Extragalactic Astronomy II

Lecture 13

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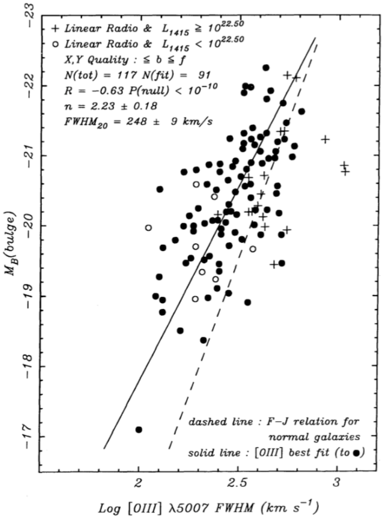
Apr-June 2021

NLR line strengths correlated with bulge luminosity



Whittle (1992)

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- AGNs with powerful radio jets lie off the correlation, having larger widths than expected.
- There can also be some non-virial component to the velocities, such as shock interactions between the radio jets and NLR gas.

Question

On what date shall we hold the seminar?

Research project for NCRA students

At NCRA, we have students do two 3-month long research projects under different research guides. If any of the NCRA students amongst you, would be interested in doing a project with me, please email me. My research interests are described at:
http://www.ncra.tifr.res.in/∼yogesh/research.html

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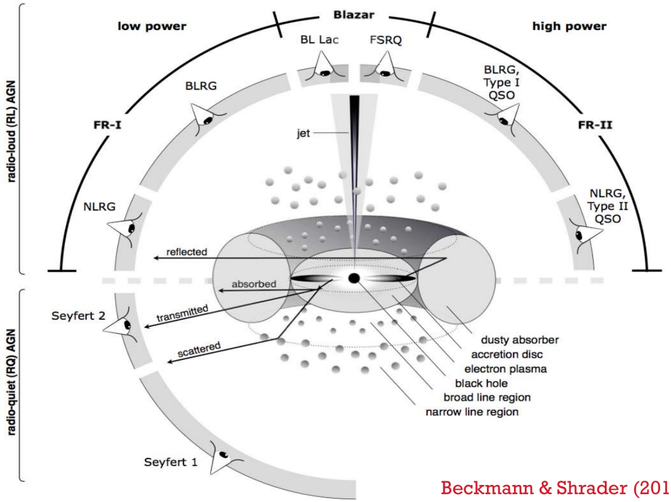
- The torus is presumed to be an axisymmetric structure of (cylindrical symmetry) large height so that, at least at low luminosities, the majority of AGNs are obscured by it.
- It is made of a combination of dusty atomic and molecular gas. The dust causes large extinction in the optical/UV and sometimes even in the NIR.
- From observations of many AGN, there appears to be substantial object-to-object variations in the covering factor and geometry of the torus.

How does the presence of the torus affect the emission from central engine?

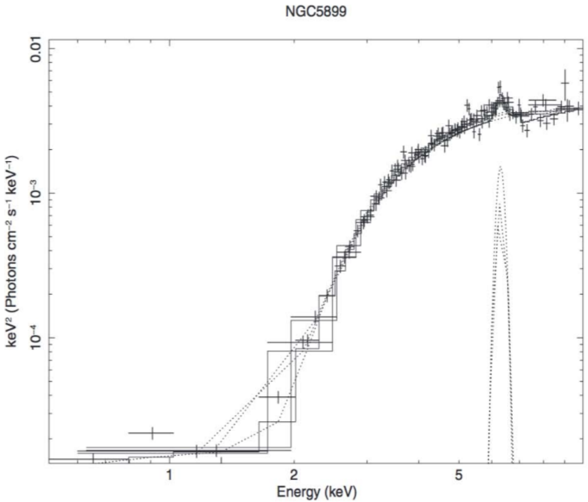


Beckmann & Shrader (2012)

What X-ray observations tell us about the torus?

- the X-ray opacity of gas is strongly energy dependent, and high-energy X-rays can in many cases pierce through the torus.
- This enables the column density through the torus to be estimated, with values of $10^{22} - 10^{24}$ cm^{-2} often being found.
- Some Type 2 AGNs have very large column densities that cannot be pierced even with high-energy X-rays - these are called *Compton-thick* AGNs.

X-rays through torus

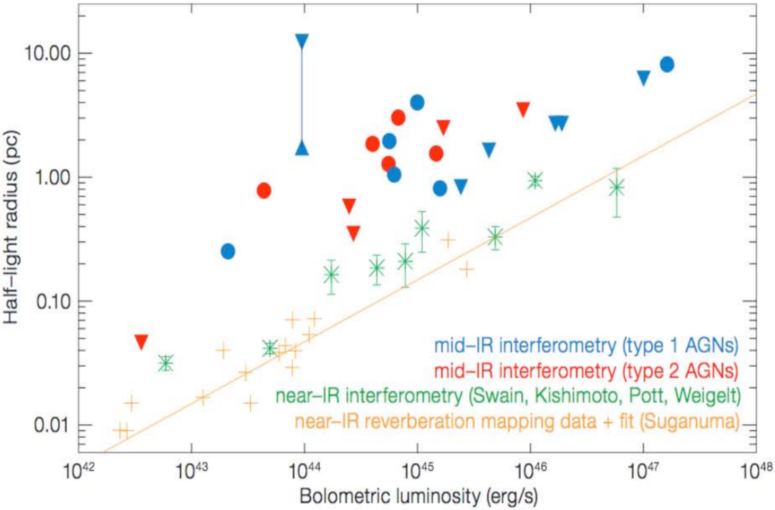


Vasudevan et al. (2013)

Size of the torus

- Dust reverberation mapping between the V-band and K-band light curves can be used to measure size
- Interferometry in the NIR and MIR.
- The size of the torus appears to scale as $L^{0.5}$. The inner edge of the torus is at about 3 times the BLR radius for H-β as determined from reverberation mapping.

How the torus size scales with AGN luminosity



Burtscher et al. (2013)

Is the torus clumpy?

If the torus were continuous over the range of radii observed, one would expect substantially hotter dust emission in Type 1 AGNs than Type 2 AGNs. Why?

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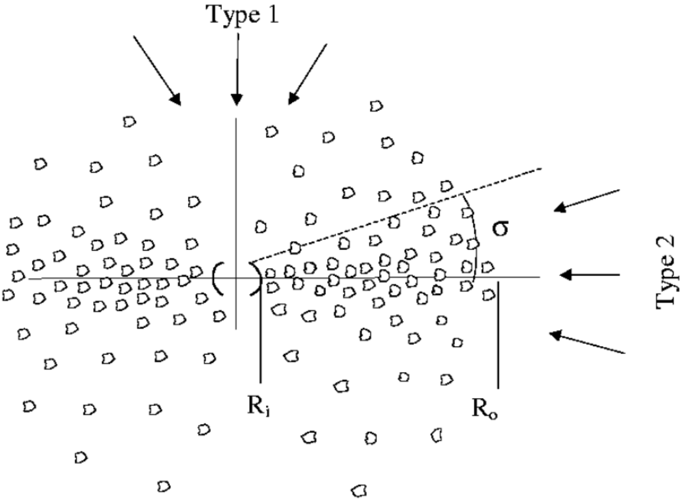
In Type 1 AGNs one could see the hot inner wall of the torus, while in Type 2 AGNs one could only see cooler dust at large radii.

But this is not observed. This result and others have led to a preference for *clumpy* torus models.

Clumpy torus



How a clumpy torus is consistent with the data

Clumpy torus models break the strict correlation between dust temperature and distance, allowing clumps further out to be heated by the central radiation. They improve agreement with the data.

AGN type would then be an orientation-dependent probability.

To explain the full NIR / MIR spectrum, one must also include NLR dust emission and a detailed treatment of the hot (1500-2000 K) graphite dust at the inner wall of the torus.

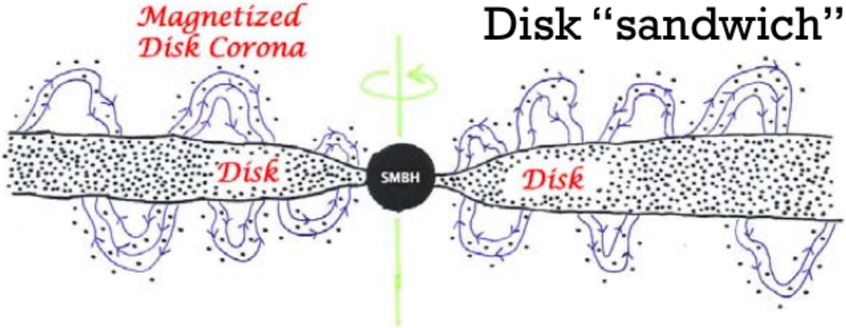
Torus density and rotation speed

Keplerian velocities at the torus distance are ~ 1000 km s^{-1}.
Density of torus *clumps* are $\sim 10^5 - 10^7$ cm^{-3}.

Question

The highest temperature reached in the accretion disk reaches to 10^5 K. How can we detect hard X-ray emission with energies upto 150 keV and beyond in this situation?

X-ray corona

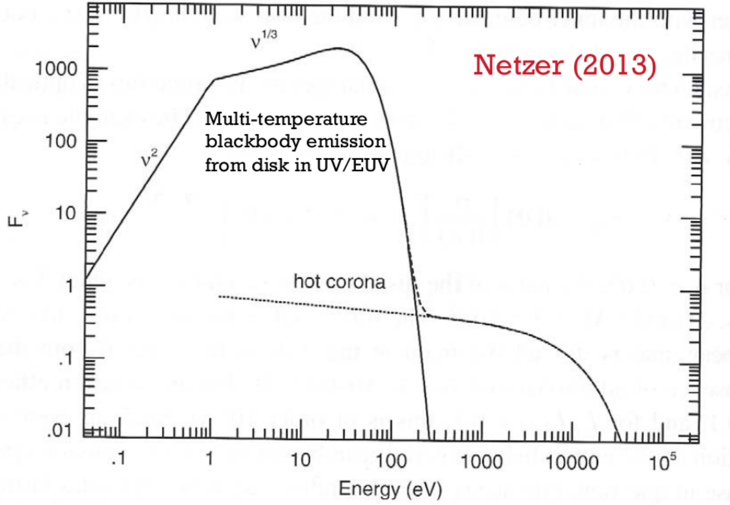


In astrophysics most unexplained phenomena are attributed to dark matter, dark energy or magnetism.

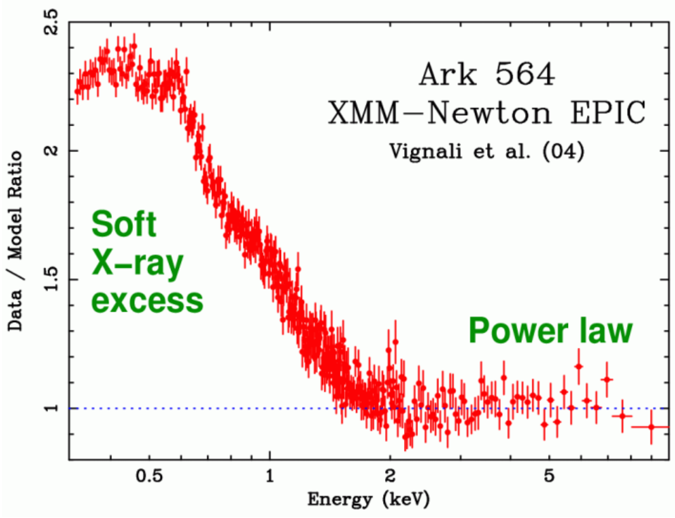
X-ray corona

Corona temperature is very high $\sim 10^8$ K.
The *corona* Compton up-scatters EUV/UV/optical photons from the disk to create X-ray emission. Corona likely heated by magnetic flares.
Corona has a temperature of ~ 150 keV, beyond which an exponential cutoff is observed.
The corona's properties cannot yet be computed from first principles.
Its nature remains uncertain. Sandwiching the disk? Base of a jet?

AGN disk-corona X-ray spectrum



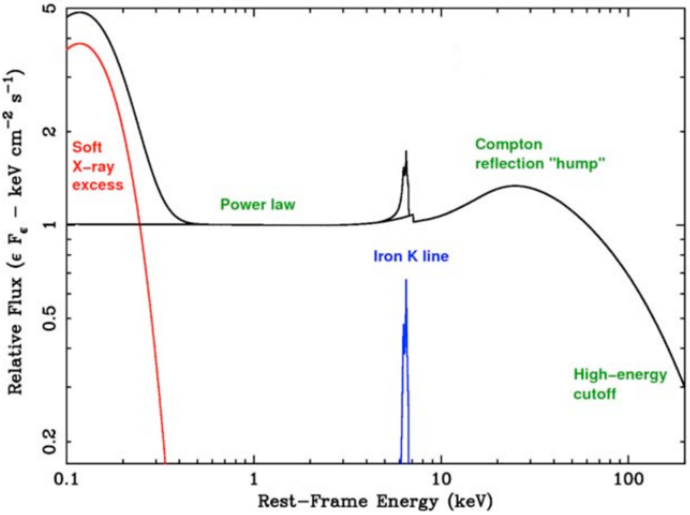
Soft X-ray excess



Soft X-ray excess

- Strong soft emission of approximately blackbody spectral form seen from some objects below ~ 1.5 keV.
- Too hot and too variable to be entirely from the standard accretion disk.
- Likely a combination of disk emission at lowest energies plus a cool Compton-scattered component and disk reflection.

Broad band AGN X-ray spectral features



AGN properties explained by AGN unification

- Strong UV to X-ray continuum

AGN properties explained by AGN unification

- Strong UV to X-ray continuum $\Rightarrow$ blackbody from accretion disk
- rapid variability in blazars, no emission lines
- gamma ray emission commonly seen in blazars
- Strong broad emission lines
- Strong narrow emission lines
- Strong jet emission in radio
- Steep spectrum emission in radio lobes
- One sided jets in most quasars $\Rightarrow$ Doppler boosting
- Jets aligned on all length scales probed
- AGN are more common at $z \sim 2$
- Superluminal motion
- zero proper motions