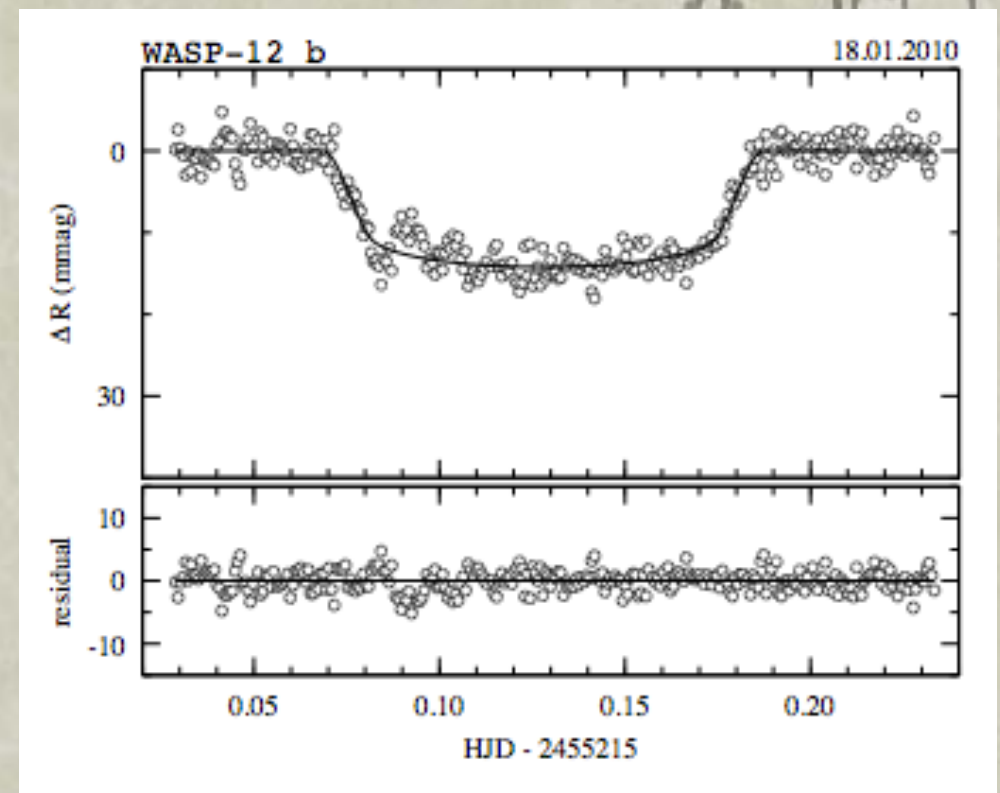
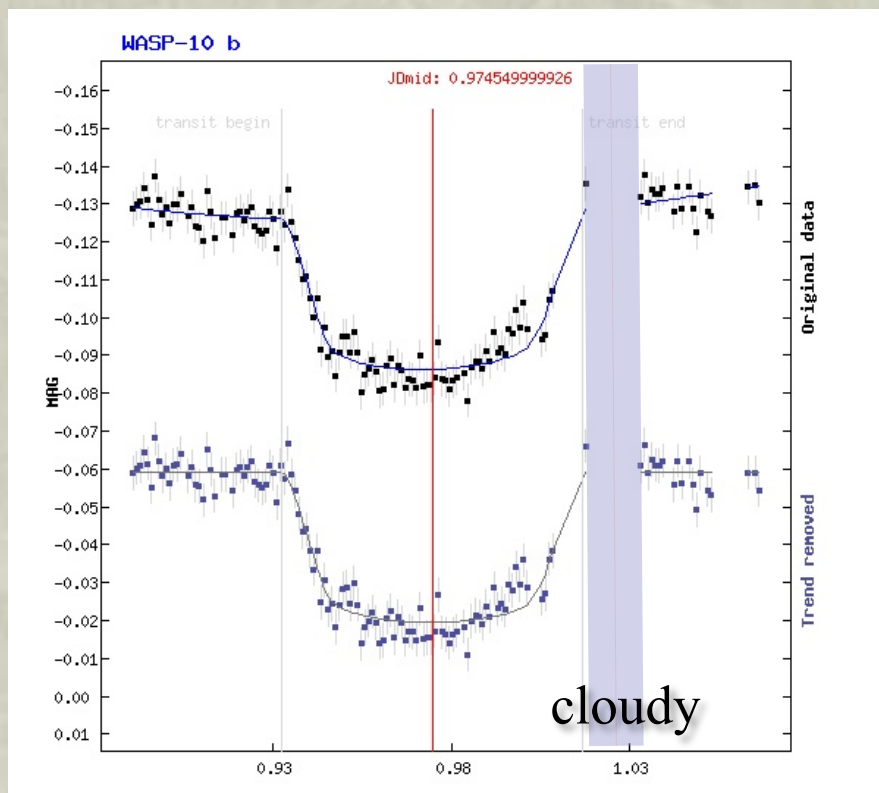
<http://www.astron.pref.gunma.jp/>

## WASP-10b

26/10/2010

## WASP-12b

18/01/2010



# YETI & TTV Observation @ GAO

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## TTV

<b>WASP-10b</b>	2009.10.23	△
	2010.09.25	○
	2010.09.28	○
	2010.10.26	◎
<b>WASP-12</b>	2009.12.25	○
	2009.12.26	◎
	2010.01.06	△
	2010.01.16	○
<b>WASP-3b</b>	2010.08.22	△
	2010.09.04	△

## YETI

<b>Ori 25</b>	2010.01.29	○
	2010.01.30	○
	2010.02.18	○
<b>Tr-37</b>	2010.05.21	△
	2010.08.07	○
	2010.09.03	◎

△:partially lacked due to bad weather or public events  
 ○:useful data (>70% complete)  
 ◎:useful data (>90% complete)

# Any Questions and Request for observations

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Contact to ...

*[nori@astron.pref.gunma.jp](mailto:nori@astron.pref.gunma.jp)*

Access to ...

*<http://www.astron.pref.gunma.jp/e/index.html>*

**See you at GAO !**

