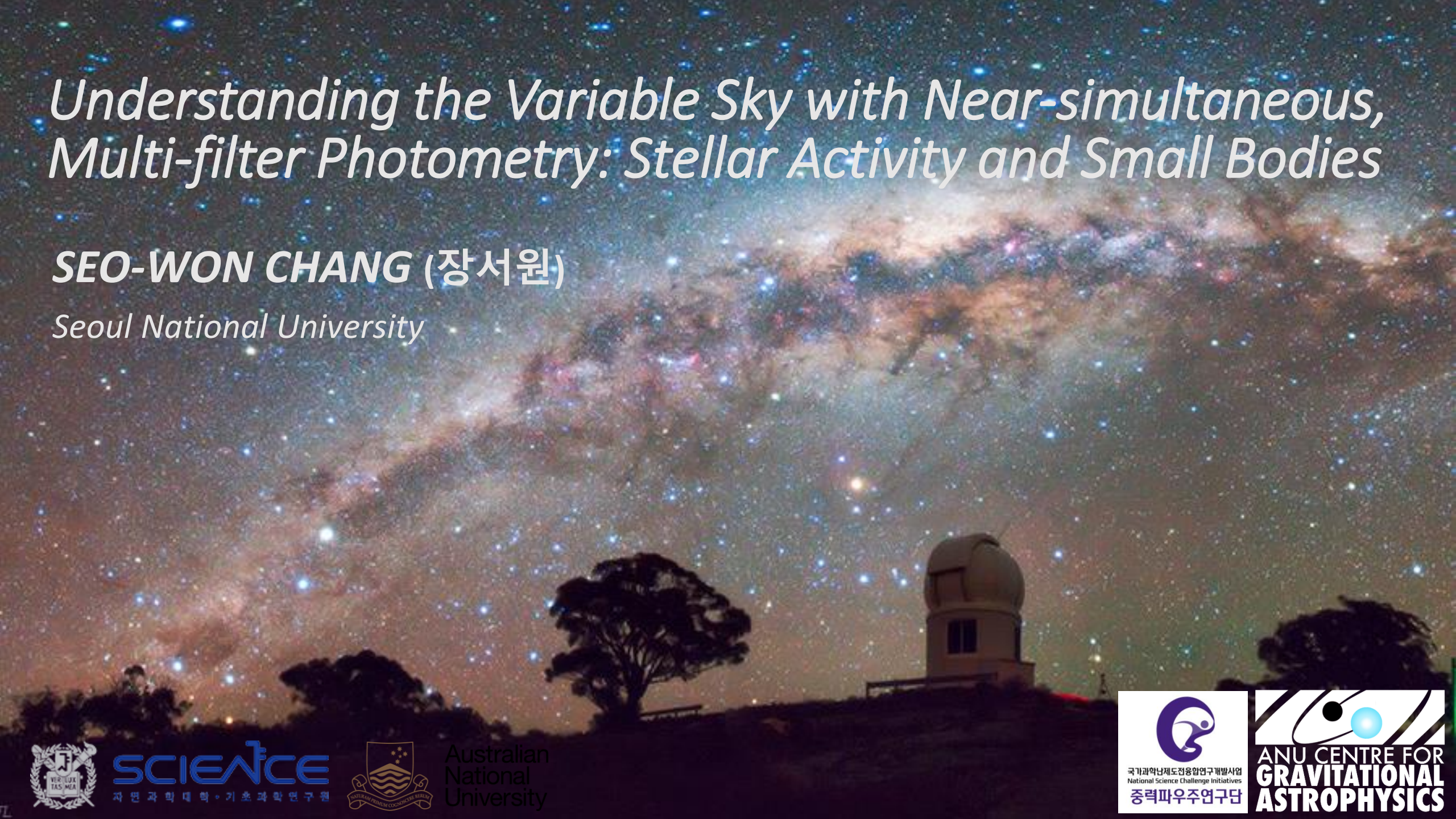

Understanding the Variable Sky with Near-simultaneous, Multi-filter Photometry: Stellar Activity and Small Bodies

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ANU CENTRE FOR GRAVITATIONAL ASTROPHYSICS

What I'm going to tell you

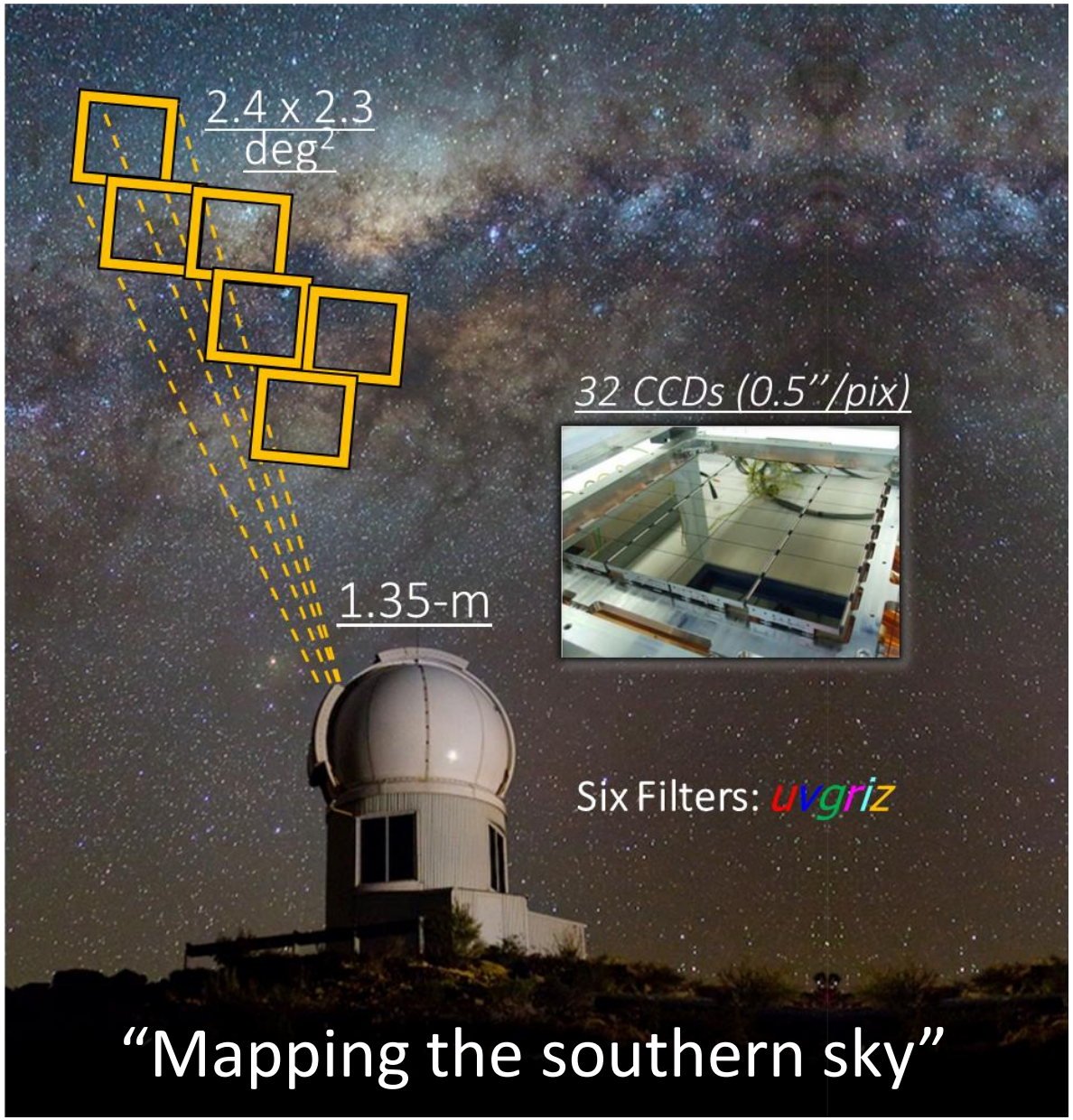
- SkyMapper Southern Sky Survey: **Near-simultaneous, Multi-filter Photometry**

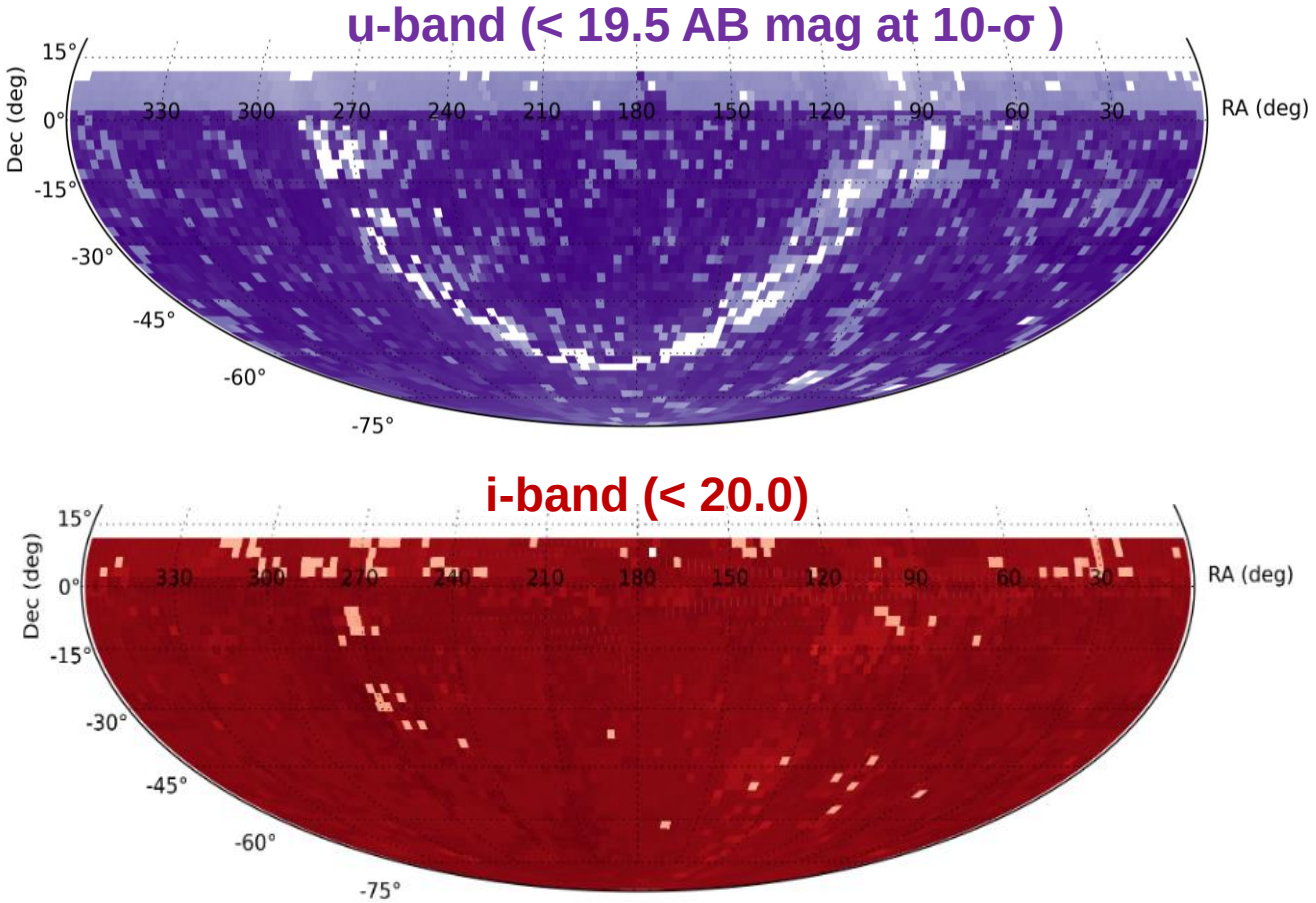
- Time-Domain Science: **Stellar Activity** and **Small Bodies**
  Part of this talk represents results from Chang+ 2020 (arXiv: 1910.06478) and Sergeyev+ 2021 (arXiv: 2110.11656)

- Recommendation for 7DT Galactic Time-Domain Science

DISCUSS MORE POSSIBLE SCIENCE CASES AND ENGAGE DOMESTIC SCIENCE TEAMS FOR FEEDBACK, NOT JUST INTERNAL CORE COLLABORATION

Intro: SkyMapper Southern Sky Survey

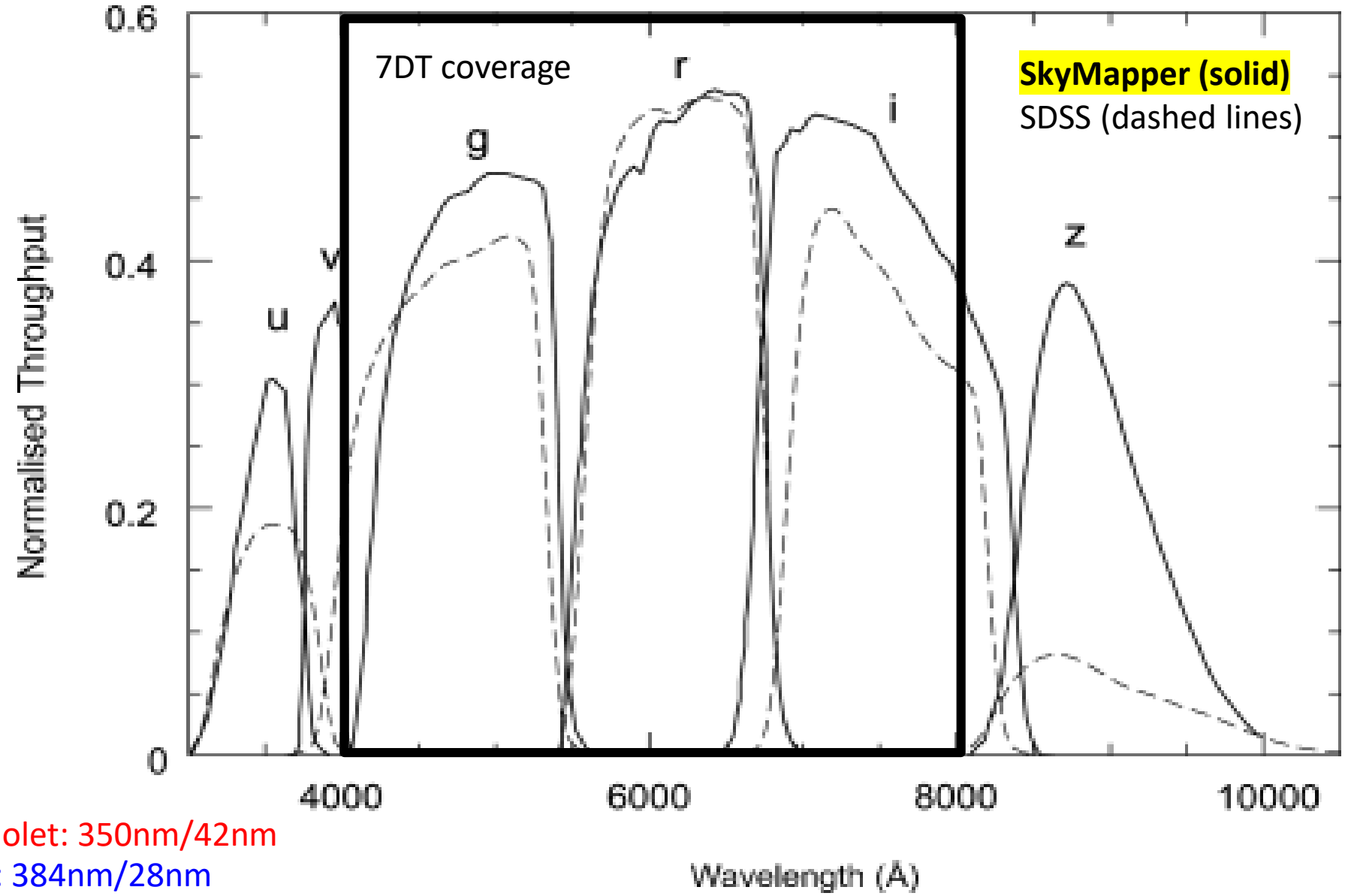




DR3 Historic data
(March 2014 to October 2019)

https://skymapper.anu.edu.au/

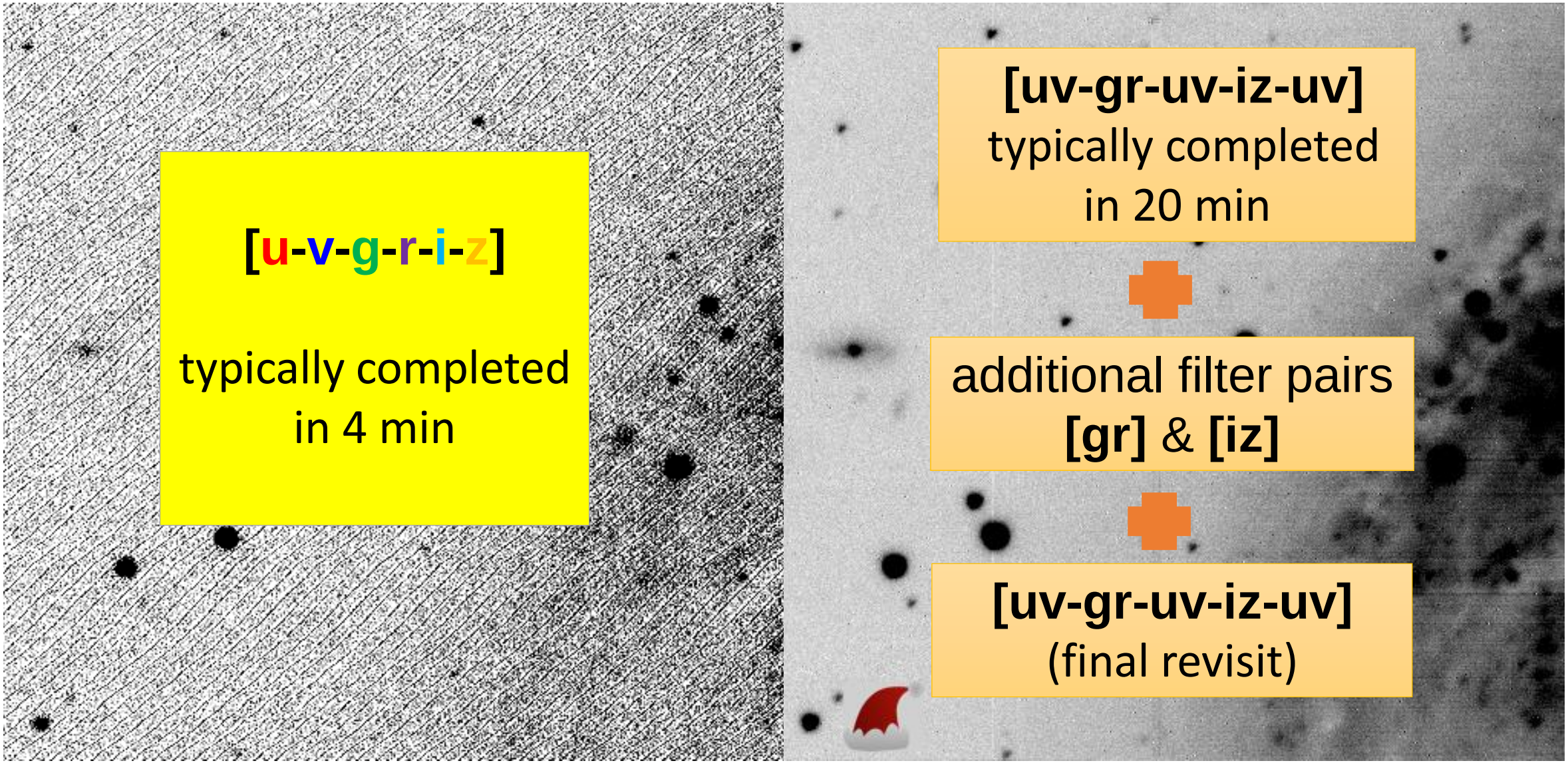
Broadband Filters: *uvgriz*



Sensitive to stellar atmospheric parameters ~ (T_{eff}, log g and [Fe/H])

Ultraviolet: 350nm/42nm
Violet: 384nm/28nm

Near-simultaneous, Multi-filter Photometry Data



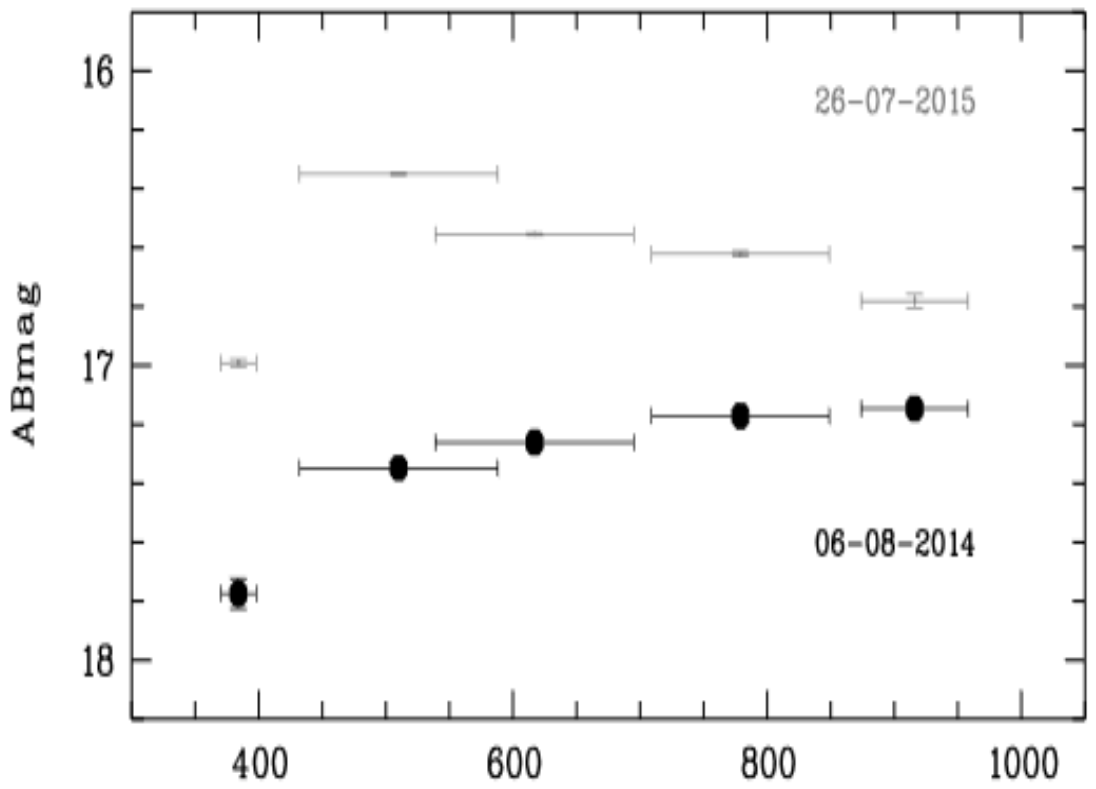
Shallow Survey (9 to 18 mag in all six bands)

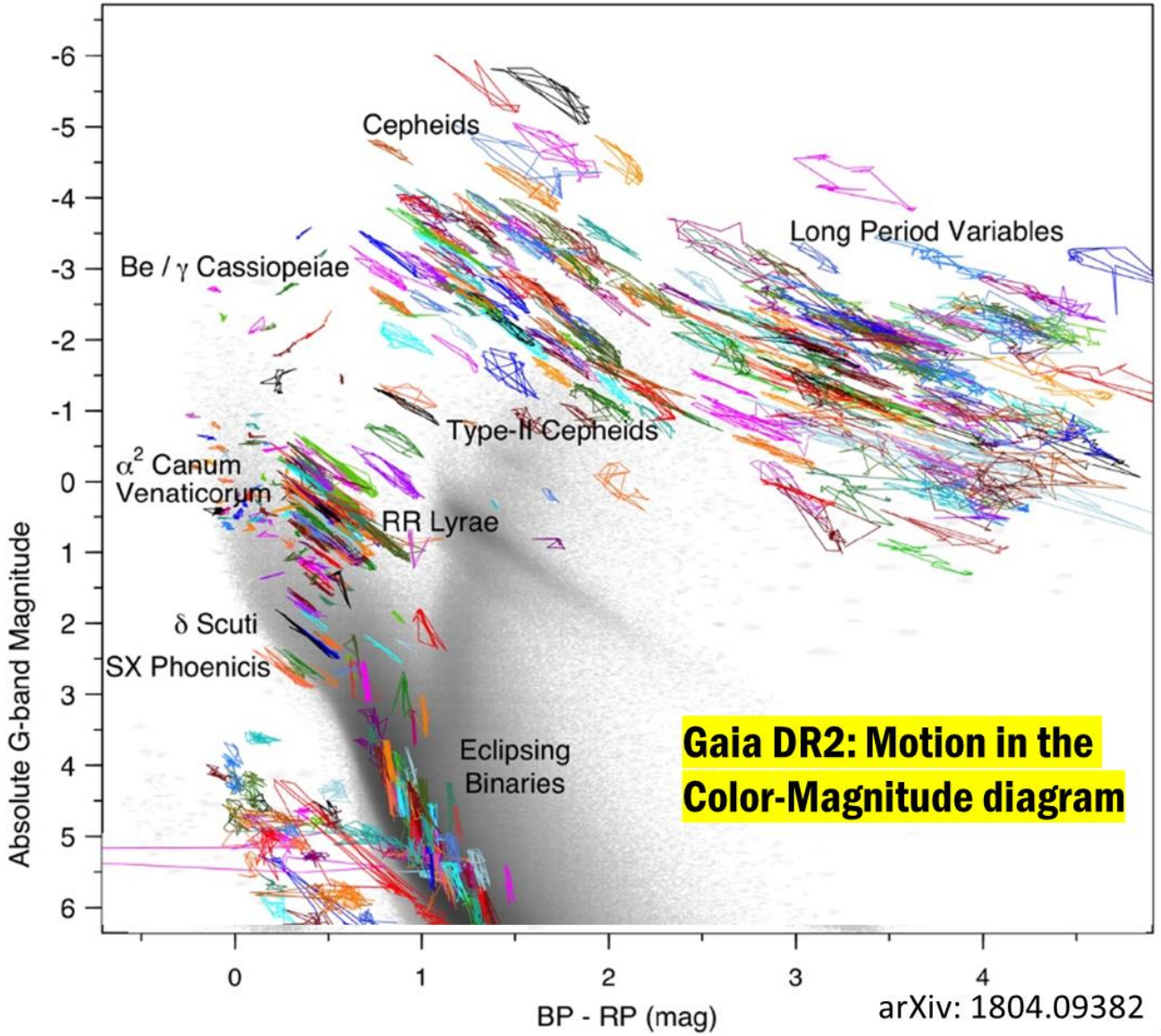
Main Survey (Down to 21 mag)

Time-dependent Spectral Energy Distribution (SED)

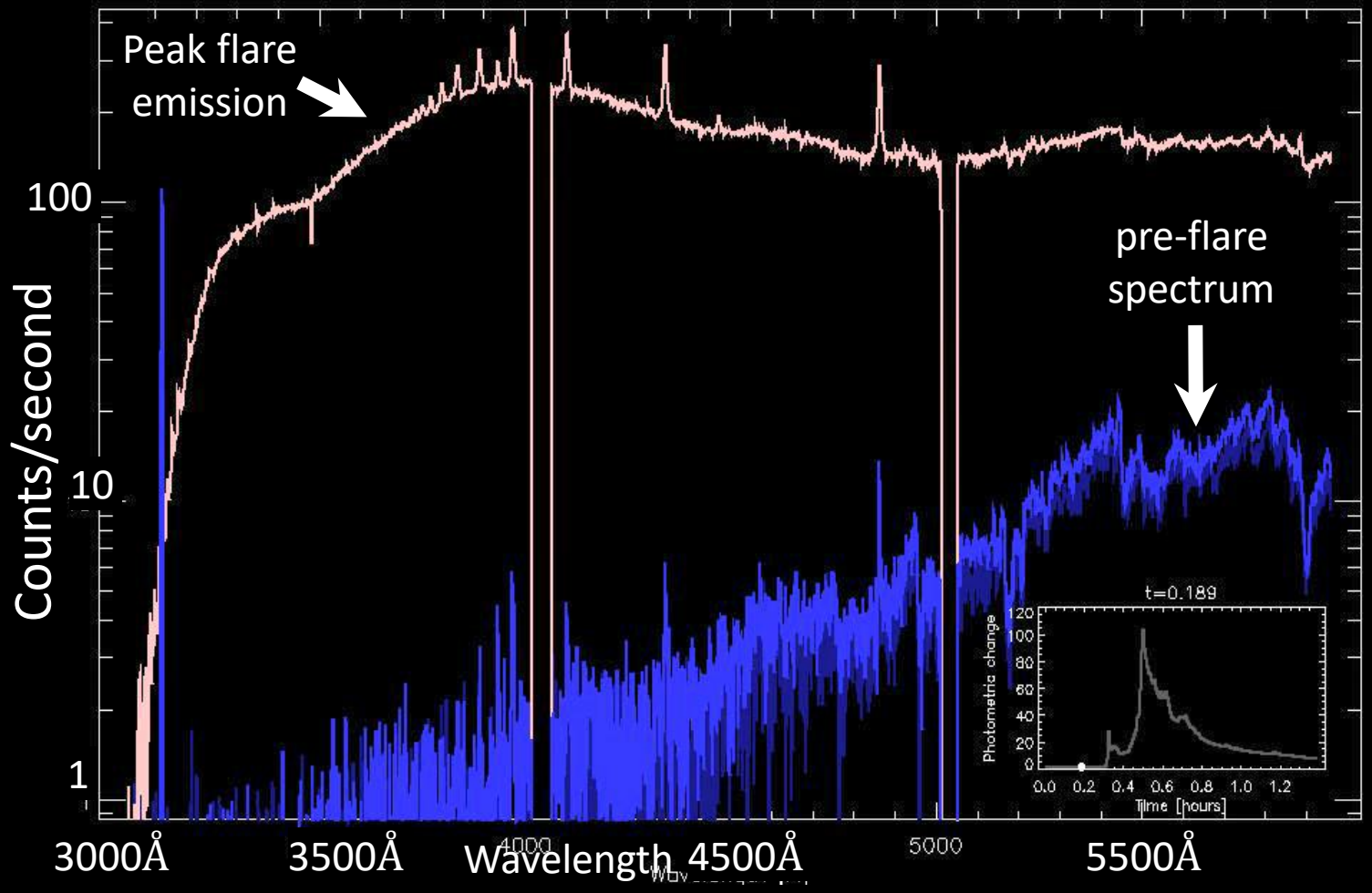
From SkyMapper's six-filter uvgriz photometry

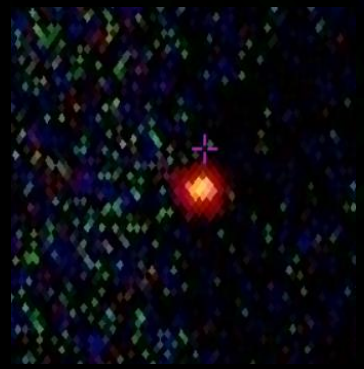
VAR





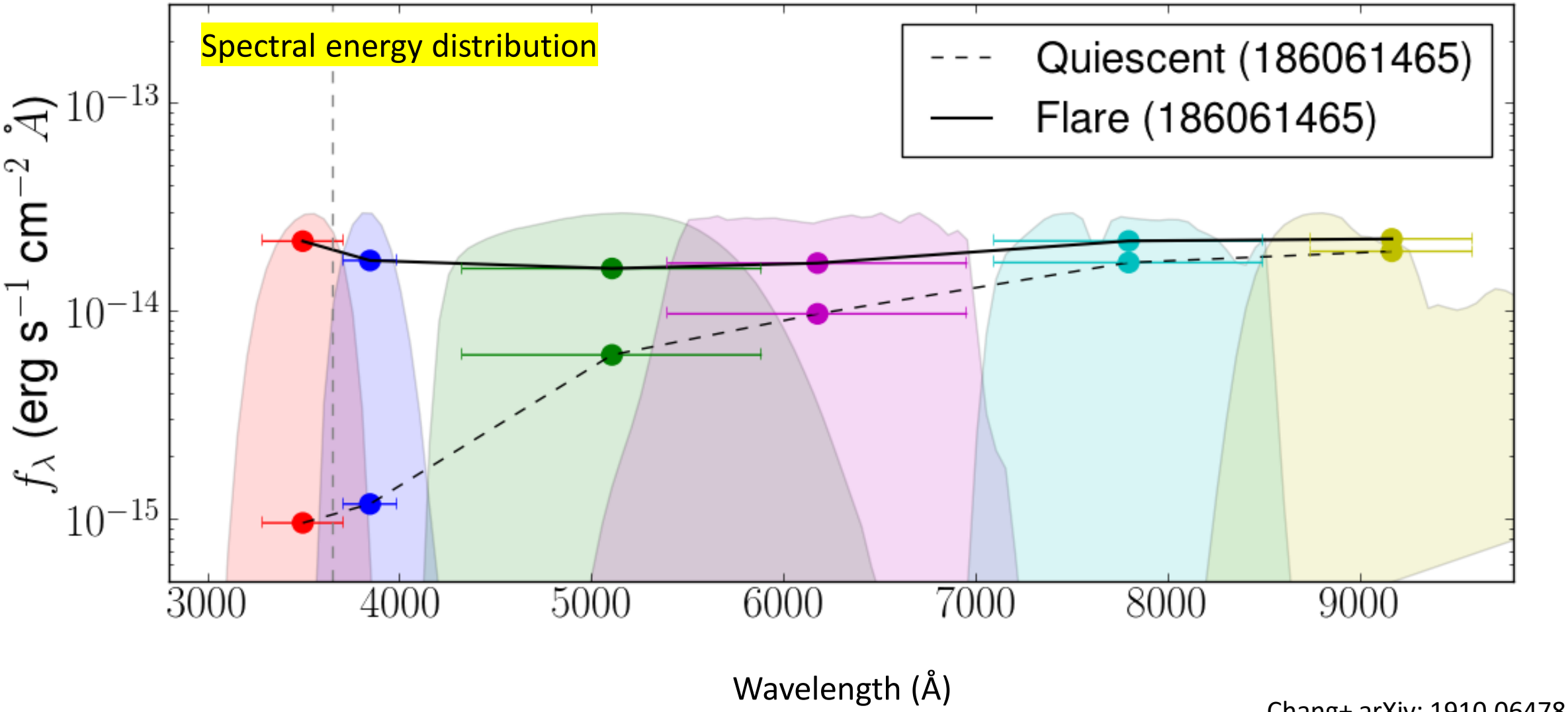
Latest Galactic Sciences: I. Magnetic Activity of M dwarf





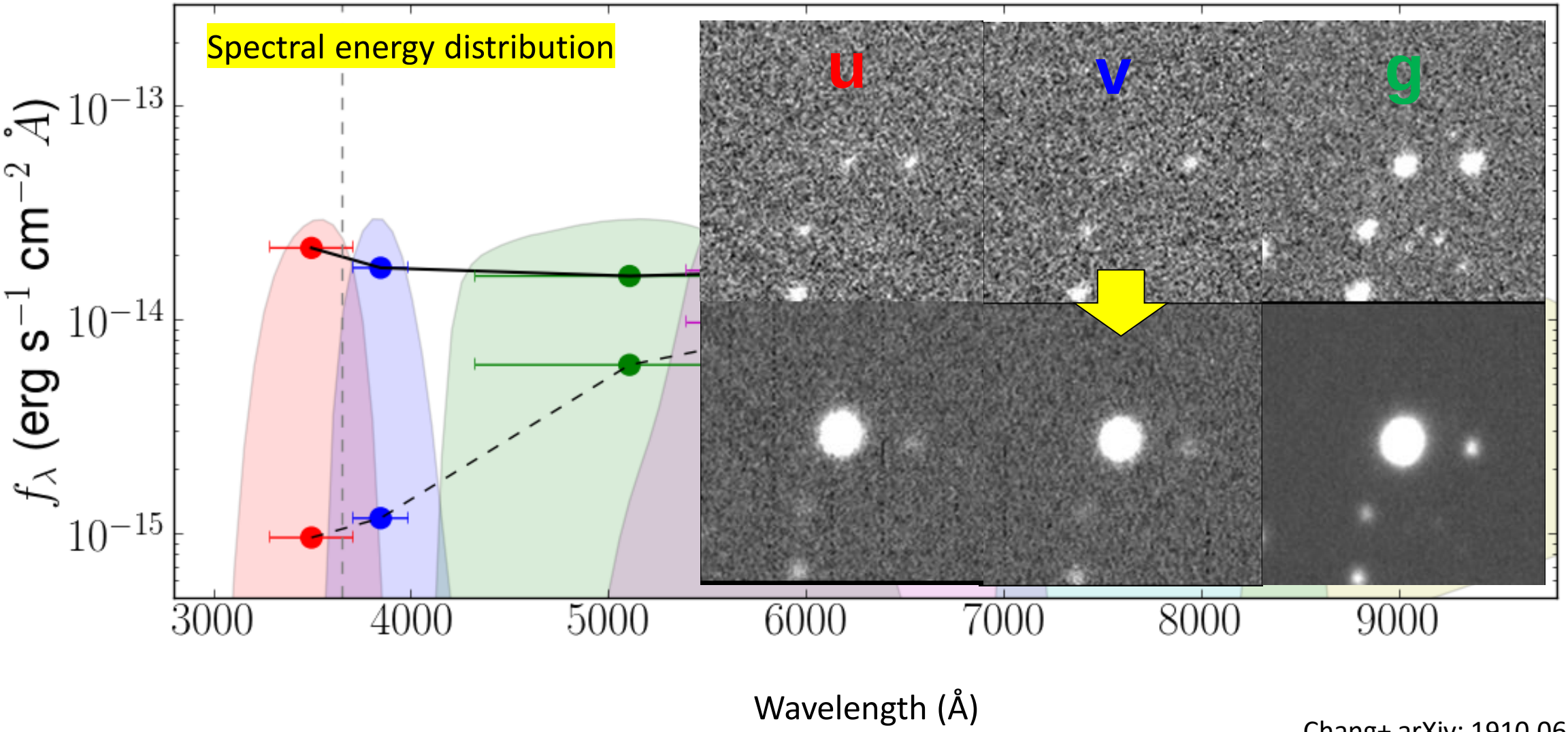
M-dwarf star (YZ CMi), 15 sec cadence, R~1000, 70x faster than VLT! (obs Jan 2012, Specta: Brown et al. SALT/RSS; photometry: Kowalski et al. WHT/La Palma)

Latest Galactic Sciences: I. Magnetic Activity of M dwarf



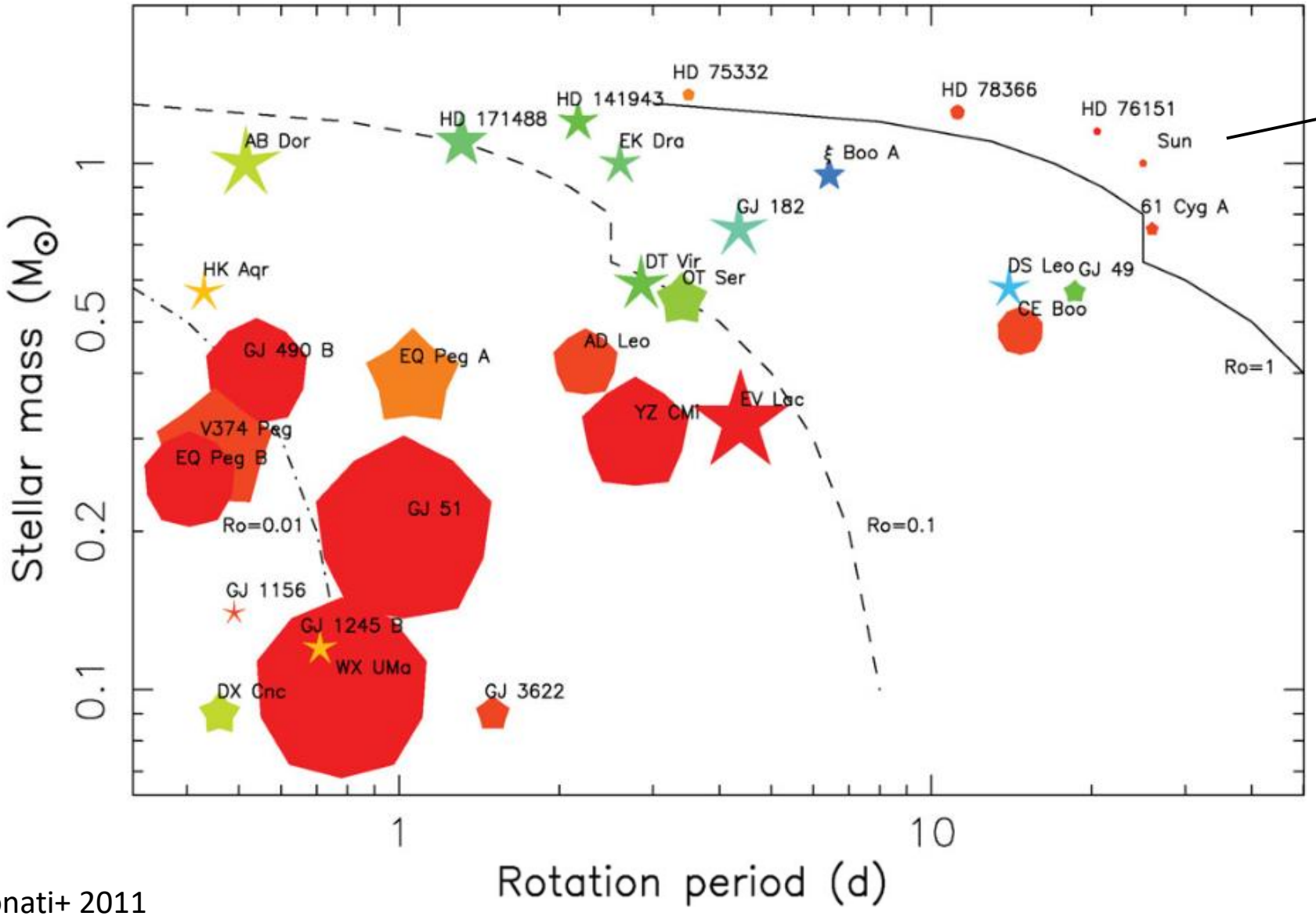
Chang+ arXiv: 1910.06478

Latest Galactic Sciences: I. Magnetic Activity of M dwarf



Chang+ arXiv: 1910.06478

Magnetic Fields of M Dwarfs



* Point size
= strength of
magnetic fields

Strongly magnetic objects (frequently exceed 1 kG)

Vs.

Sun (10-50 G)

Donati+ 2011

National Radio Astronomy Observatory

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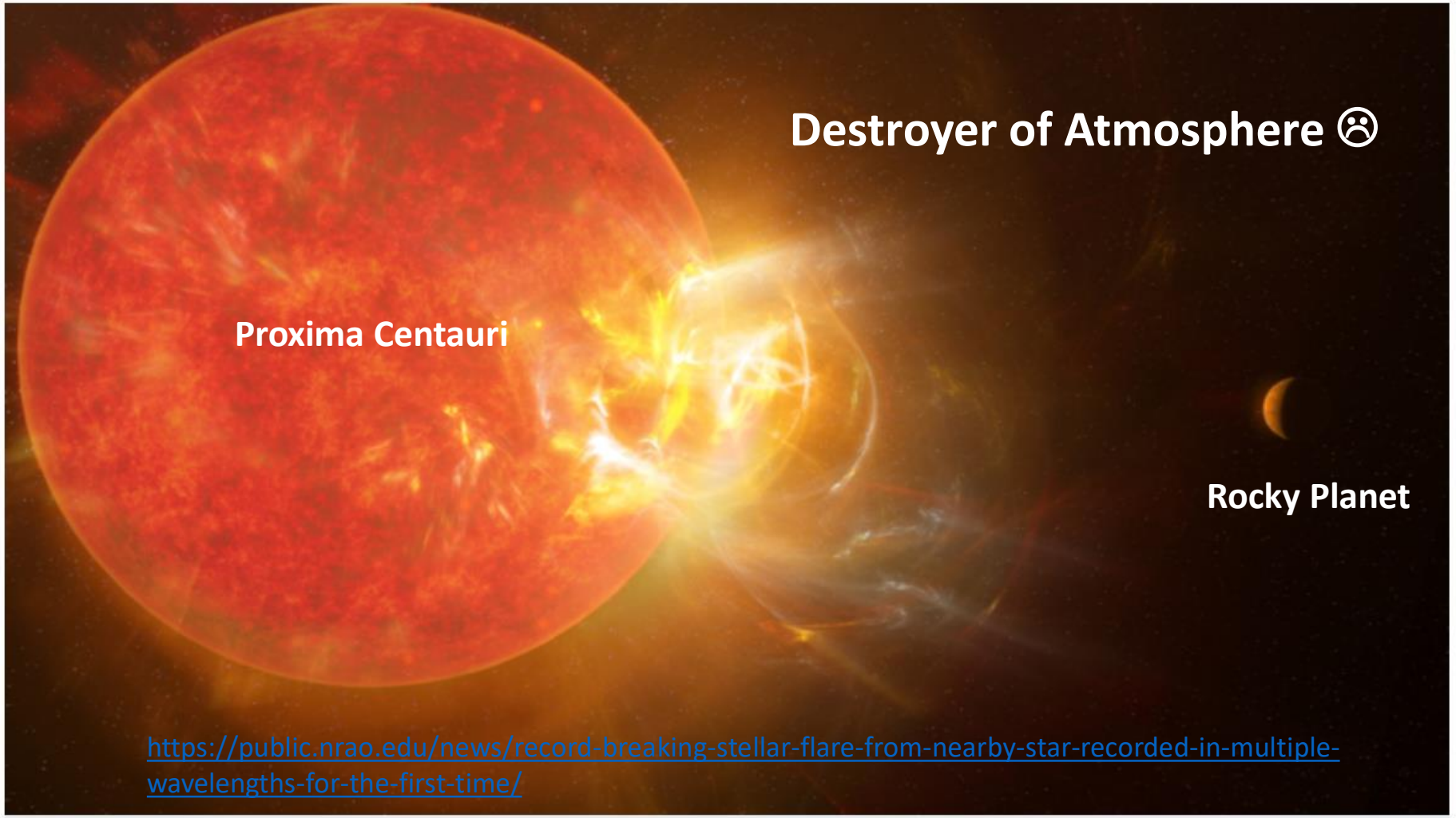
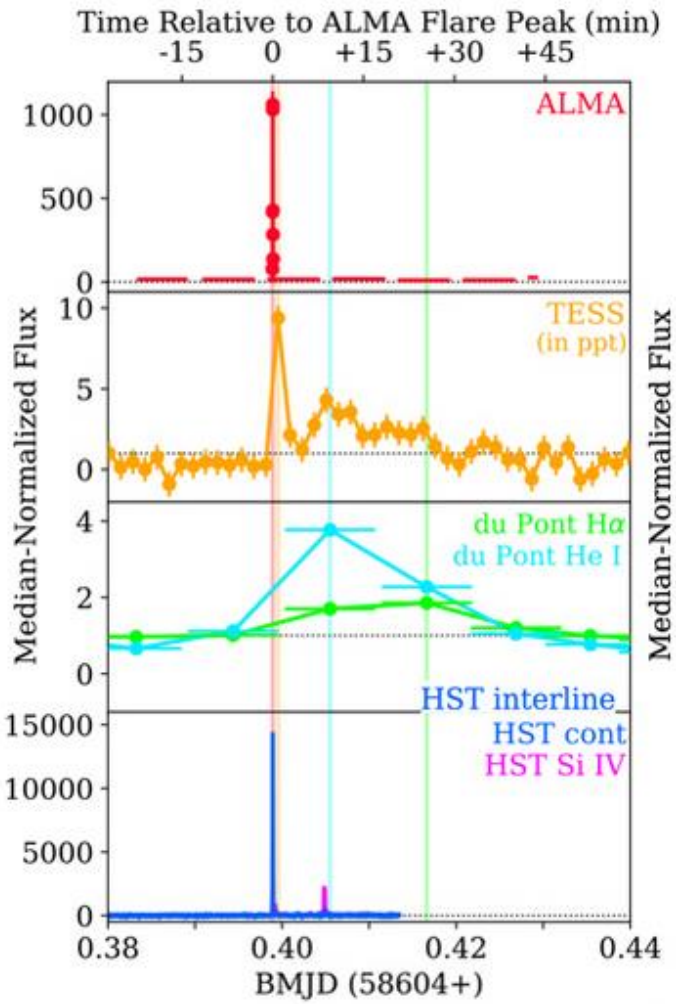
Home › News › News Release: April 21, 2021 at 10:00 am EDT

Record-breaking stellar flare from nearby star recorded in multiple wavelengths for the first time



https://public.nrao.edu/news/record-breaking-stellar-flare-from-nearby-star-recorded-in-multiple-wavelengths-for-the-first-time/



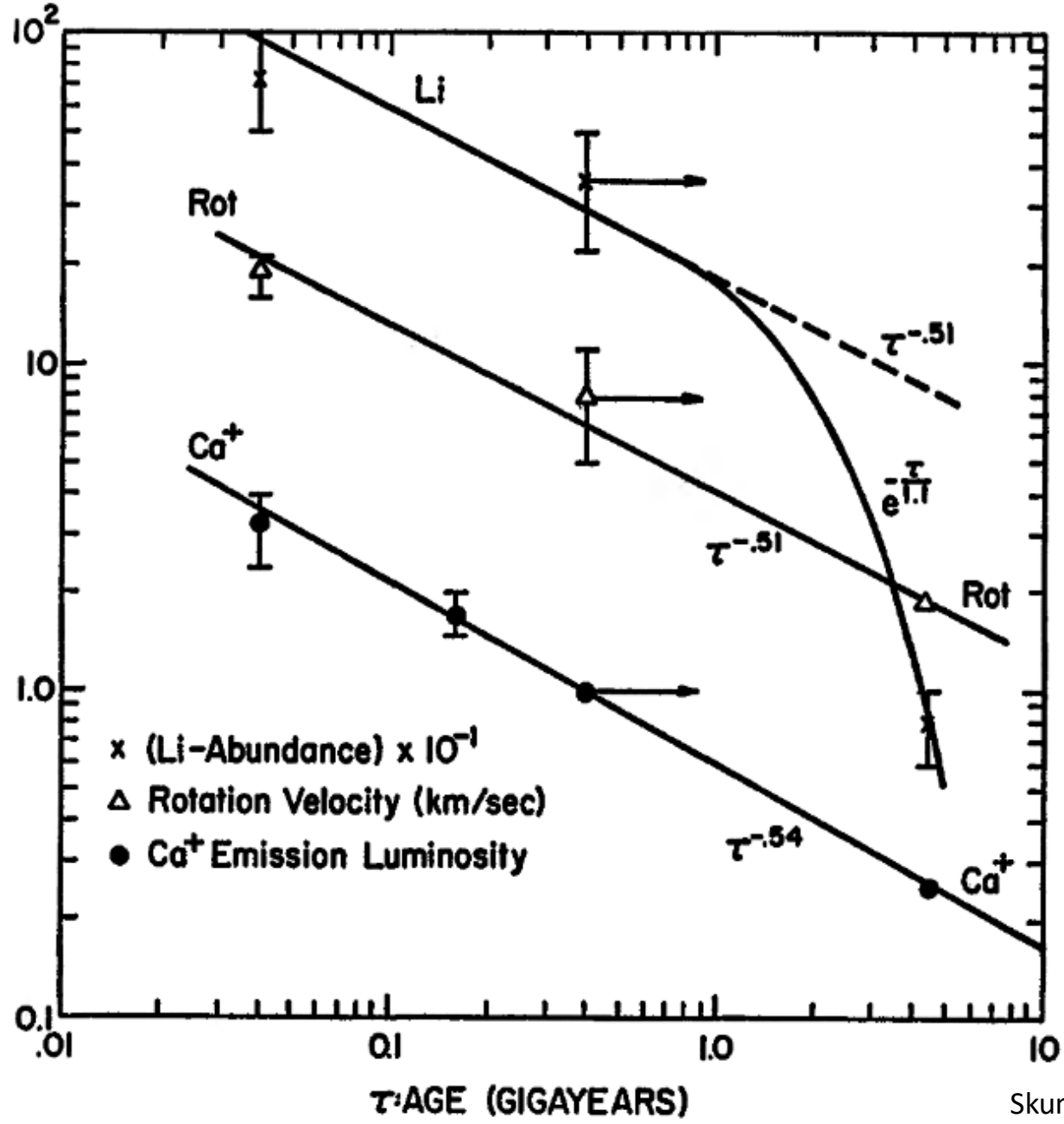
2019 May 1 event at all wavelengths
(MacGregor+ arXiv: 2104.09519)

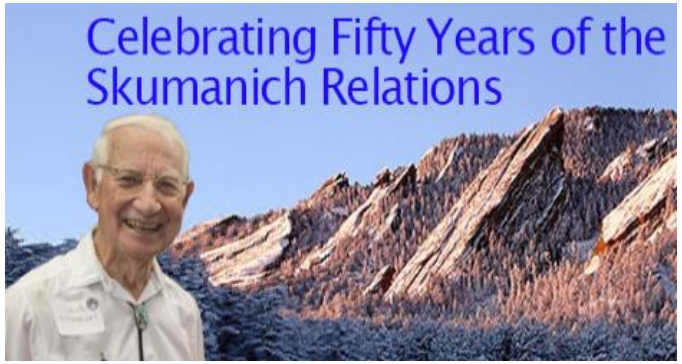
Skumanich Law: Age-Rotation-Activity Relation

Strong

Activity Strength

Weak





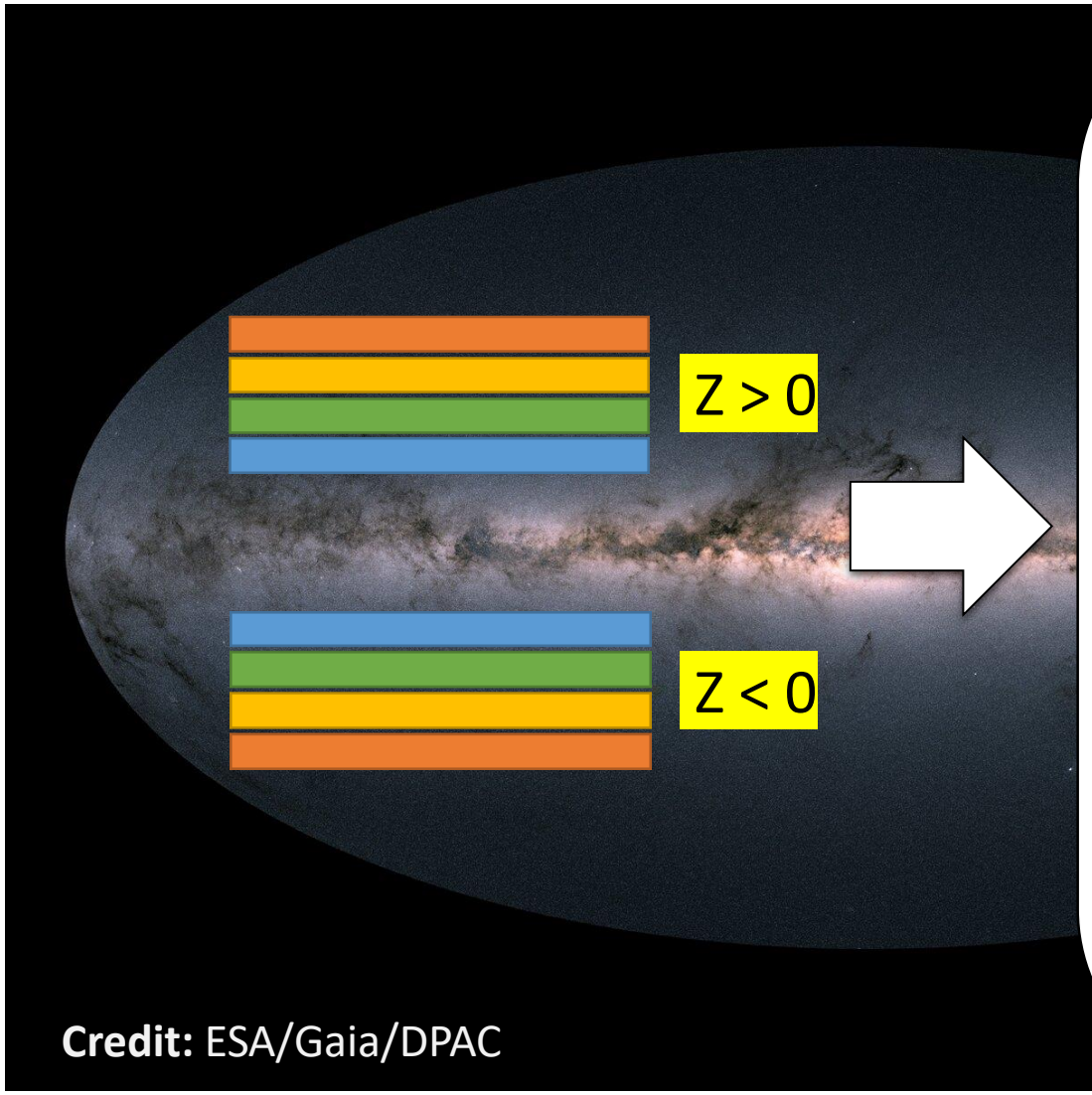
https://skumanich.wdrc.org/

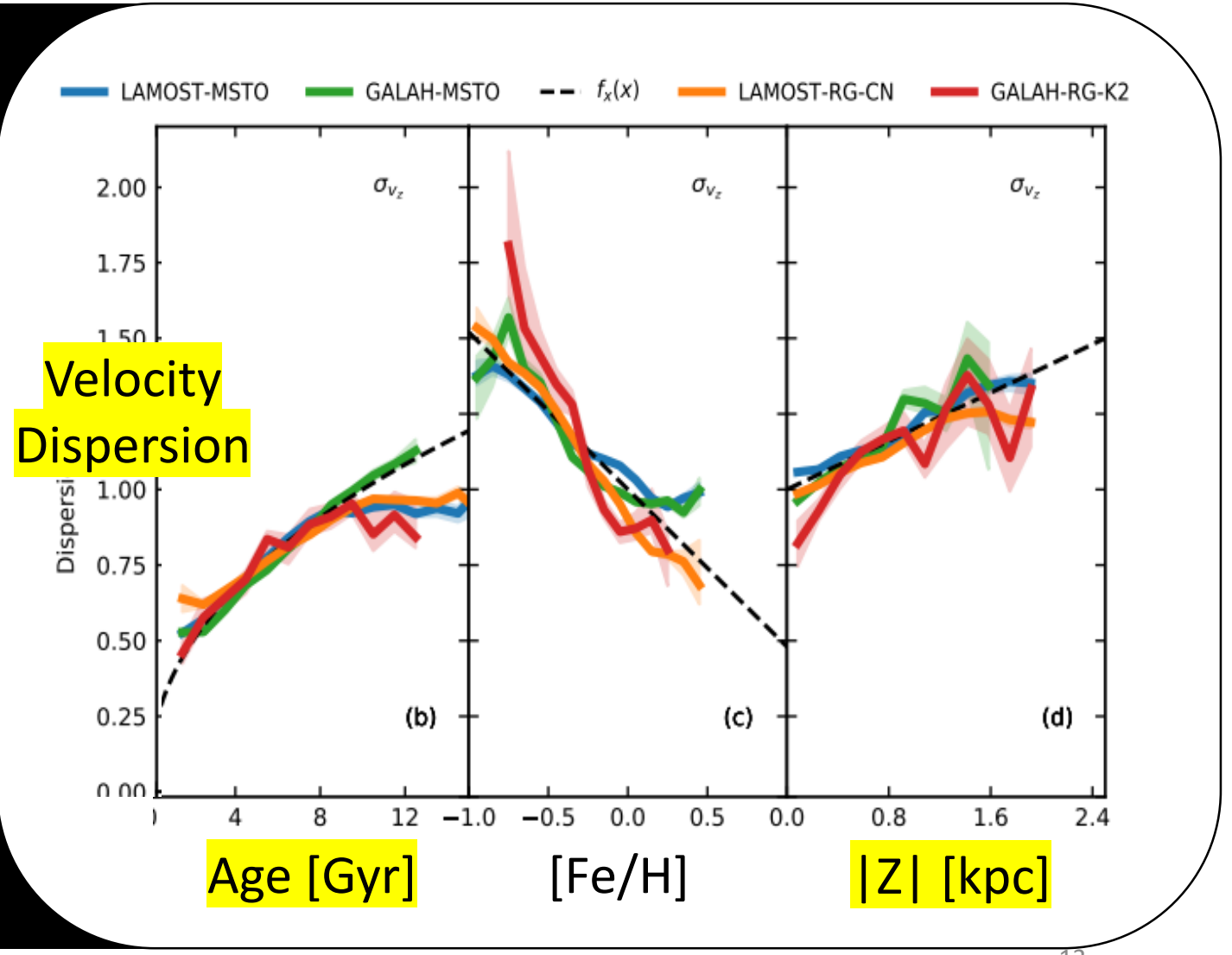
← Stellar rotation

Young ← Age → Old

Skumanich (1972; 3 pages, 1 figure; 1458 citations)

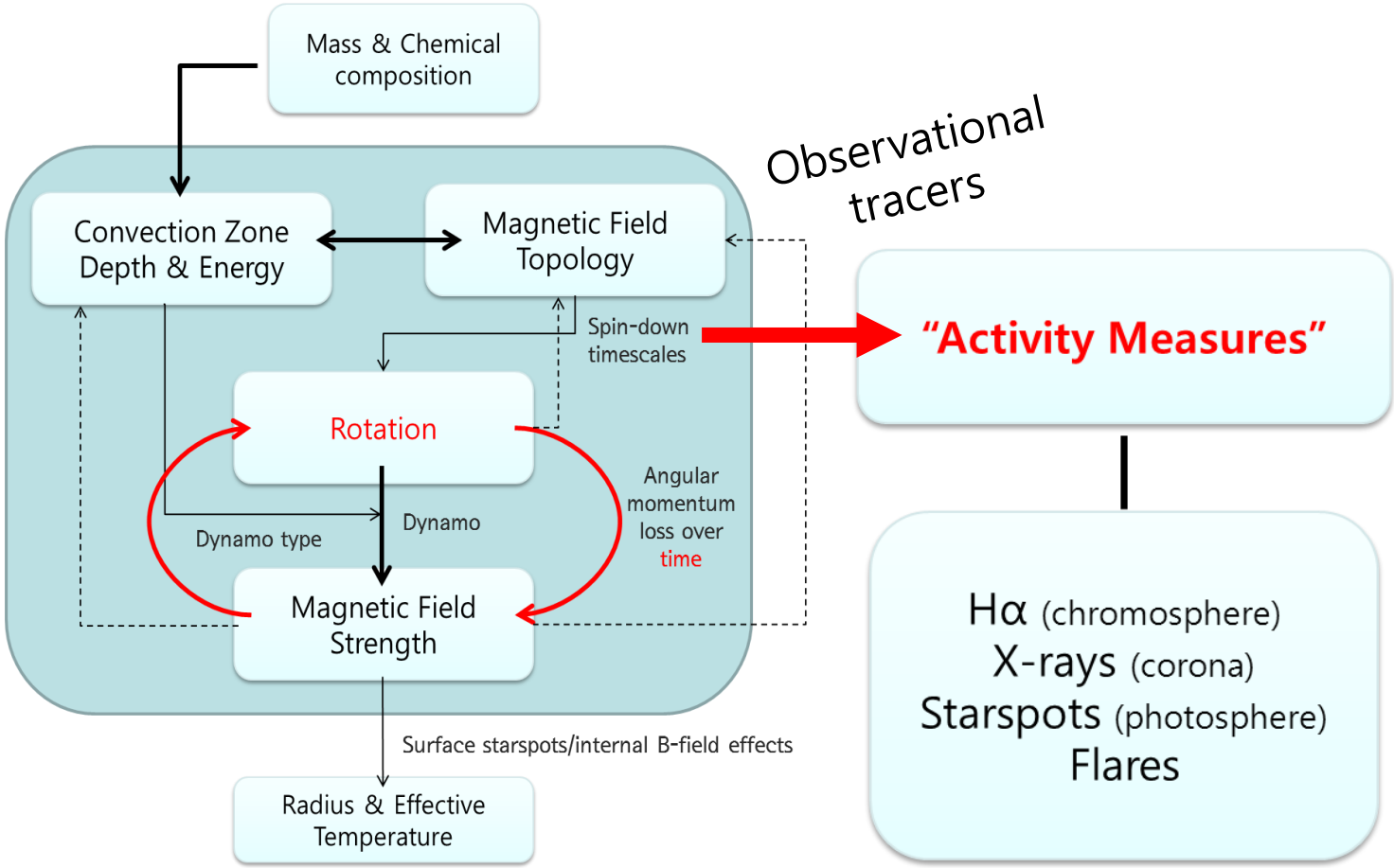
Vertical _AGE_ gradient in the Milky Way disc: Dynamical Evolution





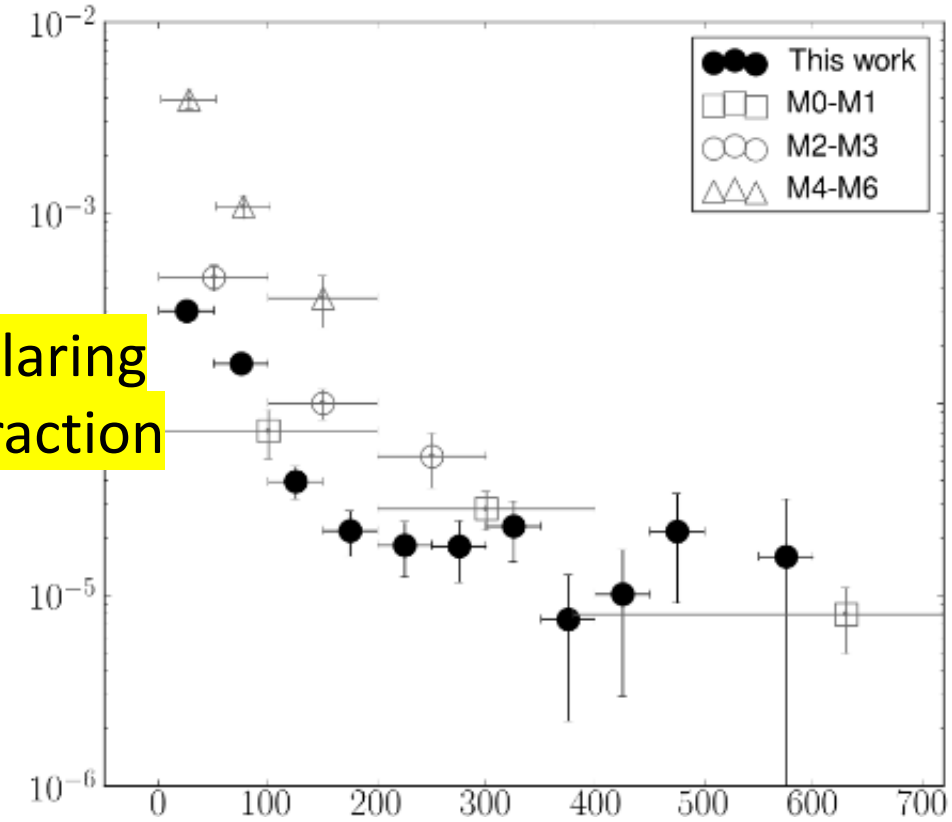
Sharma+ (arXiv:2004.06556)

Another Proxy for _AGE_



Ageing

Strength Varying



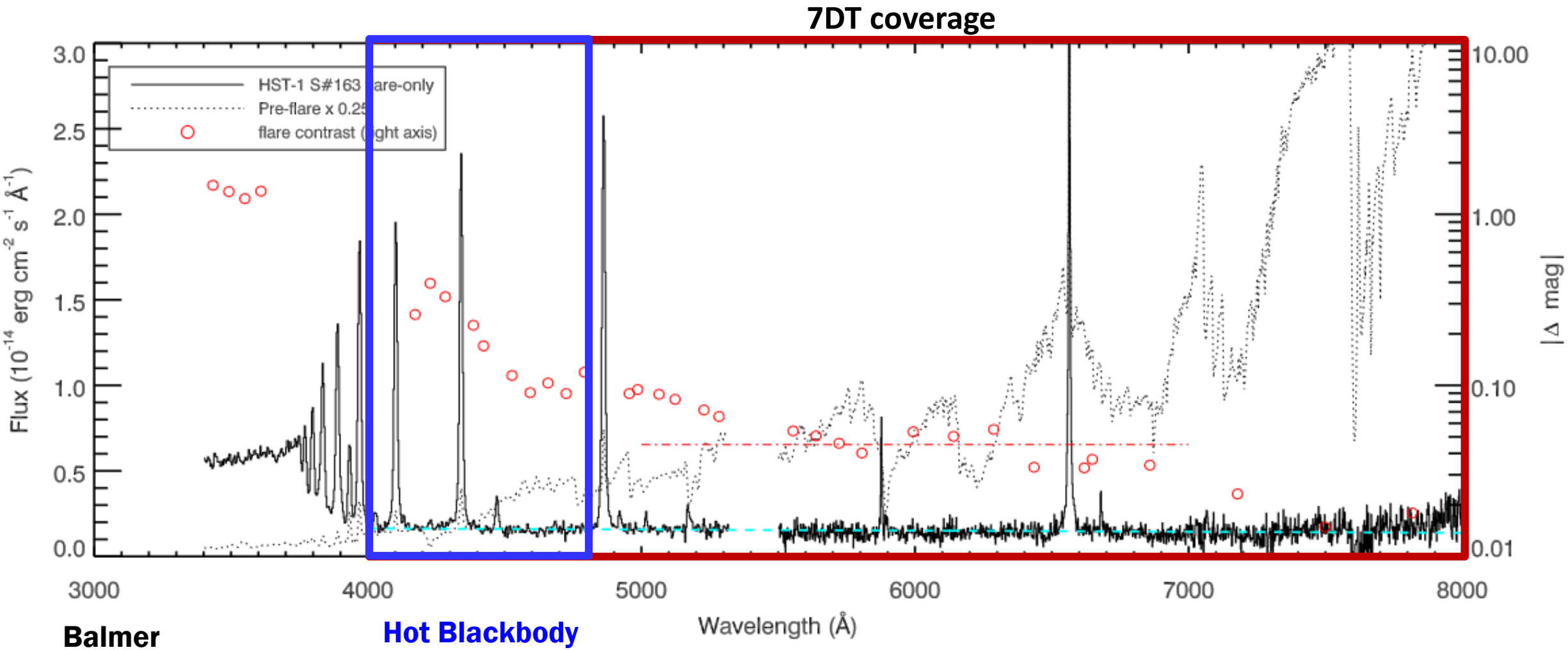
Flaring Fraction

|Z| [pc]

Stassun+ (2011)

Chang+ arXiv: 1910.06478

Two- or Three-component flare model



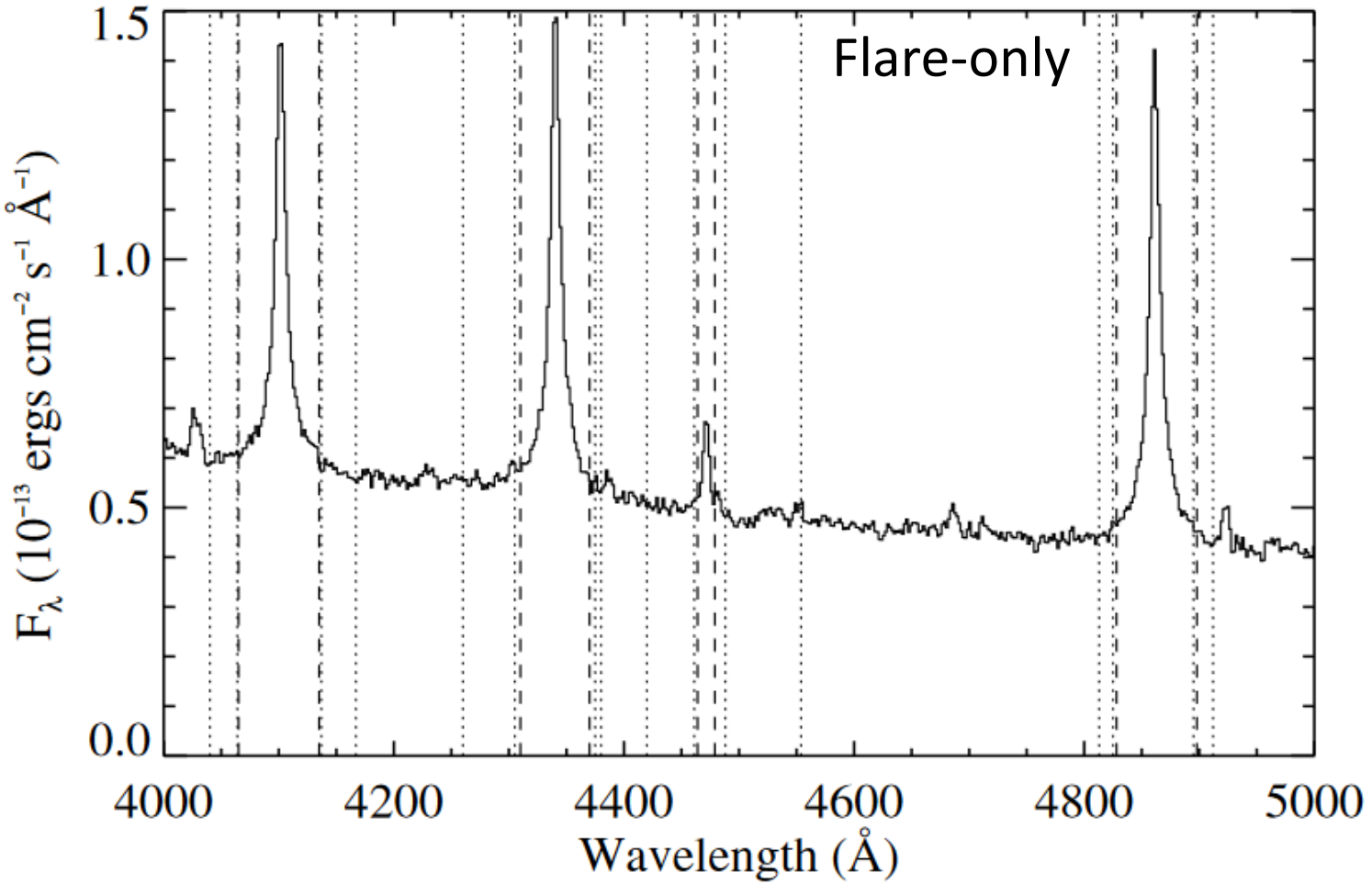
Balmer Continuum Component: < 3,647Å

Hot Blackbody Component (~10,000K; 4,000 ~ 4,800Å)

Redder continuum: > 4,900Å

Kowalski+ arXiv:1811.04021

Key Emission Lines: hydrogen Balmer, Helium I, …

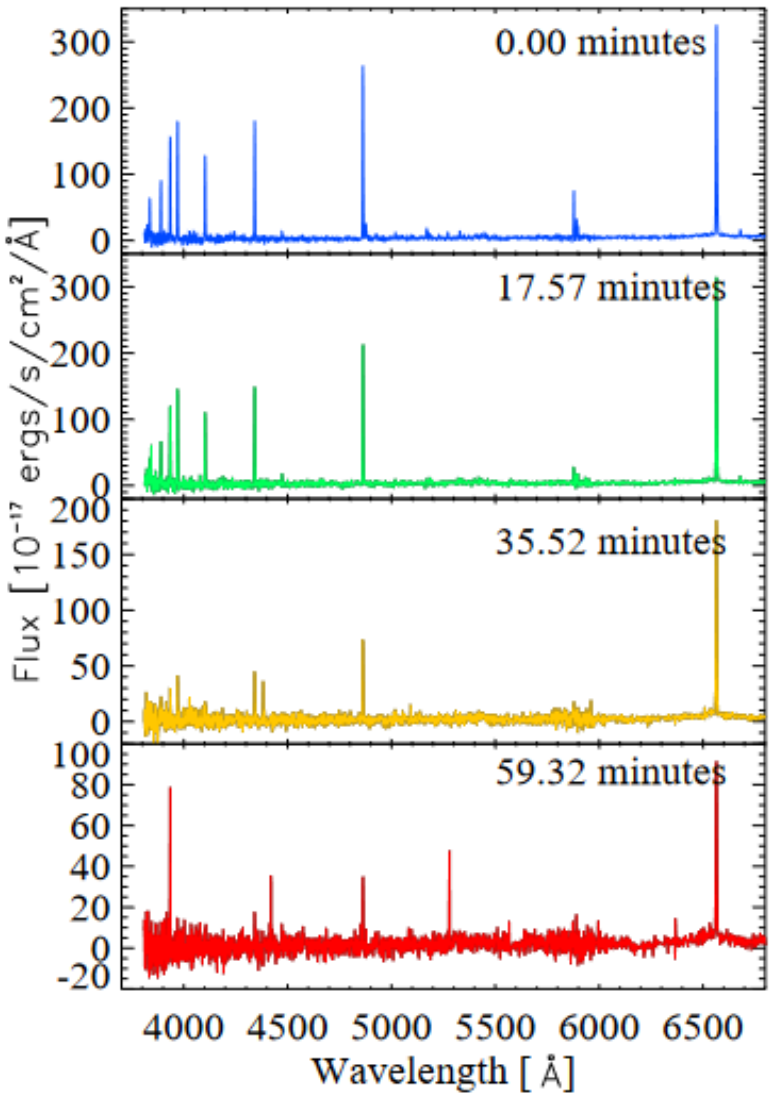


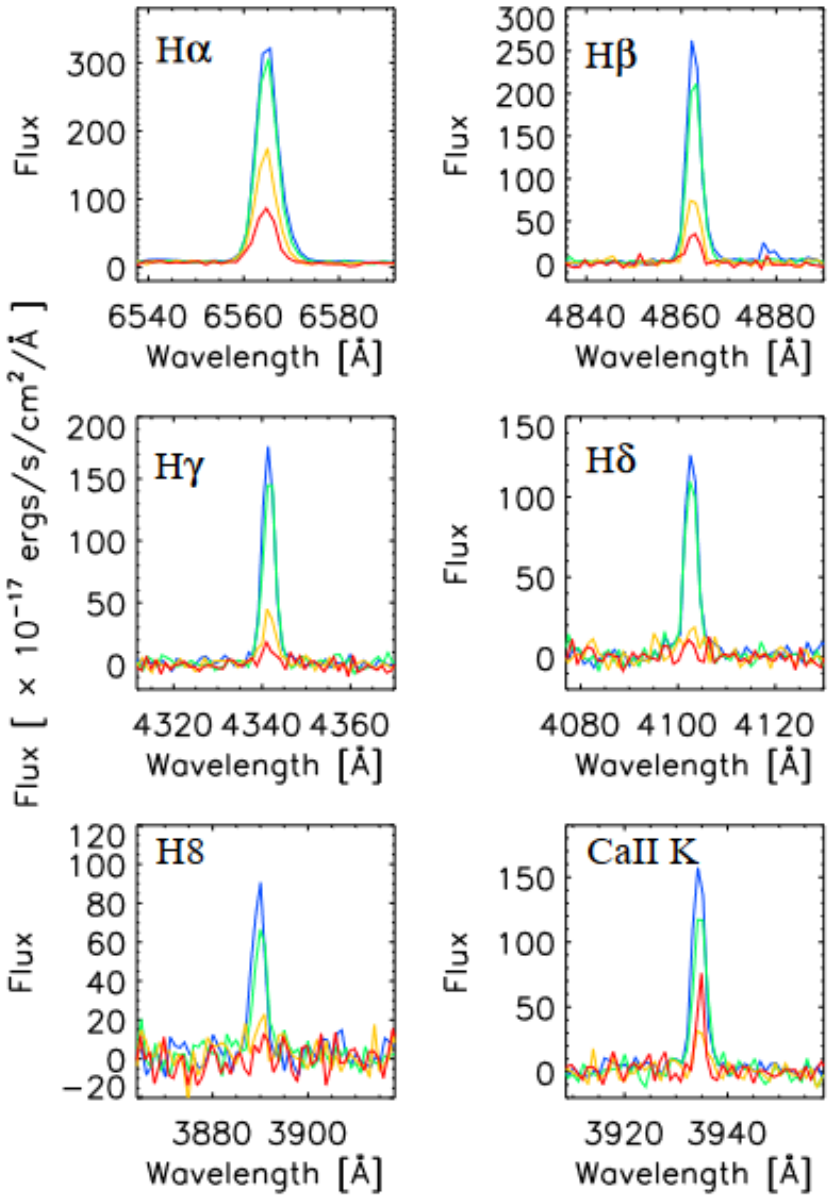
Line	Line Integration Window (Å)
Hα	6520–6610
Hβ	4828–4898
Hγ	4310–4370
Hγ	4321–4361
Hδ	4065–4135
Hδ	4084–4122
He I λ4471	4464.6–4481
He I λ4471	4460–4495

= 5-12 7DT medium-band filters for line and continuum measures

Kowalski+ arXiv:1307.2099

Homogeneous analysis of line and continuum emissions?

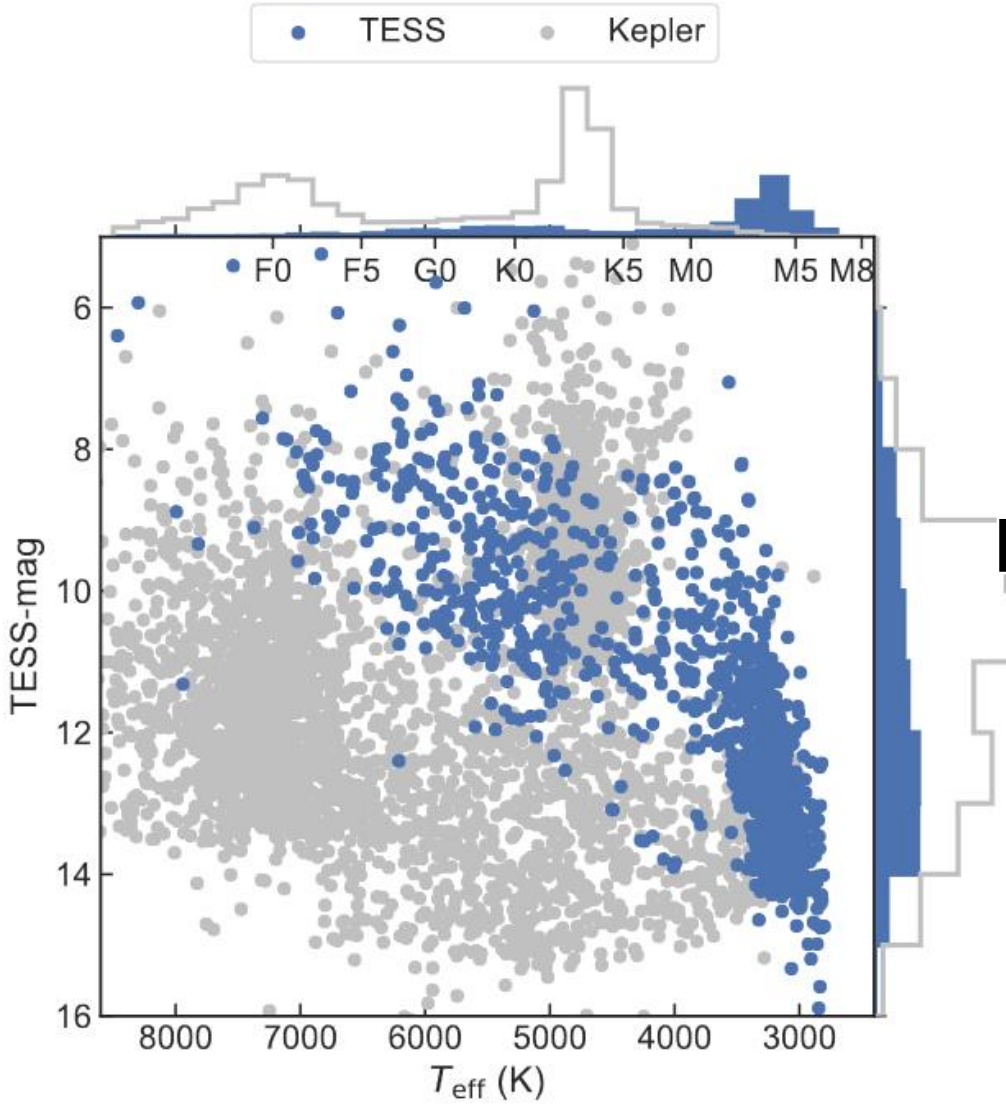


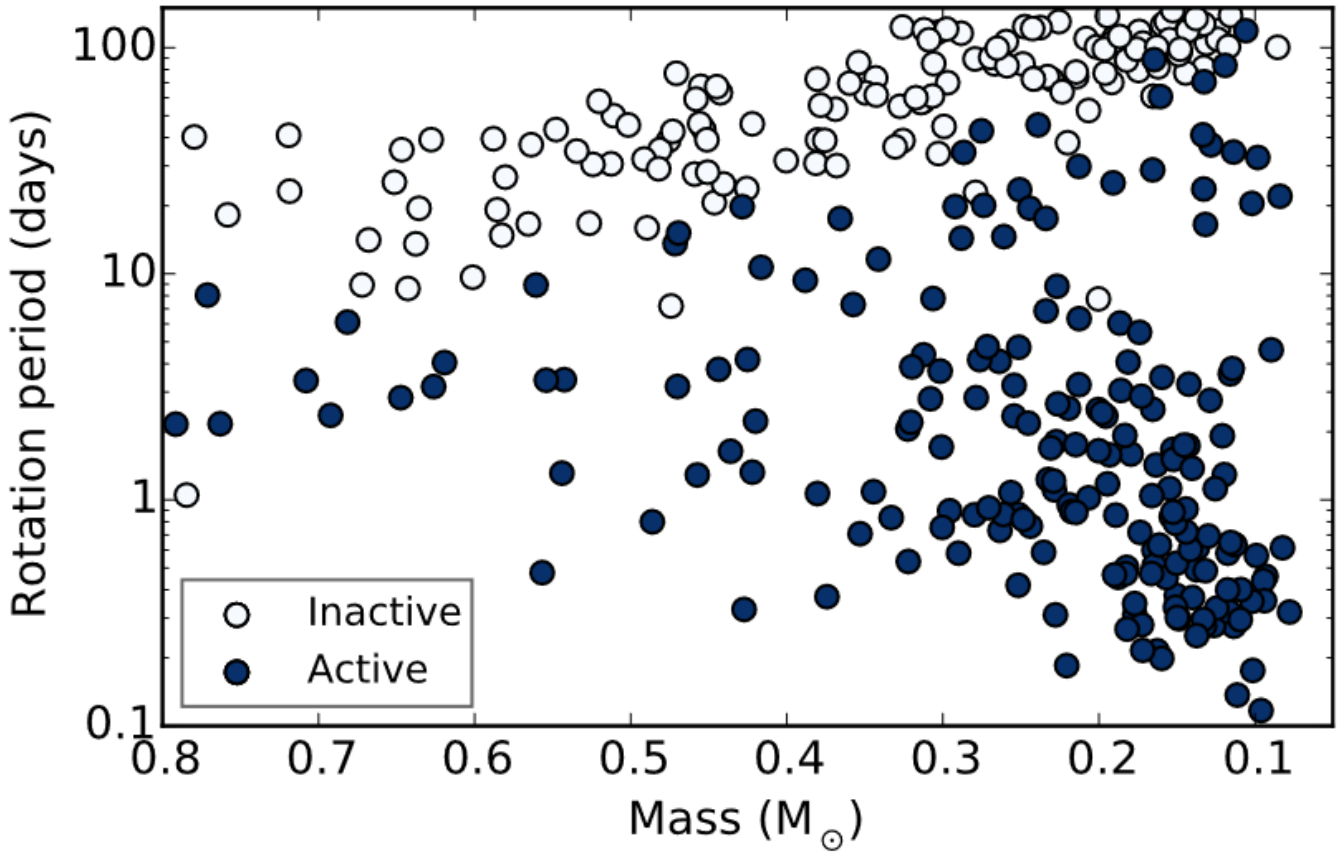


- Previously, the entire Balmer series and several prominent lines have not been captured simultaneously
- Important diagnostic for the evolution of electron densities
- And to break the degeneracy between emission mechanisms

Hilton+ arXiv:1009.1158

Further constrain the Chromospheric activity of Planet hosts?

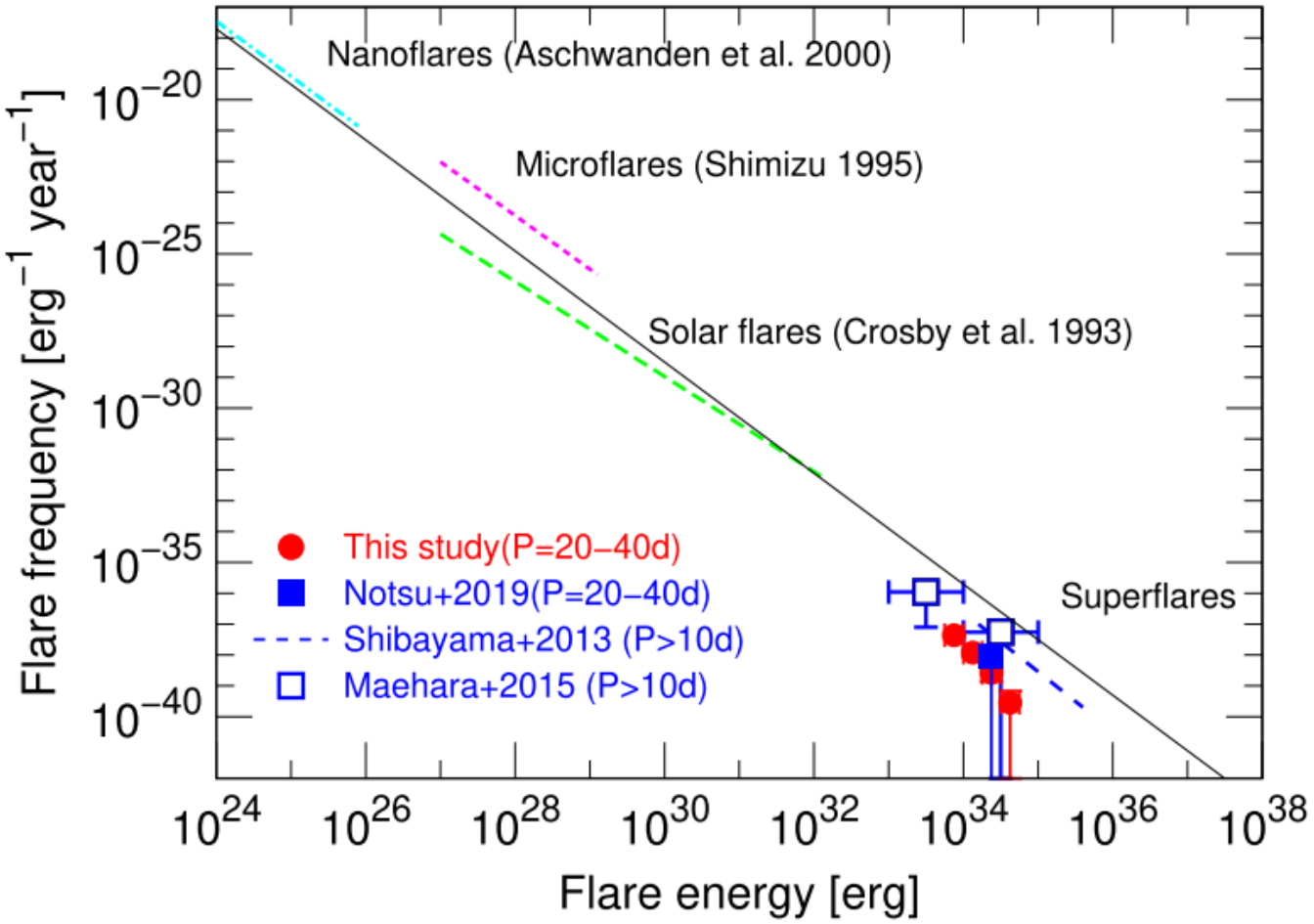




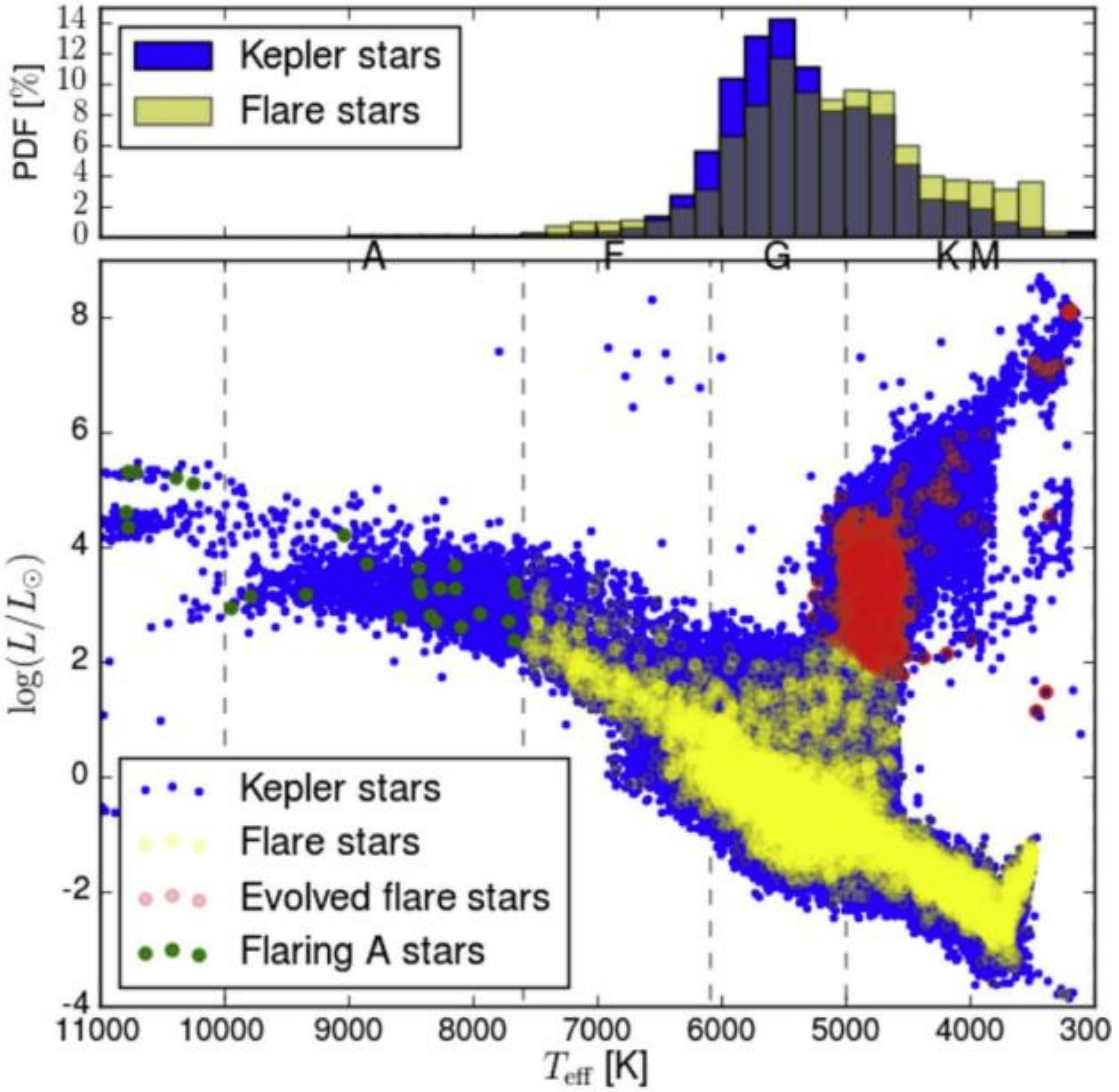
e.g., Hα activity-Rotation relation

Gunther+ arXiv:1901.00443; Newton+ arXiv: 1611.03509

Statistical Properties of Stellar Magnetic Activity?



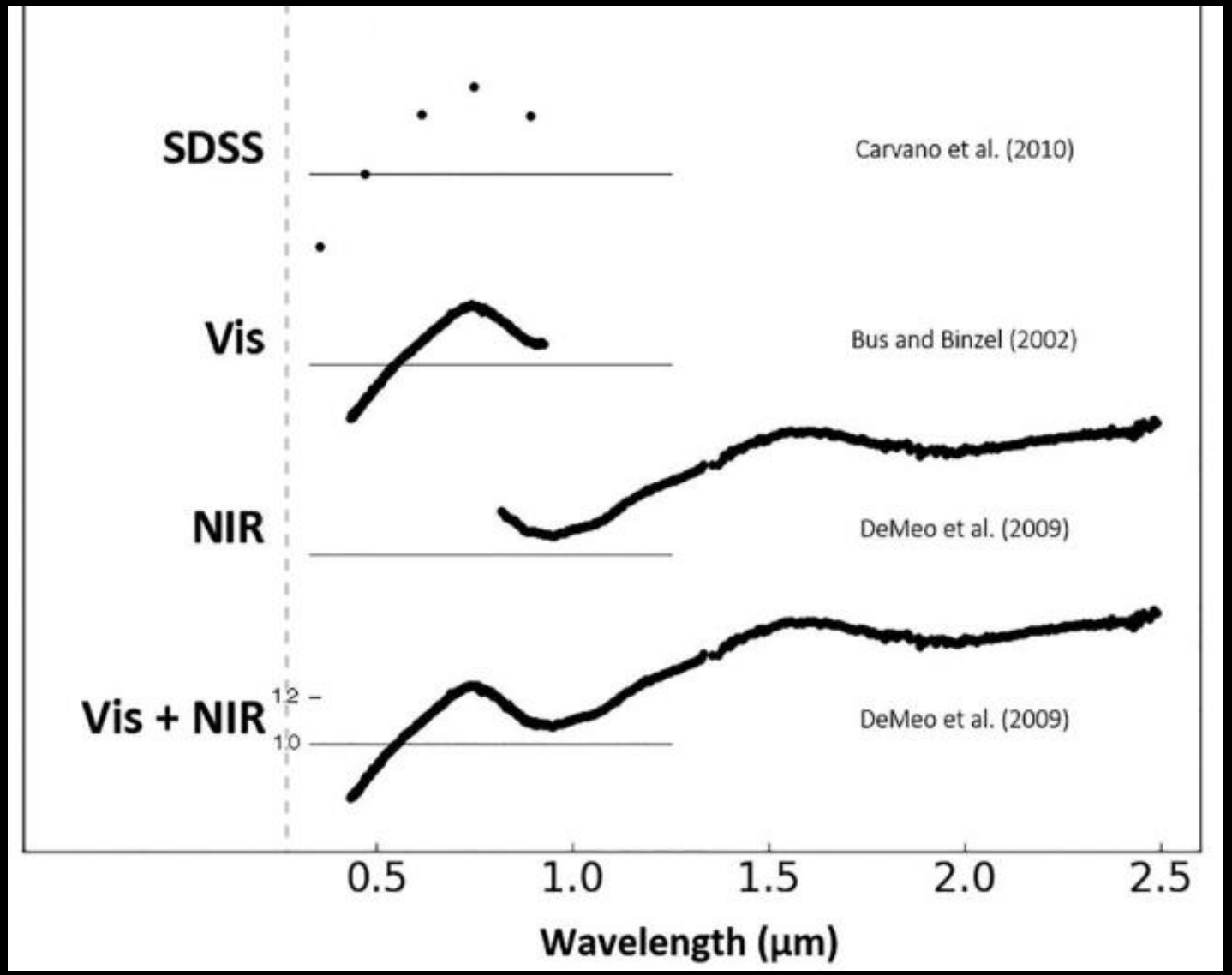
Solar-type stars



AFGKM + even evolved ones

Okamoto+ arXiv:2011.02117 ;Van Doorsselaere+ arXiv:1711.02587

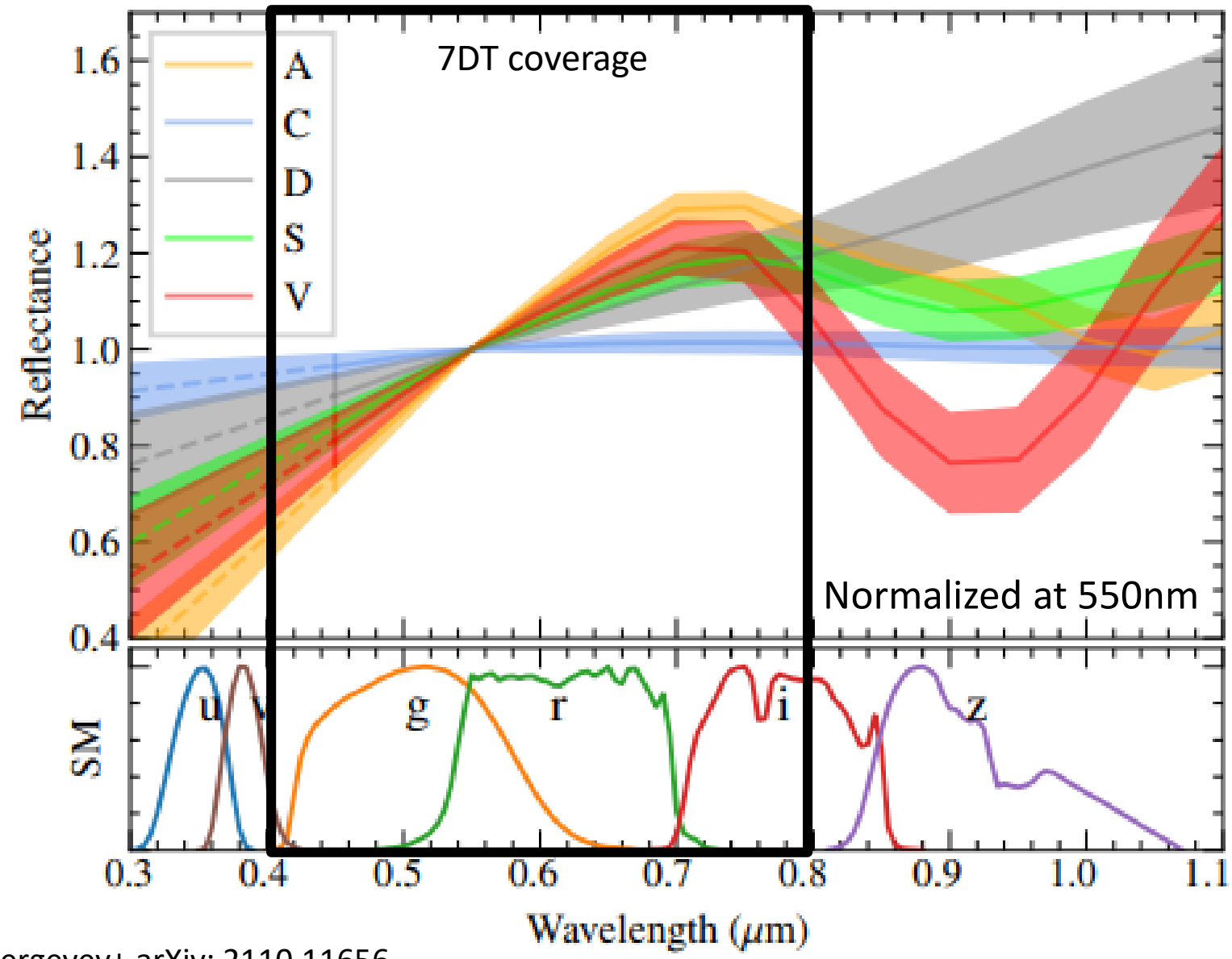
Latest Galactic Sciences: II. _Compositional_ mapping of the asteroids



- **~9,000 asteroid spectra: just a tip of the iceberg**
- **Multi-filter photometry**: provides strong constraints on asteroid composition and classification, providing less details but on large samples
- SDSS photometry has been the source of a variety of studies for almost two decades (e.g., dynamic families and surface aging)

Binzel+ arXiv: 2004.05090

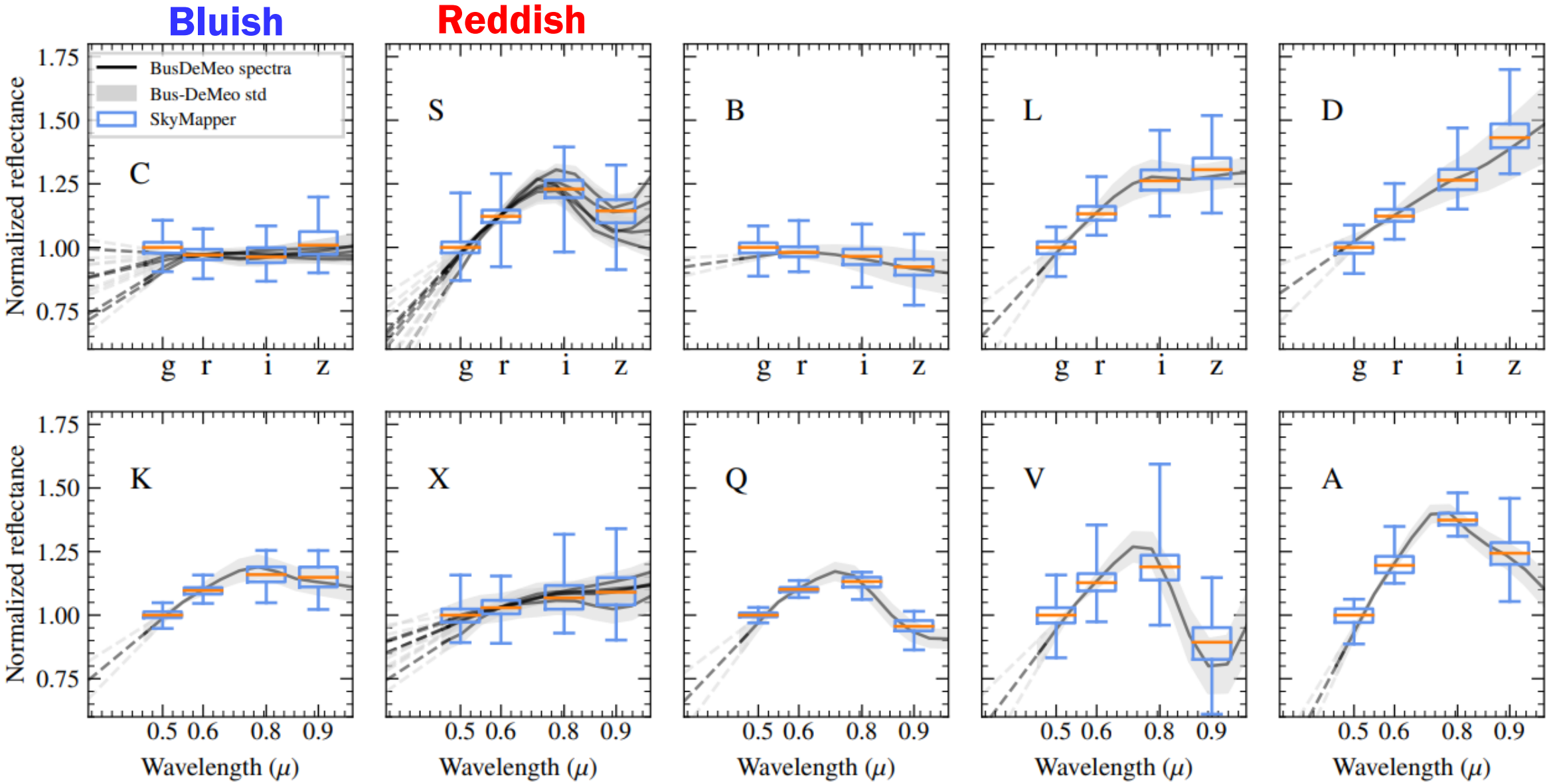
Advantage of SkyMapper multi-filter observations



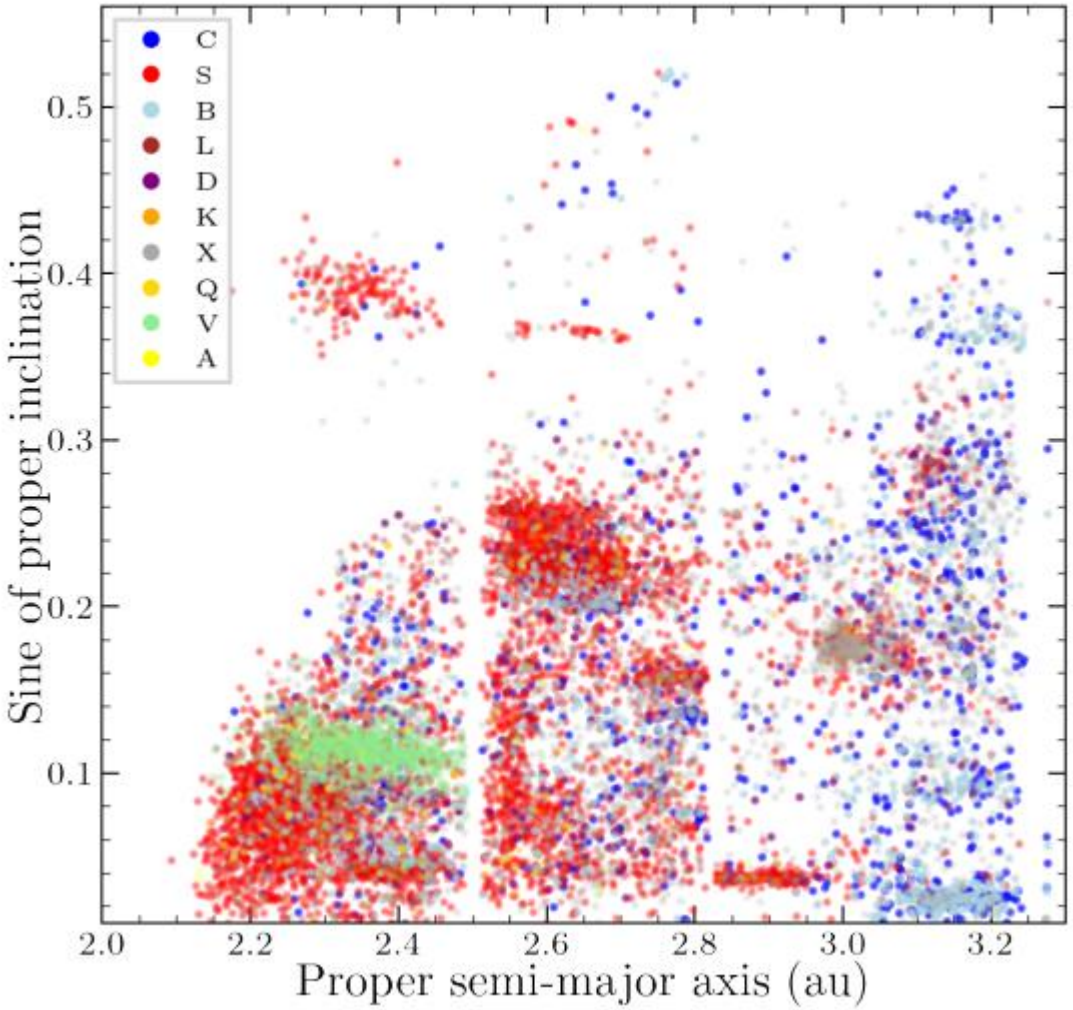
- Spectral degeneration of asteroid spectral classes over visible only (see 7DT coverage)
- **Near-simultaneous acquisition of different filters → Instantaneous determination of colours.**
- z filter probes the 1 μm band → the most characteristic spectral feature in all major taxonomies

Sergeyev+ arXiv: 2110.11656

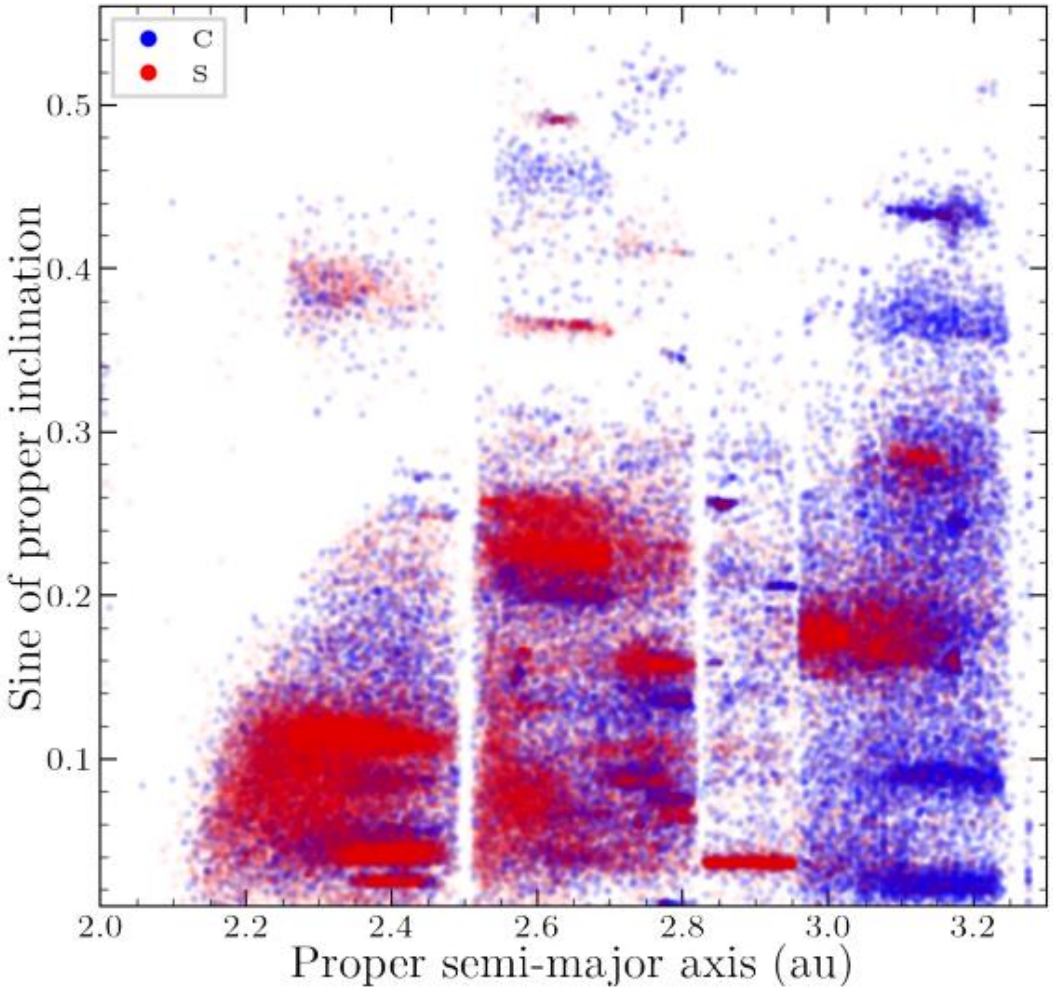
Pseudo-reflectance spectra of asteroids: [g-r-i-z] colours



Potential of multi-filter taxonomic classification: Dynamical populations?



[g-r-i-z] colours

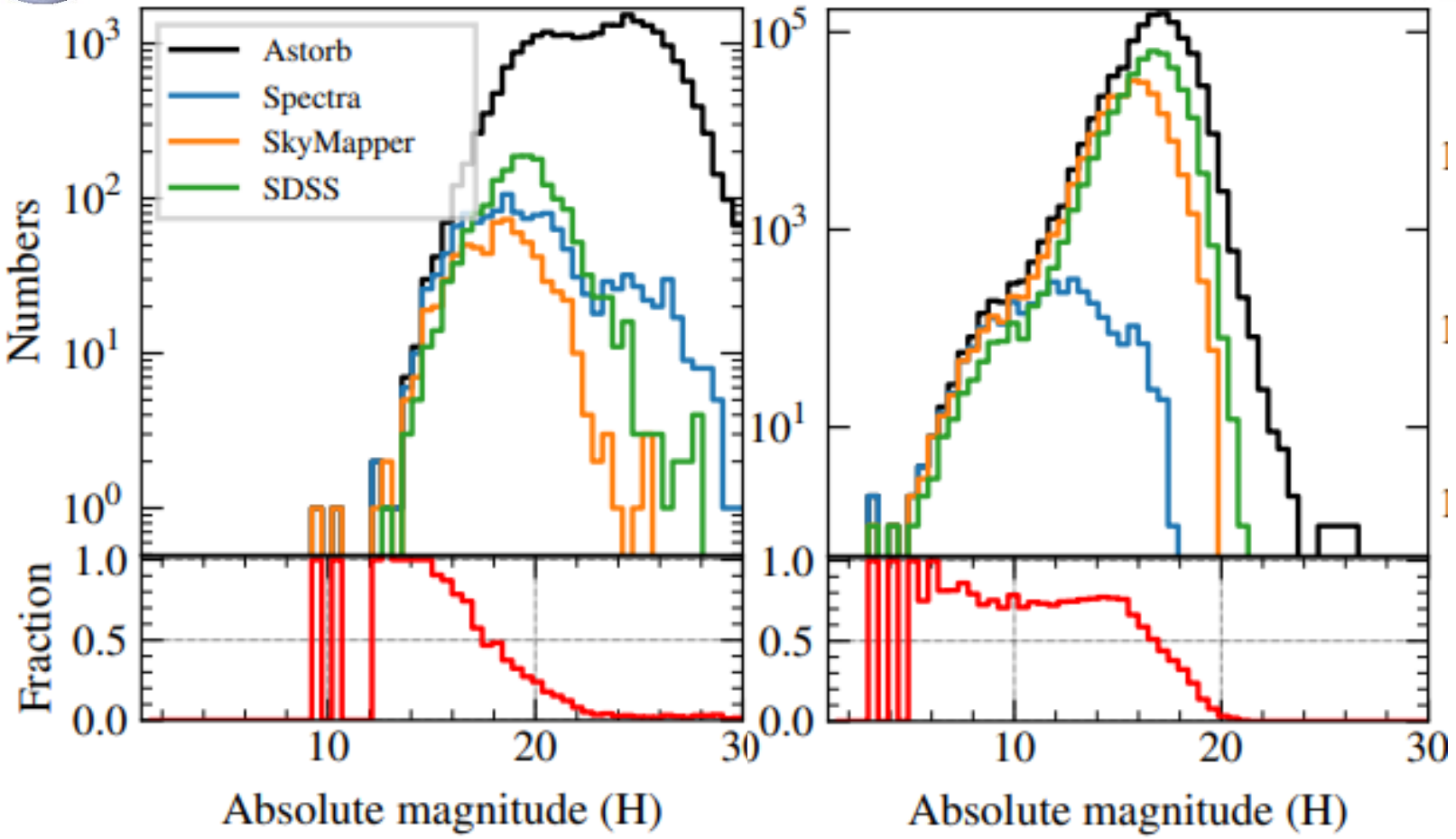


[g-r] colour only (7DT coverage)

Move toward completeness of taxonomic classification?

Near Earth Asteroid

Main Belt Asteroid



- DR3 205,515 known solar system objects → only a half of them observed by SDSS
- **SkyMapper** + **SDSS** → completeness almost 80% of all MBAs with an absolute magnitude between 10 and 16

Last slide: Recommendations for 7DT Galactic Time-Domain Science

The 7DT data will form a time-dependent, multi-colour movie of Southern sky.

- Due to the step-by-step construction of 7DT, the filter sequence (or filter prioritization: blue to red) and the distribution of revisit interval are essential to characterizing variability on various timescales from a single survey.

- All 7DT Galactic Time-Domain sciences are enhanced with Near-simultaneous (< 4-5 minutes), Multi-filter measurements as seen in the SkyMapper:

For stellar activity studies: most commonly hydrogen Balmer emission lines and continuum around them.

For small body studies: still benefit from a visible only coverage.