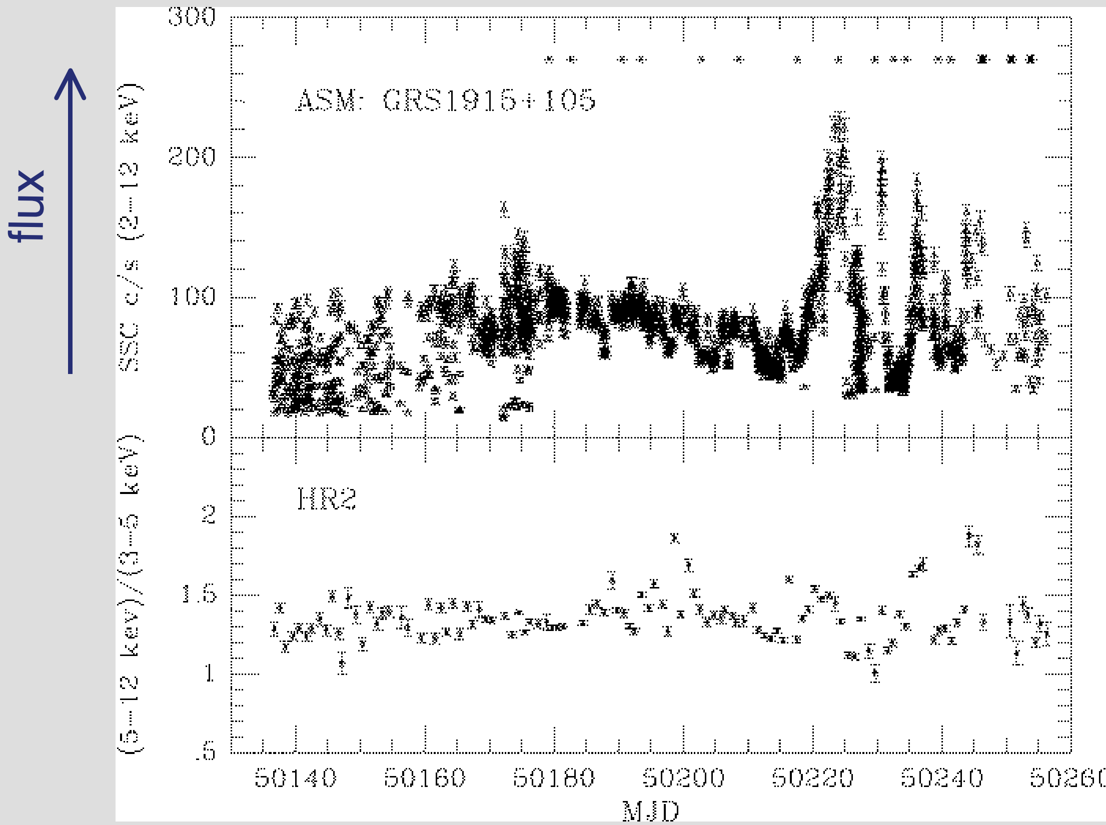
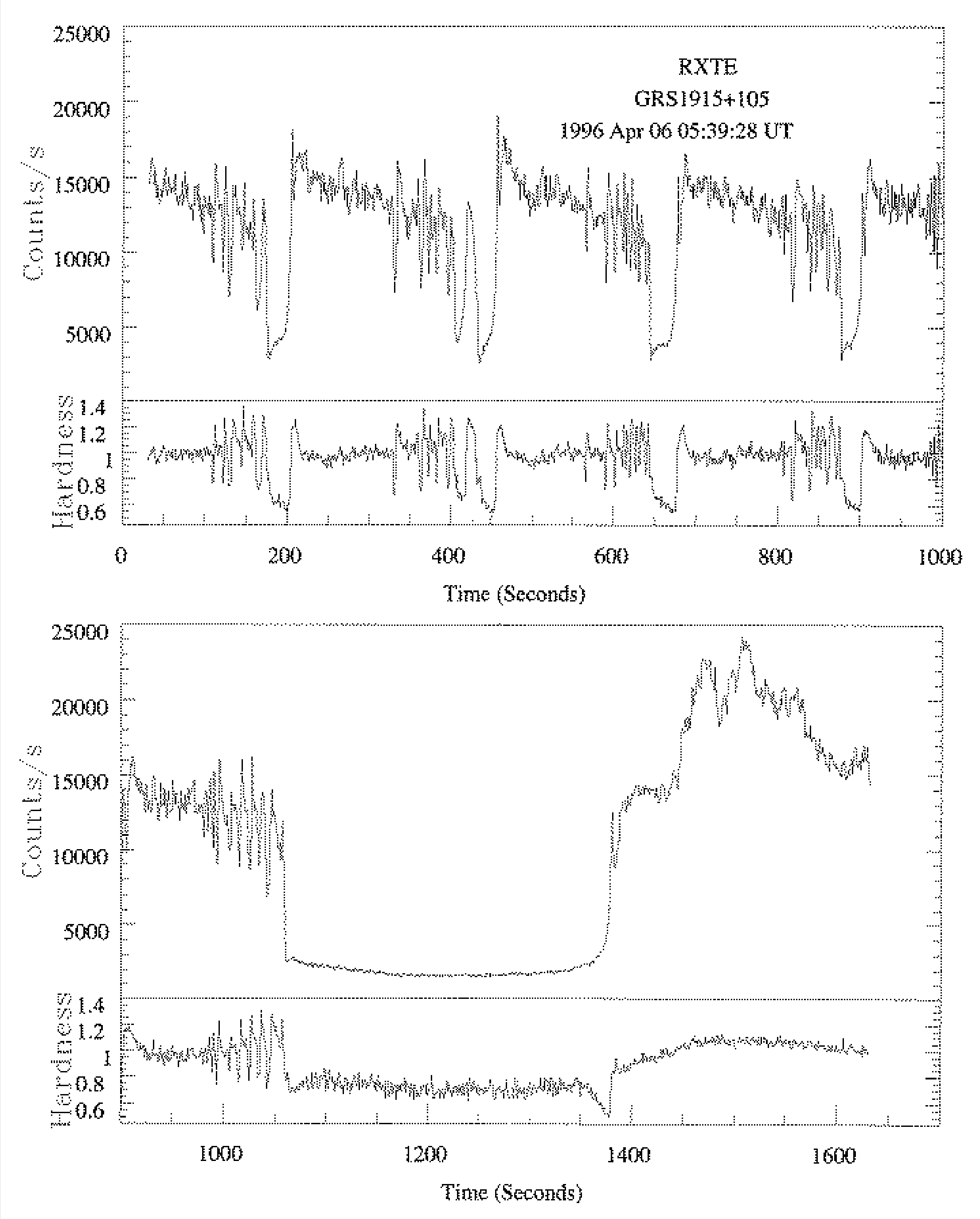
Variability of accretion onto black holes

Luminosity generated as gas spirals in to the black hole is highly variable:

- many sources are X-ray nova - previously unknown sources that flare up for months or years
- very complicated pattern of variability on shorter time scales - days down to ms



X-ray light curve of GRS1915+105 over a period of ~120 days



Same source, but now observed over a period of ~half an hour.

Complex, only partly random behavior that may be related to:

- instabilities in the mass flow near the black hole
- episodes of gas ejection from the system

Very well observed, but not well understood…

At a particular radius from the black hole, most rapid variability will occur on the dynamical or orbital time scale:

$$t_{orbital} = \frac{2\pi R}{v_\phi}$$

$$= \frac{2\pi R}{\sqrt{GM/R}} = 2\pi\sqrt{\frac{R^3}{GM}}$$

Newtonian formula for orbital velocity, so not (quite) right very close to the black hole

Shortest time scale when R ~ $R_s = 2GM / c^2$:

$$t_{R=R_s} \approx 4\sqrt{2}\pi \times \frac{GM}{c^3}$$

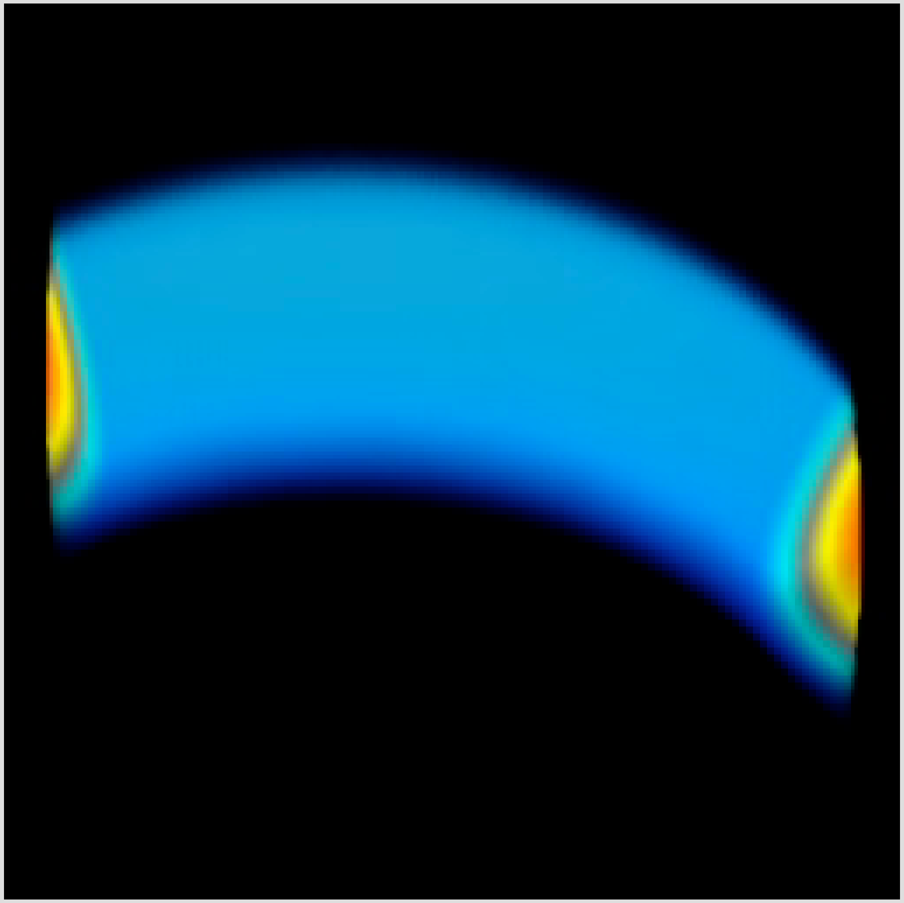
← light crossing time of the black hole x numerical factors

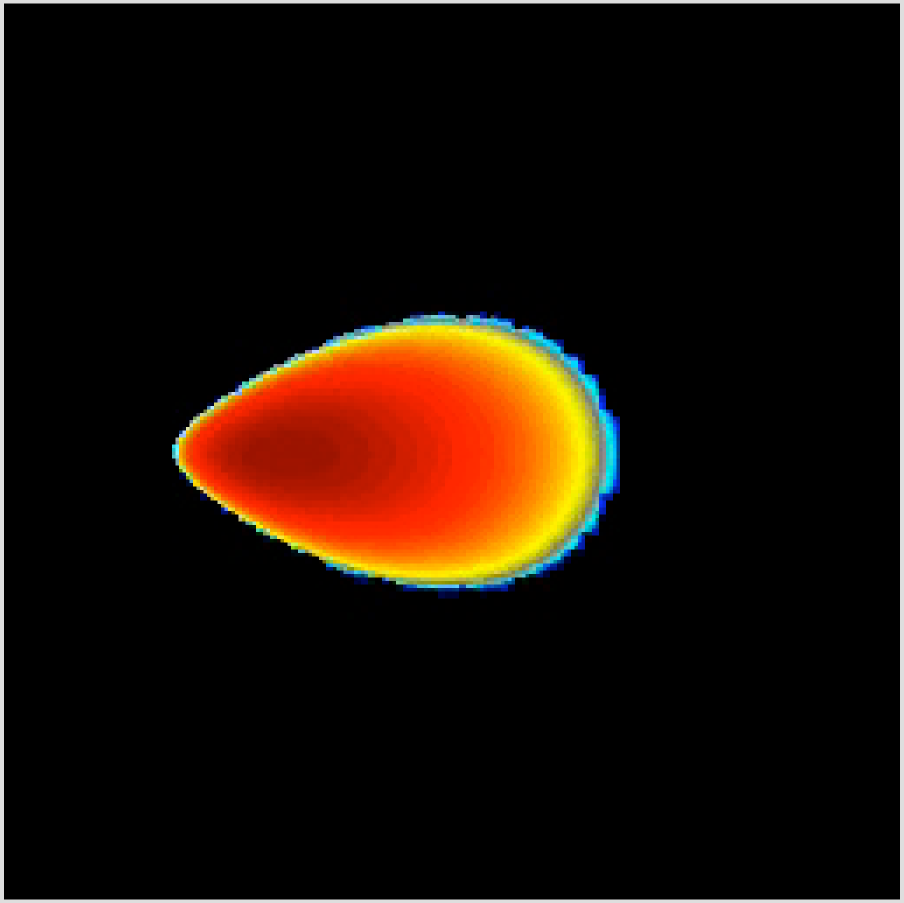
$$\approx \left(\frac{M}{10\ M_{sun}}\right) \mathrm{ms}$$

ms variability for stellar mass black holes, hour scale variability for supermassive black holes with $M \sim 10^7\ M_{sun}$

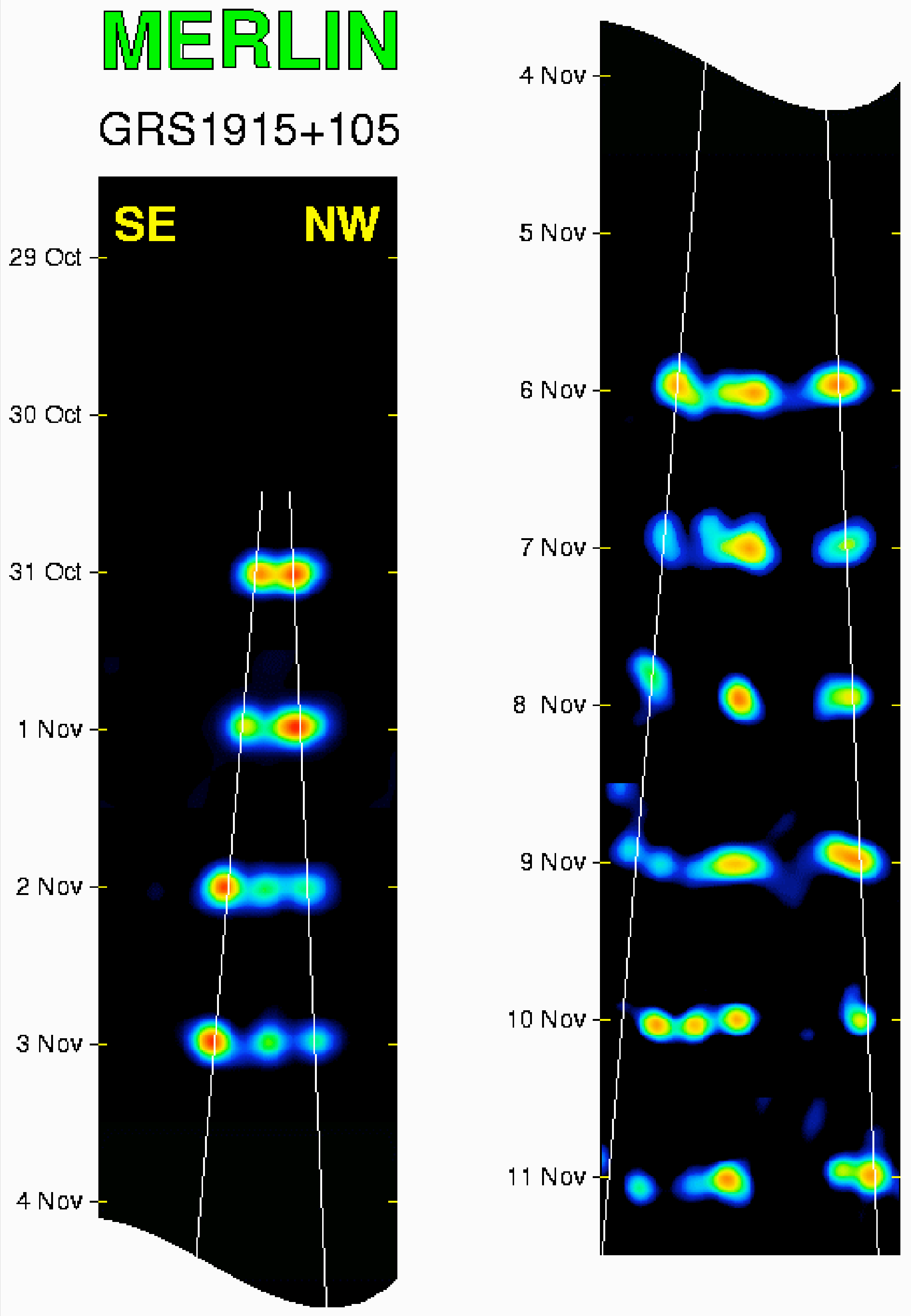
Expect the gas flow to be turbulent and variable, harder to explain is what's causing the different states of the system:

Simulation of magnetized gas flowing in to a black hole





Note: some gas flows away from the black hole instead of being accreted (movies by John Hawley).



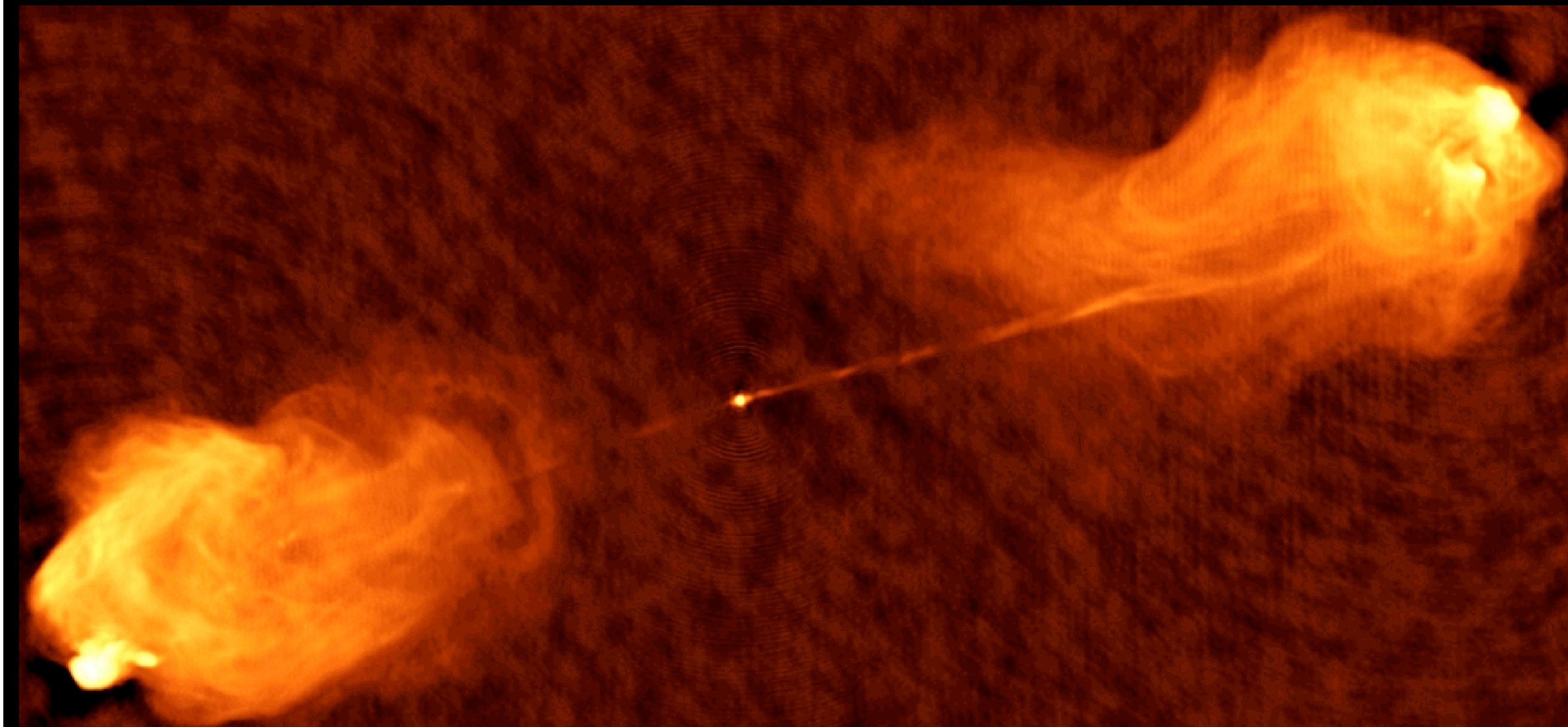
Relativistic jets

Very high resolution radio observations show that stellar mass black holes can eject matter with v ~ c - **relativistic jets**.

Another poorly understood phenomenon: thought to involve magnetic fields near the black hole and / or the tapping of the rotational energy of the black hole.

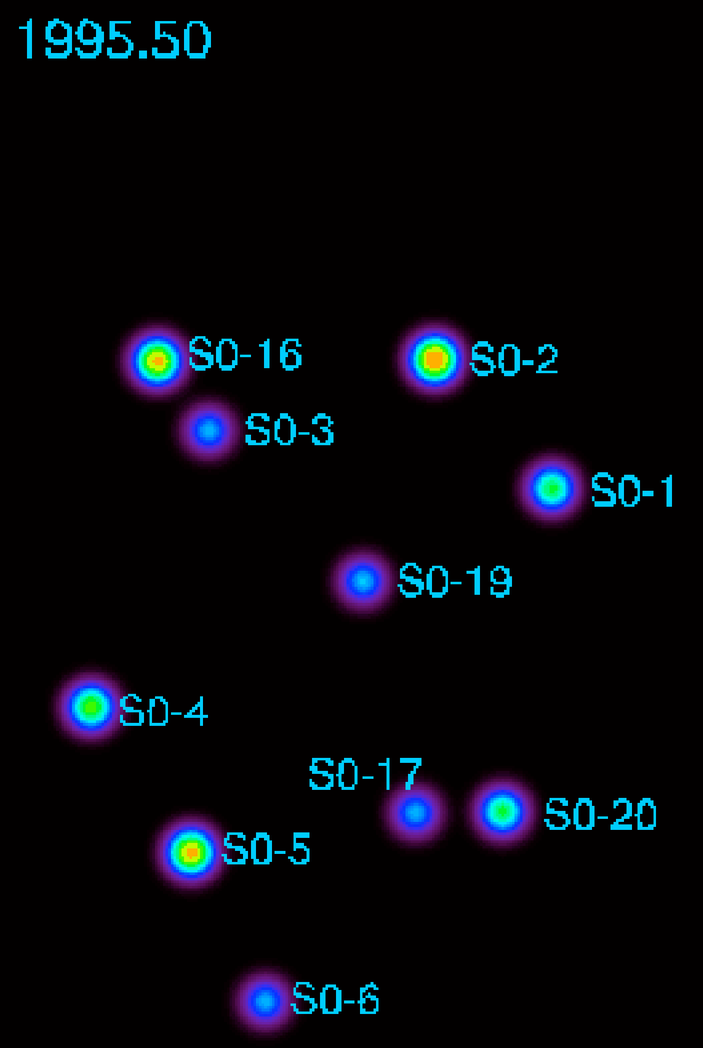
Same phenomenon seen in some **radio galaxies** with supermassive black holes.

Radio galaxy Cygnus A



Example of an Active Galaxy - to be discussed next semester: same phenomenon as a stellar mass black hole but here you can see clearly the interaction of the jet with the surrounding gas.

No sign of a jet from our own Galactic Center, but deduce the presence of a black hole from motions of nearby stars…



Movie from Andrea Ghez’s group at UCLA