



DARA Basic Training

NAMIBIA-BOTSWANA 2020

UNIT 1: INTRODUCTION TO ASTROPHYSICS

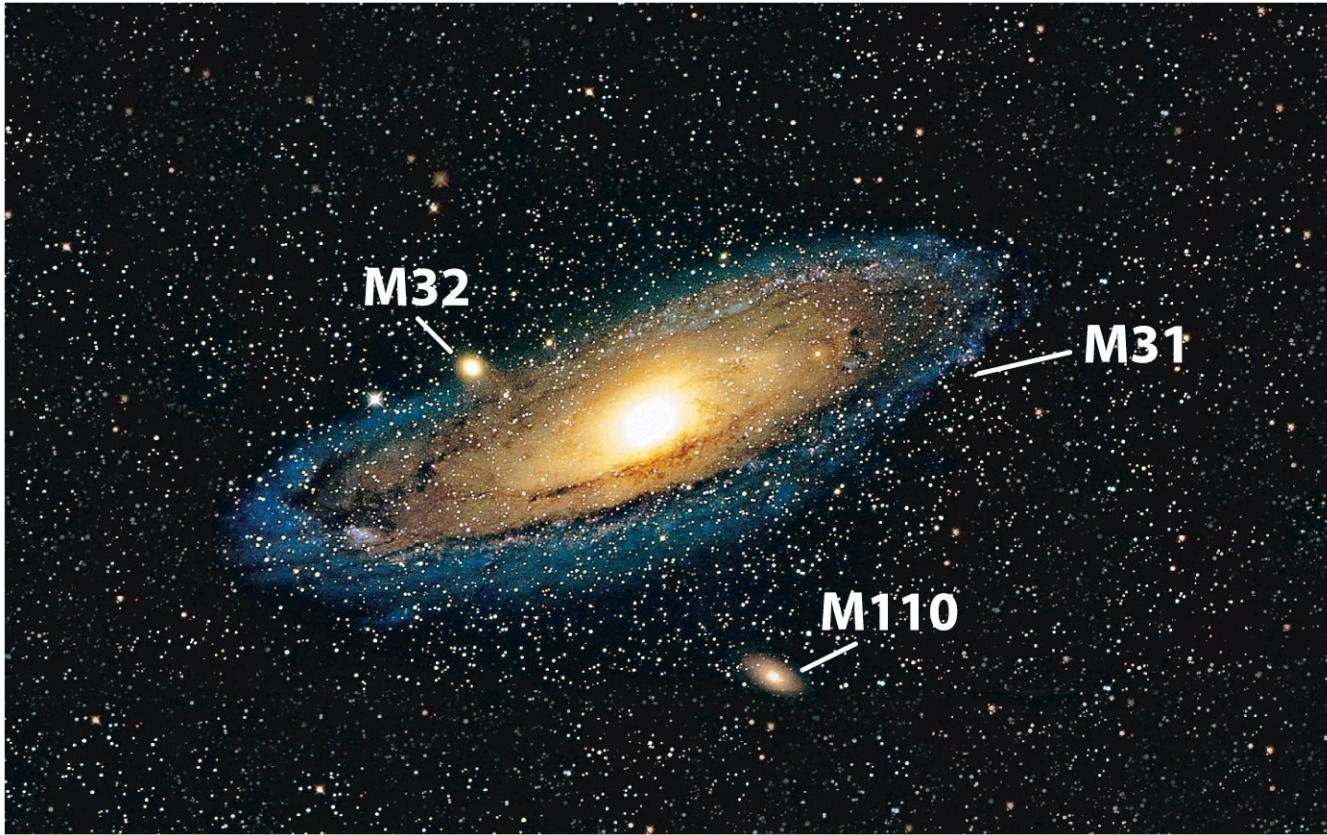
Windhoek, 13 – 24 January 2019

Galaxies

- Galaxy Types
- Hubble's Tuning Fork Diagram
- Redshift
- Expansion of the Universe and the Big Bang

Galaxies

- A galaxy is a gravitationally bound collection of stars, gas and dust
 - e.g. our Galaxy contains of order 10^{11} stars
- Usually isolated in space, although can interact with near neighbours
- The main visible component of the Universe



Galaxy Types

- Galaxies are seen in three major types
 - Spirals
 - Ellipticals
 - Irregulars

Spiral Galaxies

- Rotating *disc* dominated by spiral arms
- Spiral Arms are
 - rich in young, hot, blue stars, i.e. Population I
 - rich in gas and dust
 - where formation of new stars takes place



Credit: Gemini Observatory, GMOS Team

- An elliptical concentration of stars at the centre is called the *bulge*
- Bulge is rich in red stars – Population II and old Population I



- Also come in *barred* form where the two arms originate from the ends of a central linear feature of bulge-like stars



Credit: NASA, ESA, and The Hubble Heritage Team (STScI/AURA)

Elliptical Galaxies

- Elliptical collections of red stars – Population II and old Population I
- Smooth variation in intensity
- Very little gas & dust
- Little organized rotation
- Come in both giant and dwarf forms





Leo I
Dwarf Elliptical

Irregular Galaxies

- No regular structure
- Contain plenty of gas and dust and blue stars
- Mixture of Population I and II
- Usually relatively small



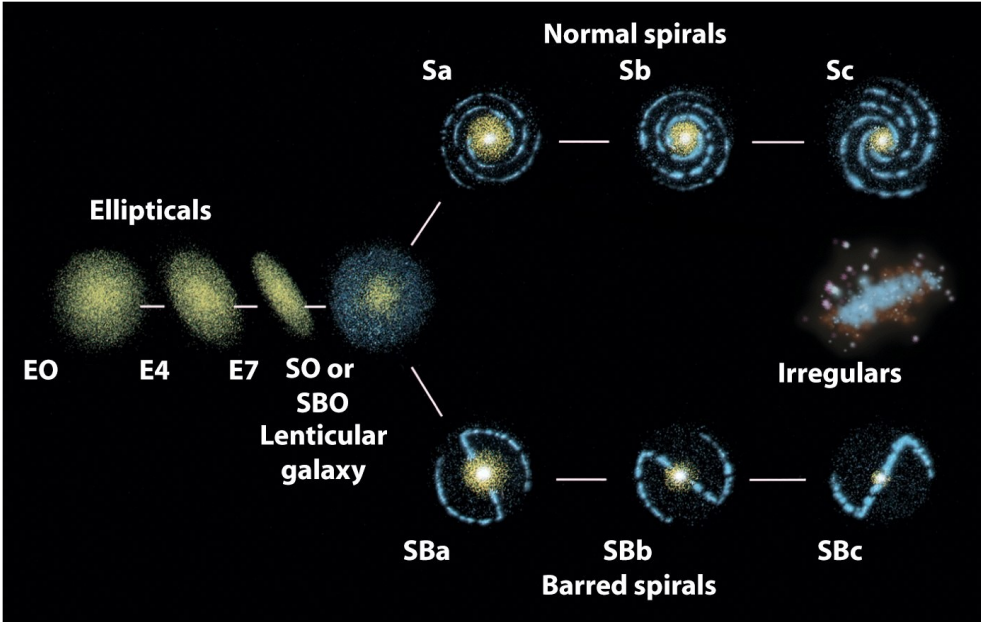
IC10: credit line: Adam Block/NOAO/AURA/NSF

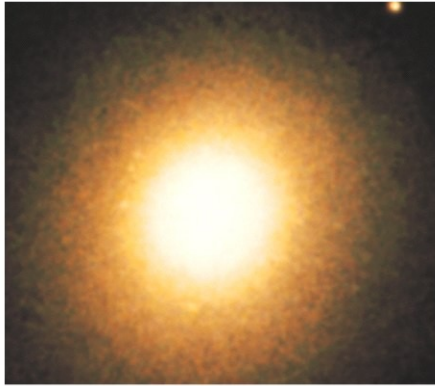


Irregular galaxy NGC 4214. Credit NASA HST

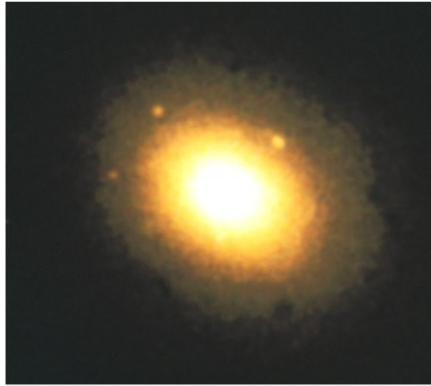
Galaxy Classification

- Galaxies are classified according to Hubble's tuning fork diagram

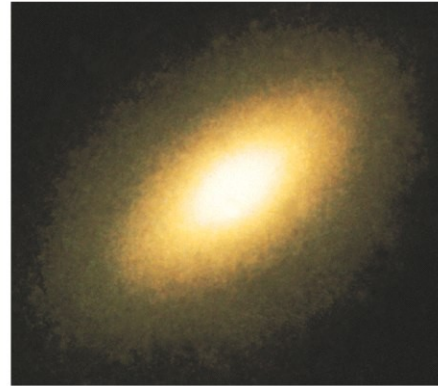




(a) E0 (M105)



(b) E3 (NGC 4365)



(c) E6 (NGC 3377)

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(a) Sa (NGC 1357)

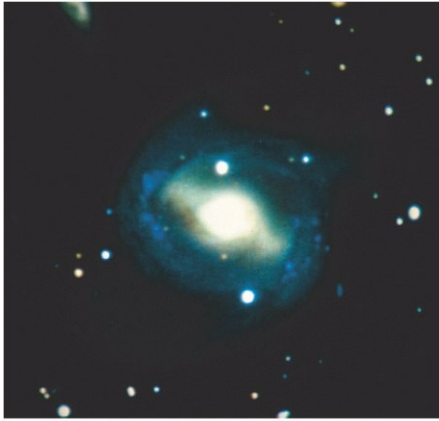


(b) Sb (M81)



(c) Sc (NGC 4321)

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(a) SBa (NGC 4650)



(b) SBb (M83)



(c) SBc (NGC 1365)

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Lenticular galaxy M102: Credit: AURA/NOAO/NSF

Redshift

- The radial velocity of a galaxy can be measured using the Doppler shift
- Redshift, z , is defined by

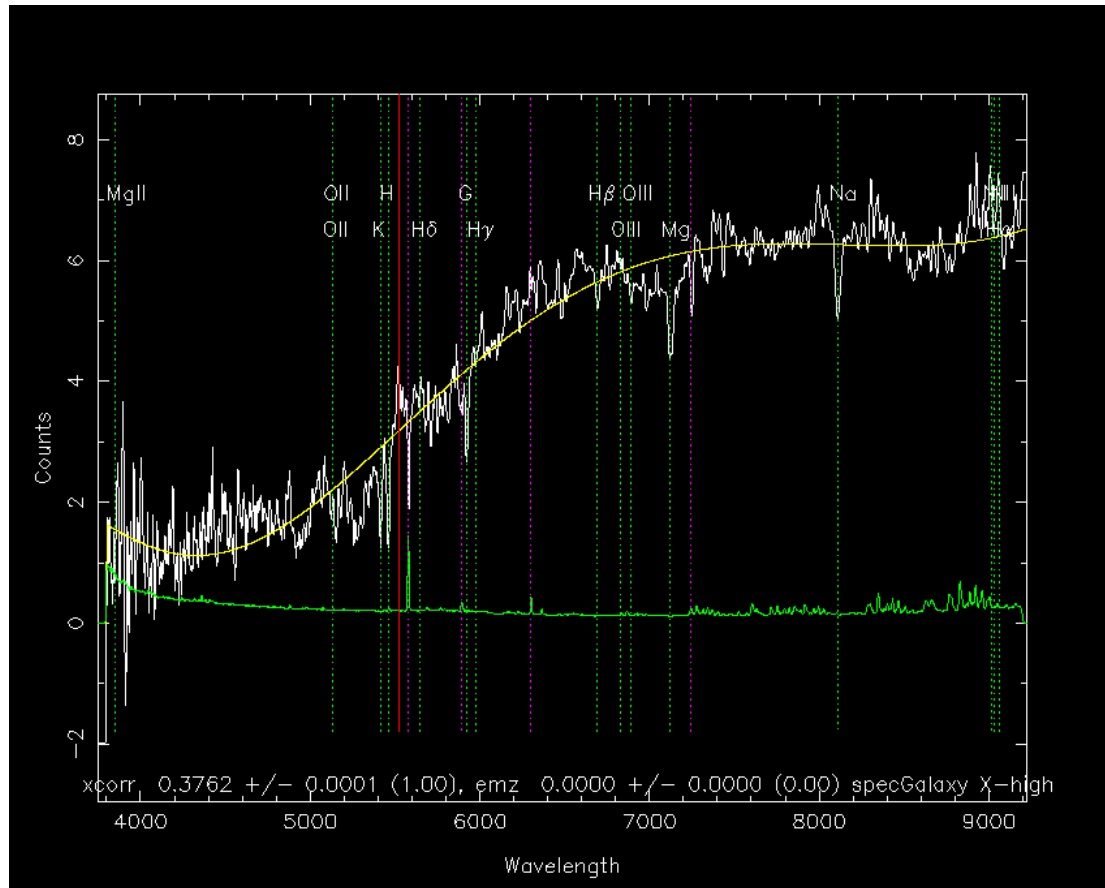
$$z = \frac{\lambda_{obs} - \lambda_0}{\lambda_0} = \frac{\Delta\lambda}{\lambda_0}$$

where the λ_{obs} is the observed wavelength of spectral features in the galaxy spectrum and λ_0 is the rest wavelength

- The radial velocity is related to redshift by

$$v = \frac{\Delta\lambda}{\lambda_0} c = cz$$

- (Note as velocities become comparable to the speed of light a different relativistic formula must be used)



A spectrum of a galaxy at redshift 0.376 from the Sloan Digital Sky Survey www.sdss.org

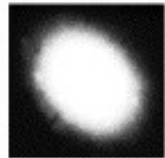
Hubble's Law

- Hubble found that the majority of galaxies have redshifted lines
- He also found that further away the galaxy the higher the redshift and the radial velocity, i.e.

$$v = Hd$$

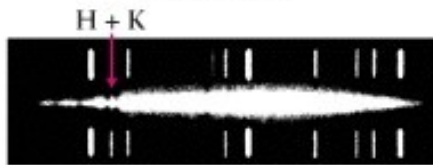
where H is Hubble's constant

GALAXIES in



Virgo

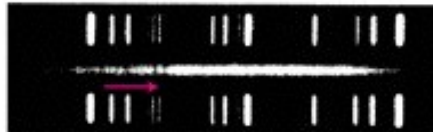
REDSHIFTS



1200 km/s



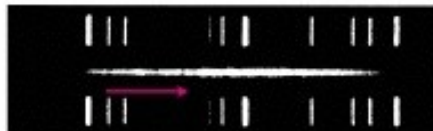
Ursa Major



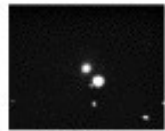
15,000 km/s



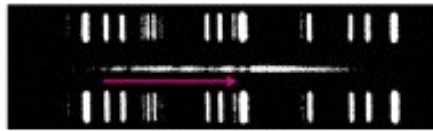
Corona Borealis



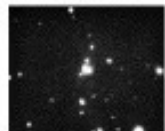
22,000 km/s



Boötes



39,000 km/s



Hydra



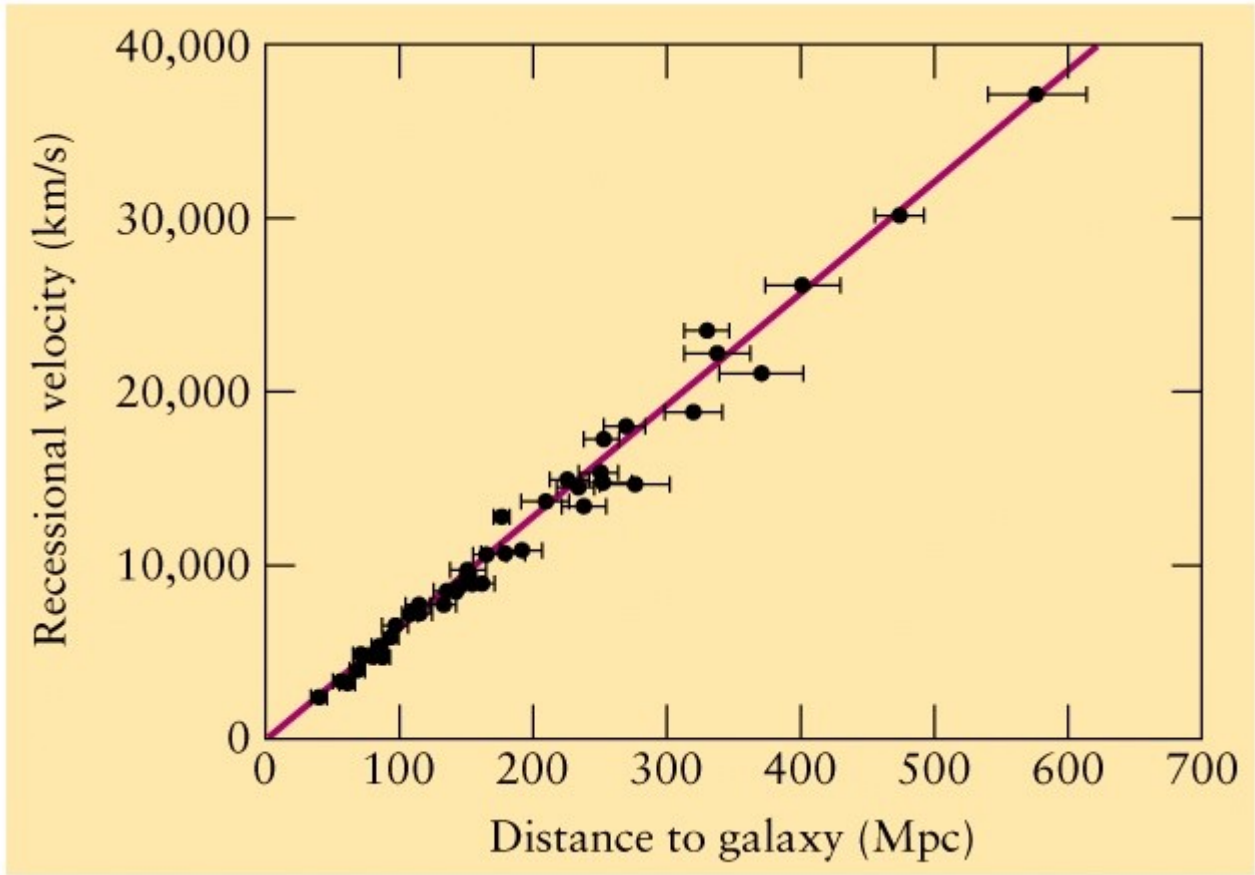
61,000 km/s

Hubble's Constant

- To determine H the distance to galaxies must be found independently
- This is done using standard candles
- The current best value is

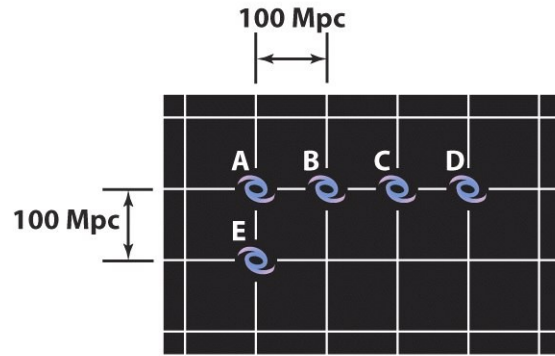
$$H_0 = 68 \pm 2 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

- (The subscript 0 indicates the value of H at the current age of the Universe)

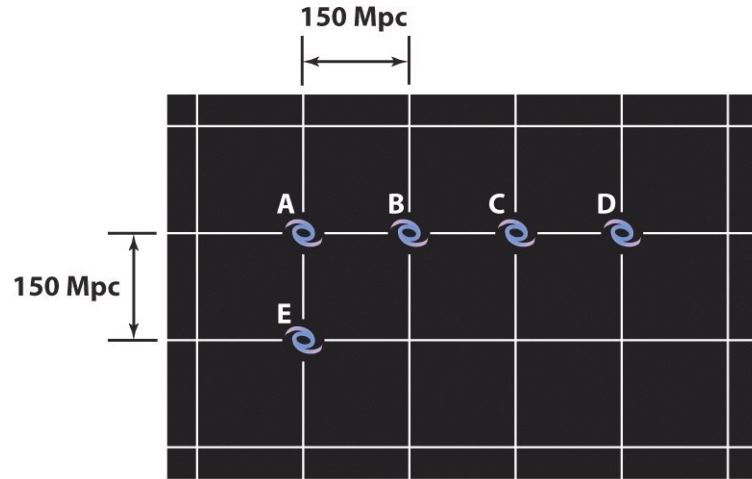


Expansion of the Universe

- The simplest explanation for Hubble's law is that the Universe is uniformly expanding
- The galaxies are not rushing through space but space itself is expanding
- We are not at a special location



(a) Five galaxies spaced 100 Mpc apart



(b) The expansion of the universe spreads the galaxies apart

The Big Bang

- As we go back in time all galaxies (all matter) will get closer and closer together
- Matter will get denser and hotter
- Eventually all of space occupied a very small volume – in fact a singularity (like a black hole)

Summary

- Galaxies can be classified as either spirals, ellipticals or irregulars
- Hubble's tuning fork diagram is a convenient memory aid but is not an evolutionary sequence
- More distant galaxies are receding faster
- We live in an expanding Universe that started with a Big Bang