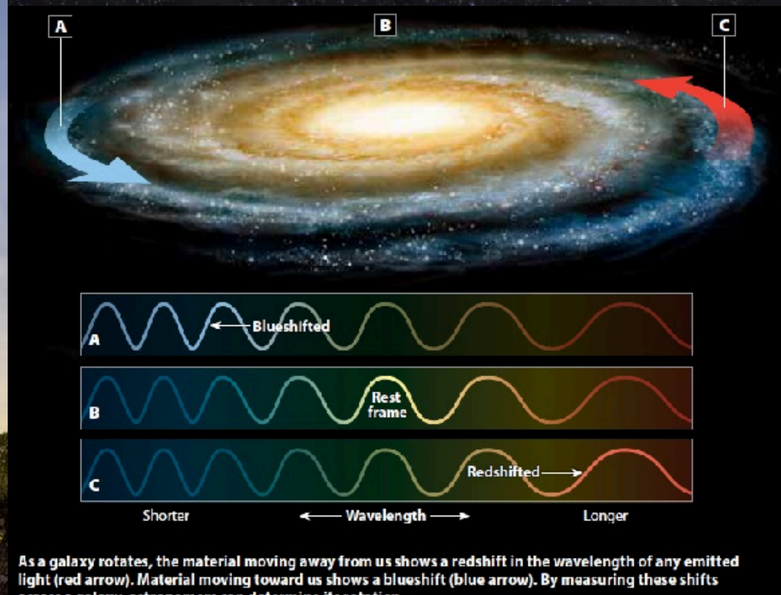
Galactic Hydrogen / Tully Fisher

2nd Year Lab experiments

Demonstrator: Emma Alexander

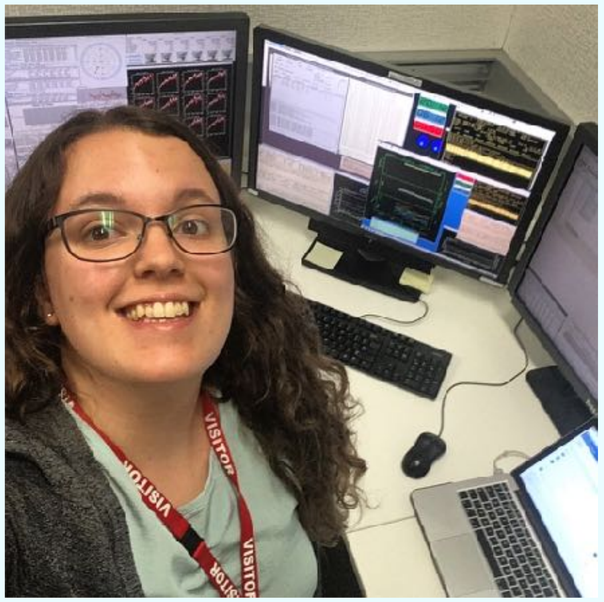


As a galaxy rotates, the material moving away from us shows a redshift in the wavelength of any emitted light (red arrow). Material moving toward us shows a blueshift (blue arrow). By measuring these shifts

First things first…

Welcome to astro lab!

- Make sure you've filled in general lab risk assessment.
- This is my 4th year demonstrating, but 1st time doing it remotely. Please send feedback, good and bad. Need to know what does and doesn't work!
- More about me: final year PhD student in the Jodrell bank Centre for Astrophysics. Former UoM undergrad so I've also done 2nd year lab as a student (albeit a while ago…).
- My research focuses are astrophysical magnetic fields and radio galaxies.



This is me (don't worry I'm not just a disembodied voice coming from a screen). This photo is from when they let me control a big telescope. I didn't break it!

Please make notes from the following slides and what I say!

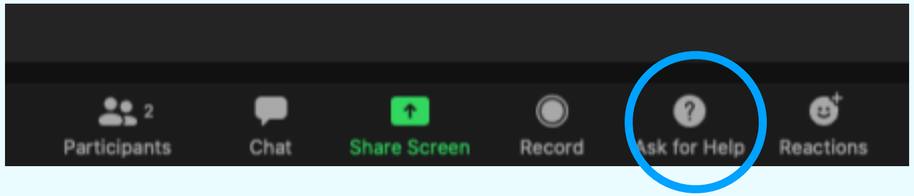
Expectations

aka how we make the best of this

- Working times: 10am-5pm Fridays (exc. lunch). But can be flexible.
- I will keep my Zoom open at these times. You can drop in and out when you have questions (i.e. you don’t have to be online all the time) or stay online.
- Would prefer you to have your camera on when we chat, but not required. Will have scheduled drop-ins as well as spontaneous questions.
- There is no such thing as a silly question! Please ask about anything you are unsure of.
- I will be marking you via the **2nd Year mark scheme** — have a look at it!
- Remember to still take thorough lab notes electronically.

Zoom & Teams

- My Zoom room link: [redacted]
- Josh Hayes (other Friday astro demonstrator; DS9 introduction) Zoom link: [redacted].
- I will be using breakout rooms for the two different experiments. Will also have chats in Teams (which we can video chat through also).
- You can summon me into your breakout room with the “ask for help” when you have questions. I will also pop by semi-regularly to informally check-in, or at a scheduled catch-up time.



Areas of physics we'll cover

Aka what to look back on from the PHYS10191 syllabus

2. Observational astronomy
    - Electromagnetic spectrum: astronomy at different wavelengths
    - Telescopes & optics
3. Distances
4. Physics of the Sun and stars
    - E.g. hydrogen spectral lines, and Doppler effect
6. Galaxies (see also **PHYS 20491**)
    - Galaxy rotation curves

Poll: please select what applies to you!

(Approximate) timetable for today

Time	Galactic Hydrogen	Tully Fisher	Time
10:00 am	**General introduction (this)**		10:00 am
		TF introduction (Zoom)	10:15 am
10:30 am	GH introduction (Zoom)	DS9 introduction (JH Zoom)	10:30 am
10:45 am	Work (drop-in available)		10:45 am
Tea break! (take 10-15 mins sometime in the morning)			
Work (drop-in available)			
Lunch hour (suggested: 1-2pm)			
Work (drop-in available)			
Tea break! (take 10-15 mins sometime in the afternoon)			
Work (drop-in available)			
4:15 pm	Day 1 summary meeting		
		Day 1 summary meeting	4:30 pm

Galactic Hydrogen:

- Specific introduction at **10:30am**
- Rejoin Zoom in 15 minutes.
- In the meantime: login to JBiO (user: lab2, password: schuster) and look at Tools & Docs:

Tully-Fisher:

- Specific introduction now

The Tully-Fisher relation

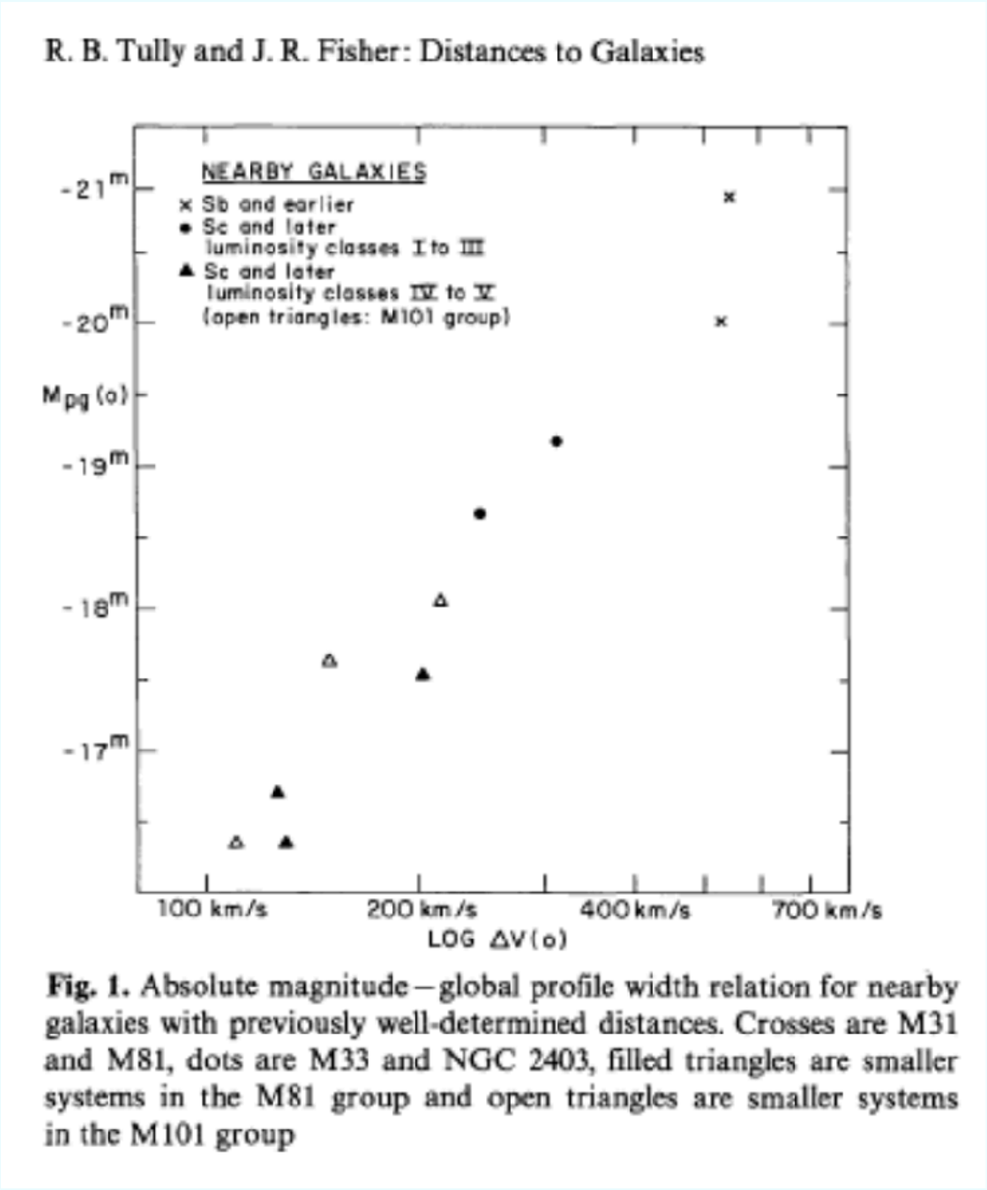
2nd Year Lab experiment

Demonstrator: Emma Alexander

Tully-Fisher Relation

$$L = Av_{rot}^{\beta}$$

- L = stellar luminosity of the galaxy
- v_{rot} = maximum rotation velocity
- A, β are constants that you will find

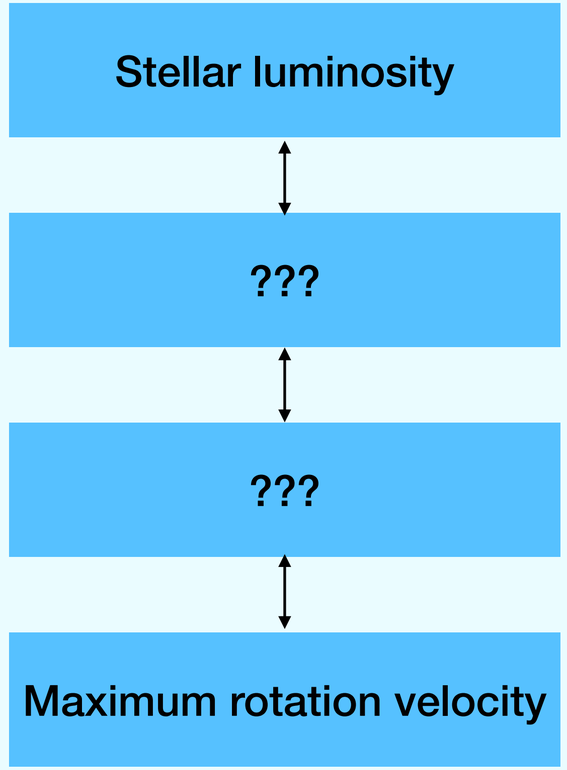


Tully-Fisher Relation

Discussion: what physical properties can be used to link L and v_{rot} theoretically?

$$L = A v_{rot}^{\beta}$$

- L = stellar luminosity of the galaxy
- v_{rot} = maximum rotation velocity
- A, β are constants that you will find



1 Aims

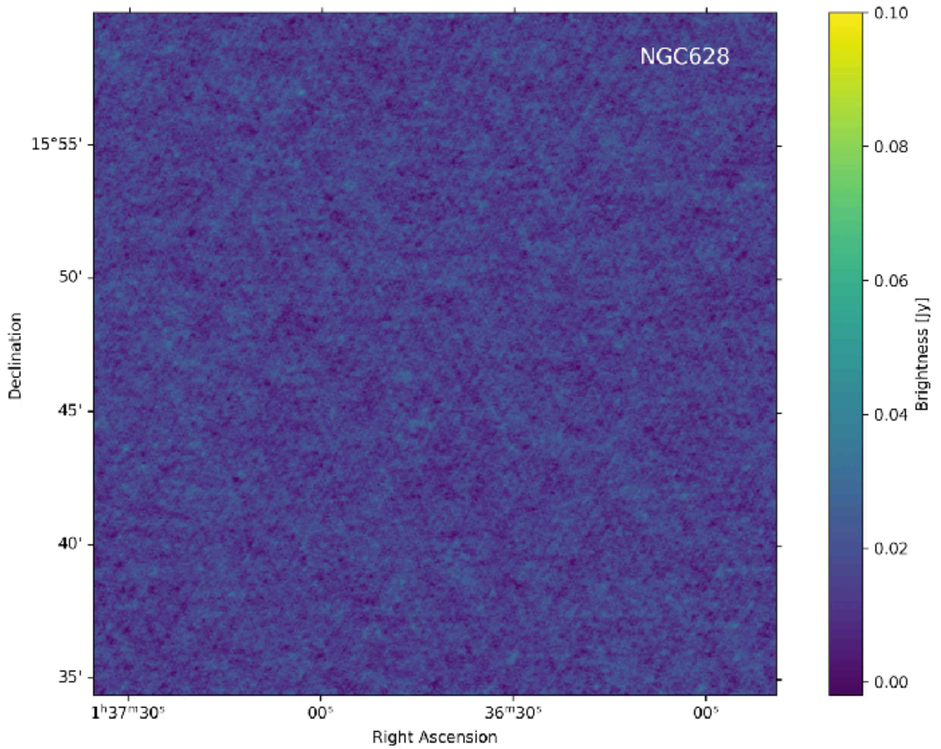
The goals of this experiment are to derive the relation between a galaxy's stellar luminosity and its rotational velocity, which is called the Tully-Fisher relation, and to use this relation to measure the distance to galaxies.

2 Objectives

1. Learn how to perform photometric and spectroscopic measurements in astronomical data.
2. Learn how to analyse astronomical spectra.
3. Derive the relation between spiral galaxy luminosity and rotation.
4. Measure the distances to spiral galaxies using the Tully-Fisher relation.
5. Derive the Hubble constant.

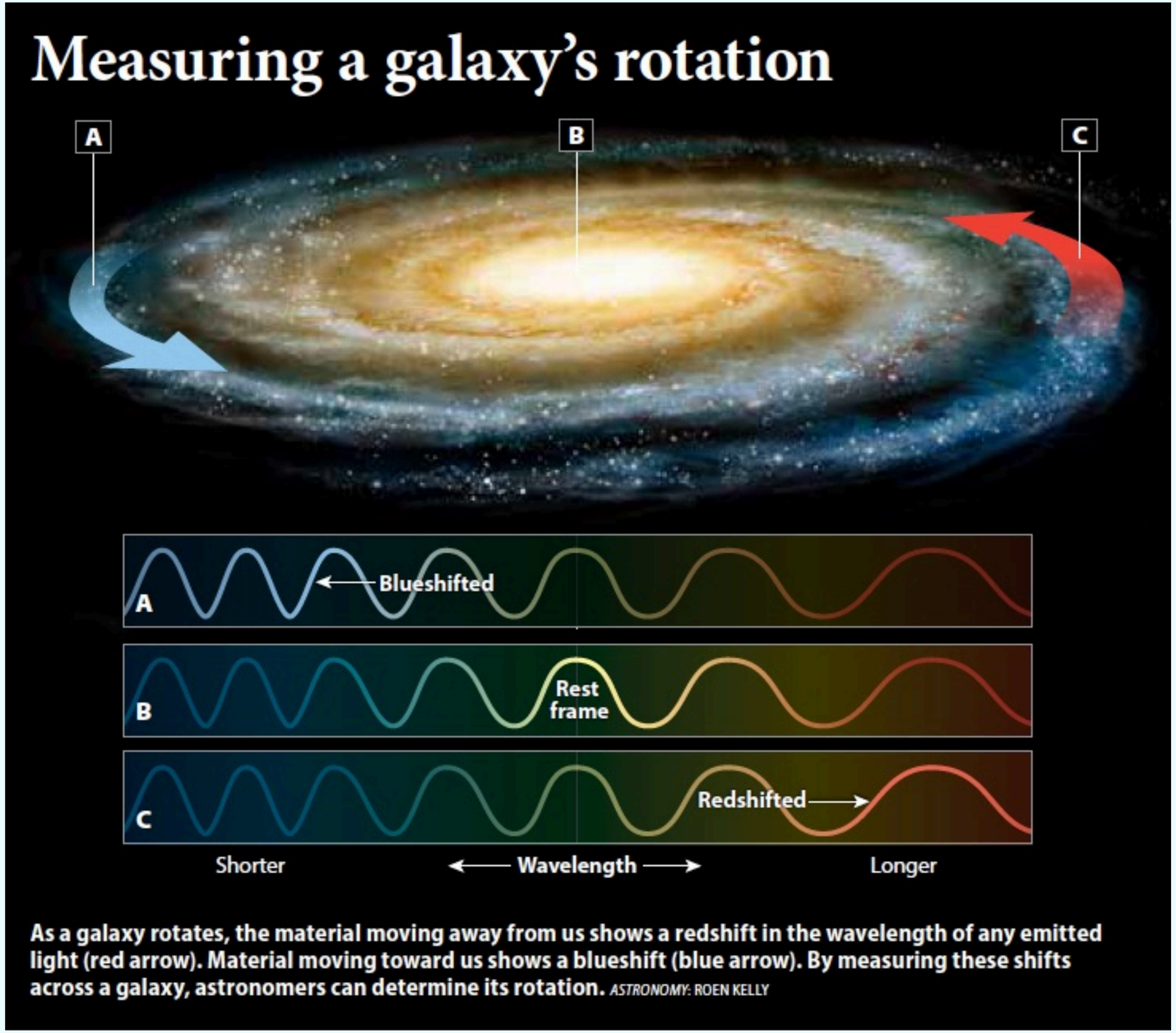
Data

Have you downloaded the data yet? If not, please start ASAP! Link in my first email to you.



Spitzer: 3.4 micron infrared

VLA: radio cube



Poll: anonymous so please answer!

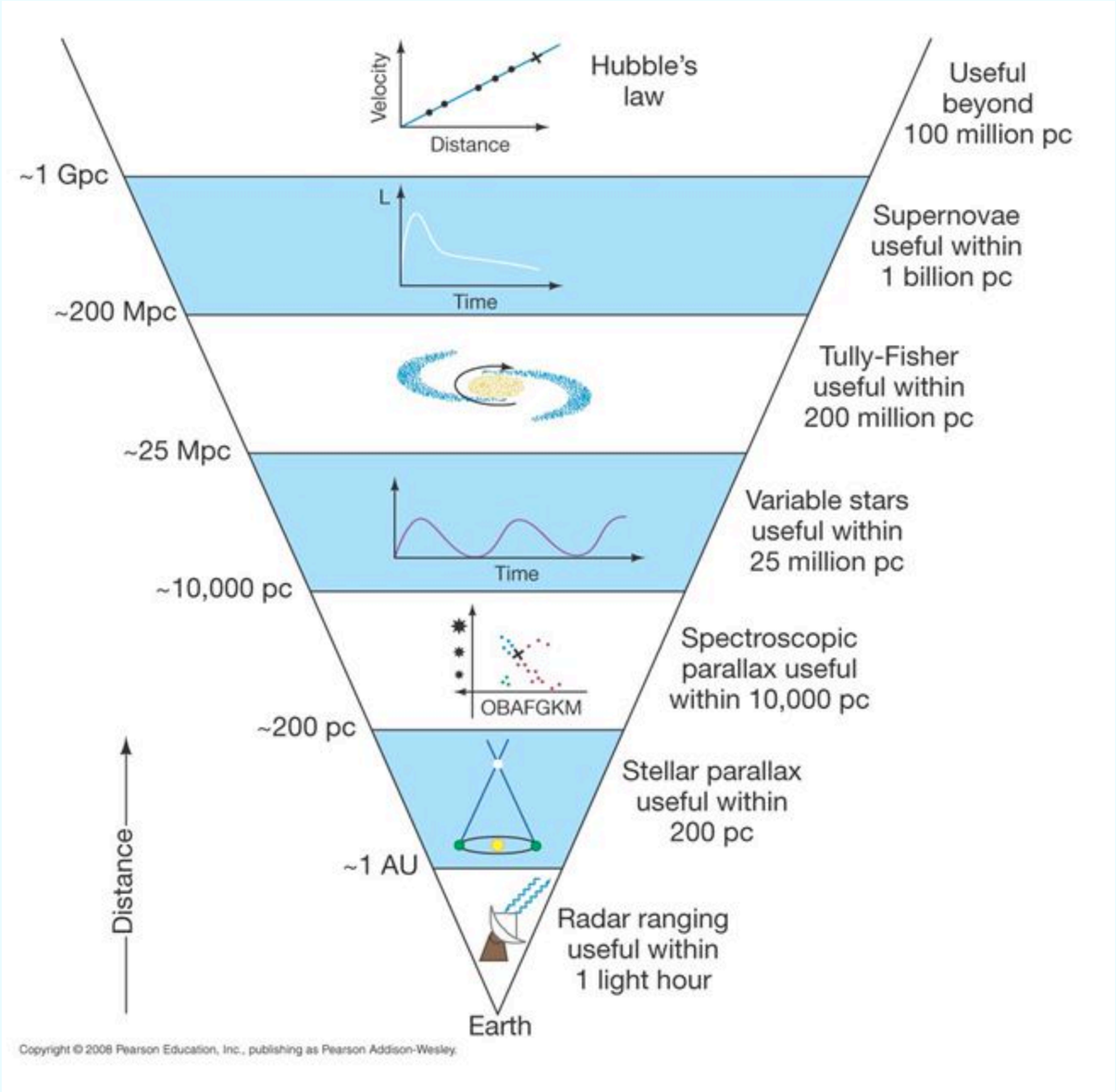
Discussion: what would the integrated spectrum look like?

Distance ladder

Aka why the TF relation is useful

- Many different ‘standard candles’ are used in astronomy, useful at different distances.
- Rely on determining the *intrinsic* brightness of an object, to compare it to the *observed* brightness.
- For more details: **PHYS10191** Introduction to Astrophysics & Cosmology.

Poll: anonymous so please answer!



Experiment overview

- Measurements you will be taking:
  - Total brightness of galaxies
  - Rotational velocities of galaxies

} DS9: see tutorial with Josh (next)

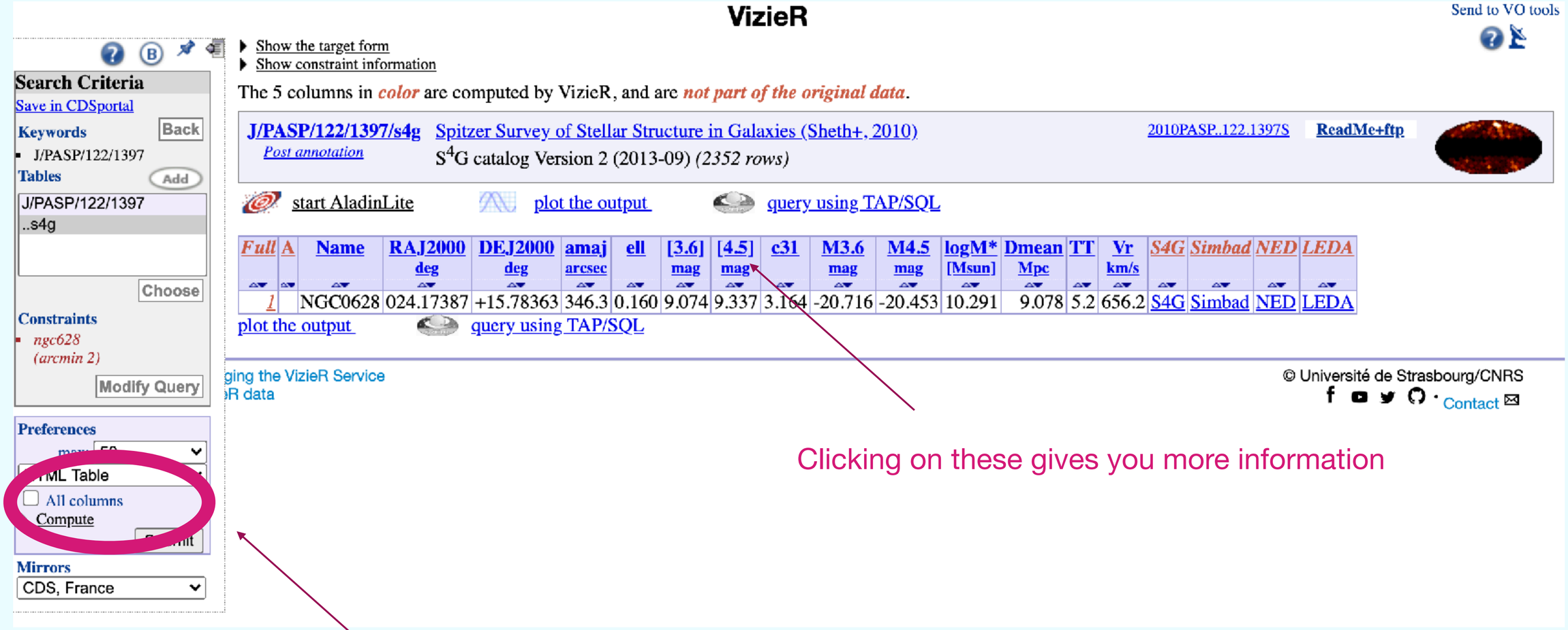
- Information you can look up:
  - Distance to some of those galaxies
  - Other properties you'll need, e.g. inclination

} VizieR/ Leda

- What you need to calculate:
  - Distance to the other galaxies

+ recessional velocity for Hubble's constant (at the end)

Using VizieR & Leda



Clicking on these gives you more information

Make sure this is selected in order to find everything you need!

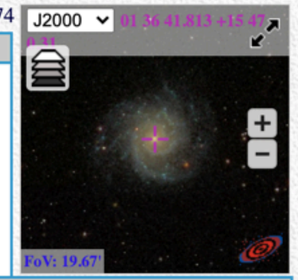
Using VizieR & Leda

Astronomical coordinate systems

Clicking on these gives you more information

NGC0628 [illegible] pgc = 5974

[illegible]tial position		Alternate names	
J2000	J013641.81+154700.3	2MASXJ01364177+1547004	AGC001149
B1950	B013400.48+153143.6	CGCG460-014	HIPASSJ0136+15
Galactic (IAU1958)	G138.61725-45.70542	IRAS01340+1531	IRAS01340+1532
Super Galactic (RC3)	SG314.52984-05.38801	LGG029:[G93]005	MCG+03-05-011
	Precision: about 1 arcsec	MESSIER074	NGC0628
		PGC005974	UGC01149
		UZC013400+15320	



Parameter	Value	Unit	Description
objtype	G		Type of object (G=galaxy; S=Star ...)
type	Sc		Morphological type
t	5.2 ± 0.5		Morphological type code
logd25	2.00 ± 0.02	log(0.1 arcmin)	log of apparent diameter (d25 in 0.1 arcmin)
logr25	0.03 ± 0.04	log	log of axis ratio (major axis/minor axis)
brief	22.51 ± 0.31	mag/arcsec2	Mean effective surface brightness
bt	9.70 ± 0.26	mag	Total B-magnitude
vt	9.31 ± 0.11	mag	Total V-magnitude
it	8.84 ± 0.11	mag	Total I-magnitude
kt	6.95 ± 0.19	mag	Total K-magnitude
ube	0.00	mag	Effective U-B color
bve	0.67	mag	Effective B-V color
vmaxg	21.8 ± 0.4	km/s	Apparent maximum rotation velocity of gas
vmaxs	0.0 ± 0.0	km/s	Apparent maximum rotation velocity of stars
vdis	66.5 ± 6.5	km/s	Central velocity dispersion
mg2	0.1760 ±0.0140	mag	Central Lick Mg2 index
m21	11.56 ± 0.09	mag	21-cm line flux in magnitude

- There is a LOT more information than you need. Picking it out is a skill!
- Take care not to confuse similarly named properties, e.g. position angle and inclination angle.

Script notes

1.

Galaxies with Distances from Cepheid Stars	Galaxies with Unknown Distances	
NGC 925	NGC 628	
NGC 2403	NGC 2903	
NGC 3031	NGC 2876	← Should be 2976
NGC 3198	NGC 3184	
NGC 3351	NGC 3521	
NGC 3621	NGC 4736	
NGC 3627	NGC 3826	← Should be 4826
NGC 5457	NGC 5055	
NGC 7331	NGC 6946	

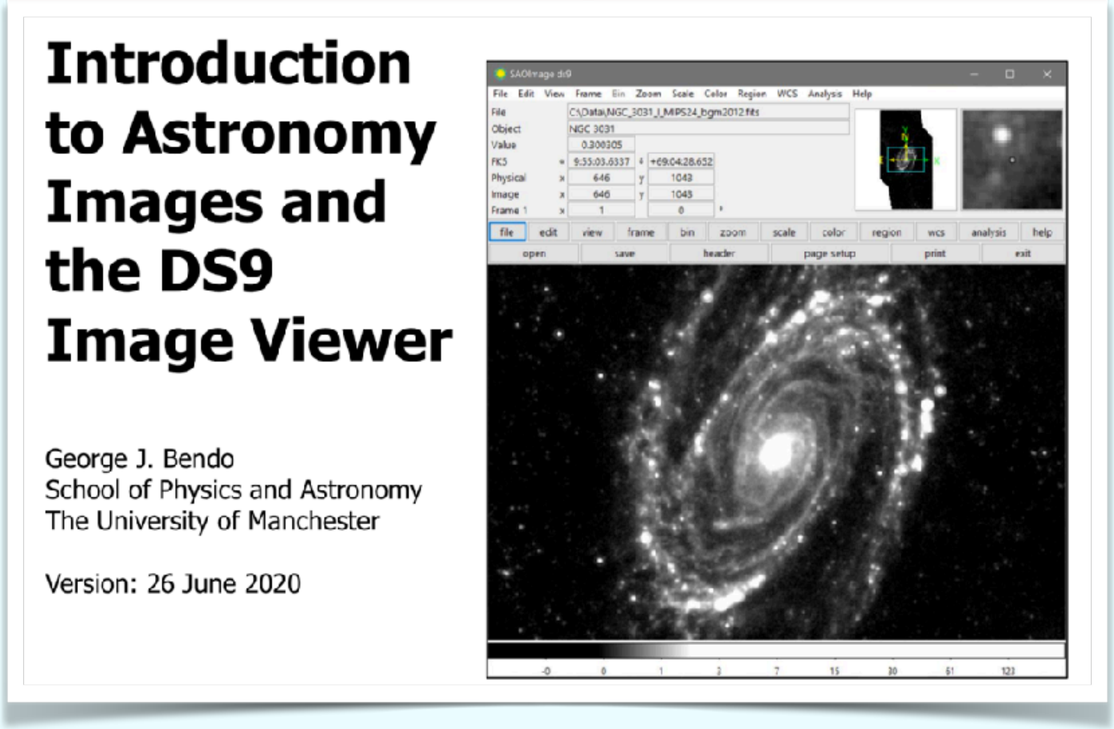
2. Astronomers are weird and we often use rms and standard deviation interchangeably when talking about noise. Pick one and be consistent.

Script notes

- “Set the ellipse parameters to the position and shape of the optical disc”
  - —> What parameters do you need for this?
  - Pay close attention to units.
- Likely to have specialist astronomy coordinate systems and units that you’ve not come across before. Try researching them yourself, and any questions I will answer.

Using DS9

- There is a lot of detail in the script! Make sure you read everything carefully.
- George's intro guide (linked in script) has a LOT of content. Don't feel like you have to do the example, but you can if you wish.
- Quick demo now to cover important parts of guide.



First steps

Poll: please select what applies to you!

- Download and install DS9 (“SAOImageDS9” to not get confused with *Star Trek*) if you haven’t done so already.
  - https://sites.google.com/cfa.harvard.edu/saoimageds9
  - Available for Windows, MacOS, and Linux.
  - Tech issues: Google specific error messages you get. Take a look at the first few results. If you still have issues, let me know straight away.
- Head over to Josh’s Zoom room for an introduction to DS9.
- Rejoin my Zoom when you’re done with that (I might still be introducing GH)

Galactic Hydrogen

2nd Year Lab experiment

Demonstrator: Emma Alexander

1 Aims

To gain practical experience of both radio-astronomical techniques and the use of astronomical coordinate systems through remote operation of a small radio telescope. To learn about the internal motion of the Galaxy by using 21-cm hydrogen line results obtained with the telescope.

2 Objectives

1. To work out where to point the telescope in azimuth and elevation in order to detect strong radio sources and neutral hydrogen from specific points on the Galactic plane.
2. To measure the beam-width of the telescope and to calibrate its sensitivity.
3. To obtain spectra of the hydrogen at as many points on the Galactic plane as possible.
4. To compare the velocities obtained with a simple model of Galactic rotation.

Experiment overview

- Learn the fundamentals of radio astronomy and practical observing.
- Take observations of the galactic plane, and analyse them to find velocity profiles.
- Take observations of strong radio sources, and use them to understand the telescope response.
- Remotely use the 7m telescope at Jodrell Bank Observatory using the web portal.

Strong radio source scans

- (Simplified) output of a radio telescope: signal strength as a function of sky position.
- Observed signal is a combination of both sky brightness and the telescope *beam*.

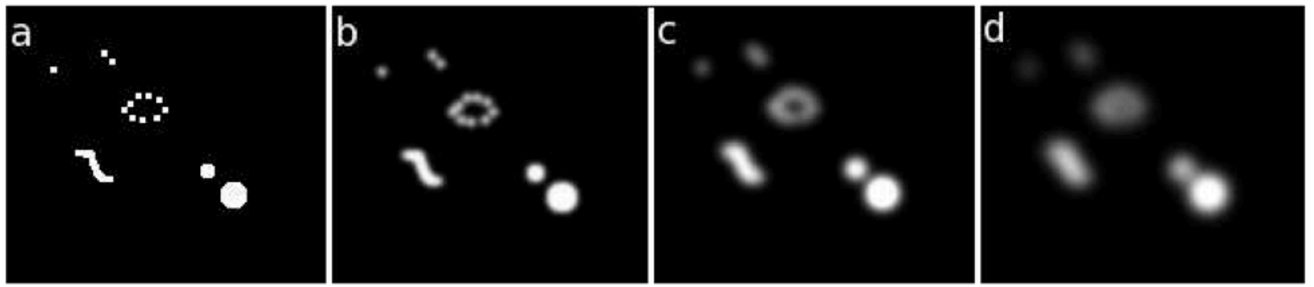
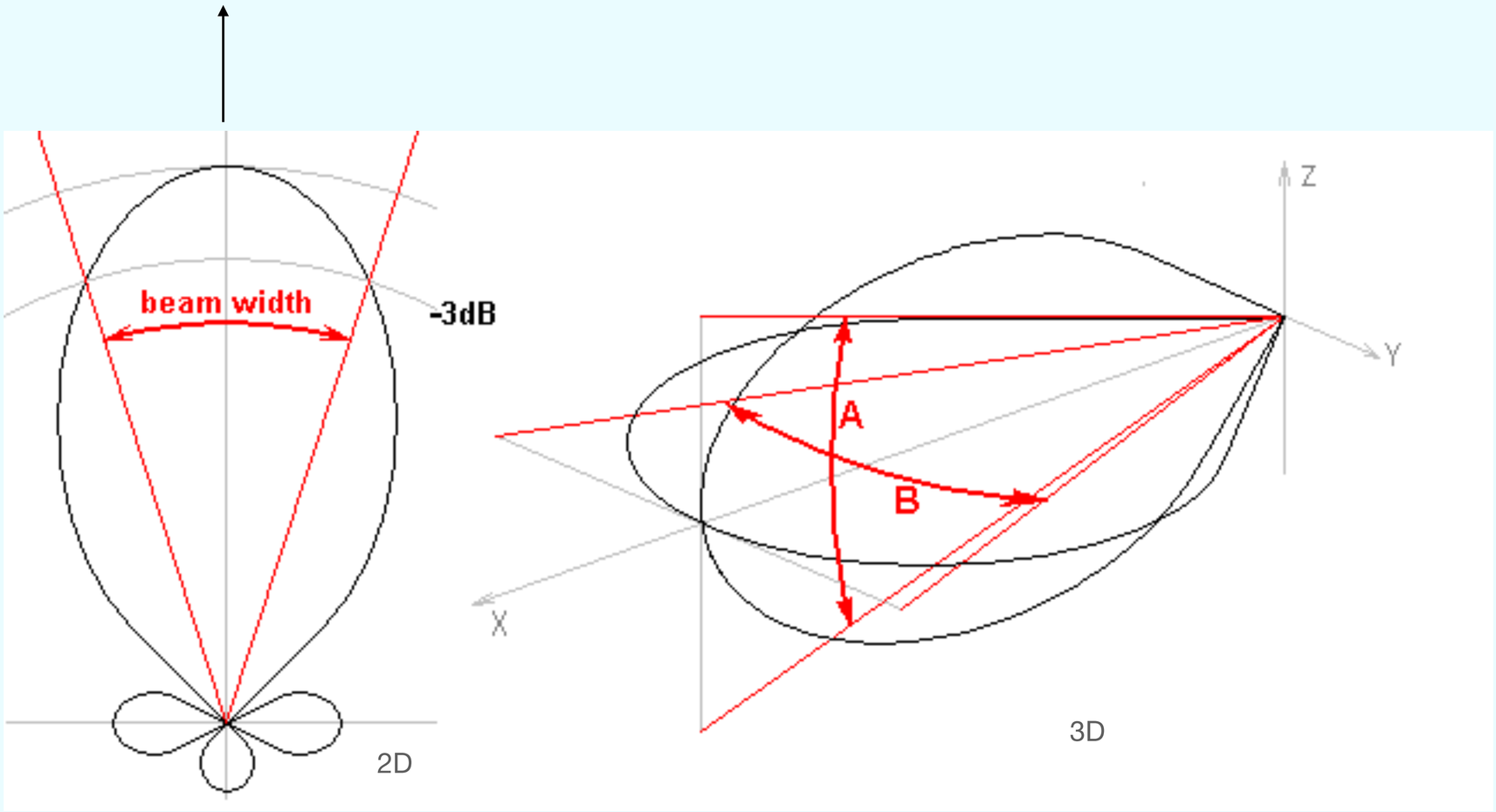


Figure 13: *(a) Simulated true radio source brightness distribution, convolved with beams of width (b) 5 units (c) 10 units (d) 15 units.*

https://avntraining.hartrao.ac.za/images/radio_astronomy_theory.pdf

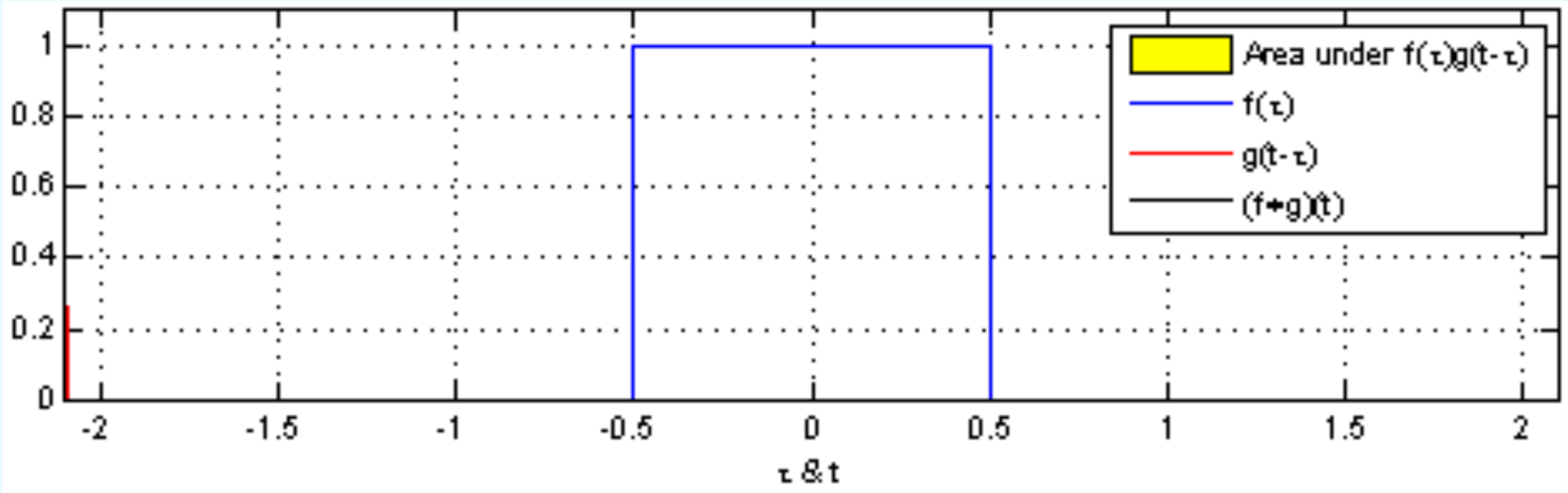
Radio telescope beams

Direction the telescope is pointing has the biggest response…



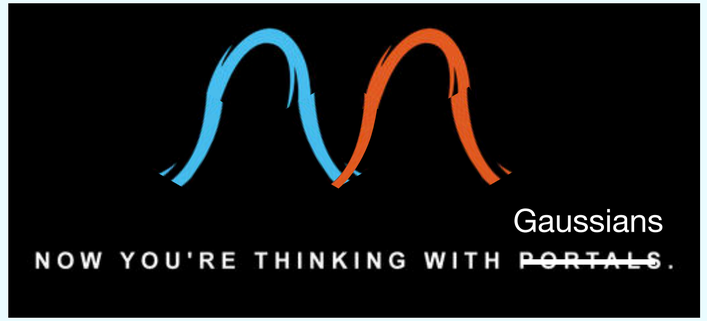
… but it also picks up small amounts of radio waves in the “sidelobes”

Convolution

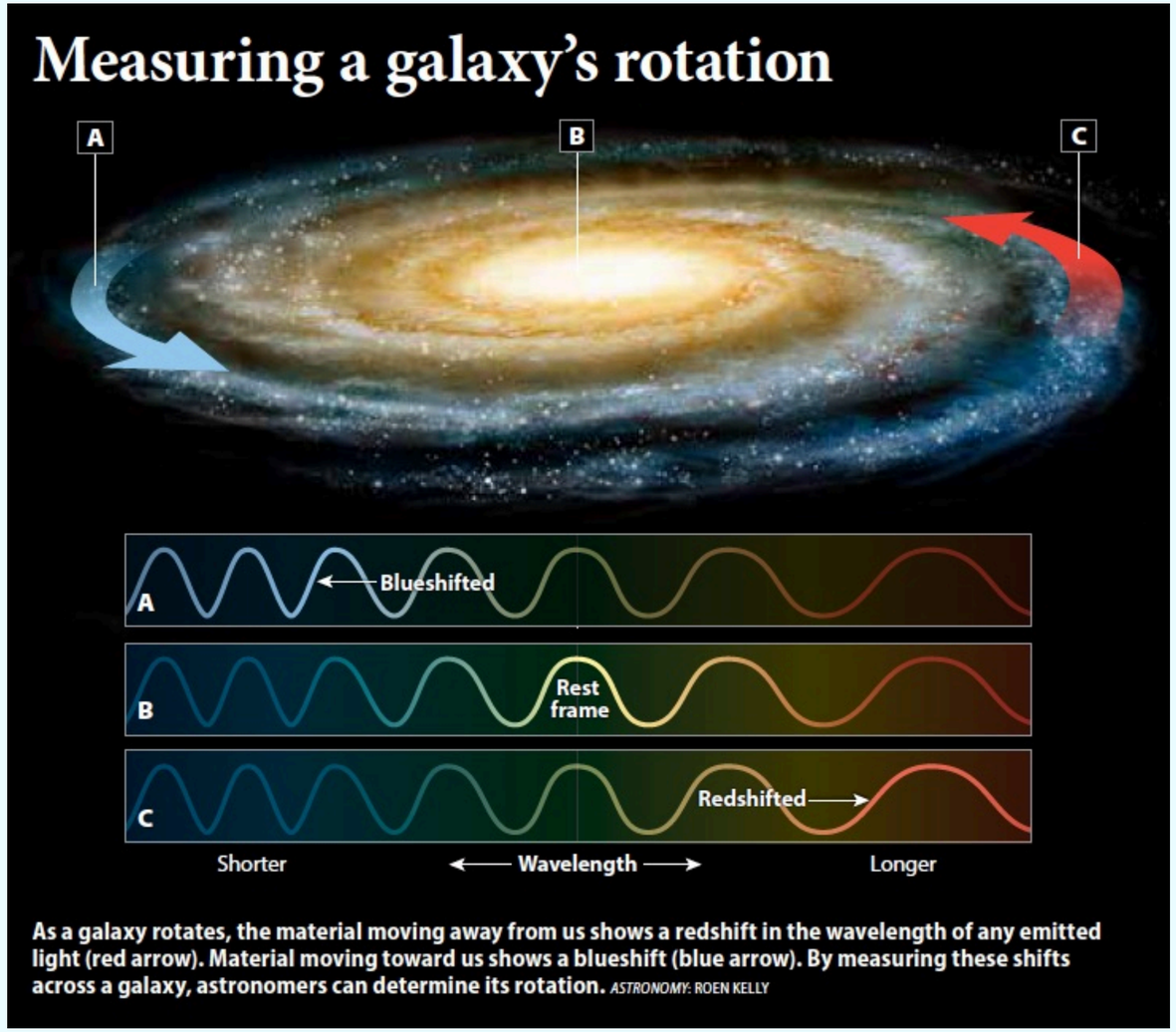


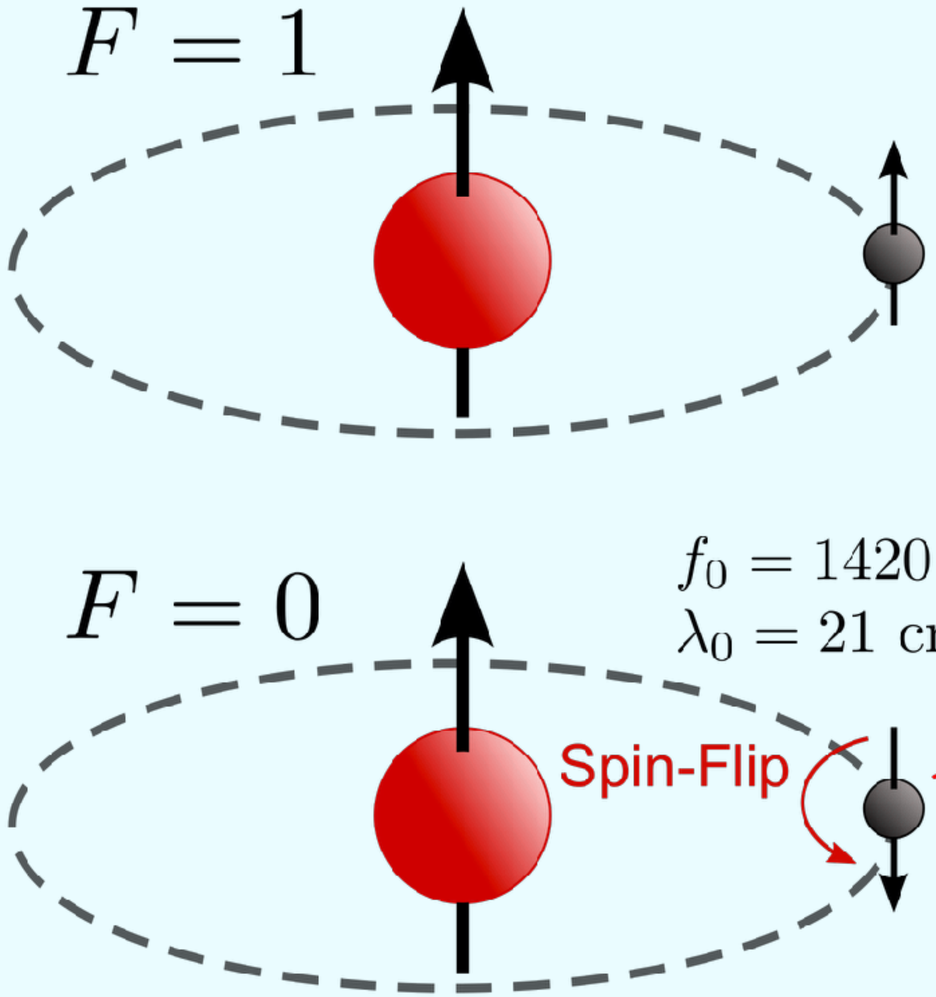
Think about how you can apply this to a real (definitely not square) radio telescope scanning a real astronomical source.

- Blue: strangely square astronomical radio source.
- Red: strangely square radio telescope beam scanning across it.
- Black: response recorded by the telescope.



21cm Hydrogen line

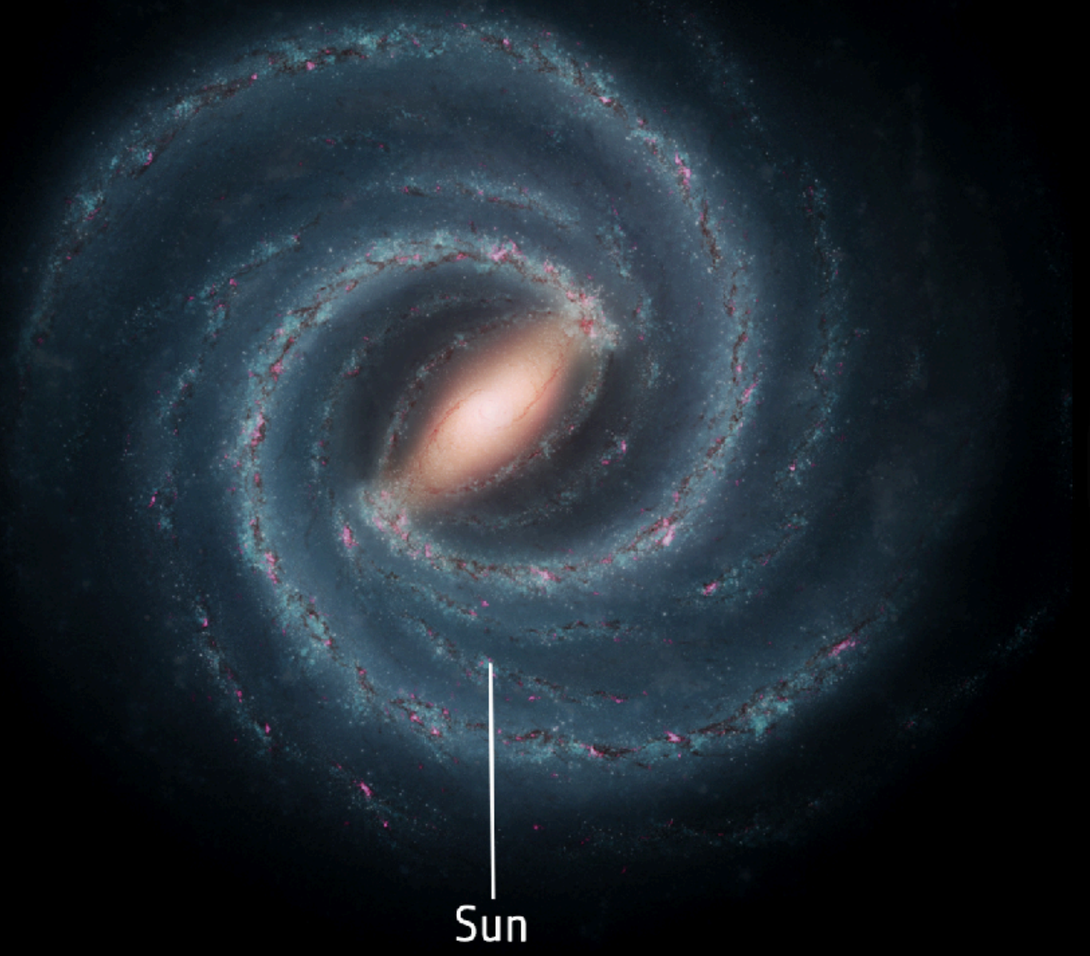


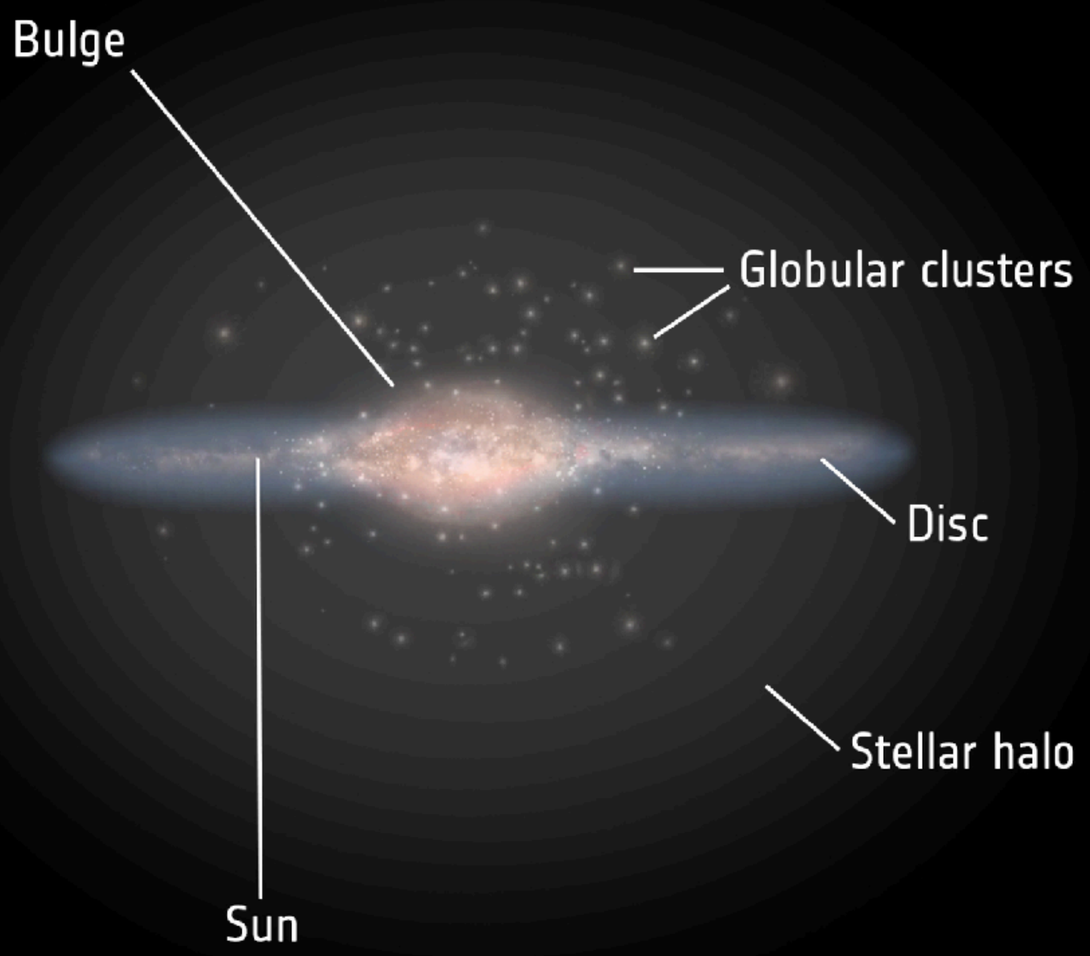


If λ = 21cm, what is the energy of the transition?

→ ANATOMY OF THE MILKY WAY

esa





www.esa.int

European Space Agency

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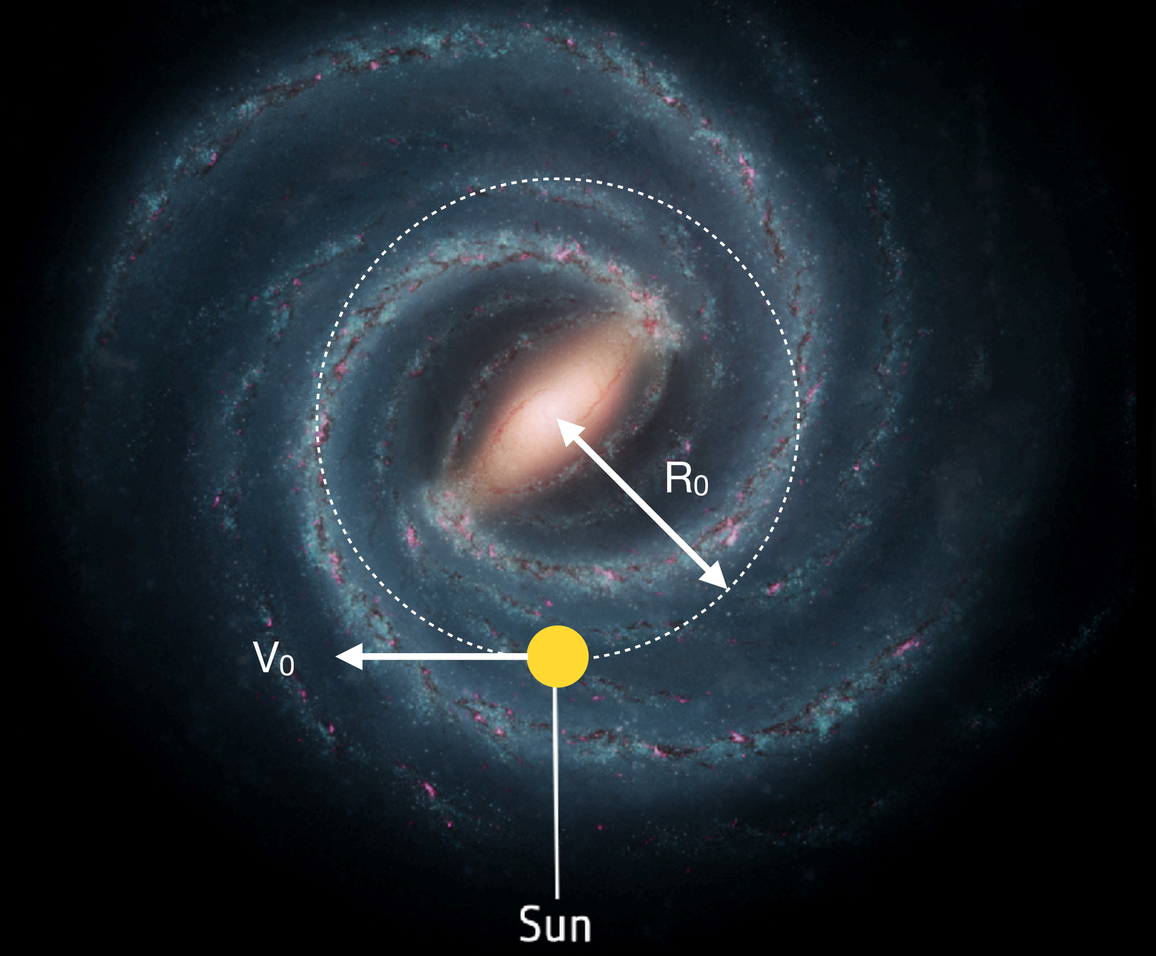

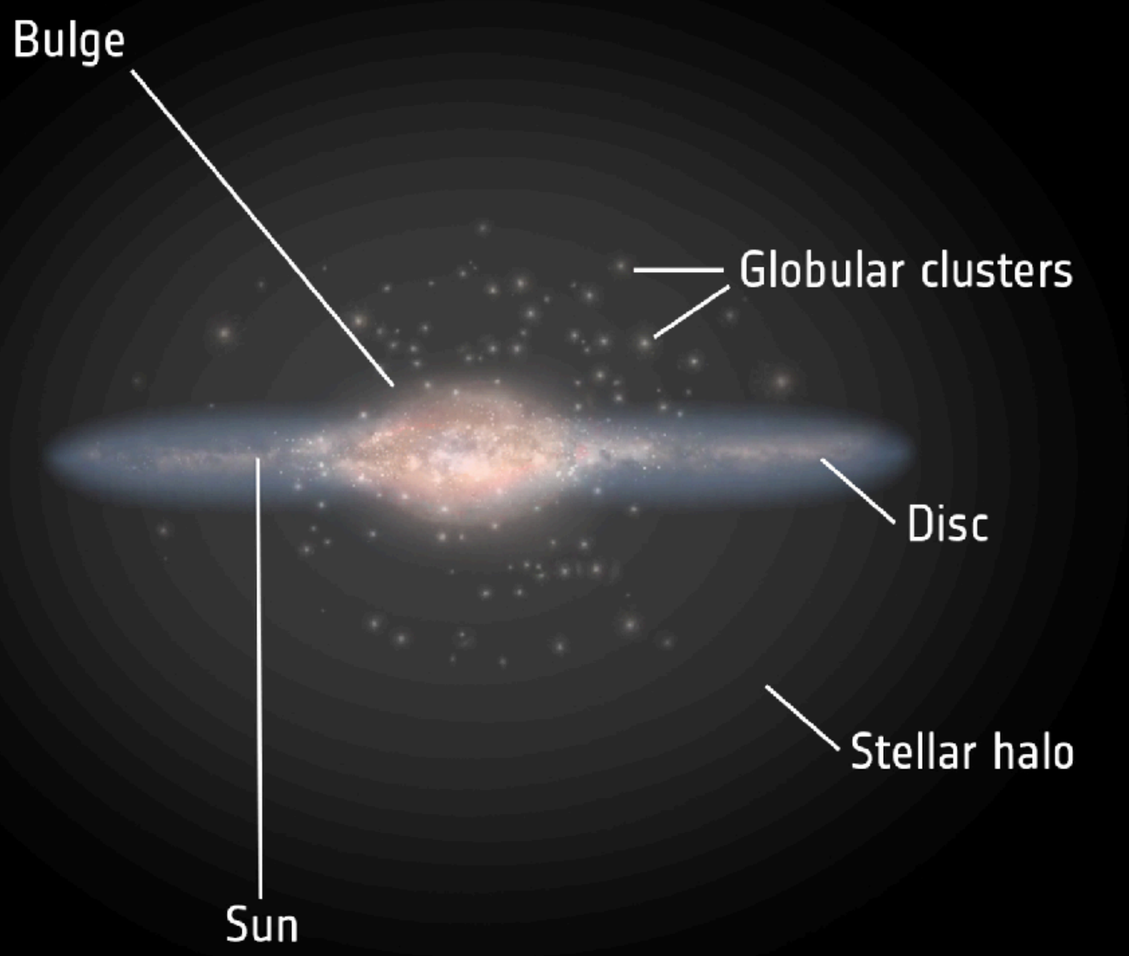

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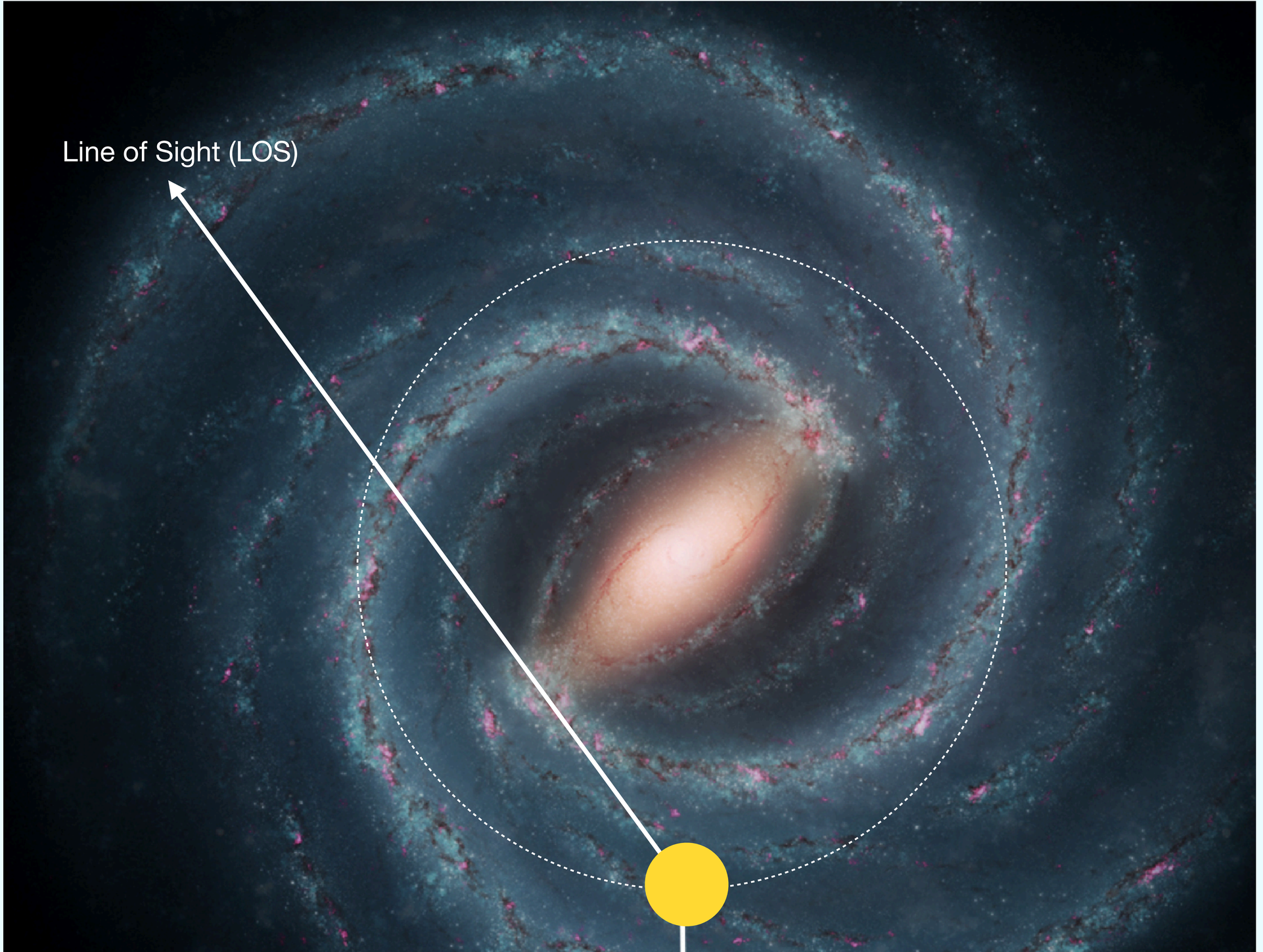
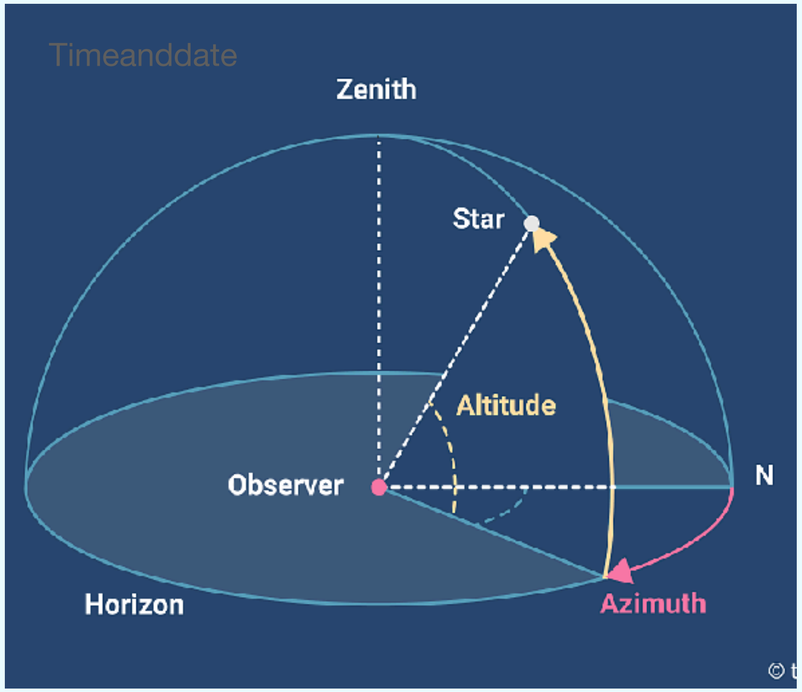
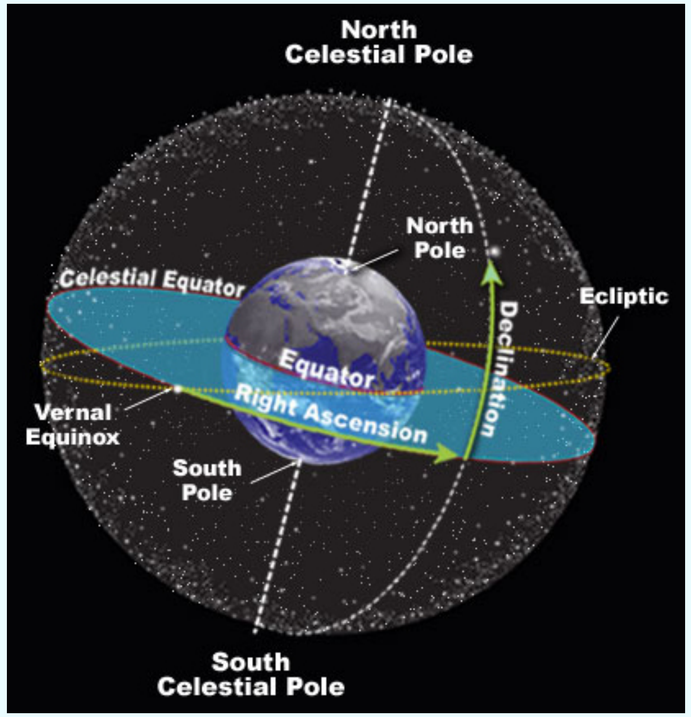


- For a given LOS, what velocities would you expect to see (via Doppler shifts)?
- Carefully consider the direction of motion and components of velocities.
- Try to obtain equation(s) that link velocity and radius.

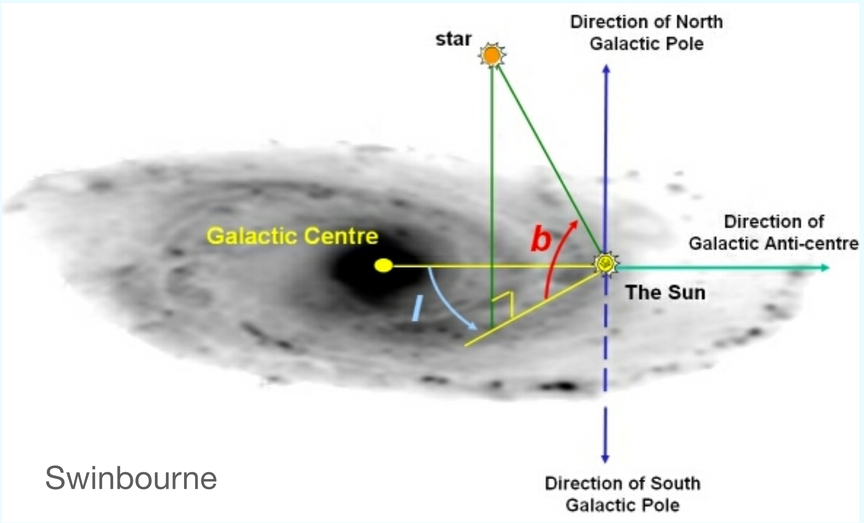
Astronomical coordinate systems



- **Alt/Az**:
- Altitude and azimuth
- *Observer-centric*



- **Equatorial**:
- Right Ascension (RA) & Declination (dec)
- *Earth-centric*

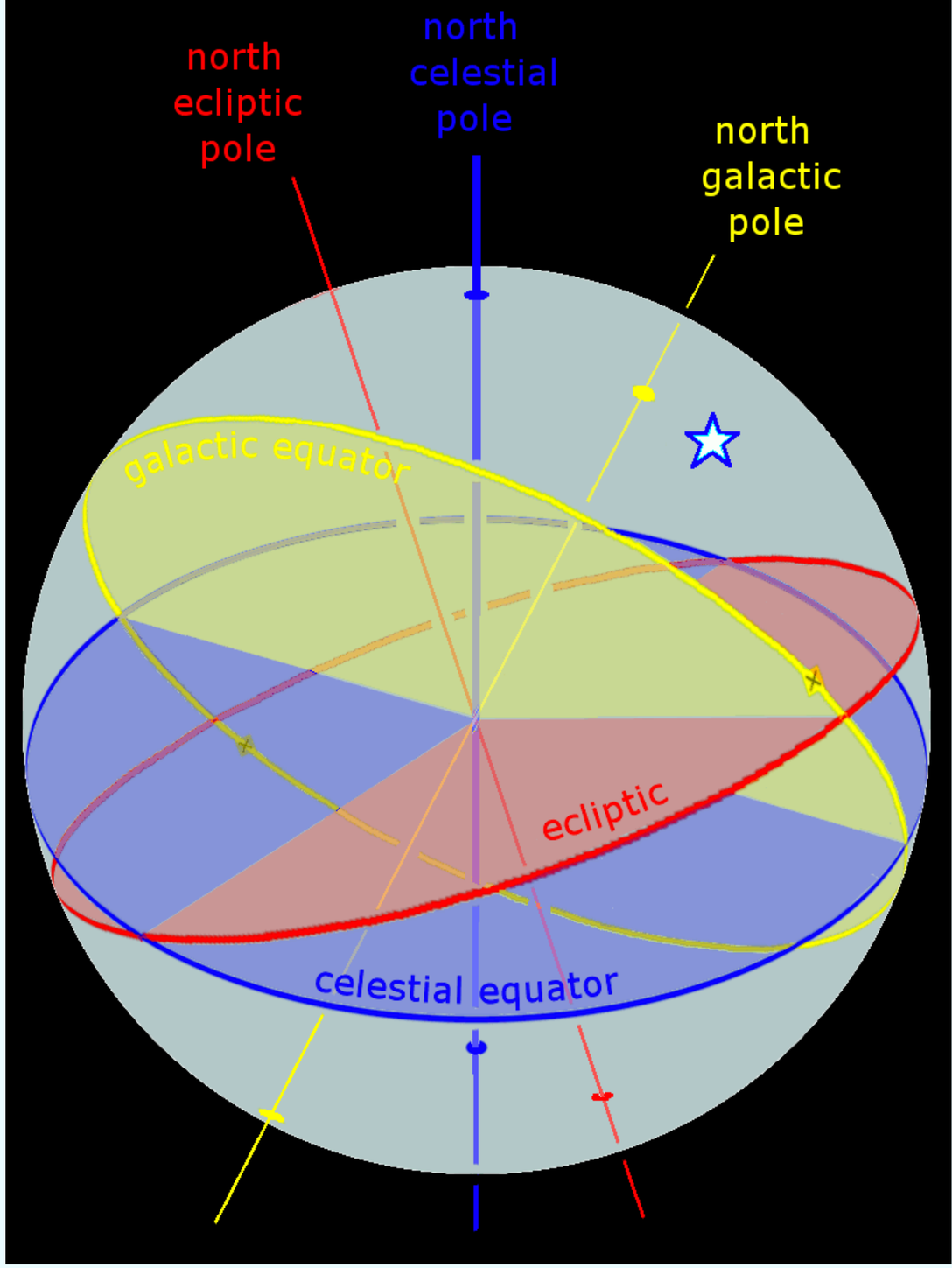


- **Galactic**:
- Latitude (b) and Longitude (l)
- *Sun-centric (from location within Milky Way)*

Astronomical coordinate systems

Try to understand the relation between the different coordinate systems. (But to convert, you can just use an online calculator).

Ecliptic: plane of the solar system. The Sun, Moon, and planets follow its path in the sky



Introduction to JBiO

Screen share

First steps

- Get to grips with JBiO. Use the source track tool to plan observations.
- Check your observations with me before you submit them!

2nd Year Lab assessment

What to expect

Overview

- Assessment conducted via interview.
- Interviews should take place within two weeks of finishing experiment (otherwise late penalties apply).
- Consist of a 10 minute presentation, followed by approx 20 mins of questions. I also aim to give 10 mins feedback (total: 40 mins).
- Will be conducted over Zoom.
- Electronic lab notes to be submitted no later than **24 hours** prior to interview time.

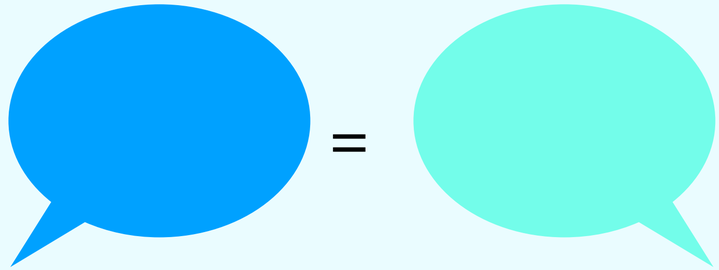
Oral presentation

- Max length is 10 minutes. Try to make the most of this time, but don’t run over!
- Ideally practice in advance so you know you’ll keep to time.
- Each person should speak for about the same amount of time, so up to 5 minutes each.
- Aim to convey the big picture.
- Target content at a fellow second year student who is unfamiliar with the specific experiment.
- Use slides as prompts if you wish (BUT… avoid slides like this one).

Oral presentation (a better slide)

Max 10 mins

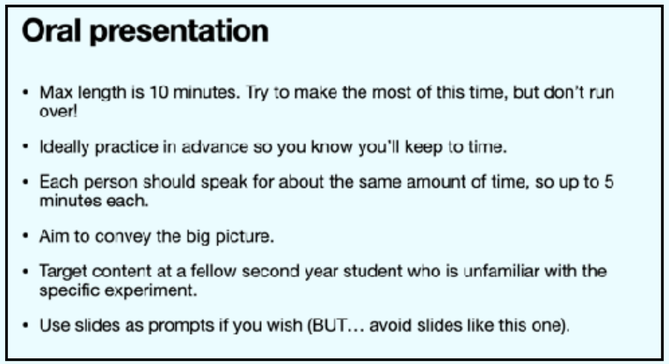
Practice first



Equal contribution

No unnecessary details

Target: unfamiliar peer



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Slides, but don't read from them!