S-PLUS Southern Photometric Local Universe Survey

Searching for rare objects with narrow-band photometry from S-PLUS

Lilianne Nakazono

PhD candidate in Astronomy, Universidade de São Paulo

AISSAI Anomaly Detection Workshop - 6th March 2024

S-PLUS

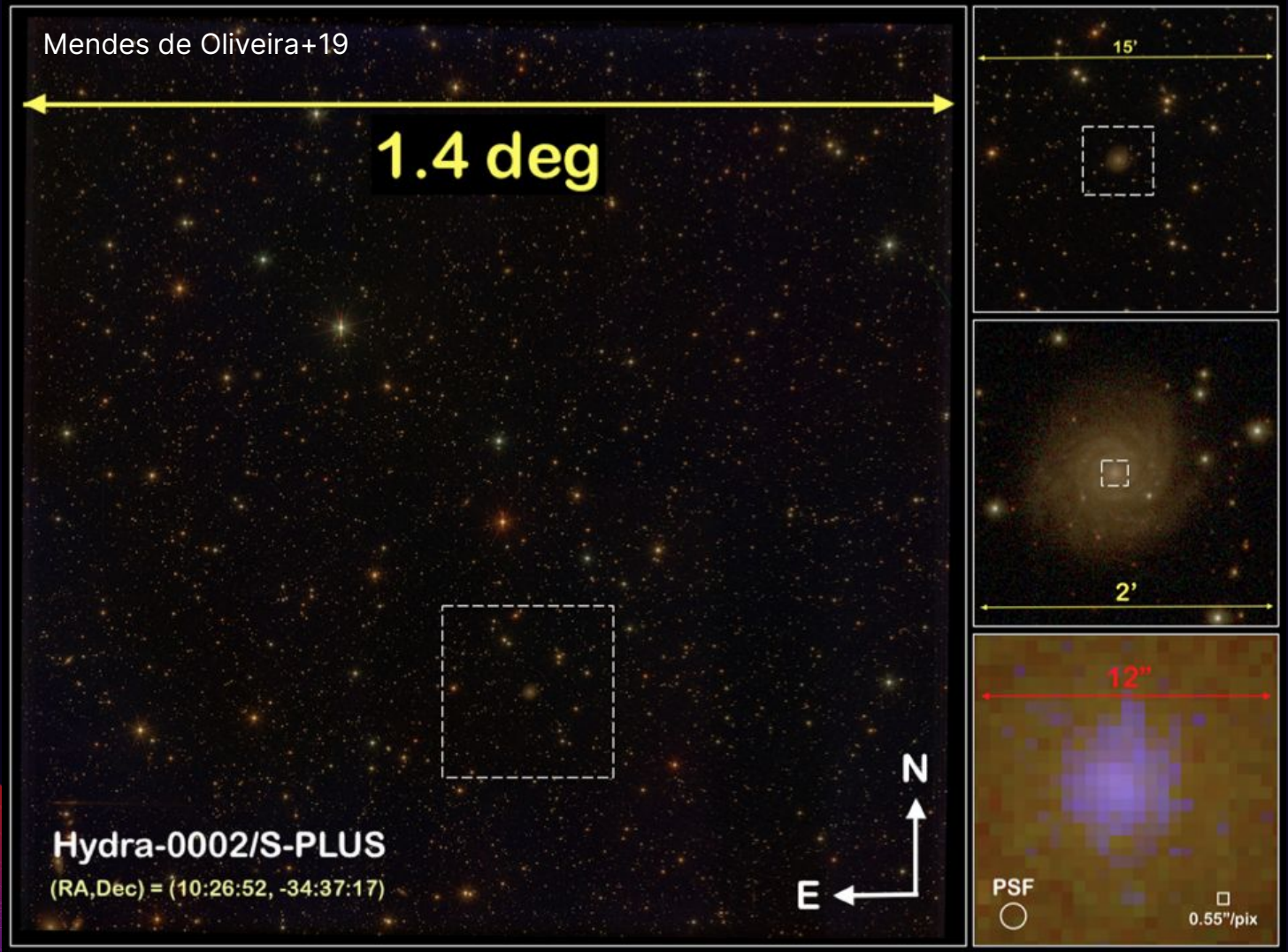
Telescope: 80-cm telescope (T80S)

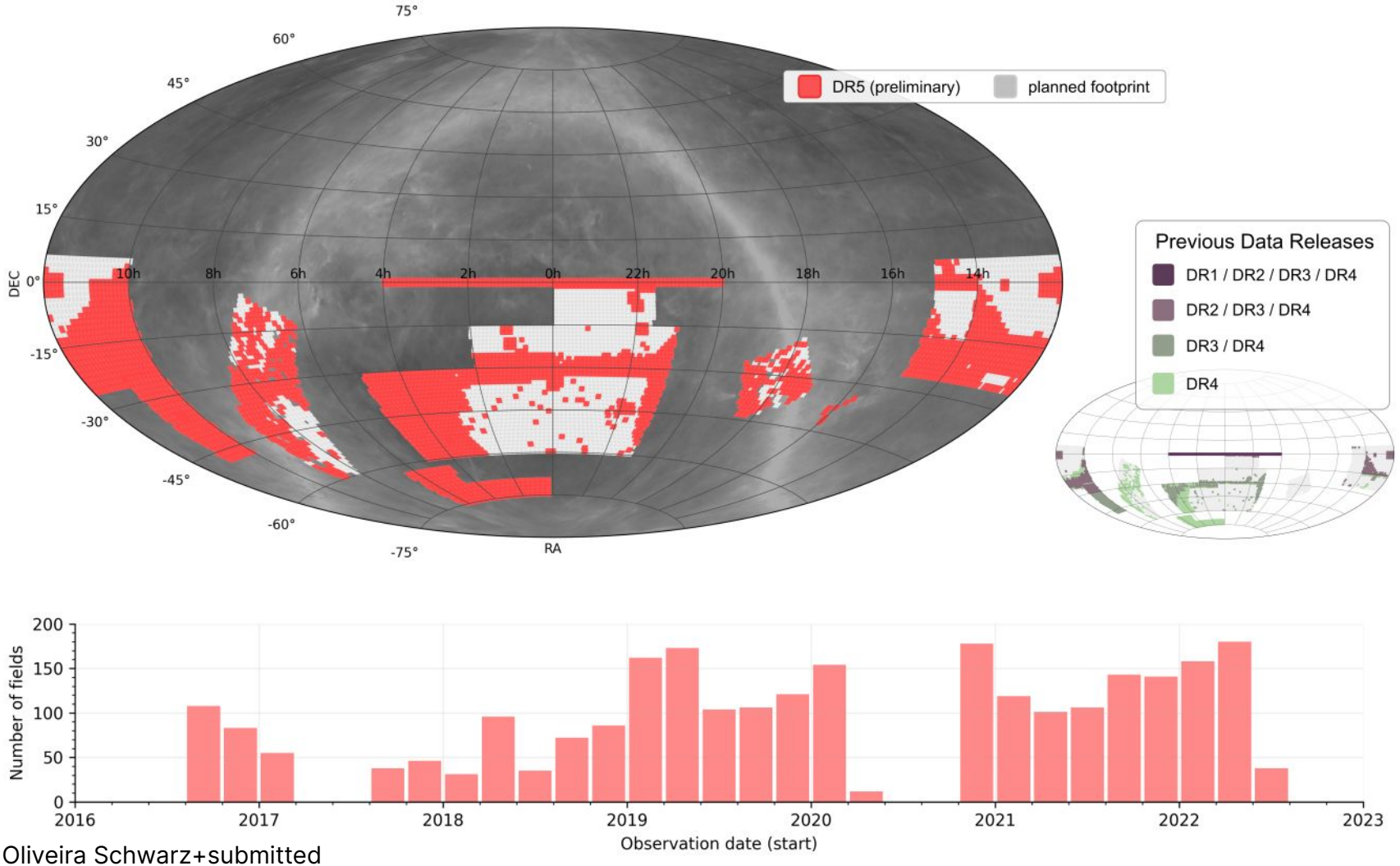
Pixel scale: 0.55"/pix

FoV: 1.4×1.4 deg^2

Cerro Tololo Inter-American Observatory, Chile

T80-South


Mendes de Oliveira+19
1.4 deg
15'
2'
12"
Hydra-0002/S-PLUS
(RA,Dec) = (10:26:52, -34:37:17)
N
E
PSF
0.55"/pix



Oliveira Schwarz+submitted

S-PLUS data flow

Observations

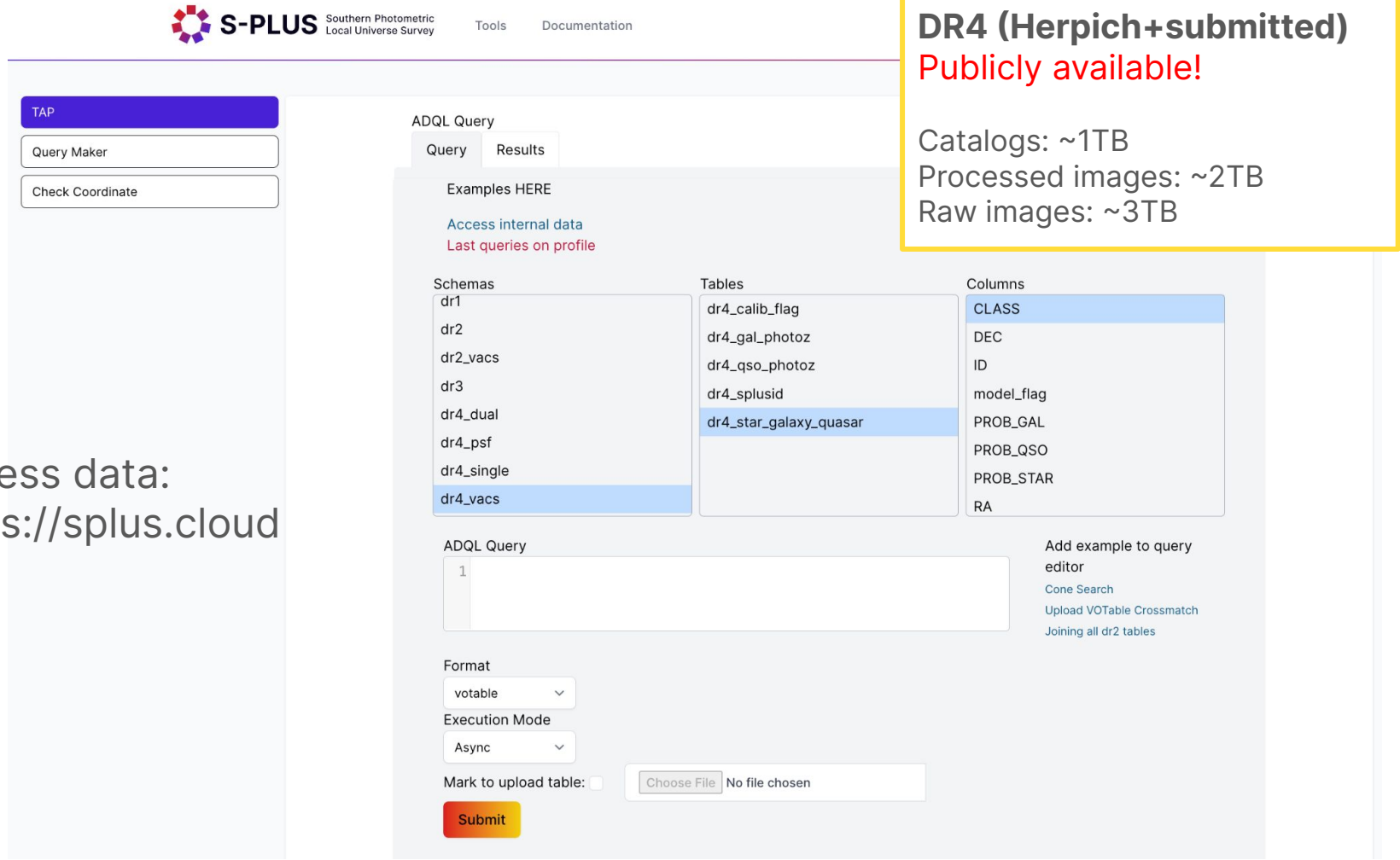
Reduction

Photometry

Photometric Calibration

Catalogs

Value Added Catalogs



DR4 (Herpich+submitted)
Publicly available!

Catalogs: ~1TB
Processed images: ~2TB
Raw images: ~3TB

Access data:
https://splus.cloud

S-PLUS

Search for rare objects/events with S-PLUS

- Quasars (Nakazono+21, Nakazono & Valença+submitted)
- Short-period white dwarfs (Ferreira Lopes+in prep)
- Supernovae (Santos+24)
- Interacting Galaxies (Oliveira Schwarz+22)
- Metal-poor stars in the Milky Way (Placco+22, Placco+21)
- Planetary Nebulae (Gutierrez-Soto+20)

Search for quasars

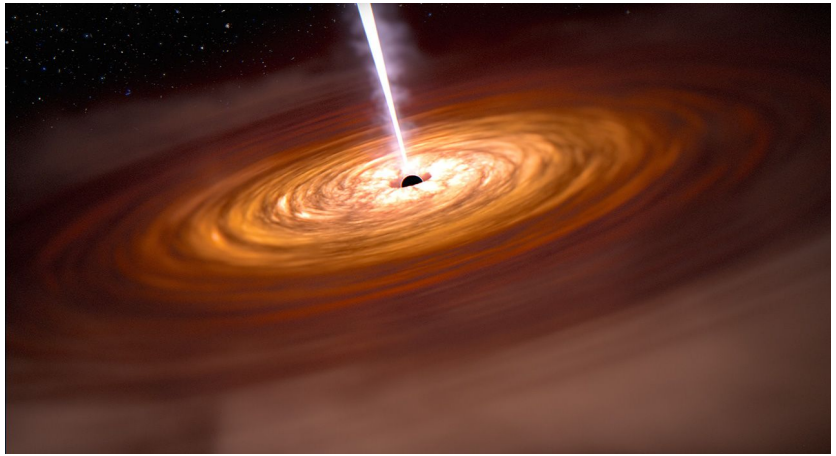


Illustration of a quasar
Credit: NASA, ESA, CSA, Joseph Olmsted (STScI)

Search for quasars

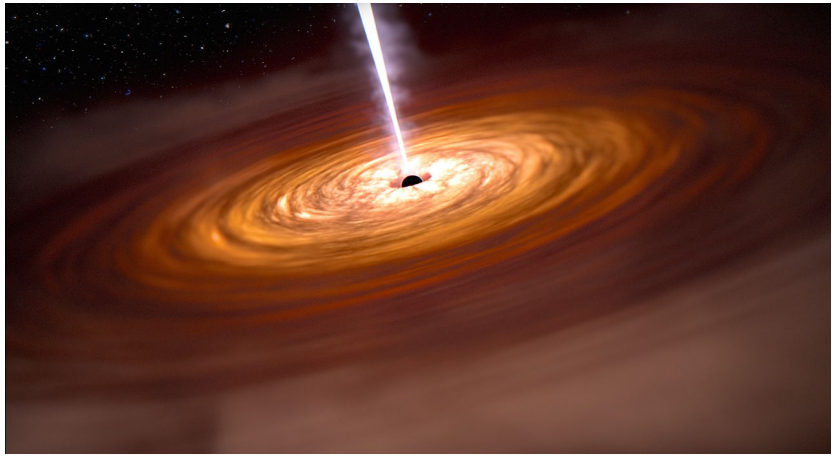
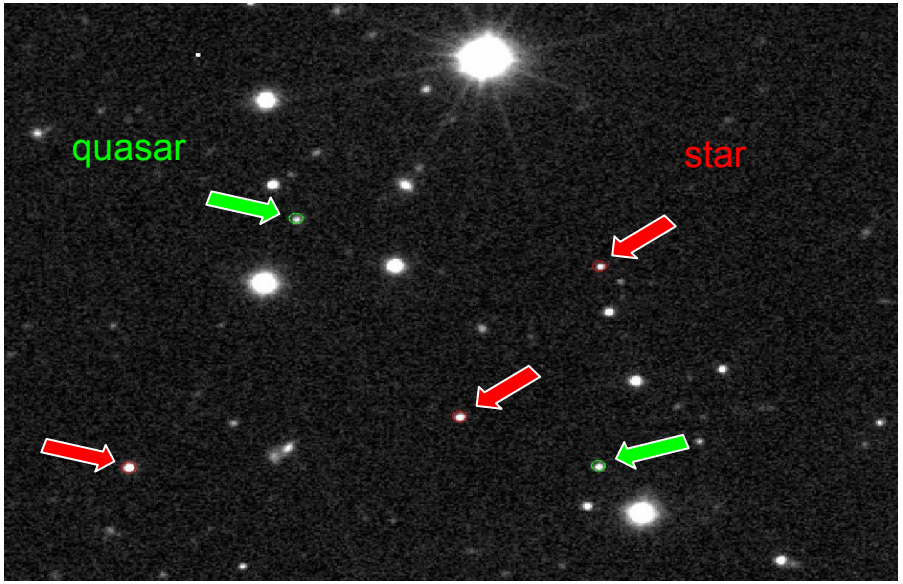


Illustration of a quasar
Credit: NASA, ESA, CSA, Joseph Olmsted (STScI)

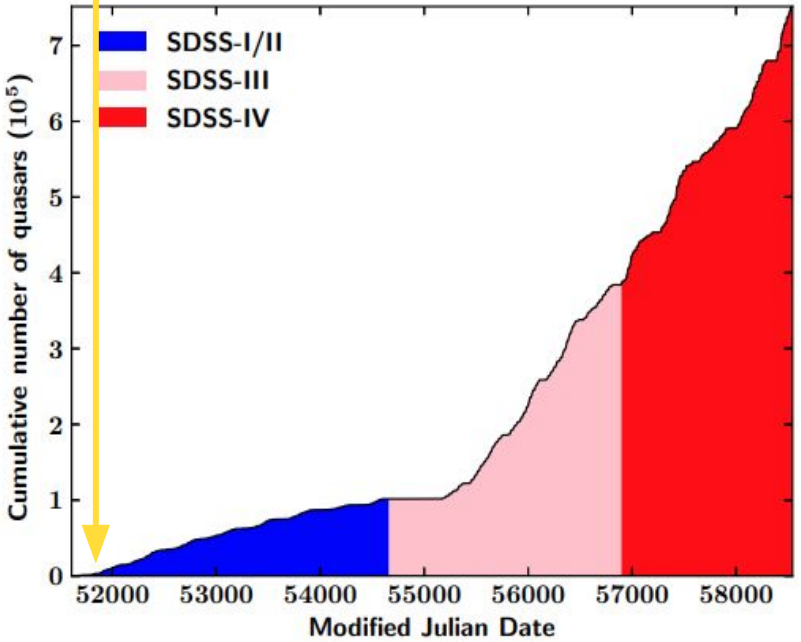


Small area of a single-band observation from S-PLUS
Confirmed quasars and stars are pointed out in green and red, respectively.

Search for quasars

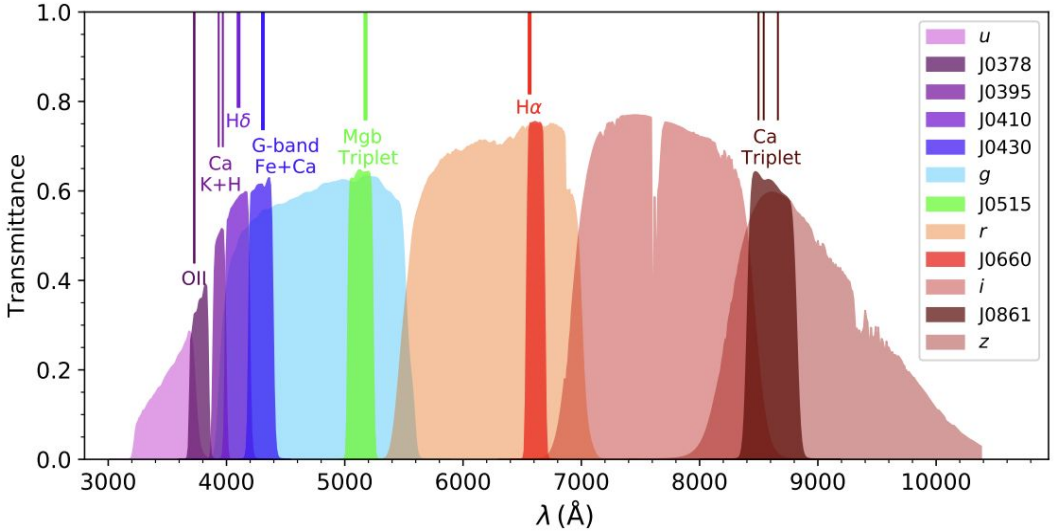
- The first quasar was discovered in 1963 by Marteen Schmidt
- The Sloan Digital Sky Survey (SDSS) was responsible for ~**750k** new spectroscopic confirmations
- However, a great majority was observed in the Northern Hemisphere and the Southern Hemisphere is scarcely observed

SDSS DR16Q (Lyke+20)

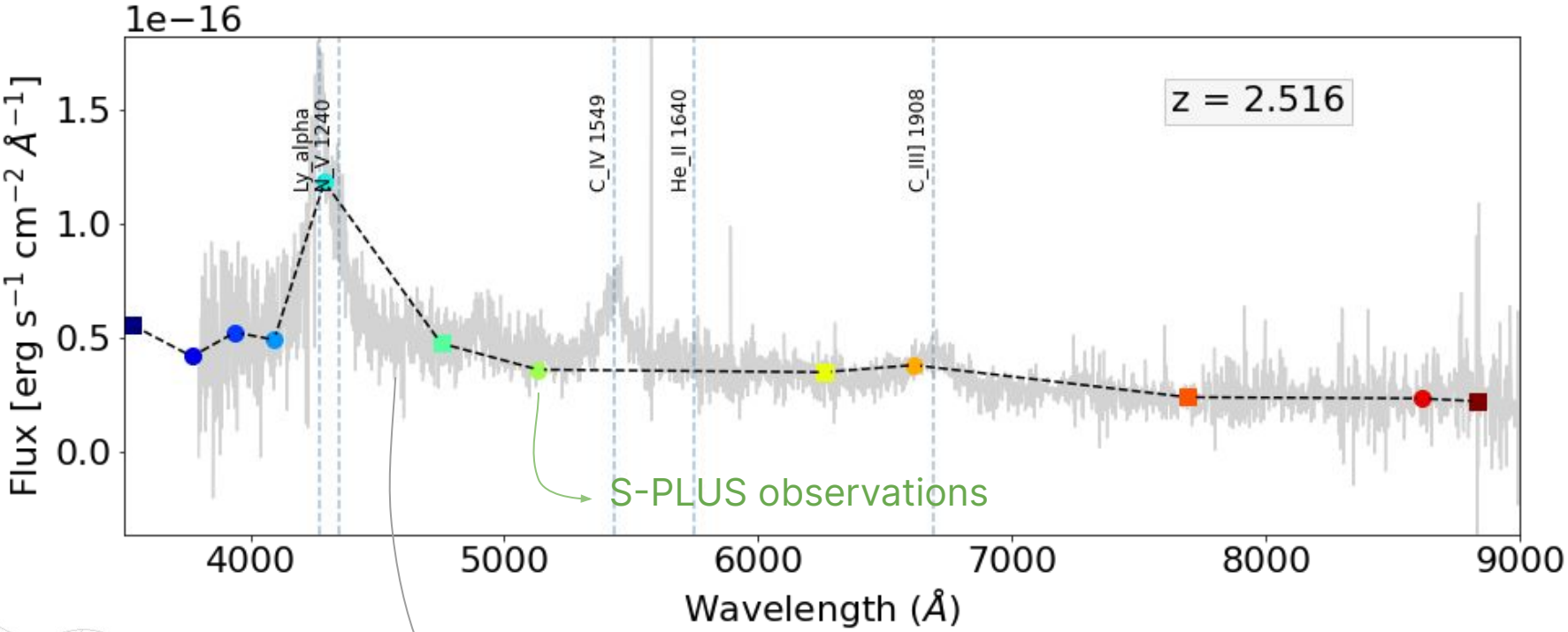


S-PLUS

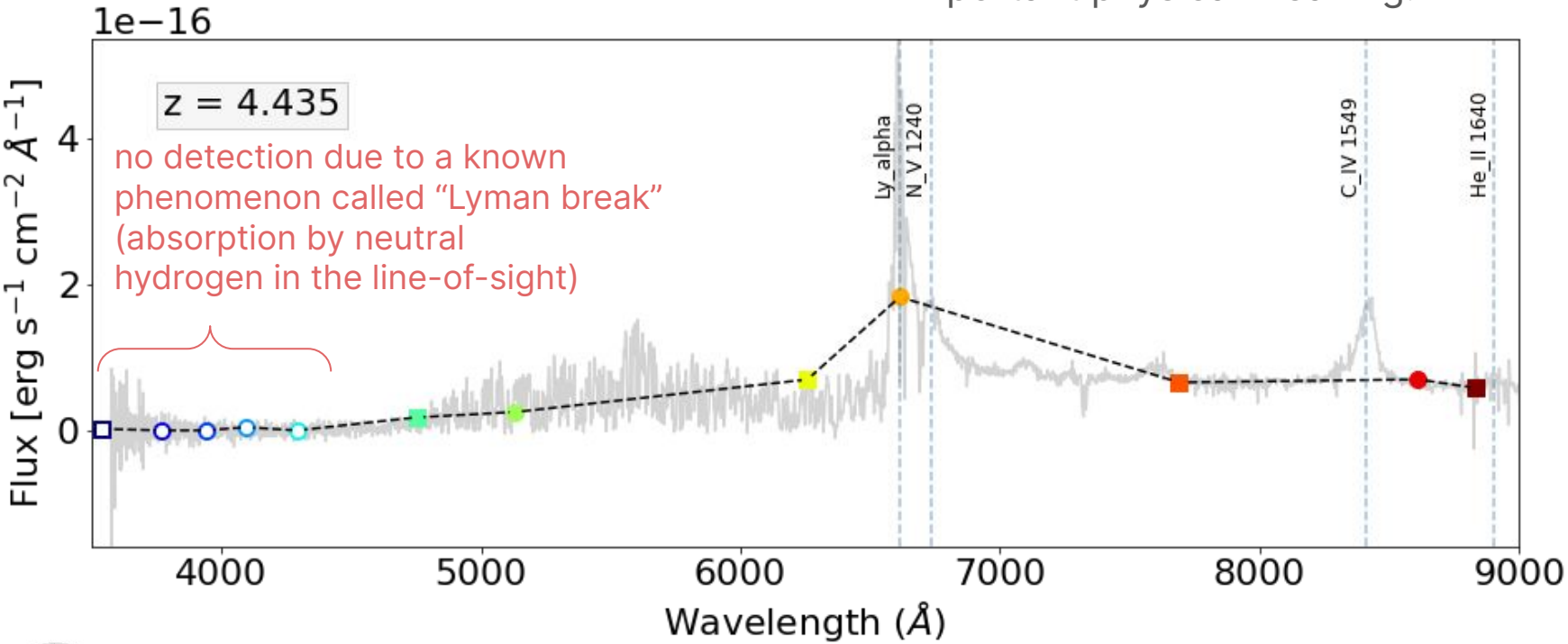
The 12-band filter system



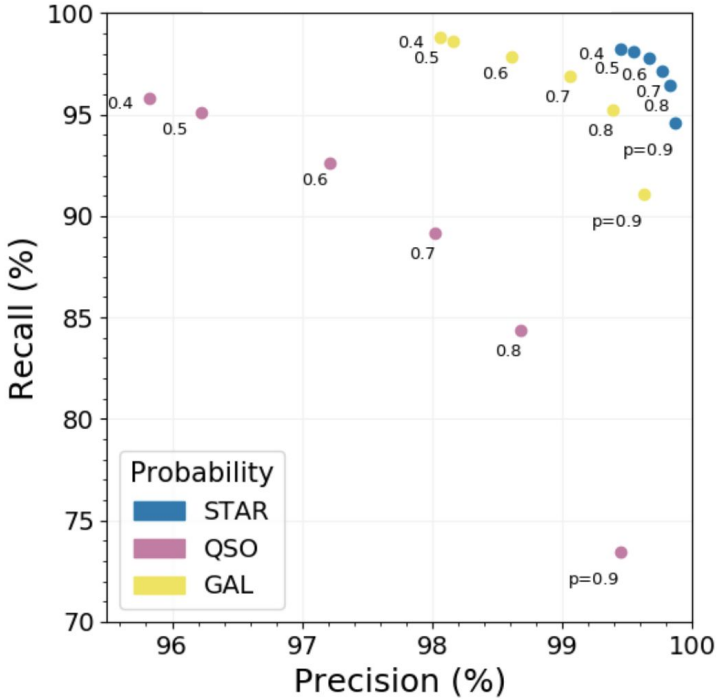
Almeida-Fernandes+22

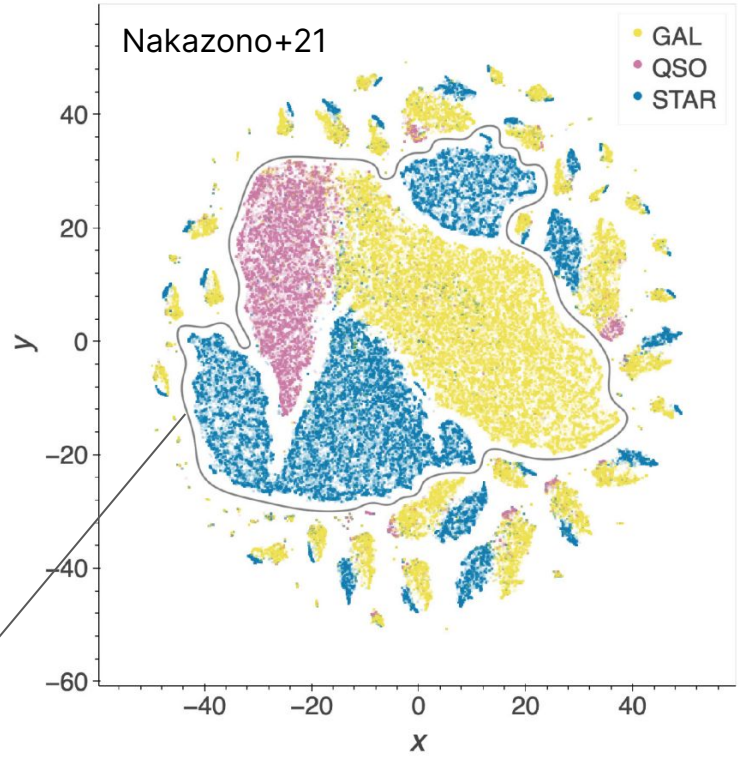

1e−16
Flux [erg s^{-1} cm^{-2} Å^{-1}]
1.5
1.0
0.5
0.0
Ly_alpha
N_V 1240
C_IV 1549
He_II 1640
C_III] 1908
z = 2.516
4000
5000
6000
7000
8000
9000
Wavelength (Å)
S-PLUS observations
spectrum from Sloan Digital Sky Survey

Some missing-band values have important physical meaning!



Star/galaxy/quasar classifier (supervised learning)





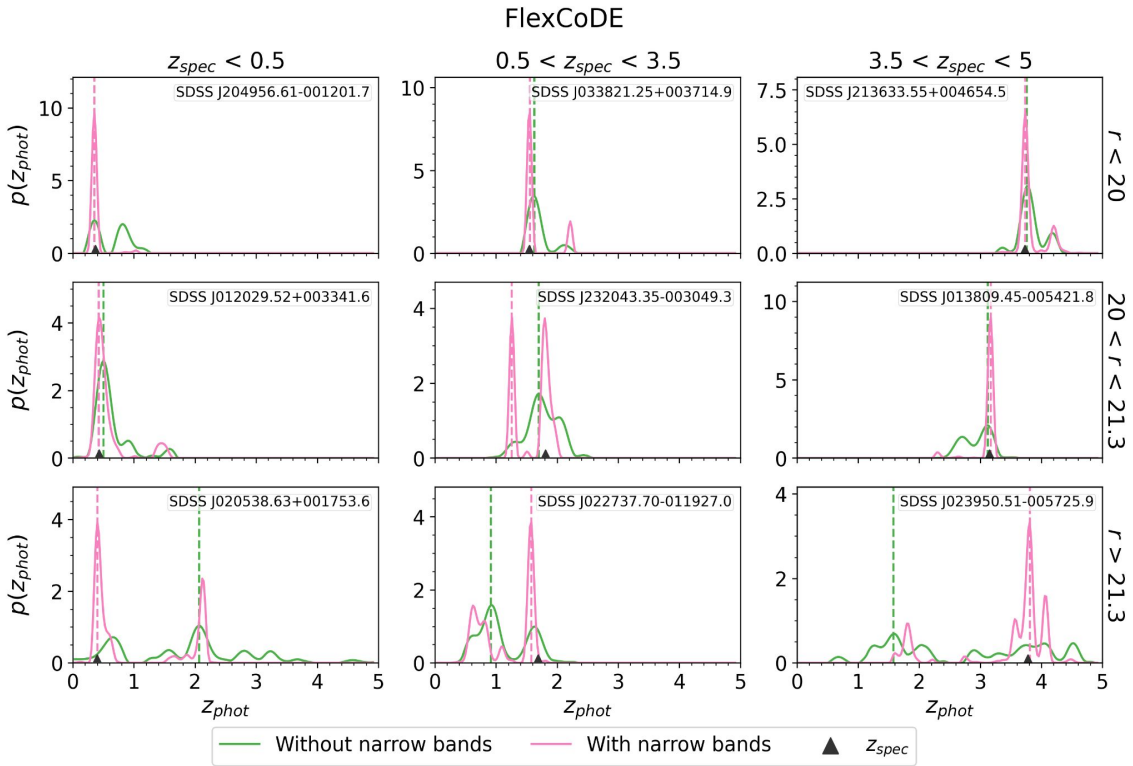
Sources with no missing-band values

Estimating redshifts (supervised learning)

- Redshifts have a direct relationship with physical distances (given a certain cosmological model)
- One of the ML models that we trained is FlexCoDE (Izbicki & Lee, 2017) to obtain conditional density estimates:

$$\hat{f}(z|\mathbf{x}) = \sum_{i=1}^{I} \hat{\beta}_i(\mathbf{x})\phi_i(z)$$

- We provide a catalog containing 258k quasar candidates with 90% classification probability over 3000 deg^2

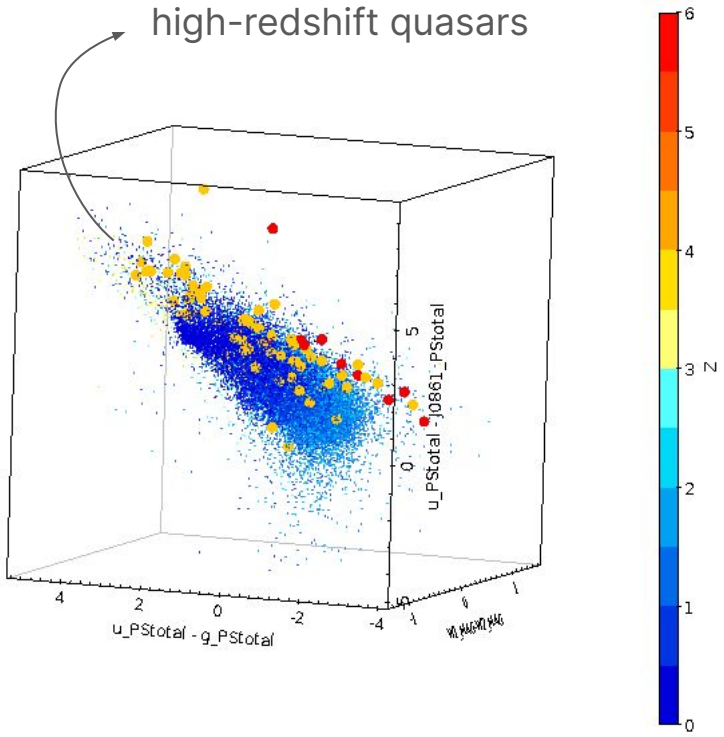


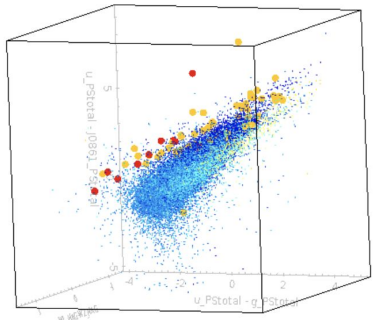
Nakazono & Valença+
(Submitted yesterday! Stay tuned)

Search for very distant quasars

- Flesch, 2023
  Only ~800 known sources with z > 5,
  246 in the Southern Hemisphere
  (Dec<-1.25°)

- Bright high-redshift quasars are even more scarce!



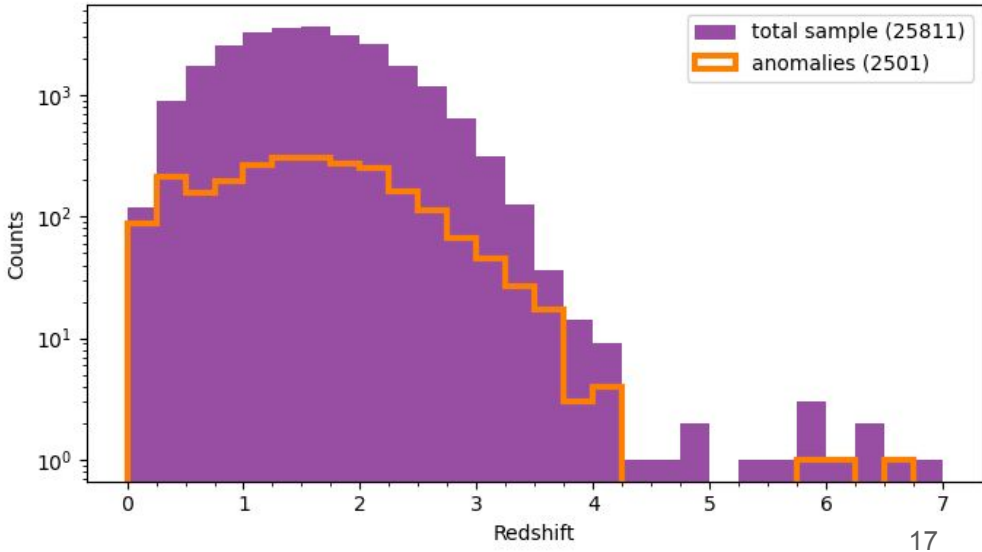


(view from another angle)

S-PLUS

Search for very distant quasars (preliminary!)

Interval	Flagged as an anomaly (Isolation Forest)	Per total in bin
3 < z < 4	87	18%
4 < z < 5	4	31%
5 < z < 6	1	20%
6 < z < 7	2	40%



Follow-up of transients with T80S

As the S-PLUS main survey move forward, more vacant observing time is available. Call for proposals are opened every year for members of the collaboration

- **Target of Opportunity (ToO)**: High-priority targets can be assigned anytime during the year.

- **Variability Follow-up (Var)**: Follow-up target for variability or other science requiring this observation form.

- **Priority Science Targets (PST)**: Targets presenting high impact potential for science and/or needed for dissertation/thesis.

S-PLUS

19th Collaboration Meeting
19-21 August 2024
Rio de Janeiro, Brazil

If you want to join the collaboration, look after me during lunch/coffee break!

S-PLUS

Thank you

I am looking for a postdoctoral position!

Email: lilianne.nakazono@gmail.com

Website: https://marixko.github.io

S-PLUS info: https://www.splus.iag.usp.br

Data access: https://splus.cloud

TAKE-HOME MESSAGES

Currently we have ~2TB of image data and ~1TB of catalog data in DR4, **publicly available**!

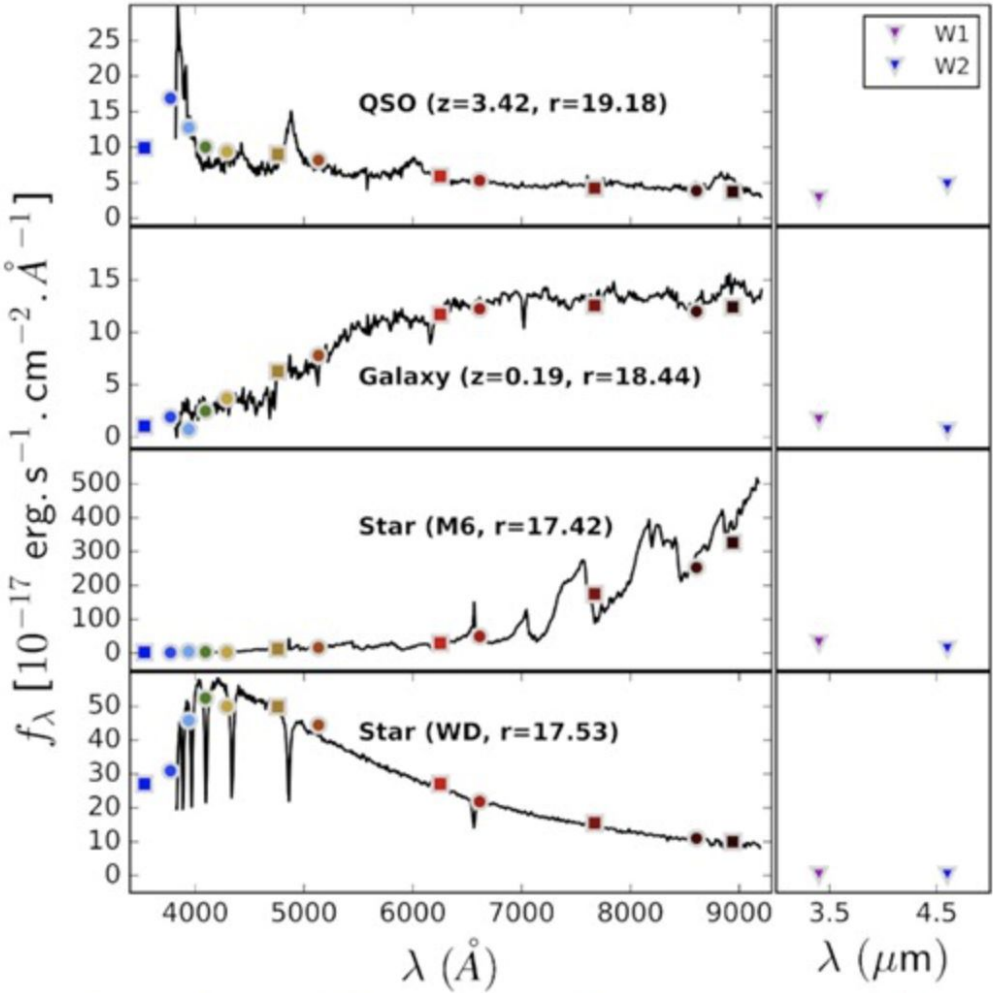
S-PLUS' facility (T80S) can provide low-resolution spectral energy distribution for a **quick** alert follow-up

There are many science cases that are feasible with S-PLUS that could take advantage of anomaly detection techniques

S-PLUS Southern Photometric Local Universe Survey

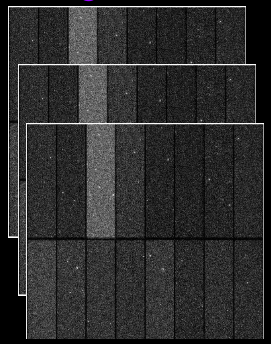
Extra slides

Nakazono+21

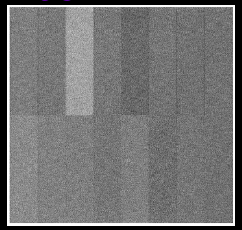

QSO (z=3.42, r=19.18)
Galaxy (z=0.19, r=18.44)
Star (M6, r=17.42)
Star (WD, r=17.53)
W1
W2
f_λ [10^{-17} erg.s^{-1}.cm^{-2}.Å^{-1}]
λ (Å)
λ (μm)

S-PLUS data flow

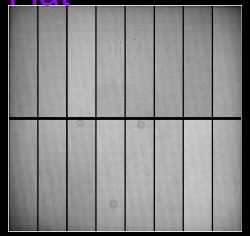
Individual images



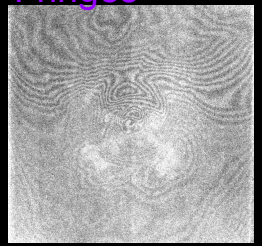
Bias



Flat



Fringes



Coadded image

Observations

Reduction

Photometry

Photometric Calibration

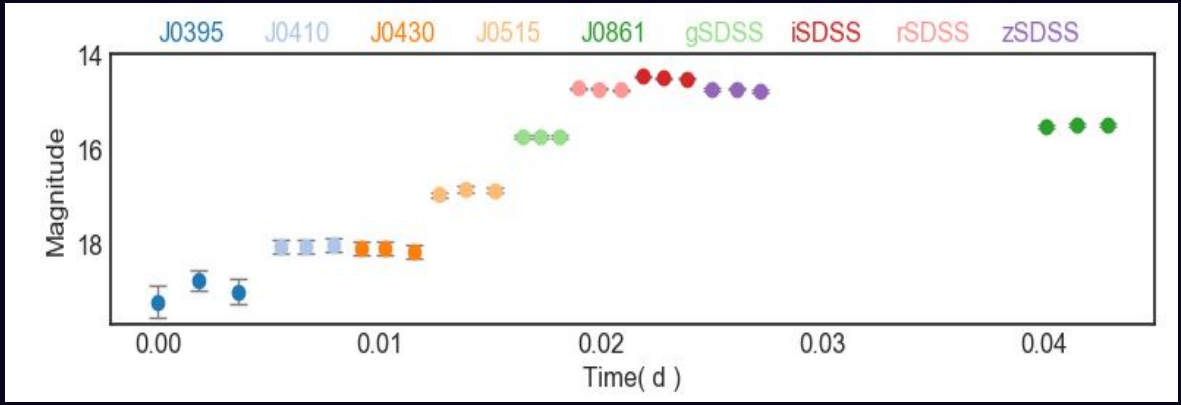
Catalogs

Value Added Catalogs

Time-domain science

Is analysis of variability possible with the S-PLUS main survey?

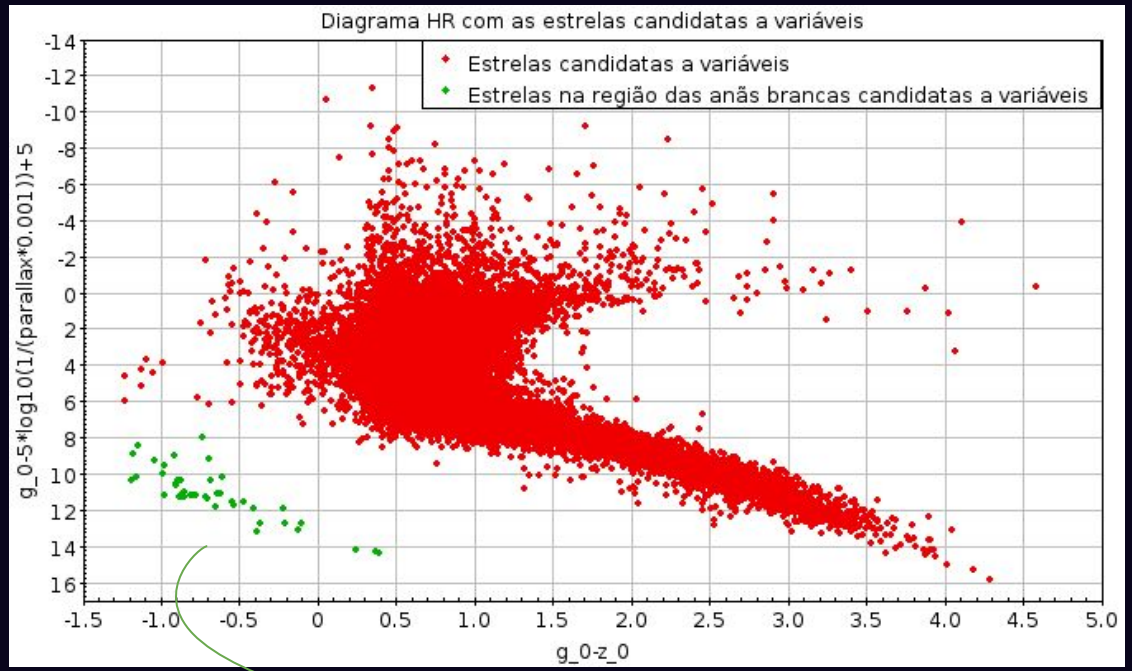
- 3 exposured for each filter → 36 individual images
- Total period of ~1.5 hours (~0.06 days)



Light curve of a star obtained with the S-PLUS individual images.

This slide is courtesy from Liana Li (adapted from Portuguese to English for AISSAI)

Selection of pulsating white dwarf candidates in S-PLUS DR4

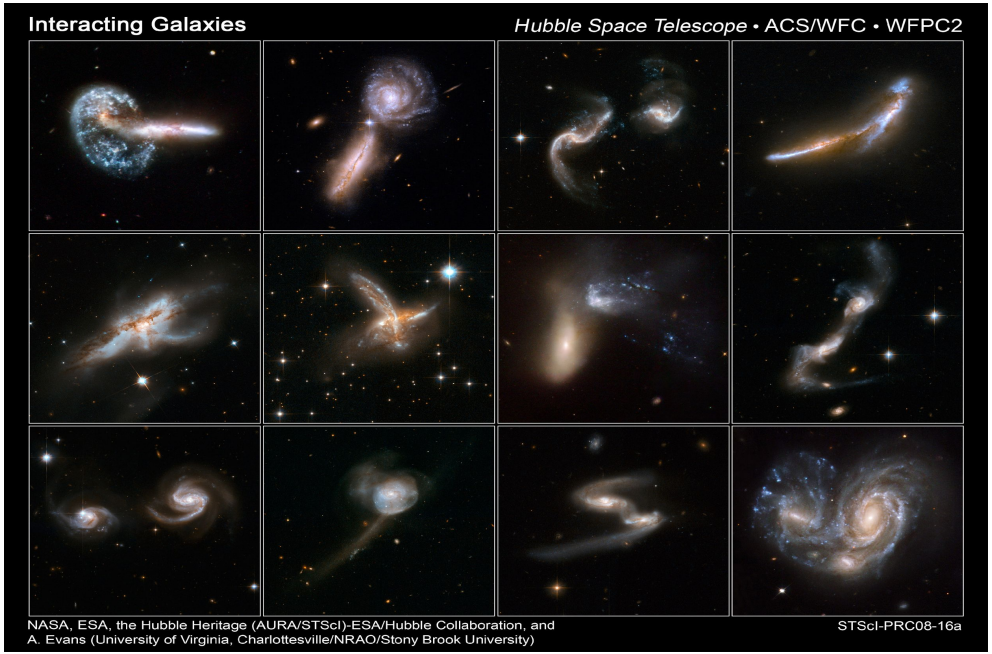


42 candidates obtained through their locus at the HR diagram

This slide is courtesy from Liana Li (adapted from Portuguese to English for AISSAI)

Galaxy collisions are rare in the local universe – but were frequent at high z

Collision rate is thought to be about 1% in the local universe



Interactions happened much more often in the early universe (40% by z=1)

This slide is courtesy from Claudia Mendes de Oliveira