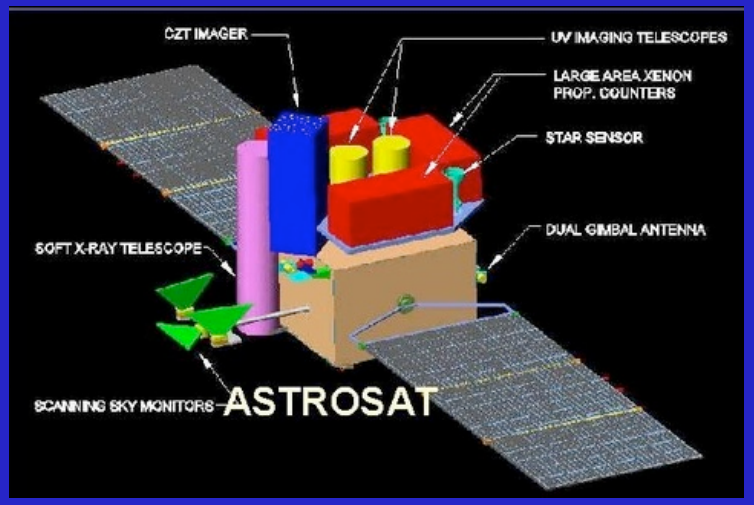

Wide Band X-ray Astronomy

"Frontiers in Timing and Spectroscopy"

Ed P.J. van den Heuvel
University of Amsterdam

January 16, 2011

THE ASTROPHYSICAL JOURNAL, 177:L5–L10, 1972 October 1

OBSERVATION OF A CORRELATED X-RAY–RADIO TRANSITION IN CYGNUS X-1

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Received 1972 July 24

ABSTRACT

Analysis of 16 months of *Uhuru* data on Cyg X-1 has shown a remarkable transition in the source which occurred during 1971 March and April. The average X-ray intensity in the 2–6-keV energy range decreased by about a factor of 4, the average X-ray intensity in the 10–20-keV band increased by a factor of 2, and a weak radio source suddenly appeared. This simultaneous X-ray and radio behavior provides strong evidence for the identification of the radio source with Cyg X-1. *Uhuru* also monitored Cyg X-1 for 35 consecutive days during 1971 December and 1972 January. The data were analyzed for an effect due to a binary system. Although large-scale fluctuations were present, no periodicity was found.

ASTROSAT

- Excellent capabilities
- Wide band in X-rays up to 100 keV, broadband spectroscopy
- Multi wavelength (including UV)
- High precision timing
- Transients detection (All Sky Monitor/ *Seetha, Remillard*)

ASTROSAT Allows study of energy dependence of time-variable phenomena:

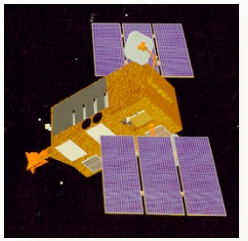
- Pulse shapes of accreting pulsars and Magnetars (*Paul,Özel*)
- X-ray Binary spectra (incl. SFXTs and obscured IGR HMXBs) (*Paul*)
- QPOs, now also at high energies (*many speakers*)
- Cyclotron lines, including proton-cyclotron lines of Magnetars (*D.Bhattacharya, Wilms*)
- Type I X-ray bursts (*Özel, S. Bhattacharyya*)
- Orbital-phase-resolved spectroscopy of HMXBs (*Naik*)
- Spectral and intensity variations of AGN (*Fabian, McHardy, Elvis*)

The X-ray sky is extremely variable (*Remillard*)

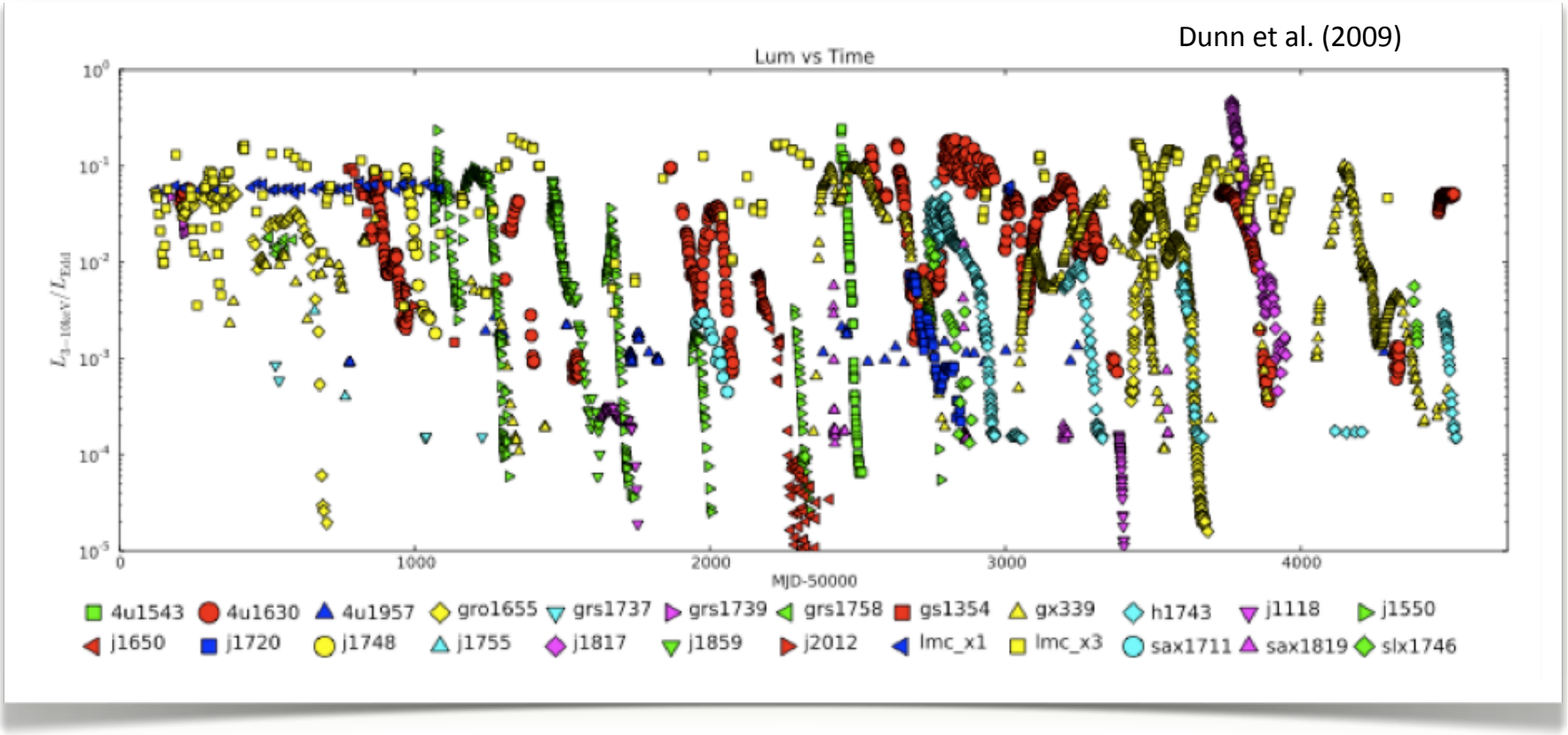
- Of 27 BH-XRBs, 23 are transients
- Of 16 Accreting MSPSRs, 13 are transients
- Of the classical accretion-powered PSRs (HMXB), about 40 % are transients
- Of the classical LMXBs, about 40 % are transients
- AGNs and QSOs are variable X-ray, radio and optical sources

FOR THIS REASON A SUFFICIENT AMOUNT OF TIME SHOULD BE RESERVED FOR TOOs

Complete RXTE dataset on BHT



Dunn et al. (2009)



Courtesy: Tomasso Belloni

Among the drivers of the ASTROSAT program are expected to be:

- Study of timing behaviour of LMXB-NS en BH-XRB
- Thermal continuum of BH sources: spins (*Narayan*); BH-disk models (*Narayan,Malzac*)
- Type I X-ray Bursts: burst oscillations, spreading of flame over surface (*S.Bhattacharyya*); (M,R) relations : Equation of State:
  In 3 systems, Masses >1.6Msun, r ~ 11 km (*Özel*)
- QPO-evolution as a function of accretion state (*vd Klis, Altamirano, Mendez, Belloni, Done, and others*)
- Coordinated X-ray and optical studies of CVs (*Mukai, Singh, Buckley*): high time resolution and polarization studies; and LMXbs (time lags*; Gandhi*); LOGISTICS COMPLICATED!
- Studies of AGNs and QSOs (*Fabian, McHardy, Elvis, Mathur*)

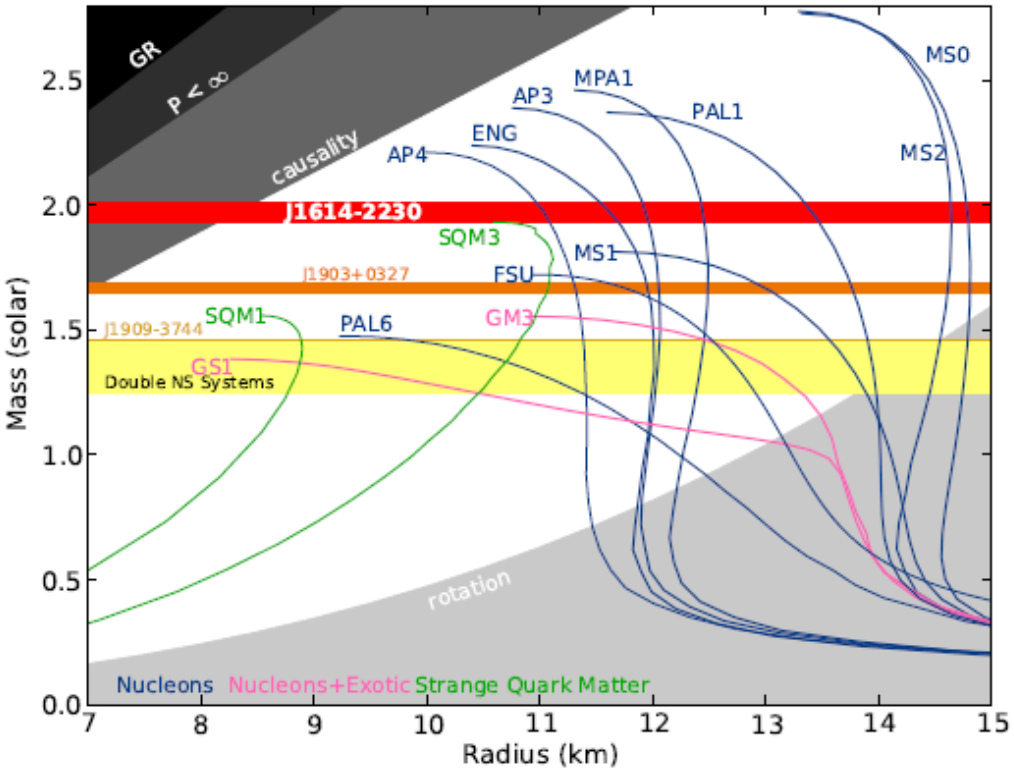


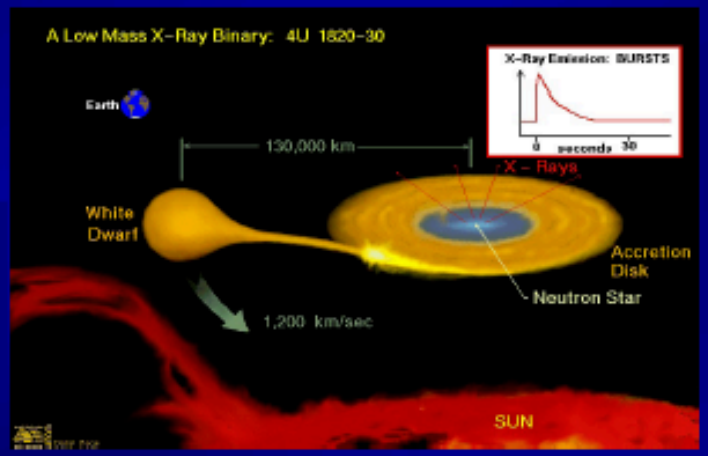
Figure 3: Neutron star (NS) mass-radius diagram. The plot shows non-rotating mass versus physical radius for several typical NS equations of state (EOS)[25]. The horizontal bands show the observational constraint from our J1614−2230 mass measurement of 1.97±0.04 $M_\odot$, similar measurements for two other millisecond pulsars[3, 26], and the range of observed masses for double NS binaries[2]. Any EOS line that does not intersect the J1614−2230 band is ruled out by this measurement. In particular, most EOS curves involving exotic matter, such as kaon condensates or hyperons, tend to predict maximum NS masses well below 2.0 $M_\odot$, and are therefore ruled out.

Courtesy: D.Altamirano

Accretion disk

Radio Jets

Spectral states



Thermonuclear Burning
(talk by S. Bhattacharyya)

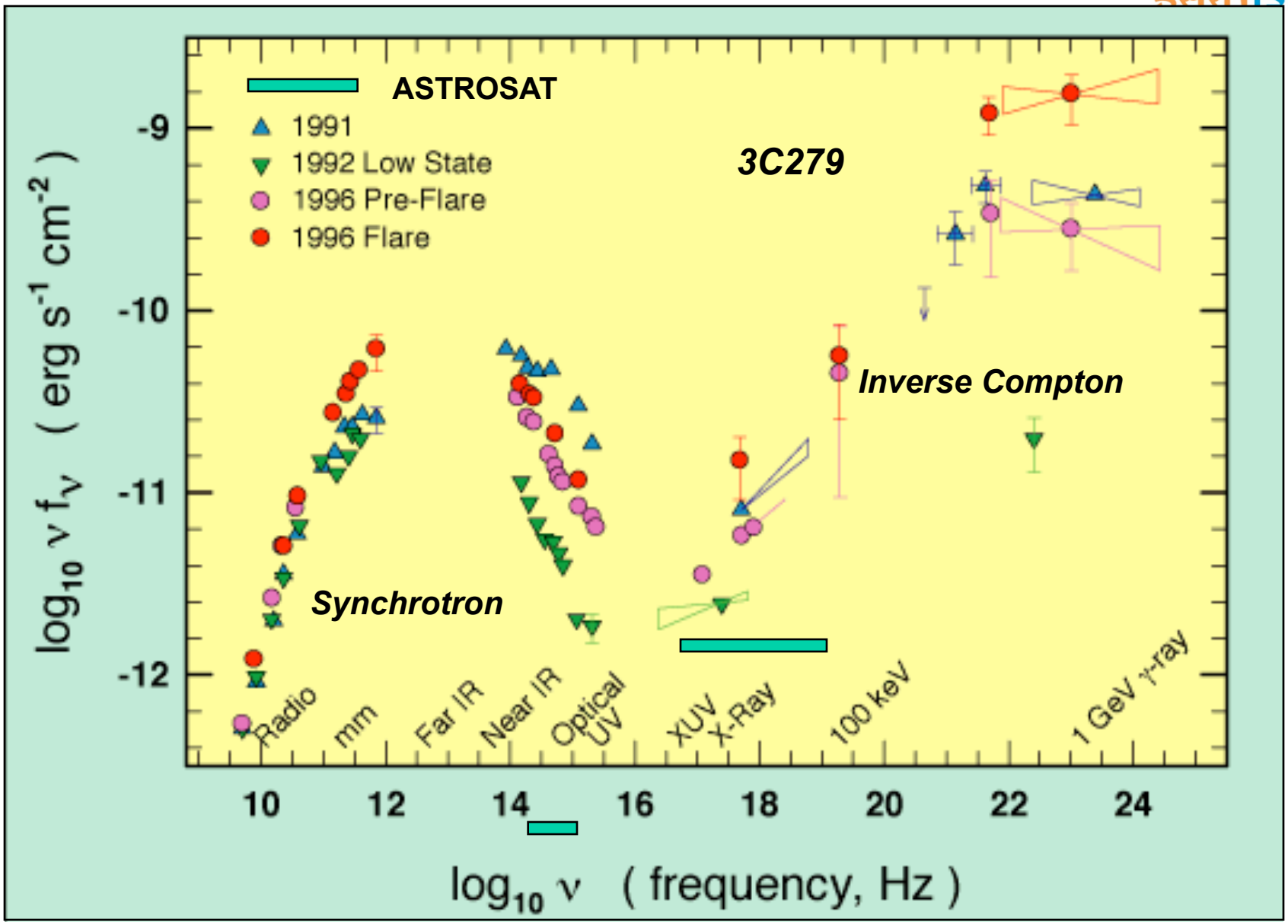
Optical variability
(talk by P. Gandhi)

Spectral lines

Pulsar/non-pulsar Magnetic field
(talk by A. Patruno)

X-ray variability
(talk by van der Klis, Mendez, Belloni, this one)

Simultaneous multiwavelength coverage: Spectral



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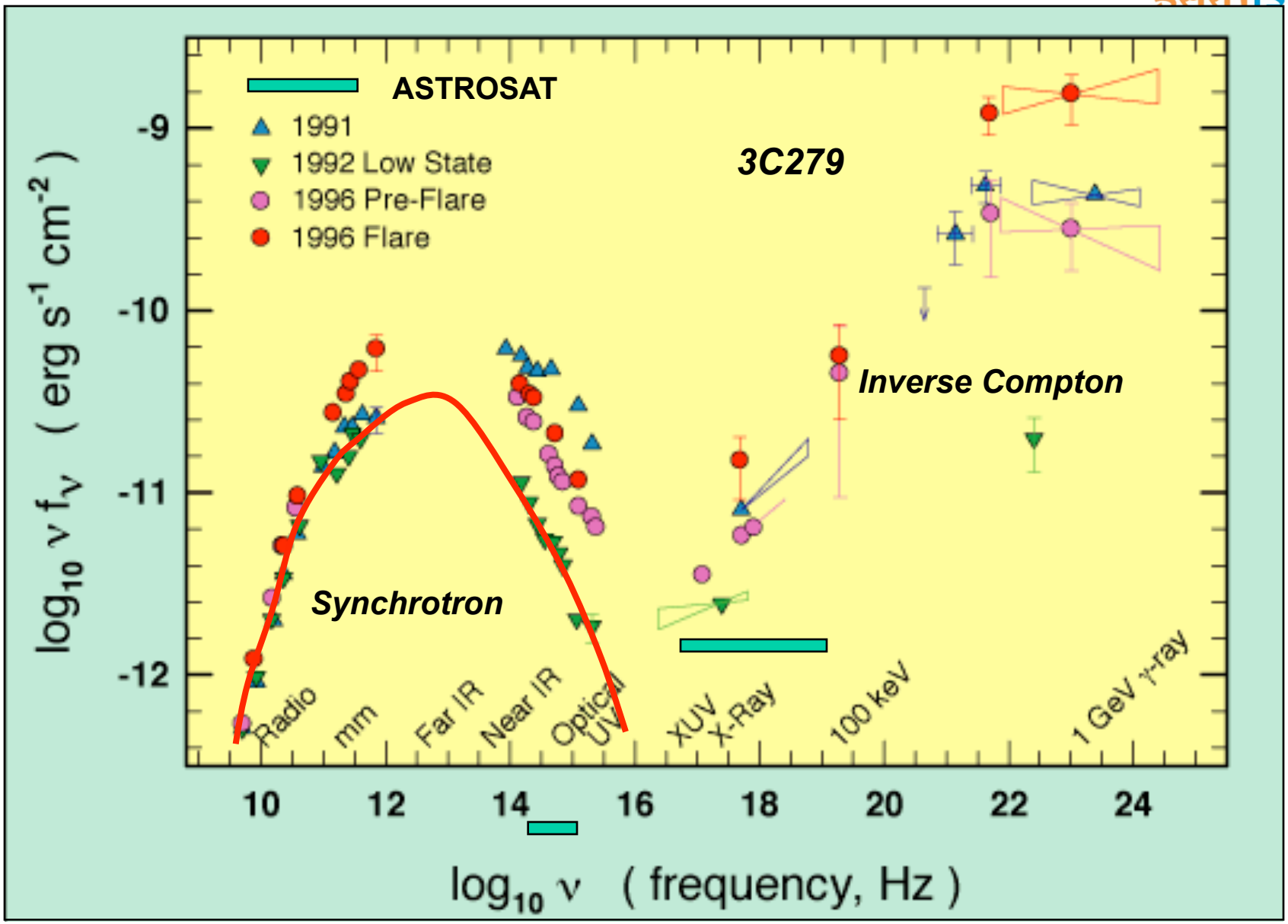

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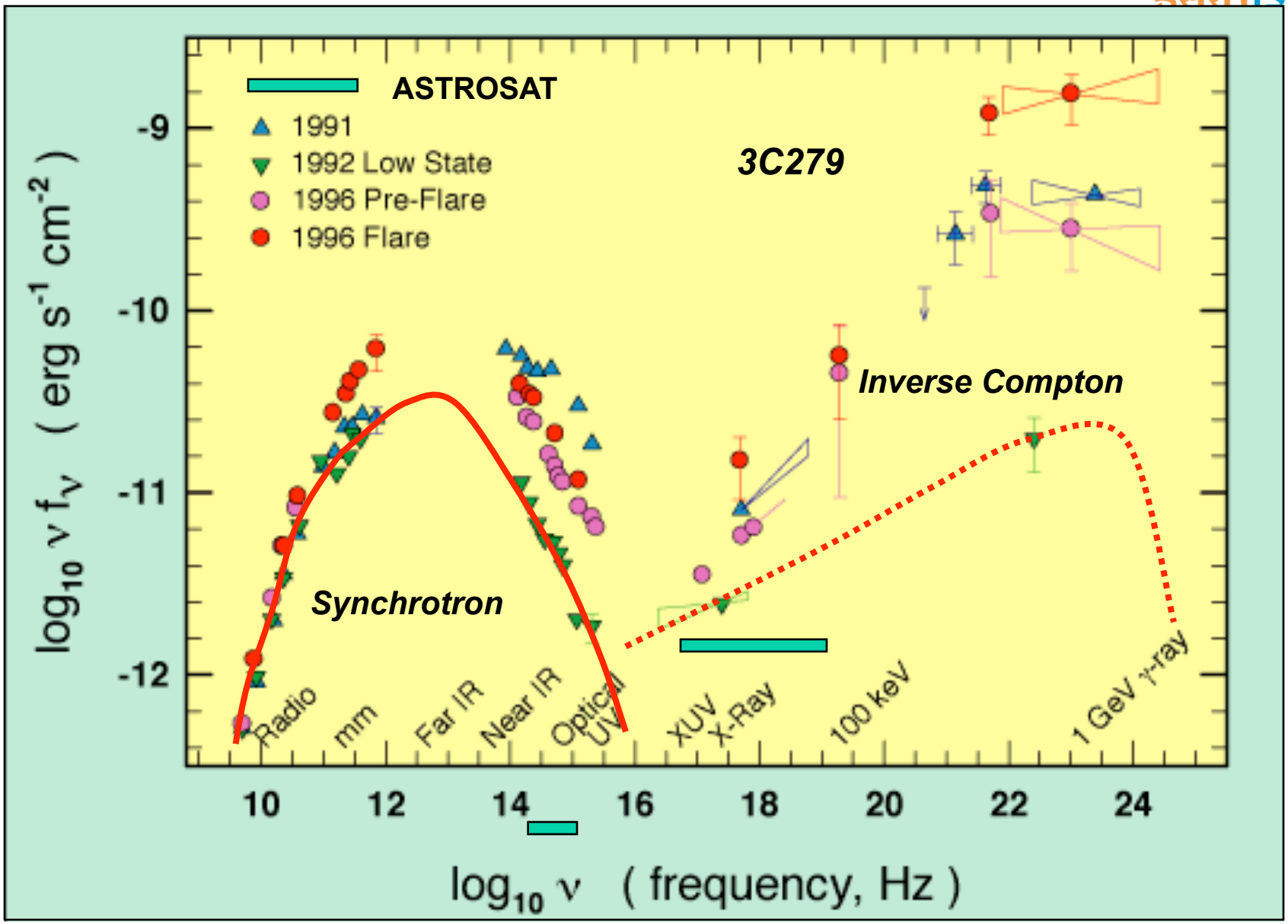

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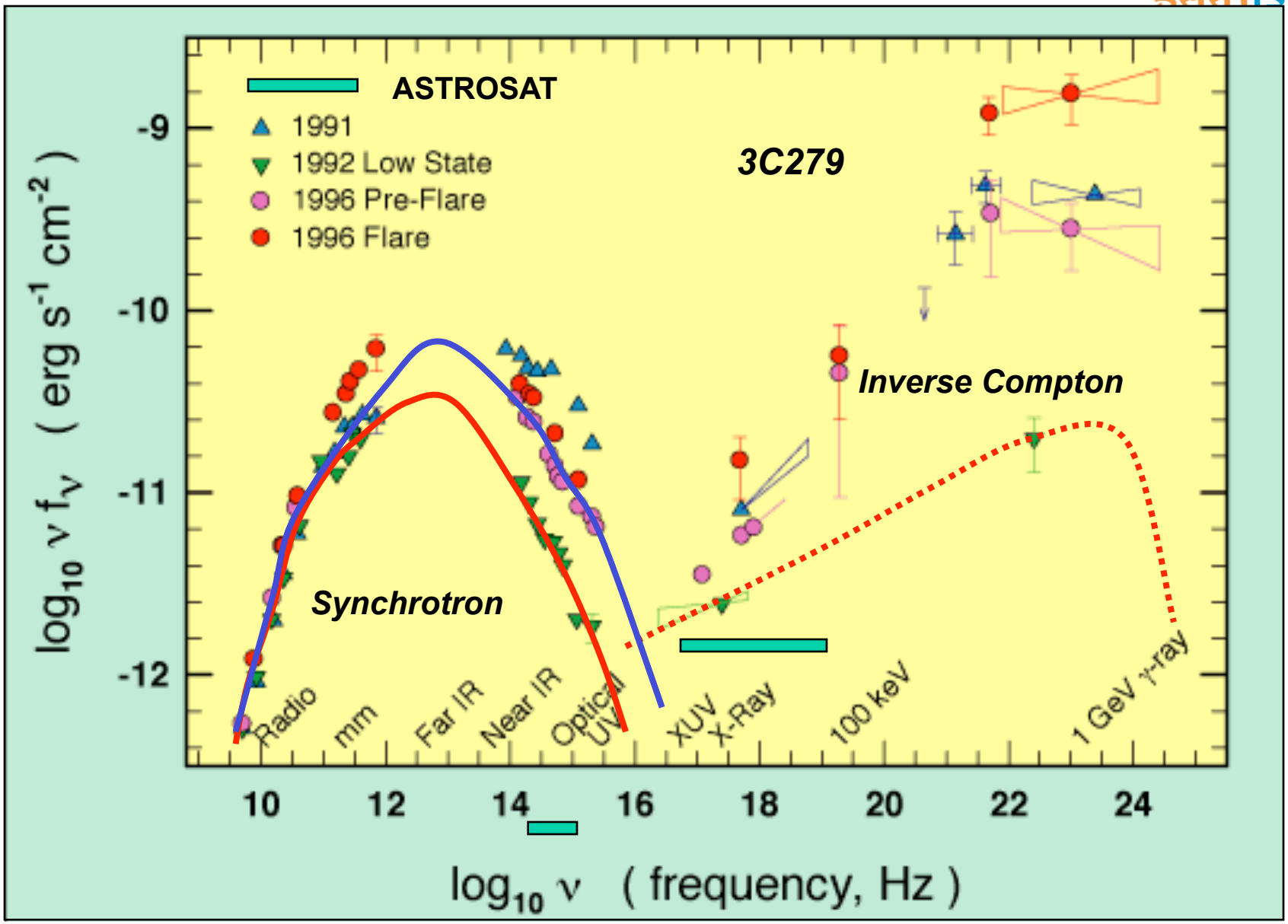

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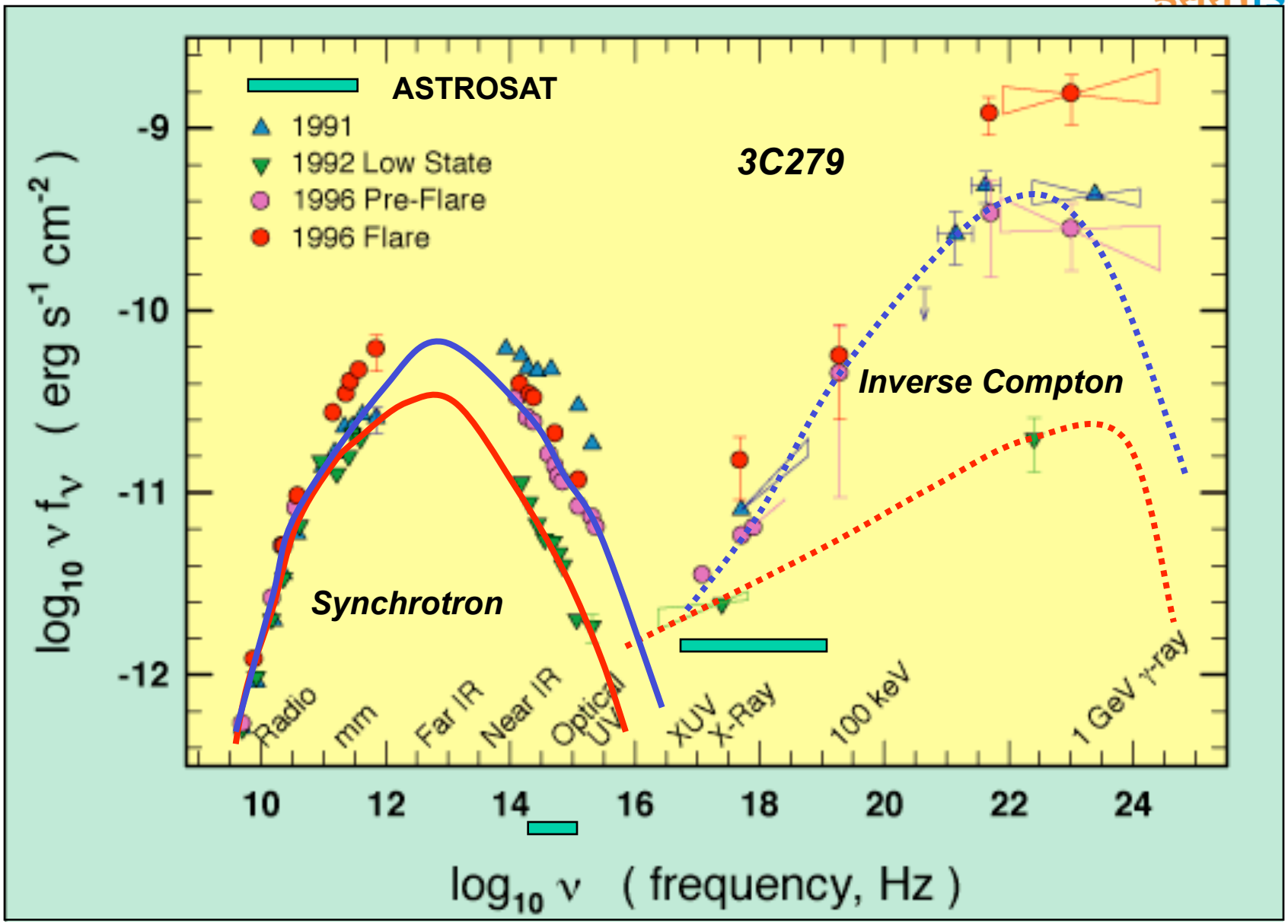

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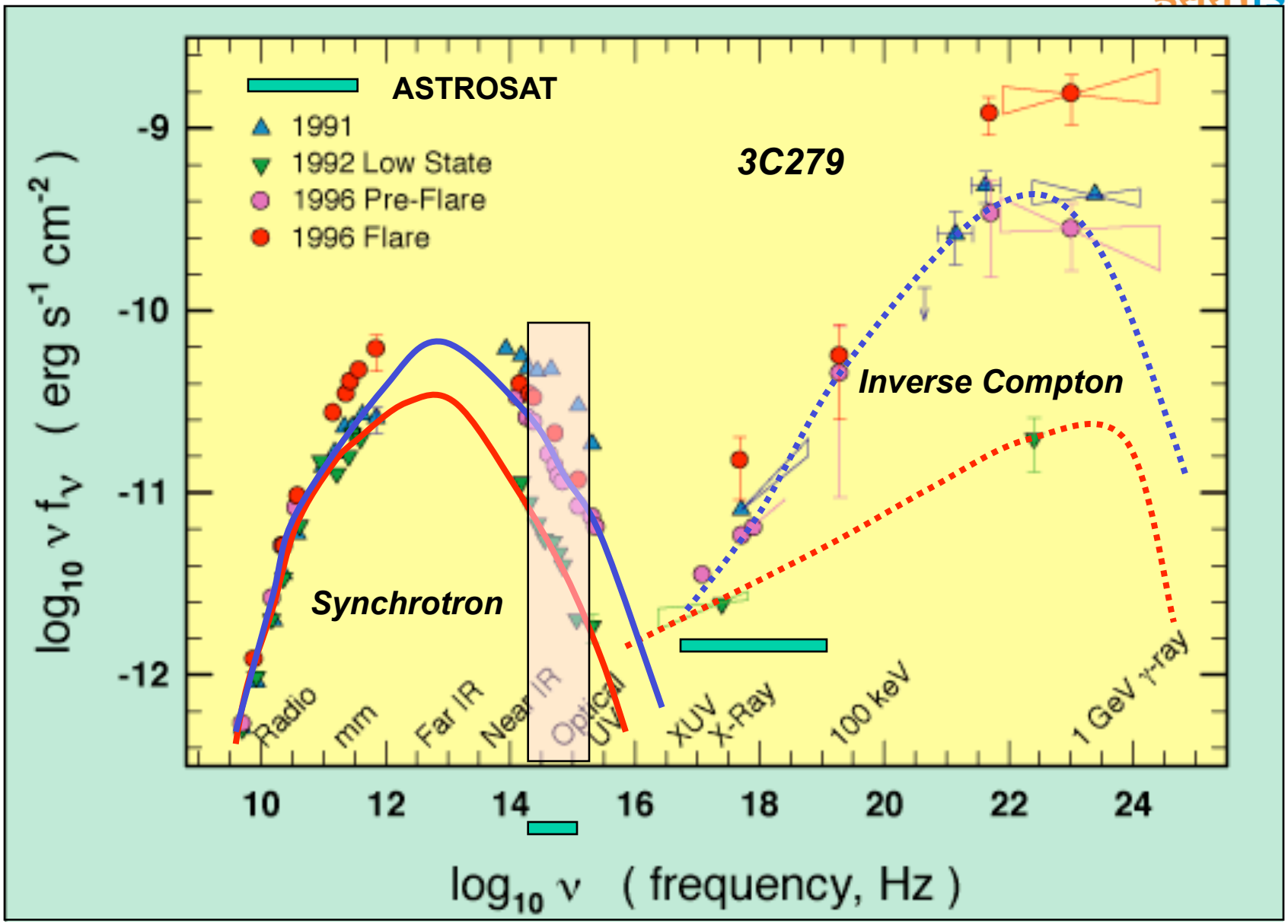

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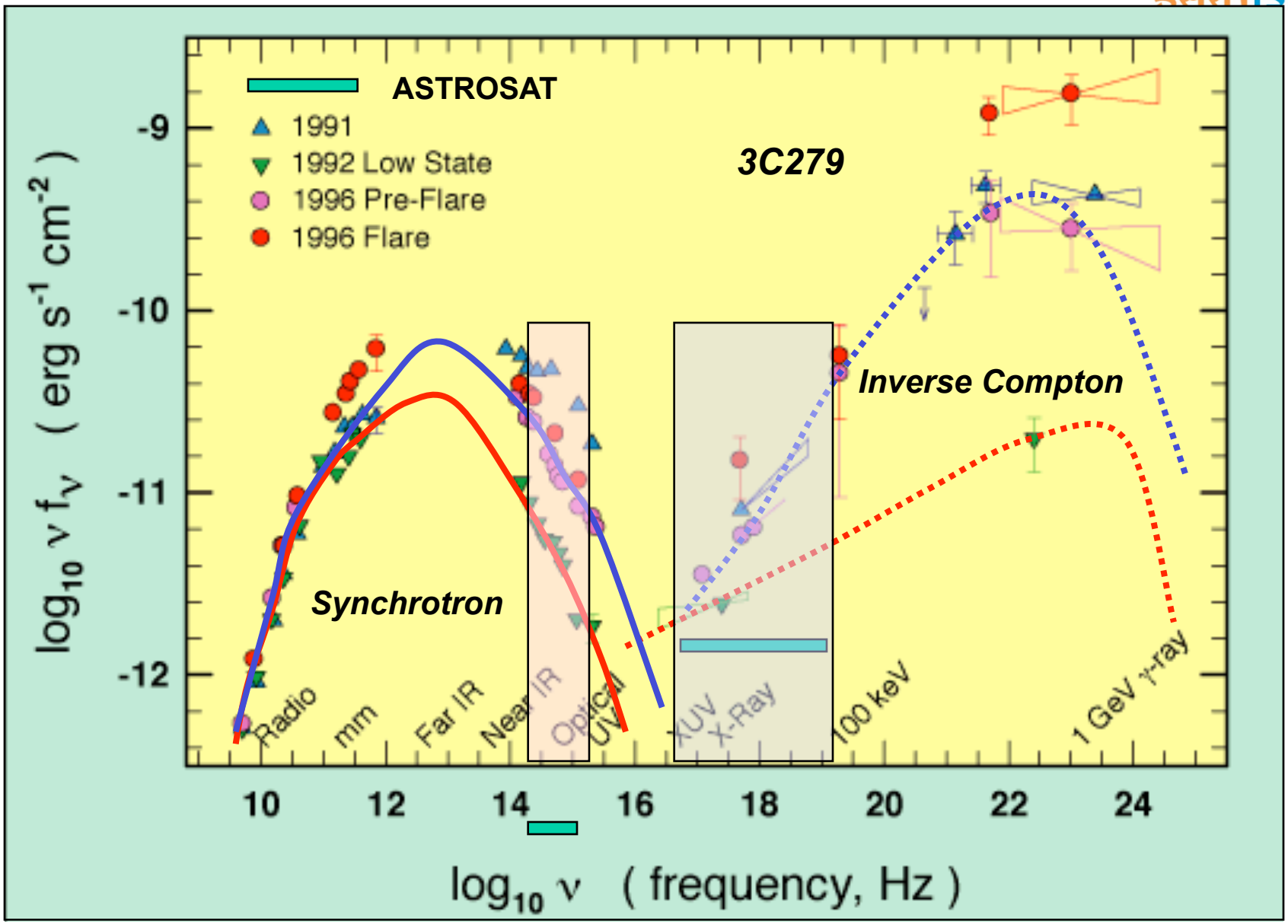


X-ray / Radio correlation studies for BH/XRBs equally important

(*Zdziarski*)

Active Galaxy Nuclei and QSOs

Fabian and McHardy's talks showed that BH-XRB and AGN have in their variability many aspects in common, only the timescales for supermassive BHs are very much longer than for BH-XRB.

Particularly, AGN timing spectra similar to Cyg X-1 (*McHardy*)

Fabian: Reflection models in case of ASTROSAT: mainly Continuum, Spectral resolution too low to resolve lines
("make sure your physical models make sense");

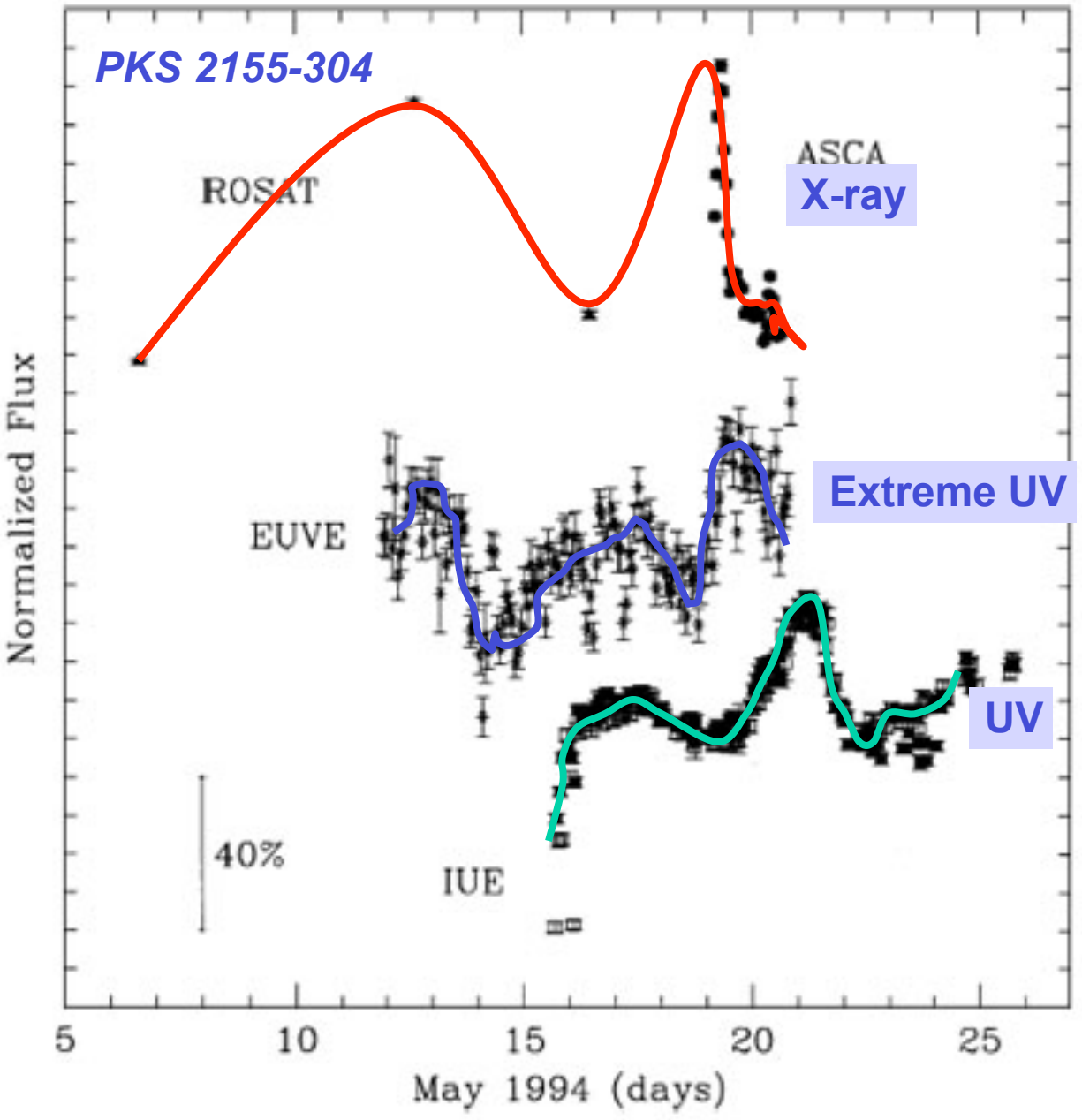
- Thermal black body spectra may give black hole spin.

- Thanks to large energy separation: time lags can be measured.

Simultaneous multiwavelength coverage: Timing

Outbursts from Quasars and AGN

The x-ray outburst is delayed by hours (EUV) to days (UV) at lower frequencies



Simultaneous multiwavelength coverage: Timing

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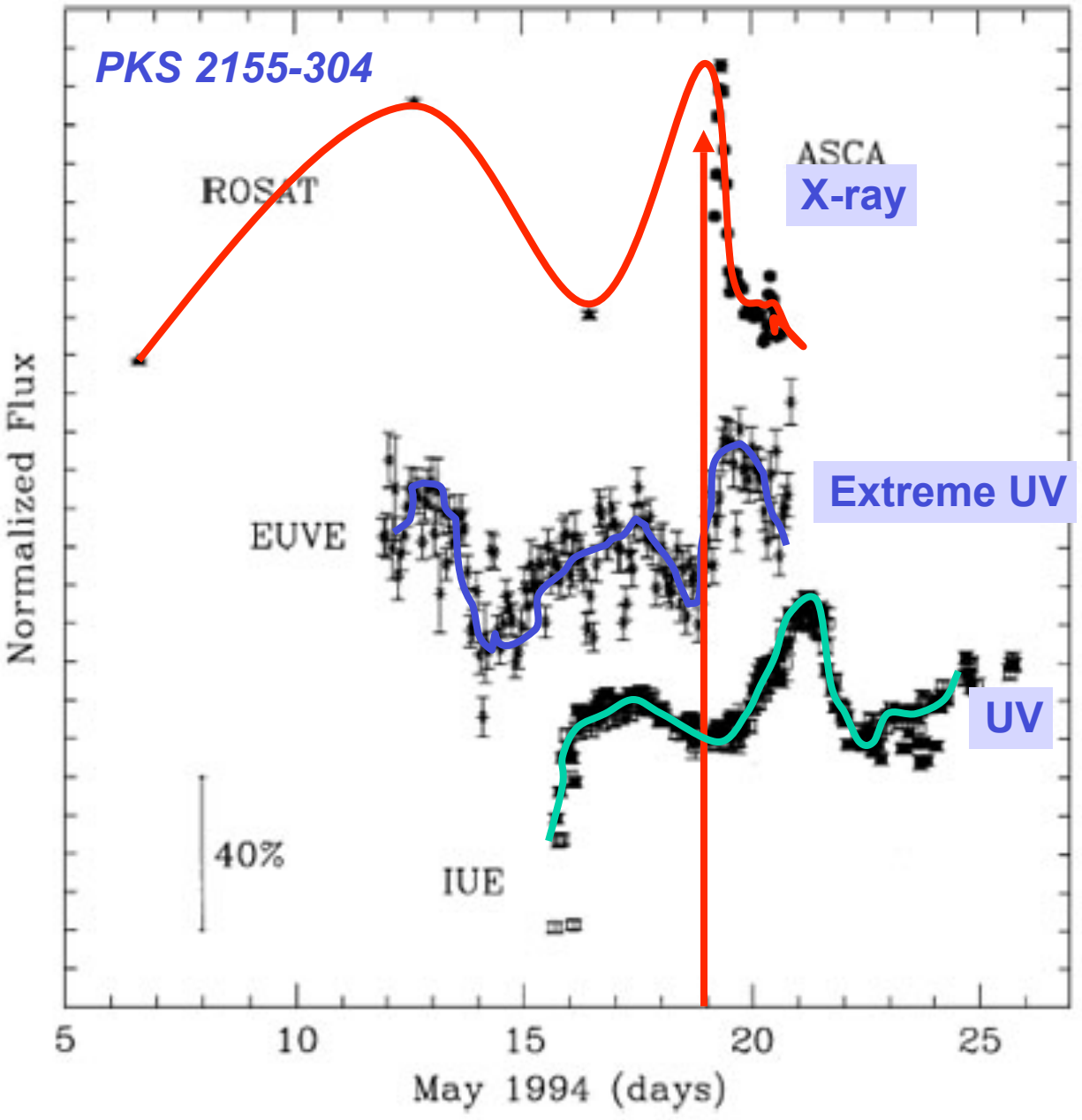

Simultaneous multiwavelength coverage: Timing

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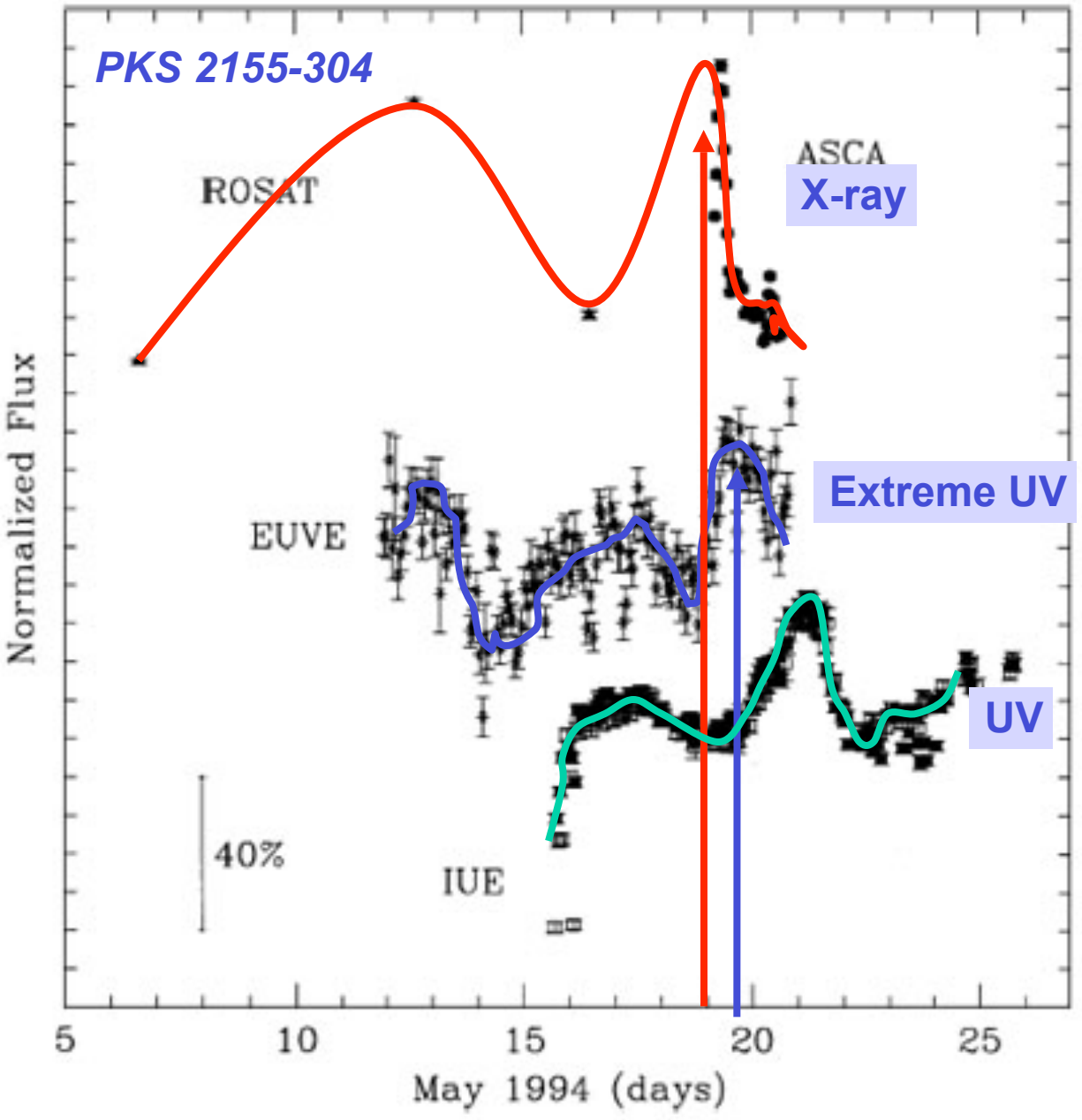

Simultaneous multiwavelength coverage: Timing

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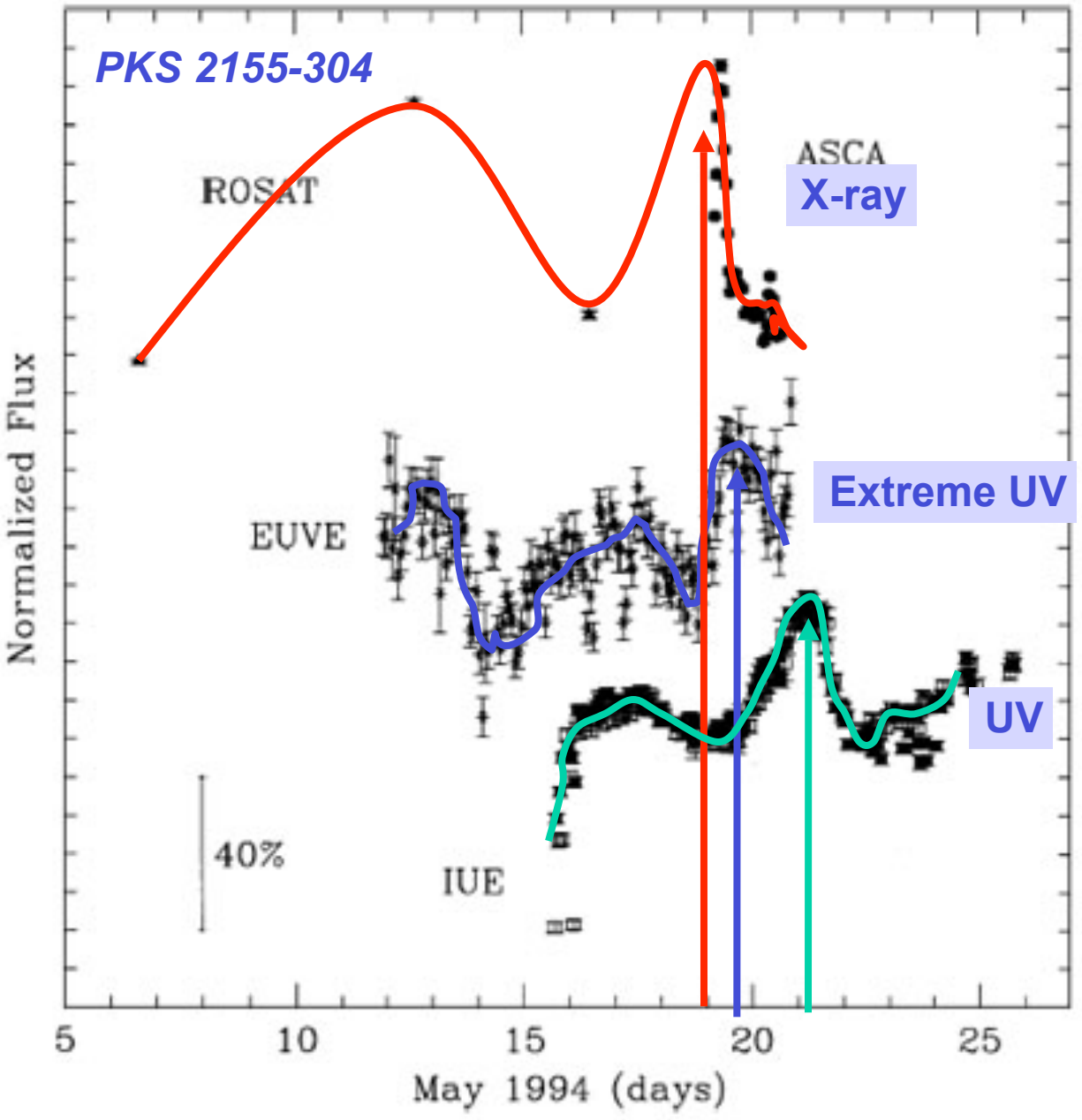


McHardy: Variability of AGN emissions

Southampton

CONCLUSIONS

AGN probably occupy all the same spectral-timing states as GBHs.

PSD bend timescales scale with mass and accretion rate; high frequency PSD normalisation probably purely mass dependent.

Direct link between X-ray timing properties and host galaxy linewidth.

Short timescale optical variability in Seyferts dominated by reprocessing of X-rays, strength dependent on disc temperature.

Optical variability on longer timescales from intrinsic disc variability.

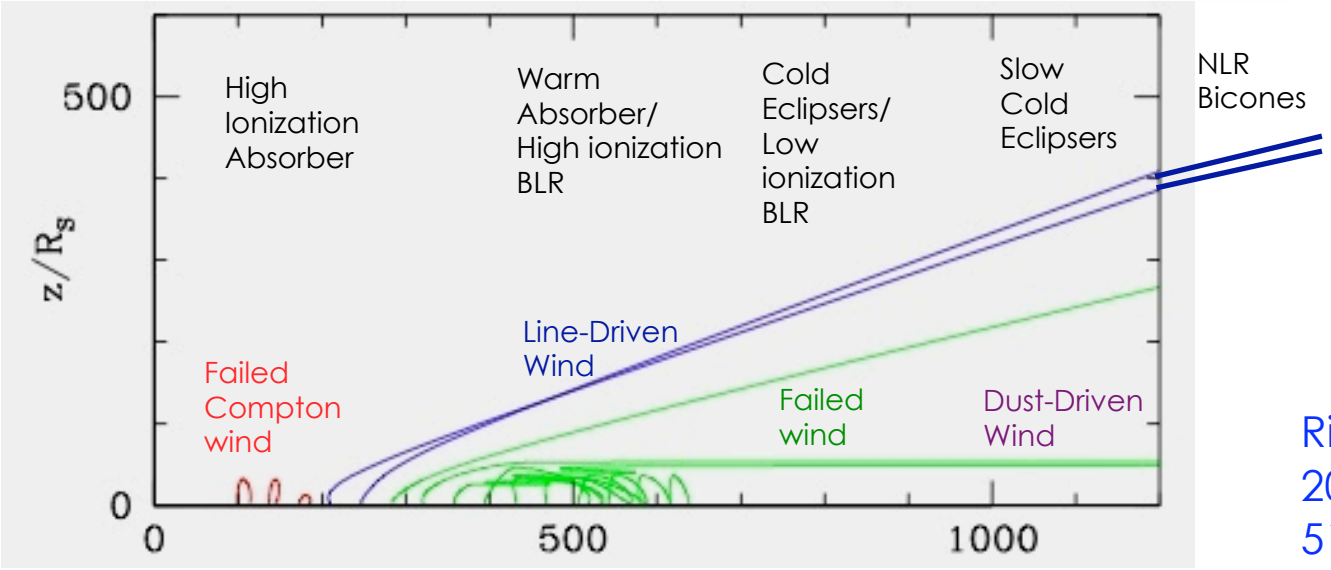
Good correlation between X-ray and radio in liners (~10^{-4} Eddington) consistent with jet emission

In higher accretion rate Seyferts, origin of radio emission is mystery.

All of these studies would greatly benefit from ASTROSAT observations

M.Elvis: ASTROSAT and Quasar Eclipses (continued)

1. Donut Torus is too simple: larger and smaller scale absorbers
2. Unified by accretion disk winds
3. Cometary Broad Line Region clouds
4. Close to resolving X-ray continuum source
5. ***ASTROSAT will be great !***
6. Definitive test and properties of GR Fe-K line
7. *Extreme Physics Explorer*



Risaliti & Elvis, 2010, A&A 516, A 89

Other extragalactic studies

- Warm Absorbers: Astrosat: disk emission, complementing XMM/Chandra high resol. Spectrosc. (*Guainazzi, Chakravorty*)
- Bulge/AGN relations ; pseudobulges (*Mathur)*
- Time variability of ULXs, if bright enough (*Fabbiano*)
- UV observations of Galaxy Cluster Cooling Flows: Star Formation (*David*)

Some remarks of speakers :

- "Tell your supervising agencies: X-ray missions should never die" (R.Remillard)

- "A misfortune of Astrophysics is that no progress is made" (S.Chakrabarty)

- "Some people are creators, other are destroyers. I am a destroyer" (M.Mendez)

- "The obscuring Torus is a Myth"(M.Elvis)

- "BH studies require a local enthousiast and a flexible observing program, taking TOOs into account. Tell this to the ASTROSAT bosses"(R.Narayan)

- "Keep your eyes open, keep your mind open" (S. Mathur)

- " Keep your ears open" (A.Kembhavi)

SUMMARY

ASTROSAT will open exciting new windows on the Universe

In the coming 5 – 10 yrs unique in 3 ways (no competition):

1. High-resolution timing (microsec) up to 100 keV:
   Fundamental properties of Neutron Stars and Black Holes

2. All-Sky Monitor: Discovery and monitoring of outbursts from:
   Black-hole binaries, X-ray pulsars, supernovae, SGR, AGN,
   etc. → Alerts for follow-up by CHANDRA, XMM, Suzaku, etc

3. Very wide band spectral coverage: soft-X to UV-optical

Great space for making new discoveries!