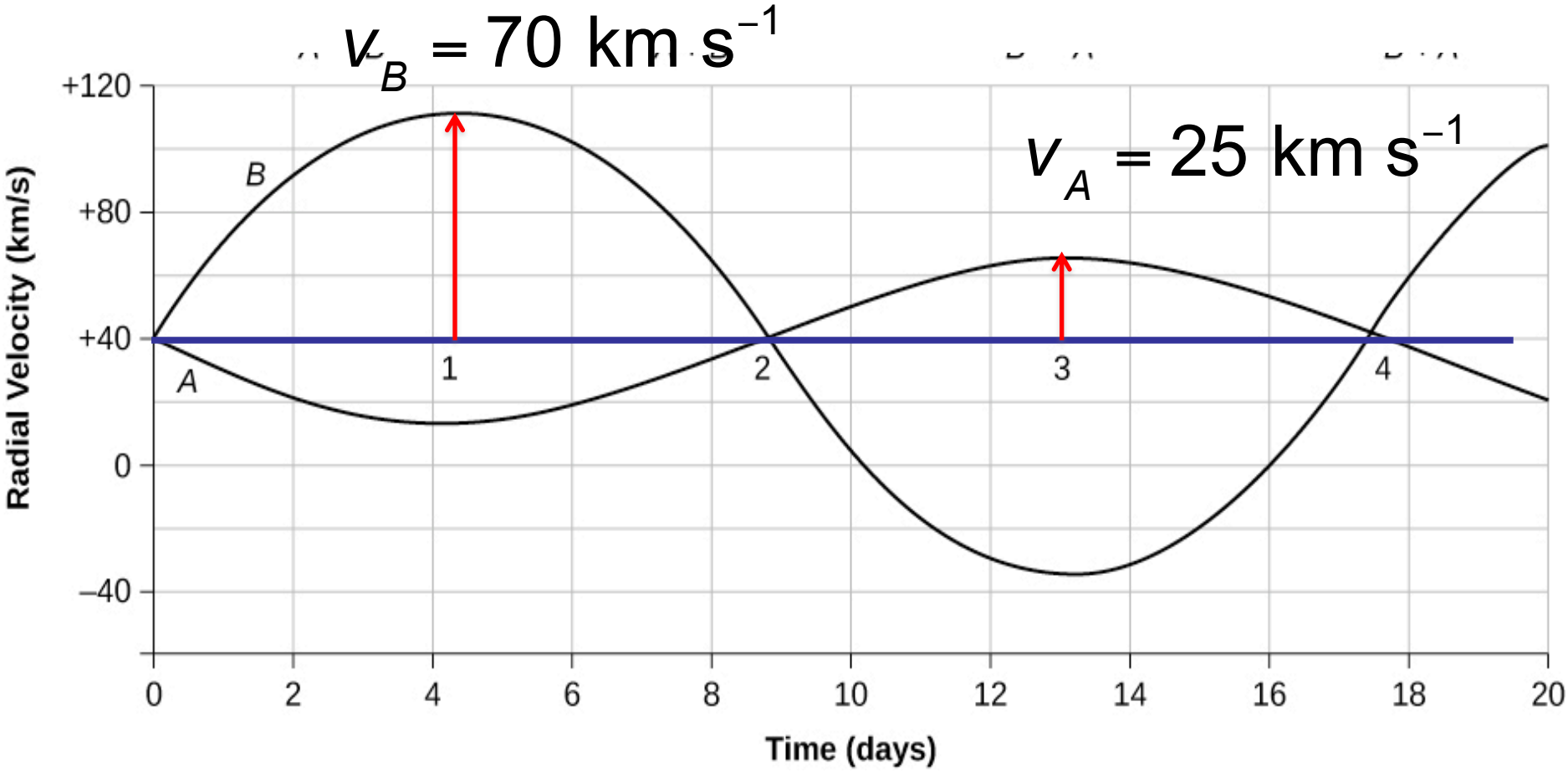


$v_{CM} = 40$ km s^{-1}

$P = 17.5$ days

- If you assume i=90^o the masses are:

$$M_A + M_B = \frac{P}{2\pi G}\left(\frac{v_{rA} + v_{rB}}{\sin i}\right)^3$$

$$= \frac{17 \times 24 \times 3600}{2\pi 6.7.10^{-11}}\left(\frac{(25+70)\times 10^3}{\sin 90^o}\right)^3$$

$$= 3.0 \times 10^{30} \text{ kg}$$

$$= 1.5 \text{ M}_{Sun}$$

$$\frac{M_B}{M_A} = \frac{v_{rA}}{v_{rB}} = \frac{25}{70}$$

$$M_A = 2.8 M_B$$

$$3.8 M_B = 1.4 \text{ M}_{Sun}$$

$$M_B = 0.37 \text{ M}_{Sun}$$

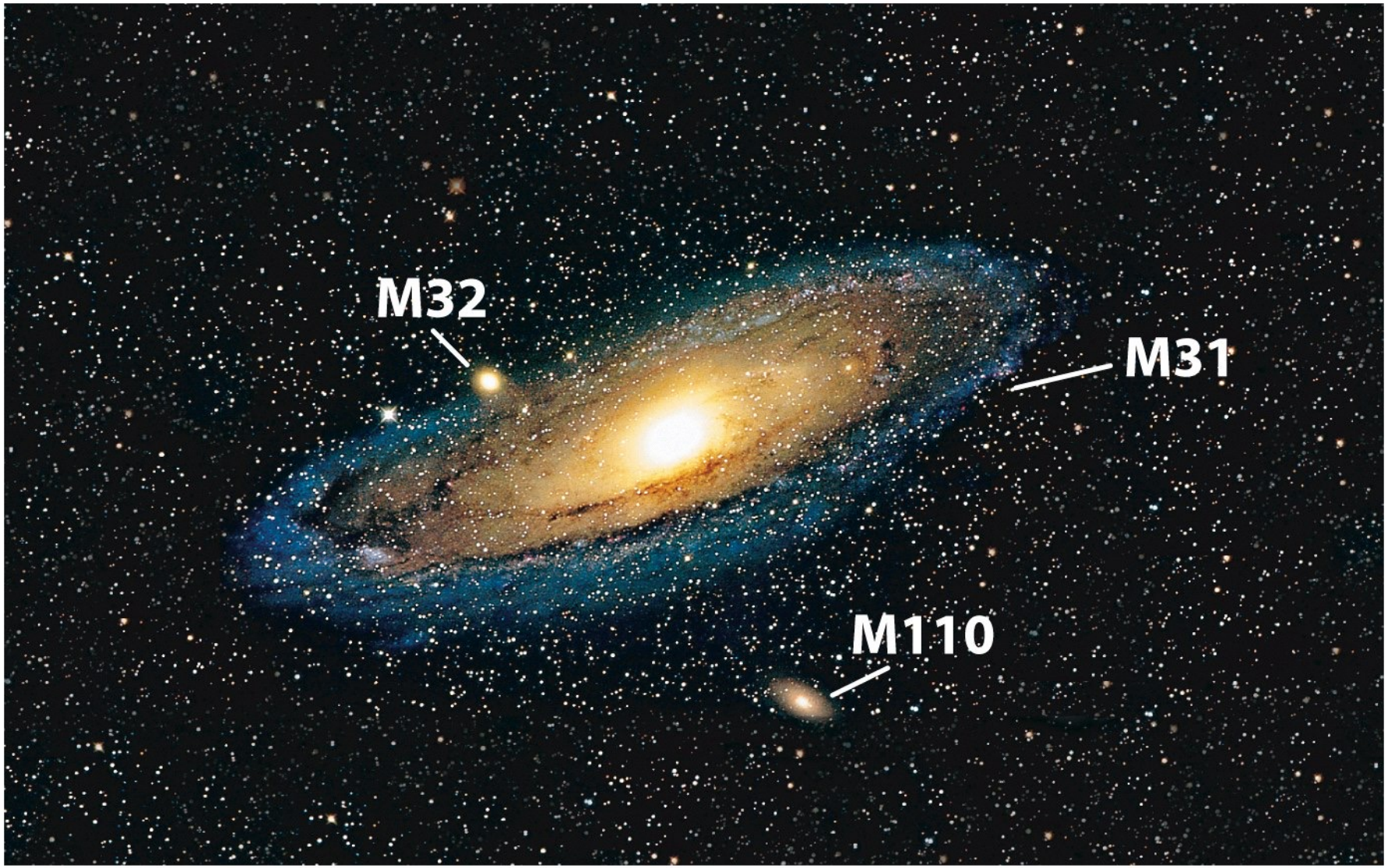
$$M_A = 1.0 \text{ M}_{Sun}$$

Galaxy Types

- Definition of a galaxy
- Galaxy Types
  - Spiral
  - Elliptical
  - Irregular
- Galaxy Classification
  - Hubble's Tuning Fork Diagram

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



From Universe textbook

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

https://apod.nasa.gov/apod/ap040409.html

- 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

From Universe textbook

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

Class Example

- What is the typical angular separation of stars that are about 1 pc apart in a galaxy that is at a distance of 1 Mpc?

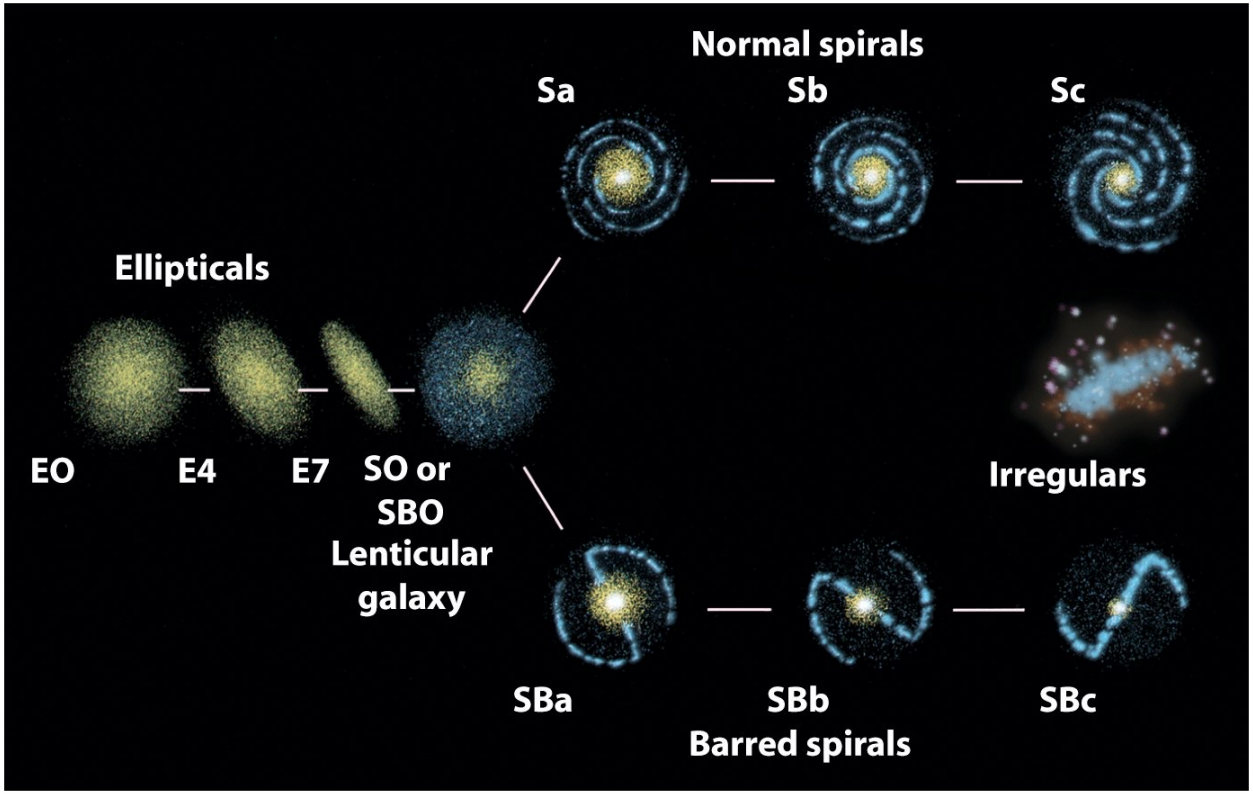
$$\theta = \frac{l}{d} = \frac{1}{1\times10^{6}} = 1\times10^{-6} \text{ radians}$$

$$= 206265\times1\times10^{-6} = 0.2''$$

https://sci.esa.int/web/hubble/-/55194-sharpest-ever-view-of-the-andromeda-galaxy

Galaxy Classification

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



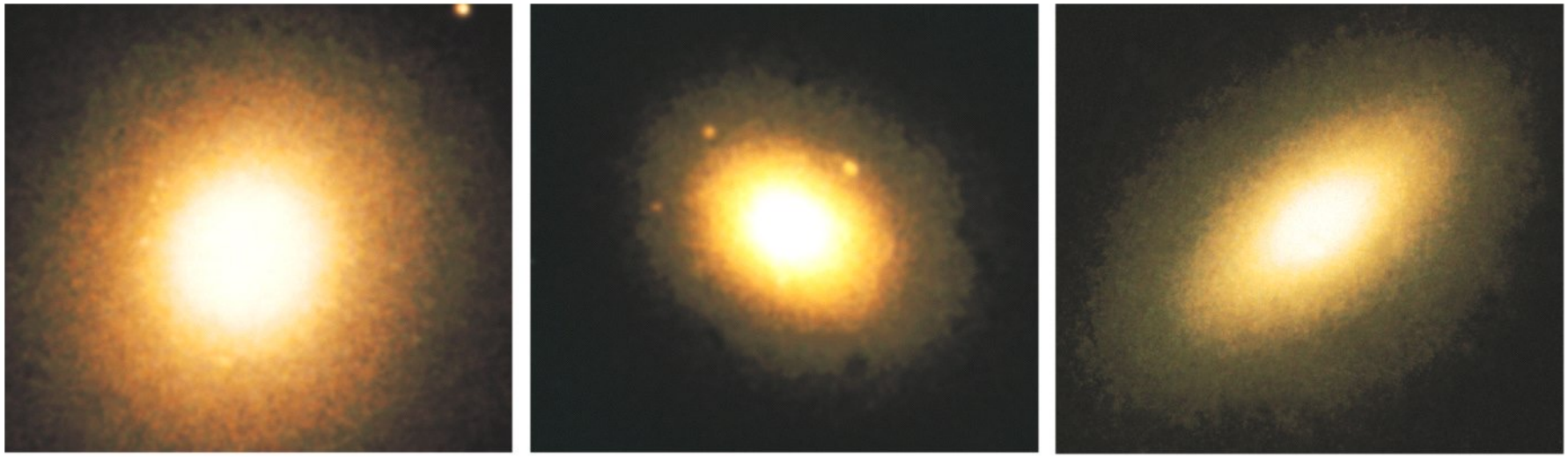
From Universe textbook

Classification of Ellipticals

- Ellipticals (E) are classified according to their apparent ellipticity by the nearest integer to

$$10\frac{(a-b)}{a}$$

  where *a* is the major axis and *b* the minor axis of the ellipse
- This is the apparent ellipticity, i.e. it is affected by the viewing angle



(a) E0 (M105) (b) E3 (NGC 4365) (c) E6 (NGC 3377)

From Universe textbook

Classification of Spirals

- Spirals (S) are classified by
  - the relative size of the bulge,
  - the amount of dust and gas,
  - the tightness of the spiral arms
- Sa galaxies have a large bulge, small disc and tight spiral arms and little gas & dust
- Sc galaxies have a small bulge, large disc and loose spiral arms and lots gas & dust
- Sb are intermediate

(a) Sa (NGC 1357)

(b) Sb (M81)

(c) Sc (NGC 4321)

From Universe textbook

- Barred spirals (SB) have an equivalent classification going from SBa to SBc with the bulge and bar being dominant in class ‘a’ and progressively less so towards class ‘c’

(a) SBa (NGC 4650) (b) SBb (M83) (c) SBc (NGC 1365)

From Universe textbook

S0 Galaxies

- S0 galaxies are intermediate between the most elliptical ellipticals (E7) and the spirals Sa or SBa.
- Has a disc and a bulge as well as an elliptical component
- A little gas but no obvious spiral arms
- Also called lenticular galaxies

Lenticular galaxy

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
- Spirals and irregulars contain gas, dust and blue stars whilst ellipticals contain only red stars

Class Example

- What is the physical diameter of the Andromeda galaxy that has an angular diameter of 3^{o} and a distance of 0.78 Mpc?

https://apod.nasa.gov/apod/ap061228.html