국가과학난제도전융합연구개발사업
National Science Challenge Initiatives
중력파우주연구단

7-Dimensional Sky Survey: Spectral Mapping Survey of the Southern Sky



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2025-01-23

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1. Seoul National University, 2. KASI, 3. KNU, 4. EWU, 5. KHU, 6. DNSM, 7. Postech

2016년 12월 곤지암 SSG workshop

다차원적 우주탐사
7-Dimensional Sky Survey (7DS)



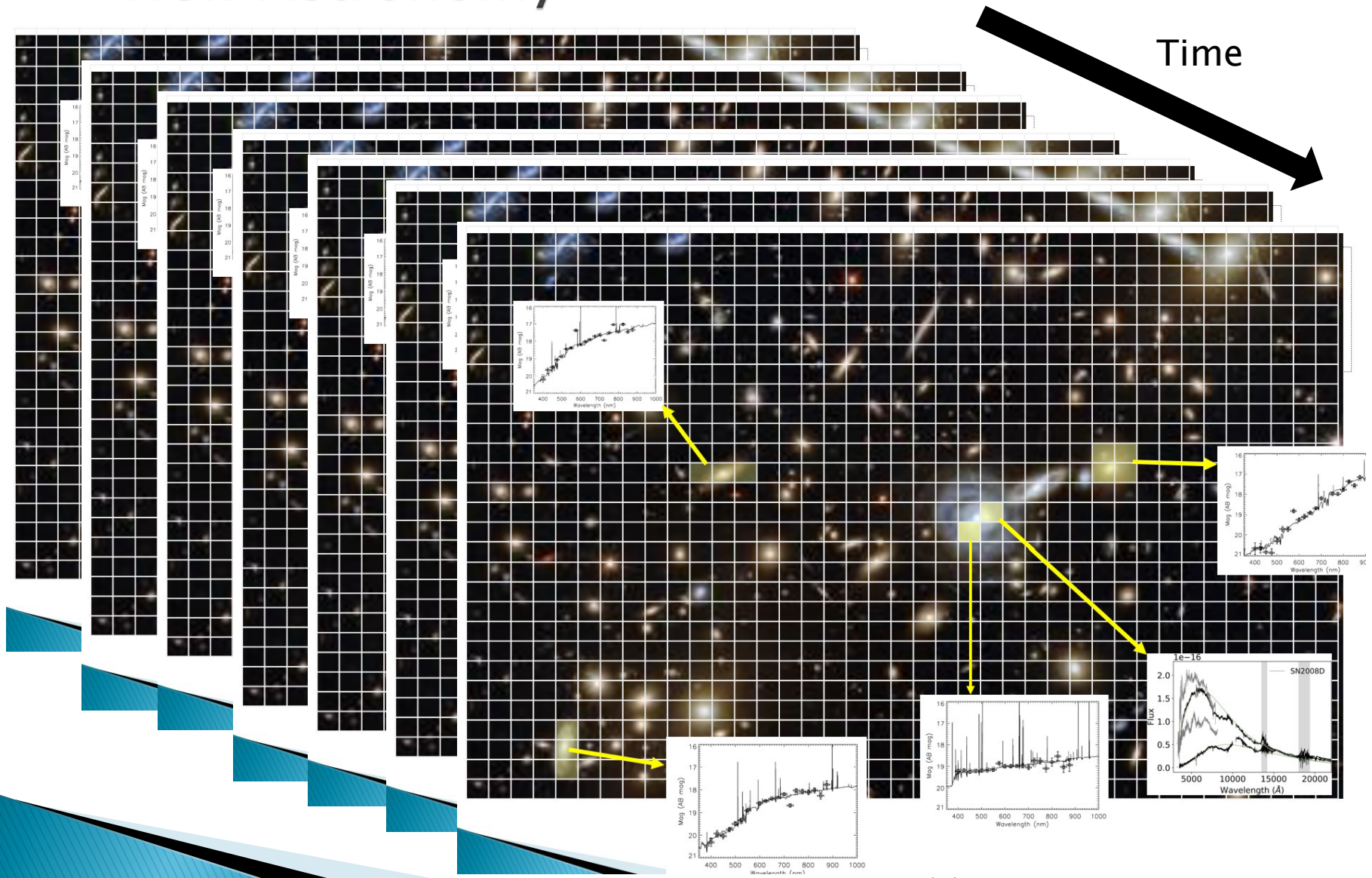
임명신
(서울대학교)
2016-12-16

7-Dimensional Sky Survey (7DS)

- Wide-area, time-series, hyperspectral imaging (spectral mapping) survey of the southern sky

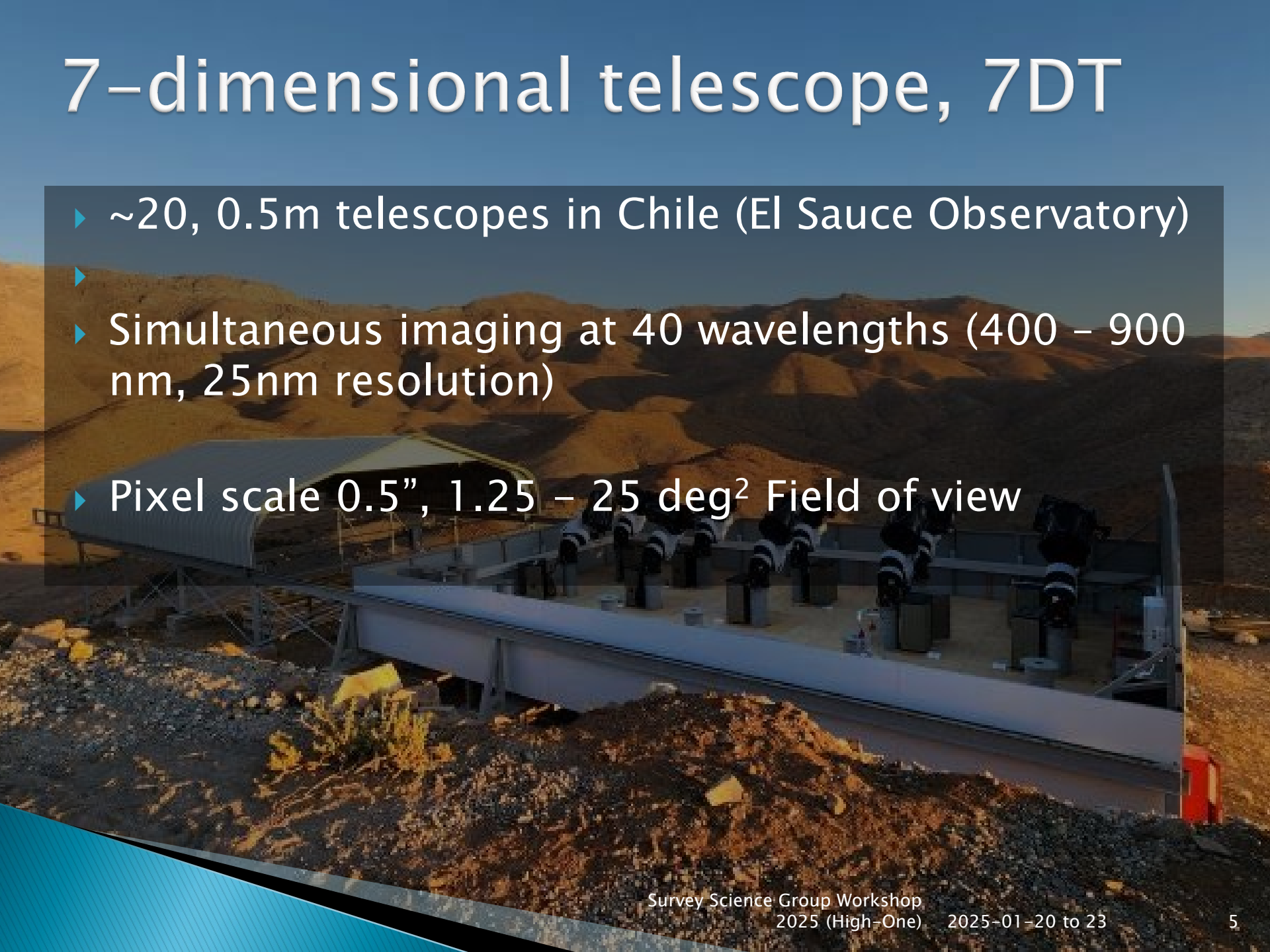
- 7D = x,y,z (3) + time (1) + flux (1) + wavelength (1) + radial velocity (1)

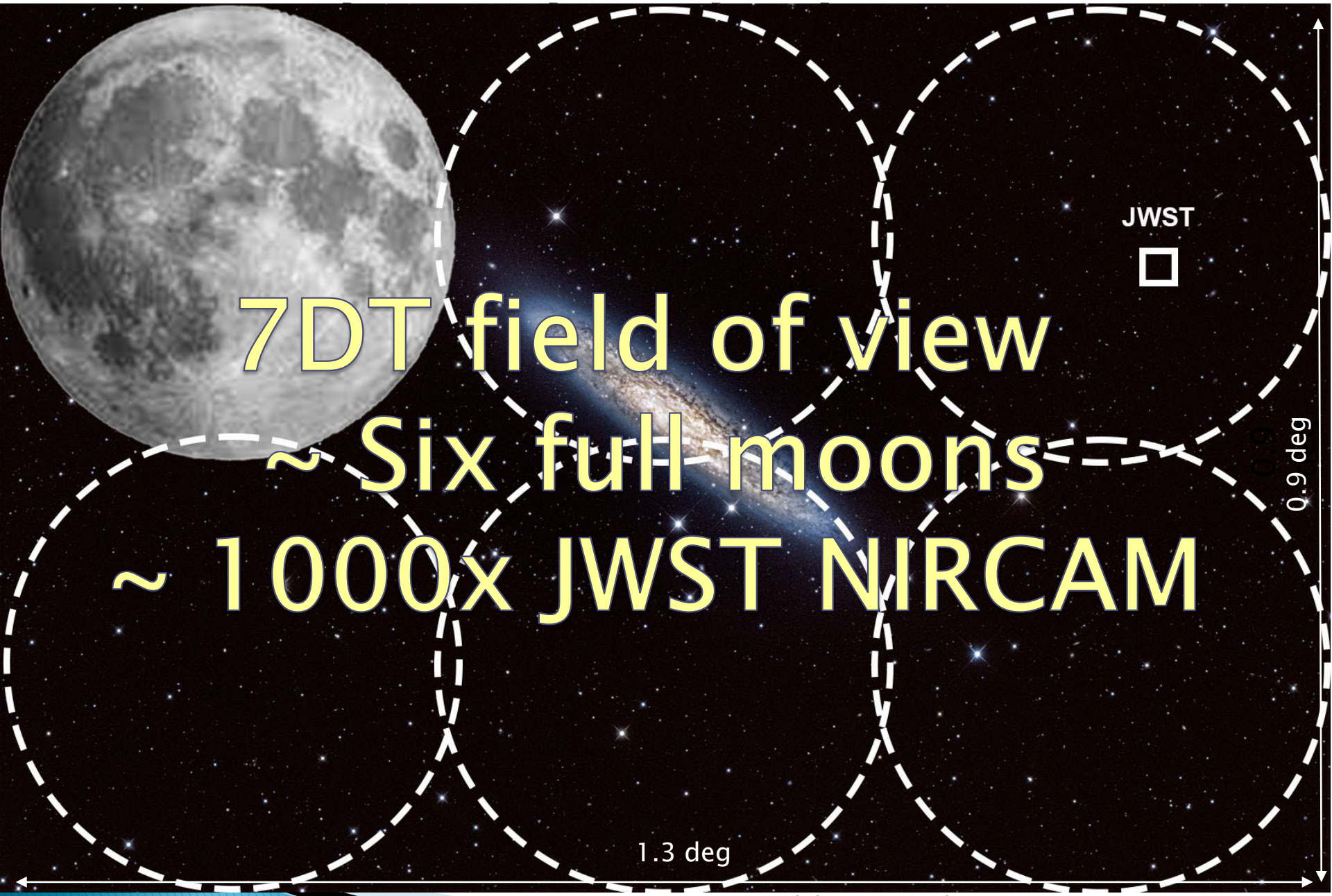
New Way to Explore the Universe for New Astronomy



7-dimensional telescope, 7DT

- ~20, 0.5m telescopes in Chile (El Sauce Observatory)
- Simultaneous imaging at 40 wavelengths (400 – 900 nm, 25nm resolution)
- Pixel scale 0.5”, 1.25 – 25 deg^2 Field of view



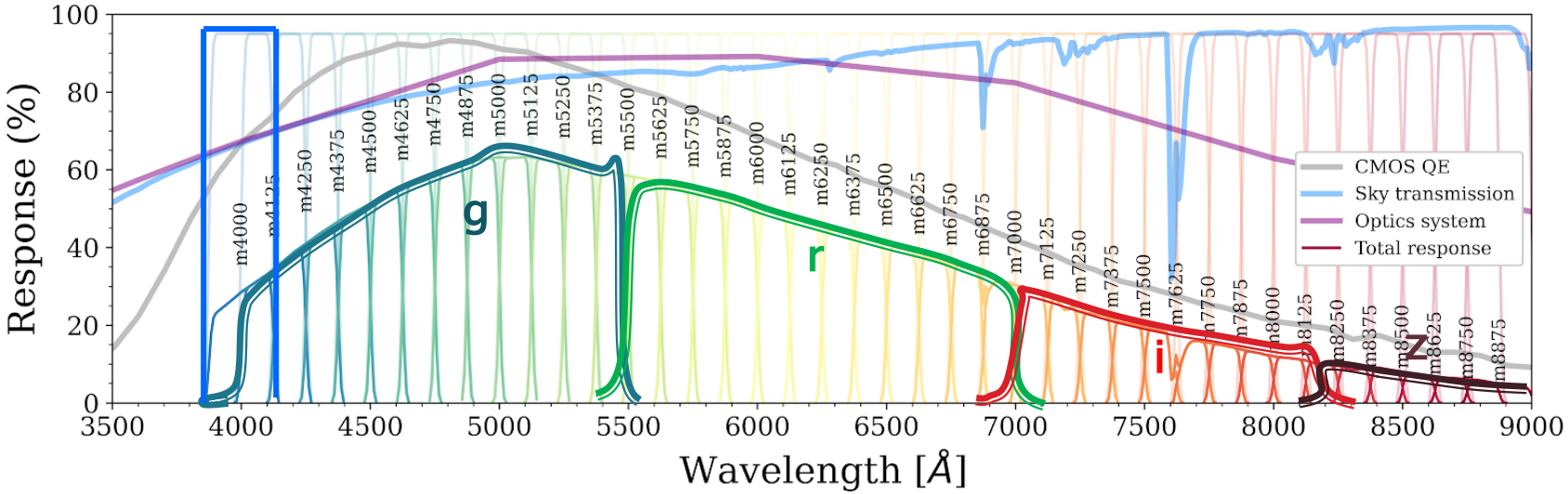


7DT field of view
~ Six full moons
~ 1000x JWST NIRCAM

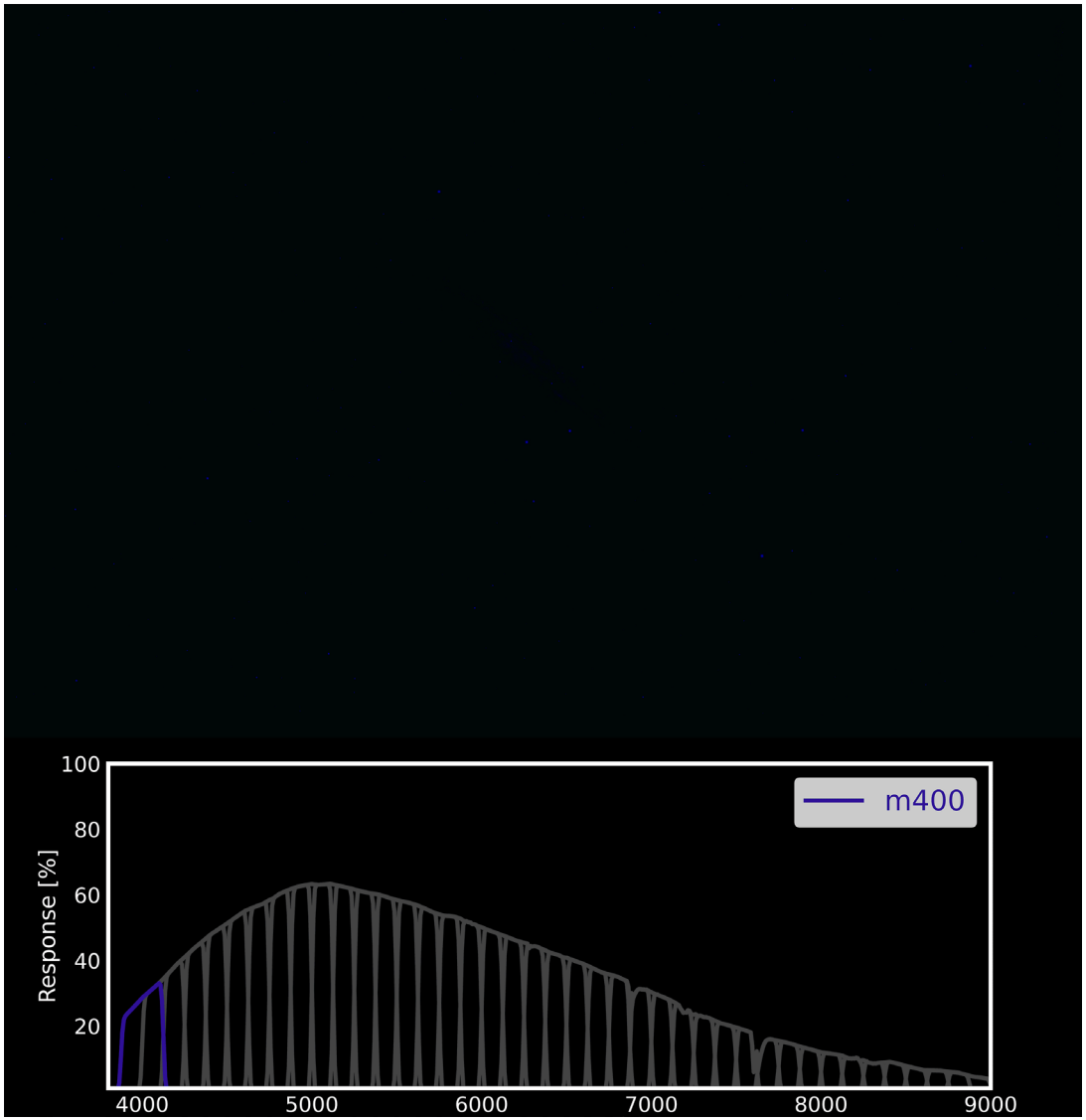
40 Medium-band Filters

- Width: 25nm (vs broad-band 150nm) at 400 – 900 nm
- Interval: 12.5nm
- Each telescope is equipped with two medium-band filters
- R ~ 40 low resolution spectra ➔ Good S/N with small telescopes
- Spectra for every pixel in the field of view (1.25 deg^2)

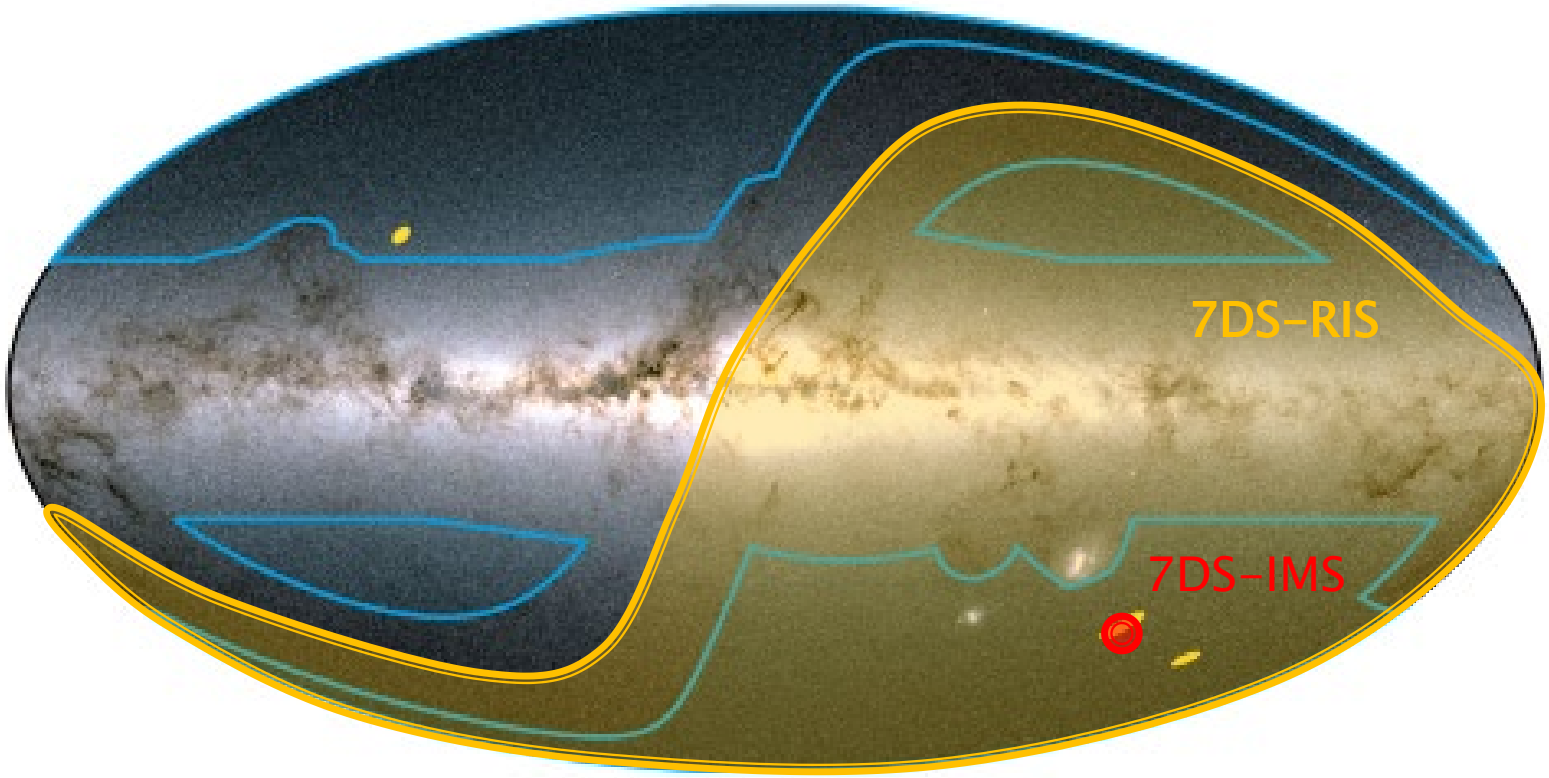
Medium-band vs Broad-band filters



7DT takes images in 40 wavelengths



7-Dimensional Sky Survey (7DS)



7DS-RIS: Entire southern hemisphere
7DS-WFS: TBD (some in the equatorial field, some near SCP)
7DS-IMS: Overlap with Euclid-deep, SPHEREx deep fields

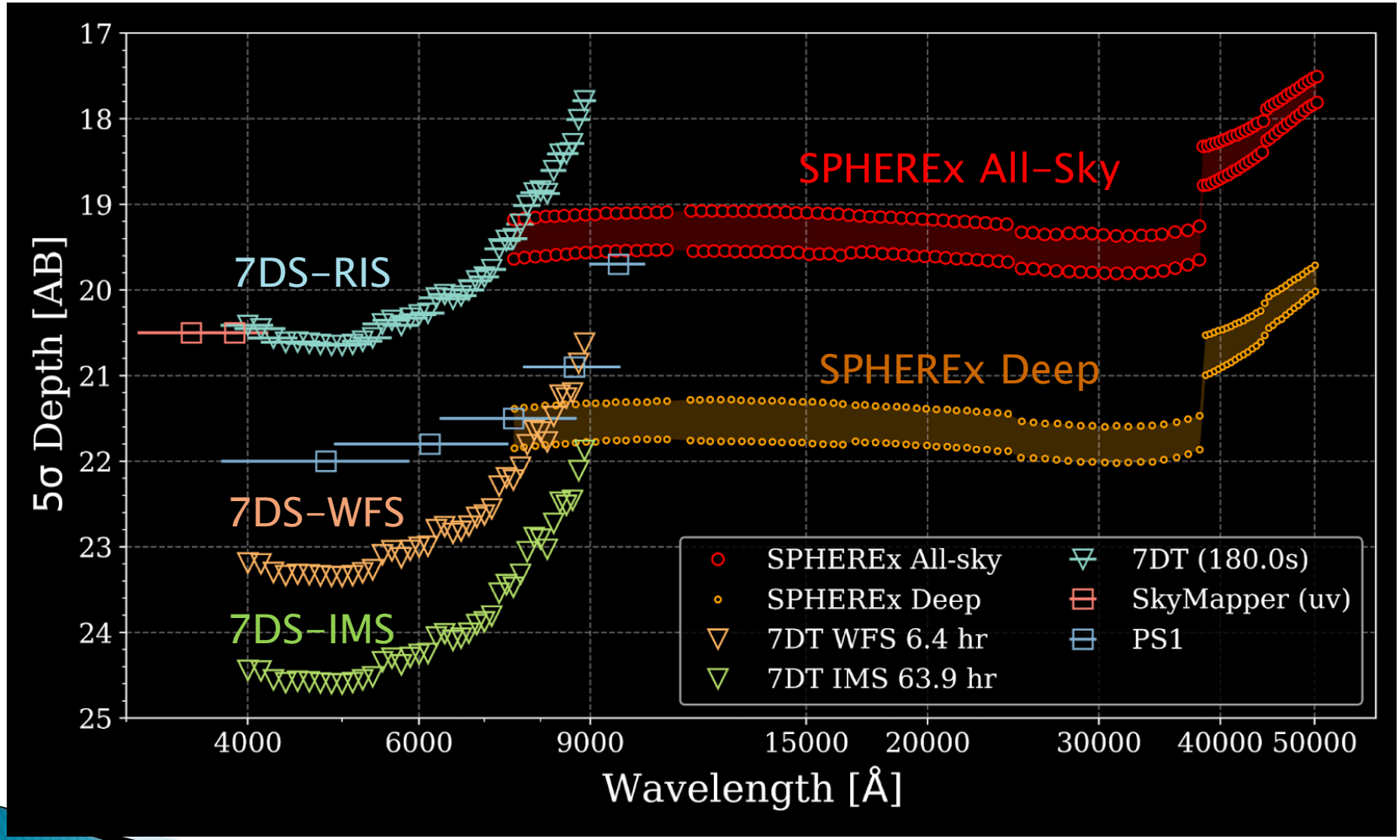
7-Dimensional Sky Survey, 7DS
>5 years, three surveys –

	Survey area (deg^2)	Cadence	Depth (1-epoch 5-σ, 475nm	depth (5 years)	Exposure time per epoch/filter
Reference Imaging Survey (RIS)	20,000 (SDSS, 15,000)	–	20.7 mag	–	5min
Wide-Field Survey (WFS)	1,620	14 days	20.7 mag	23.2 mag	5min
Intensive Monitoring Survey (IMS)	12.6	1 day	20.7 mag	24.7 mag	5min

+ Target-of-Opportunity Observation for Transients

Assumption: 1.5" seeing, 70% efficiency

7DS detection limits



7DS Research Topics

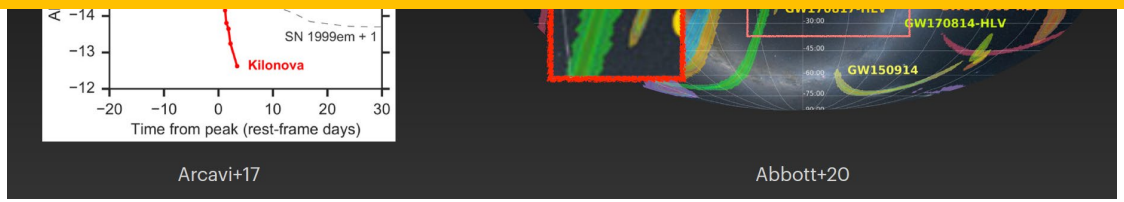
1. Multi-messenger astronomy
2. Supermassive black holes & AGN
3. Galaxy evolution
4. Cosmology
5. Stellar population/our galaxy
6. Transients (SNe, TDE, etc)
7. Solar system objects

7-Dimensional Sky Survey Scientific Cases Document
http://astro.snu.ac.kr/~mim/7ds.html

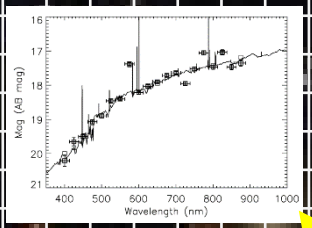
Challenges to overcome for MMA

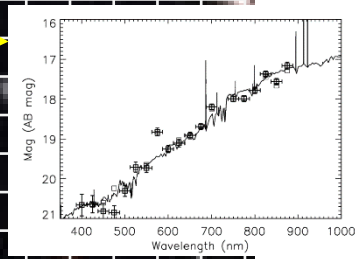
- Search aera is too wide (~100 deg^2 or more)
- Kilonovae (Kne): Faint, fast-decaying transient (> 20 mag)
  : A KN needs to be found fast (first 1-2 days)
- Too many other tranients (10-100/deg^2)

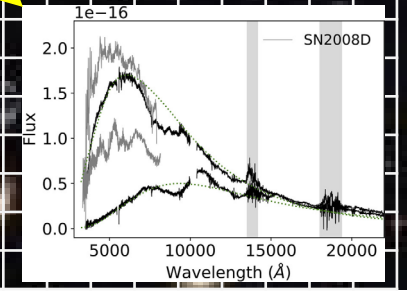
Rapid, wide-field spectral mapping is desired

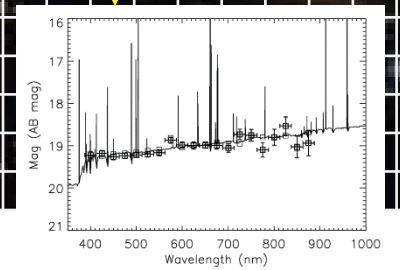


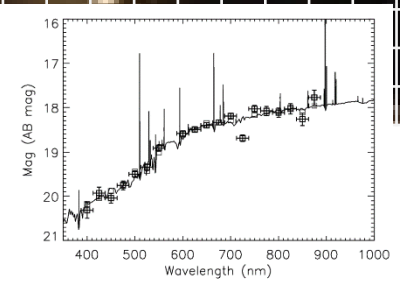
Wide-field spectral mapping can identify KN fast







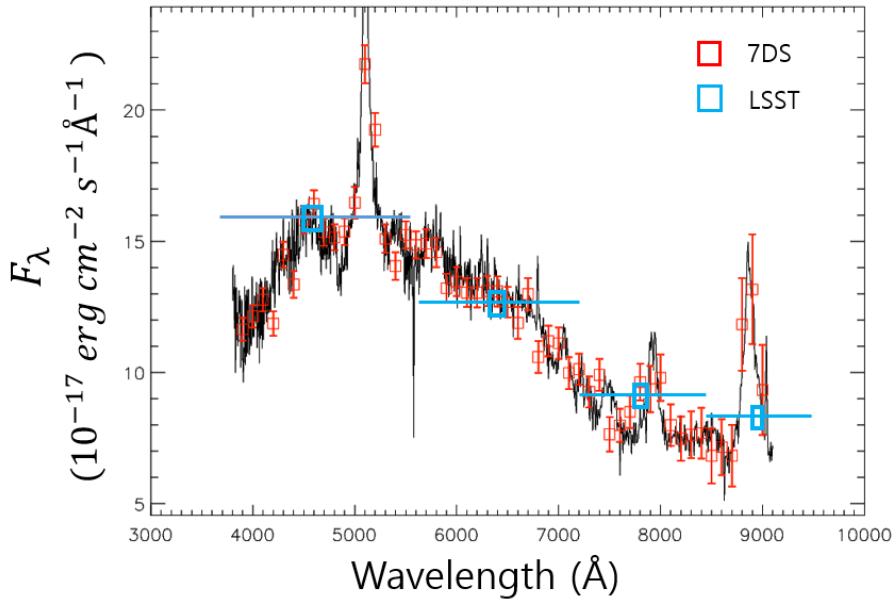




AGN: 7DT trace spectra of AGNs well

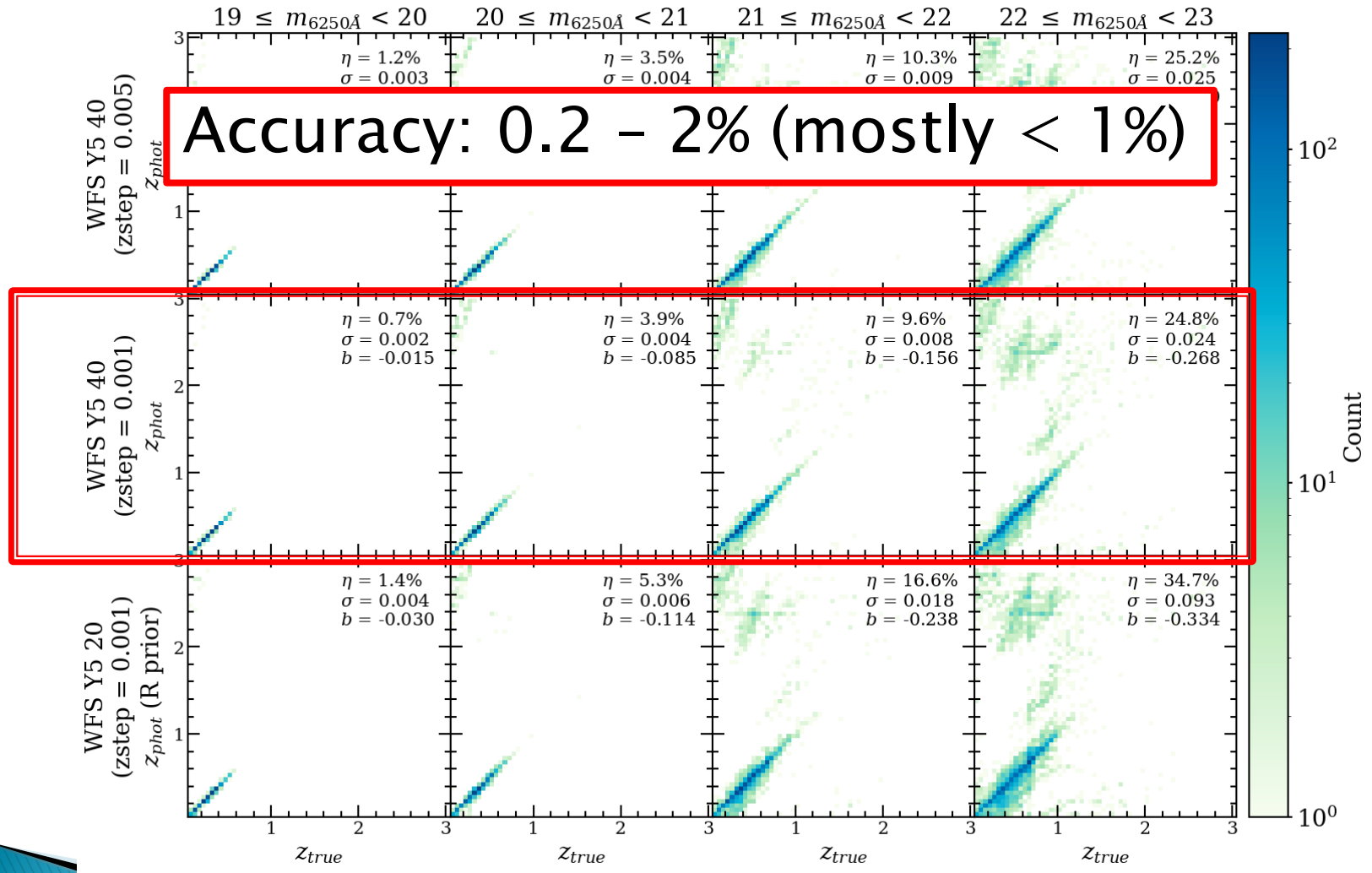
- 7DT can sample emission lines (BEL) and continuum separately
- AGN variability time lag between BEL and continuum (reverberation mapping) ➔ direct measures of BH masses

7DT will trace spectral variability of
> 10,000 AGNs (vs 100s now)



z = 0.822,
i = 18.3 mag quasar

Galaxies: 7DS provide highly accurate redshift information

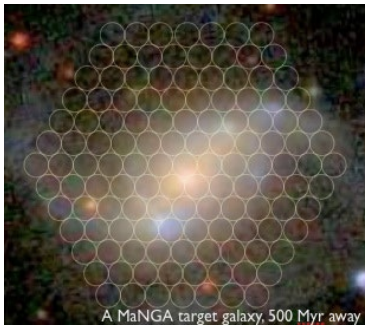


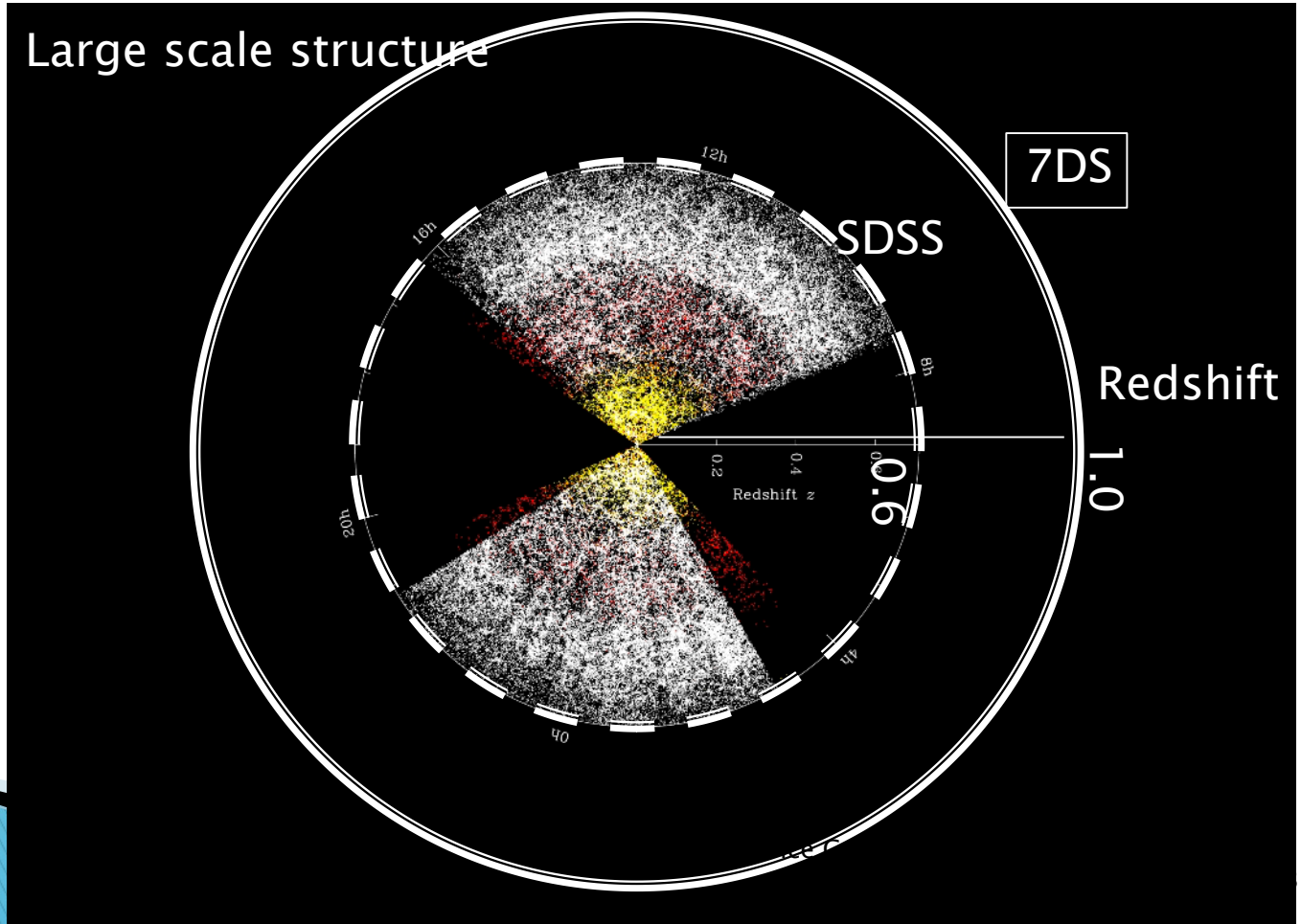
Accuracy: 0.2 – 2% (mostly < 1%)

Ko+24, Bae+25

7DS Galaxy Map

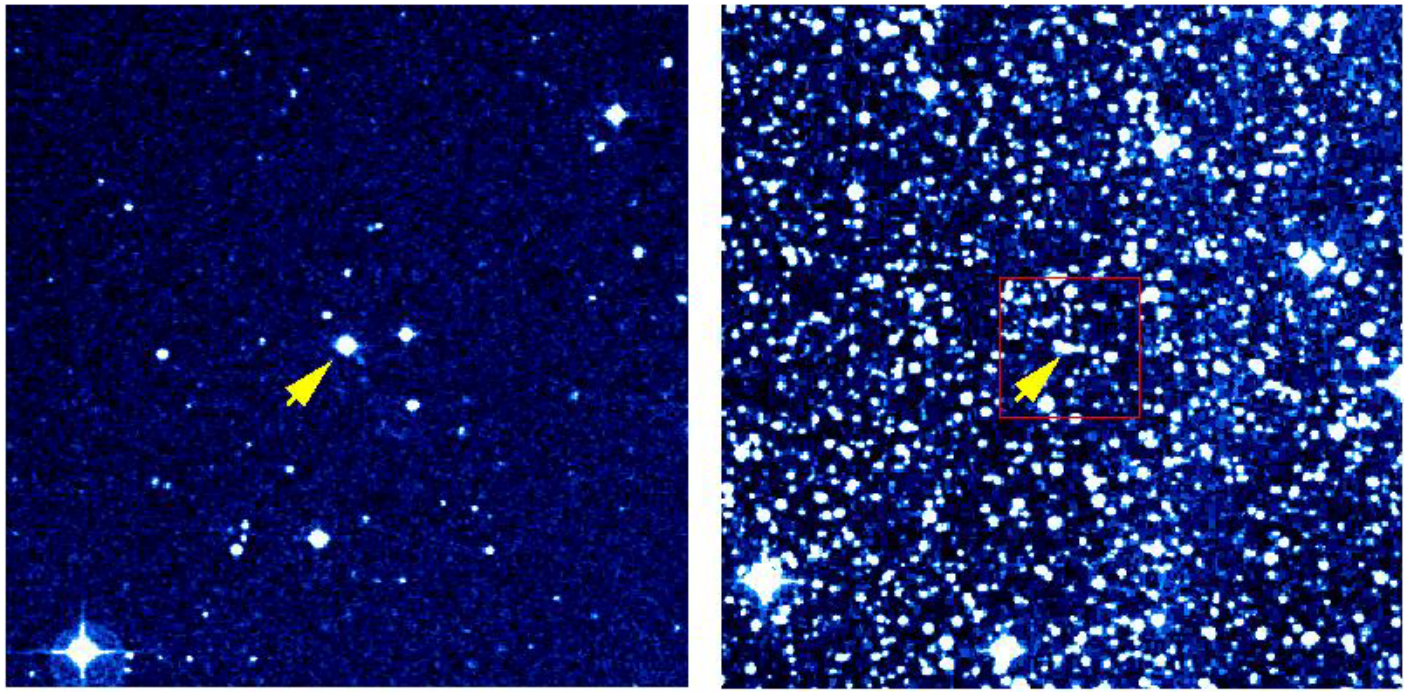
- Galaxy redshifts at 0.2-1% accuracy
- Large scale structures up to z ~ 1
- Environmental-dependent evolution
- Spatially resolved stellar population for 10M galaxies





Filling the gap: galaxies and quasars in the zone of avoidance

Quasar in High Galactic Latitude vs Quasar in the Zone of Avoidance



3C273 (High Galactic Latitude Quasar)

SNUQSO J2109+3532
(Quasar in the Zone of Avoidance)

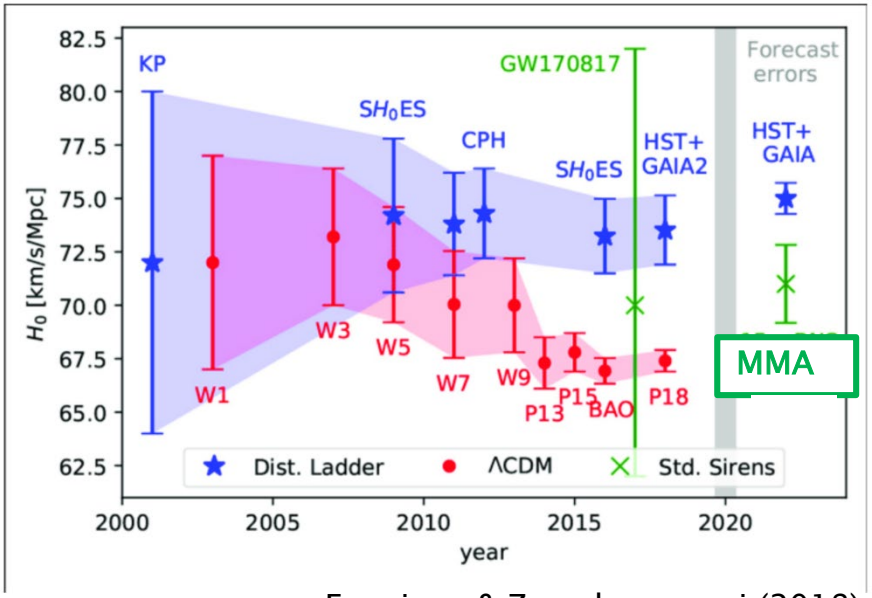
Im+07

Cosmology

- Quasars: T-L relation, UV vs X-ray luminosity
- GW sources: Standard Siren
- Galaxy clusters, BAO

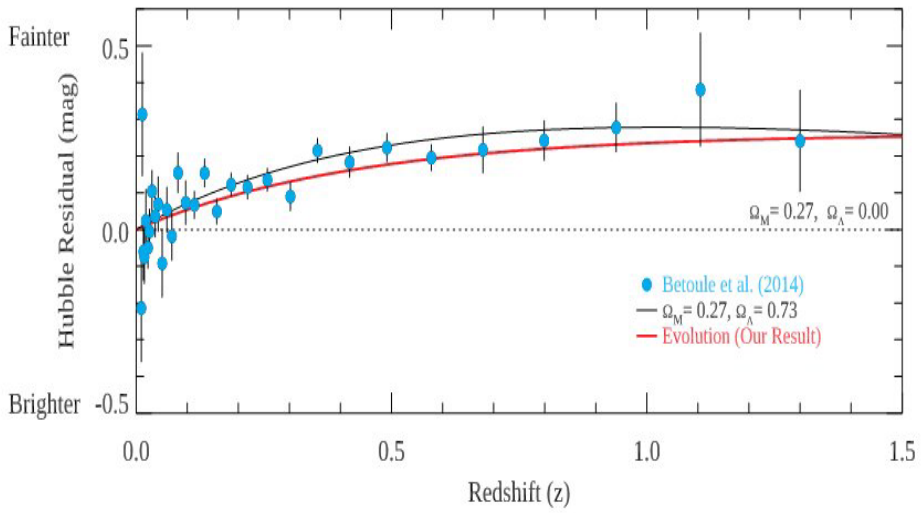
- Hubble constant at different redshift bins
- Cosmological parameters at a few % accuracy of better

Hubble Tension



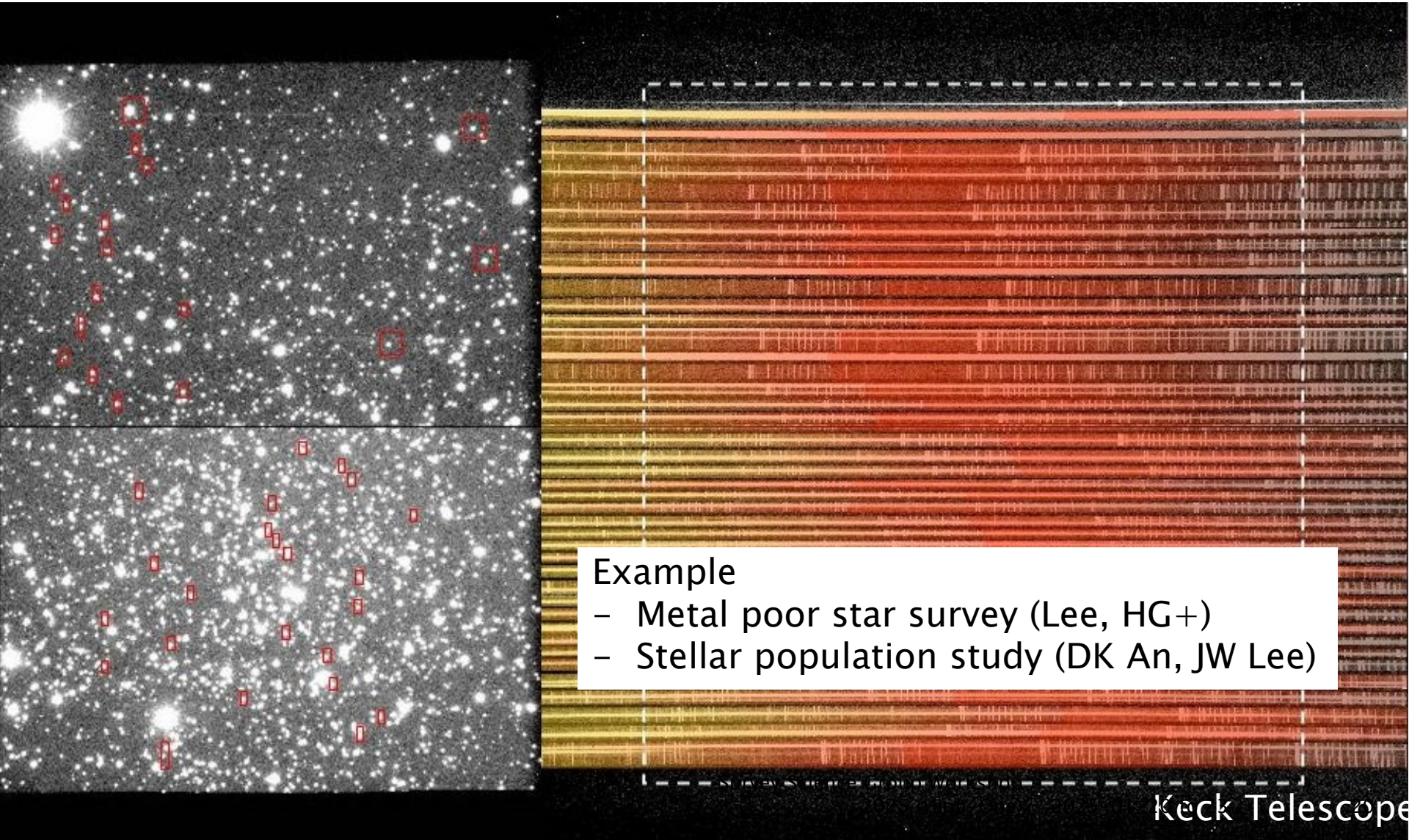
Ezquiaga & Zumalacarregui (2018)

Dark energy controversy



Kang, Lee, YW, et al. (2019)

~10^9 Stellar spectra for stellar population study

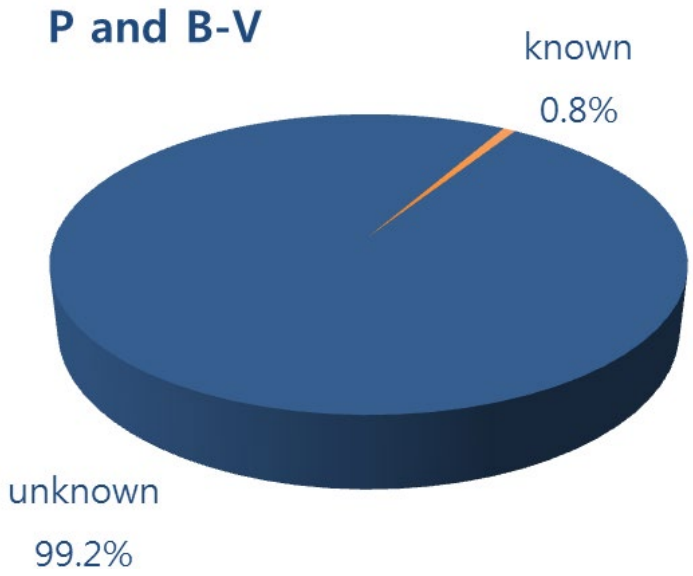


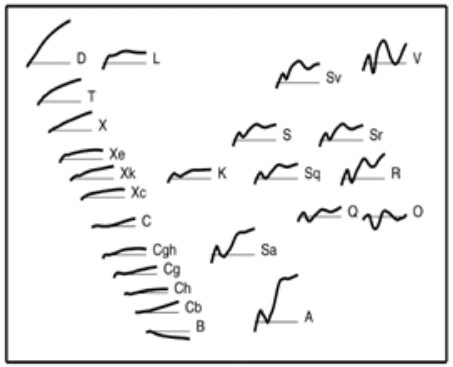
Example
- Metal poor star survey (Lee, HG+)
- Stellar population study (DK An, JW Lee)

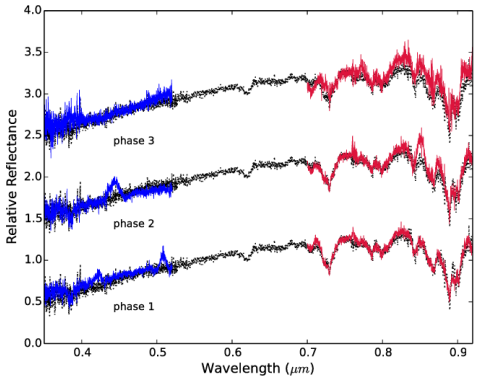
Keck Telescope

Solar system objects

- Comets, Asteroids, etc: key for understand the formation and evolution of the solar system
- > 10,000s time-series spectra for comets, asteroids





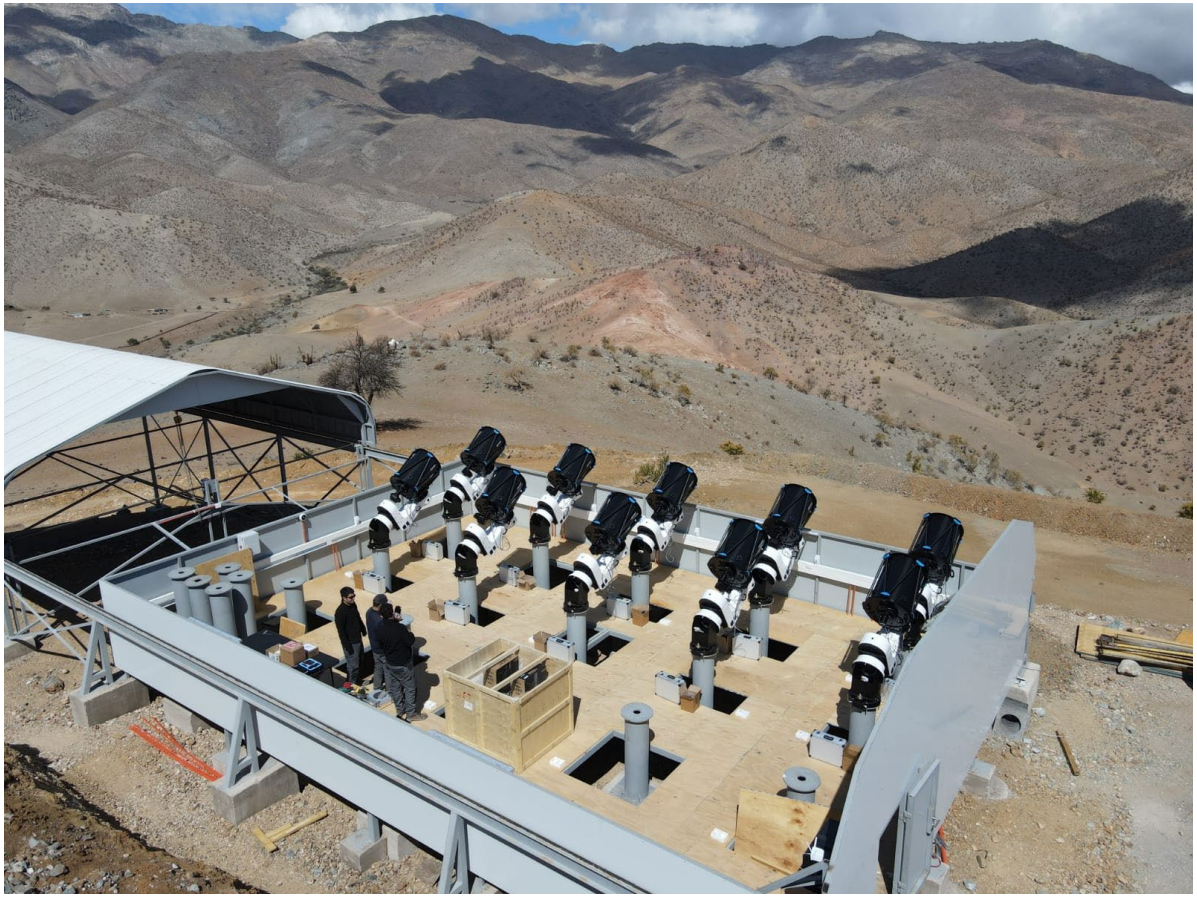


Period and colors are very little known for NEOs

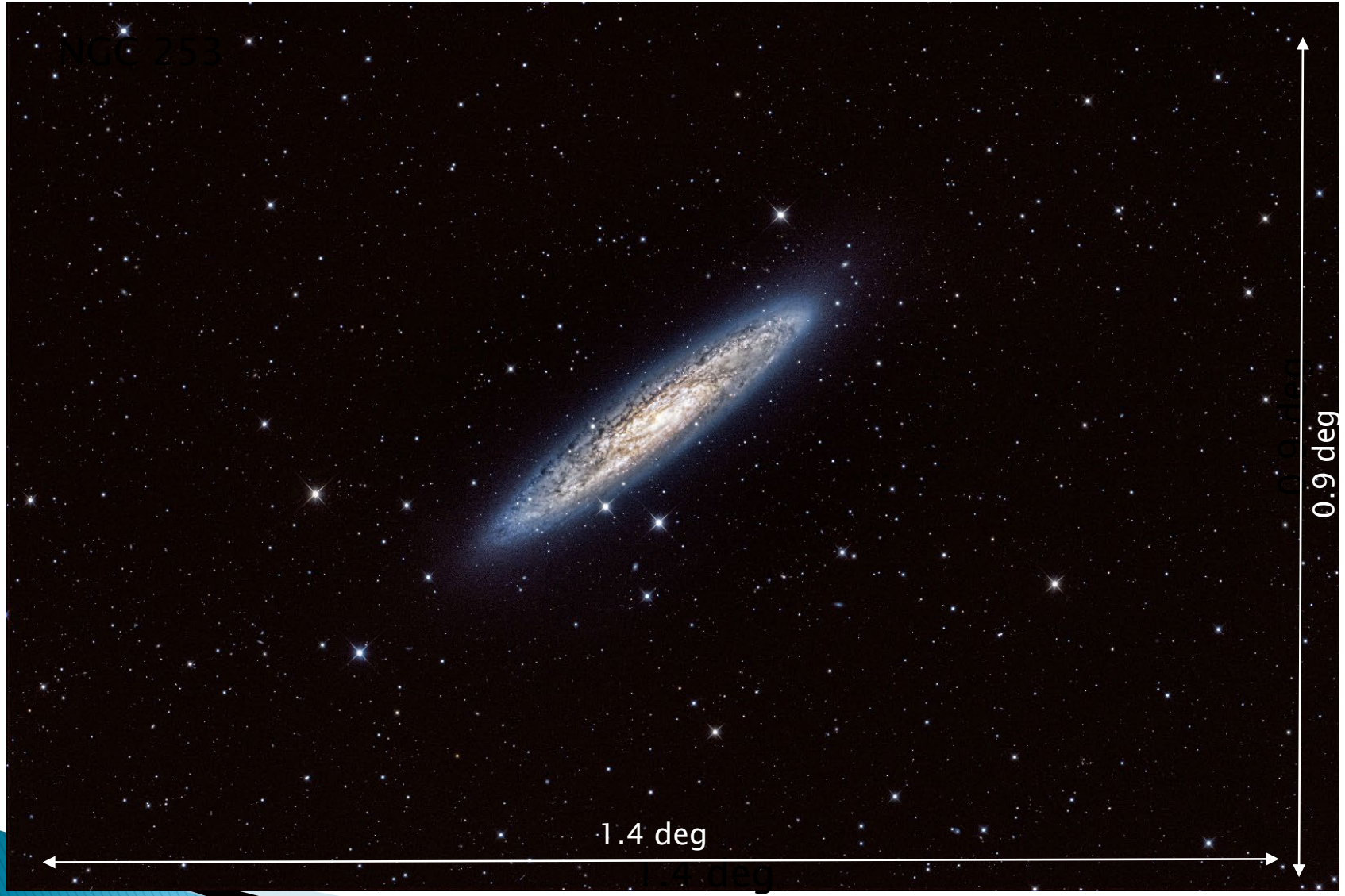
-Spectral classification based on only 371 objects
-Spectra can tell us the composition and surface history of asteroids

Current Status

15 telescopes are in place
Operation started at 2023 October



7DT First light image (2023-10-10)



7DT image of Trifid Nebula (NGC 6514)

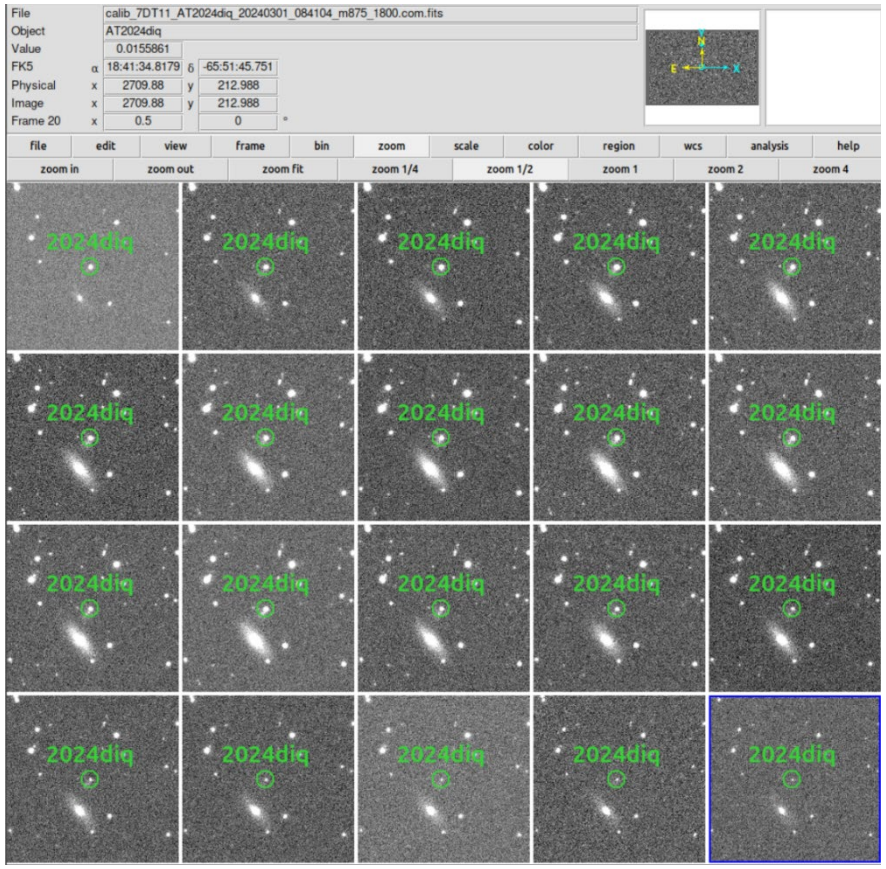


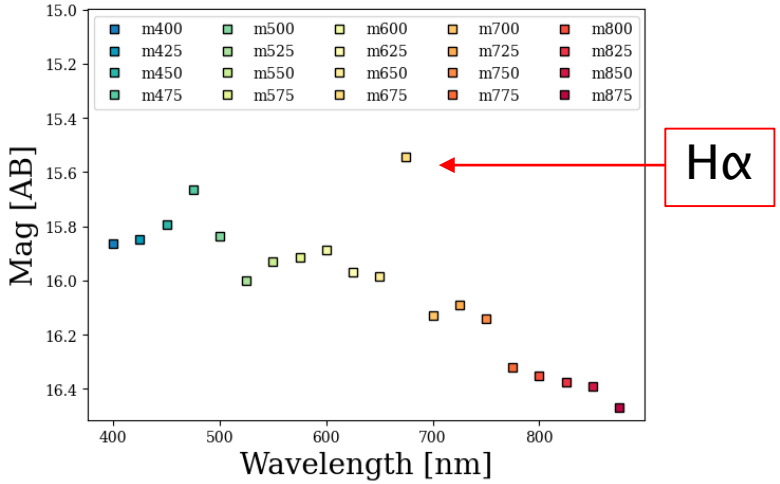
https://sites.google.com/view/7dtfirstimages

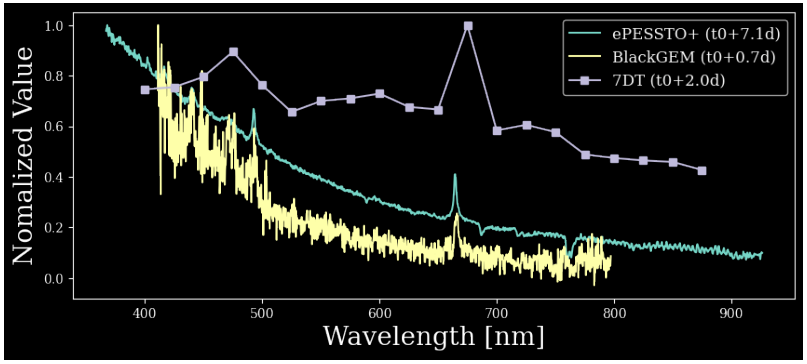
7DT Night Time Operation (2024 December)



SN 2024diq (AT2024ett): SN II in a galaxy at z=0.013

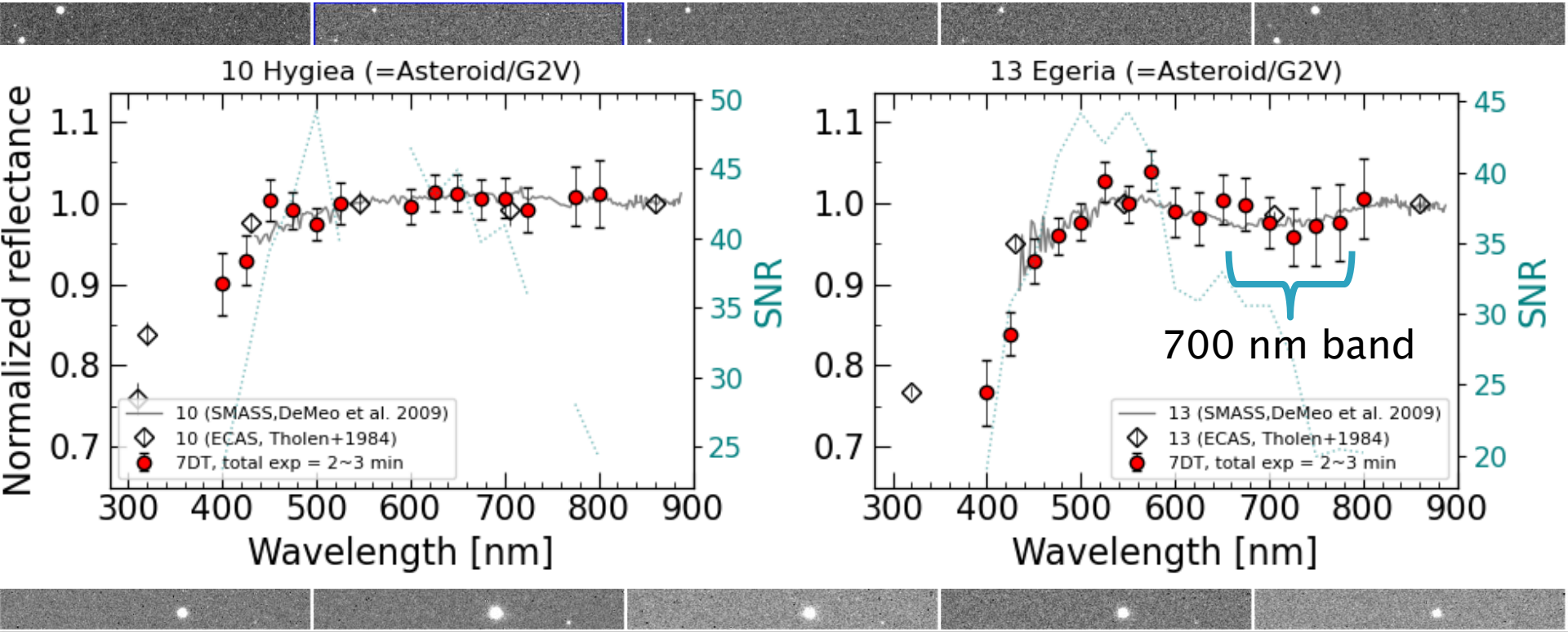






G Paek, H. Choi, et al.

7DT observation of carbonaceous asteroids (Ishiguro M, Kim J., et al.)

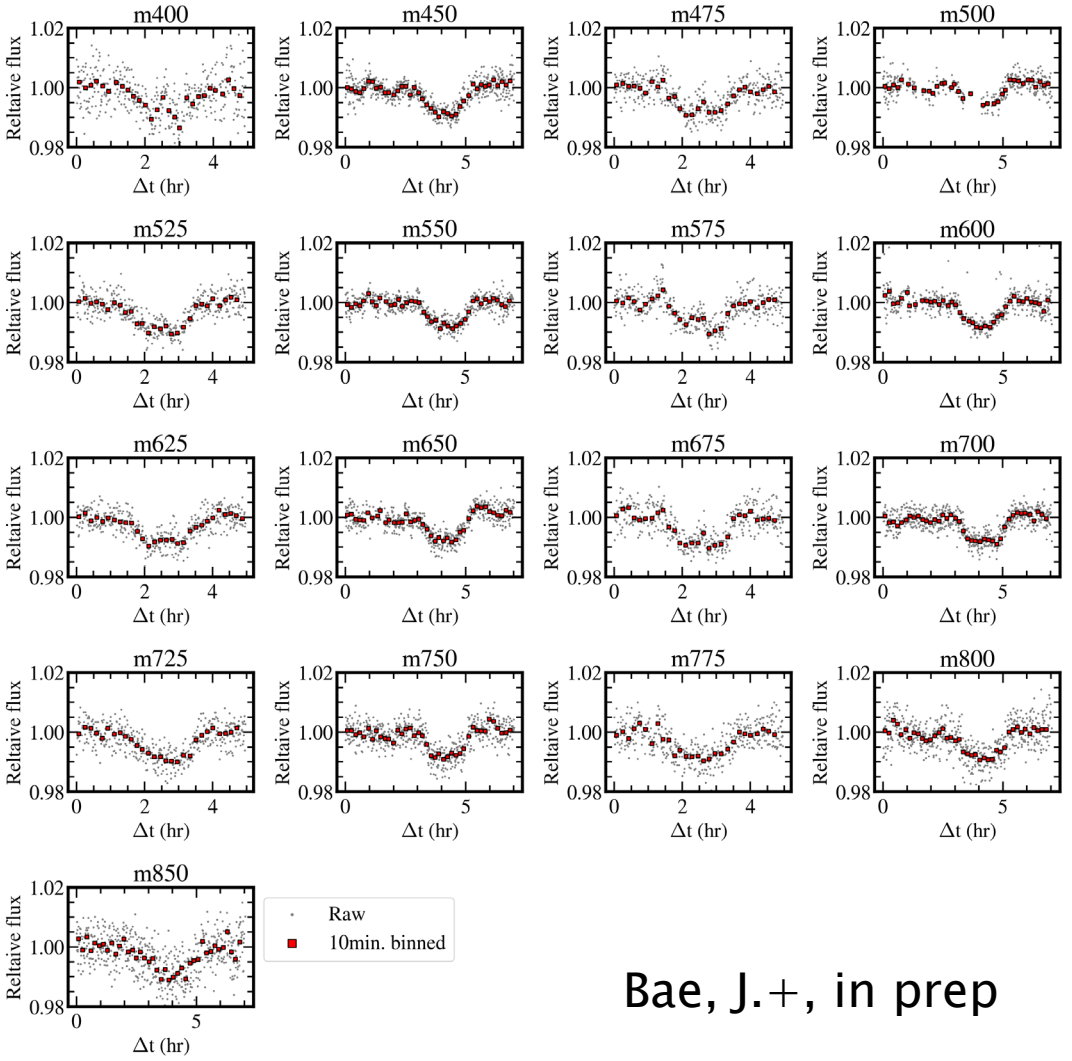


700 nm H_2O feature can be detected

Exoplanet

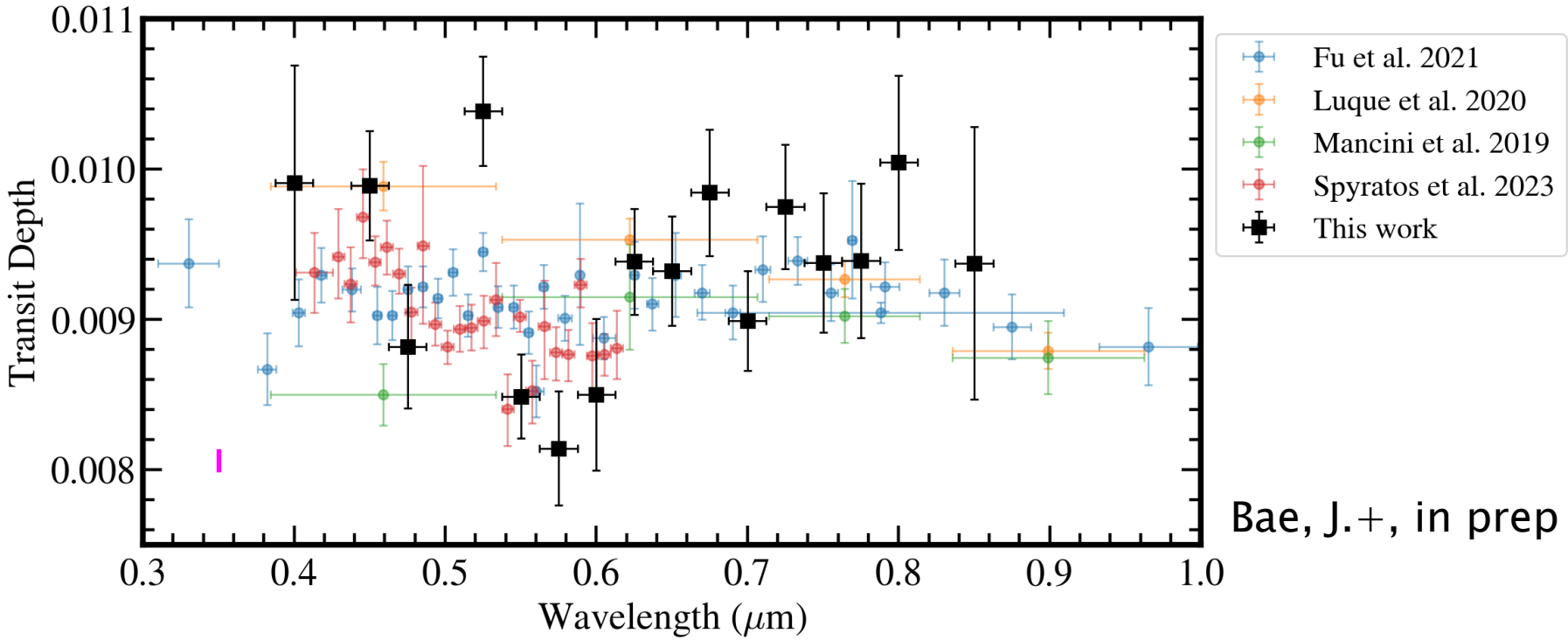
- WASP-74b
- Bloated hot Jupiter around a F9 star
- Transit signal at 0.9%
- Studied by many ground-basd facilities and HST

Transit signals at 400, 450, 475, …, 850 nm



Bae, J.+, in prep

One epoch 7DT observation



Bae, J.+, in prep

- Already provides overall trend of transit spectrum revealed by other studies

7DS

- 7DT: Wide-field, spectral mapper made of 20 telescopes
- 7DS: Time-series spectral mapping of the sky, has just started (~20% RIS completed)
- 7DT is gathering data and we are open for collaboration

https://gwuniverse.snu.ac.kr/
7DS homepage will be open soon