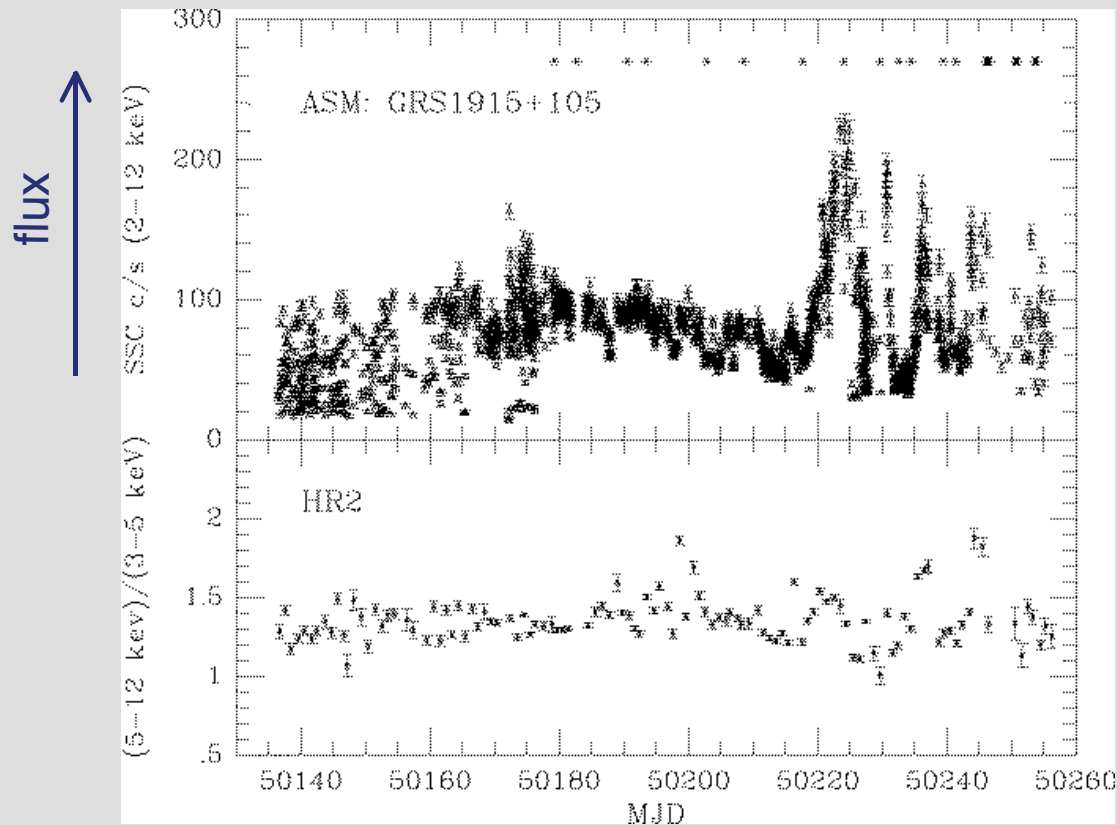


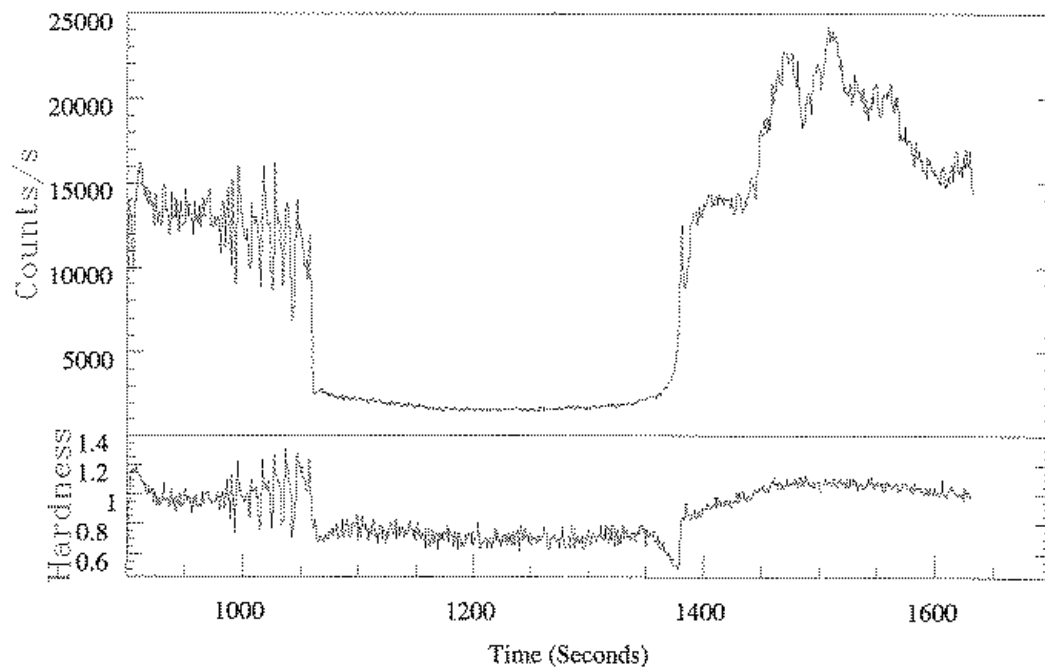
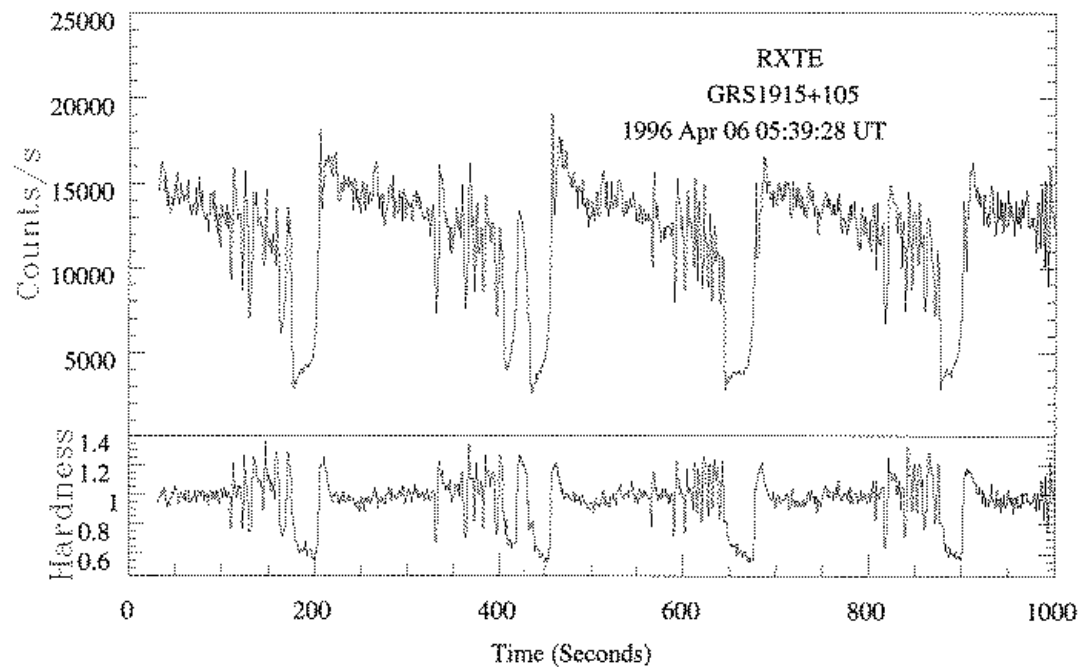
## Variability of accretion onto black holes

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  $\sim 120$  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:

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

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

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

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

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

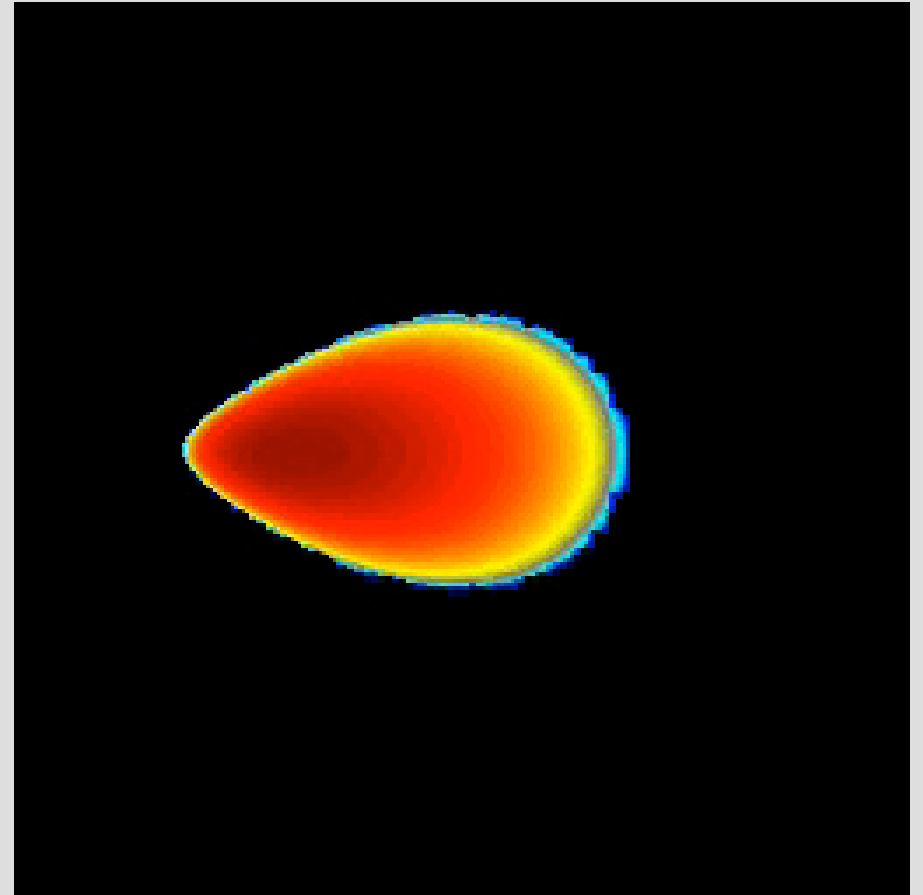
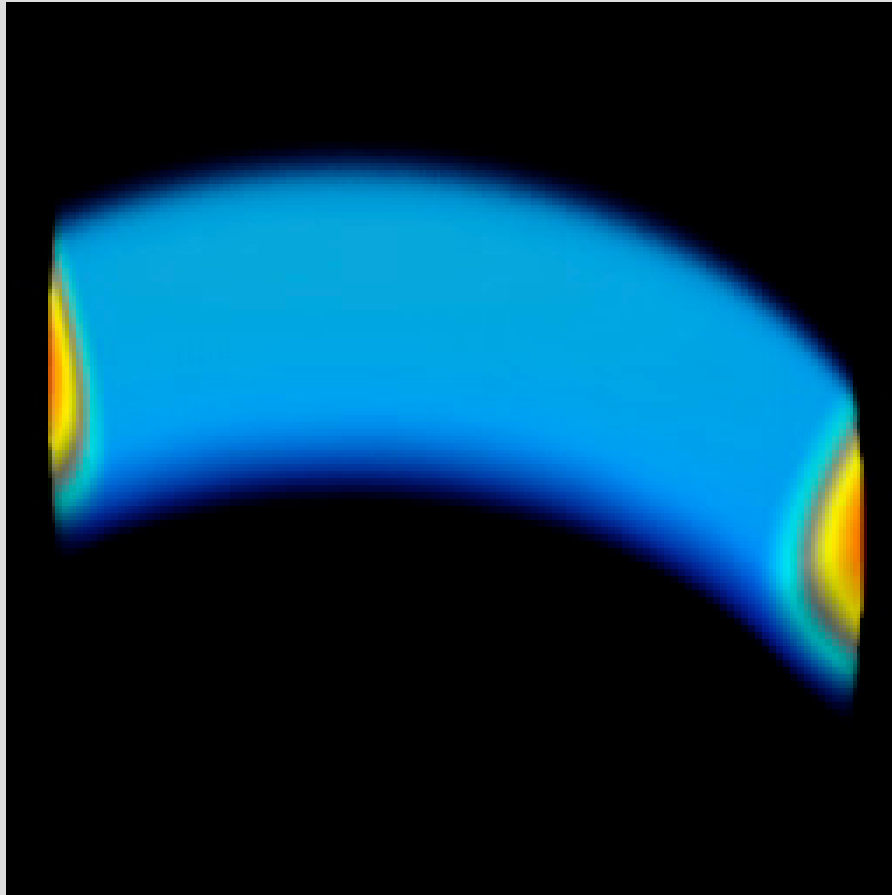
← light crossing time of the black hole x numerical factors

$$\approx \left[ \frac{M}{10 M_{\text{sun}}} \right] \text{ms}$$

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

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

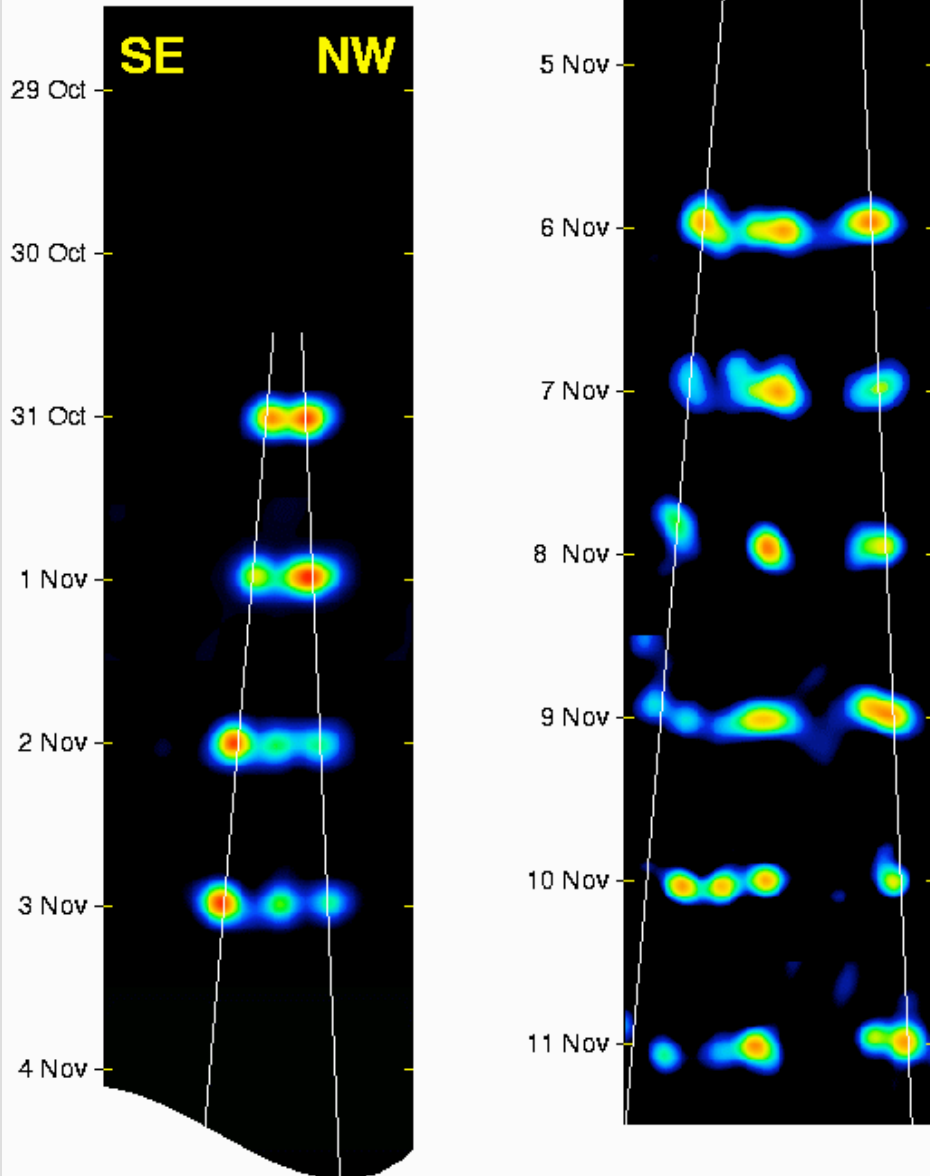
Simulation of magnetized gas flowing in to a black hole



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

# MERLIN

GRS1915+105



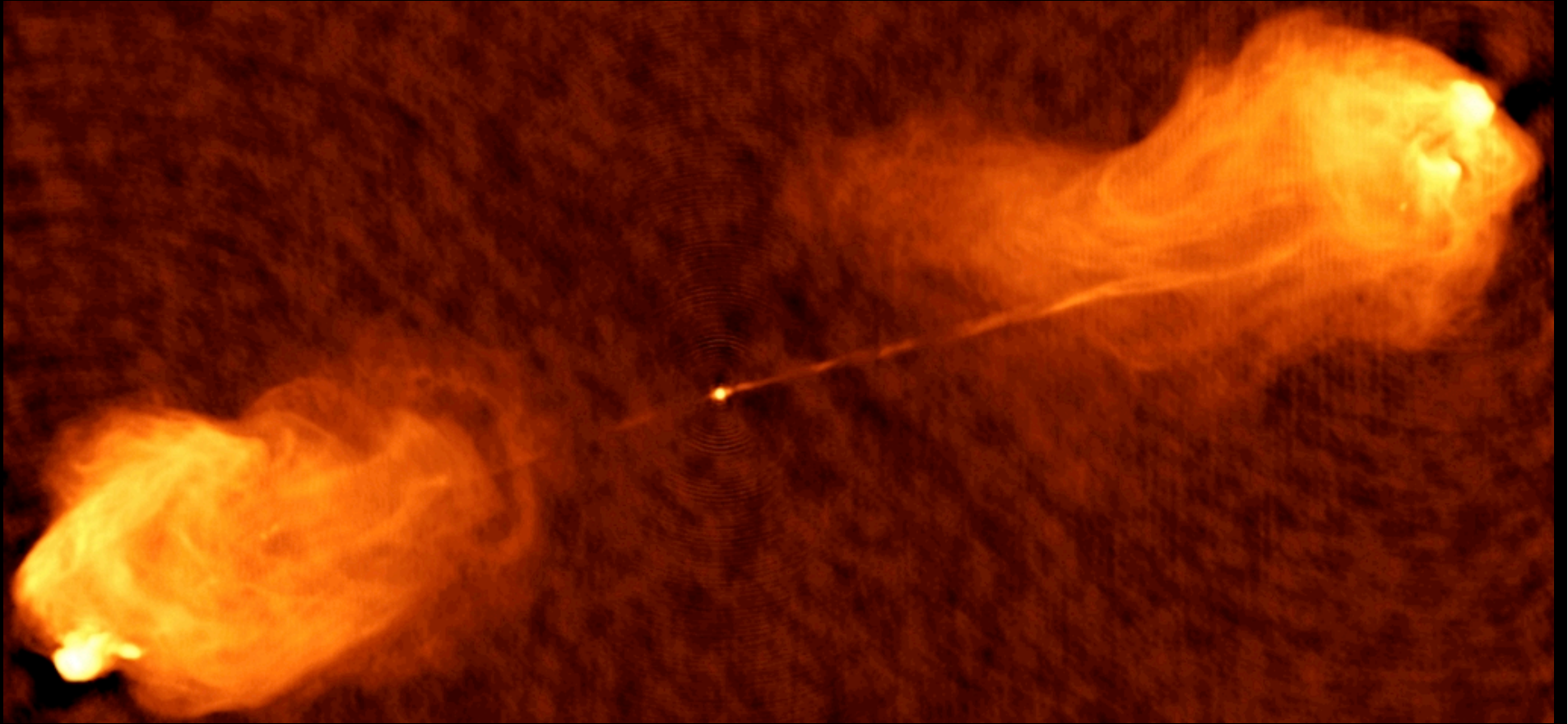
## Relativistic jets

Very high resolution radio observations show that stellar mass black holes can eject matter with  $v \sim c$  - **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.

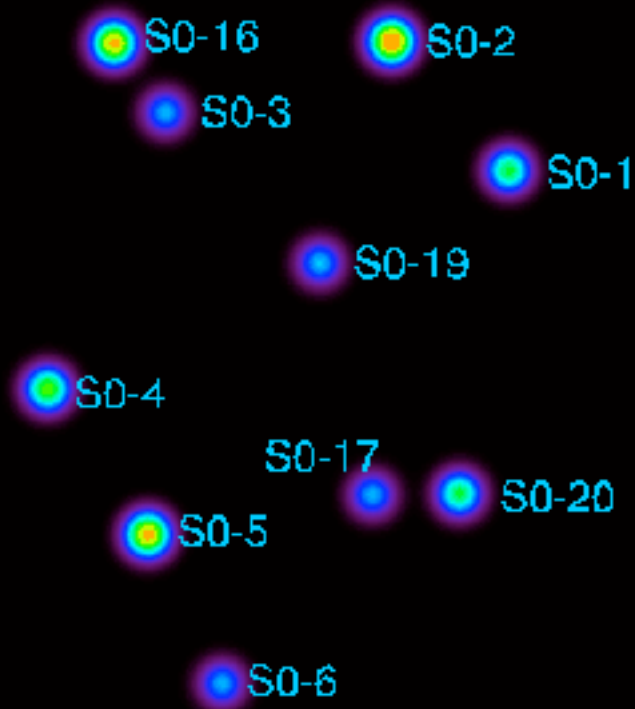
## Radio galaxy Cygnus A



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...

1995.50



Movie from Andrea Ghez's group at UCLA