Doppler Boosting of Radio jets

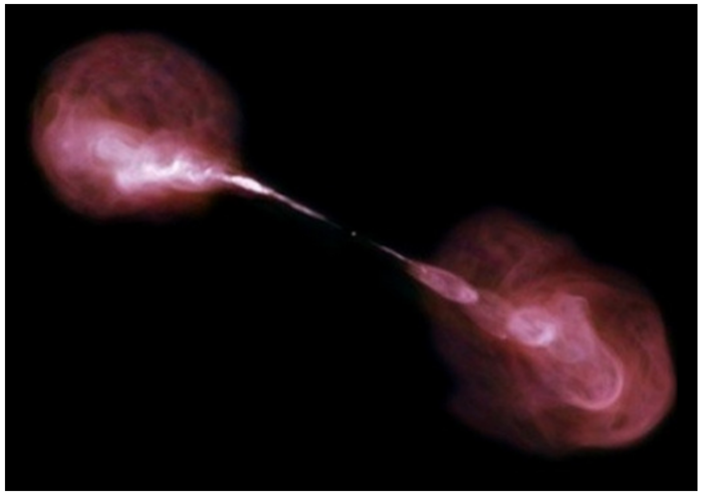

Figure 1: Radio jets from AGN

- One noticeable feature in the above is that one if the jet path is visible while the other is not.The reason for such a feature is the shift in frequencies of both the jets as a result of doppler effect.
- For the jet directed towards us,the frequency will be higher and for the one moving away it will be lower as given by doppler formula,
- For beam directed towards us,

$$\nu_{obs} = \frac{\nu_{rest}}{\gamma(1-\beta\cos\theta)} \tag{1}$$

- For beam directed away,

$$\nu_{obs} = \frac{\nu_{rest}}{\gamma(1+\beta\cos\theta)} \tag{2}$$

- For this beam the flux density is very less because frequency is reduced and also because it is coming from a very thin region so it is not visible.
- Hence the fact that the beams undergo doppler boosting is another hint(in addition to being apparently superluminous) that it is relativistic.

Variability

- The time period of variability can be utilized to constrain the size of the region which is emitting the signals.This is based on the principle of causality.

- Suppose you have a spherical paper lampshade surrounding an electric light bulb. When the lamp is turned on, the light from the bulb will travel at a speed c and will reach all parts of the lampshade at the same time, causing all parts to brighten simultaneously. To our eyes the lampshade appears to light up instantaneously, but that is only because the lampshade is so small. In fact, light arrives at your eyes from the nearest point of the lampshade a fraction of a second before it arrives from the furthest visible point

- The time delay for the brightening, t, is given by,

$$\triangle t = \frac{R}{c} \tag{3}$$

- Now imagine the shade to be much larger, perhaps the size of the Earth's orbit around the Sun, and the observer is far enough out in space that the shade appears as a point source of light.

$$\triangle t = \frac{1.5 \times 10^{11}}{3 \times 10^{8}} = 500s \tag{4}$$

- So even if the lamp is switched on instantaneously, the observer will see the source take about eight minutes to brighten. Now suppose the bulb starts to flicker several times a second. What will an observer see? Even though the lampshade will flicker at the same rate as the bulb, it's clear that the flickering will have no effect on the observed brightness of the lampshade, since each flicker will take 500 seconds to spread across the lampshade and the flickers will be smeared out and mixed together. There is a limit to the rate at which a source (in this case the lampshade) can be seen to change in brightness and that limit is set by its size.

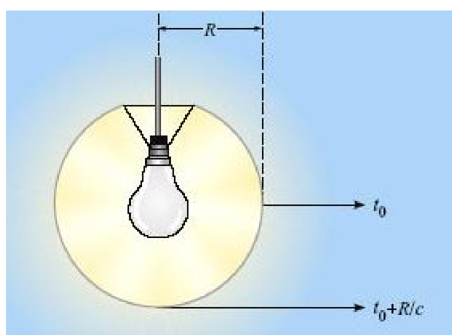

Figure 2: Illustration of the correlation between variability period and size of the emitter

- Light from the most distant visible point of a spherical lampshade will reach the observer a time R/c later than light from the near side. Fluctuations on timescales of less than R/c will not be observed.

- This argument may be inverted to state that if the observer sees a significant change in brightness of an unresolved source in a time t, then the radius of the source can be no larger than R= c $\triangle t$

- So size of the emitting region has to be smaller than $c \triangle t$
- For a typical variability period of roughly 1 day (10^5sec),$R_{max} = 10^{-3}$pc
- Thus the emitting region is very compact.