Extragalactic Astronomy II

Lecture 10

Yogesh Wadadekar

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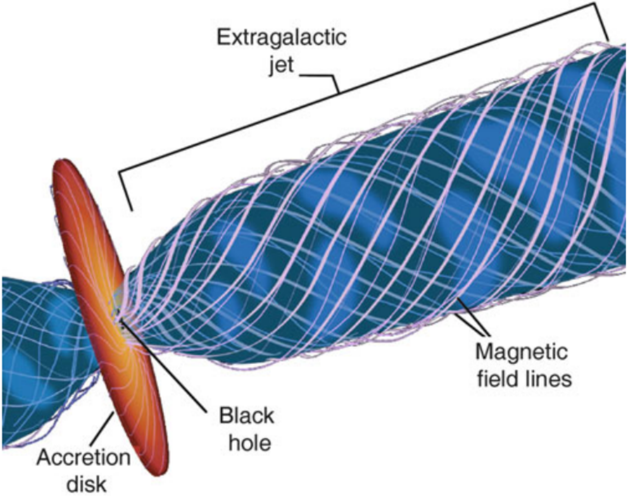
Temperature of accretion disk

can reach values upto 10^5 K. So we see a peak in thermal emission at 50 nm from the innermost parts of the accretion disk.
As we saw last time, high BH spin, and lower BH masses favour an inward extension of the accretion disk $\Rightarrow$ implying higher temperatures and stronger thermal emission.

Assignment 1

was put on the website last evening. Deadline: 11 June, 1700 hours.

AGN Jet


Extragalactic
jet
Magnetic
field lines
Black
hole
Accretion
disk

AGN Jet

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- Shock fronts within the jet lead to acceleration processes of relativistic electrons, which then strongly radiate and become visible as *blobs* in the jets.
- By rotation of the accretion disk in which the magnetic field lines are frozen in, the field lines obtain a characteristic helical shape. It is supposed that this process is responsible for the focusing (collimation) of the jet.

Flux amplification by beaming

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- Another effect described by Special Relativity is that a moving source which emits isotropically in its rest-frame has an anisotropic emission pattern, with the angular distribution depending on its velocity.
- If the emitting source is moving towards us

$$D_+ = \left(\frac{1}{\gamma(1 - \beta \cos \phi)} \right)^{2+\alpha}$$

  where α is the spectral index and ϕ is the angle between the velocity vector of the source and the line of sight.
- Even at $\beta = 0.9, \phi = 0$, $D_+ = 40$

Beaming

- For a emitting source that is moving away from us,

$$D_{-} = \left(\frac{1}{\gamma(1 + \beta \cos\phi)} \right)^{2+\alpha}$$

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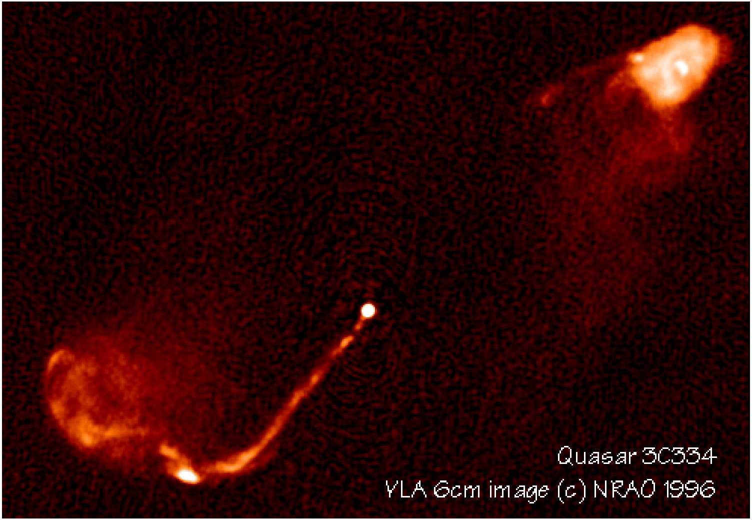
- Hence the ratio of the jet to counter-jet boosting ratios

$$\frac{D_{+}}{D_{-}} = \left(\frac{1 + \beta \cos \phi}{1 - \beta \cos \phi} \right)^{2+\alpha}$$

This is known as *Doppler favoritism*. Blazars are highly polarised because synchrotron emission is boosted but unpolarised thermal emission is not. Does this also explain why blazars are variable?

One sided jet in quasars



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Most radio loud quasars show one sided jets. What does this imply about their relativistic nature on kpc scales?

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On kpc scales, jets must be at least semi relativistic $\gtrsim 0.2c$

Question

Can you use polarisation data to figure out if the jet is closer than the counter-jet?

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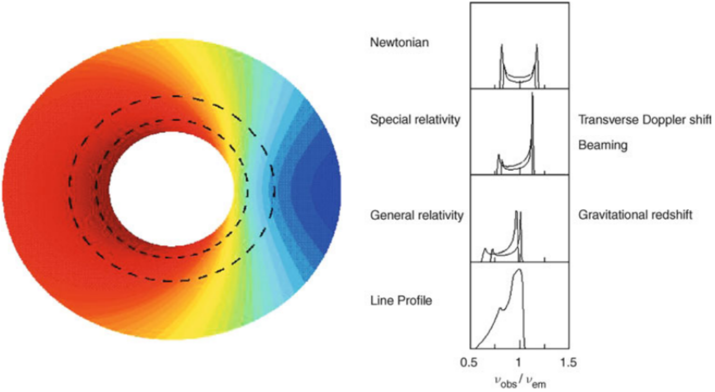
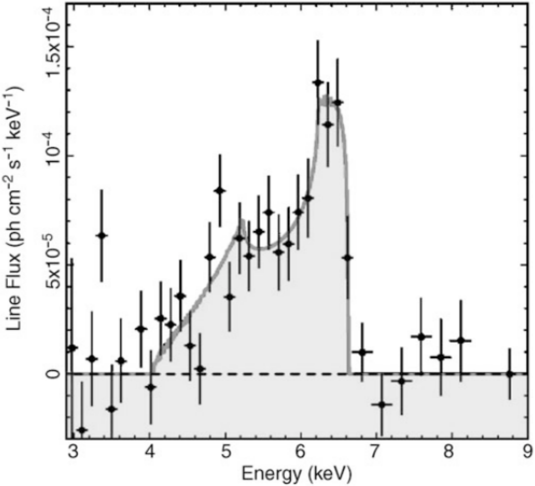
6.35 keV Fe line from the inner accretion disk



Observed Fe line profile



With this kind of modeling, the spin parameter of the SMBH can be estimated. How?

Question

Observed spin parameter $a > 0.9$, in most galaxies where it has been measured. What does this indicate about the mechanism for angular momentum transfer into the black hole?

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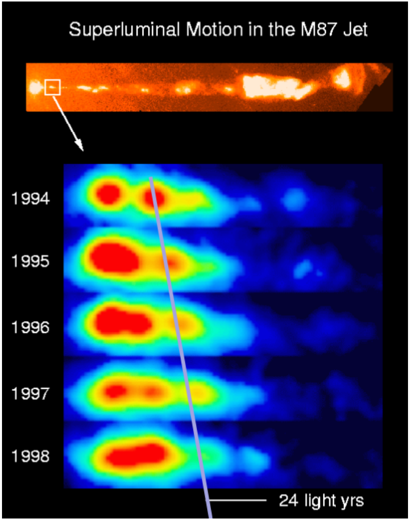
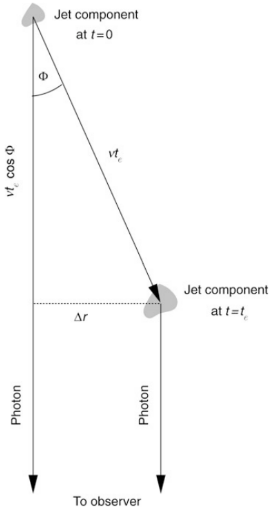
Observed spin parameter $a > 0.9$, in most galaxies where it has been measured. What does this indicate about the mechanism for angular momentum transfer into the black hole? Does this mean that the SMBH has built up its mass primarily by accretion?

M87 Superluminal motion of VLBI Jet



Apparent speed - 6c, physical speed of jet or motion of illumination patterns.

Superluminal motion



Superluminal motion

$$\Delta r = v t_e \sin\phi$$

$$\Delta t = t_e(1 - \beta\cos\phi)$$

$$v_{app} = \Delta r/\Delta t = v\sin\phi/(1 - \beta\cos\phi)$$

How will this equation be modified for high redshift galaxies?

Superluminal motion

$$(\sin\phi)_{max} = \frac{1}{\gamma}$$

$$(v_{app})_{max} = \gamma v$$

Outflow speeds and escape velocity

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Examples are the Solar wind, stellar winds in general, or the jets of neutron stars. Jets in AGN must be formed at accelerated very close to the Schwarzschild radius of the SMBH.

How are jets powered?

- Such fields may be anchored in the accretion disk, and then spun up and thereby amplified. The wound- up field lines may then act as a kind of spring, accelerating plasma outwards along the rotation axis of the disk.

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- In addition, it is possible that rotational energy is extracted from a rotating black hole, a process in which magnetic fields again play a key role.
- As is always the case in astrophysics, detailed predictions in situations where magnetic fields dominate the dynamics of a system (like, e.g., in star formation) are extremely difficult to obtain because the corresponding **coupled equations for the plasma and the magnetic field** are very hard to solve.

Stability of AGN Jets

Direction of jet on VLBI scales is the same as the large kpc jets which produce the lobes. The central engine must be stable over $\sim 10^7$ years. A SMBH is a an excellent gyroscope.