PHY306/406
Cosmology

Course:
17 lectures (2 per week); 3 examples classes

Assessment:
1x Exam: PHY306: 80%; PHY406: 75%
2x Class tests: PHY306: 10% each; PHY406: 7.5% each
1x Directed reading: PHY406 *only:* 10%

Recommended reading:
Introduction to Cosmology by B. Ryden

Lectures

01: Fundamental Observations
02: Shape of universe and cosmological distances
03: The Friedmann Equation
04: Solving the Friedmann Equation I
05: Solving the Friedmann Equation II
06: Model universes
07: The Benchmark Model and measurable distances
08: The Dark Universe
09: The Cosmic Microwave Background I
10: The Cosmic Microwave Background II
11: Nucleosynthesis I
12: Nucleosynthesis II
13: Inflation
14: Structure Formation I
15: Structure Formation II
16: Baryons & Photons I
17: Baryons & Photons II

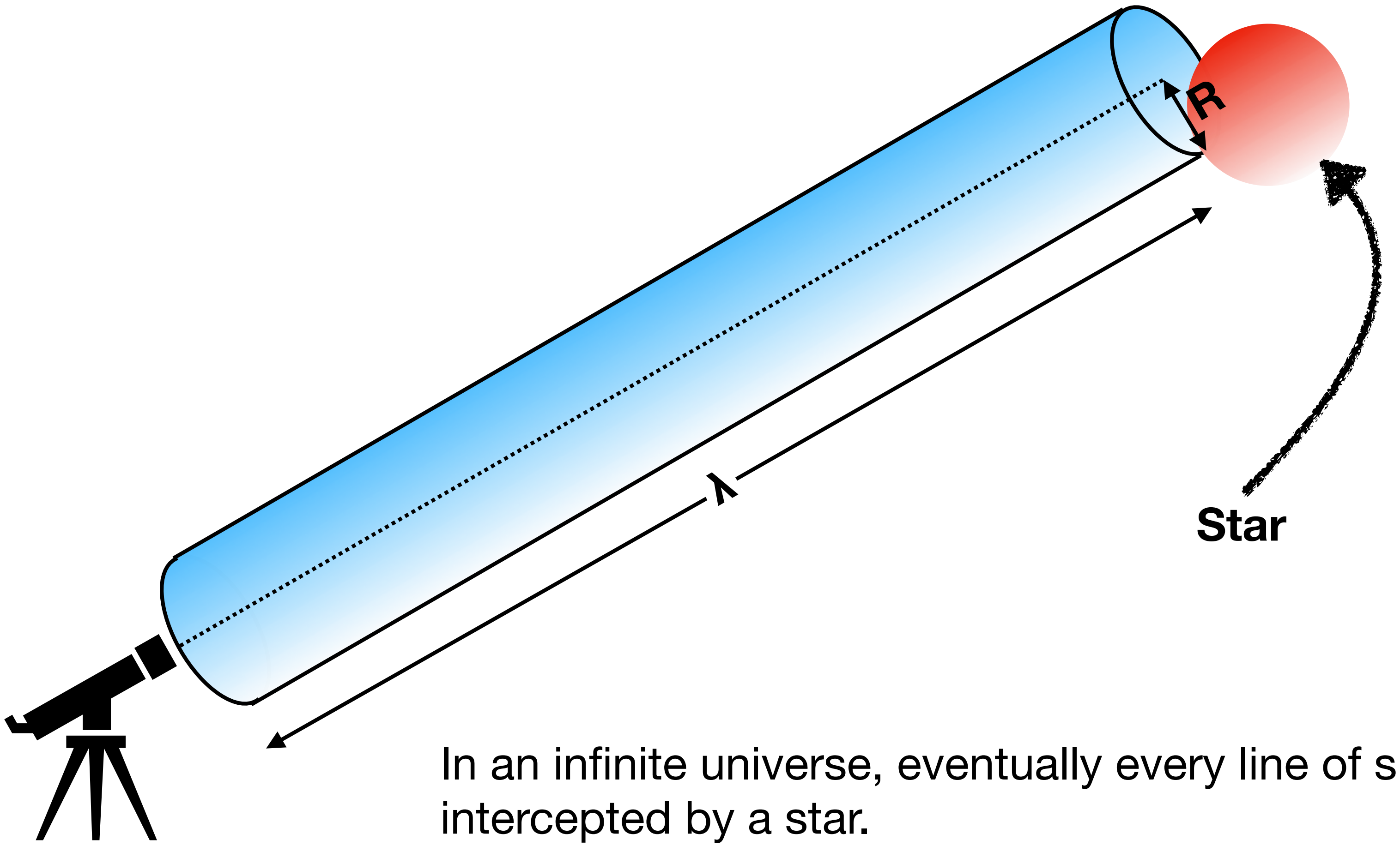
Cosmology Lecture 1: Observations

See chapter 1 of Ryden

Learning objectives

- Historical evidence for an evolving Universe.
- Fundamental observations: *isotropy* and *homogeneity*
- Real coordinates
- Co-moving coordinates
- The scale factor, a(t)
- The Hubble constant and the Hubble parameter.

Olber's Paradox
or, "Why is the night sky dark?"



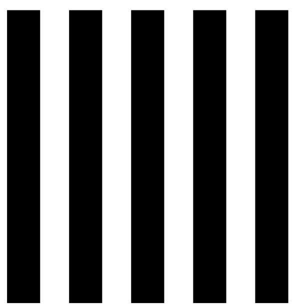
In an infinite universe, eventually every line of sight will be intercepted by a star.

On average, how far would we be able to see before our line of sight is intercepted?

The Universe is…

isotropic: it appears the same in all directions
and
homogeneous: there are no preferred locations

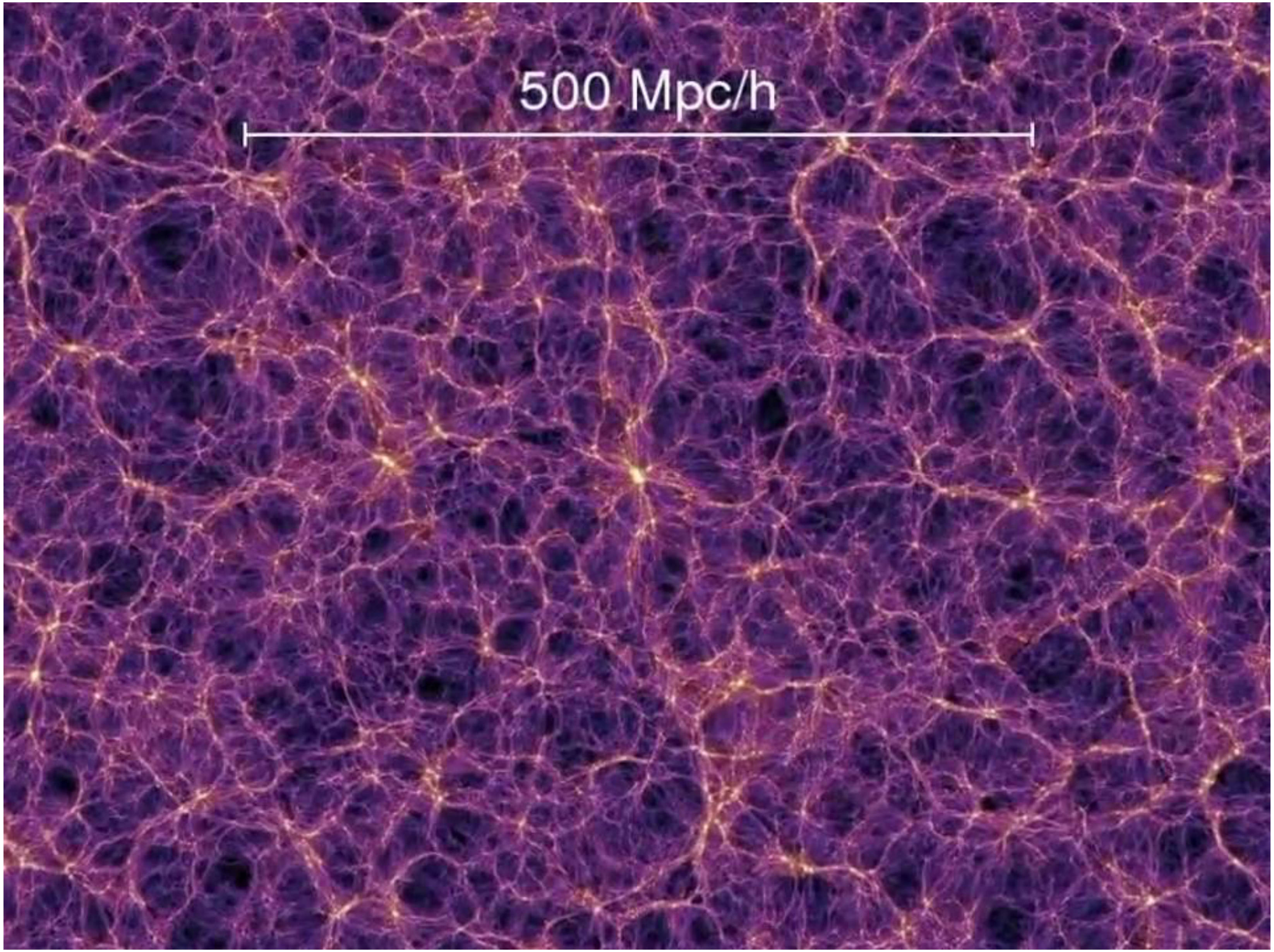
Note: One doesn't imply the other…



Homogeneous,
but not isotropic

Isotropic,
but not homogeneous

but, this is clearly only true on large scales…

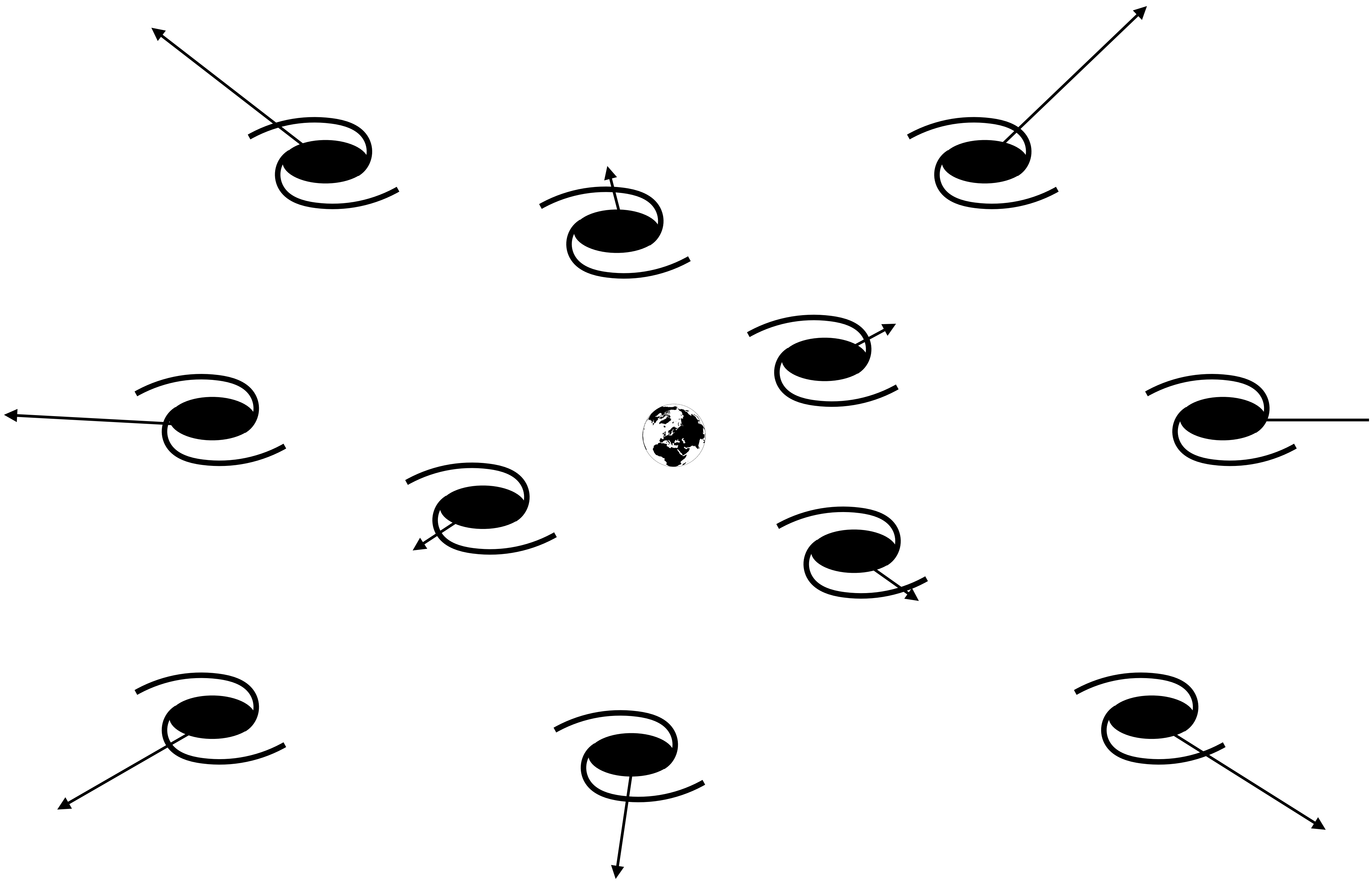


credit: Millenium simulation

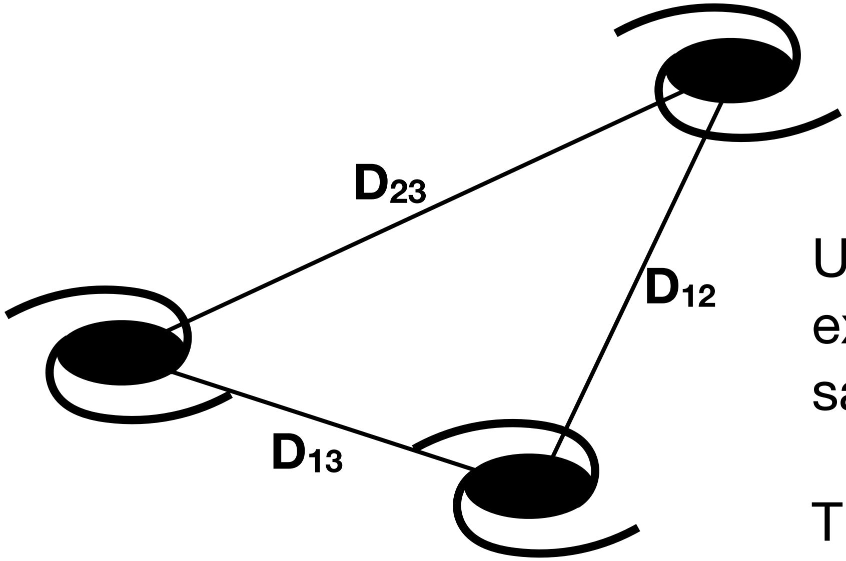
Things to take away from our elastic universe:

- **Co-moving coordinates**
- **Scale factor, a(t)**
- $$D_{x,y}(t) = a(t) r_{x,y}$$
- $$a(t_0) = 1$$
- t_0 is the time *now*.

Redshift is proportional to distance



Redshift is proportional to distance



Under homogeneous and isotropic expansion all directions expand by the same amount.

The *shape* of the triangle *must* remain the same as the Universe expands…

$$D_{1,2} = a(t)r_{1,2}$$
$$D_{2,3} = a(t)r_{2,3}$$
$$D_{3,1} = a(t)r_{3,1}$$

Redshift is proportional to distance…

…exactly as we expect from isotropic, homogeneous expansion.

With…

$$v = Hr$$

where…

$$\boxed{H = \frac{\dot{a}}{a}}$$

A note on notation

The Hubble constant is the *current value* of the Hubble parameter. It is denoted H_0.

As we shall see later in the course, the Hubble parameter changes with time. It is denoted $H(t)$ or, often, simply H.

Getting the feel for it…

- When not acted upon by any significant force, the co-moving coordinates of an object does not change as the Universe expands/contracts.

- The distance between two objects is equal to their distance in co-moving coordinates multiplied by the scale factor, a(t).

- Hubble's law follows directly from the realisation that the Universe is Isotropic and Homogeneous.

- The Hubble constant *is* the relative rate at which the Universe expands; the rate of expansion per unit distance.

Pop quiz

- If the Hubble parameter has remained constant throughout the history of the Universe, how long (in years) has it taken for the Universe to reach its current “size”?
  (You’ll need to look up the value for the Hubble constant, H_0)

- If I marked a separation of 20cm on a piece of elastic, then stretched the elastic so that the separation increased by 10cm/s, what is the instantaneous Hubble parameter (i.e., Hubble constant) of the elastic?