WINERED fully commissioned at the Magellan Clay Telescope

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WINERED is a PI-type near-infrared (z, Y, J-bands) high dispersion spectrograph developed by Koyama Astronomical Observatory of Kyoto Sangyo University and the University of Tokyo (Ikeda et al. 2022). In 2022, WINERED was moved to the 6.5-m Magellan II - Clay telescope at Las Campanas Observatory (LCO) to take advantage of its extremely high sensitivity (the instrumental total throughput ~60%), which is its best feature, and started scientific observations in 2023. For the relocation to LCO, a new instrument transport cart was manufactured. This allows for installation on the Nasmyth platform within about 30 minutes, without the need of special alignment tasks, and with highly reproducible accuracy. Since the 125mm back-focal length of the Magellan telescope was too short for WINERED, a new focal extender was fabricated and introduced to ensure proper focus on the slit. In addition, an original guider system was constructed by combining the Auto-Guider function of the Magellan telescope and WINERED's pre-existing slit viewer, and it was confirmed that a tracking accuracy of about 0.1 arcsec was achieved. Up to this point, utilizing WINERED on Magellan telescope, we have been able to obtain spectra with an SNR=30 (R=28,000) for point source as faint as J=16 mag with just 1-hour of exposure even under a natural seeing environment. This sensitivity exceeds that of infrared high dispersion spectrographs on a 10-m class telescope, even though these spectrographs are usually utilized with AO. Currently, WINERED is operated under the collaboration of the Carnegie Observatories and LCO with the WINERED team responsible for the setup of the instrument, observing support in nighttime, and initial data reduction including the provision of data-reduction pipeline. As compensation, 20% of the total observation time, equating to 6 nights in the achievement of 2023, has been allocated to the WINERED team.

1. OVERVIEW OF WINERED

NIR high-resolution spectrograph, WINERED

- **"No Cold Stop"**
  - Only camera system & IR array are cooled
  - Ambient BG Radiation is reduced to 0.05e-/pix/sec
- **"Wide Spectral Coverage"**
  - $\Delta\lambda/\lambda$ ~ 1/6 realized with a large format array (2K × 2K) and X-disperser echelle spectrograph
- **"High Sensitivity"**
  - Total throughout of optics: >60%
  - High QE array: >80% at 1.2μm
  - Low noise electronics systems (σ_r=5.3e-/pix for NDR=32)

Figure 1. Throughputs of IR-HRS

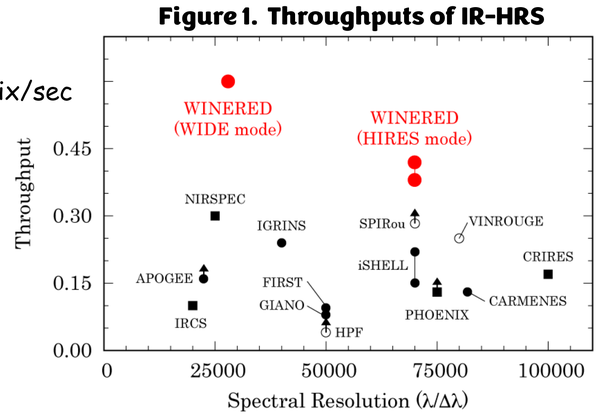


Table 1. Specification of WINERED (Ikeda et al. 2022)

	WIDE mode	HIRES-Y mode	HIRES-J mode
Wavelength Coverage	0.90-1.35μm	0.95-1.11μm	1.14-1.35μm
Maximum Spectral Resolution	28,000 (2 pix sampling)	70,000 (2 pix sampling)	
Slit Width	100μm (= 0.3" at Magellan telescope), 140μm and 200μm		
Slit Length	3.12mm (= 9" at Magellan telescope)		
Total Throughput	> 50%	~ 40%	~ 42%
Volume	1750mm(L) × 1070mm(W) × 500mm(H)		
Operation Temperature	270-300K (except for camera lens and IR array)		

Relocated to Magellan telescope for the deeper universe

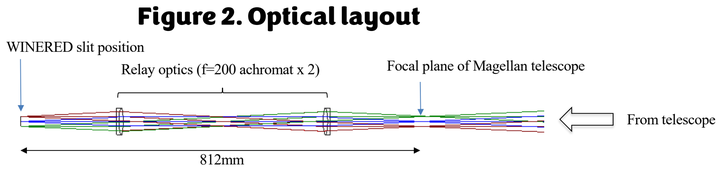
Table 2. Limiting magnitude of each telescope

Instrument	WINERED			IRCS
Telescope	Araki	NTT	**Magellan**	Subaru
Location	Japan/KAO	Chile/La Silla	**Chile/LCO**	Hawaii/Maunakea
Tel Diameter	1.3 m	3.58 m	**6.5m**	8.2 m
Seeing	3.0"	0.8"	**0.6"**	0.2" w/ AO
Spectral resolution	28,000	28,000	**28,000**	20,000
Limiting Mag. (J) ※ 8hrs, SNR=30	13.8	16.5	**17.3**	15.5

2. UPGRADES FOR MAGELLAN TELESCOPE

Focal extender optics

Figure 2. Optical layout

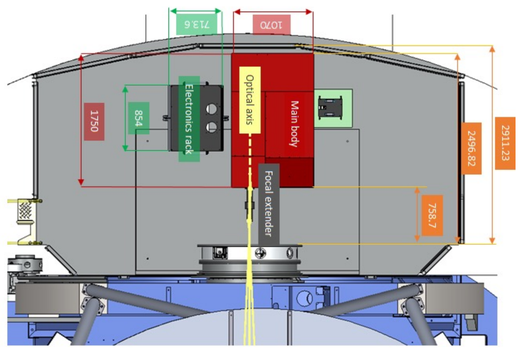


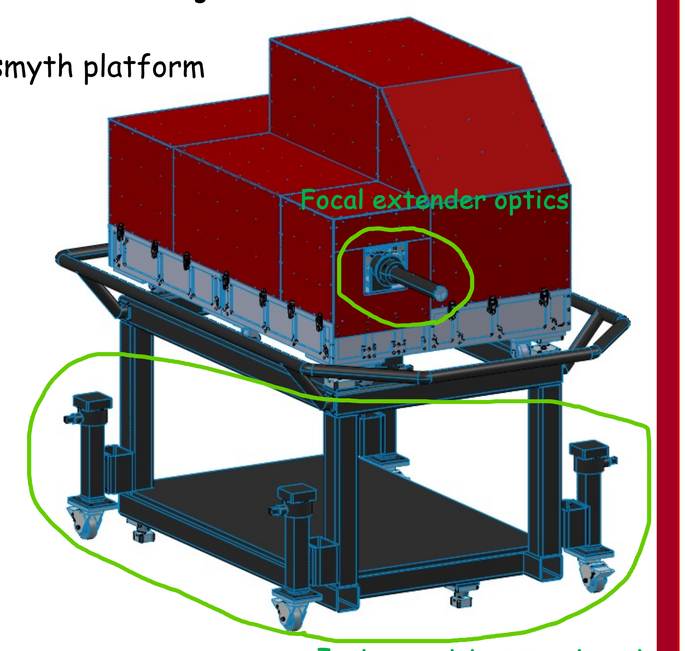
- The optical interface to the Magellan telescope
- WINERED has no flange back instrument
- Magellan telescope has a back focus of 125 mm
- Simple optical system to maintain high efficiency

Instrument transport cart

- The mechanical interface on the Nasmyth platform
- No need to align with the telescope
- Compensation for thermal shrinkage

Figure 3. CAD model of WINERED

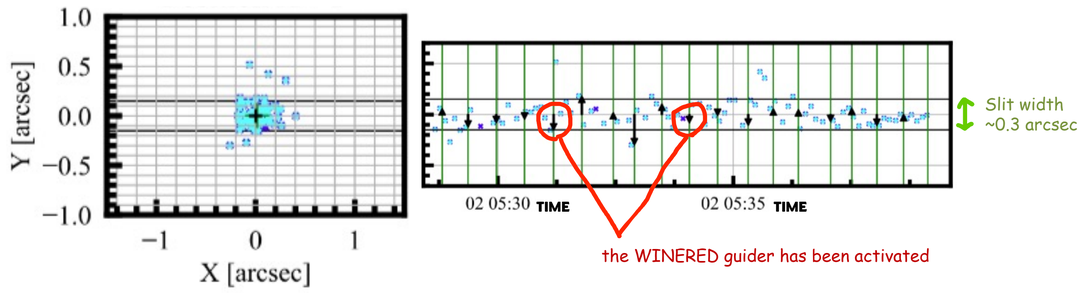




WINERED Guider system

- WINERED guiding systems (e.g., automatic scissoring) to aid observation
- The observer only needs to enter the initial parameters
- Tracking performance combined with Magellan Guider achieves about 0.1 arcsec

Figure 4. An example of tracking results, 0.12 arcsec is achieved.

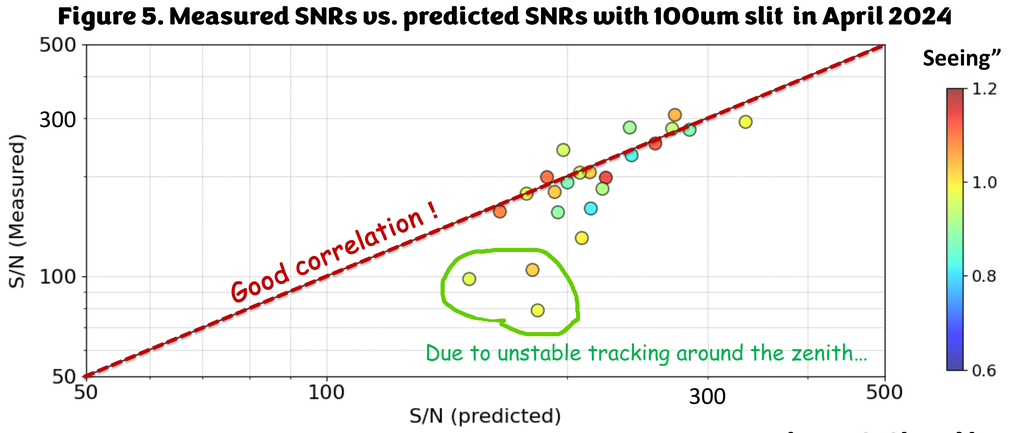


3. PERFORMANCES AT MAGELLAN TELESCOPE

Sensitivity

- **Comparison of predicted and observed SNRs**

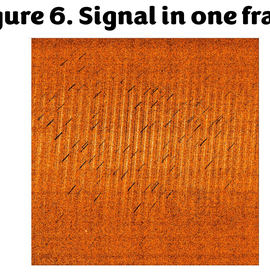
Figure 5. Measured SNRs vs. predicted SNRs with 100um slit in April 2024



- **Observation of fainter objects**

TARGET: QSO J0439+1634 (Z = 6.5), Jmag ~ 16.5
OBS. MODE: HIRES-Y mode, Slit = 200μm, R ~45,000
ACHIEVED: SNR~8 (Texp = 25200 sec, Seeing ~1.2", Airmass ~ 1.5)
REMARKS: Using he blind offset method, which shows that the tracking is very good during the 900 s exposures

Figure 6. Signal in one frame



Spectral resolution w/ 100μm slit

Figure 7. Spectral Resolution of WIDE MODE

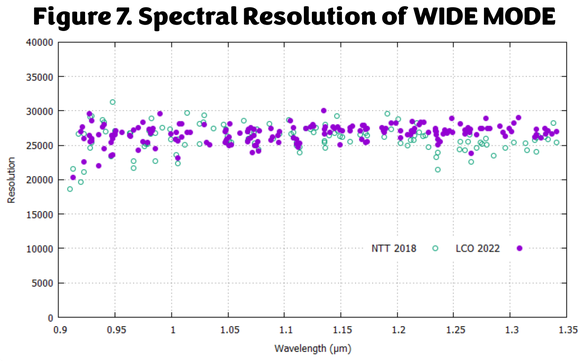
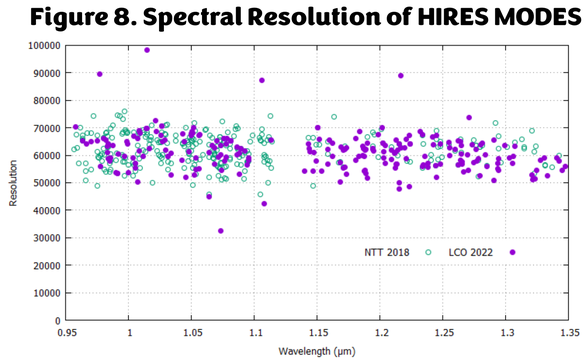


Figure 8. Spectral Resolution of HIRES MODES



4. OBSERVING OPERATION

- **Open to the Magellan community from 2023**
  - Preparation of instruments for observation
  - Providing observation support personnel from the WINERED team
  - Provision of user interfaces for remote observation
  - Conduct mode conversion (to be automated in the future)
  - Acquisition of calibration data
  - Provide analysis pipeline (WARP: Hamano et al. 2023)

- **Observation status of the WINERED team**
  - 5 engineer nights in 2022
  - 5 nights in 2023
  - 6 observation planned in 2024

Figure 9. Observing with the Magellan Telescope

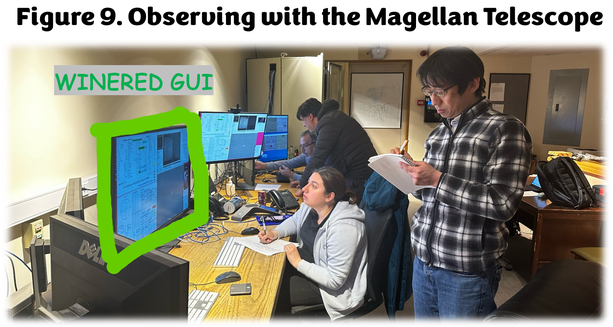


Figure 10. Spectra sample with Magellan (Minniti et al. 2024)