Advancements in AGN, Galaxy Cluster and IGM Research

Jointly organised by Central University of HImachal Pradesh & IUCAA Pune

X-ray spectral study of the AGN Mrk 335 using AstroSat data

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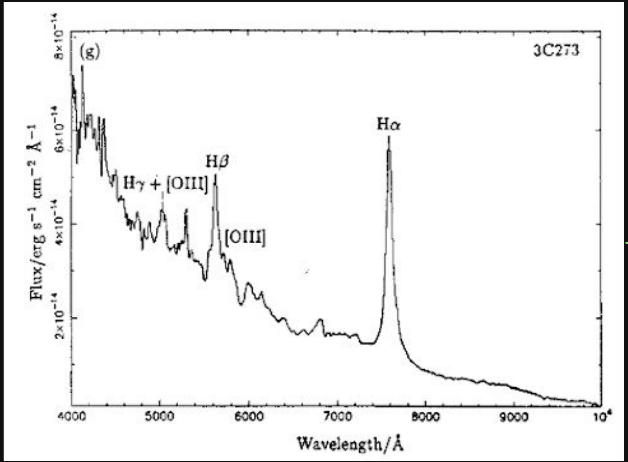
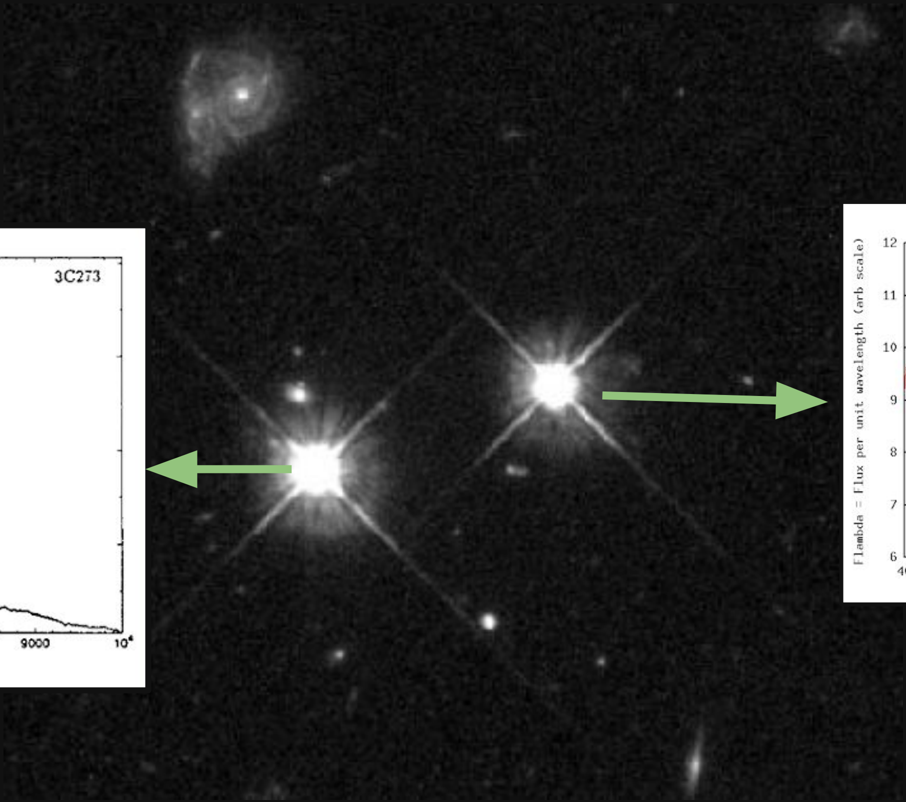
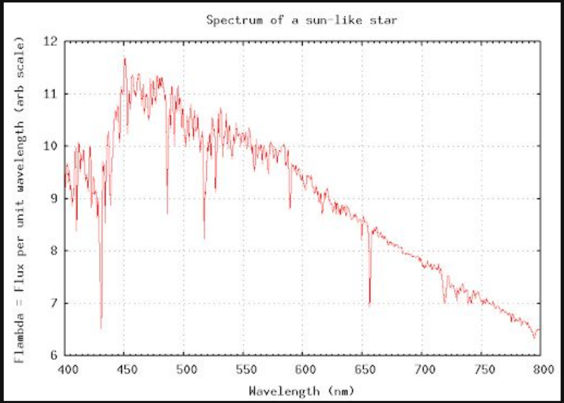
CONTENTS:







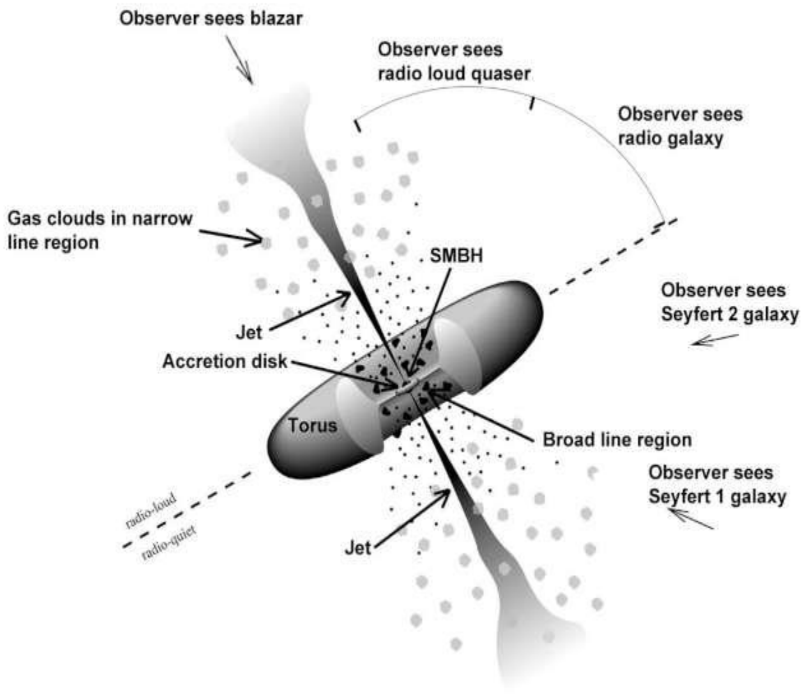
[Image credit: C. Steidel (Caltech) & NASA]

Active Galactic Nucleus (AGN)

★ Extremely luminous central region of a galaxy (Lbol ~ 10^42 - 10^48 ergs/s).

★ AGN emits radiation across the entire electromagnetic spectrum.

★ The radiation is produced by the action of a central accreting supermassive black hole.

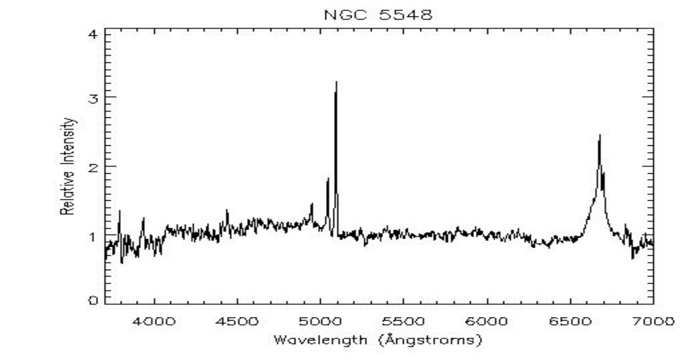


Seyfert Galaxy

- **Lower-luminosity AGN**
  - **Normally found in spiral galaxies.**

Two subclasses:

- **Type 1 Seyfert galaxies have two sets of emission lines in their spectra:**
  - **Narrow lines, with a width (measured in velocity units) of several hundred km/s**
  - **Broad lines, with widths up to thousands of km/s.**
- **Type 2 Seyfert galaxies: Only the narrow line component**



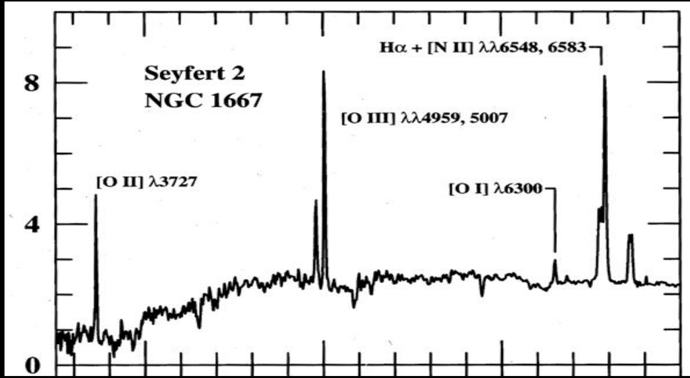
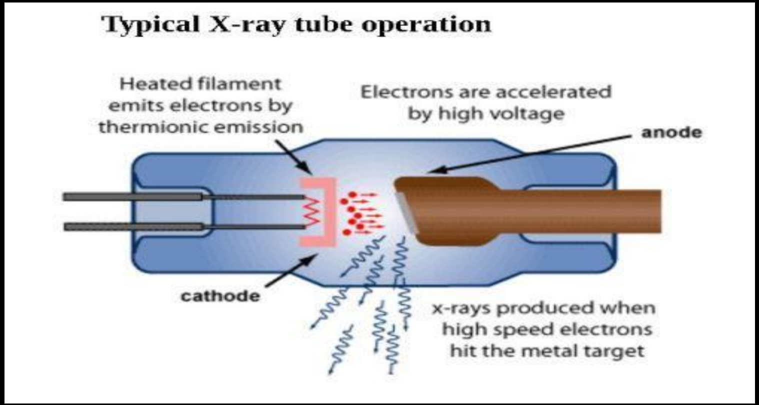
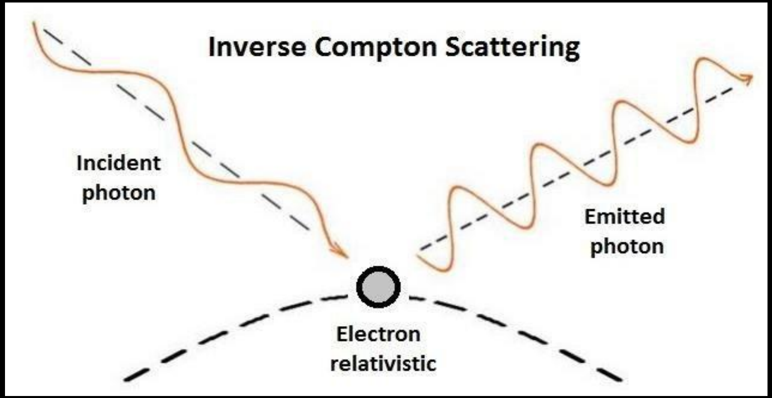


Image Source: https://ned.ipac.caltech.edu/level5/Glossary/Essay_seyfert.html

X-Ray Emission

- X-Ray emission takes place by several processes such as inverse compton scattering, bremsstrahlung, Synchrotron emission and so on.
- Energy of the X-ray photon lies in the range of 0.1 keV to 500 keV.
- Classification of the X-Ray on the basis of energy:-
  - Soft X-Ray: 0.3-10 KeV
  - Hard X-Ray: above 10 KeV
- X-rays are produced in the cosmos when matter is heated to millions of degrees. Such temperatures occur where high magnetic fields, or extreme gravity, or explosive forces, hold sway. For example: supernova explosion, binary stars, AGN, etc.





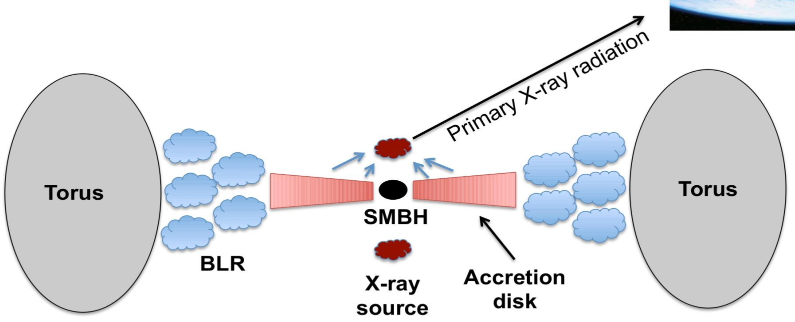
PC: https://www.researchgate.net/alfred/brunno

X-Ray Emission from AGN:

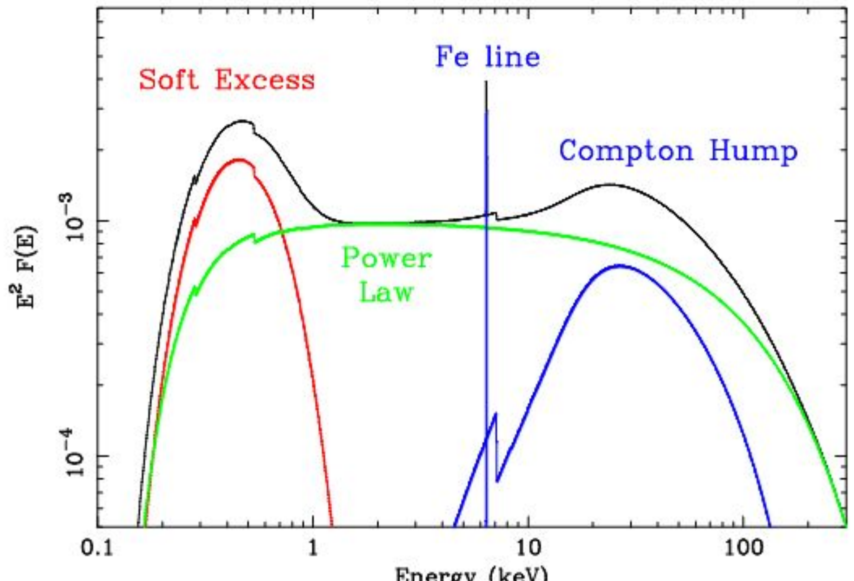
- X-ray emission in Active Galactic Nuclei (AGN) is generated through inverse Compton scattering.
- Comptonization involves high-energy electrons in a corona interacting with photons from the surrounding disk, converting optical and UV photons into X-rays.
- This process results in a power-law continuum emission with a characteristic photon index ($\Gamma \sim 1.8$-2).
- At higher energies, due to multiple inverse compton scattering corona's electron can't provide more energy to the photon. Consequently, there comes a point where the rate of increase in X-ray intensity with increasing energy starts to slow down and eventually diminishes, leading to a drop-off or roll-over in the intensity spectrum at high energies.
- X-rays produced by the corona interact with surrounding material like the molecular torus and the accretion disk, leading to re-emission of X-rays.
- Reprocessed X-rays produce features such as a Compton hump (peaking around 30-40 keV) and an iron Kα emission line (at 6.4 keV).

- The Compton hump is a feature observed in the X-ray spectrum of AGN, typically peaking around energies of 30-40 keV. It arises from the scattering of X-ray photons by free electrons in the accretion disk or other material surrounding the black hole. This scattering redistributes the energy of the X-ray photons, resulting in an enhancement in the X-ray spectrum at these energies.
- The iron Kα line typically exhibits broad and narrow components, originating from reflection off different regions of the AGN environment.
- Many AGN show an excess of X-ray emission at lower energies (<2 keV), known as a Soft excess.
- The Soft excess has different origins for AGN, potentially arising from processes like blurred reflection, absorption by an ionized wind, or the presence of warm corona.
- X-ray emission can be affected by absorption processes like photoelectric absorption and Compton scattering, which modify the observed X-ray spectrum based on the column density of absorbing material.

X-ray emission from AGN



★ Low energy photons from the accretion disc scattered to high energies by relativistic electrons from the corona through inverse Compton scattering.



AstroSat Payloads:

AstroSat

Singh, Kulvinder Pal;2022

1: AstroSat is an unique space based observatory orbiting 650 km above the Earth.

2: It can simultaneously observe the celestial objects in multi wavelength regime.

3: AstroSat carries five different telescopes on-board. These can collect incoming radiations in visible range, near and far ultraviolet rays, soft and hard X-rays all at the same time.

Payloads

1.UVIT: Ultraviolet Imaging Telescope, consists of two identical telescopes of aperture 380mm. One telescope covers FUV(130-180nm) and other covers NUV(200-300 nm) and Visible band(320-550 nm).

2.LAXPC: Large Area X ray Proportional Counter, has three identical proportional counters with effective area of 8000 cm^2.It's main purpose is to record the variation of total intensity of sources.

3. CZTI: Cadmium Zinc Telluride Imager,is a hard X ray imager takes observations of X ray binaries, AGNs and other bright X ray sources.

4.SXT: Soft X ray telescope, uses X ray reflecting mirrors and X ray CCD for imaging.

5.SSM: Scanning Sky Monitor, is an all sky monitor for detecting and monitoring transient sources.

Payload & Respective Energy Ranges

Sr. No.	Payloads	Energy Range(KeV)	Wavelength Range(nm)
1	Ultraviolet Imaging Telescope (UVIT)	0.0095-0.0068 0.0068-0.0041 0.0038-0.0023	FUV: 130–180 nm, NUV: 180–300 nm Visible: 320–530 nm.
2	Soft X-ray imaging Telescope (SXT)	0.3-8.0	4.13-0.15
3	Large Area X-ray Proportional Counter (LAXPC)	3.0-80.0	0.41-0.015
4	Cadmium Zinc Telluride Imager (CZTI)	10-100	0.12-0.012

Mrk 335 (Markarian 335)

L. C. Gallo et al..2014

- Mrk 335 is a Narrow-line Seyfert 1 (NLS1) source with RA and Dec as follow:

RA	DEC	Redshift
1.58134	20.20291	0.025785

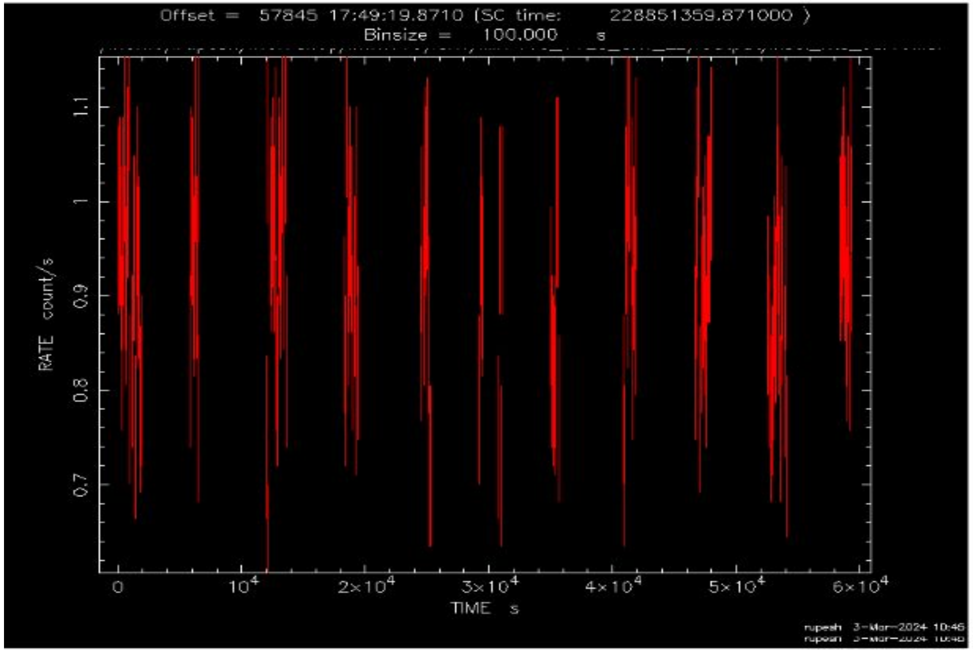
- Historically known as one of the brightest X-ray sources, even detected by UHURU in 1978.
- Over the last decade, it has transitioned into an X-ray weak state, maintaining a low to moderate flux level consistently.
- Studies show its lowest flux level in recent years to be about 1/30 of its previously observed flux.
- Despite its significantly diminished X-ray flux, Mrk 335 remains relatively bright, making it an excellent target for studying AGN behavior at low flux levels with respectable signal-to-noise ratios.
- This transition to a low X-ray flux state challenges previous understandings and offers a unique opportunity for detailed investigation into AGN variability and activity.

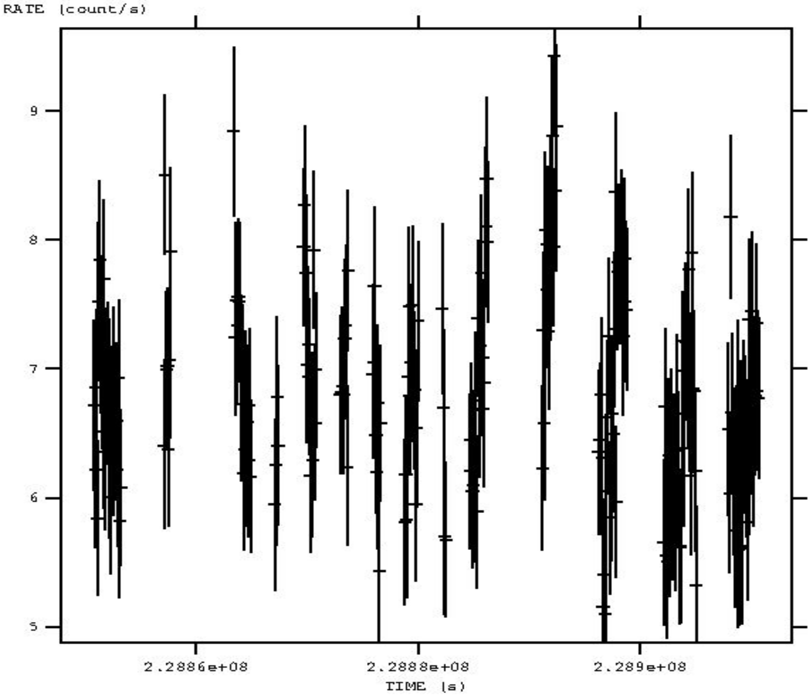
AstroSat Observations

OBS_ID	Date	SXT Exposure (sec)
A04_137T01_9000001654	31st-Oct-2017	16817.115

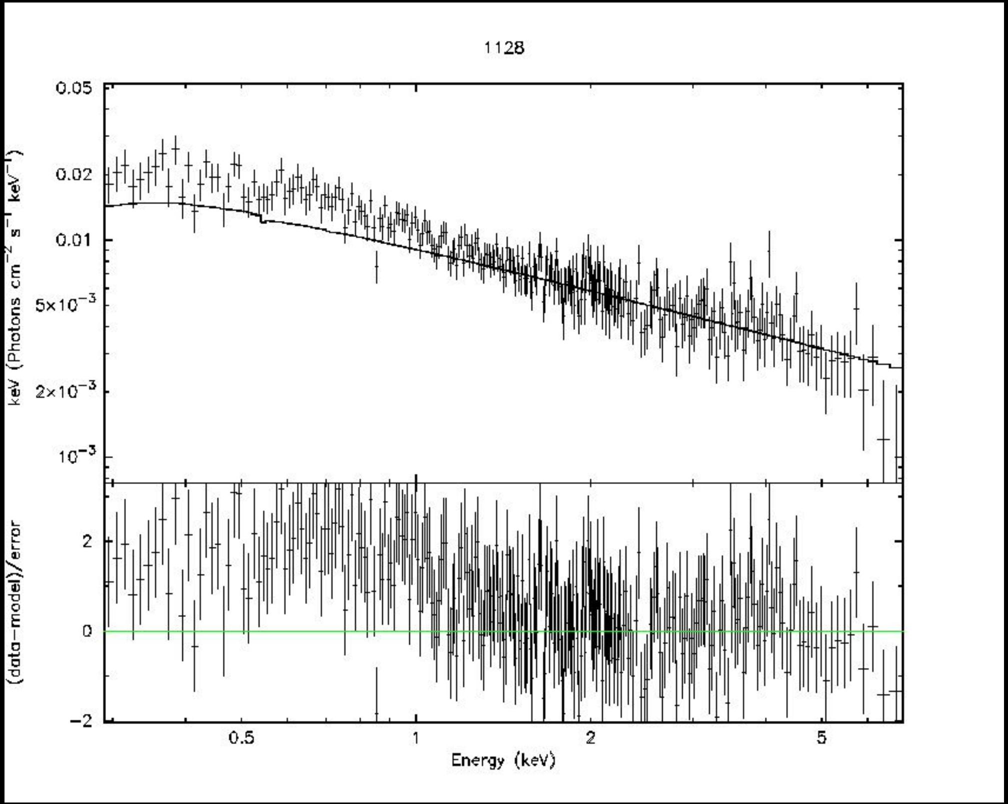
Generated SXT & LAXPC (LaxpcSoft) Spectra and light curves

SXT (0.3-7 keV) & LAXPC (4-30 keV) Light Curves

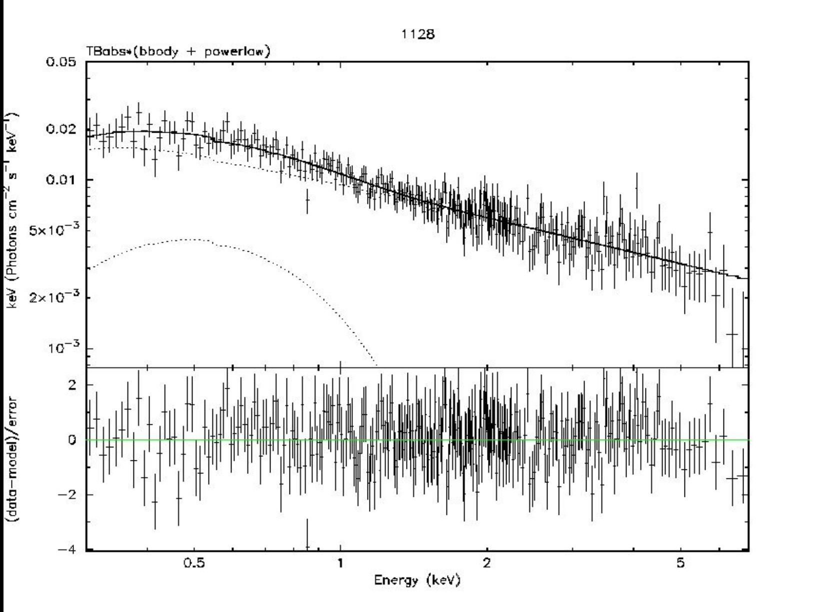




Soft X-ray Excess

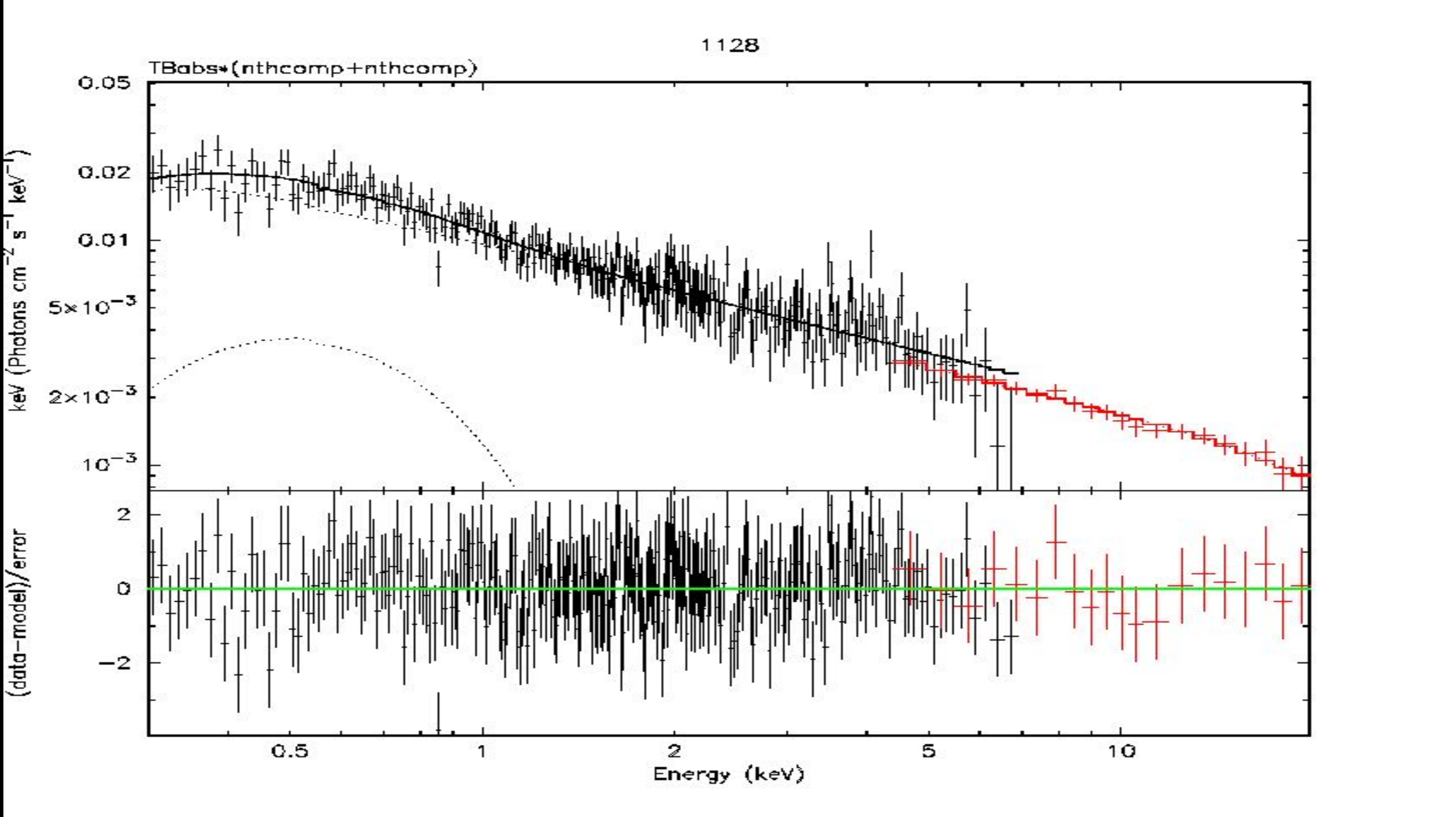


Power-Law and Blackbody Models



Model	Parameter	Value
TBabs	nH ($\times 10^{22}$ cm^{-2})	0.0330
bbody	kT (keV)	$0.158^{+0.019}_{-0.020}$
bbody	norm ($\times 10^{-5}$)	$6.826^{+2.697}_{-2.854}$
powerlaw	PhoIndex	$1.686^{+0.056}_{-0.073}$
powerlaw	norm ($\times 10^{-3}$)	$9.620^{+0.482}_{-0.641}$

Spectra Fitted with Two Comptonisation Models (nthcomp): Warm Corona & Hot Corona



Model Parameters

Parameter	nthComp (1)	nthComp (2)
Gamma	$1.001^{+0.658}_{-1.001}$	$1.746^{+0.046}_{-0.044}$
kT_e (keV)	$0.162^{+0.050}_{-0.021}$	$7.133^{-7.111}_{-1.650}$
kT_bb (keV)	0.01	0.01
inp_type	0.0	0.0
Redshift	**0.025785**	**0.025785**
norm ($\times 10^{-3}$)	$1.2746^{+0.6931}_{-0.6189}$	$9.9277^{+0.5358}_{-0.5255}$
TBabs	nH	**0.0330** $\times 10^{22}$ cm^{-2}

Summary:

- ➢ We analyse the Mrk 335 data for one epoch using the SXT and LAXPC.
- ➢ We generated the light curves and spectra for one epoch from SXT and LAXPC.
- ➢ After fitting all the spectras using XSPEC we found soft X-ray excess.
- ➢ We found that source is showing variability.

Future Work:

We will try to extract physics from our results and will do Multi epoch X-ray spectral analysis.

Thank You…..