Synchrotron emission study of extreme blazars using *AstroSat*

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ICRC2021, 12 - 23 July, 2021

Blazars and extreme blazars

AGNs with the relativistic jet oriented towards the observer
Emission is non-thermal, highly variable & Doppler boosted.

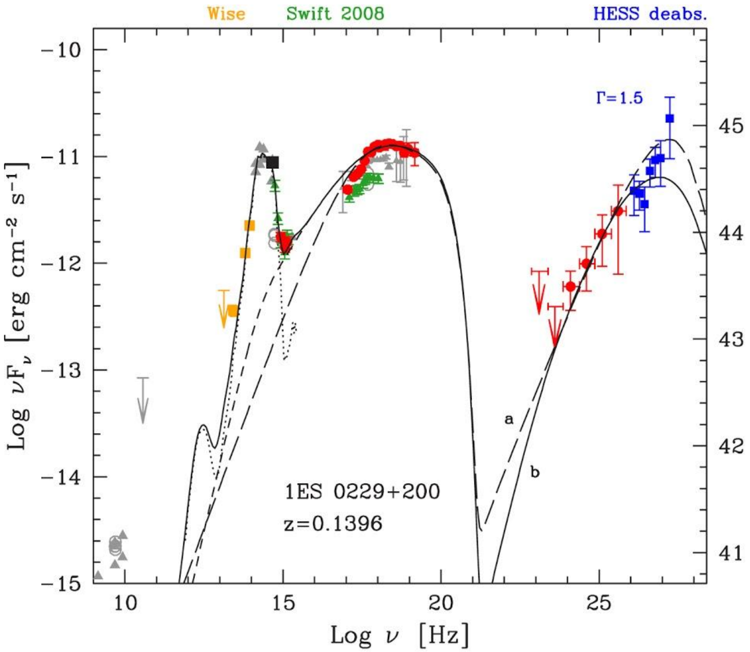
Broadband emission characterised by double-peaked SED
Viable mechanisms are: Synchrotron & inverse Compton.

The first peak falls in the range IR/optical to X-rays and the high energy peak at GeV/TeV energies.

What are Extreme HBLs (EHBLs) ?

➔ A new population of blazars

- Spectral properties:
  - ➢ Extreme synchrotron with $E_{p,syn}$ > 1keV
  - ➢ Extreme Compton with $E_{p,IC}$ > 1 TeV, Or both
  - ➢ Hard X-ray/TeV spectrum
- Relatively low luminosity as compared to FSRQ type



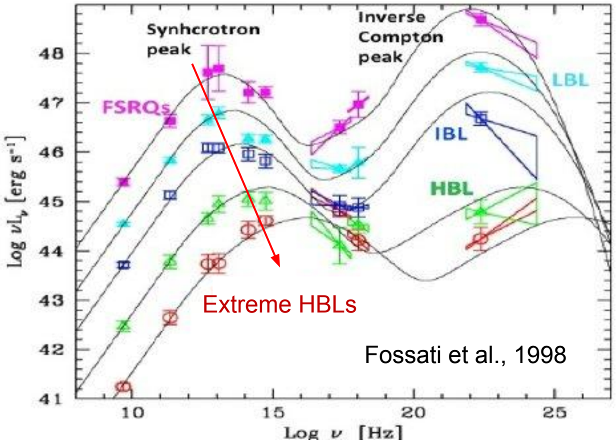
Costamante et al., 2018

Why Extreme blazars ?

- Challenges the blazar emission mechanisms,
  - ➢ Extreme accelerators?
  - ➢ Shorter cooling scales
  - ➢ Modest variability in all frequencies

- Suggest modifications to the blazar sequence,
  - ➢ EHBLs at the edge of the sequence?

- Hard TeV spectrum: ideal probes for cosmological studies

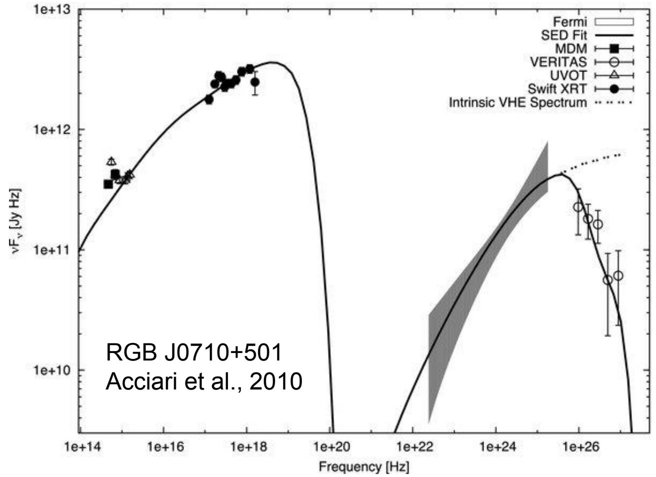


Observation limitations ?

Constraining SED peaks is essential!

- MWL observations are needed

- Challenges for new telescopes



AstroSat Proposals and Motivation

Focusing on the high energy peaked blazar population for which,

- ➢ Spectral properties are poorly understood in X-rays
- ➢ Unexplored in hard X-rays
- ➢ Includes mostly EHBLs

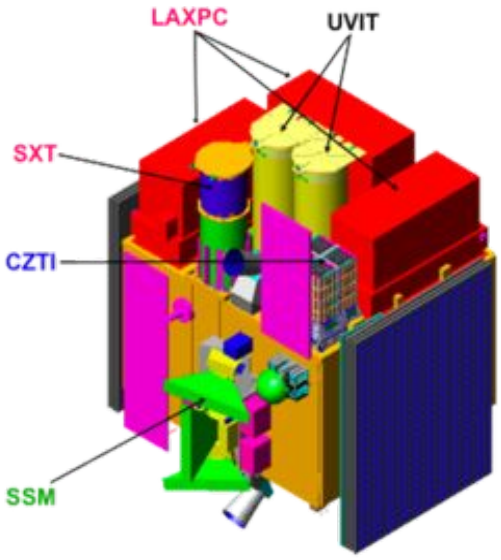


Fig: Schematic diagram of various instruments aboard *AstroSat*

AstroSat: Indian's first MWL satellite mission

- **Launched in 2015 from ISRO, India.**

- **LAXPC:** Large Area X-ray Proportional Counter
  3 – 80 keV energy band
- **SXT:** Soft X-ray Telescope
  0.3 – 8 keV
- **UVIT:** UV Imaging Telescope
  NUV and FUV, 6 filters
- **CZTI:** Cadmium Zinc Telluride Imager
  10 - 100 keV energy band

Agrawal 2006; Singh et al 2016,2017; Misra et al. 2017

Observational details

We proposed the 2 HBLs 1ES 1741+196 & 1ES 2322-409 as a part of AO cycle during 2018 & 2020;

PI: Pranjupriya Goswami

1ES 1741+196: 3 pointing observed during March, July, August 2019 (30 ks exposure each);

SXT : 0.3 - 7 kev, 0.45 cts/s in PC mode

LAXPC: 3-10 keV, 0.87 cts/s

UVIT : 2 FUV filters

* Data publicly available in *AstroSat* archive

1ES 2322-409: 1 pointing observed during July 2020 (total 40 ks exposure).

SXT: 0.3 - 7.0 keV, 0.25 cts/s in PC mode

LAXPC: 3-10 keV

UVIT: 1 FUV filter

* Data is private till date!

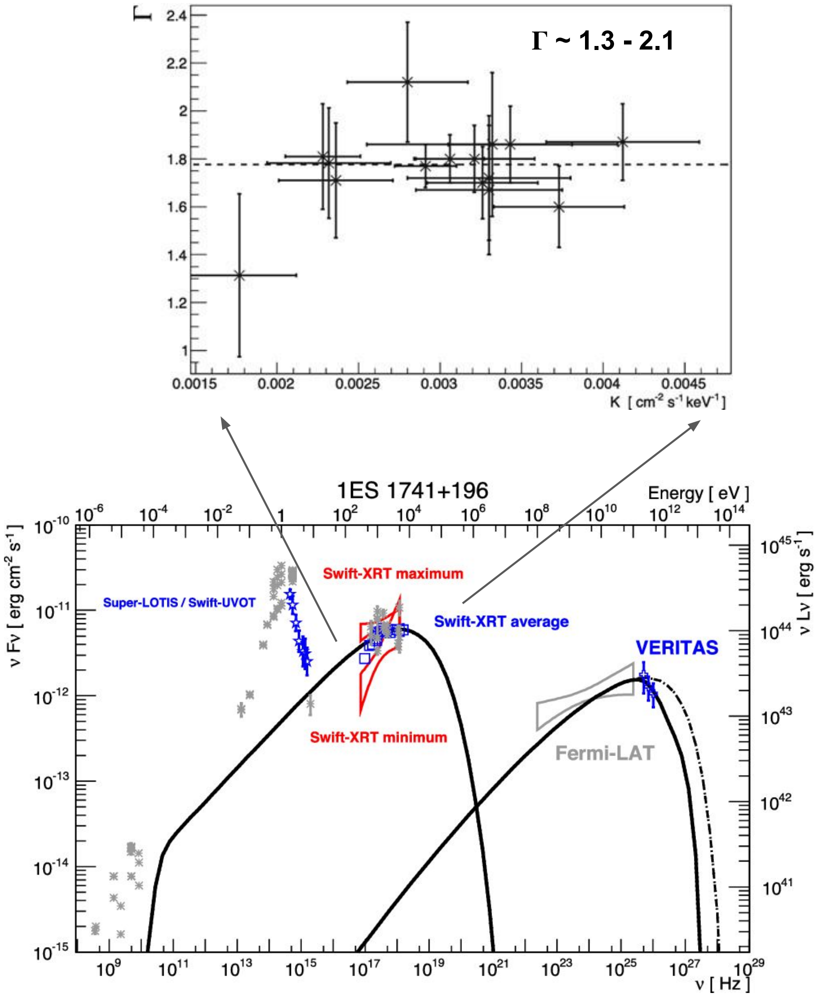
1ES 1741+196

z=0.084

Highlights:

Abeysekara et al (2016) & Ahnen et al. (2016)

- No hint of significant variability or detection of flares at any wavelength
- Optical/UV emission is strongly contributed by host galaxy, where the host is known to be located in a triplet of interacting galaxies
- XRT observations suggests the synchrotron peak may locate above 1 keV, indicating its an extreme HBL source.



To accurately locate the X-ray peak, the hard X-ray data beyond XRT range in needed.

1ES 2322-409

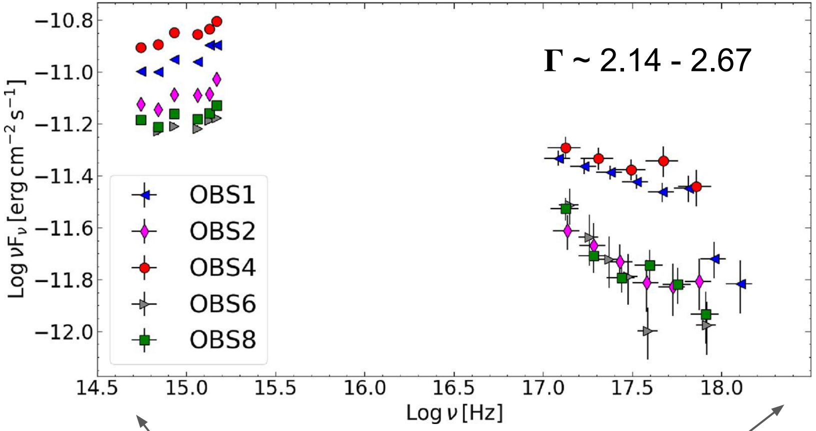
z=0.174 (?)

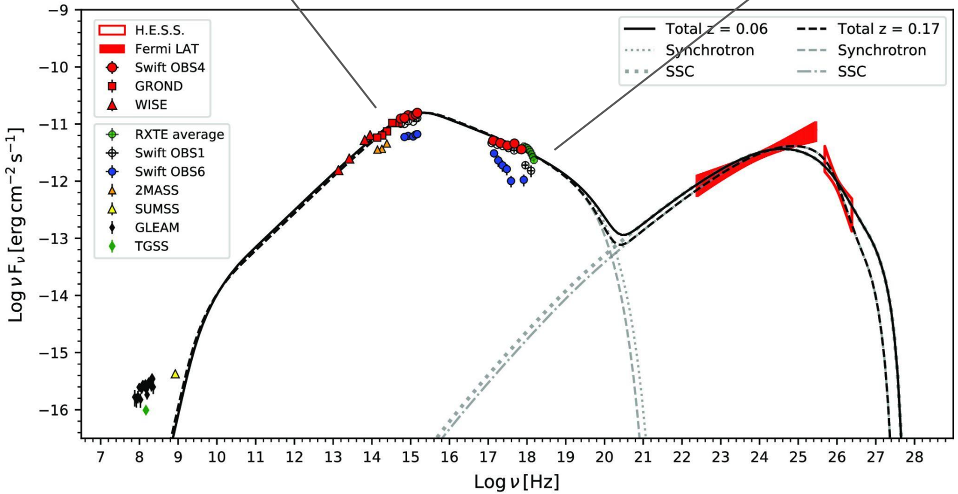
Highlights:

H.E.S.S. Collaboration (2019)

- Detected by H.E.S.S. and reported in 2018, as an HBL with synchrotron peak energy falls in a few eVs.
- Optical/UV and X-ray data from *Swift* show strong variability at longer scales.
- Relatively soft X-ray spectrum by XRT in the range

Simultaneous data in hard X-ray would be useful to determined the synchrotron limit.





1ES 1741+196: Prelim. *AstroSat* spectral analysis

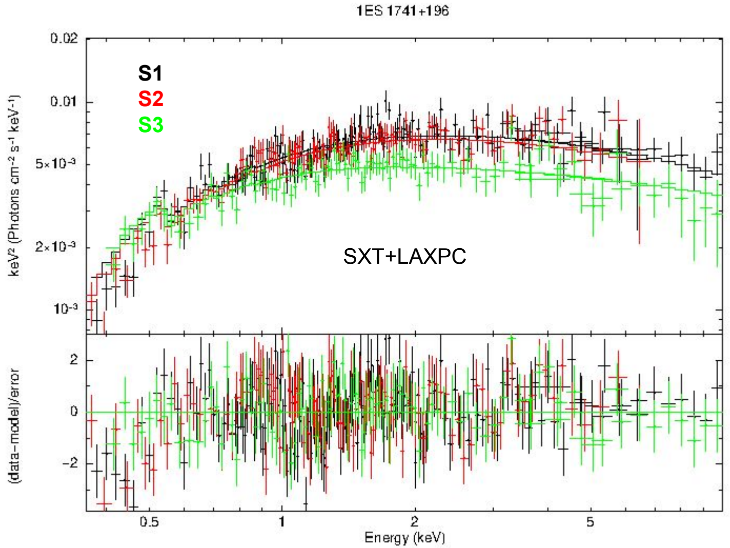
Best-fit log-parabola parameters:

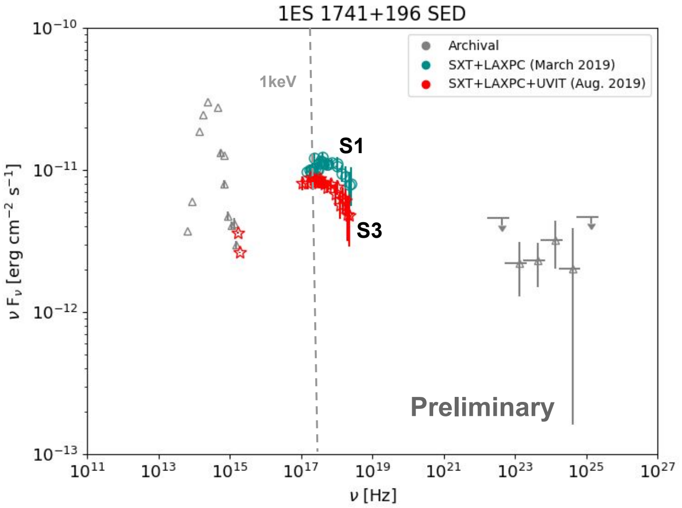
State	Energy	Constant†	α	β	E_p (keV)
1ES 1741+196	0.3 – 10 keV				
S1	–	$1.08^{+0.13}_{-0.13}$	$1.75^{+0.05}_{-0.05}$	$0.41^{+0.10}_{-0.09}$	$2.07^{+0.22}_{-0.20}$
S2	–	$1.17^{+0.54}_{-0.48}$	$1.73^{+0.06}_{-0.05}$	$0.45^{+0.13}_{-0.12}$	$1.98^{+0.21}_{-0.19}$
S3	–	$0.91^{+0.17}_{-0.14}$	$2.01^{+0.06}_{-0.06}$	$0.16^{+0.14}_{-0.13}$	$0.98^{+0.27}_{-0.38}$

* E_p is estimated using *eplogpar* model. Error at 90% confidence level

2 of the spectra showed significant curvature

Synchrotron peak for all 3 spectra are well constrained in the range 0.98 -2.1 keV, within SXT-LAXPC observation range.





1ES 2322-409: Prelim. *AstroSat* spectral analysis

Best-fit model parameters:

Model	α (/Γ)	β	E_p (keV)	Stats (Chi sq./dof)
PL	$2.36^{+0.02}_{-0.02}$	–	–	1.27 (174.58/137)
LP	$2.34^{+0.05}_{-0.05}$	$0.32^{+0.20}_{-0.19}$	$0.31^{+0.27}_{-0.20}$	1.13 (154.39/136)

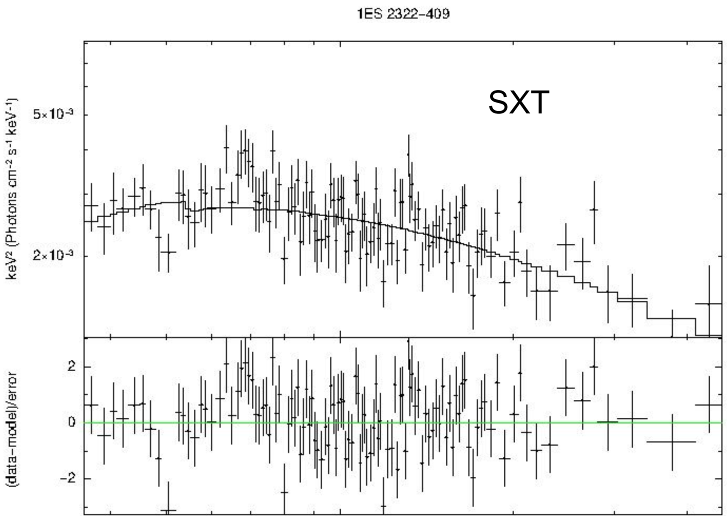
* Error at 90% confidence level

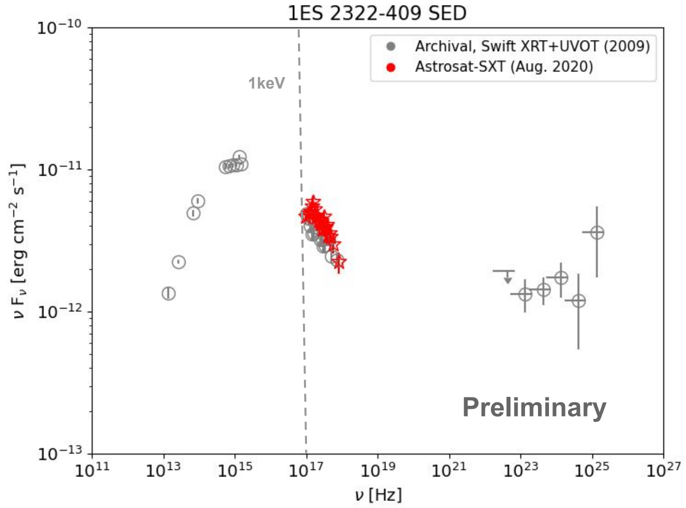
F-statistic value= 17.78 and probability= 4.48e-05

SXT spectrum is soft with index $\Gamma \sim 2.3$ and is consistent with prev. studies.

A log-parabola fit is statistically better than a simple power-law

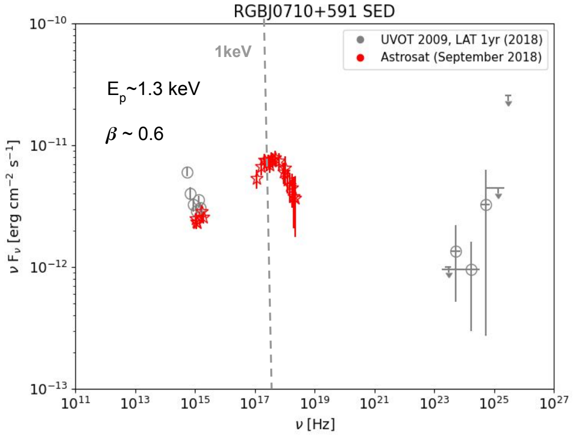
This hints the presence of mild spectral curvature in its X-ray spectrum





More extreme blazars observed by *AstroSat*: archival data

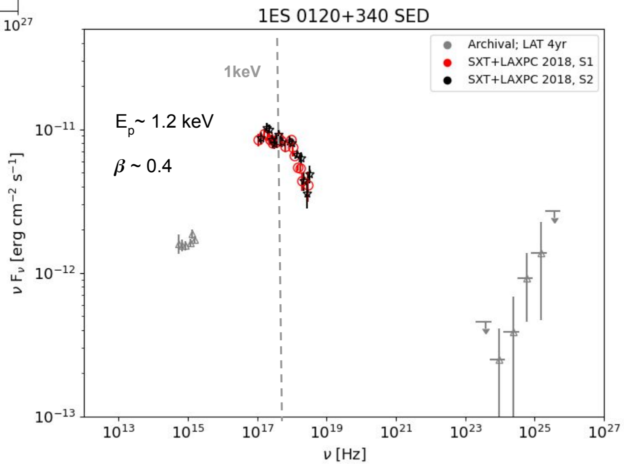
RGB J0710+591



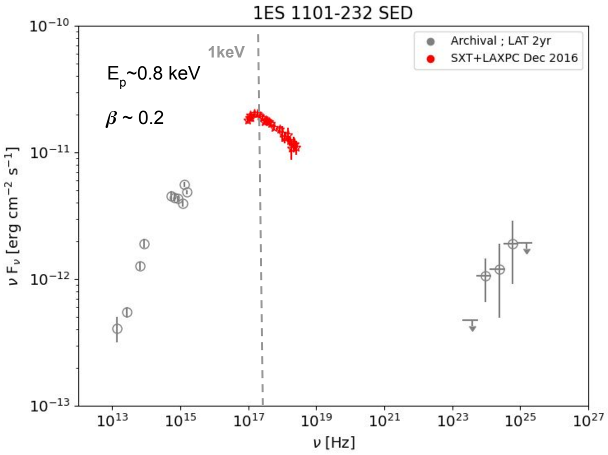
Goswami+ 2020

Preliminary!!

1ES 0120+340



1ES 1101-232



Goswami et al., in preparation

Conclusion

- ➢ Extreme blazars are intriguing, but there many observational limitations!
- ➢ Constraining the SED peaks are essential!
- ➢ We studied a tiny part of the SED, the X-ray spectral features for the EHBLs 1ES1741+196, RGB J0710+591, 1ES1101-232 & 1ES0120+340.
- ➢ To have a better understanding of the underlying physics, multi-wavelength observations with wide coverage in X-rays and VHE is highly necessitated.

The data from upcoming CTA and Athena observatories will provide significant progress ….!

Thank you for attending!!