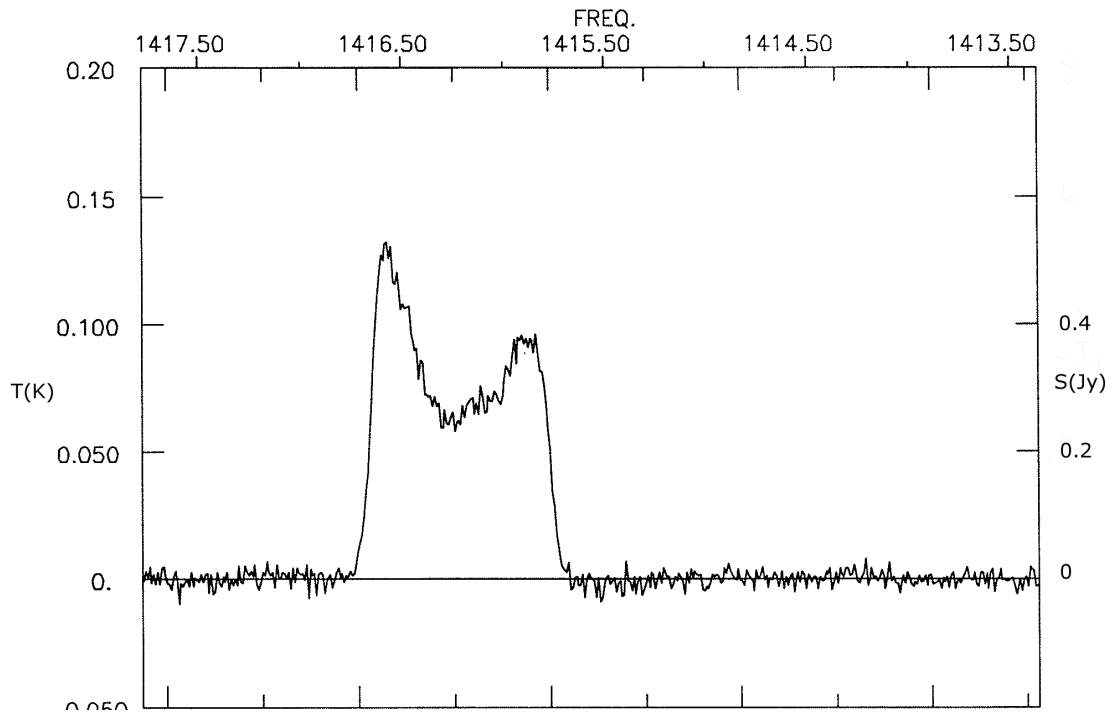


DARA Unit 1

Workshop 6

1. The figure below shows the spectrum of the H I emission line from a spiral galaxy.



The small external tick marks on the top x axis indicate the frequency in MHz and the rest frequency of the 21 cm line is 1420.41 MHz.

a) By measuring the central frequency of the emission line determine the radial velocity, v , of the galaxy in kms^{-1} . Then, by applying Hubble's Law

$$v = Hd$$

where $H=71 \text{ kms}^{-1}\text{Mpc}^{-1}$ find the distance, d , to the galaxy.

b) By considering the double-peaked profile of the line estimate the rotation speed of the galaxy.

c) It can be shown that under that assumption that the 21 cm line emission is optically thin then the total column density of hydrogen

present is given proportional to the brightness temperature of the line emission integrated over the line such that

$$N_H/\text{cm}^{-2} = 1.8 \times 10^{18} \int T_B(v)/\text{K} dv/\text{kms}^{-1}$$

Estimate the area under the line on the T_B scale on the spectrum to estimate the total column density of hydrogen in the spiral galaxy.

d) Since

$$T_B \propto I_\nu \propto \frac{S_\nu}{\Omega} \propto S_\nu \frac{d^2}{A}$$

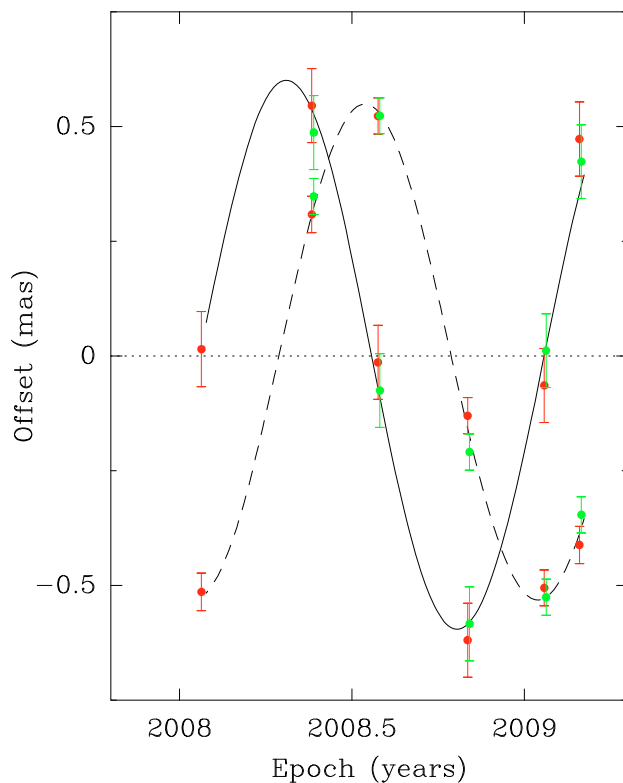
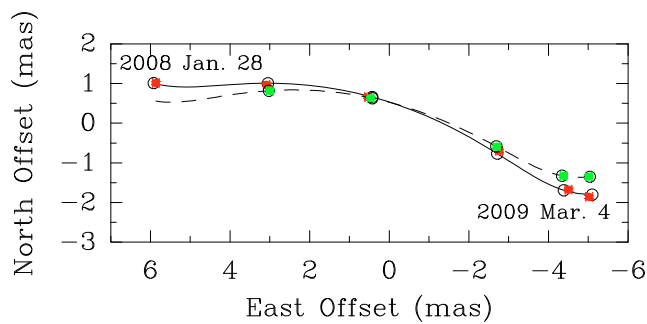
it can be further shown that the under that assumption that the 21 cm line emission is optically thin then the total mass of hydrogen present is given by

$$M/M_\odot = 2.4 \times 10^5 \left(d/Mpc\right)^2 \int S_\nu/\text{Jy} dv/\text{kms}^{-1}$$

Estimate the area under the line on the S_ν scale on the spectrum to estimate the total mass of hydrogen in the spiral galaxy. In a subsequent lecture/workshop you will be shown how to estimate the total mass of the galaxy (all of the gas, stars and dark matter) from spatially resolved H I spectra. For this galaxy that gives $\sim 3 \times 10^{10} M_\odot$. Compare your answer for atomic hydrogen to this value to indicate the fraction of a galaxy that is made up by interstellar gas.

2. We are going to look at the water masers associated with a massive star in the process of forming. The figures below show how the locations of two maser spots (red and green colours) measured over six epochs change over just over a year. The top plot shows their relative positions on the

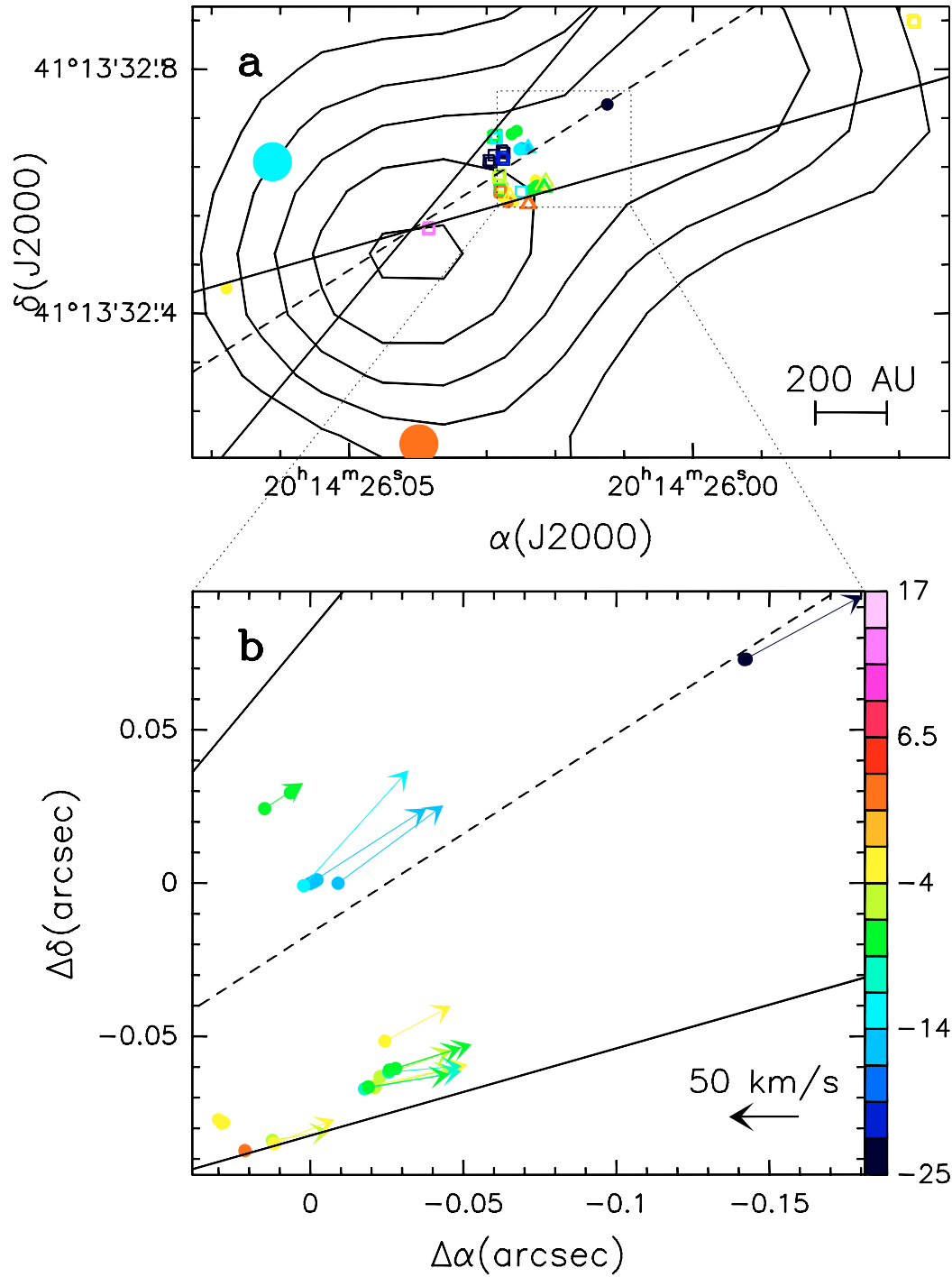
sky in milli-arcseconds (mas) and the bottom plot shows the residual motion after the proper motion has been removed.



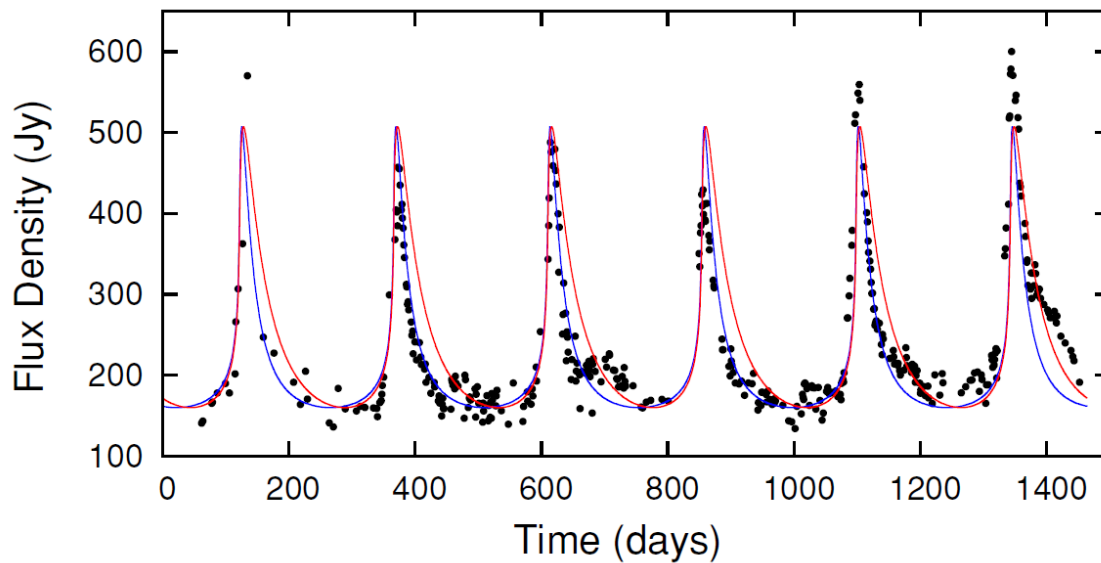
a) What is the distance to this object?

b) Estimate the velocity of the spots in kms^{-1} from the information in the top plot.

The plots below show the locations, proper motions and radial velocities of water masers relative to the 8 GHz radio continuum emission from this object (black contours). The continuum is thermal free-free emission. The systemic velocity of the central object is -3.5 kms^{-1} . How would you interpret the information below in a physical picture?



3. The curve below shows the flux of the methanol maser line in the source G9.62+0.20E as a function of time. Note the periodic flaring behaviour.



One model for these systems involves the interaction between the stellar winds of two massive young stars in the process of forming a close binary system. The only other parameter known for this system is the total luminosity of $3 \times 10^5 L_{\odot}$.

Make some assumptions and estimate an average separation of the two stars in a plausible binary system consistent with these data. You should use the mass-luminosity relation for main sequence stars

$$\frac{L}{L_{\odot}} = \left(\frac{M}{M_{\odot}} \right)^{3.3}$$

And Kepler's Third law:

$$M_1 + M_2 = \frac{4\pi^2 a^3}{GP^2}$$

that relates the period P and separation, a , to the sum of the masses of the two stars.

What would be the typical angular separation in arcseconds of the two binary stars if the source was 5 kpc away?