국가과학난제도전융합연구개발사업
National Science Challenge Initiatives
중력파우주연구단

7-Dimensional Sky Survey



Myungshin Im
(Seoul National University)

2024-11-01

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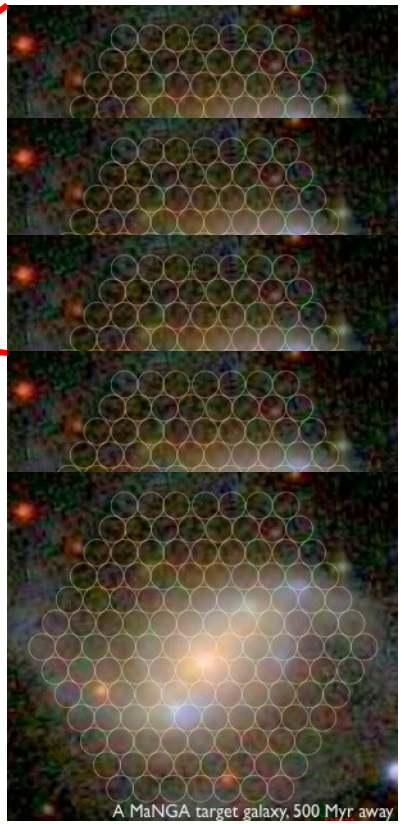
1. Seoul National University, 2. KASI, 3. KNU, 4. EWU, 5. KHU, 6. DNSM, 7. Postech, 8. PNU

7-Dimensional Sky Survey:

Wide area + Spectrum in each pixel + Time-series observation

A New Eye to Explore the Universe in A New Way





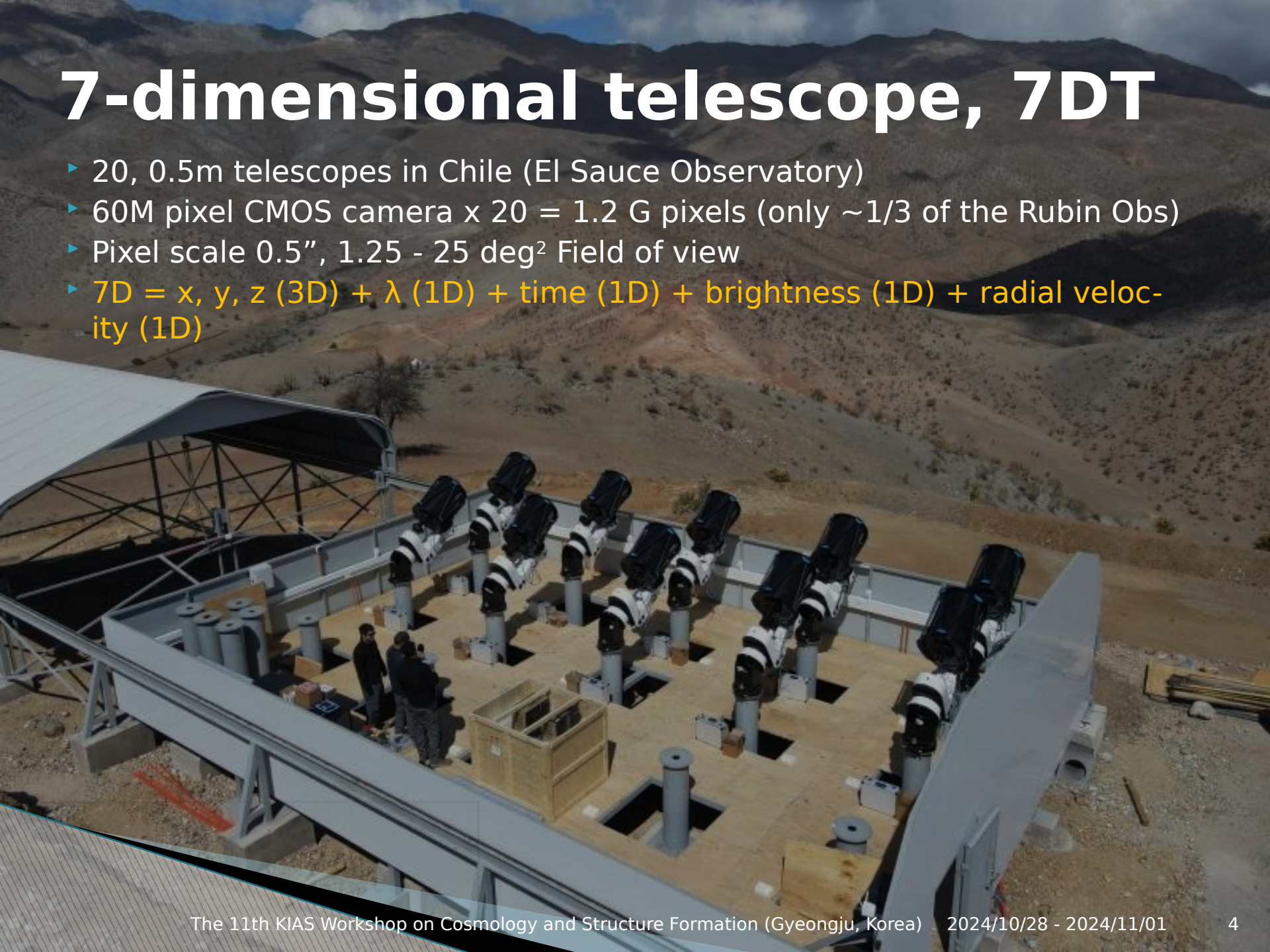
7DS Research Topics

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 + Exoplanets

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

7-dimensional telescope, 7DT

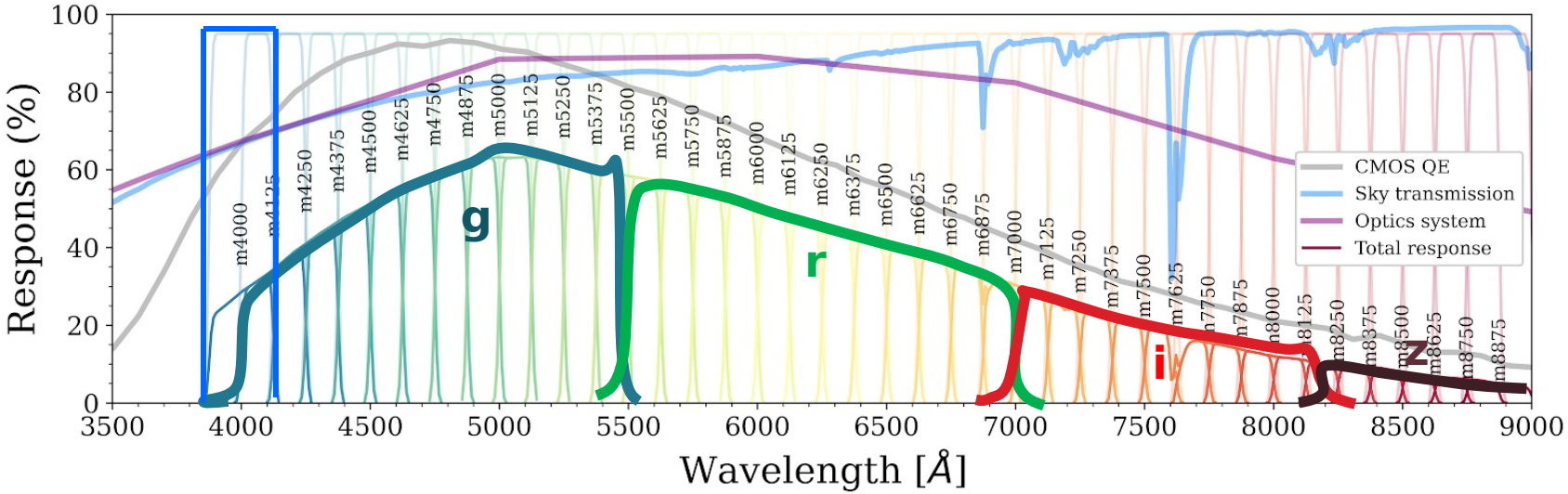
- 20, 0.5m telescopes in Chile (El Sauce Observatory)
- 60M pixel CMOS camera x 20 = 1.2 G pixels (only ~1/3 of the Rubin Obs)
- Pixel scale 0.5”, 1.25 - 25 deg^2 Field of view
- 7D = x, y, z (3D) + λ (1D) + time (1D) + brightness (1D) + radial velocity (1D)



40 Medium-band Filters

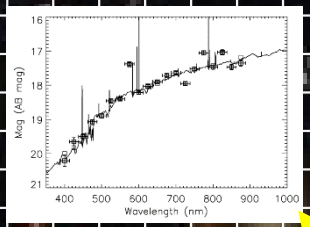
- Width: 25nm (vs broad-band 150nm) at 400 – 900 nm
- Interval: 12.5nm
- R ~ 36 - 70 low resolution spectra Good S/N with small telescopes
- Spectra for every pixel in the field of view (1.25 deg^2)

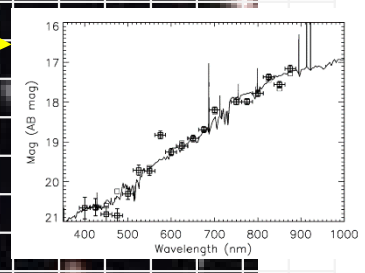
Medium-band vs Broad-band filters

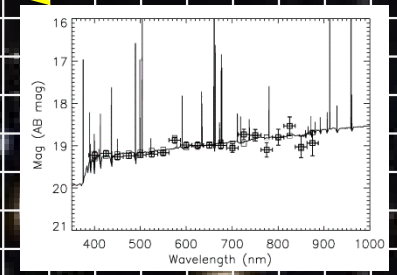


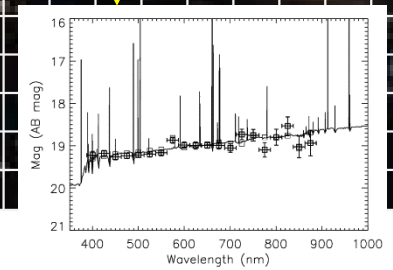

1.3 deg x 0.9 deg
JWST
7DT field of view
~ Six full moons
~ 1000x JWST NIRCAM

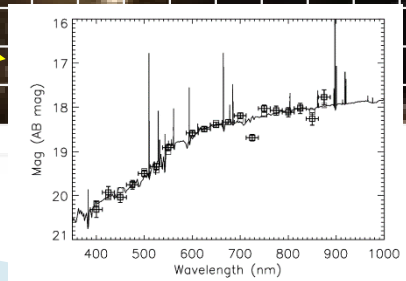
60M spectra in one shot, 60M spectral movie/field











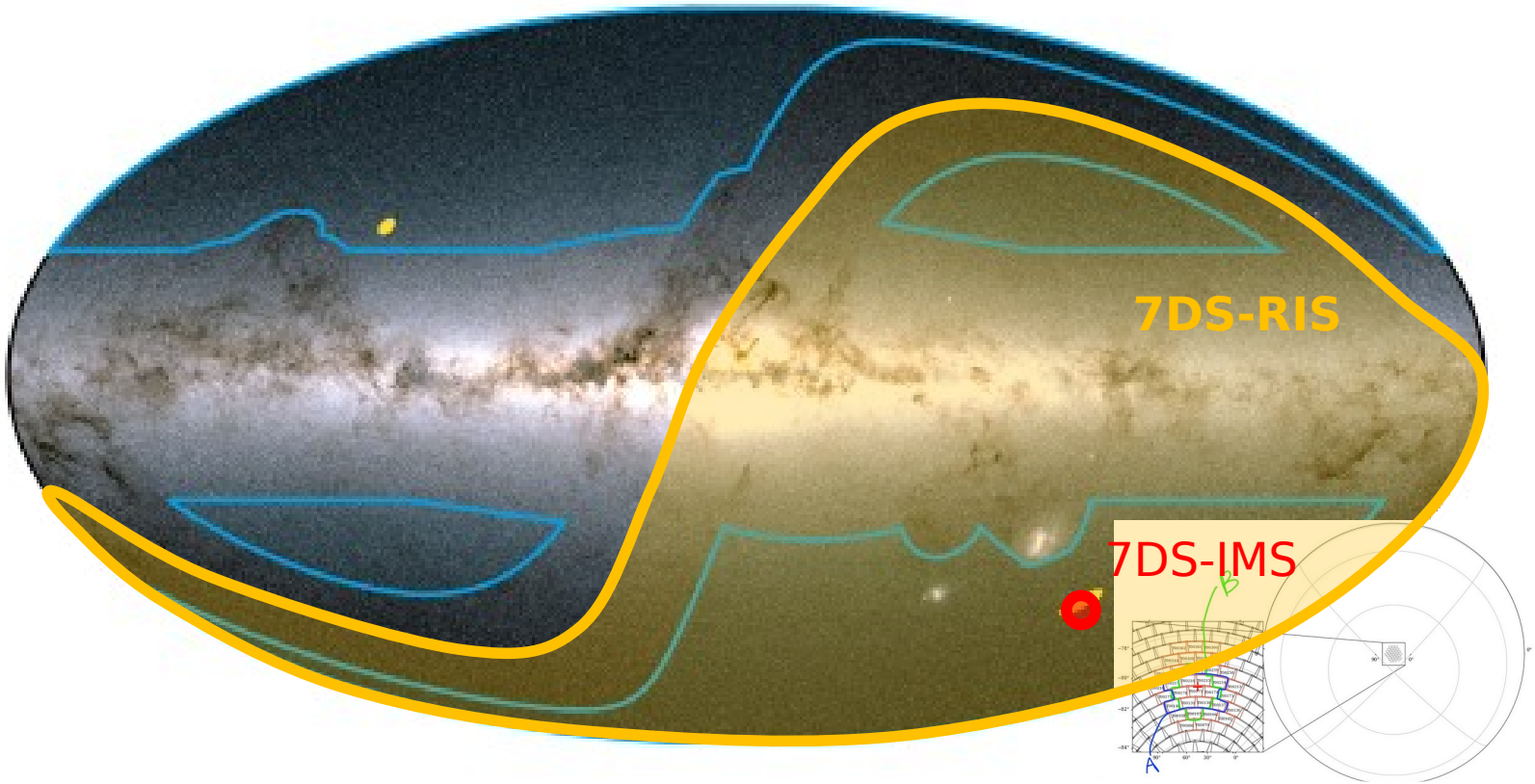
7-Dimensional Sky Survey, 7DS
>5 years, three surveys -

	Survey area (deg^2)	Ca-dence	Depth (1-epoch 5-σ, 475nm	depth (5 years)	Exposure time per epoch/fil-ter
Reference Imaging Sur-vey (RIS)	20,000 (SDSS, 15,000)	-	20.7 mag	-	5min
Wide-Field Survey (WFS)	1,000	14 days	20.7 mag	23.2 mag	5min
Intensive Moni-toring Survey (IMS)	10	1 day	20.7 mag	24.7 mag	5min

+ Target-of-Opportunity Observation for Transients

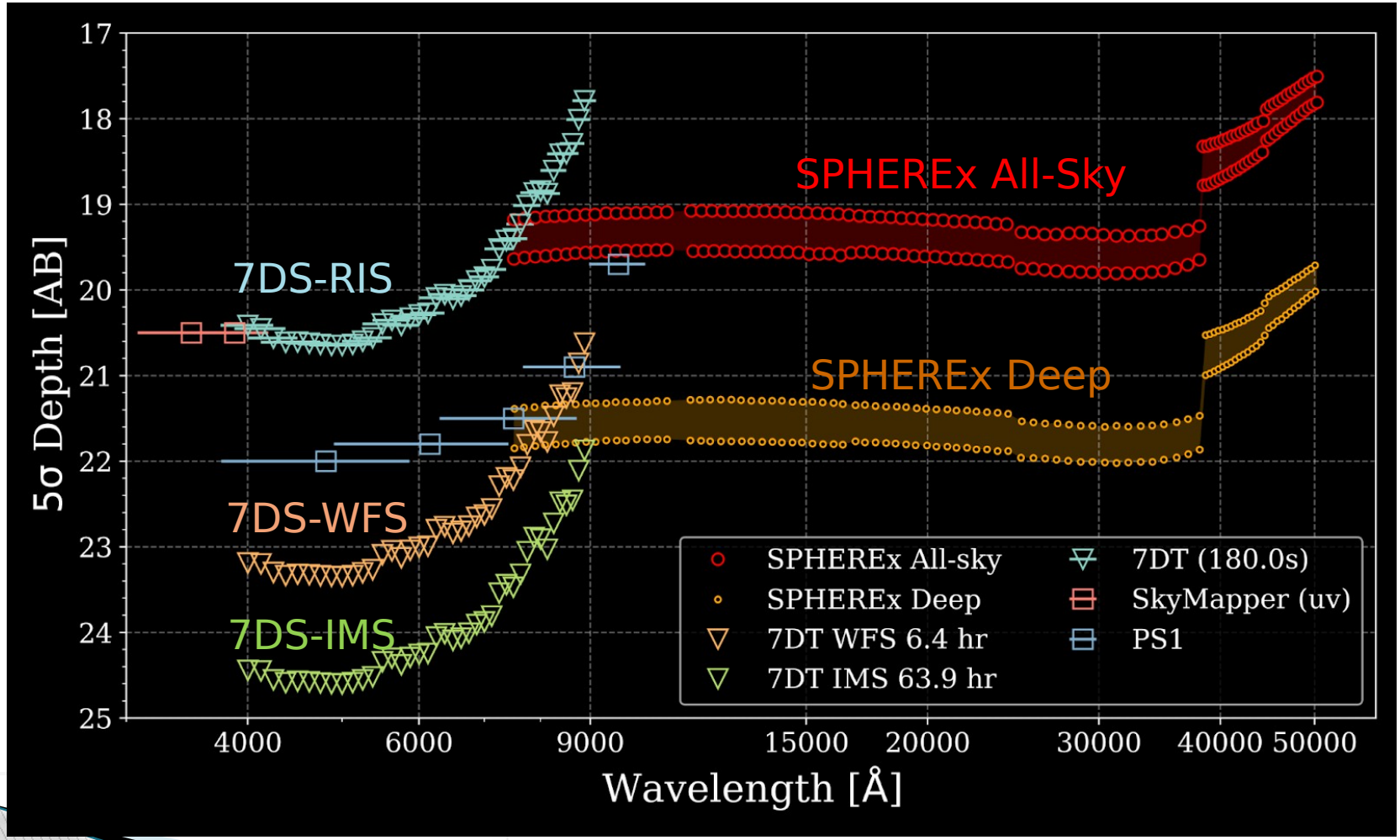
Assumption: 1.5” seeing, 70% efficiency

7-Dimensional Sky Survey (7DS)



7DS-RIS: Entire southern hemisphere
7DS-WFS: TBD (some in the equatorial field, LSST Deep Drilling Fields, area around the SPHEREx deep field, etc)
7DS-IMS: Overlap with Euclid-deep, SPHEREx deep fields

7DS detection limits



GW170817: NS-NS merger Multi-Messenger Astronomy

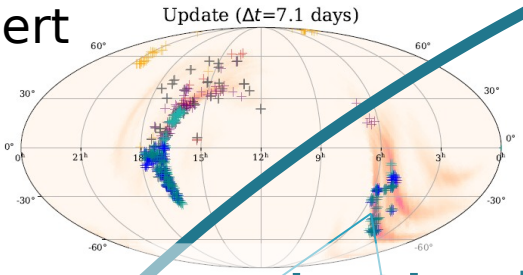
- **2017-08-17 GW event marked the start of MMA using GW and EMW signals**
- 3700 (39@Korea, 45 countries, 900+ institutions, 80 facilities), 59 page ApJL paper

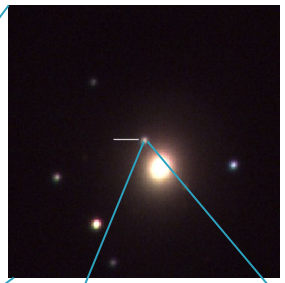


The only GW event with EM counterpart ID so far

Search for KN

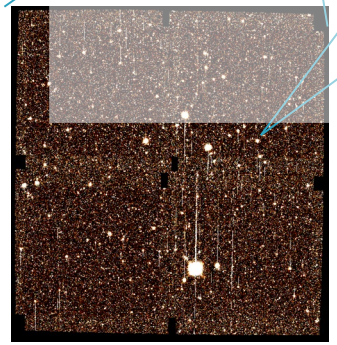
GW Alert



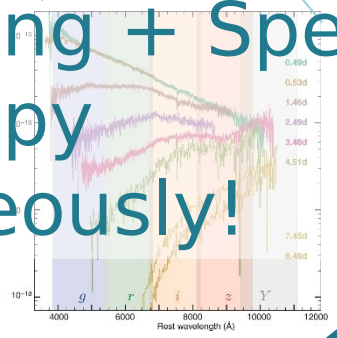


Transient search

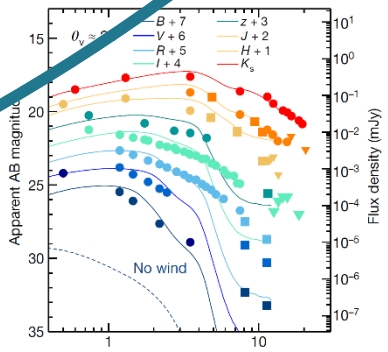
Let’s do Imaging + Spec-troscopy Simultaneously!



Imaging Observations
(~a few 100,000 sources per field)



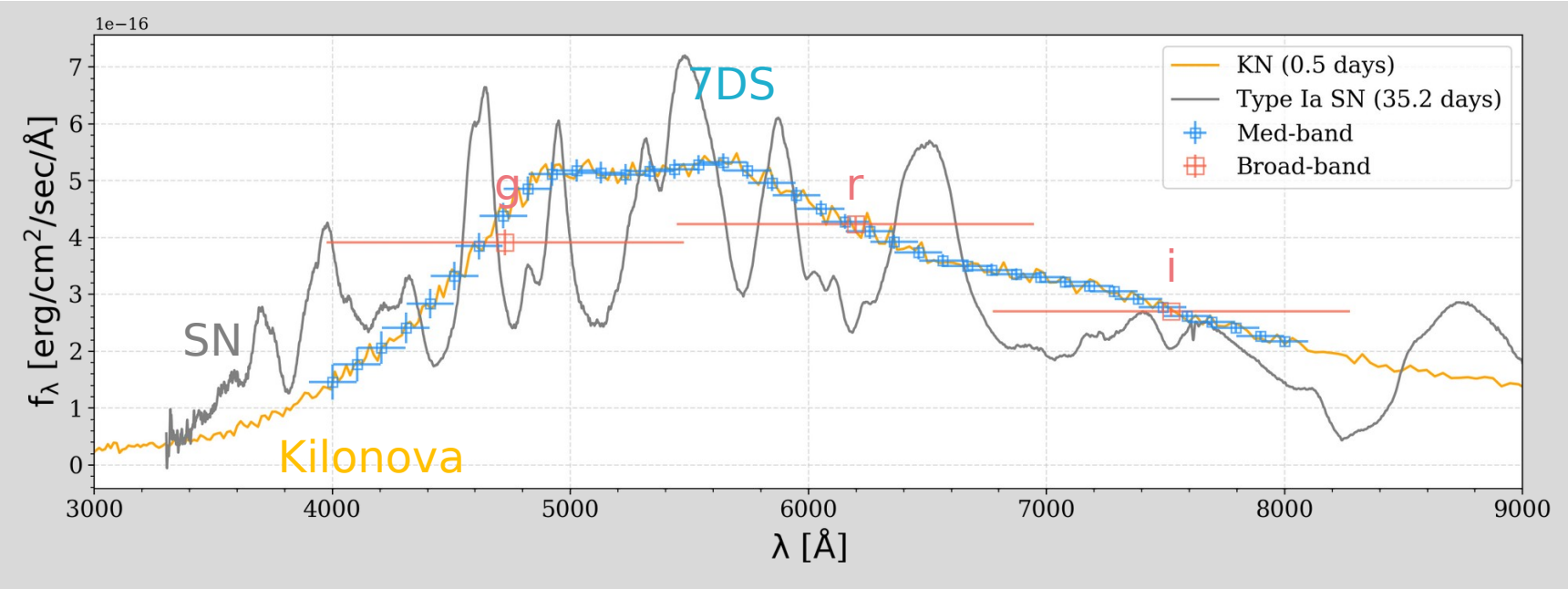
Spectroscopy and KN identification



Time series follow-up

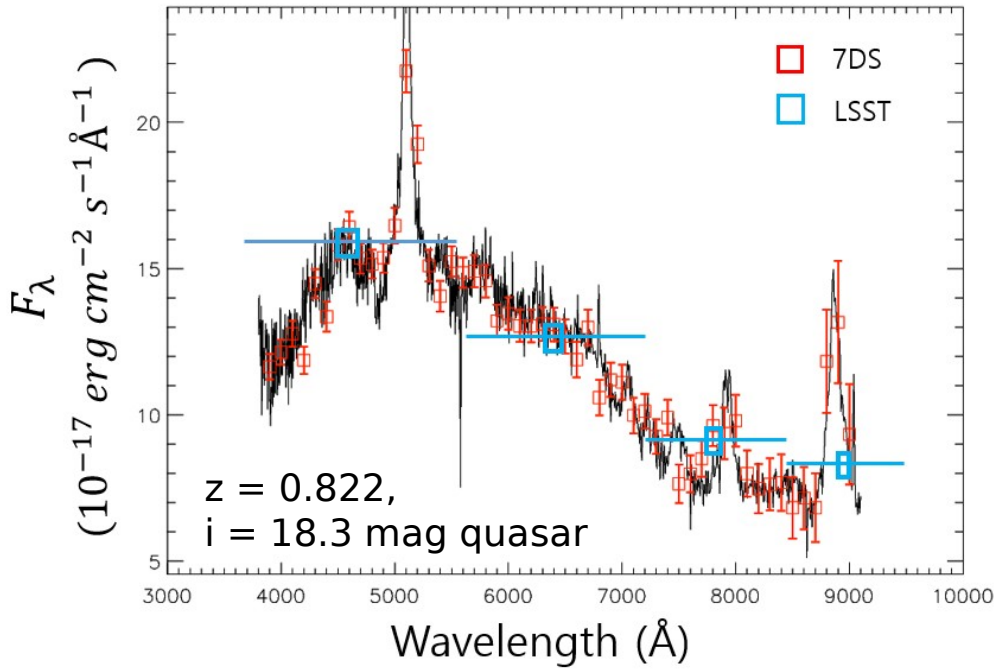
Multi-messenger Astronomy with 7DT

- R ~ 40 spectroscopy for the entire field of view
- Best suited for sampling broad continuum features and broad emission lines continuum good for KN spectral id in one shot



7DT can trace line and continuum variability of AGNs separately

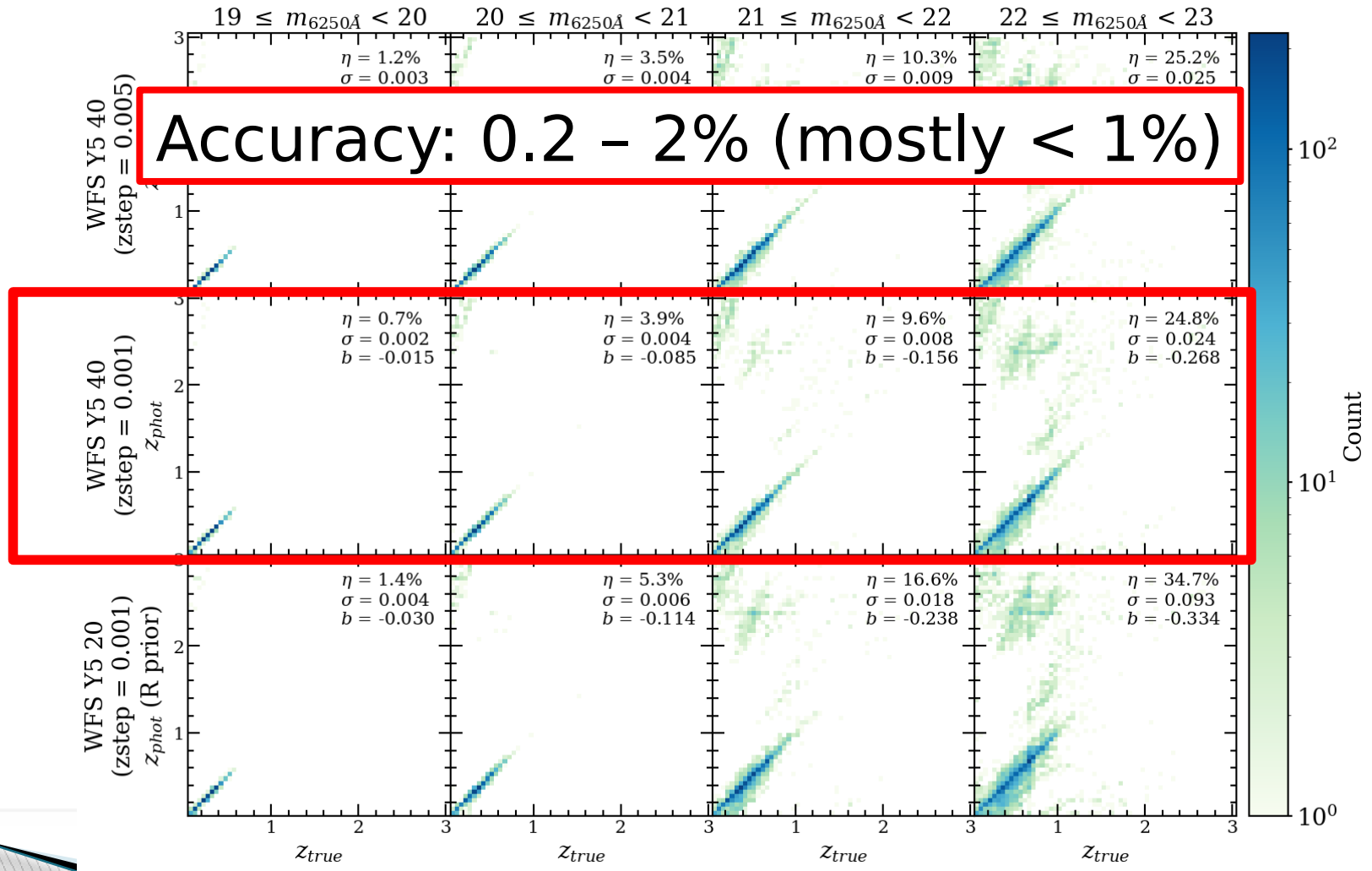
- 7DT can sample emission lines (BEL) and continuum separately
- AGN variability time lag between BEL and continuum (reverbera-tion mapping) direct measures of BH masses



Reveberation mapping
- 7DS: >3,000 AGNs vs 100s now

Spectral Evoluiton
- 7DS: 30,000 AGNs

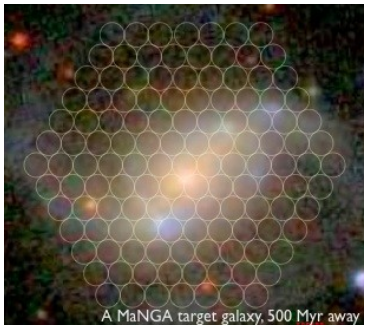
7DS redshift accuracy: Eunhee Ko, Jangho Bae, Donghwan Hyun

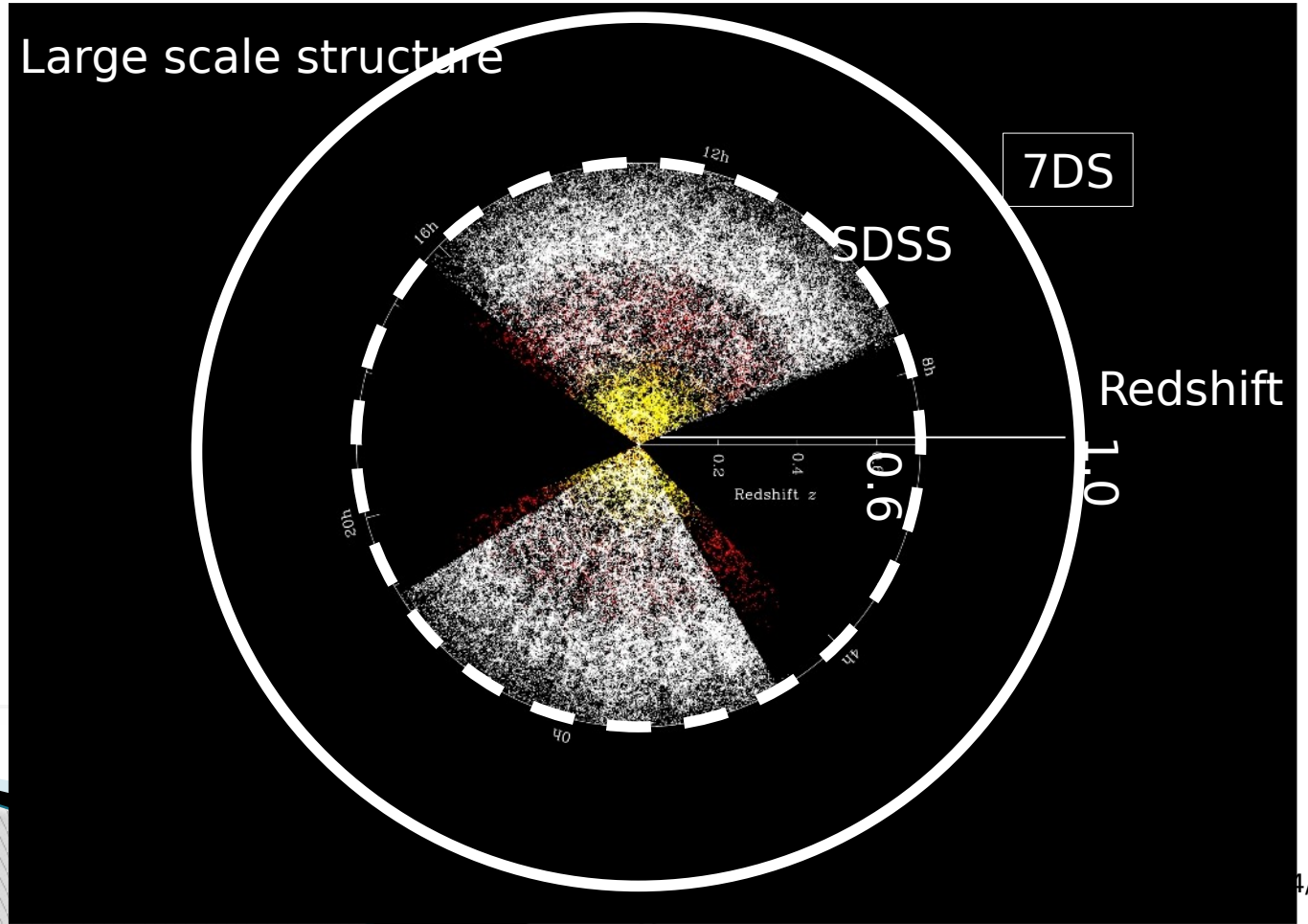


Accuracy: 0.2 – 2% (mostly < 1%)

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

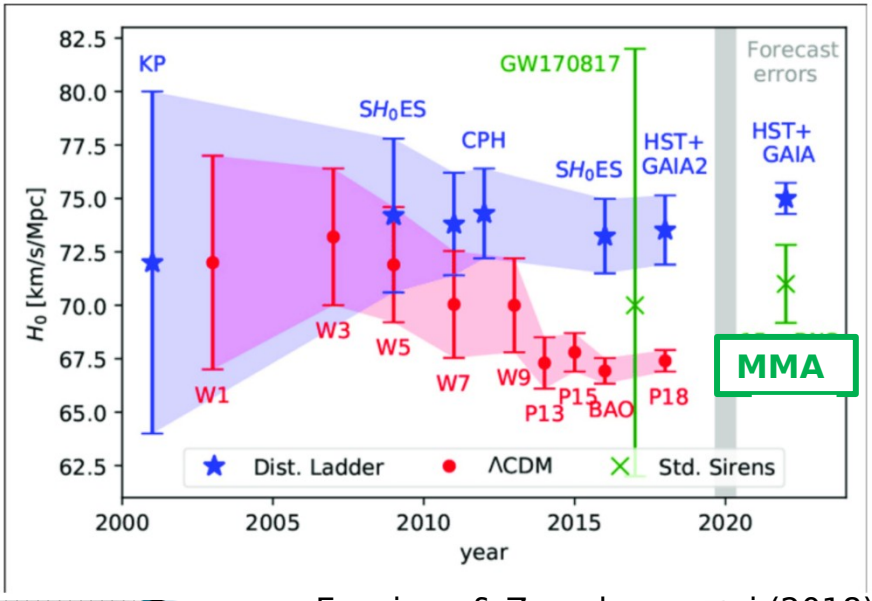




Cosmology

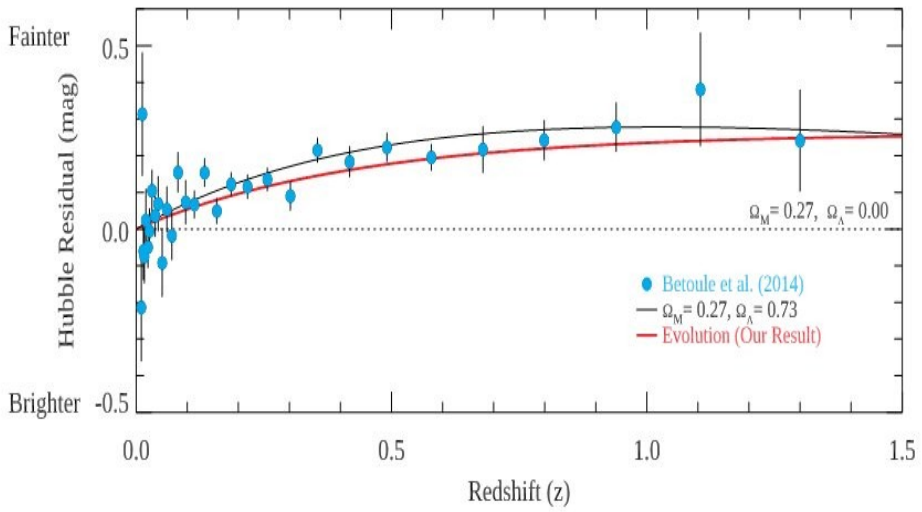
- Quasars: T-L relation, UV vs X-ray luminosity
- GW sources: Standard Siren
- Galaxy clusters, BAO

Hubble Tension



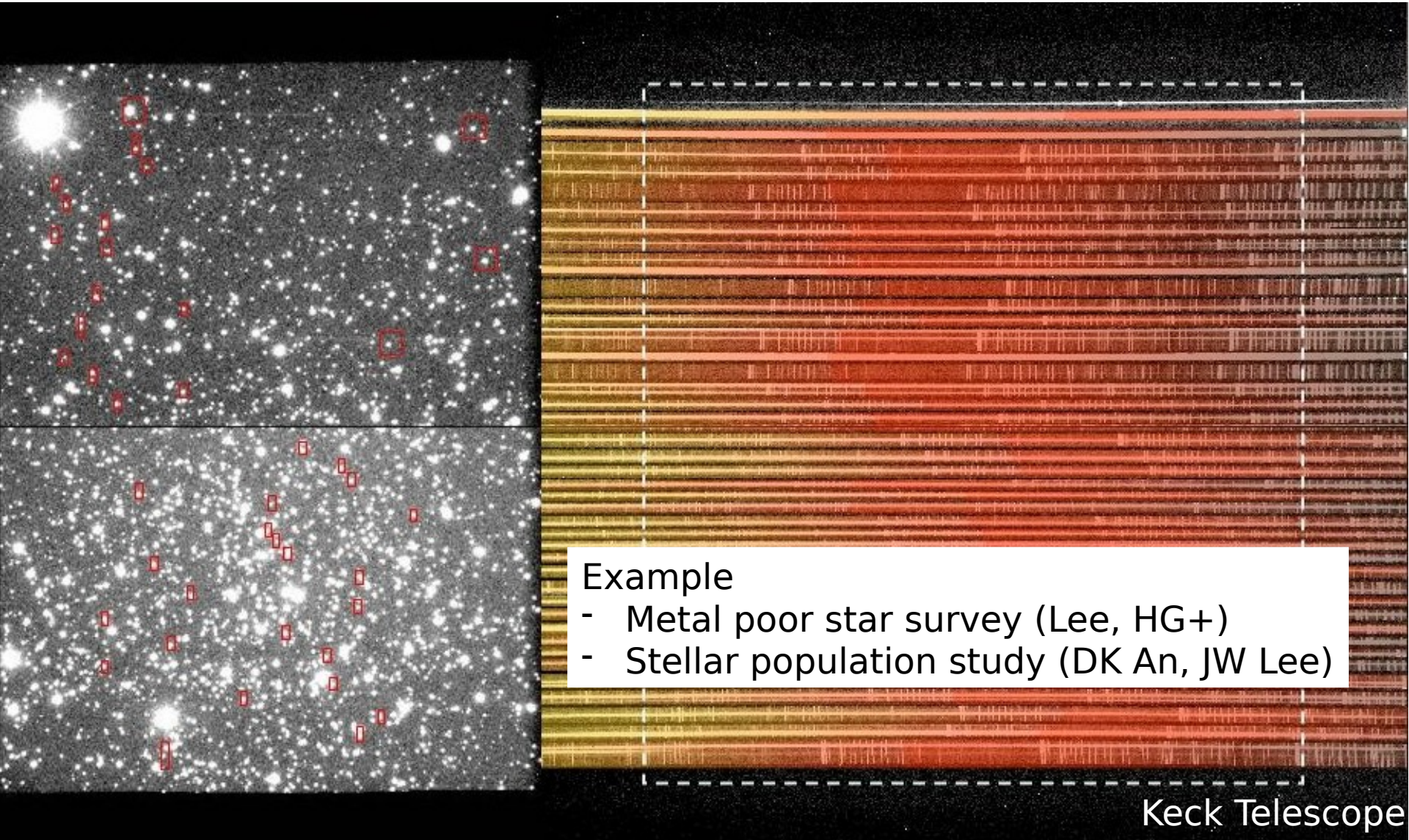
Ezquiaga & Zumalacarregui (2018)

Dark energy controversy

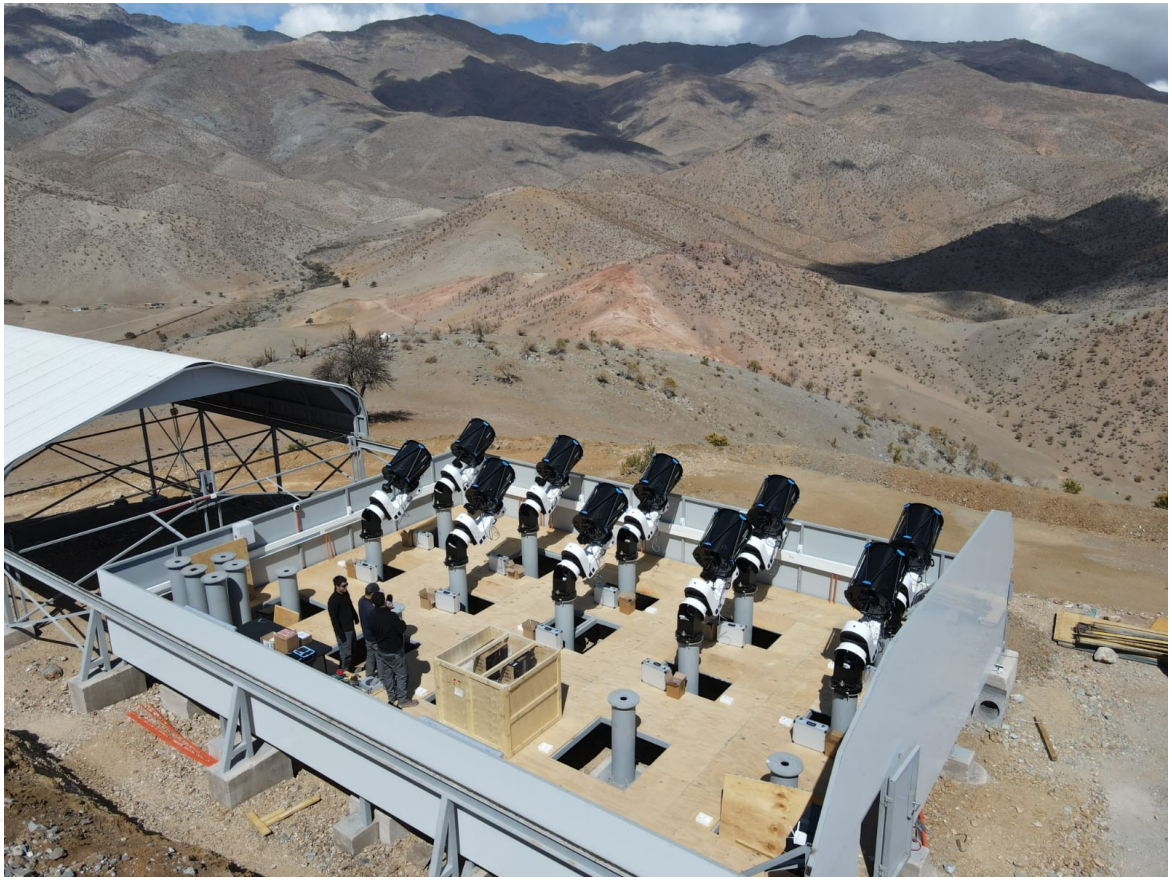


Kang, Lee, YW, et al. (2019)

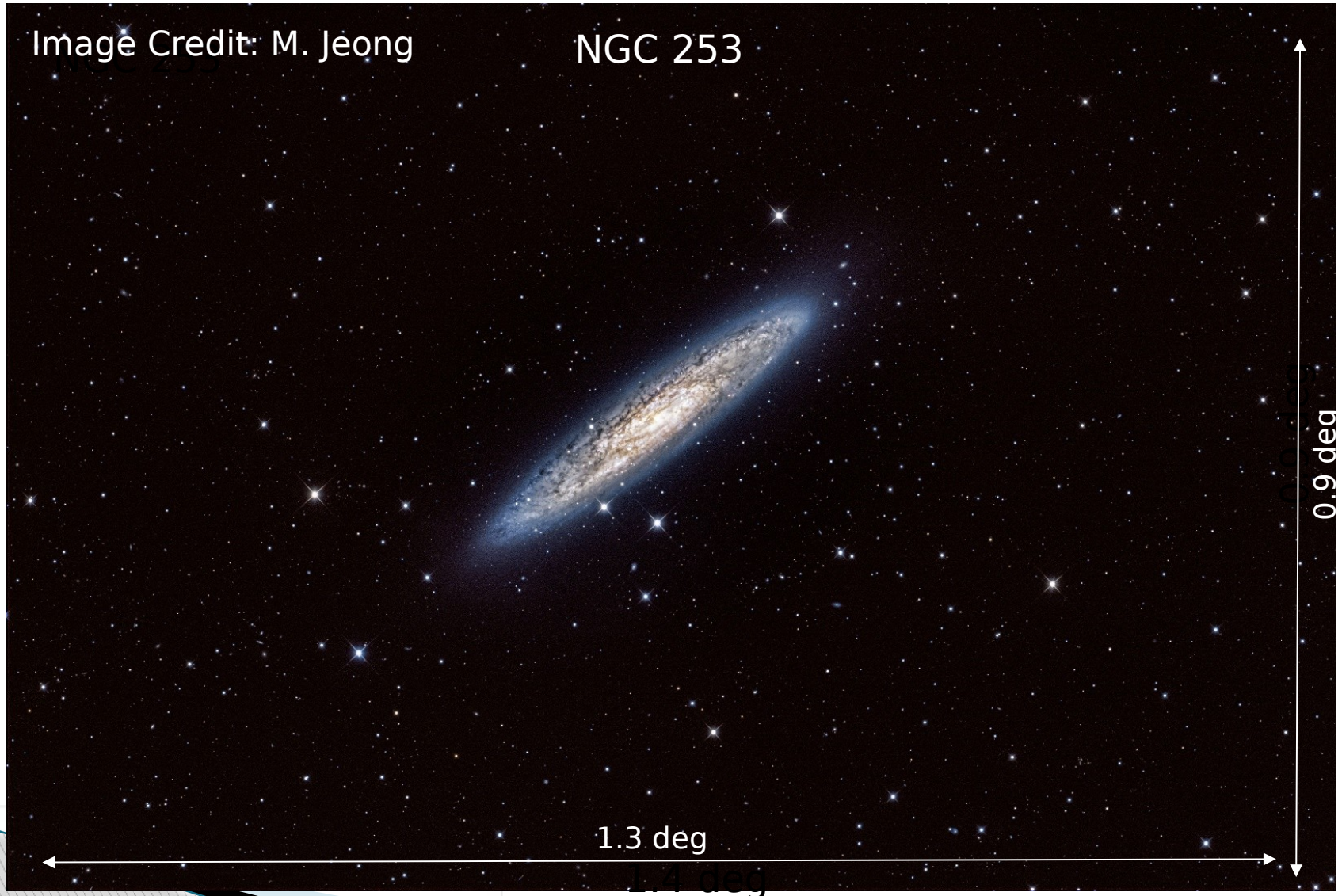
~10^9 Stellar spectra for stellar population study



Current Status
- 15 telescopes are installed
- Commissioning observation, started (2023-10)
- 7-Dimensional Sky Survey, started (2024-06)



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



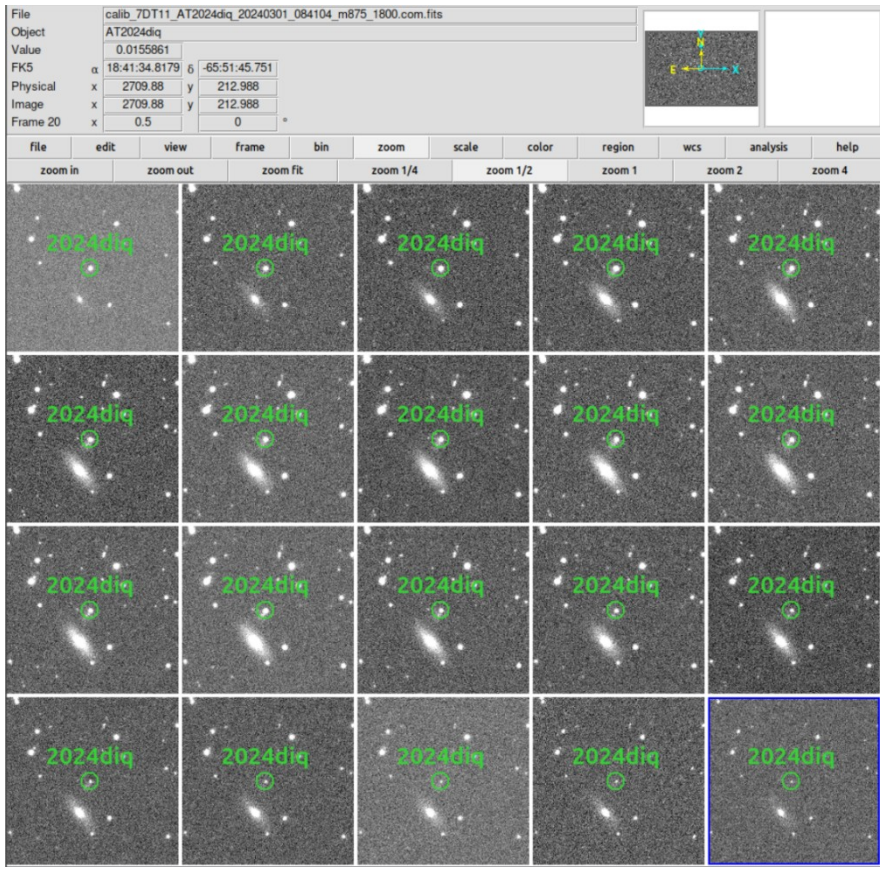
7DT View of Helix Nebula

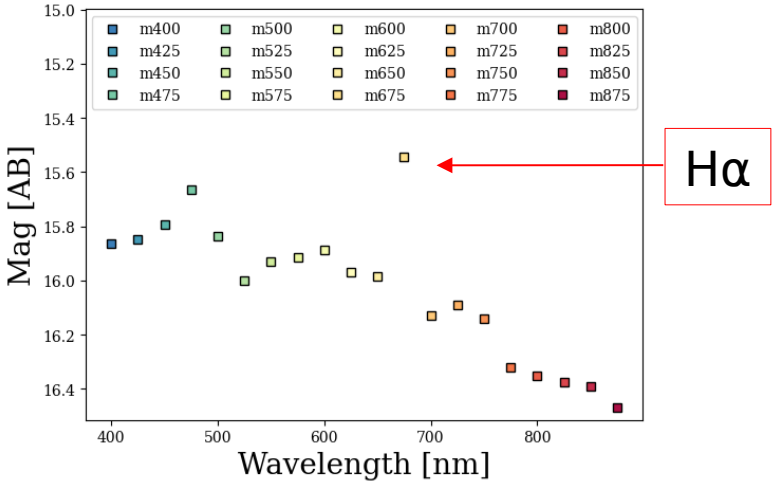


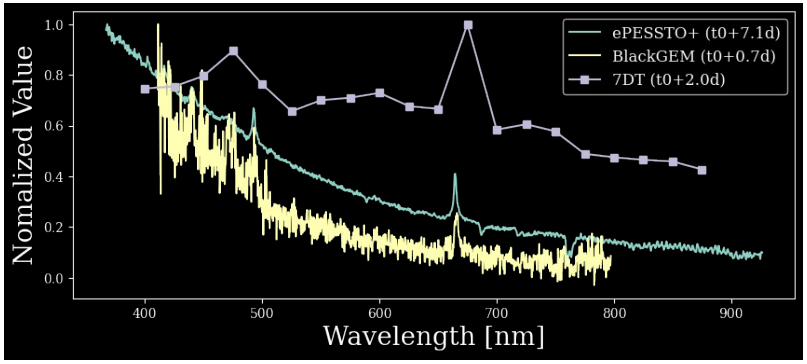
Science verification targets

- Nearby galaxies (PHANGS sample+, JH Kim, H Shim+)
- Deep imaging of UDS, and COSMOS fields (J Sohn, M Im+)
- Galaxy clusters (H Hwang, M Im+)
- AGN (M Kim, J Woo, DH Kim, M Im+)
- Asteroids/comets (M Ishiguro+)
- Stellar clusters (DK An, JW Lee+)
- Young stellar objects/Orion nebula (JE Lee+)
- Transients (SNe, GRBs, etc)

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

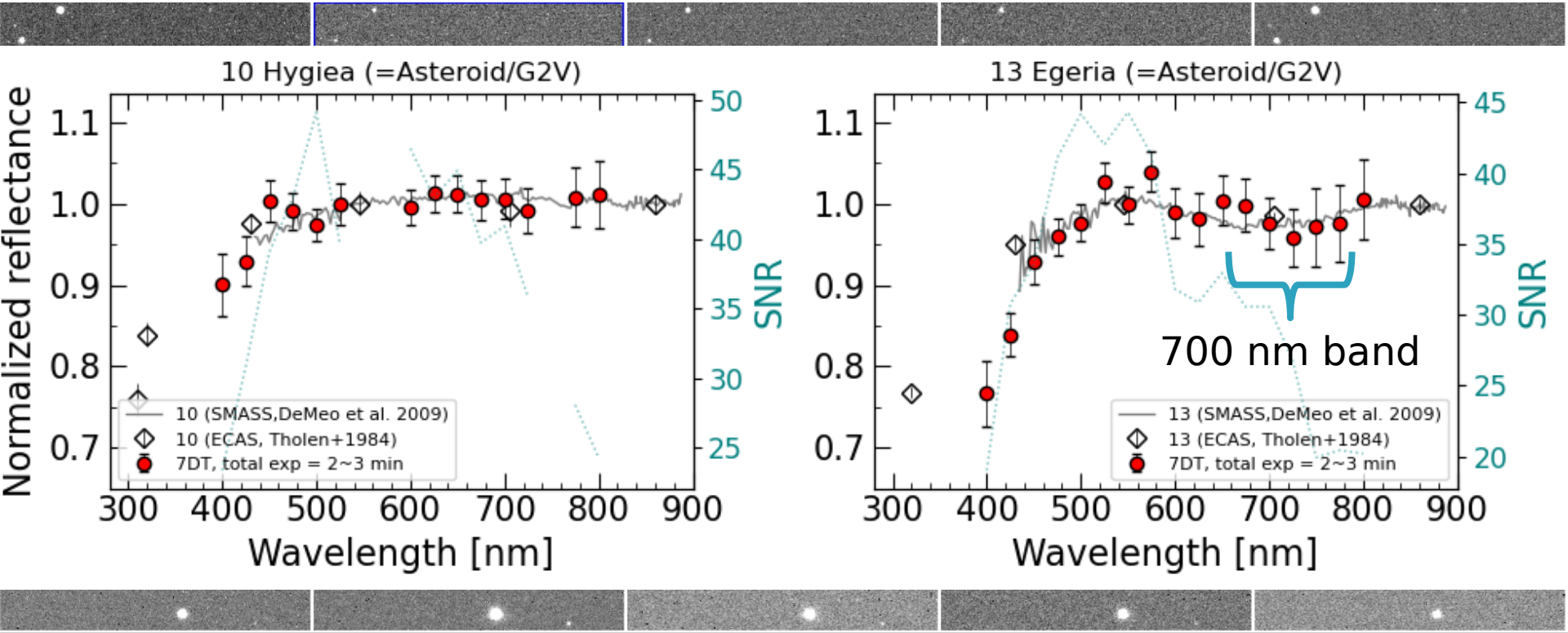






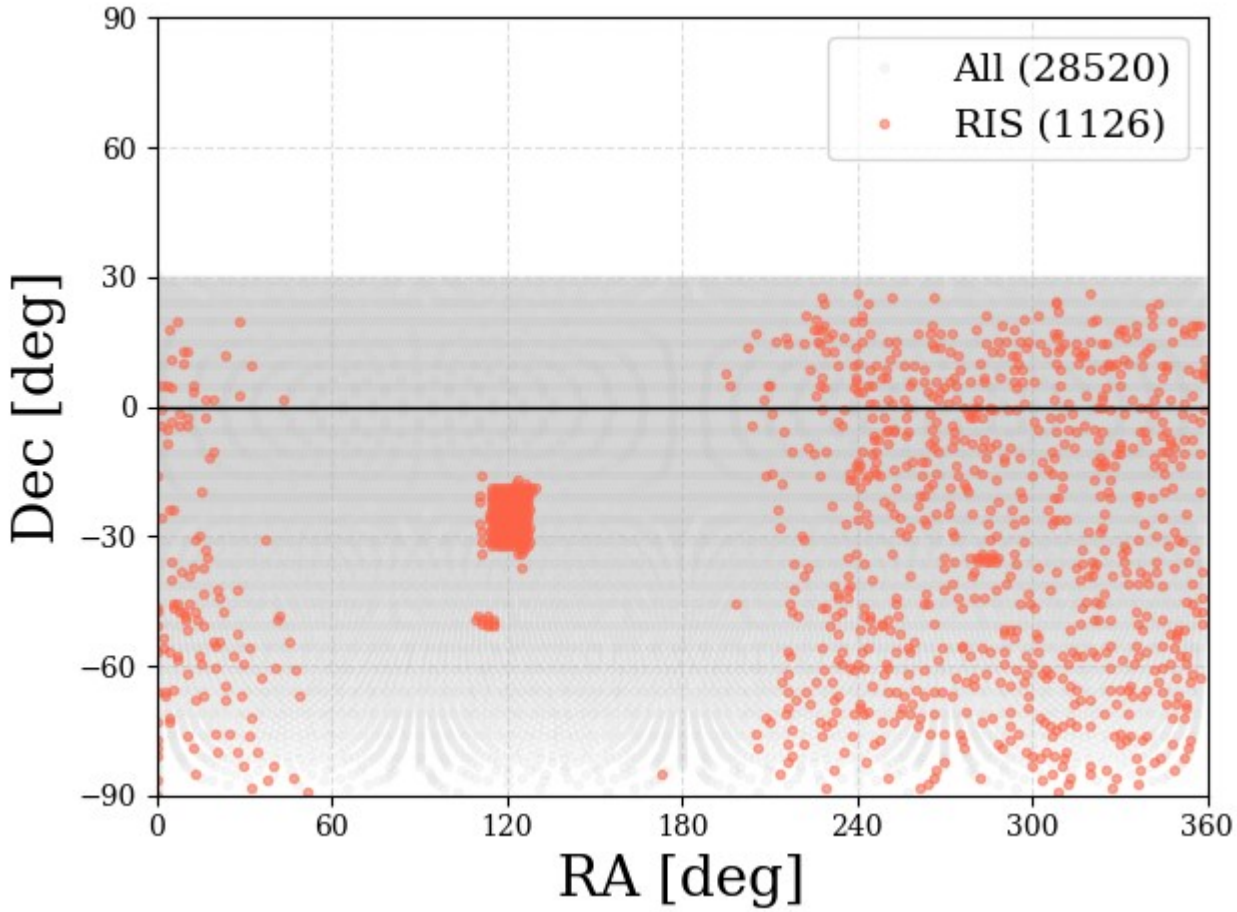
G Paek, H. Choi, et al.

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



700 nm H_2O feature can be detected

7DS Reference Imaging Survey is ongoing (> ~10%)



7DS

- 7DS: Time-series, spectral mapping survey of the southern sky
- 7DT: multiple telescope system with 20 wide-field, 0.5m telescopes
- 7DS is ongoing, and we welcome collaborations

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