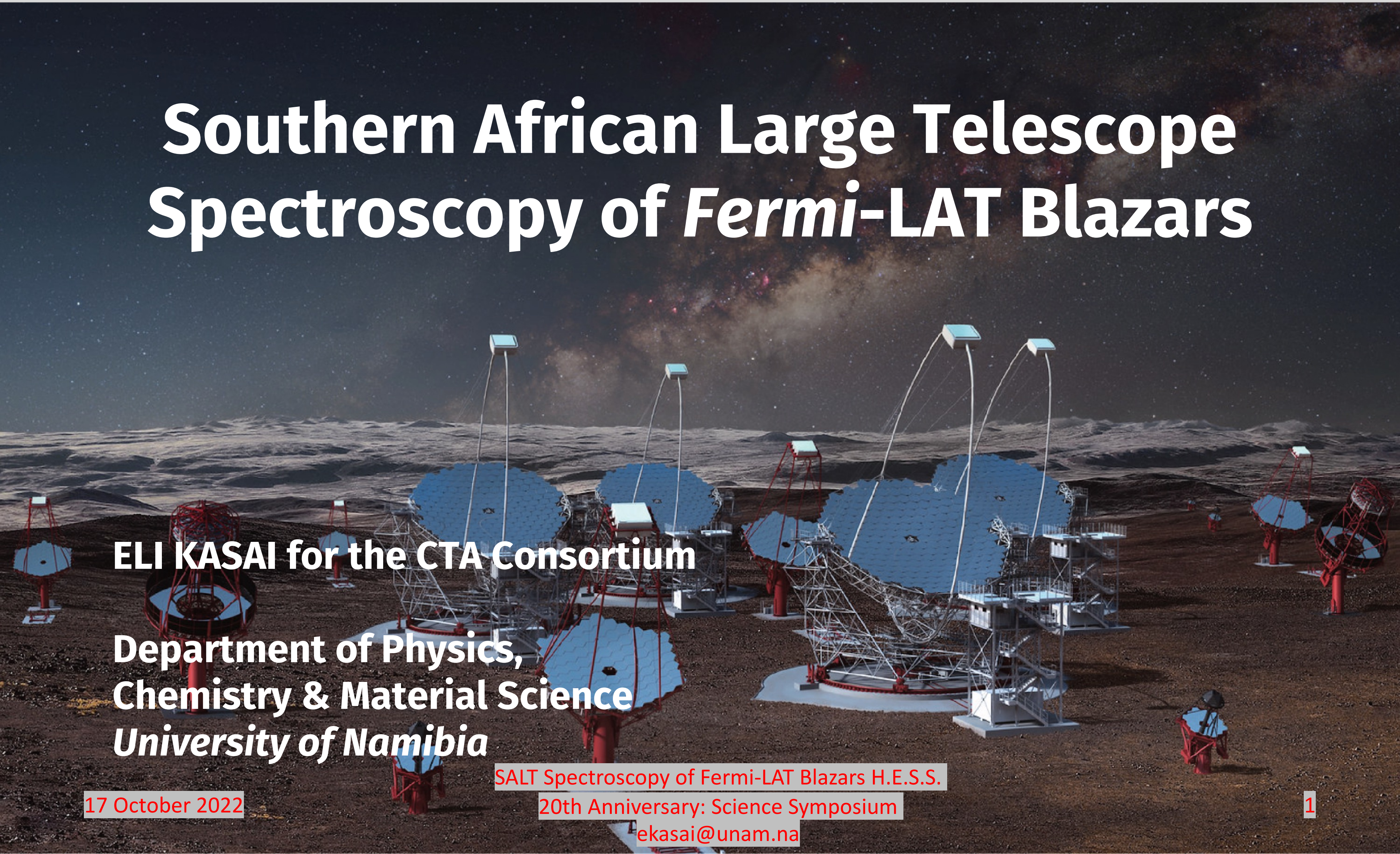

Southern African Large Telescope Spectroscopy of *Fermi*-LAT Blazars

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Outline

- Overview of CTA Redshift Task Force
- Motivation for the SALT redshift program of *Fermi*-LAT blazars
- Sample selection
- Observing strategy
- SALT Robert Stobie Spectrograph observations
- Results
- Summary & future work

Overview of CTA Redshift Task Force: Observational Campaigns

SPECTROSCOPY

Telescope	Mirror size (m)	Spectrograph	λ coverage (Å)	λ / Δλ
SALT	11	RSS	4500 - 7500	~ 1000
Keck-II	10	ESI	3900 – 10000	~ 10000
ESO/NTT	3.5	EFOSC2	3860 – 8070	~ 500
Shane-3m	3	KAST double (B)	3500 – 5600	~ 1000
Shane-3m	3	KAST double (R)	5400 – 8000	~ 1500
ESO/VLT	8.2	FORS2	3300 – 11000	260 - 1600
GTC	10.4	OSIRIS	3650 - 10000	300 - 2500

PHOTOMETRY

- NOT (ALFOSC)
- SOAR (SAM)
- Gemini (GMOS)

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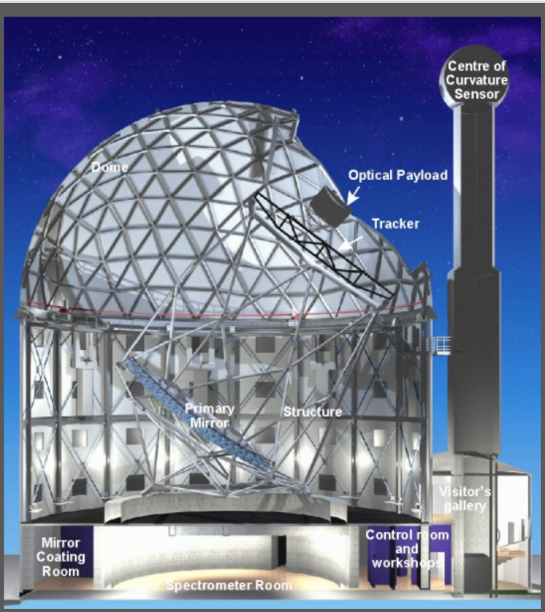
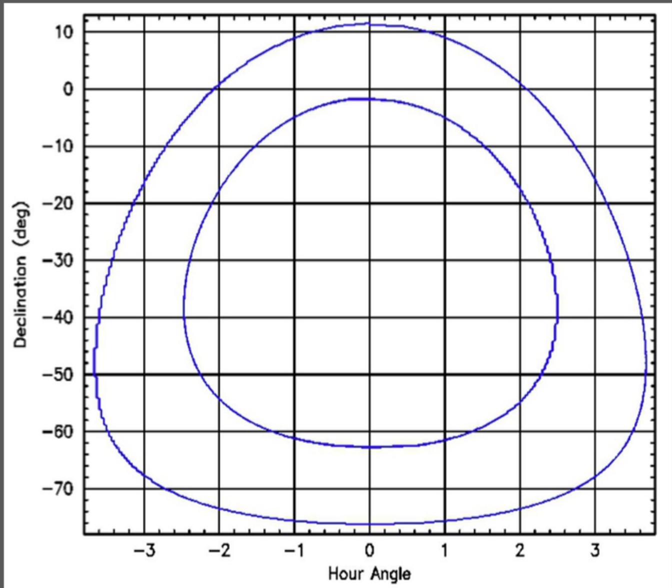
Brief overview of the Southern African Large Telescope (SALT)

- Location: Sutherland Observatory, 32.4° S, 20.8° E
- Altitude: 1.798 m a.s.l
- Observations conducted at declinations between +10° and -80°





SALT visibility window

- Sources must be within the annular region to be observed
- Objects in equatorial zones have longer annulus crossing times
- Instruments:
  - **Robert Stobie Spectrograph: Long-slit**, MOS, Spectropolarimetry, Fabry-Perot

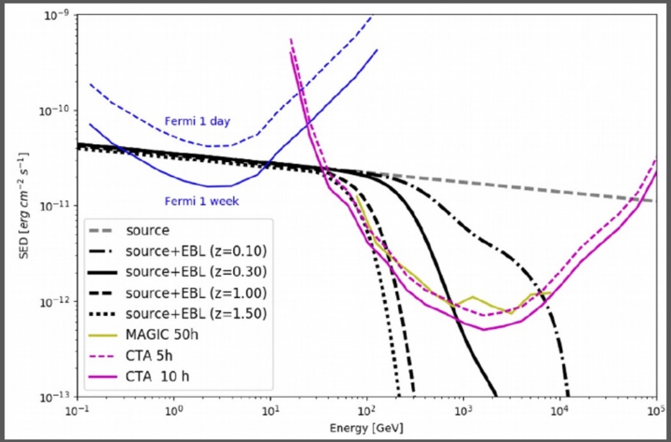
Motivation for the SALT redshift program of *Fermi*-LAT blazars

The primary motivation is to

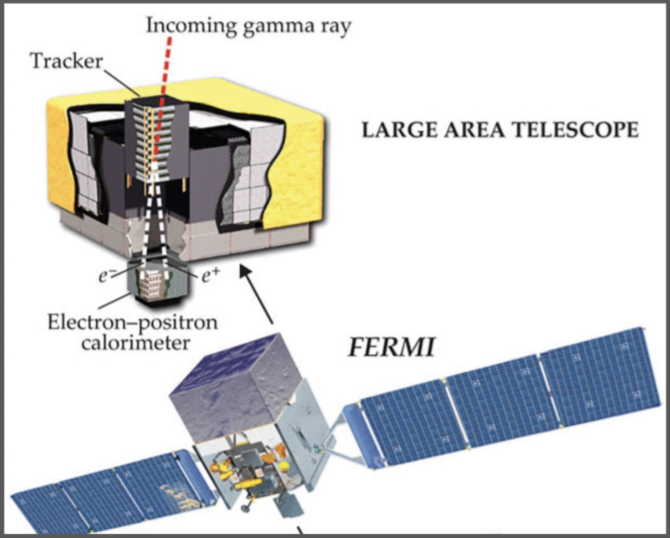
- compile a special blazar sample with redshifts for the CTA observations
  - VHE BL Lacs cosmological evolution studies
  - Constrain the EBL density
  - Constrain the photo-axion coupling theories

Redshifts are also crucial to the *Fermi*-LAT collaboration science objectives (Atwood et al. 2009):

- Resolving the gamma-ray sky
- Understanding the particle acceleration mechanisms
- Studying the high-energy behaviour of GRBs and transients
- Probing the nature of DM
- Probing the early universe



SED simulation for a distant blazar
credit: J. Becerra González



credit: D. J. Thompson et al. 2012

Sample selection

1. The focus is on 1040 BL Lacs and BCUs from the 3FHL catalogue, of which only 373 have a known redshift.

2. MC simulations were performed using Gammapy to estimate the minimum CTA 5σ detection observation time.

3. The resultant 221 sources detectable in under 50 hours by CTA underwent a second phase of MC simulations, after revision of 32 redshifts, leading to 165 sources detectable at 5σ in under 30 hours.

Observing strategy

- The goal is to search for the stellar absorption features of the host galaxy

- As the host galaxies are usually luminous ellipticals (Urry et al. 2000), the main features that we expect are the:

  1. CaHK doublet
  2. Mgb
  3. NaID

- We also search for the emission lines such as [O II], [O III], Hα and [N II]

- In both cases, we expect to measure feature equivalent widths EWs $\lesssim 5$ Å and, to achieve this, we require that each spectrum has
  1. a spectral resolution $\lambda/\Delta\lambda \sim 1000$ or higher
  2. an average S/N ratio of ~ 100 (or higher) per pixel

Observing strategy (continued)

- If we do not have both these properties, we choose an instrument configuration that allows us to obtain at least one of them.

- We look for the previous spectroscopic results and evidence of extension in the literature, e.g. 2MASX catalogue, and classify the results as high- or low-priority targets:

  1. high-priority target: source has a low S/N spectrum and a tentative redshift
  2. low-priority target: source has at least one deep and featureless spectrum and/ or is not extended

- For low-priority targets, we have decided to trigger spectroscopic observations during periods of low optical activity.

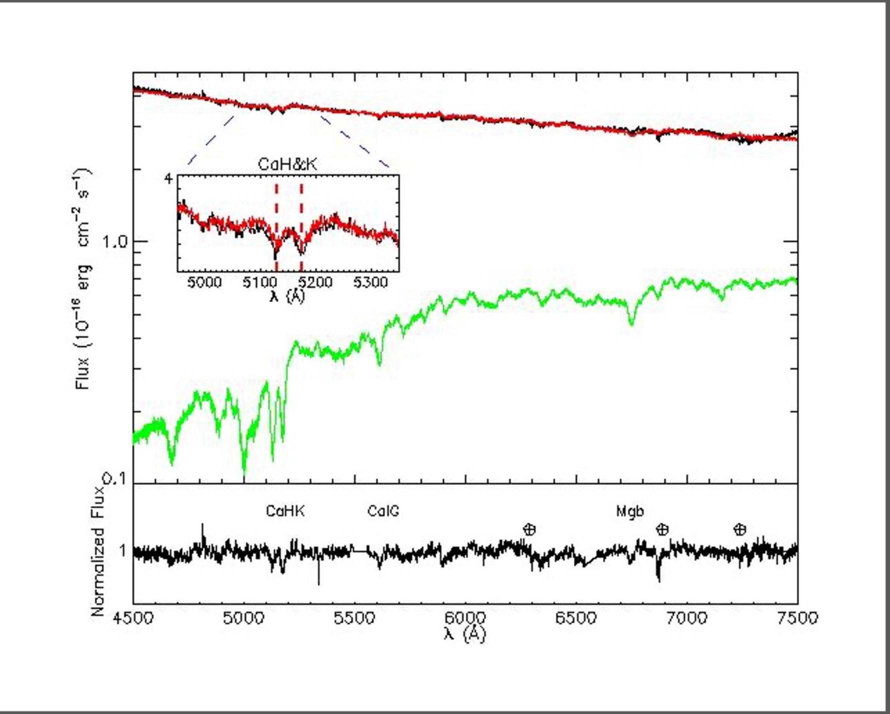
SALT Robert Stobie Spectrograph (RSS) observations

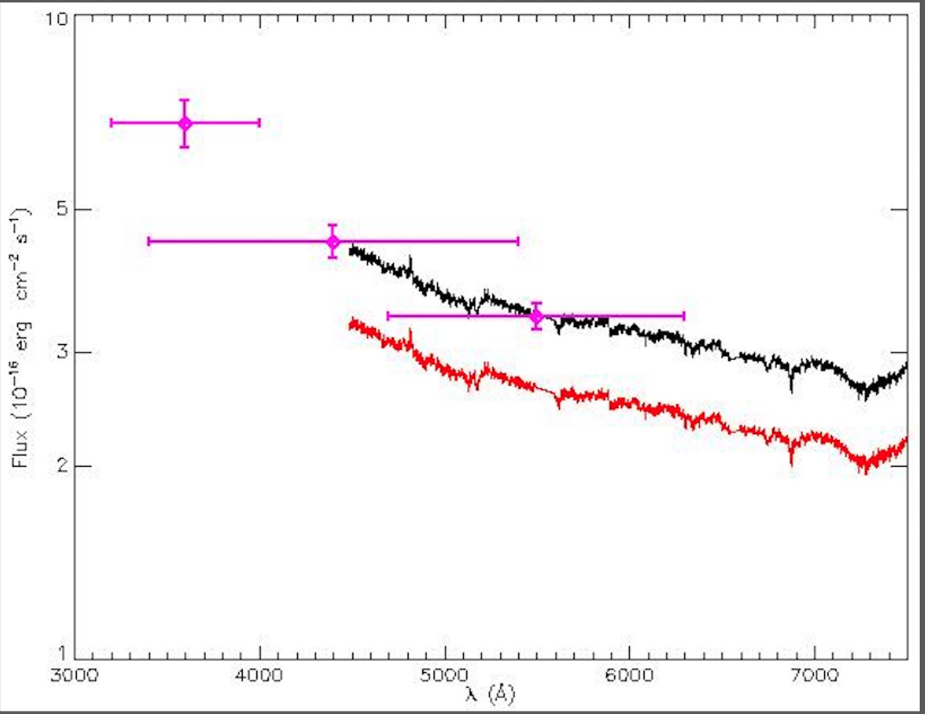
- Our spectral observations are conducted with the **RSS in long-slit mode** with a slit width of 2” and a PG0900 grating.
- The above configuration results in a **spectral range of ~4500 to ~7500 Å**, with a throughput of > 20 %.
- From **November 2019 to February 2022**, we have observed a total of **24 BL Lacs**.
- Out of the 24, **two turned out to be too faint to obtain sufficient S/N**. We determined redshifts for 10, i.e. 45% success rate.
- Spectral features could not be detected for the rest.

Southern African Large Telescope

Some results

1RXS J015658.6−530208, $z = 0.3043 \pm 0.0004$

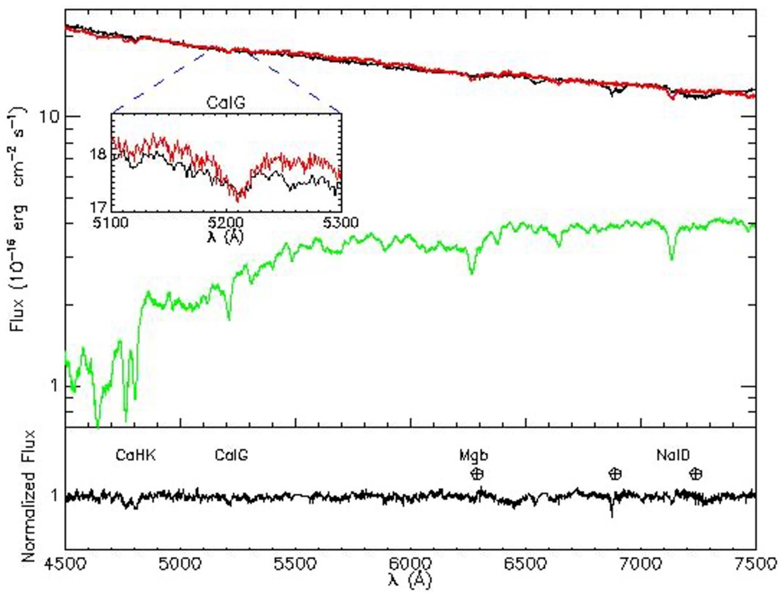


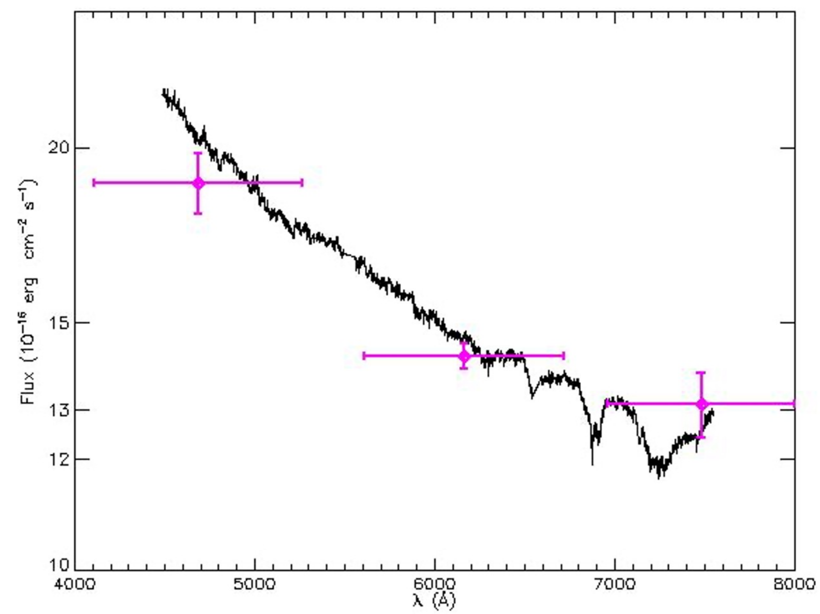


Left: SALT/RSS spectrum from two observations in November 2019. ***Right:*** The same source spectrum in red and scaled (black) to match the average *Swift*/UVOT u, b, and v photometry. Goldoni et al. (2021)

Some results

1RXS J020922.2-522920, z = 0.2110 ± 0.0002

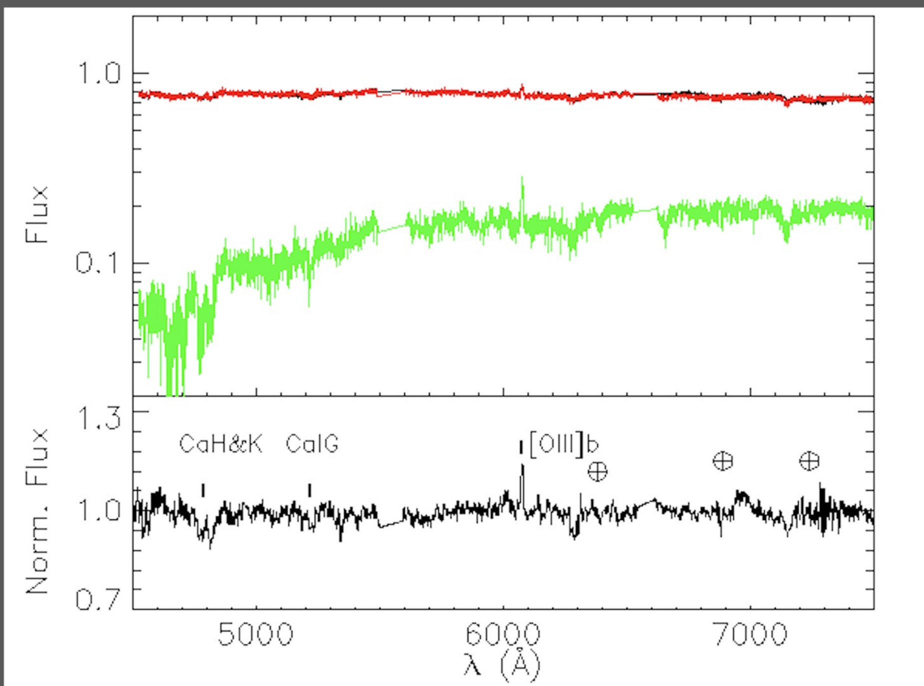




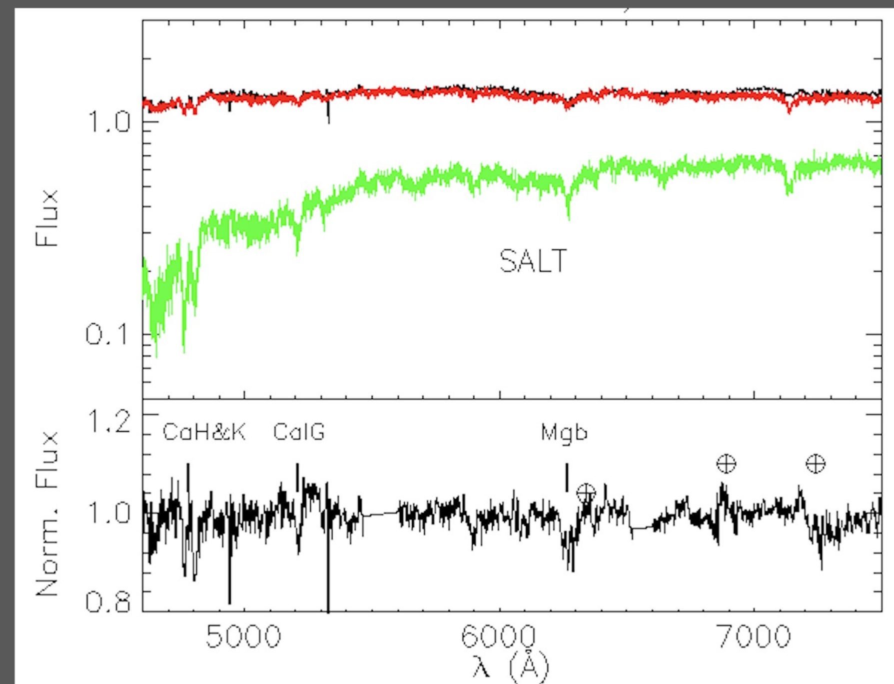
Left: SALT/RSS spectrum taken in December 2019. ***Right:*** The same source spectrum superimposed on the average REM/ROSS2 *g, r* and *i* photometric data points. Goldoni et al. (2021)

Some results

SUMMS J0500-4912
$z = 0.2129 \pm 0.0001$



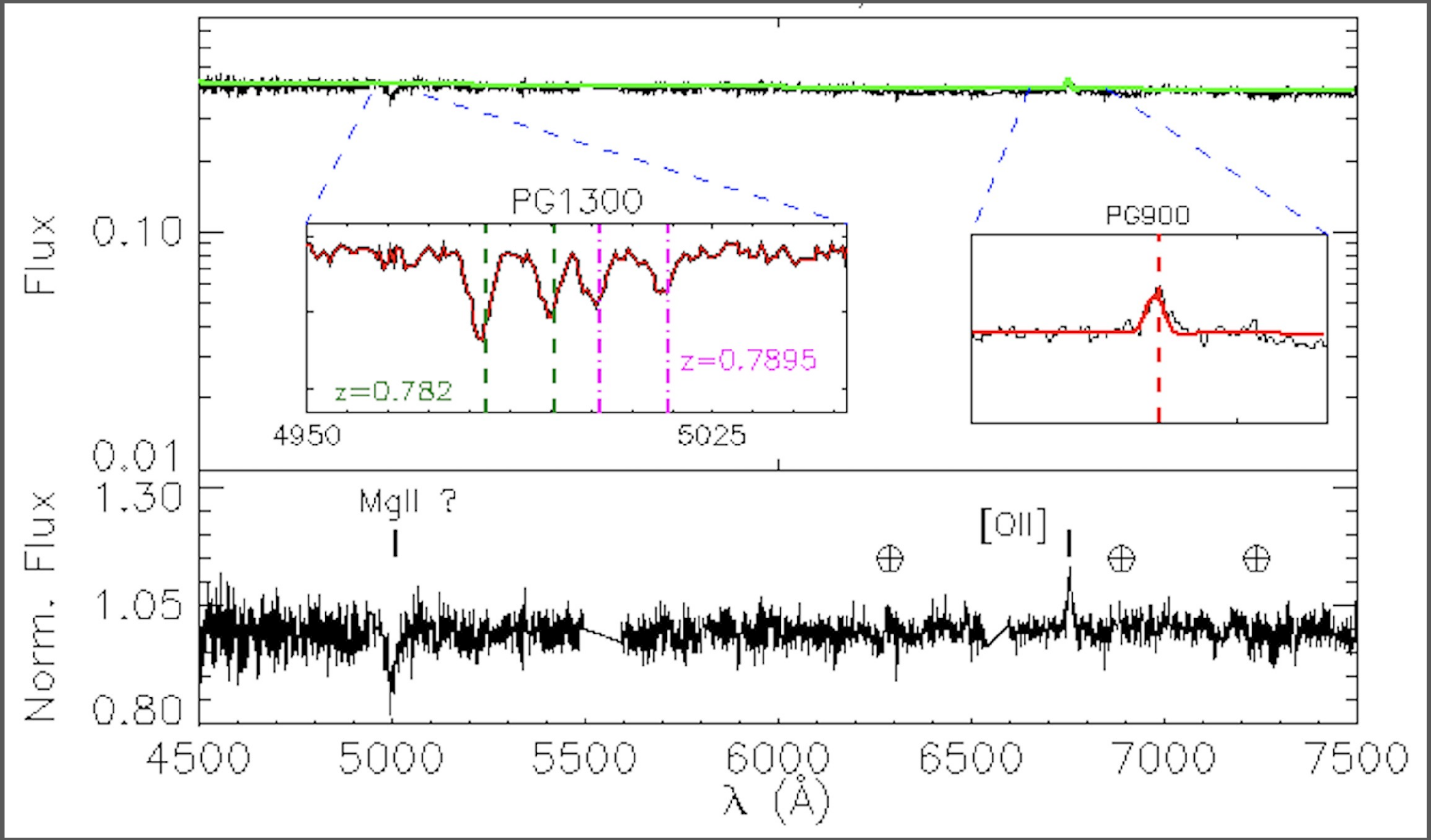
NVSS J125949-37485
$z = 0.2107 \pm 0.0002$



Left: SALT/RSS spectrum from two observations during January 2020. ***Right:*** SALT/RSS spectrum taken during May 2020. Kasai et al. (2022), submitted to MNRAS

Some results

PMN J2321-6438, z = 0.8126 ± 0.0002



SALT/RSS spectrum from three observations during September and October 2020.
Kasai et al. (2022), submitted to MNRAS

Summary & future work

- Over 90% of the spectra for 22 sources had reasonably good S/N (50 – 150).
- Despite this success, only about half of our spectra resulted in successful redshift measurements.
- For the sources we could not measure redshifts for, we successfully secured a ToO program on SALT to observe them during periods of low optical activity. Dedicated photometric monitoring programs are in place for this purpose.
- To conclude, the program “SALT Spectroscopy of *Fermi*-LAT Blazars” for the CTA project, involving institutions in Africa, Europe, North and South America is ongoing. **We have an approved multi-semester observing proposal on SALT, covering the period November 2022 to April 2024, in which we plan to obtain spectra for at least 15 sources.**