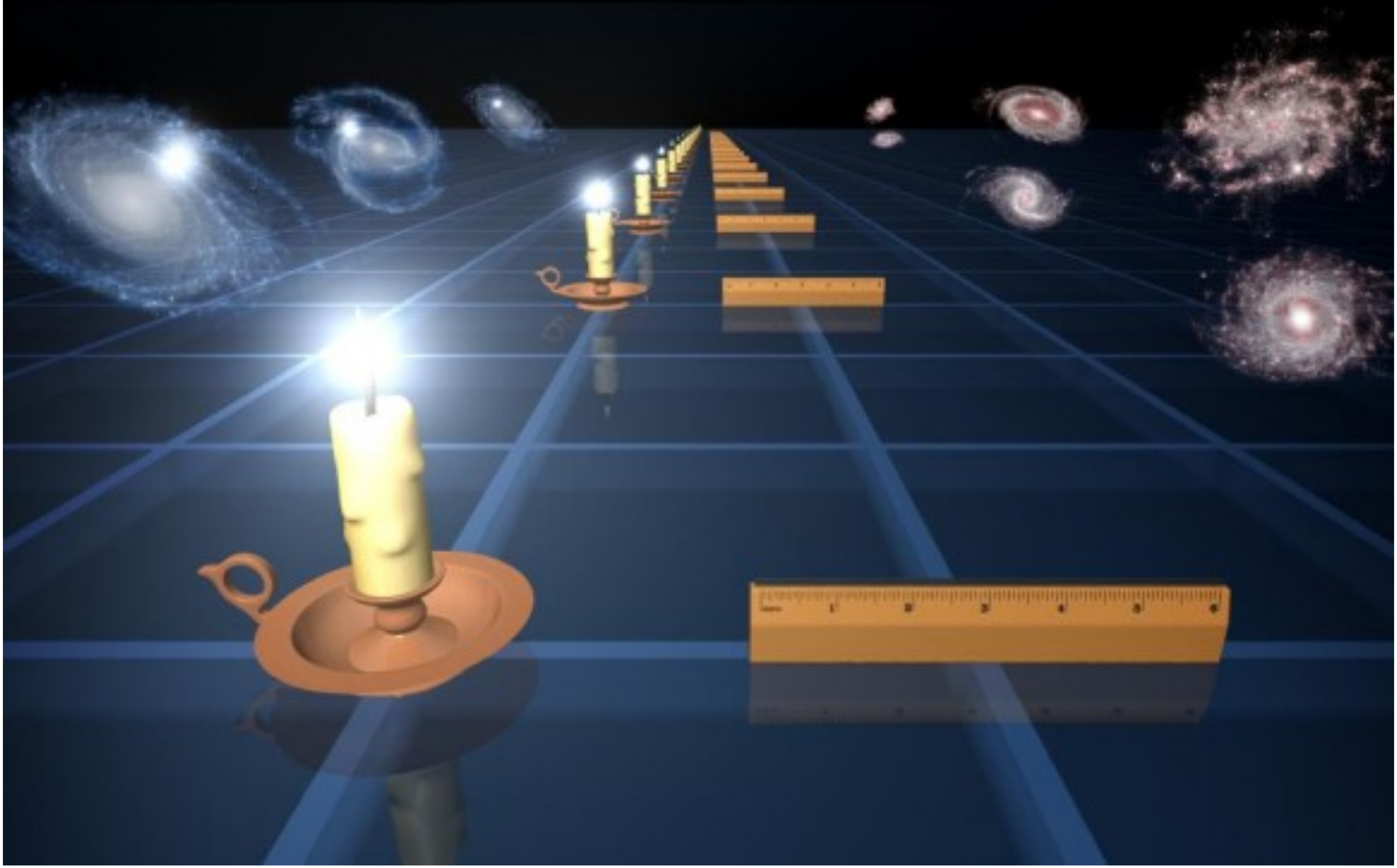
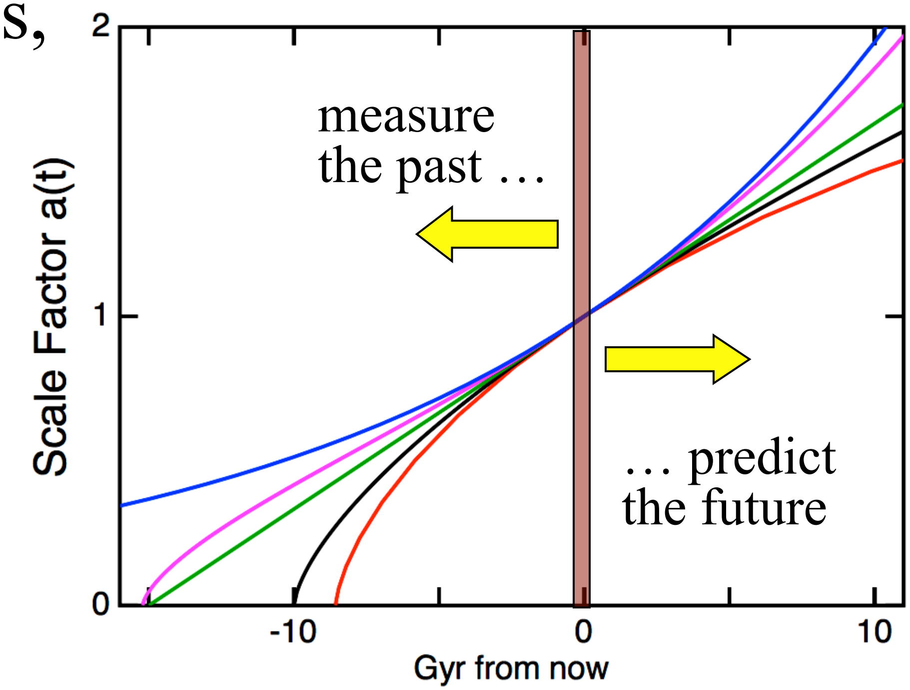
Cosmological Tests: An Introduction

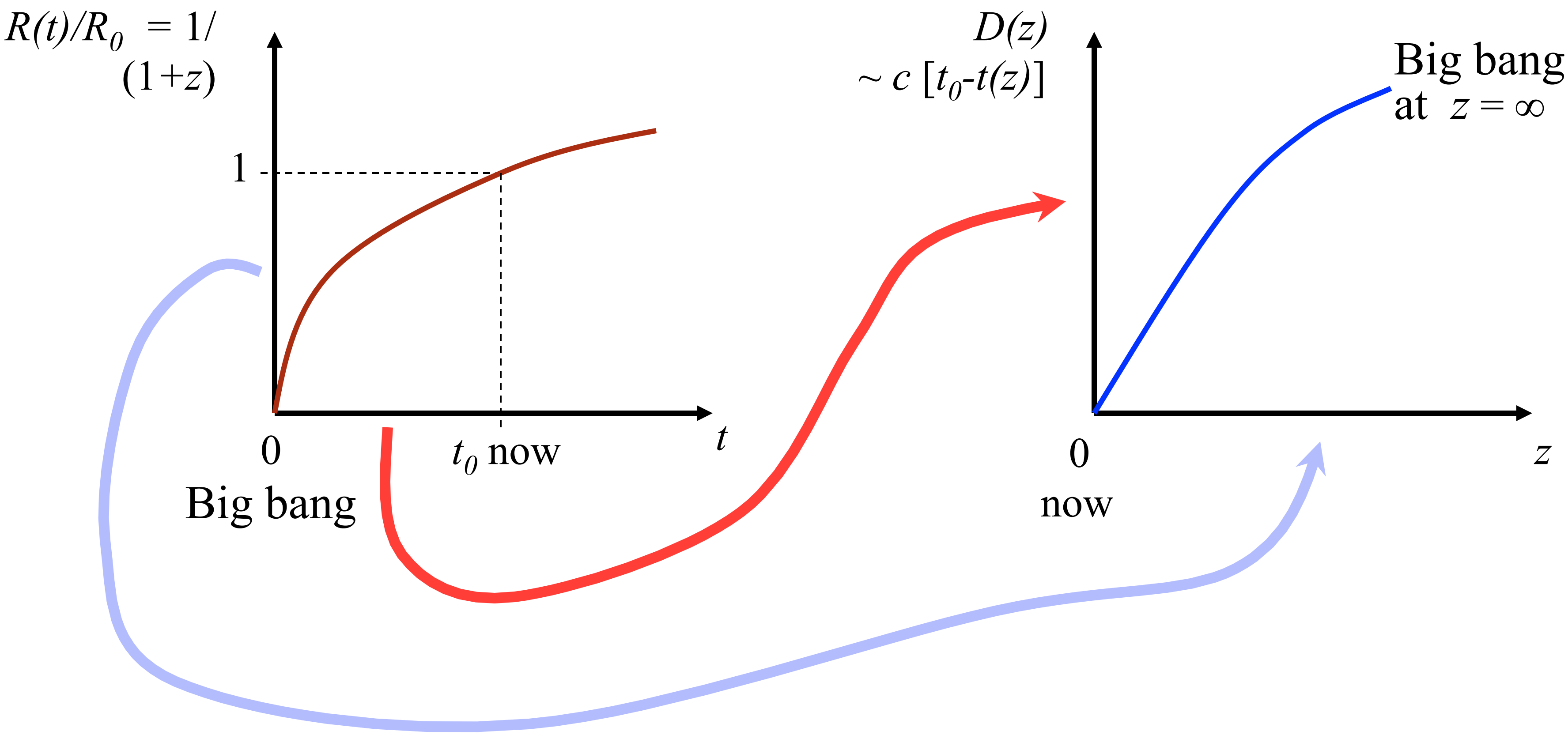


Cosmological Tests: The Why and How

- The goal is to determine the global geometry and the dynamics of the universe, and its ultimate fate
- The basic method is to somehow map the history of the expansion, and compare it with model predictions
- A model (or a family of models) is assumed, e.g., the Friedmann-Lemaitre models, typically defined by a set of parameters, e.g., H_0, $\Omega_{0,m}$, $\Omega_{0,\Lambda}$, q_0, etc.
- Model equations are integrated, and compared with the observations

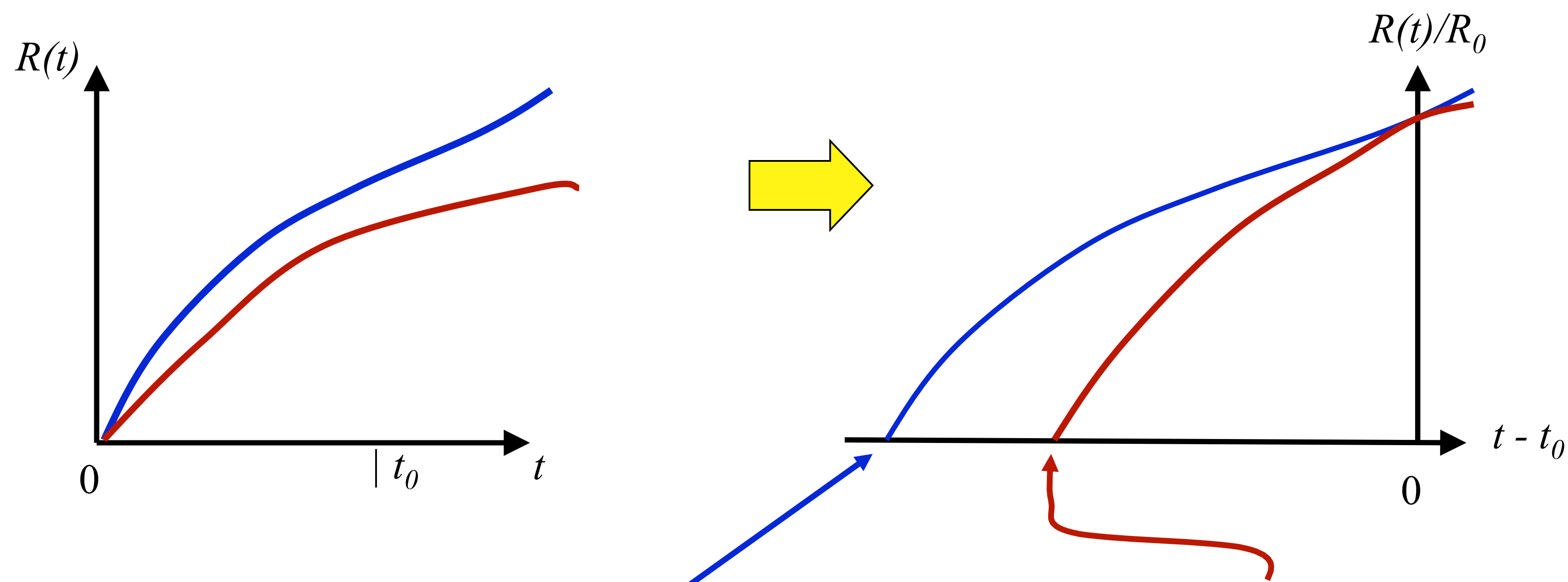


The Basis of Cosmological Tests



All cosmological tests essentially consist of comparing some measure of (relative) distance (or look-back time) to redshift. Absolute distance scaling is given by the H_0.

Cosmological Tests: Expected Generic Behavior of Various Models



Models with a lower density and/or positive Λ expand faster, are thus larger, older today, have more volume and thus higher source counts, at a given *z* sources are further away and thus appear fainter and smaller

Models with a higher density and lower Λ behave exactly the opposite

The Types of Cosmological Tests

- **The Hubble diagram:** flux (or magnitude) as a proxy for the luminosity distance, vs. redshift - requires **"*standard candles*"**
- **Angular diameter** as a proxy for the angular distance, vs. redshift - requires **"*standard rulers*"**
- **Source counts** as a function of redshift or flux (or magnitude), probing the evolution of a volume element - requires a population of sources with a constant comoving density - **"*standard populations*"**
- Indirect tests of age vs. redshift, usually highly model-dependent - **"*standard clocks*"**
- Local dynamical measurements of the mass density, Ω_{m0}
- If you measure H_0 and t_0 independently, you can constrain a combination of Ω_{m0} and Ω_Λ

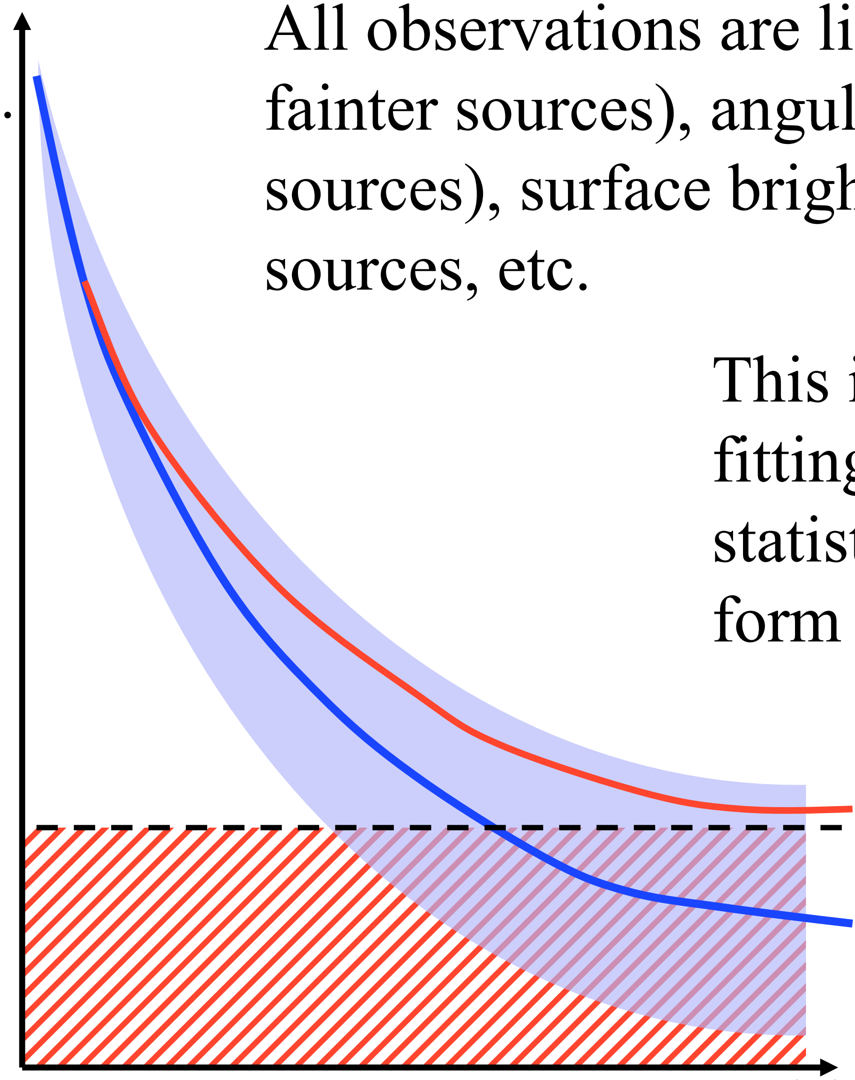
Cosmological Tests: A Brief History

- A program of "classical" cosmological tests (Hubble diagram, angular diameter test, source counts) was initiated by Hubble, and carried out at Palomar and elsewhere by Sandage and others, from 1950s through 1970s
- Galaxies, clusters of galaxies, and radio sources were used as standard candles, rulers, or populations. Unfortunately, all are subject to strong and poorly constrained ***evolutionary effects***, which tend to dominate over the cosmology - this foiled most of the attempted tests, and became obvious by 1980's
- In the late 1990's, Supernova Ia Hubble diagram, and especially measurements of CMBR fluctuations power spectra (essentially an angular diameter test) completely redefined the subject
- The cosmological parameters are now known with a remarkable precision - a few percent; this is the era of "***precision cosmology***"

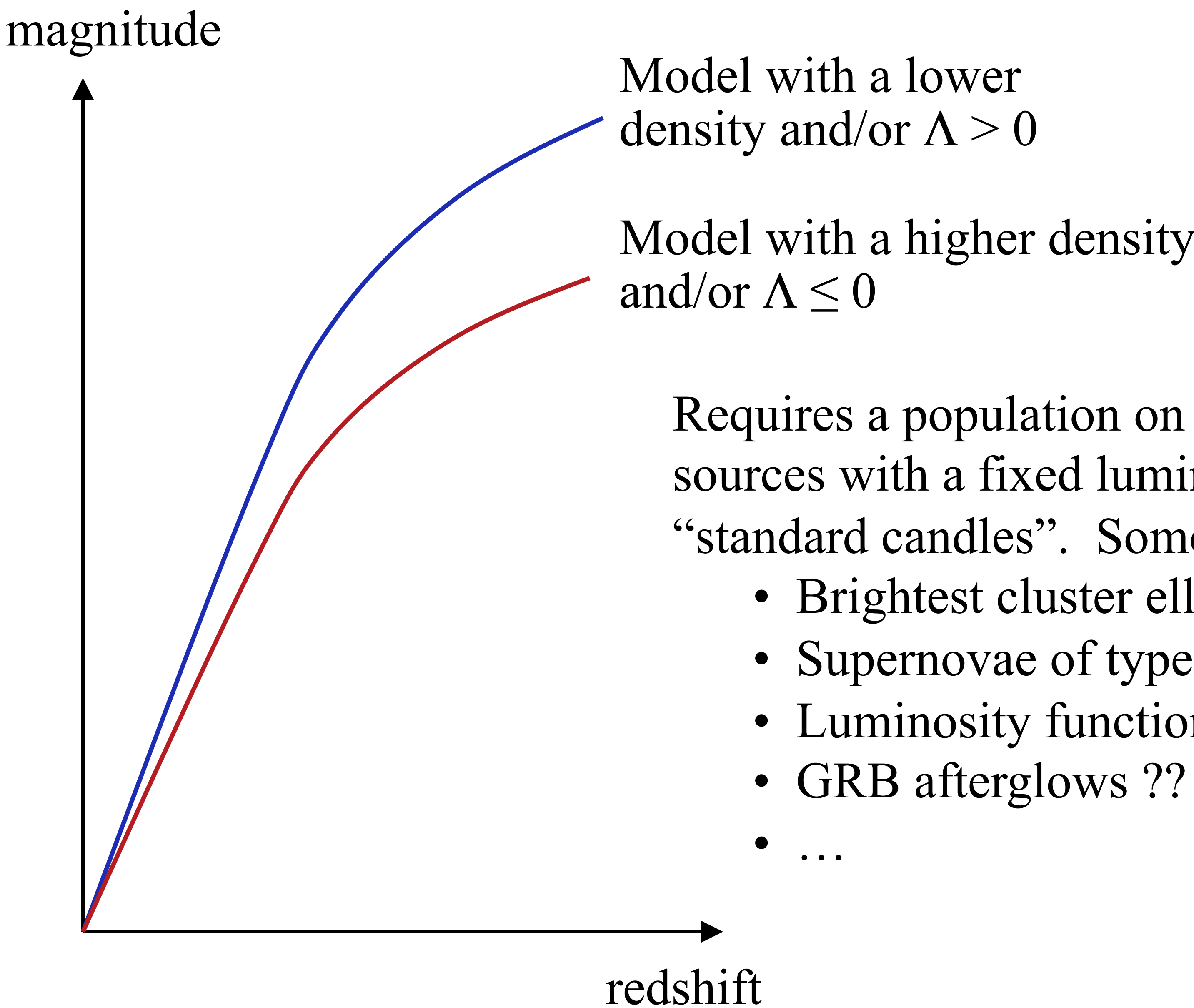
Selection Effects and Biases

All observations are limited in sensitivity (we miss fainter sources), angular resolution (we miss smaller sources), surface brightness (we miss very diffuse sources, etc.

This inevitably introduces a bias in fitting the data, unless a suitable statistical correction is made - but its form may not be always known!



The Hubble Diagram



Requires a population on non-evolving sources with a fixed luminosity - "standard candles". Some candidates:

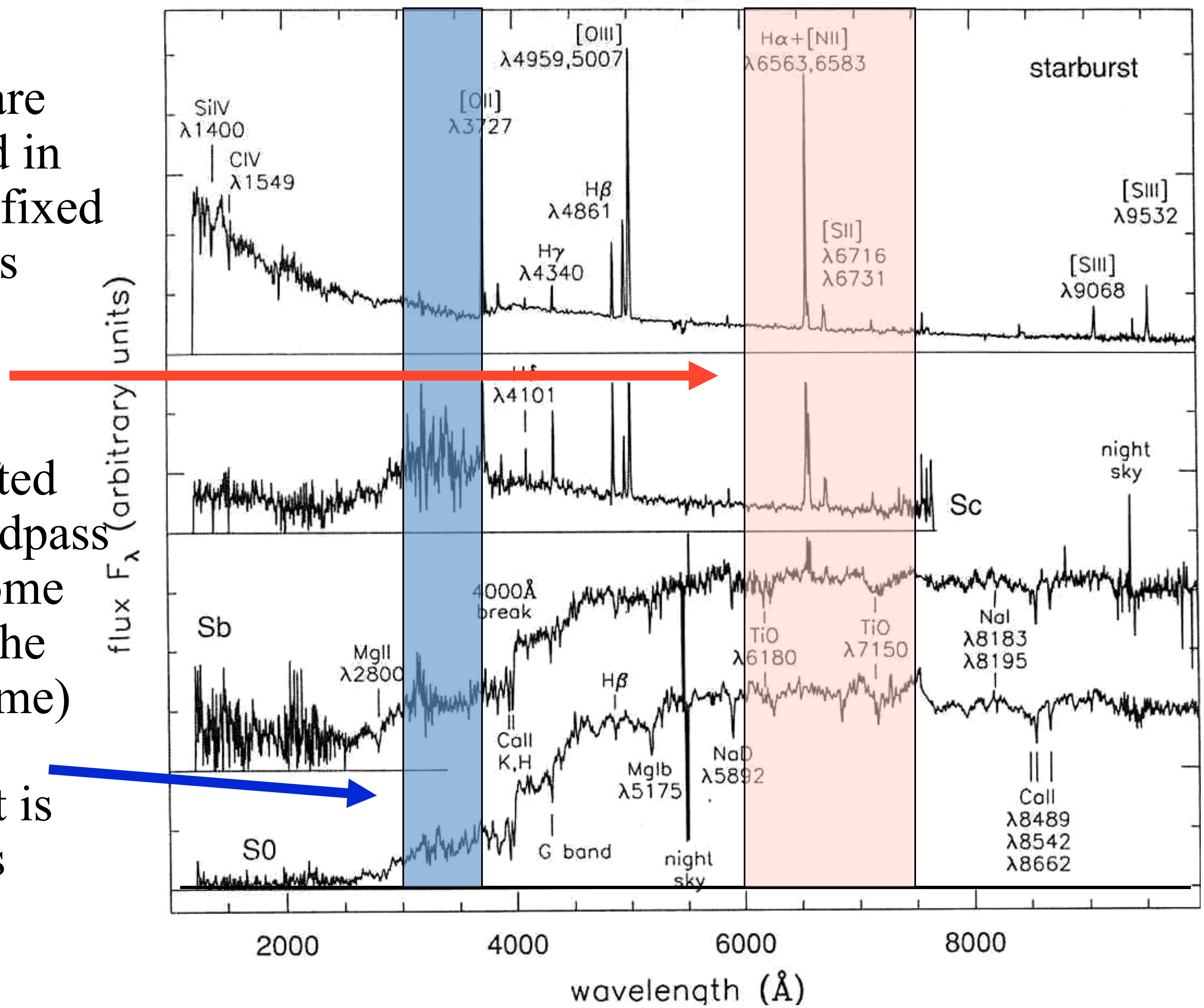
- Brightest cluster ellipticals
- Supernovae of type Ia
- Luminosity functions in clusters
- GRB afterglows ??
- …

The K-Correction

Photometric measurements are always obtained in some bandpass fixed in the observer's frame, e.g., the *U,B,V,R*…

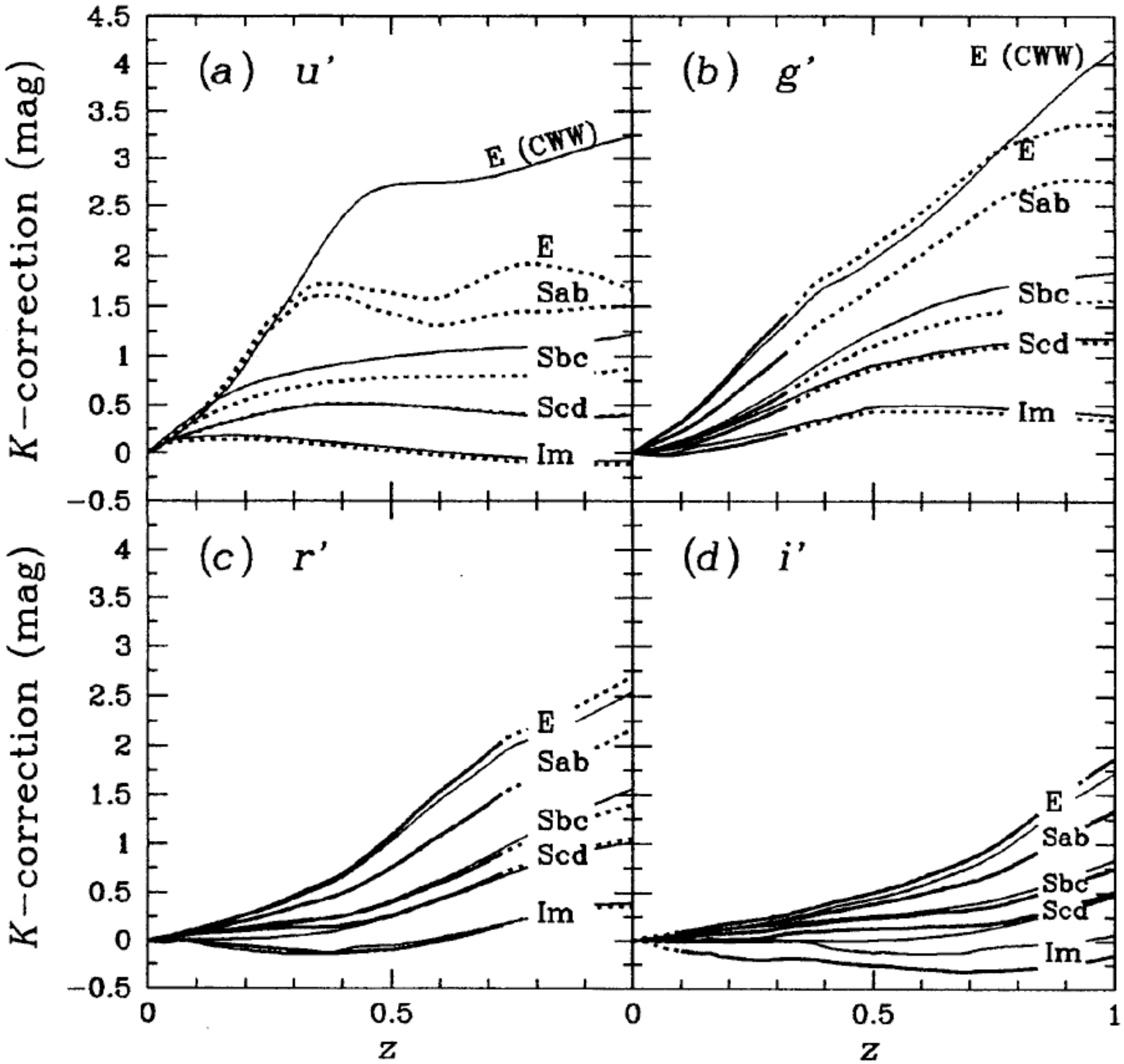
But in a redshifted galaxy, this bandpass now samples some other (bluer in the galaxy's restframe) region of the spectrum, and it is also (1+*z*) times narrower

Galaxy spectra of different types



The K-Corrections

Thus, we integrate the spectrum over the bandpass in the observed frame, and in the galaxy's restframe, take a ratio, express it in magnitudes, and that is the **K-correction**



It has to be done for all different types of galaxy spectra, as it depends on the star formation rates, and it varies with bandpass

(from Fukugita *et al.)*

Next:

Hubble Diagram as a Cosmological Test