MPAGS Astrophysical Techniques Assignment 3: Interferometry

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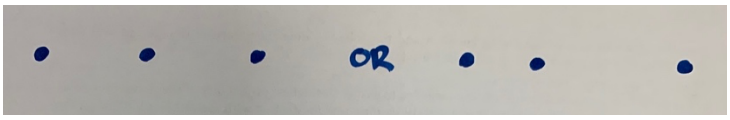
Please email your answers to me within a week from the lecture (e.g., 22 November 2023). You can make scanned/photographed copies of hand-written notes. Do not worry about not perfectly answering each question; they goals is for you to engage with the topic of the lecture.

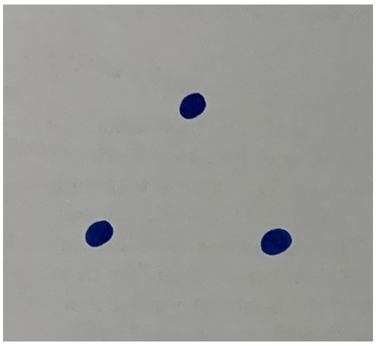
The final exercise is optional, as it requires installing some python-based software, but, in my opinion, also the most fun – I look forward to seeing your own versions of the radio observations.

Question 1: interferometric array design

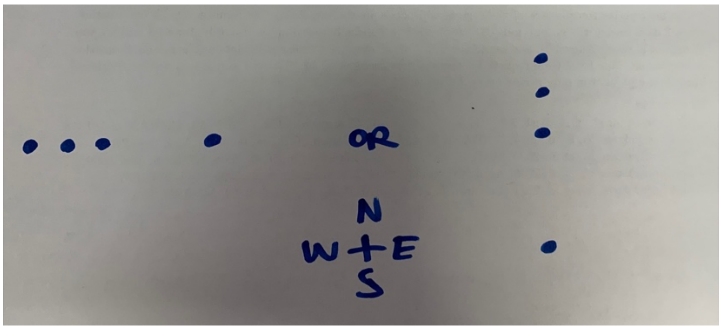
1a. Imagine you are constructing a three-element interferometric array. Which of the two designs below would you choose (each dot represents one antenna)?



1b. Continuing with three elements: what is an advantage and a disadvantage of the below design?



1c. Which of the two three-element arrays below provides better images, and why?



1d. How many baselines does an array with N elements have?

1e. Take a look at the Event Horizon Telescope array on https://eventhorizontelescope.org/array. If you could add one extra telescope, where on Earth would you place it? Why that location?

Question 2: angular scales

For this question, use the VLA / NRAO website (https://science.nrao.edu/facilities/vla) and Google.

2a. what are the field of view, resolution, and maximum scale for observations with the VLA in its A configuration?

2b. Which of these numbers will change when the three outmost antennas of the array (i.e. the outmost antenna of each of the arms of the VLA's Y-shape) moves inwards slightly, and how will that number change?

2c. Similarly, which of these numbers will change if the innermost antenna on each arm is moved slightly outwards, and why?

2d. Imagine you are observing the accreting black hole Swift J1727.8-1613 (that is, at the time of writing, November 2023, going through a bright accretion outburst), with the VLA in its A configuration. You are observing at 10 GHz, taking observations every week. Your radio observations measure the brightness and position of relativistic jet material launched from the accretion flow.

Assuming a 3 kpc distance to the black hole and ignoring '[apparent superluminal motion]' (i.e., treating this as a classical problem), after how many weeks will you start seeing the material move?

Hint: use that movement can be deduced one the source position starts to shift by approximately 10% of the image resolution and assume the most optimal jet viewing angle.

<u>Question 3: simulating interferometric observations</u>

Try to install the Friendly Virtual Radio Interferometer application following the instructions here: https://crpurcell.github.io/friendlyVRI/ (needs python, and conda makes it straightforward).

Pick your own image (in .png format) and try to recreate the same three effects as below for my image. How can you explain the observing effects in the observed image, based on the assumed telescope?

Alternatively, if installing the software doesn't work, you could simulate ALMA images and observations using https://almaost.jb.man.ac.uk/. Make sure to pick 'Single' for pointing strategy, pick an existing source model, and add a number for the Image peak (for instance 10 mJy). You can change the required resolution to change the image outcome – but note that these simulations are quite extensive and take longer than the Friend Virtual Radio Interferometer, so try one at a time!