The 7-Dimensional Sky Survey: Time-series, Spectral Mapping Survey of the Southern Sky



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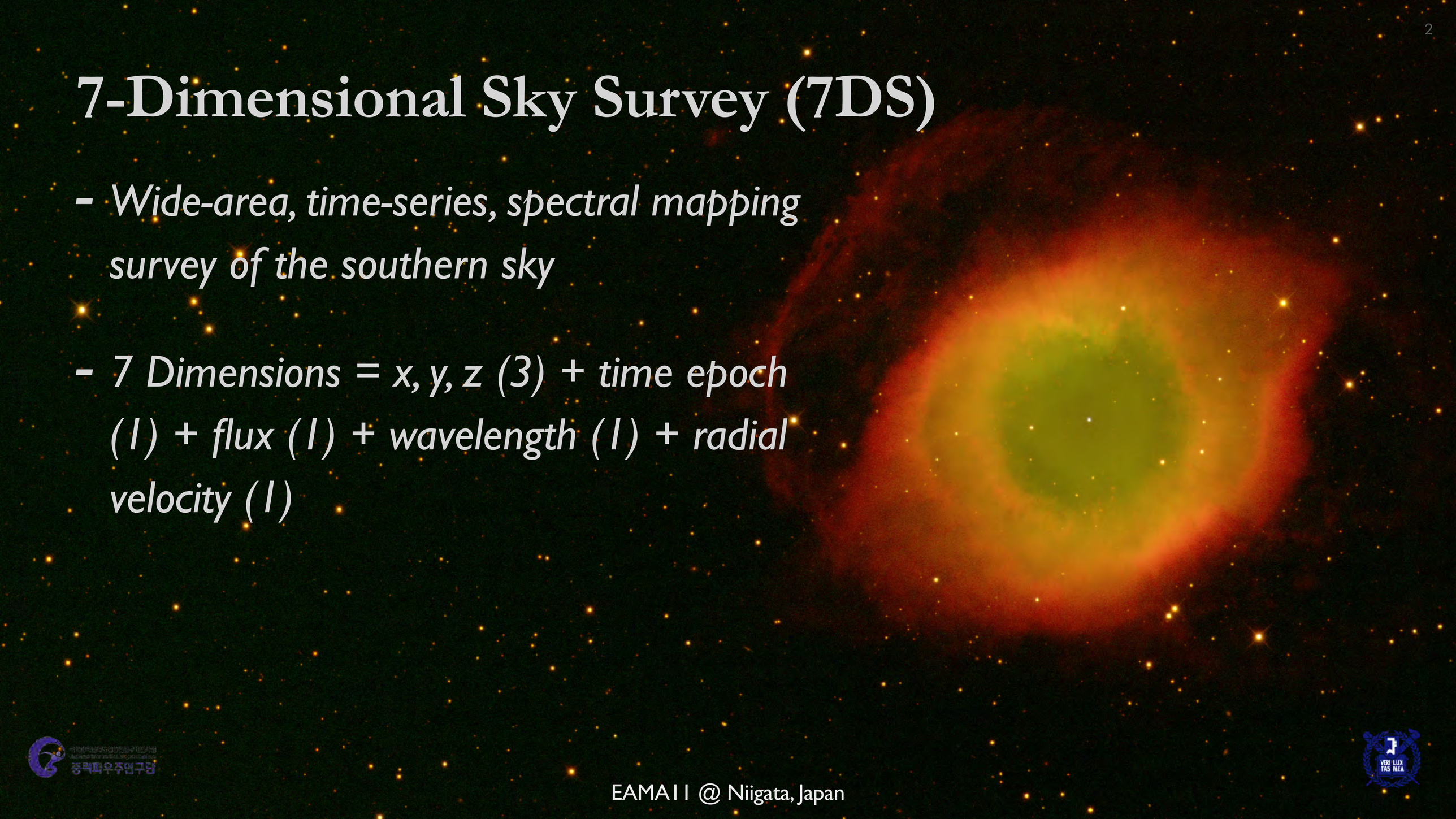
December 12 2025

EAMA11 @ Niigata, Japan

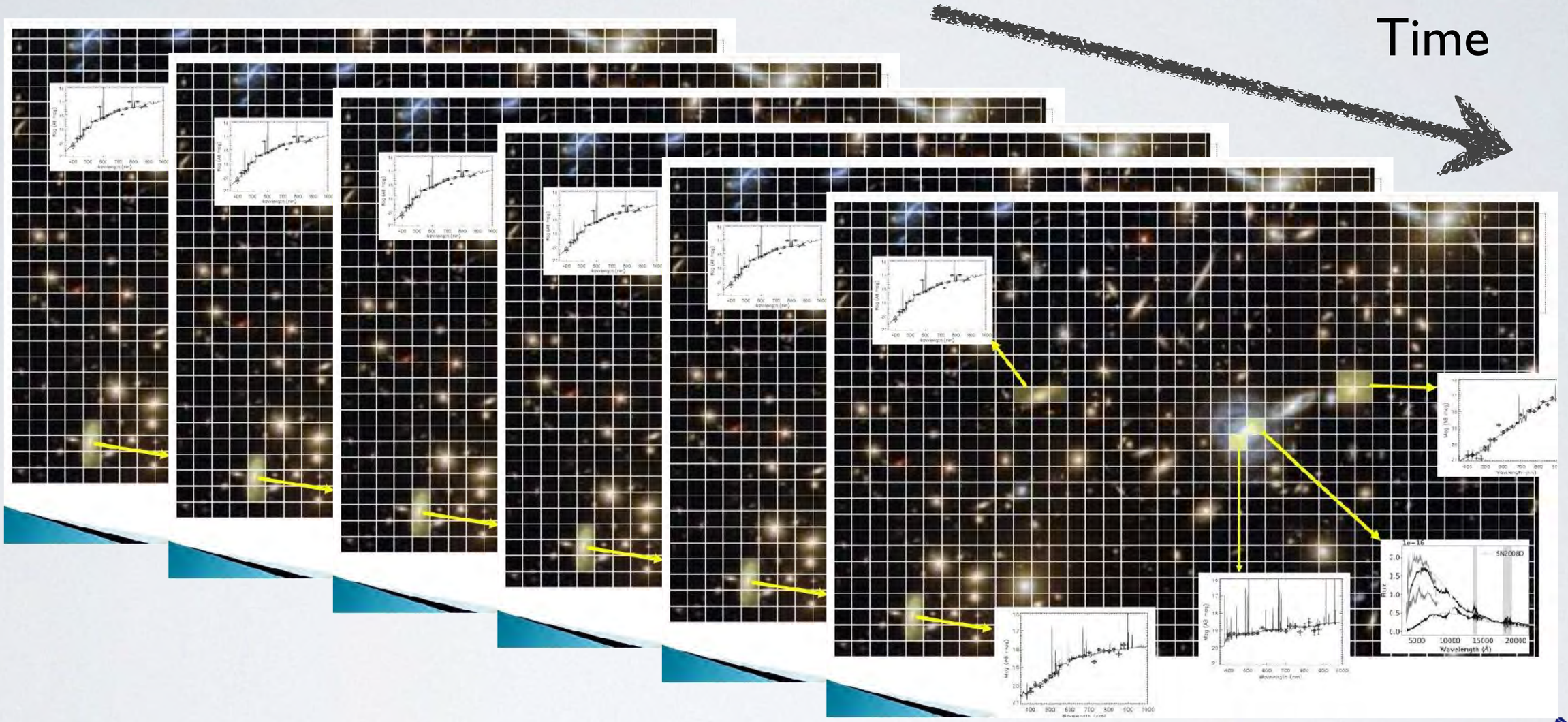
7-Dimensional Sky Survey (7DS)

- *Wide-area, time-series, spectral mapping survey of the southern sky*

- *7 Dimensions = x, y, z (3) + time epoch (1) + flux (1) + wavelength (1) + radial velocity (1)*



7DS: Time-series, Spectral Mapping Survey



7-Dimensional Telescope in a Nutshell

- ***20 × 50-cm*** *commercial off-the-shelf astrographs*
- ***40 × 25 nm*** *medium band filters + Sloan Broad-band filters*
- *IFU-style data for* ***a large FoV*** *(~ 1.25 deg² with R of 30~70)*
- *Hosted by ObsTech at Observatorio El Sauce, situated in the Río Hutardo Valley in Chile.*
- ***Fully remote observation*** *accommodating automated survey, alert brokers, GW follow-up rankings, etc.*





- *altitude: 1700 m*
- *more than 300 clear nights (up to 320 nights)*
- *the median seeing: 1.3″*
- *the mean sky brightness: ~22 mag/″²*

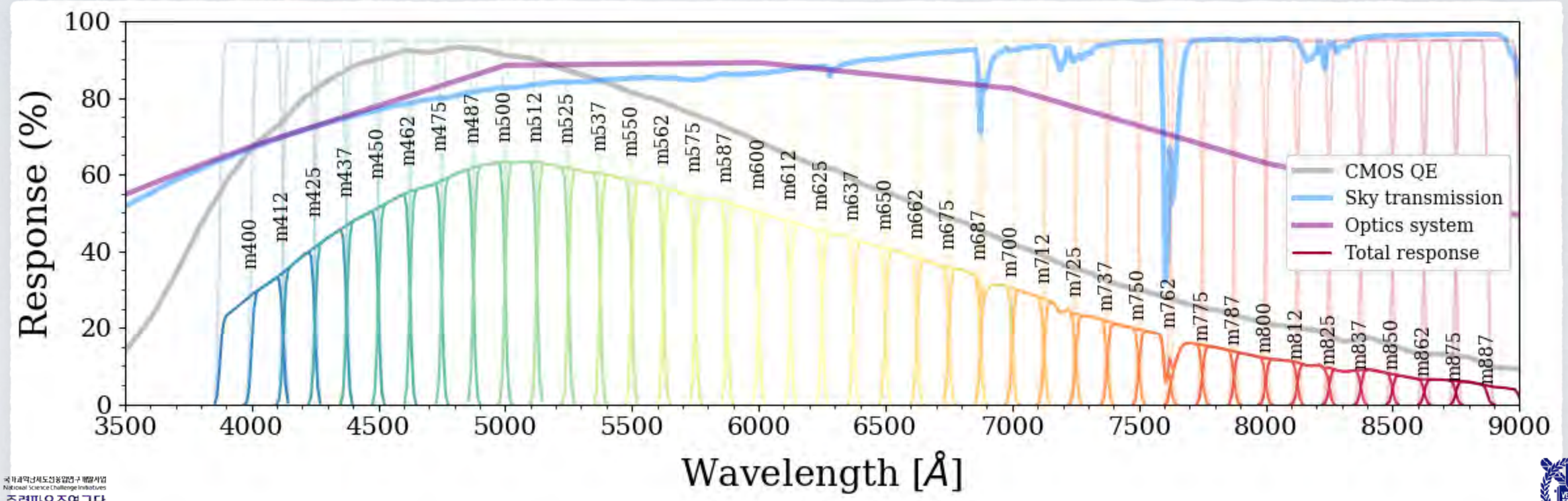


7DT Field of View
~ Six Full Moons
~1000 × JWST NIRCAM

40 Medium-band Filters

1. *40 medium-band filters with **FWHM of 25nm** from **400 nm through 900 nm** with gaps of 12.5 nm.*

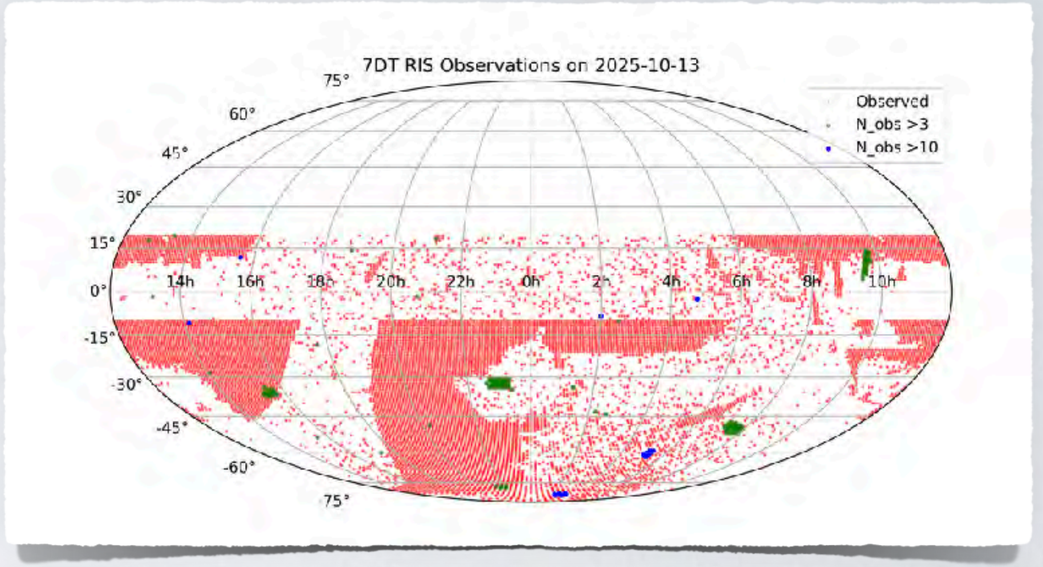
2. ***Low Resolution Spectra (R ~ 30-50)** for **every pixel in the field of view (~1.25 deg²)***

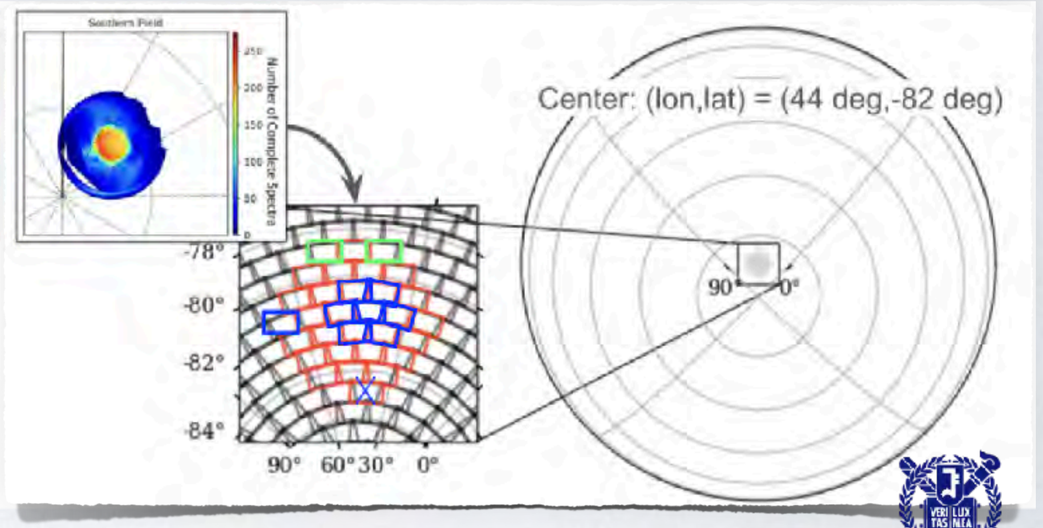


Survey Plan

1. ***Reference Imaging Survey (RIS)***: *>30% completion*
   - *1 visit with 5-minute total exposure*
   - *the Southern Hemisphere (Dec <20°, ~23,000 square degrees)*
2. ***Wide-Field Time-Domain Survey (WTS)***
   - *1 visit per 10 ~ 14 days; 80 ~ 100 minutes per year; up to 6.5 hours for 5-year operation*
   - *Target field candidates: Rubin's Deep Drilling Fields, VIKING, VIDEO, etc.*
3. ***Intensive Monitoring Survey (IMS)***:
   - *SPHEREx Deep Field South (~8 square degrees)*
   - *1 visit per day; 1,200 ~ 1,500 minutes per year; up to 65 hours for 5-year operation*

RIS Completion Map





IMS target field

Survey Plan

Surveys	Survey Area (deg^2)	Cadence	Depth (1-epoch 5σ at 475nm)	Depth (5yr)	Exposure Time per epoch per filter
Reference Imaging Survey	20,000	-	20.5 mag	-	5min
Wide-field Time-Domain Survey (WTS)	800-1,200	10-14 days	20.5 mag	23.2 mag	5min
Intensive Monitoring Survey (IMS)	8	1 day	20.5 mag	24.7 mag	5min

Target of Opportunity Observation for Transient Objects

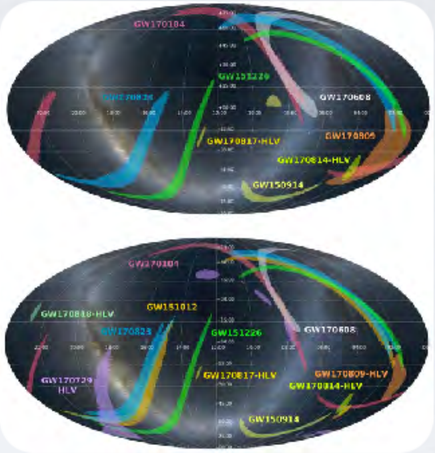
Assumption: 1.5 seeing, 70% efficiency

Research Topics

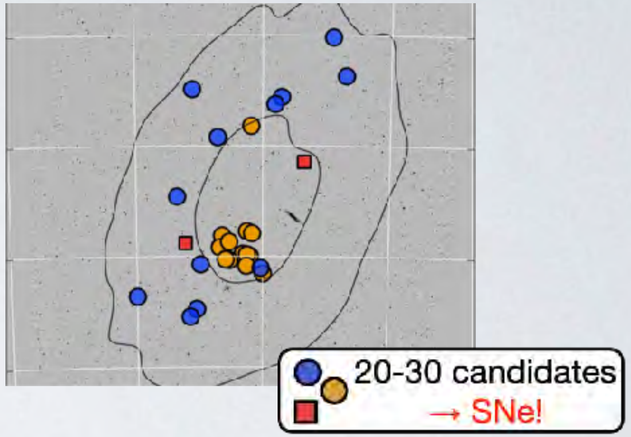
1. *Multi-messenger Astronomy*
2. *Supermassive Black Holes & AGN*
3. *Galaxy Evolution*
4. *Cosmology*
5. *Stellar Populations in the Galaxy and Local Group*
6. *Transients (SNe, GRBs, TDEs, etc.)*
7. *Solar System Objects*

Challenges and Needs for Kilonova Hunting

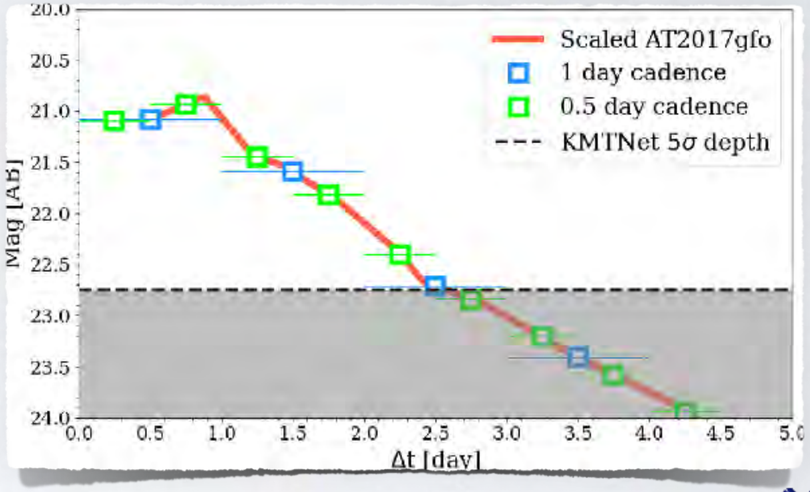
1. *Large localization areas: a few hundred square degrees*
   - ***Large FOV***
2. *Faint, fast-declining transients: 3~4 mag fainter than SN Ia and becoming fainter very rapidly*
   - ***Flexible operation***
3. *Too many transients with large FoVs: a few hundred of transients in 10 square degrees*
   - ***Spectroscopy even with low-R***
   - ***Real-time data reduction***
   - ***Real-time data analysis***



Abbot et al. (2020)



Thakur et al. (2019)



G. Paek, Im, et al. (2025)

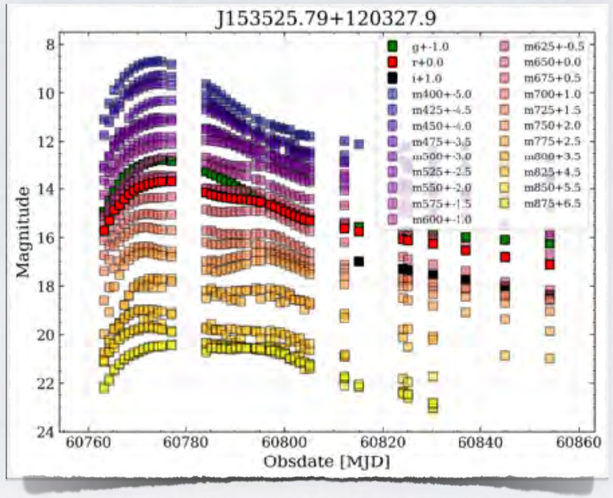
GW Follow-up Observations during O4 Run

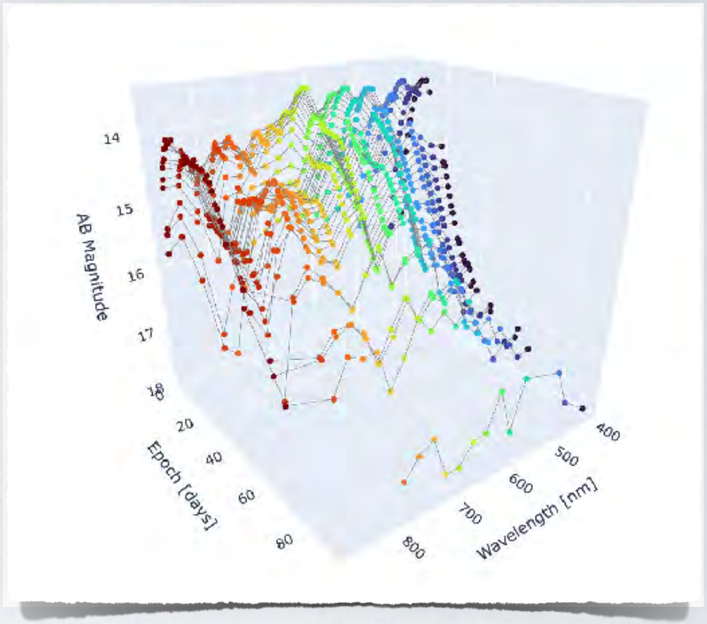
Name	Class	False Alarm Rate	CR90 Area	Distance [Mpc]	Notes
S240422ed	Terrestrial 93%, BNS 5%	1/35 days	259 deg^2	188 ± 43	NSBH 99% Early
S24090ci	BBH	1/100 yr	394 deg^2	662 ± 166	NSBH 31% Early
S240915b	BBH	1/100 yr	18 deg^2	872 ± 149	NSBH 14%
S240925n	BBH	1/7.9 × 10^9 yr	14 deg^2	331 ± 70	NSBH 26% Early
S241125n	BBH	1/33 yr	76 deg^2	4174 ± 1591	
S250206dm	NSBH 55%, BNC37%	1/25 yr	547 deg^2	373 ± 104	Probability of Remnant 30%
S250328ae	BBH	1/100 yr	14 deg^2	511 ± 82	Mass Gap 7%
S250725j	BBH	1/744 yr	19 deg^2	379 ± 92	
S250830bp	BBH	1/100 yr	3.7 deg^2	427 ± 69	Extremely tight CR90

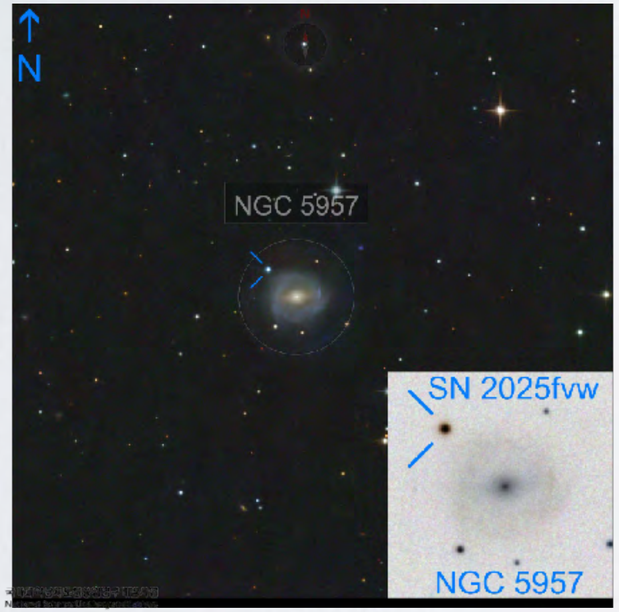
Transients and their Classification

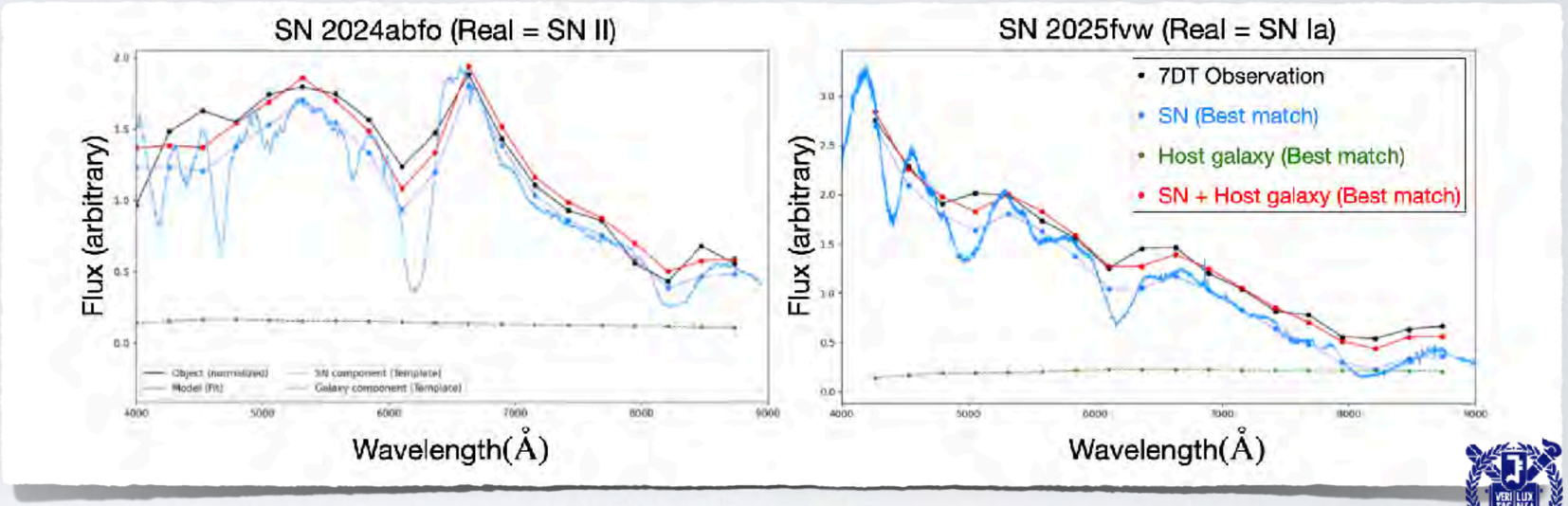
- ***SN2025fvw***
  - *Normal SN Ia*
  - *NGC 5957*
  - *D = 34.9 Mpc*

Time-series spectra of SN 2025fvw



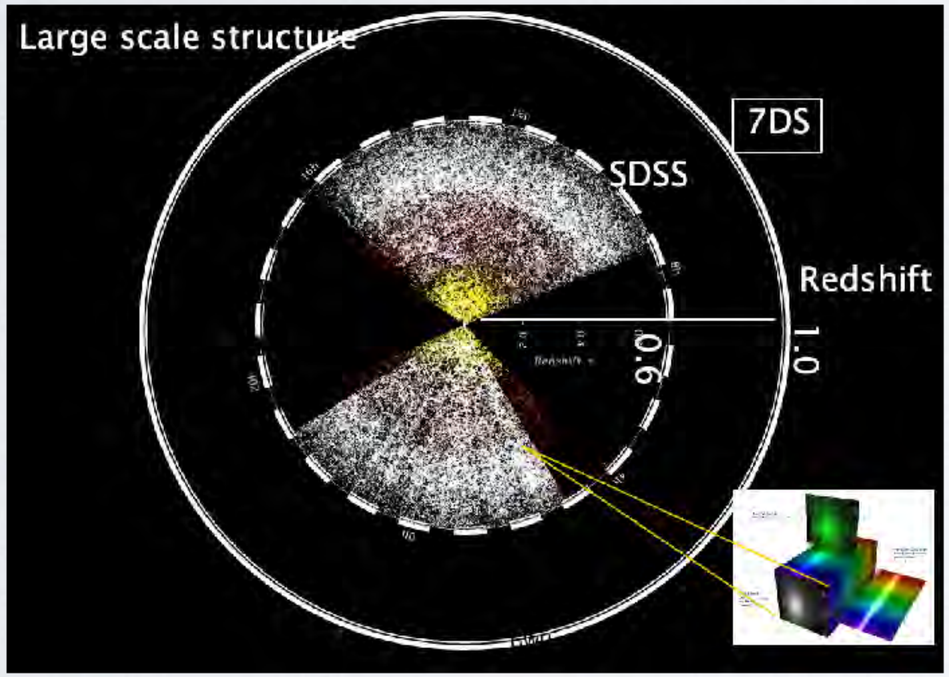


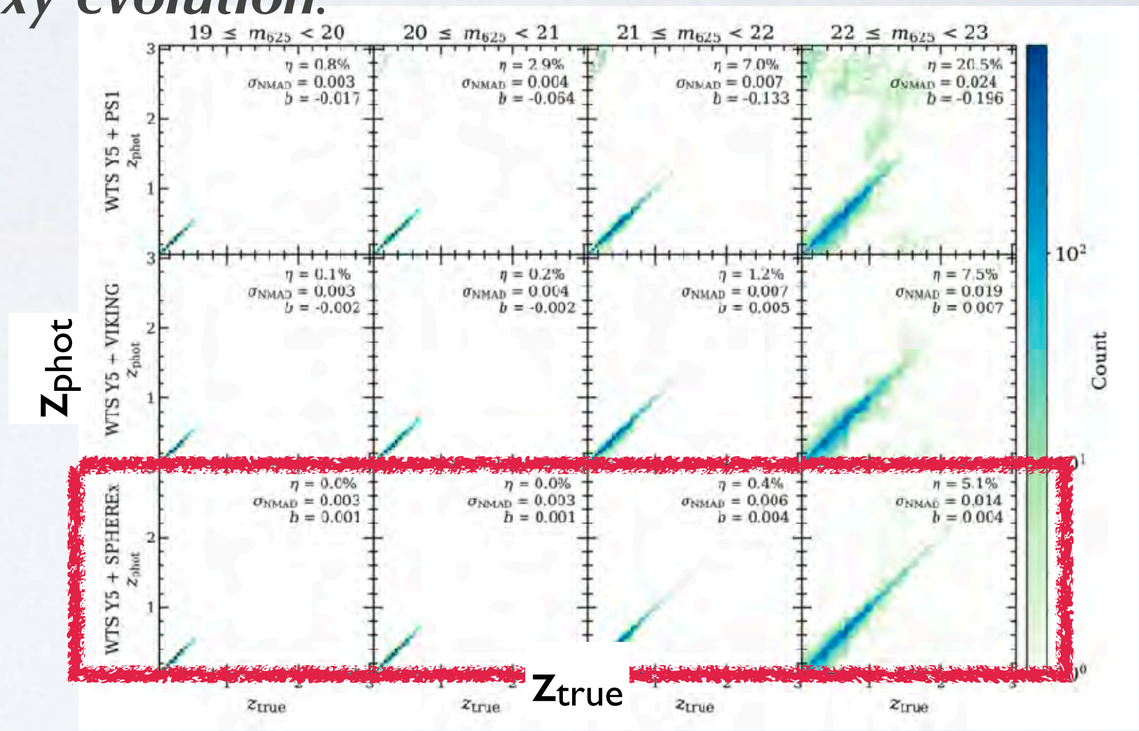




Photometric Redshift Estimation

- *We aim to obtain redshift and SED-fitted properties of 50 million galaxies, including 5 million in low-b, with **redshift accuracy of 0.2 – 1%** up to z~1.*
- *The phot-z measurements lead to **the galaxy catalog for GW events, cosmology with LSS, and the environmental dependence of galaxy evolution**.*



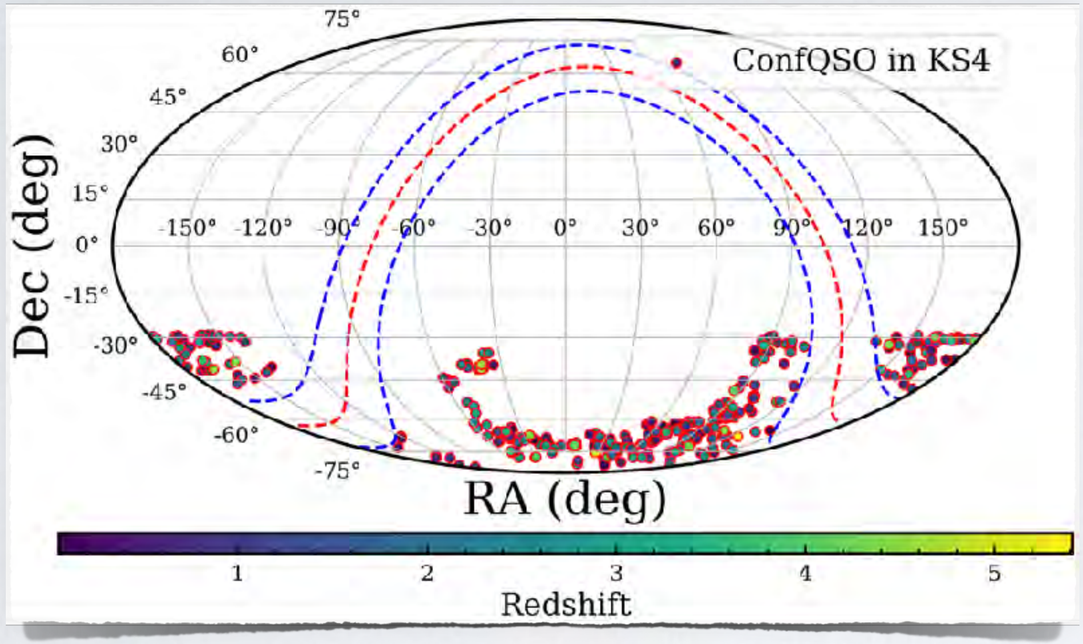


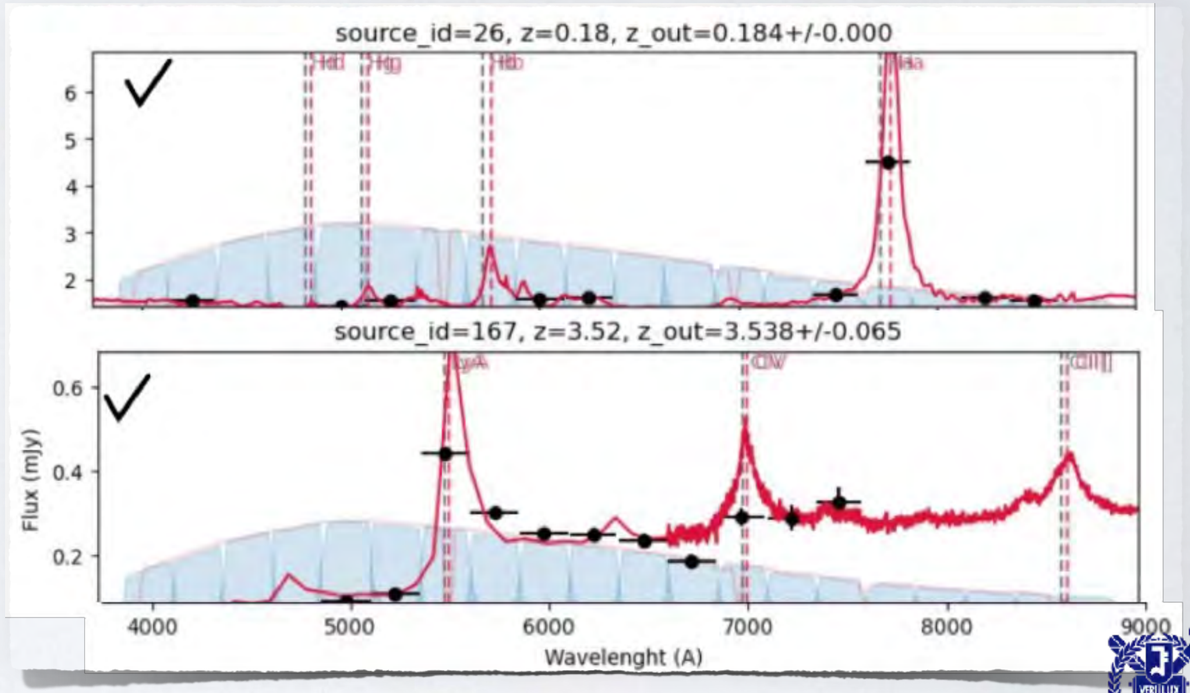
Ko et al. (*2025*)

KS4-7DS Quasar Survey

- *KS4: KMTNet Synoptic Survey of Southern Sky*
- ***Reliable identification of quasars and accurate determination of redshifts** is possible.*
- *Y. Kim et al. (2024) identified quasar candidates in the KS4 area.*

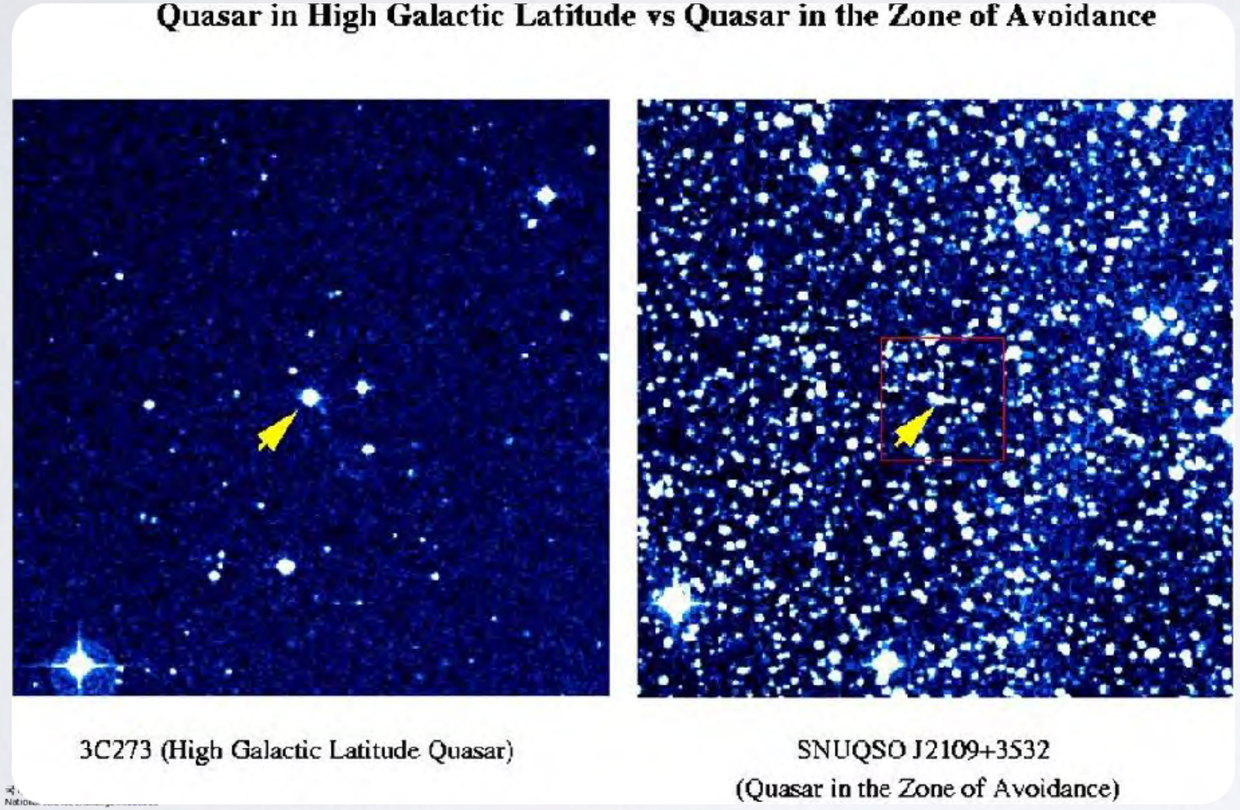
Phot-z estimation based on 7DT data for confirmed quasars within KS4 fields by Y. Kim



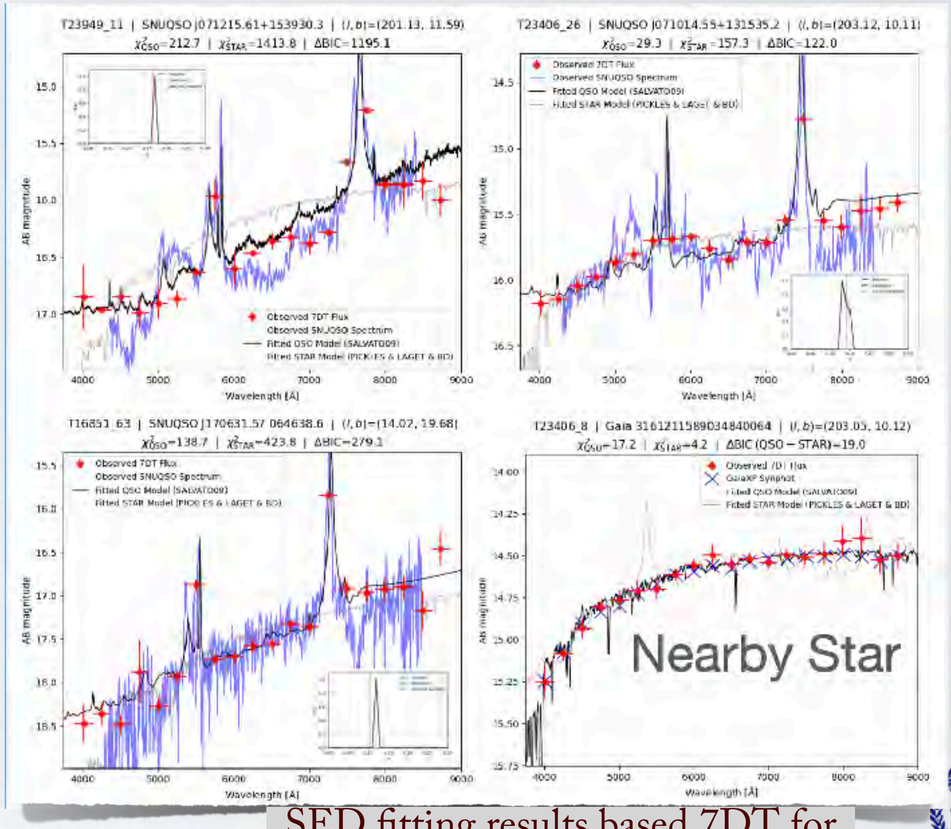


Galaxies and Quasars near Galactic Plane

- *7DS will find ~5 **million galaxies and 20,000 quasars in the zone of avoidance (ZOA).***
- *A complete galaxy catalog at ZOA will provide a useful sample to resolve the **cosmic dipole anomaly** and **stochastic gravitational-wave background**.*



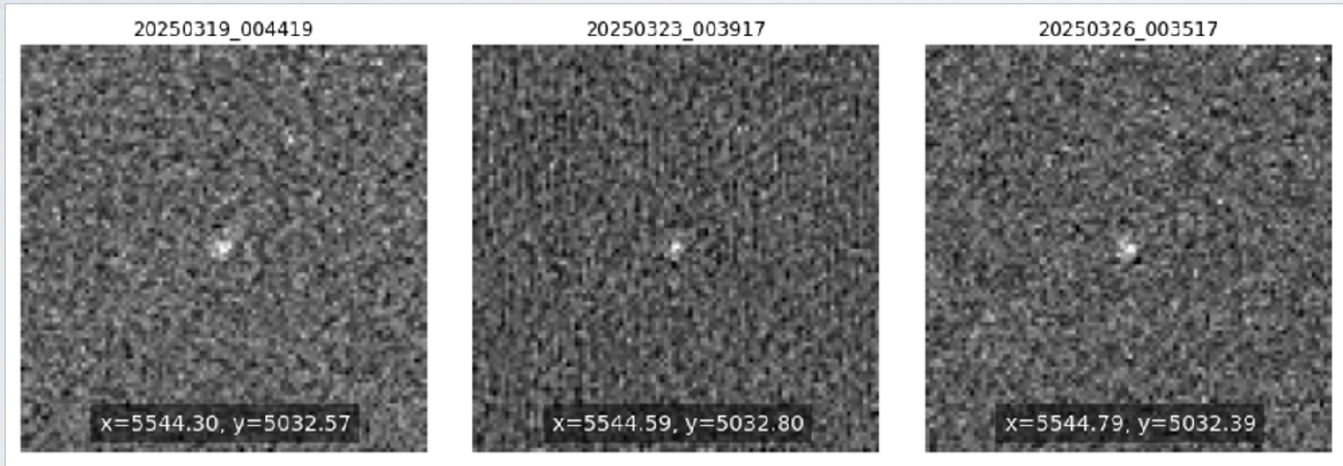
Im et al. (2007)

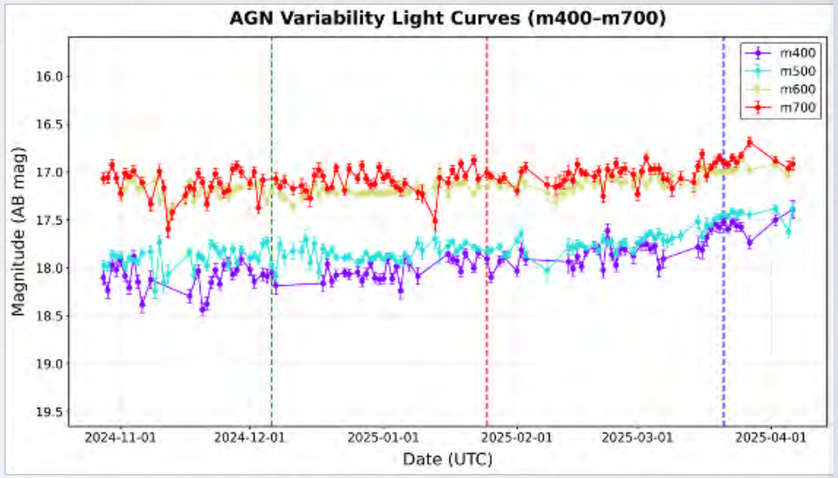


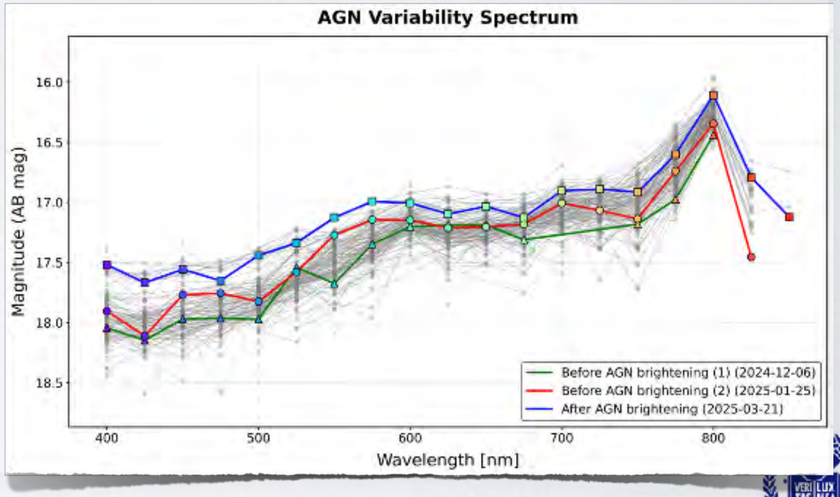
SED fitting results based 7DT for confirmed quasars at low-b regions

Case Study with Quasar in Time-Domain Verification Field

- ***Time-domain Verification Field**: RA = 03:00:00.0, Dec = - 82:21:30.60*
- *124 days of monitoring of seven 7DT tiles with 1-day cadence*
- *Separation of continuum and emission line is possible.*
- ***Reverberation mapping of ~10,000 quasars***



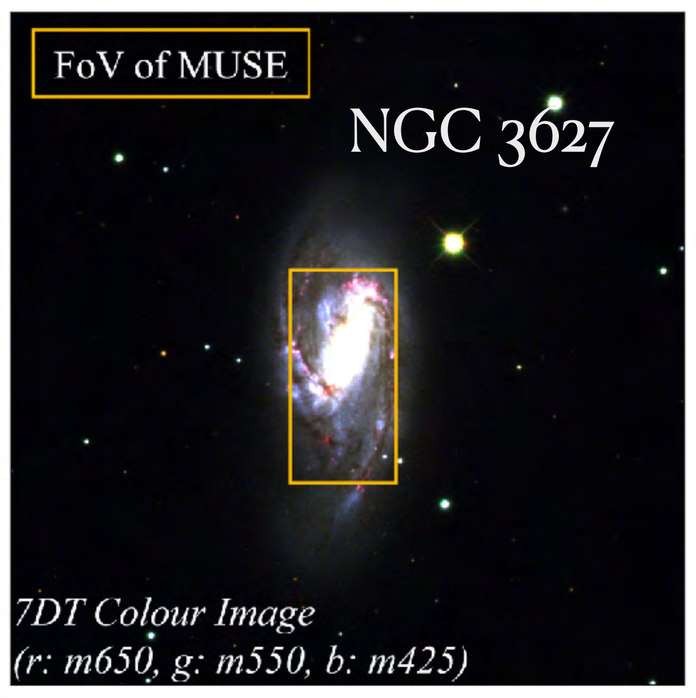


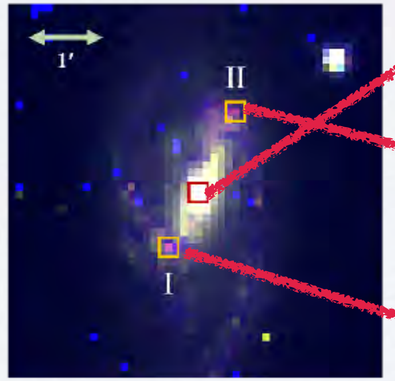


2MASS J02581066-8207449 at z ~ 0.199

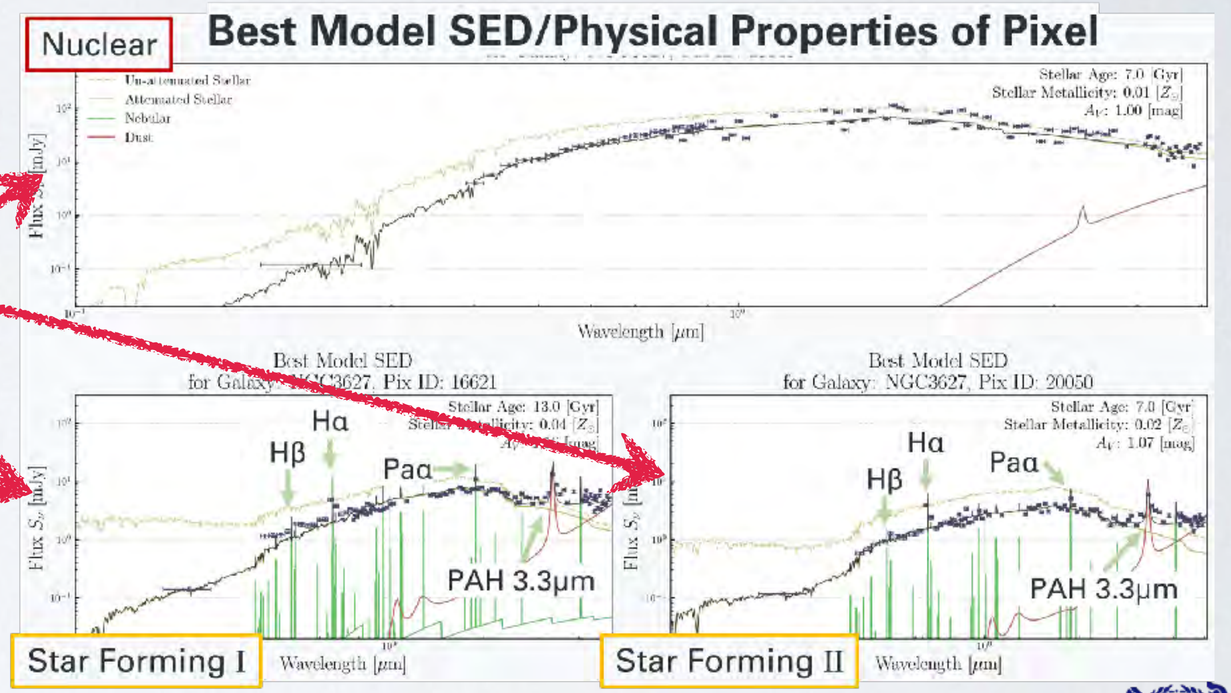
Resolved SEDs of Nearby Galaxies

- *7DS will construct **spatially resolved SED maps for up to 50 million galaxies at z<0.3**.*
- ***Age and Metallicity Gradient, SFR, Dust Properties**:These properties provide crucial information on galaxy evolution paths, such as **the inside-out growth of late-type galaxies and the outside-in growth of early-type galaxies**.*

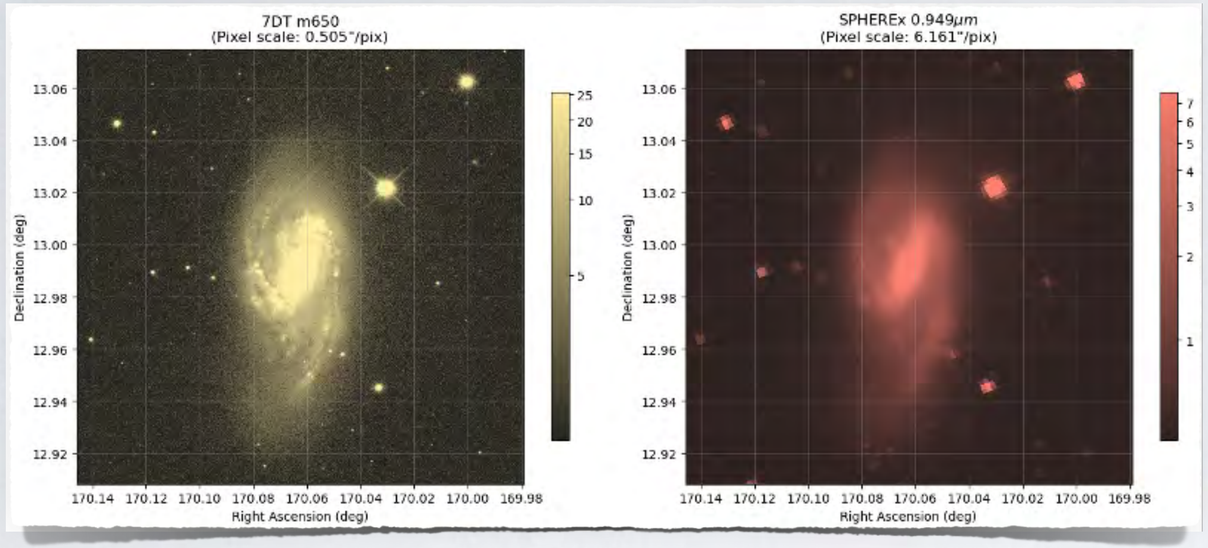


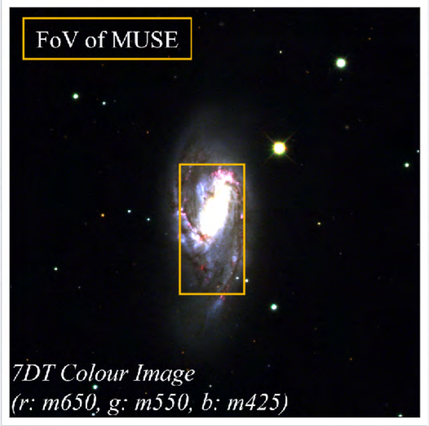


7DT Colour Image
(r: m650, g: m550, b: m425)



Resolved SEDs of Nearby Galaxies

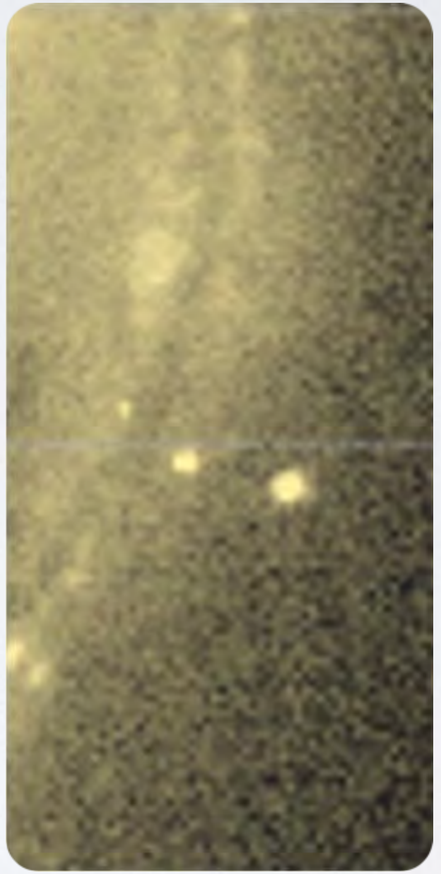


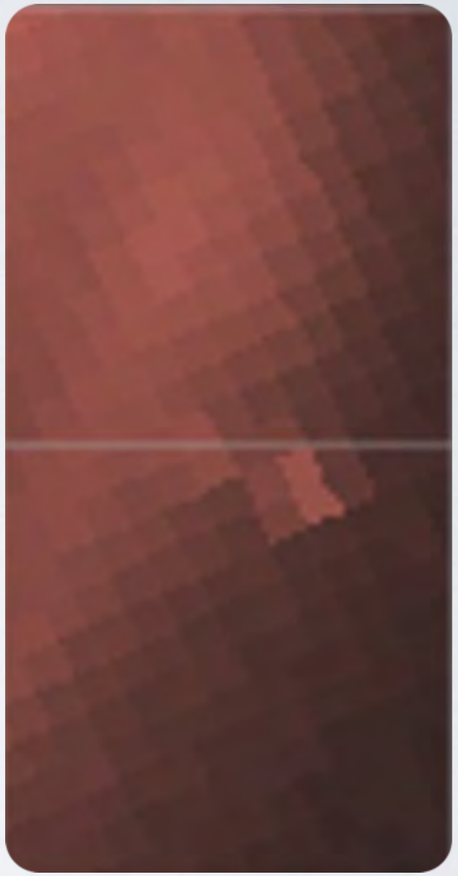


Spatially resolved SED fitting is carried out along with SPHEREx data.

7DT

SPHEREx



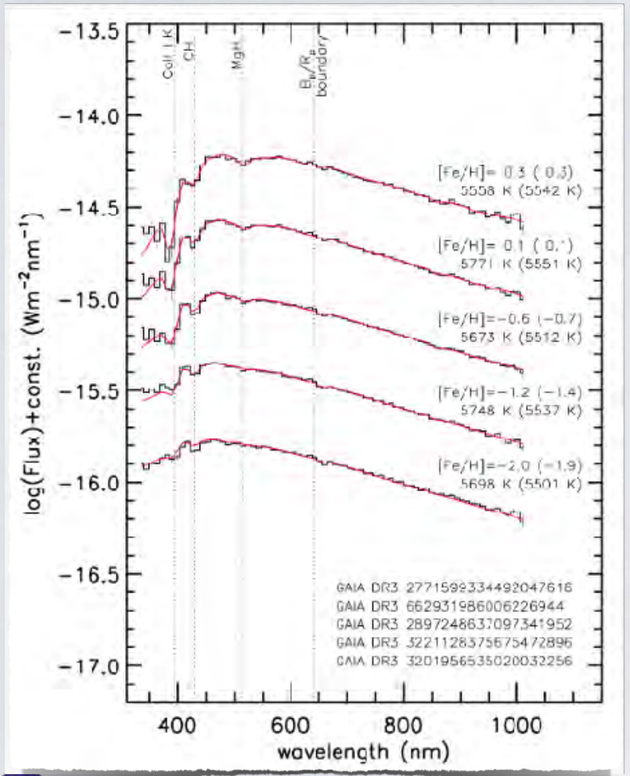


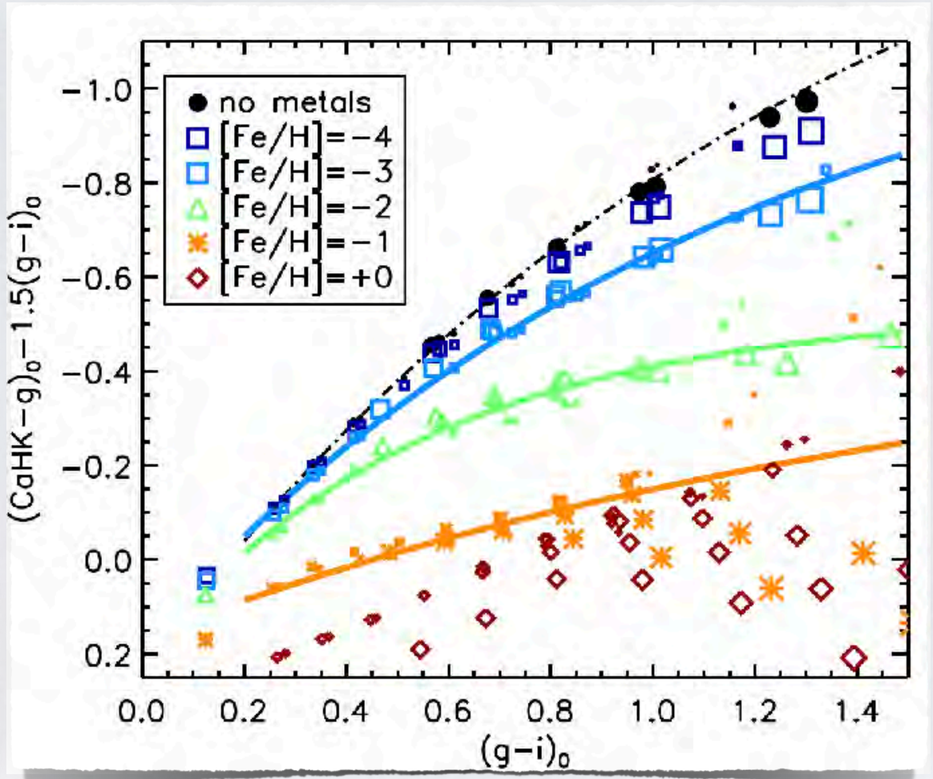
650 nm

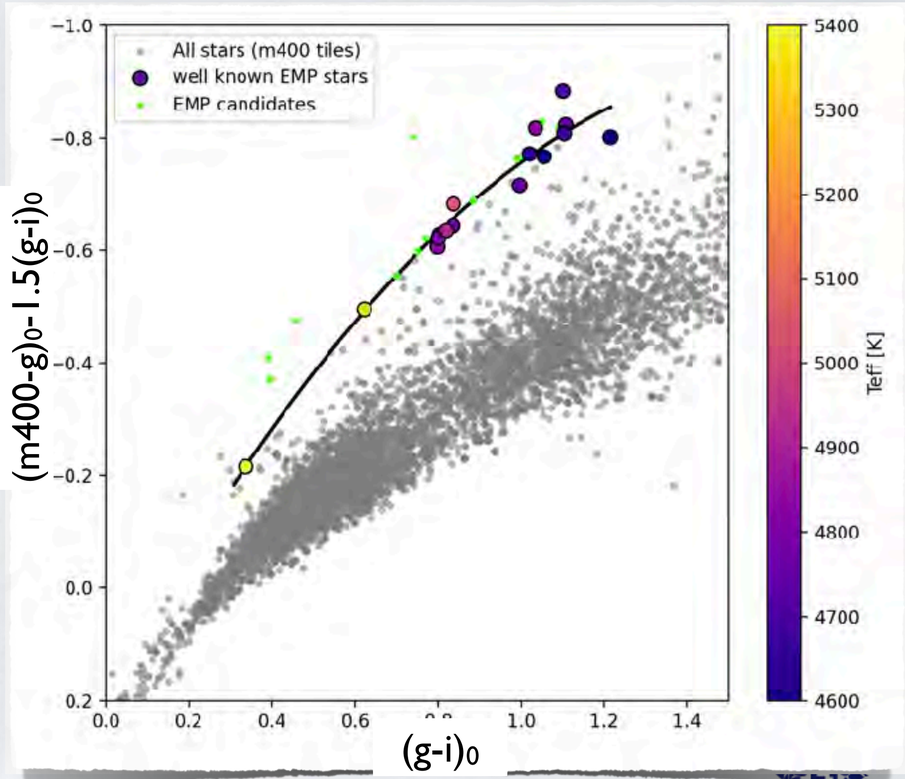
0.94 μm

Stellar Populations of the Galaxy

- *7DS can accurately determine key stellar parameters, including **effective temperature, distance, metallicity, and foreground extinction**.*
- ***Galactic Archeology**: the merging history of the Galaxy and the Local Group*



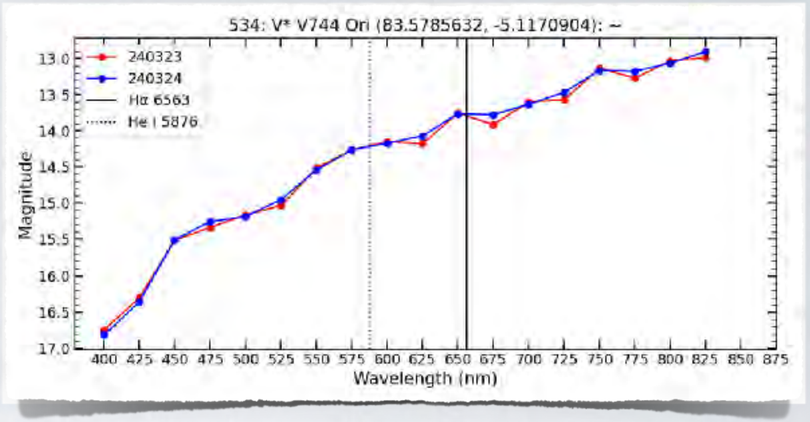


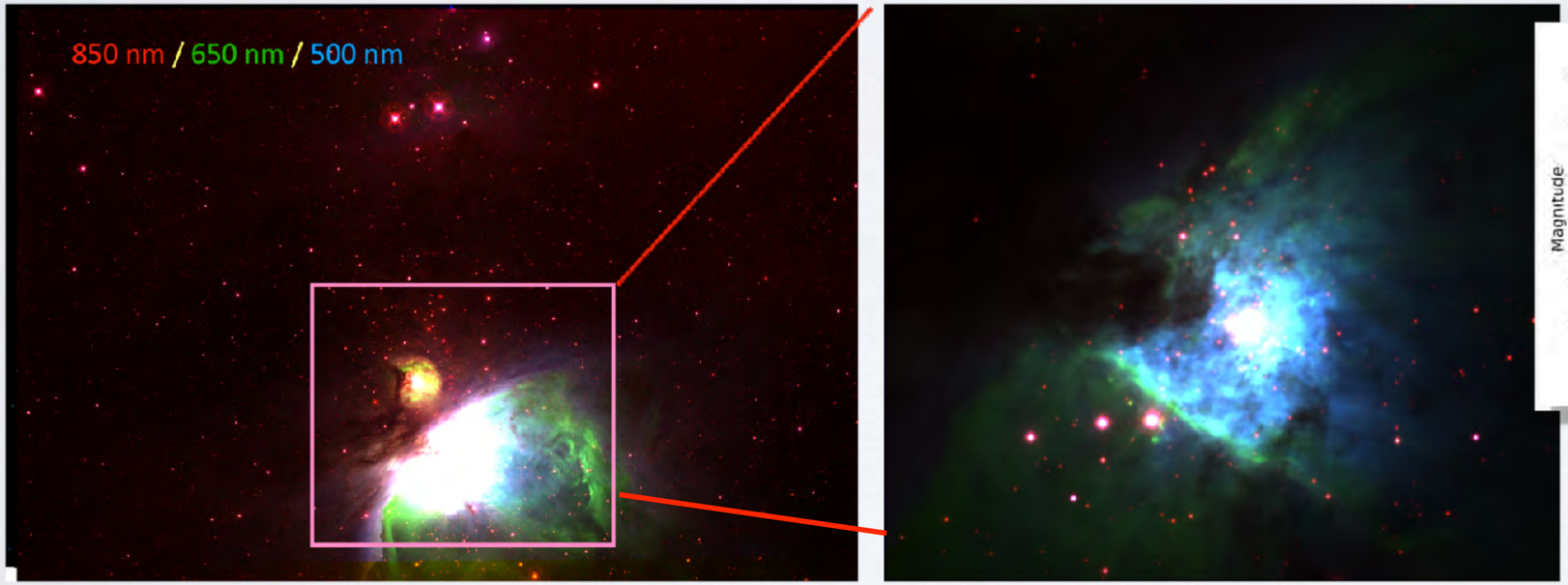


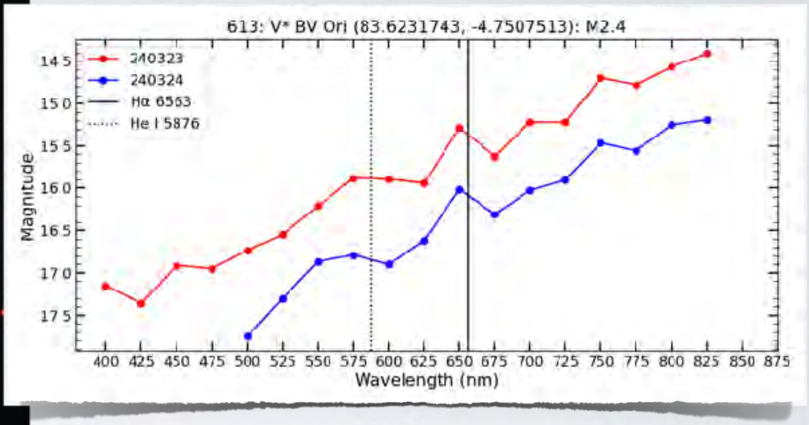
Color-color schemes to separate stellar metallicity tracks

Young Stellar Objects of the Orion Nebula

- ***Discovery of low-mass YSOs, T-Tauri stars***
  - *Variability of H-α emission*
  - *Variability of YSOs is driven by starspots, variations in accretion rates, and the dynamic structure of circumstellar disks.*





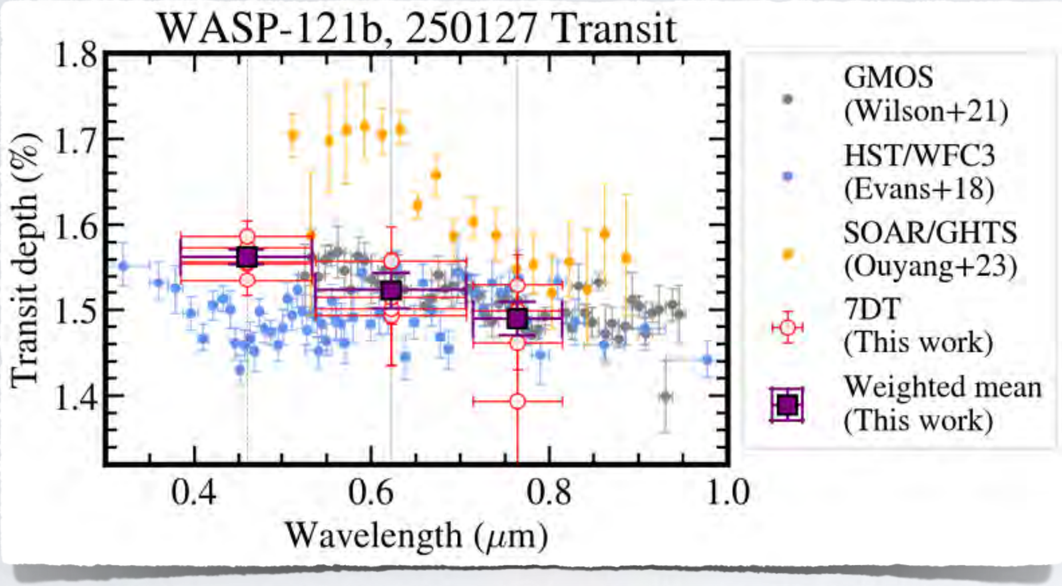


Various spectra of T-Tauri stars obtained by 7DT

Composite images of the Orion Nebula obtained by 7DT (Courtesy of M. Kim)

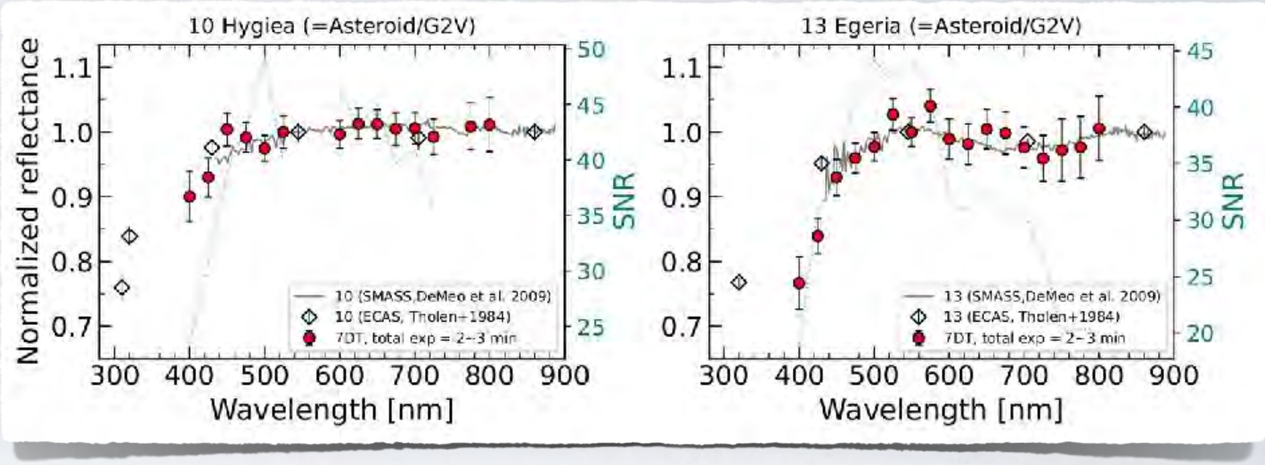
Exoplanets and Asteroids

- ***Composition of Exoplanet Atmosphere***
  - *Ultra-hot Jupiter with T_{eq} ~2400 K*
  - ***Temporal variation***
  - *Presence of TiO/VO*



Transition Depth of WASP-121b

- ***Composition of Asteroids***



7DT spectra of 10 Hygiea and 13 Egeria provided by J. Geem

- *0.7μm absorption feature of hydrated asteroids*
- *Constraints on **thermal evolution** on the asteroids*

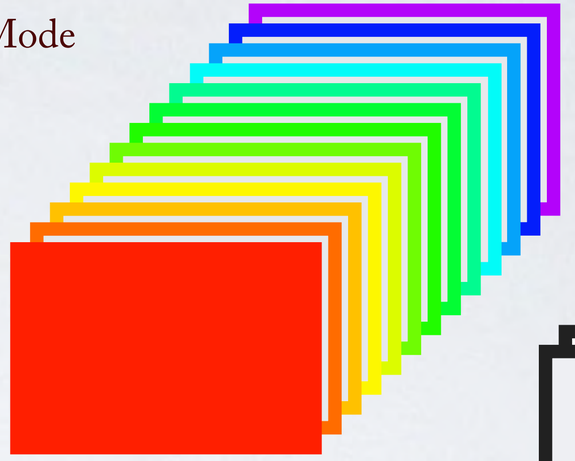
Summary

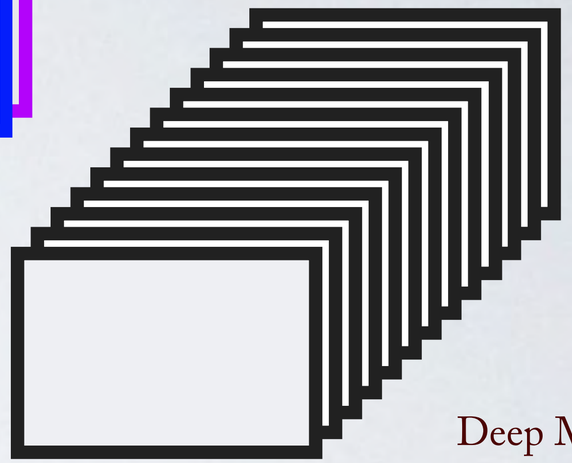
- *7DT is* ***a multi-telescope array with 20 50-cm astrographs****; now 16 of the planned telescopes are in operation.*
- *Equipped with* ***40 25-nm medium-band filters****, 7DT provides* ***IFU-like data with low spectral resolution*** *for a FoV of 1.25 deg^2.*
- *7DT is carrying out a* ***time-series, spectral mapping survey of the southern sky, 7DS****.*
- *7DS consists of 3 layers:* ***RIS, WFS, and IMS****.*
- *Beyond the detection of GW electromagnetic counterparts, 7DT/7DS provides data for a wide range of scientific goals, including* ***transient objects, cosmology, AGN & quasars, nearby galaxies, Galactic stellar objects, solar system objects, and more****.*
- *We are* ***open for collaboration! Email:*** *myungshin.im@gmail.com, jhkim.astrosnu@gmail.com*

Observation Mode

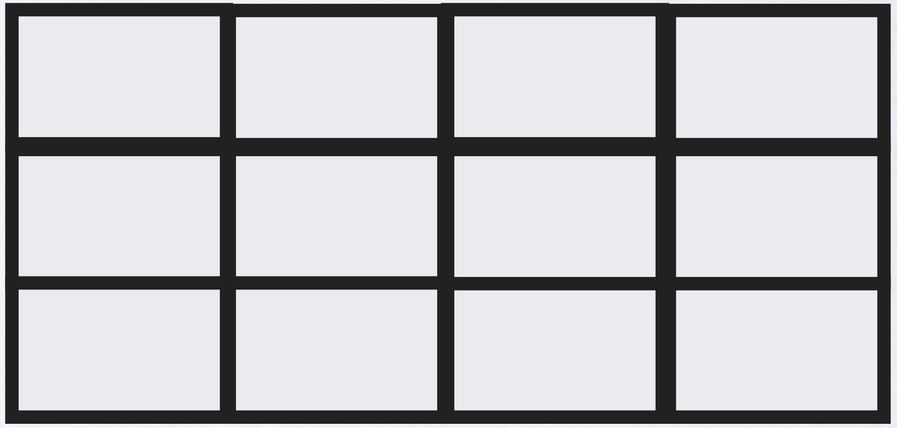
1. ***Spec Mode - Color Mode:***
   - *One pointing with 40 medium-band filters*
   - *FoV: ~1.2 square degrees*
   - *Spectral maps of the entire FoV (R= 30~70)*
2. ***Deep Mode:***
   - *One pointing with one broadband filter*
   - *FoV: ~1.2 square degrees*
3. ***Search Mode:***
   - *20 pointings with one broadband filter*
   - *FoV: ~25 square degrees*

Spec Mode





Deep Mode



Search Mode



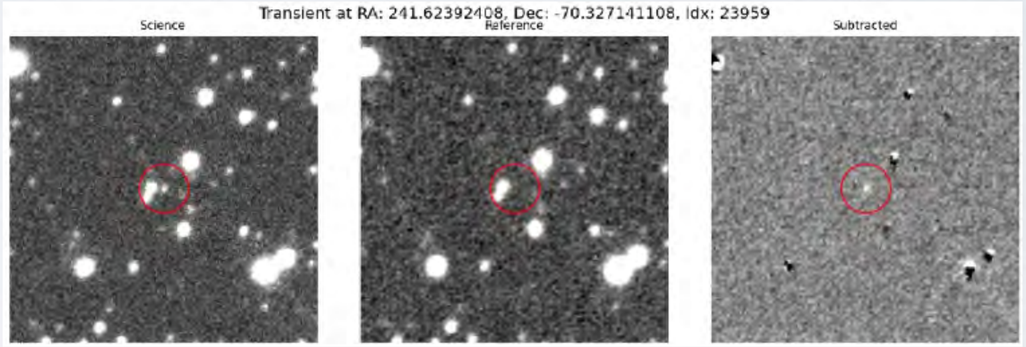
Research Topics

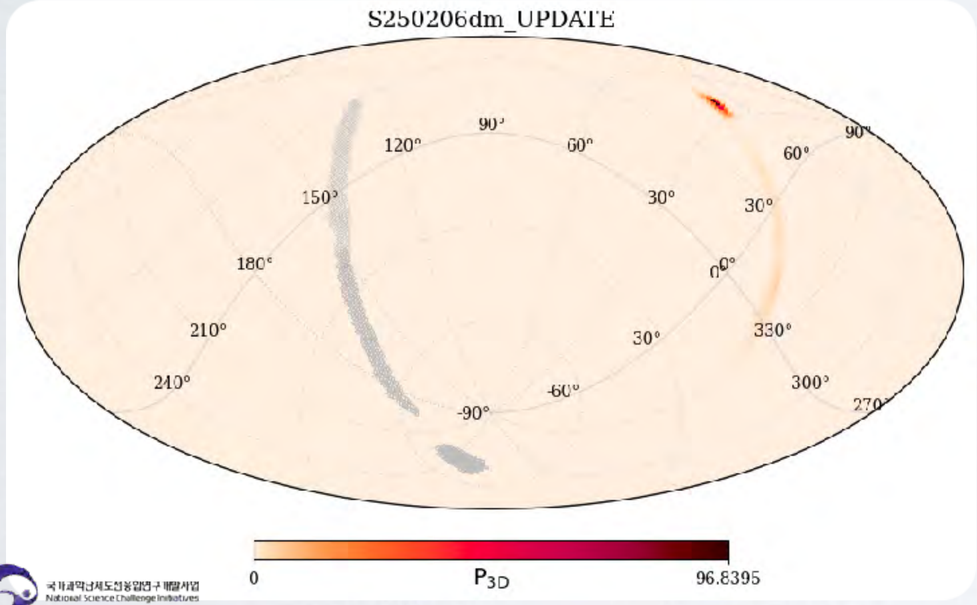
Subject	Now	7DS	Scientific Value
Time-series Spectra of Quasars	~1000	>30,000	Complete Census of SMBH AGN Variability
RM Measurement of SMBH Mass	~100	10,000	Growth History of SMBHs
Velocity Maps of Galaxies	~10,000	50,000,000	Galaxy Evolution
Galaxy Clusters	100,000	100,000	Cosmology, Galaxy Evolution
Early Spectra of SNe	~10	>1,000	Physical Mechanism of SNe
Time-series Spectra of Stellar Objects	1,000,000	10^9	Stellar Evolution
Time-series Spectra of Small Bodies of the Solar System	100	>10,000	Origin of the Solar System, Census of Asteroids/Comets

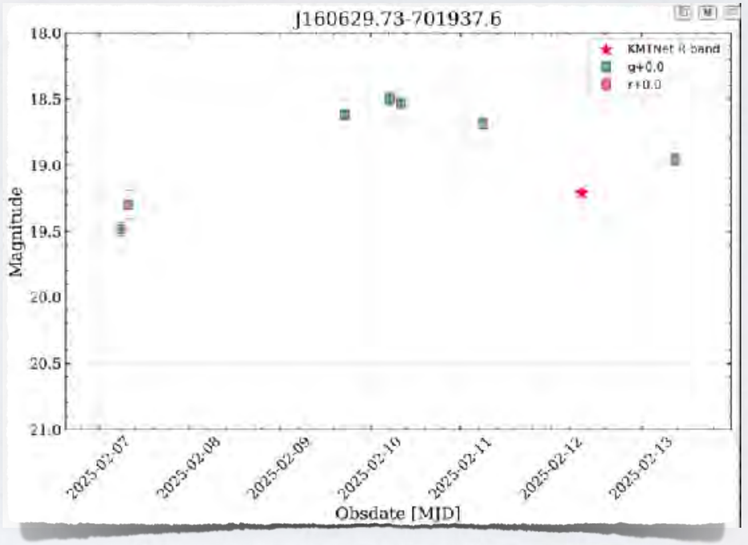
GW Follow-up Observations during O4 Run

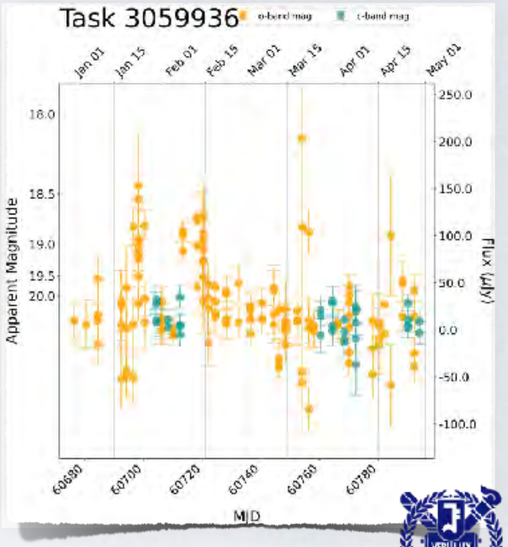
- ***S250206dm***
- ***Localization area:*** *~910 deg²*
- ***FAR****: 1 per 25 yr*
- *5 transients are detected.*

J160629.73-701937.6: Possible SN?





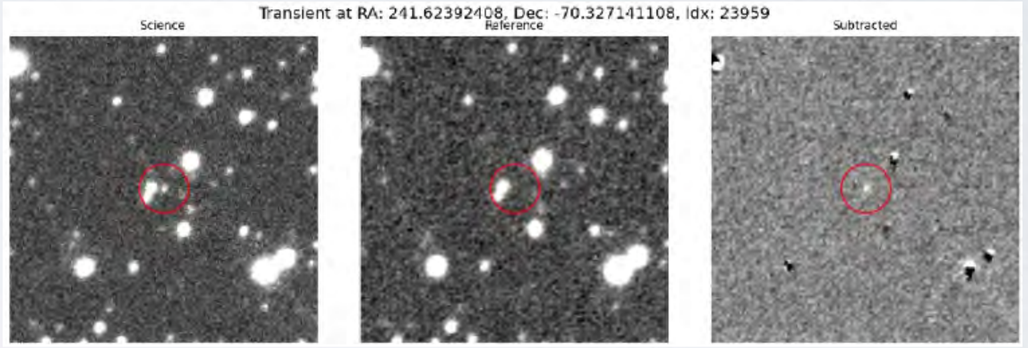


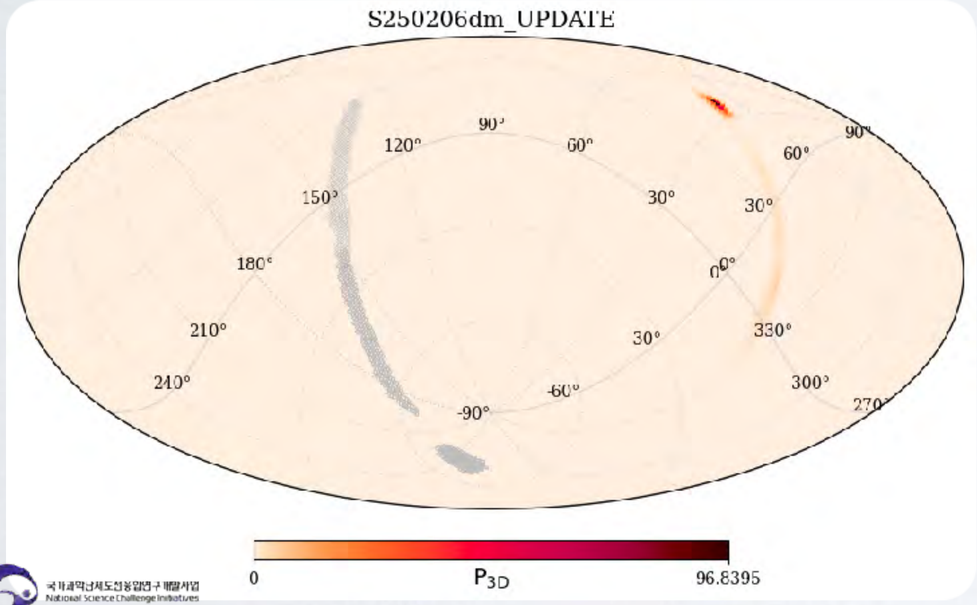


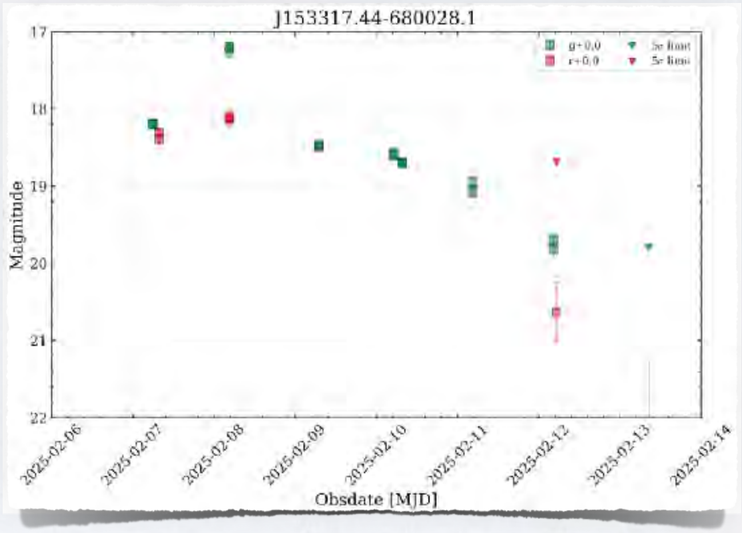
GW Follow-up Observations during O4 Run

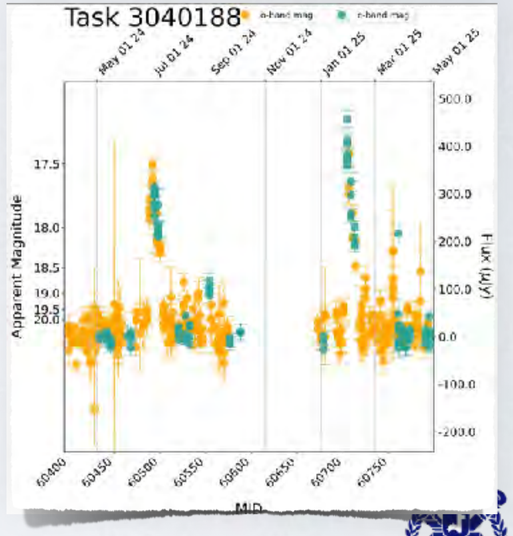
- ***S250206dm***
- ***Localization area:*** *~910 deg²*
- ***FAR****: 1 per 25 yr*
- *5 transients are detected.*

J153317.36-680028.5: No ATLAS detection







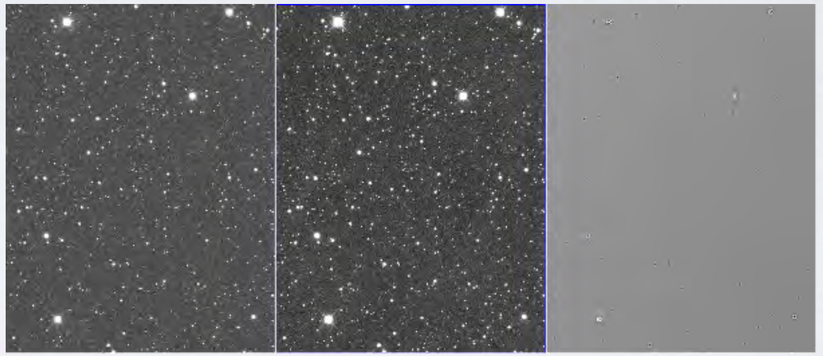


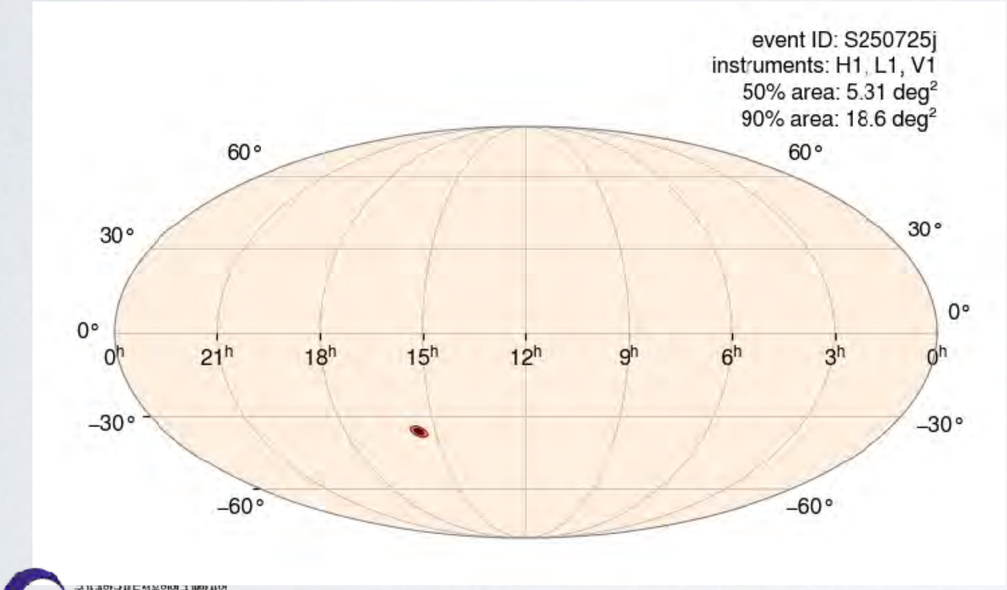
27

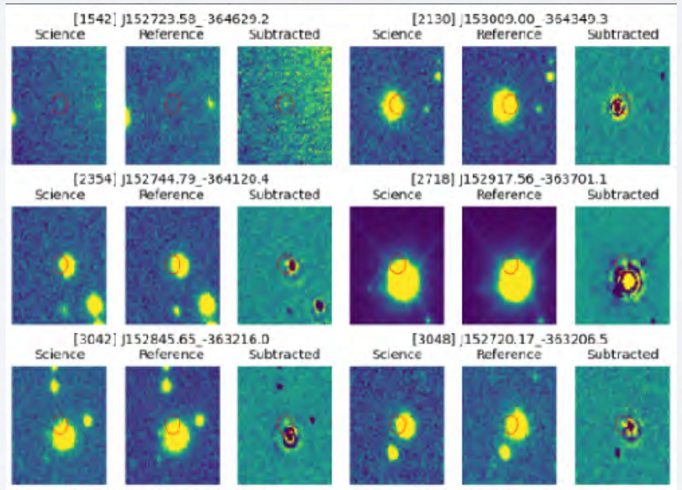
GW Follow-up Observations during O4 Run

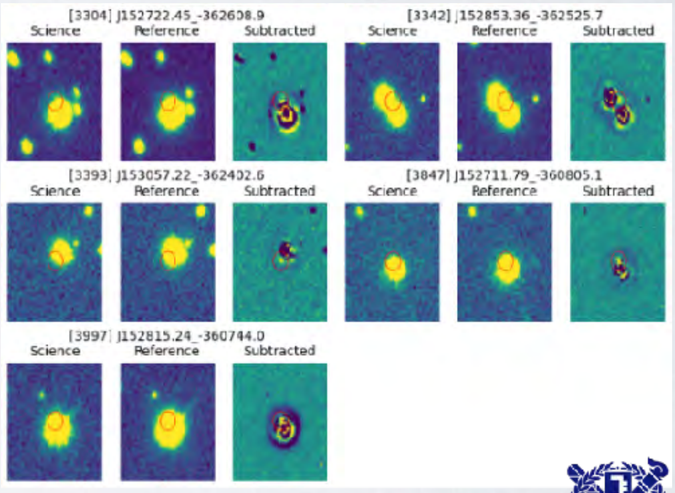
- *S250725j*
- *Localization area: ~19 deg²*
- *FAR: 1/725 yr*
- *45 transients are detected.*

T07804: One of 17 FoVs observed for the CR90 area









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National Science Challenge Initiatives
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