AST7939: Homework 4

Due at the beginning of class on Monday, April 4

Instructions: *To receive partial/full credit you must show your work or explain your answer thoroughly. Please circle your final answer to each problem if it is a number.*

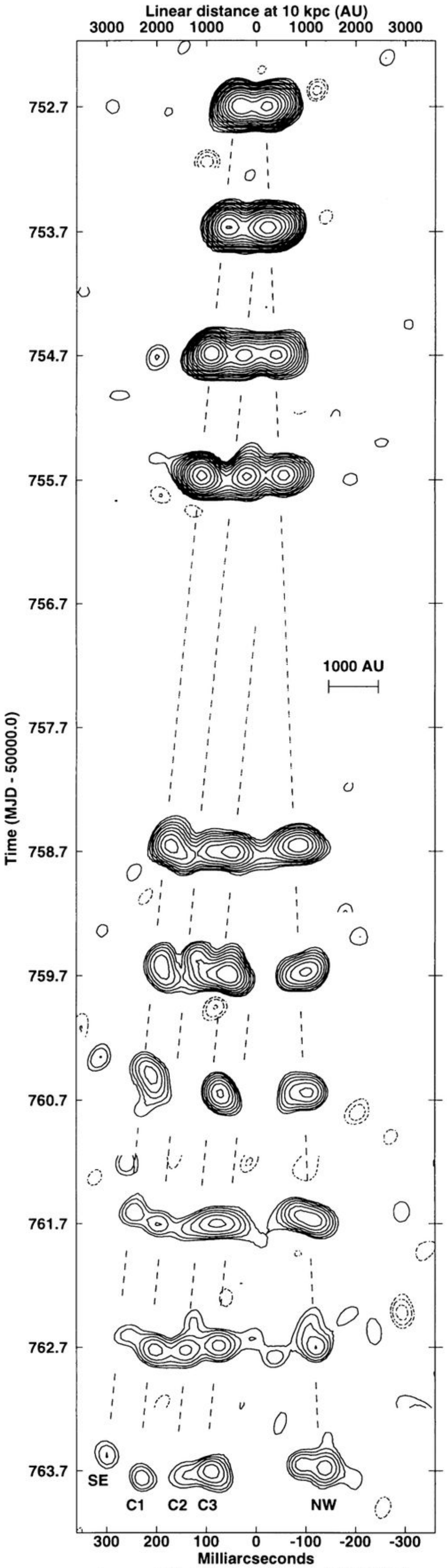
1. For a blob moving toward us at an angle to the line of sight, θ, the apparent velocity as a fraction of the speed of light is

$$\beta_{\mathrm{A}} = \frac{\beta \sin\theta}{1 - \beta \cos\theta}$$

   For $\beta = 0.50$, $\beta = 0.90$, and $\beta = 0.99$, plot β_A as a function of θ. This function peaks at some $\theta_{\mathrm{max}} = f(\beta)$ and $\beta_{\mathrm{A,max}} = f(\beta)$. Find these simplified functional forms and then also overplot this function, $\beta_{\mathrm{A,max}} = f(\theta_{\mathrm{max}})$, running through the extrema of the first three curves. Then finally reflect: under what situations do we most preferentially observe superluminal motion?

2. A Galactic microquasar jet was observed to show a two-sided jet, with ejections traveling in both directions.
   (a) From the figure below, estimate the proper motion (in micro-arcsec per day) for both sides of the jet (components SE and NW).
   (b) For a distance of 10 kpc, work out the apparent velocity in cm/s for NW and SE.
   (c) Assuming that NW and SE are identical but traveling in opposite directions, solve (including numerical answers) for the actual velocity $\beta_{\mathrm{jet}} = v_{\mathrm{jet}}/c$ and line–of–sight angle θ of the jet.

3. Long term high resolution monitoring of the star cluster around the Galactic center indicates the presence of a dark, massive object with a total mass of about $M \approx 4 \times 10^6\ \mathrm{M}_\odot$. Radio observations show that this object emits a faint glow and episodic flares. Based on the radio position, the object is called Sgr A* (short for Sagittarius A*) and, since there is no other viable explanation for such a large mass concentration inside such a small volume, we will assume that the object is a black hole.
   (a) **Basic properties for a black hole like Sgr A*:** For a non-rotating black hole with this mass, calculate the radius of the innermost stable circular orbit (ISCO), the Eddington luminosity, and the Eddington accretion rate (assuming the canonical radiative efficiency).
   (b) **The Salpeter time:** How long would it take for Sgr A* to double its mass if it were accreting at the Eddington rate? Does your answer depend on the mass of the black hole?
   (c) **Bondi accretion onto Sgr A*?** High resolution X-ray observations with Chandra show that the ISM in the immediate vicinity of Sgr A* has a temperature of $T \approx 1.3$ keV and a density $n \approx 26\ \mathrm{cm}^{-3}$. Calculate the Bondi radius, Bondi accretion rate, and inferred luminosity of Sgr A* in this case. By comparing this luminosity to that in the first part and the measured value, $L \approx 10^{36}\ \mathrm{erg\ s}^{-1}$, what do you conclude about the nature of the accretion flow?



Left: Proper motion of the jet components on one side

Below: Flux of the jet components as a function of angular distance from the BH