PHY306/406
Cosmology

Course:
17 lectures (2 per week); 8 problems classes

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

- Thursday 7th March at 12pm (during problems classes)
- Thursday 2nd May at 12pm

1x Directed reading: PHY406 *only:* 10%

Recommended reading:
Introduction to Cosmology by B. Ryden

PHY306/406
I have one rule

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

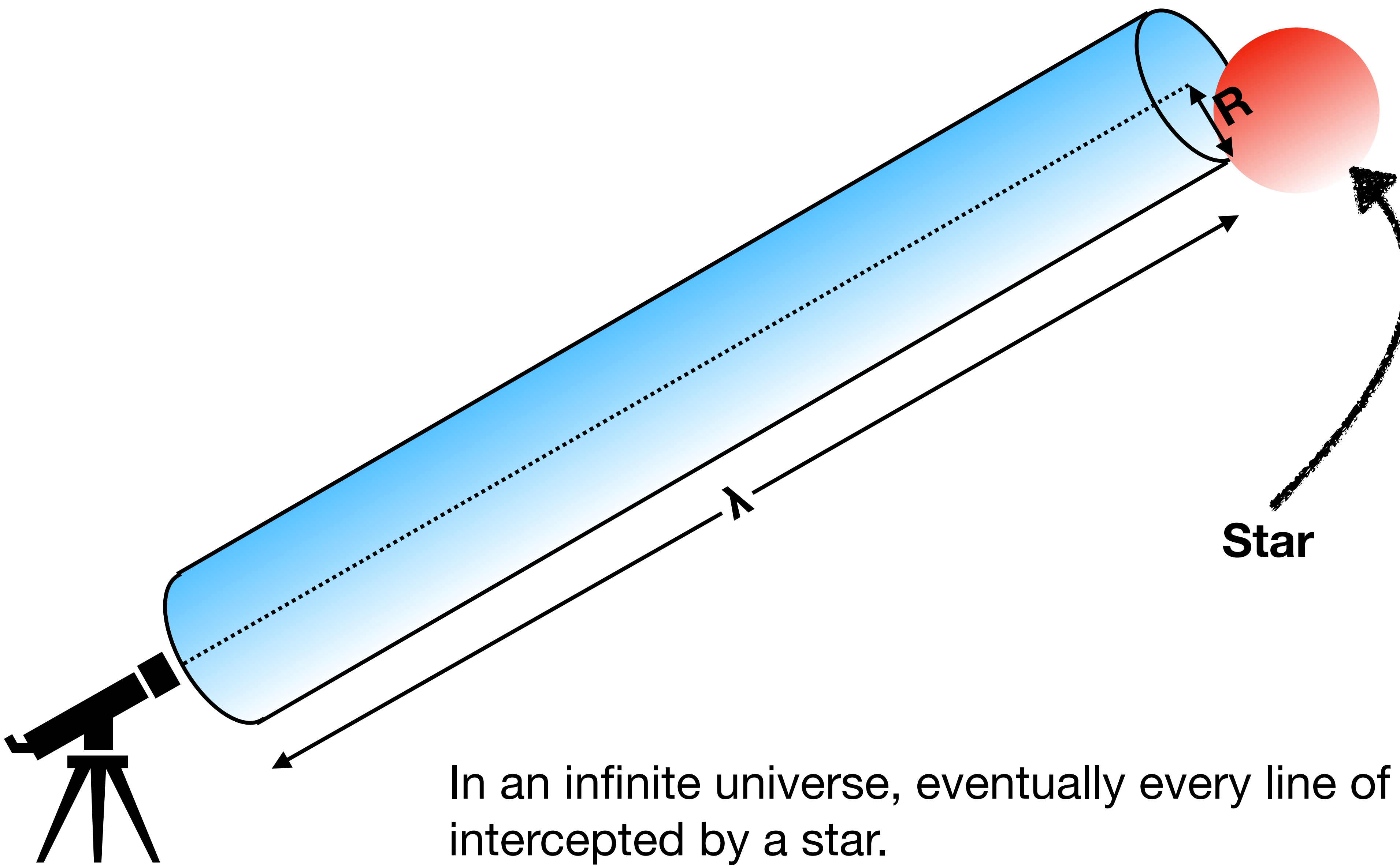
Cosmology Lecture 1: Observations

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?"



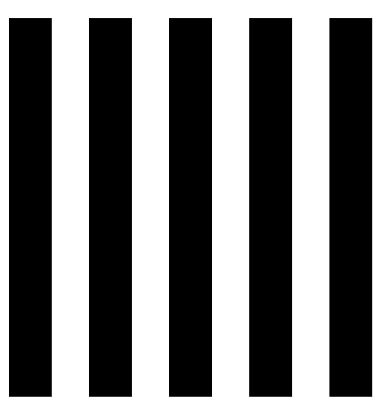
In an infinite universe, eventually every line of sight will be intercepted by a star.

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

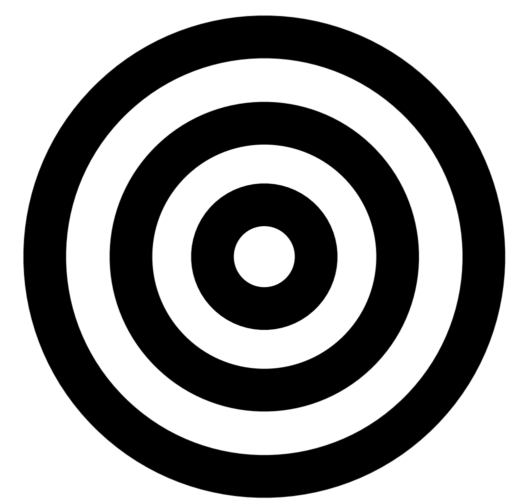
The Universe is…

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

Note: One doesn't imply the other…

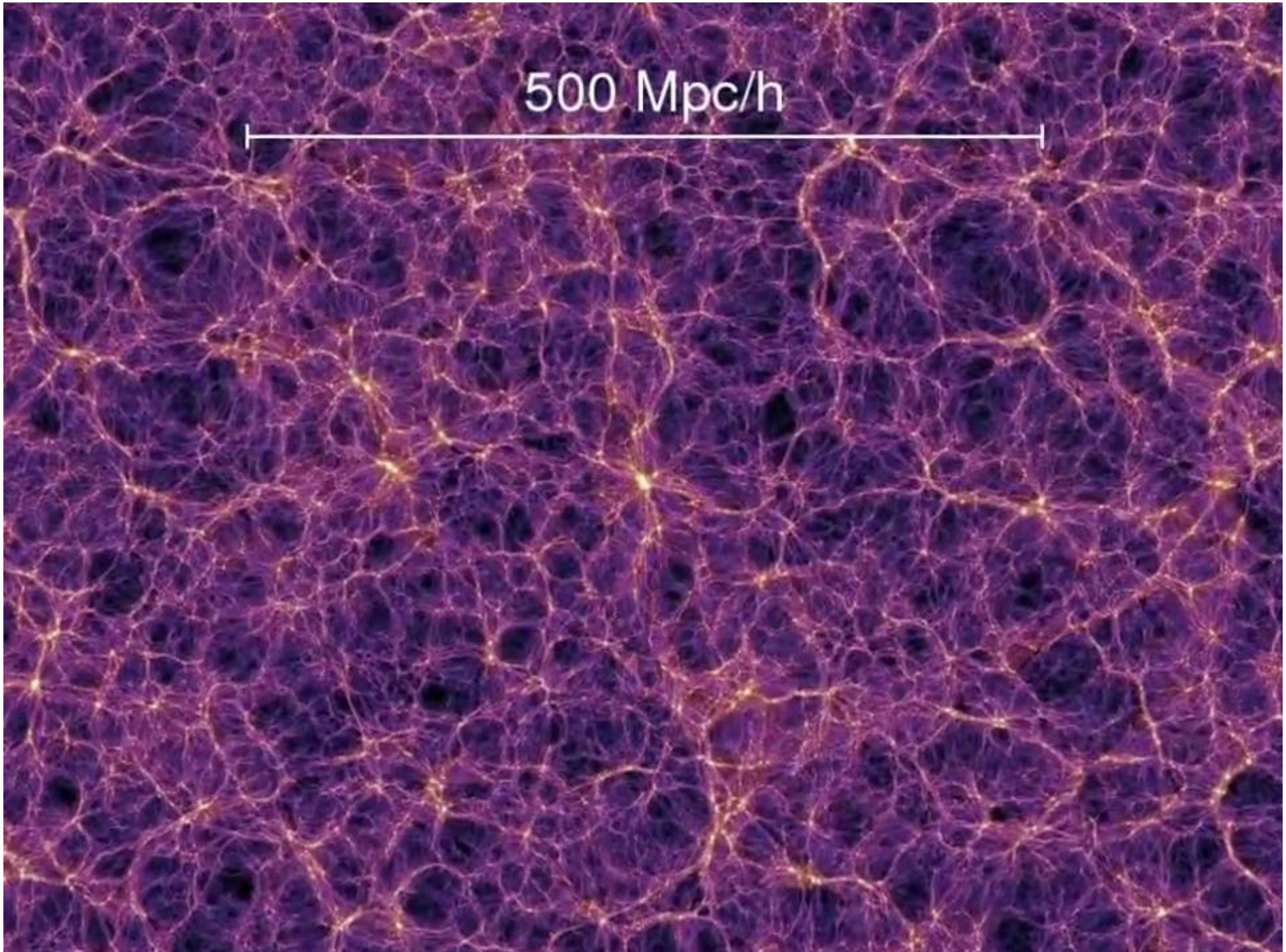


Homogeneous,
but not isotropic



Isotropic,
but not homogeneous

but, this is clearly only true on large scales…

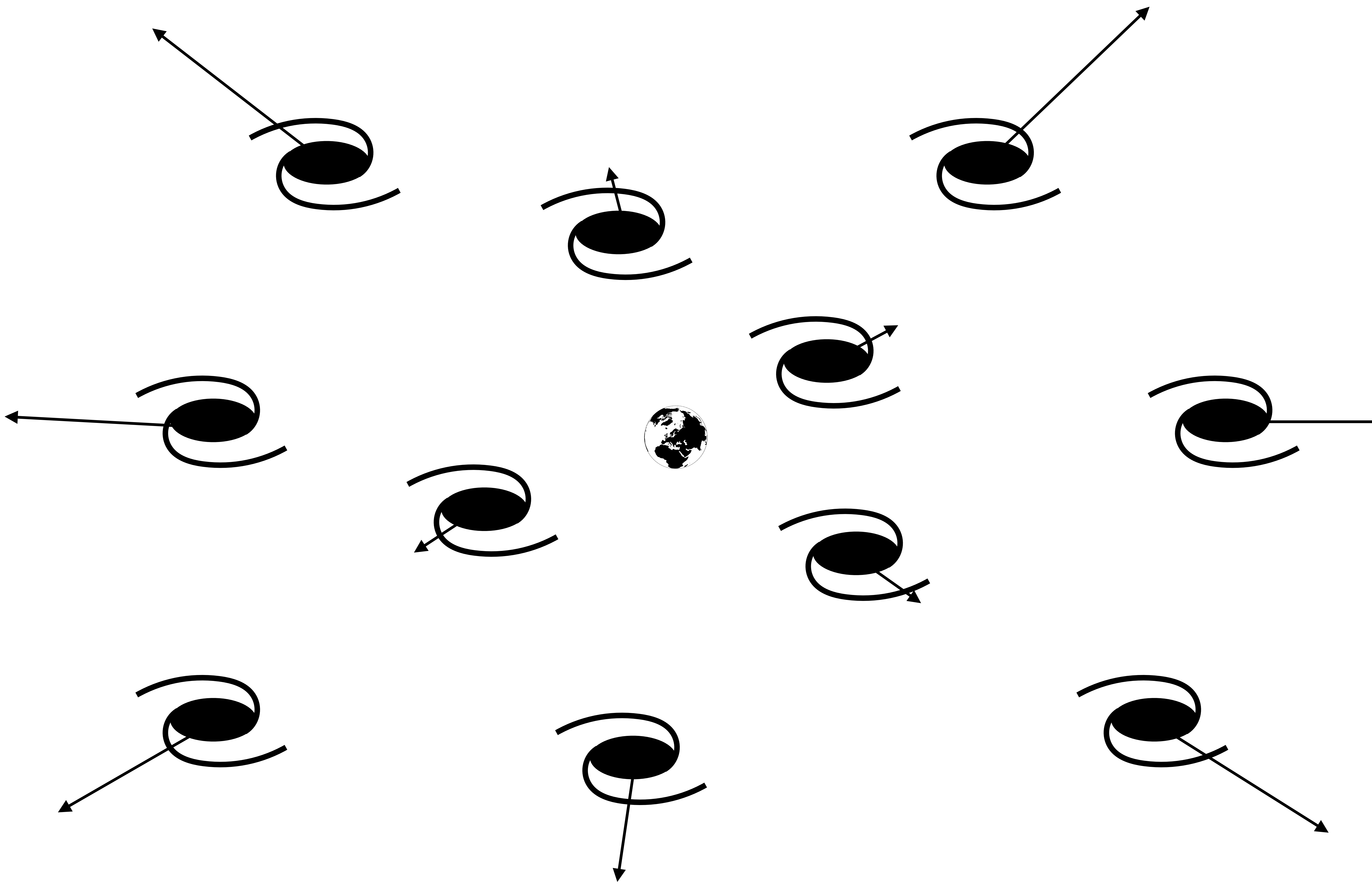


credit: Millenium simulation

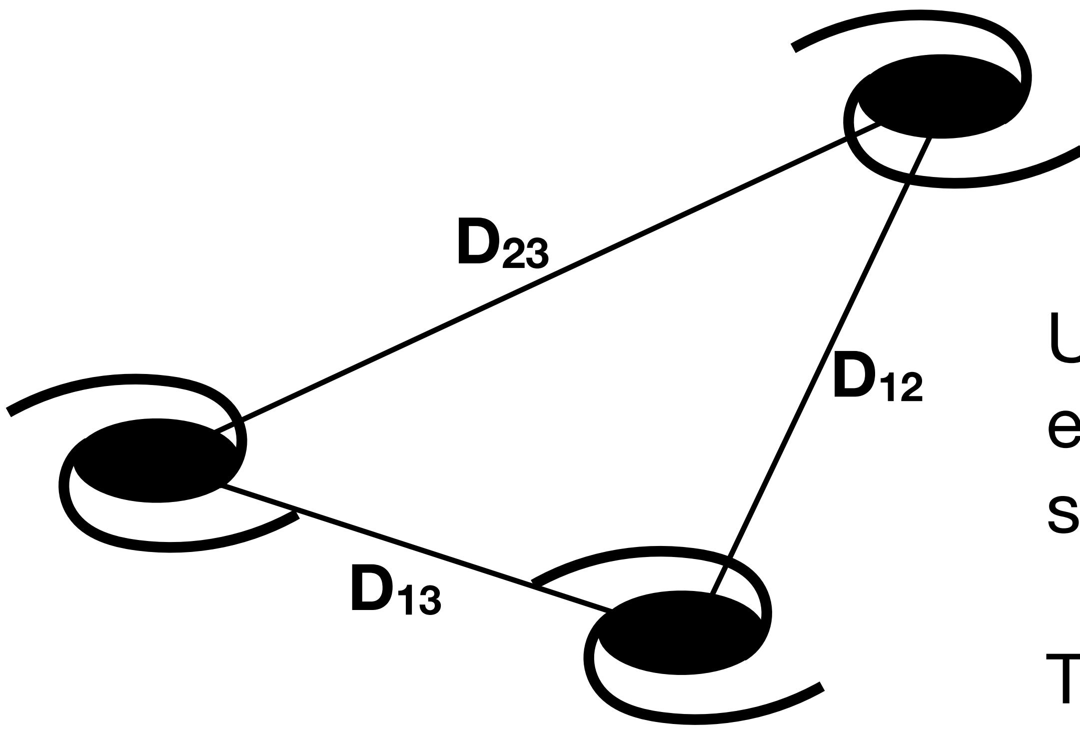
Things to take away from our elastic universe:

- **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.