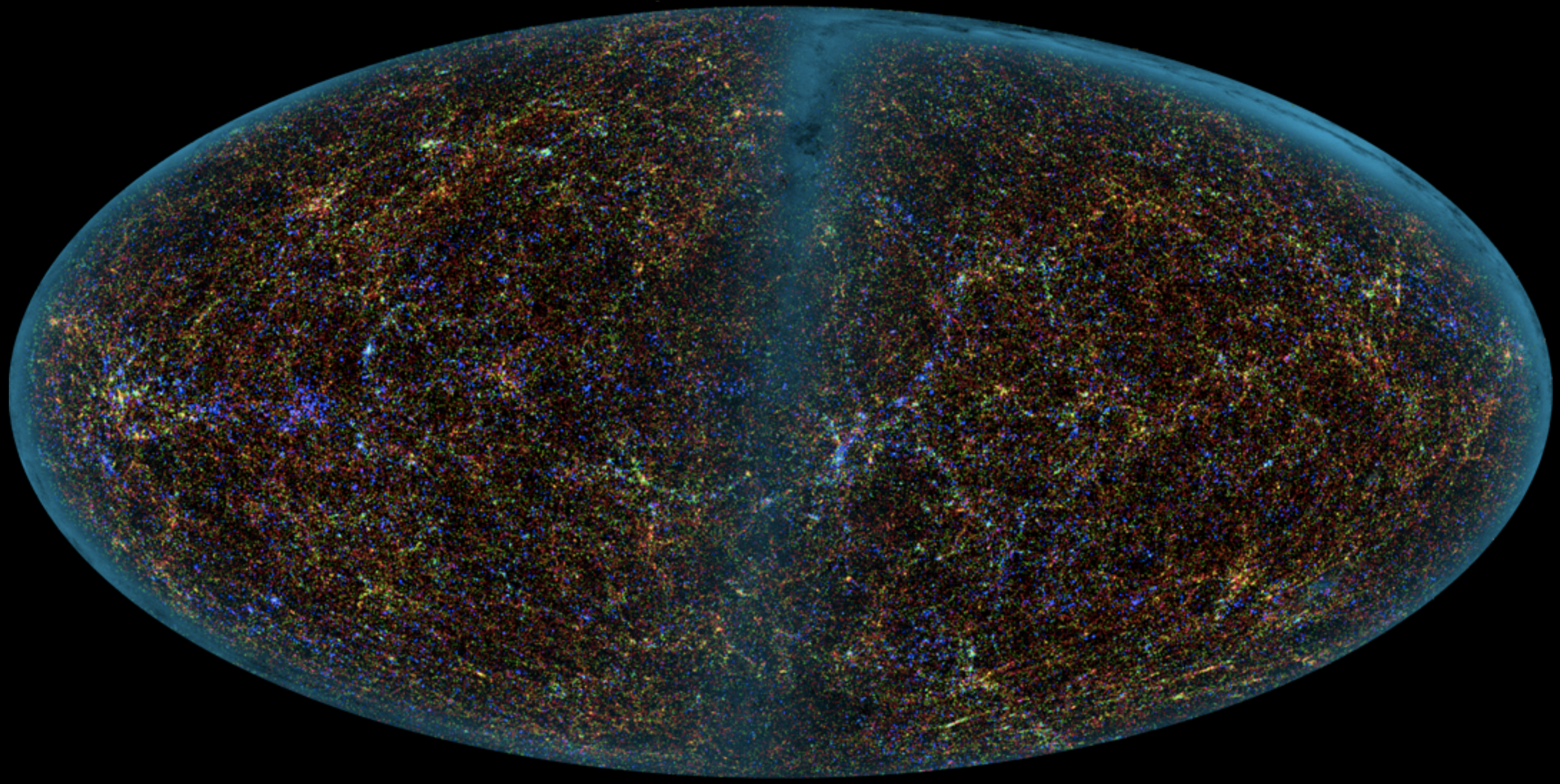
Cosmology

and Large Scale Structure



Today
Galaxy Evolution
K-corrections
Distance Scale

12 October 2020

http://astroweb.case.edu/ssm/astr328/

Basic parameters of cosmology

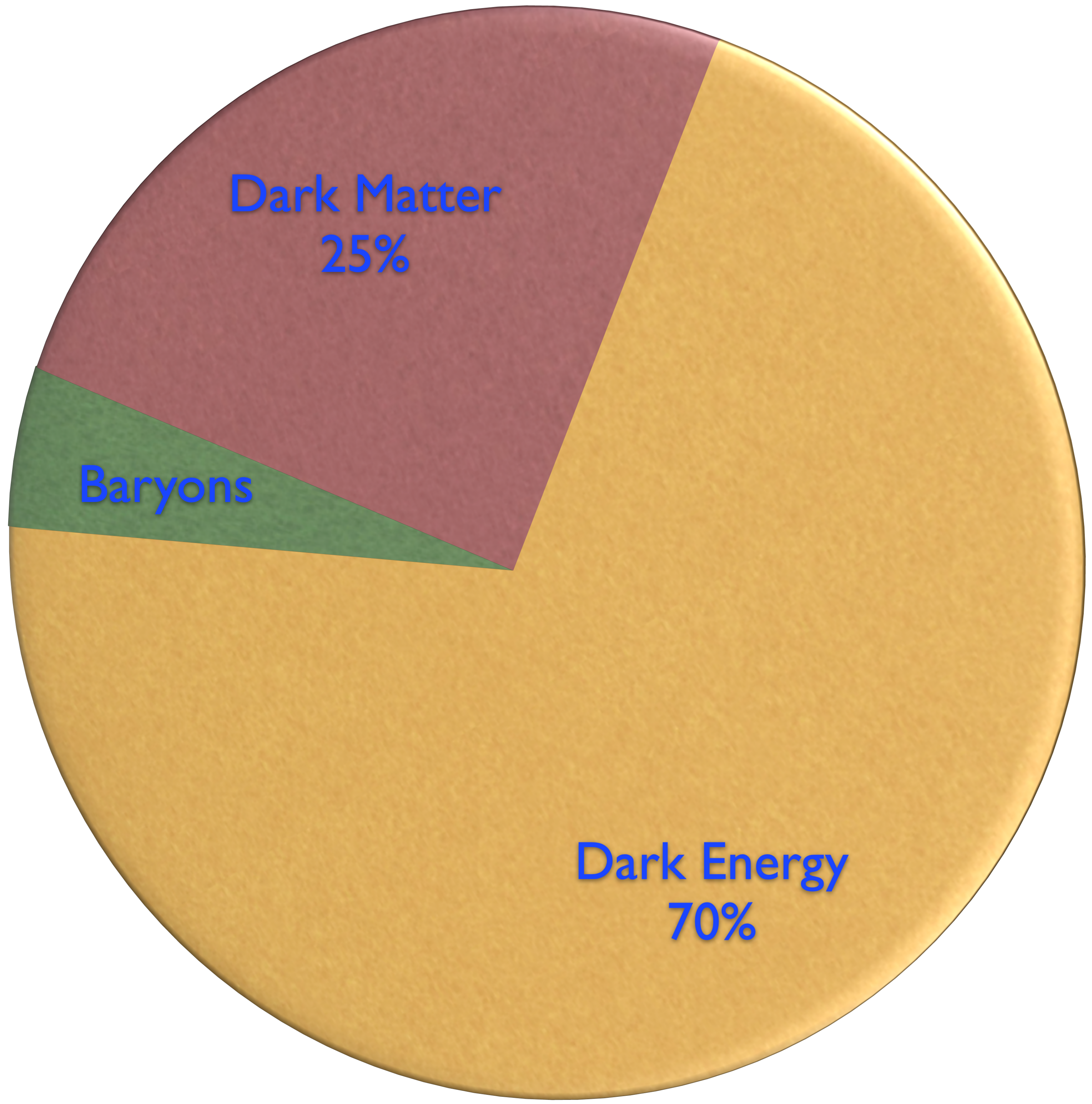
All parameters subject to change. No guarantee expressed nor implied.

Expansion rate	H_0	Hubble constant	72 km/s/Mpc (or 67 or 75)		$H = \frac{\dot{a}}{a}$
mass density	Ω_m		0.3	*total*	$q = -\frac{\ddot{a}a}{\dot{a}^2} = \frac{1}{2}\Omega_m - \Omega_\Lambda$
	Ω_b		0.05	baryons	
	Ω_{CDM}		0.25	cold dark matter (not baryons)	
dark energy	Ω_Λ	cosmological constant	0.7	dark energy	
Large Scale Structure	σ_8	power spectrum	0.8	distribution of mass fluctuations	
	n_s		0.96		

This is how theorists talk about it

ΛCDM Cosmology

- non-baryonic cold dark matter
  - whatever it is (e.g., WIMPs)
- dark energy
  - whatever that even means
- baryons
  - normal matter



We have direct knowledge of < 5% of the mass-energy density of the universe

This is what astronomers observe

Galaxy Evolution

Early Types
(Ellipticals)

Star formation rate

ETG formed most their stars early.

LTGs continue to form stars today.

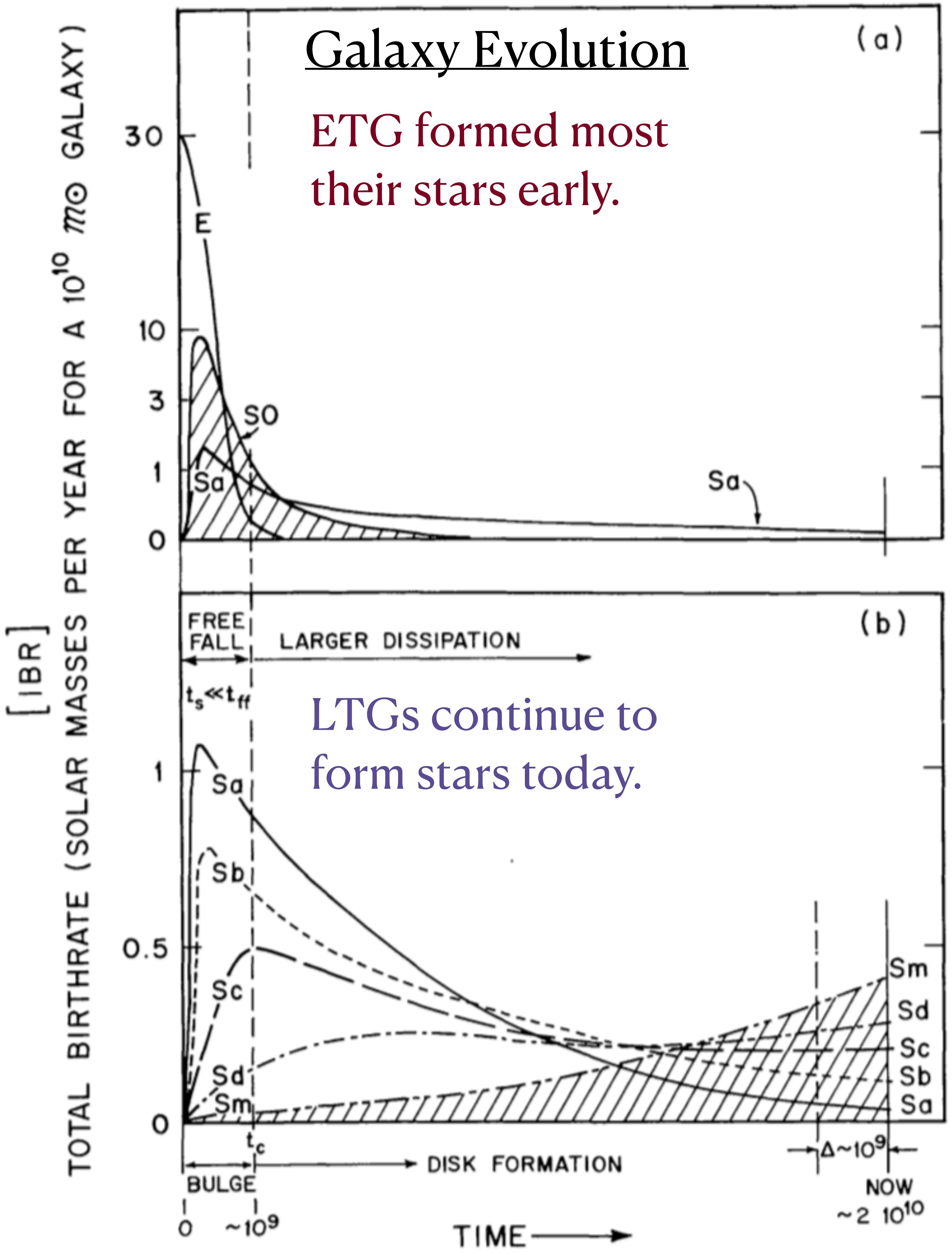
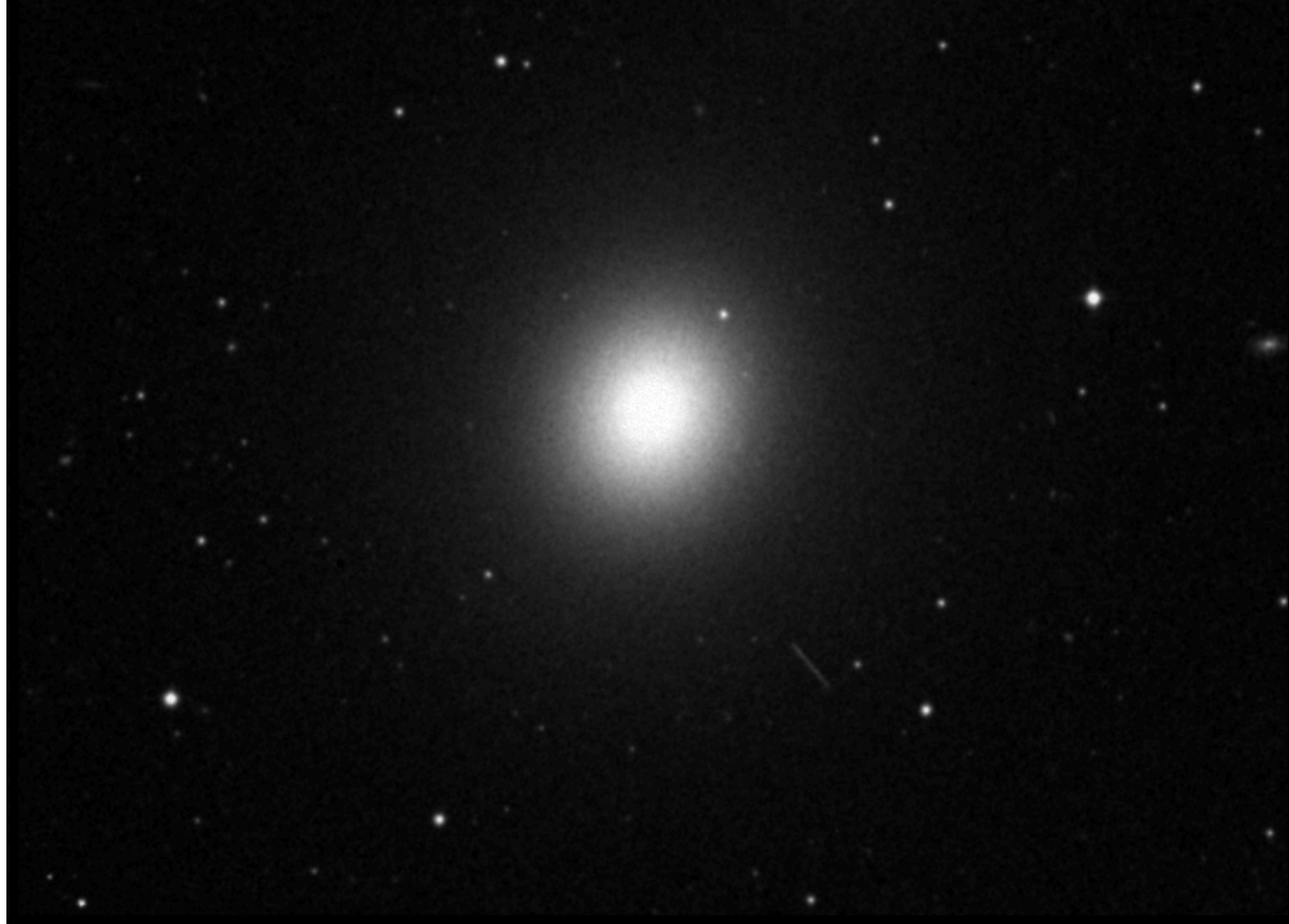
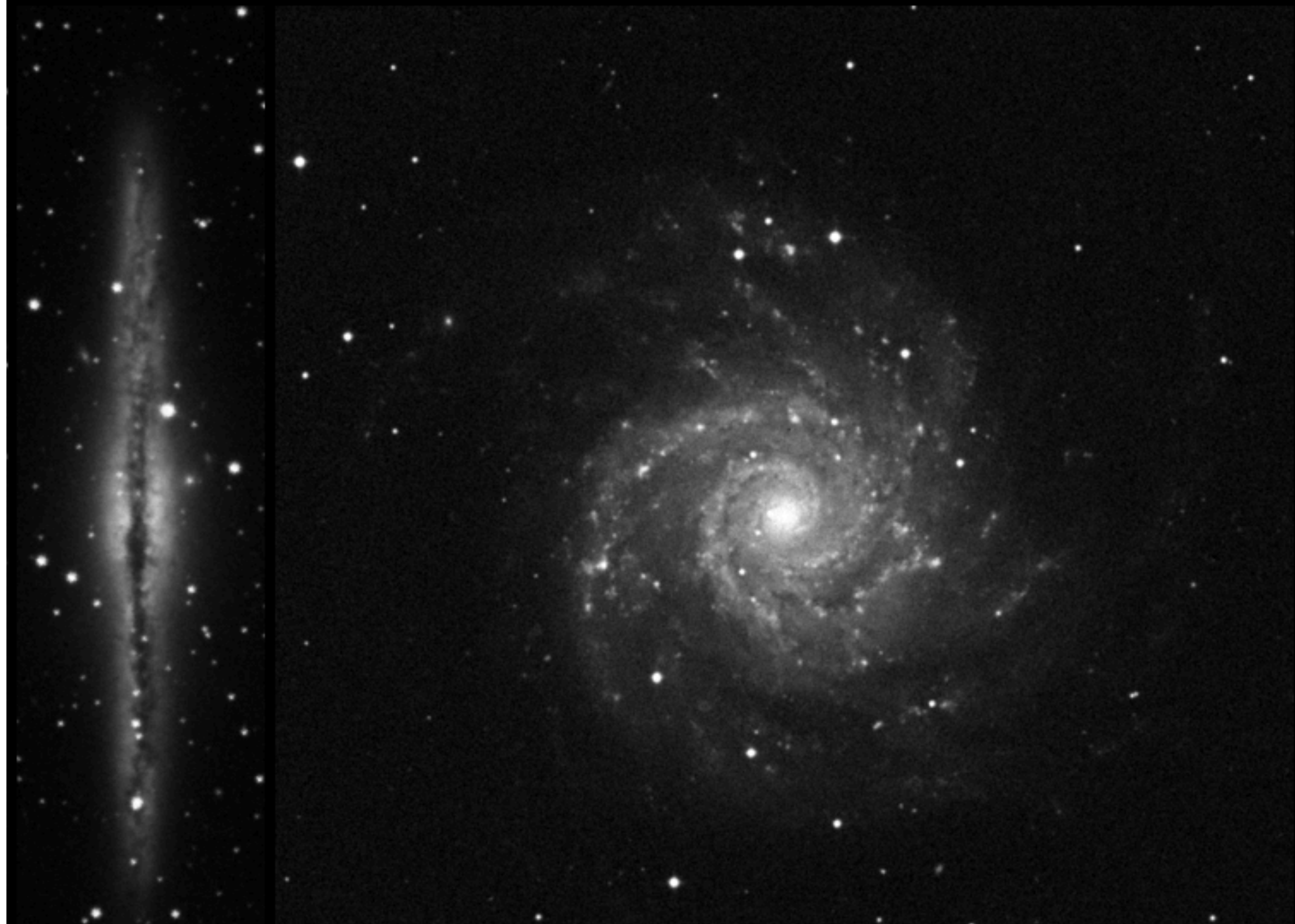


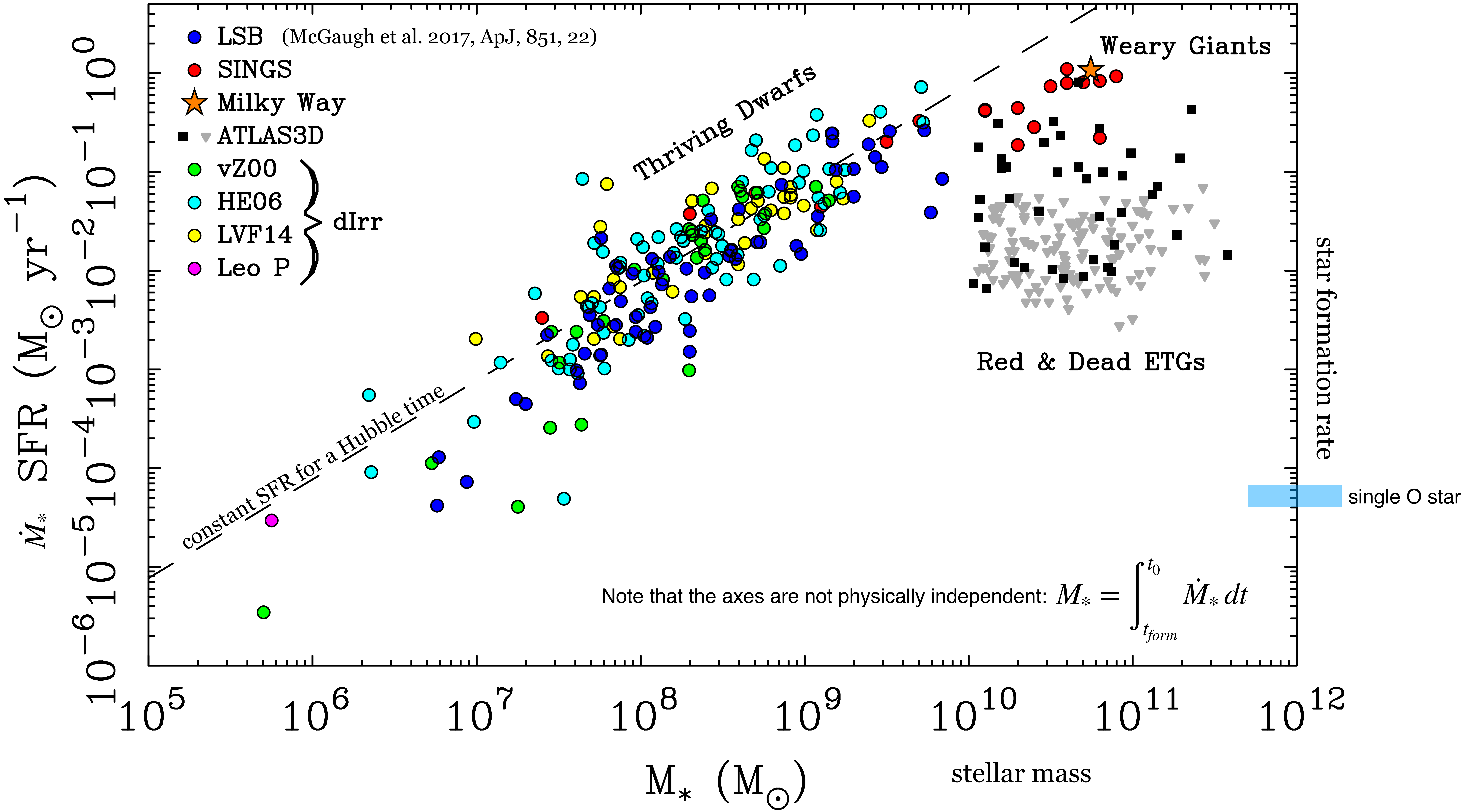
Fig. 10. Same as Fig. 9 with later Hubble types shown in the lower panel. The integral under the Sm curve is shaded for illustration. The curves are only schematic showing the trends that have been established by Gallagher et al. (1984)





Late Types
(Spirals & Irregulars)

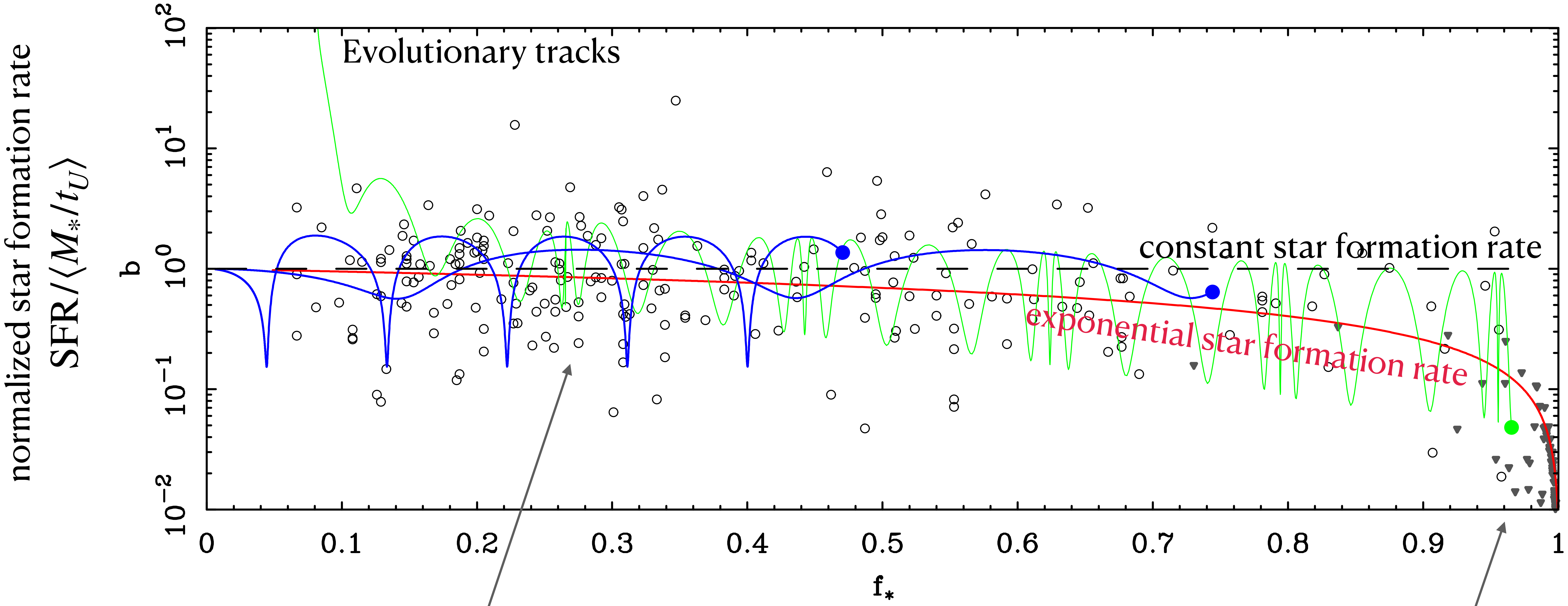
Star formation and Stellar mass - the "star forming main sequence"



Note that the axes are not physically independent: $M_* = \int_{t_{form}}^{t_0} \dot{M}_* \, dt$

Galaxy Evolution

ETGs typically have small $\tau \approx 1$ Gyr;
LTGs typically have longer timescales,
often roughly constant ($\tau \to \infty$).



LTGs still forming stars;
some gas present to do so.

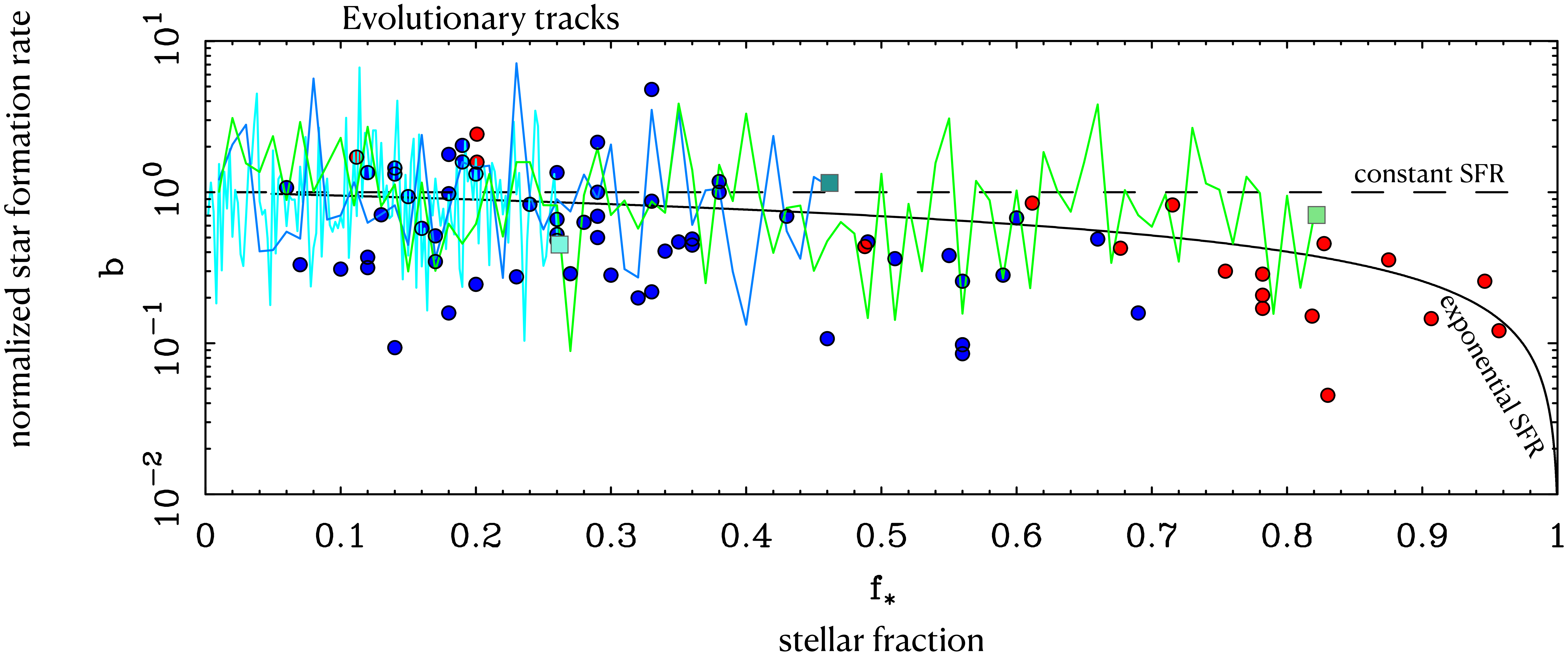
ETGs have converted nearly
all of their gas into stars.

$$b = \frac{\dot{M}_*}{\int_0^t \dot{M}_* \, dt} = \frac{\dot{M}_*}{\langle \dot{M}_* \rangle} \approx \frac{\text{SFR}}{\langle M_*/t_U \rangle}$$

$$f_* = \frac{M_*}{M_* + M_g}$$

Galaxy Evolution

ETGs typically have small $\tau \approx 1$ Gyr;
LTGs typically have longer timescales, often roughly constant but usually with substantial short-term variations.

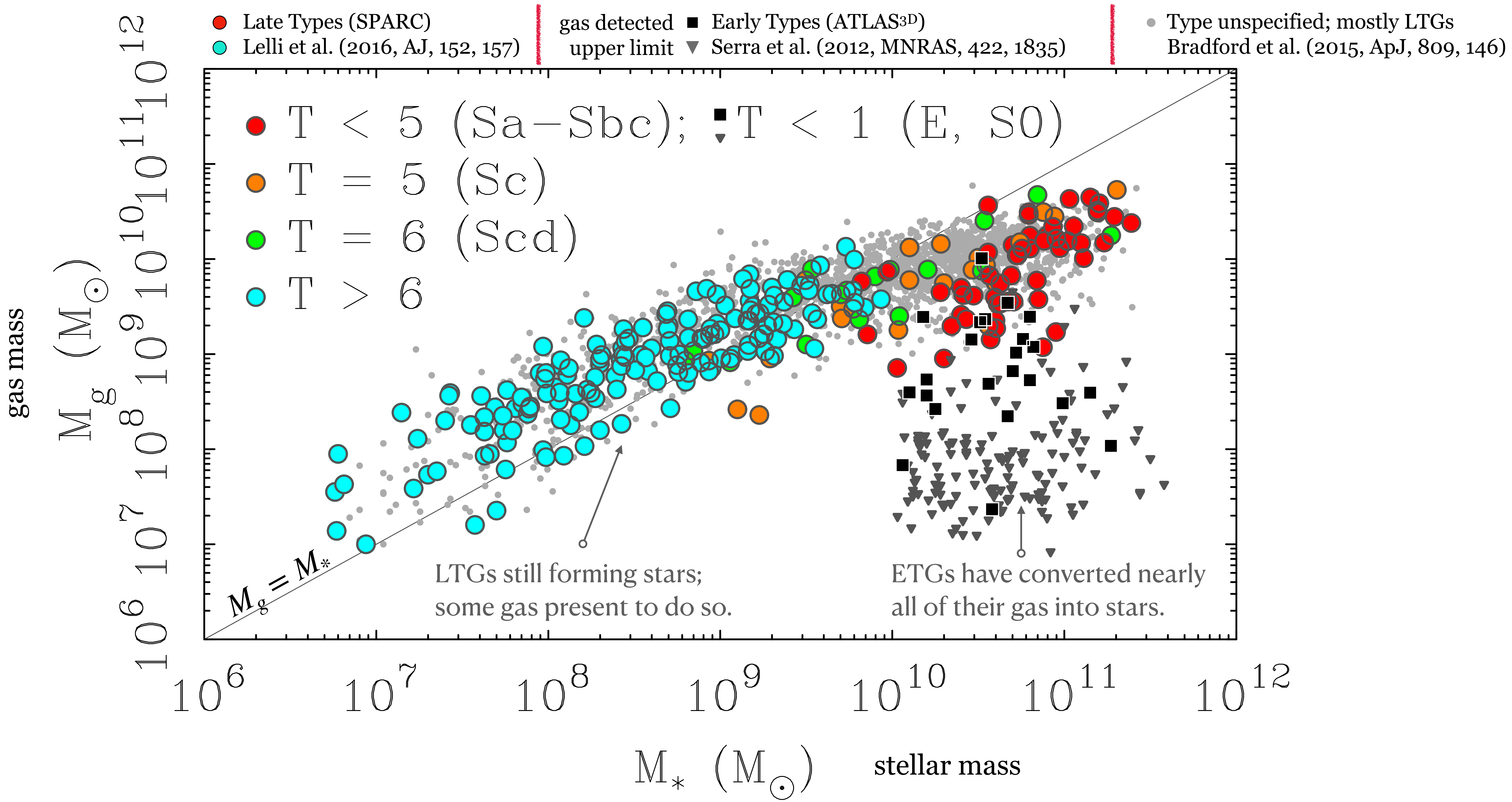


$$b = \frac{\dot{M}_*}{\int_0^t \dot{M}_* \, dt} = \frac{\dot{M}_*}{\langle \dot{M}_* \rangle} \approx \frac{\text{SFR}}{\langle M_*/t_U \rangle}$$

$$f_* = \frac{M_*}{M_* + M_g}$$

Gas mass and Stellar mass

morphologically similar to the star forming main sequence

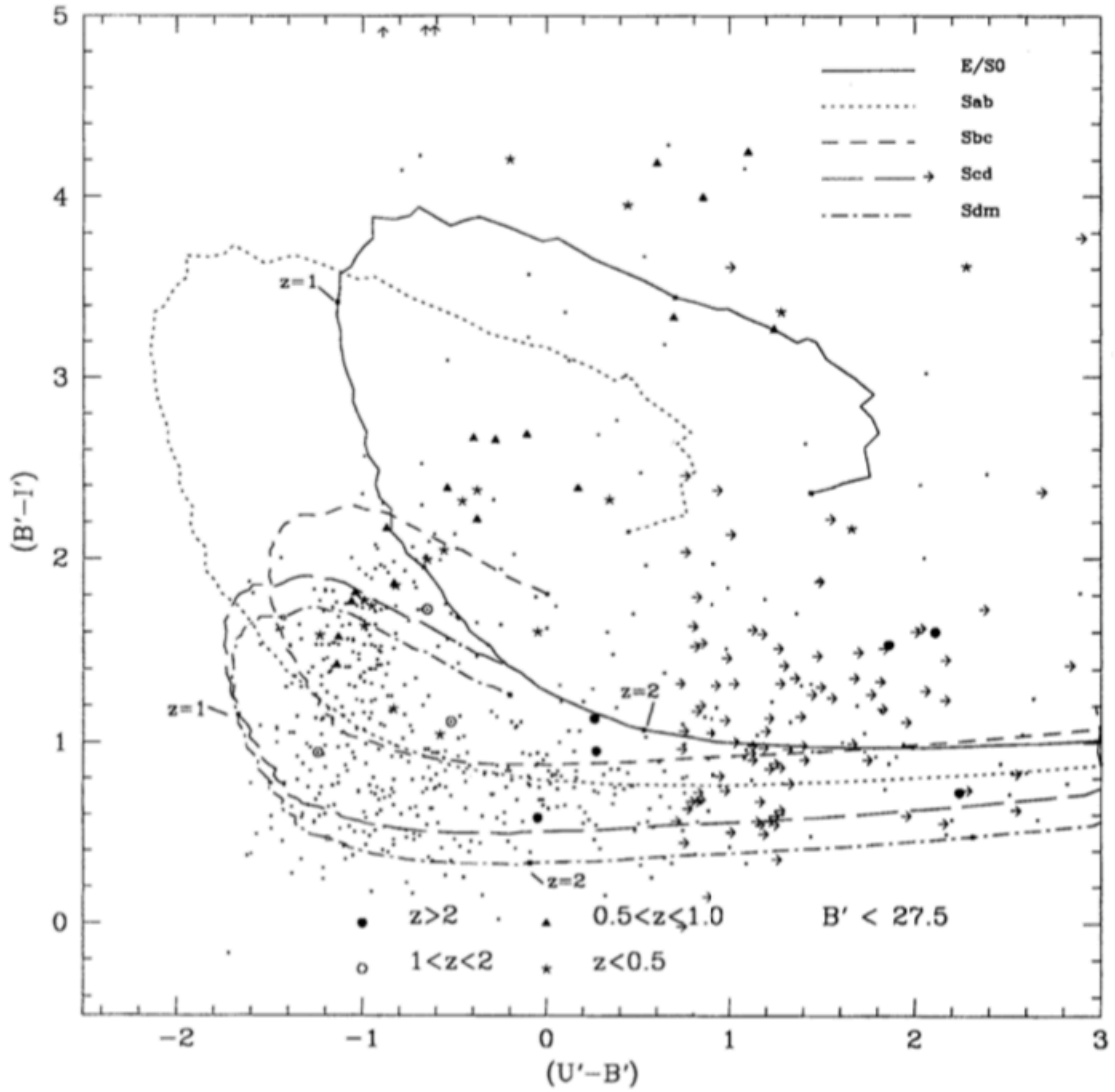


Galaxy tracks with redshift

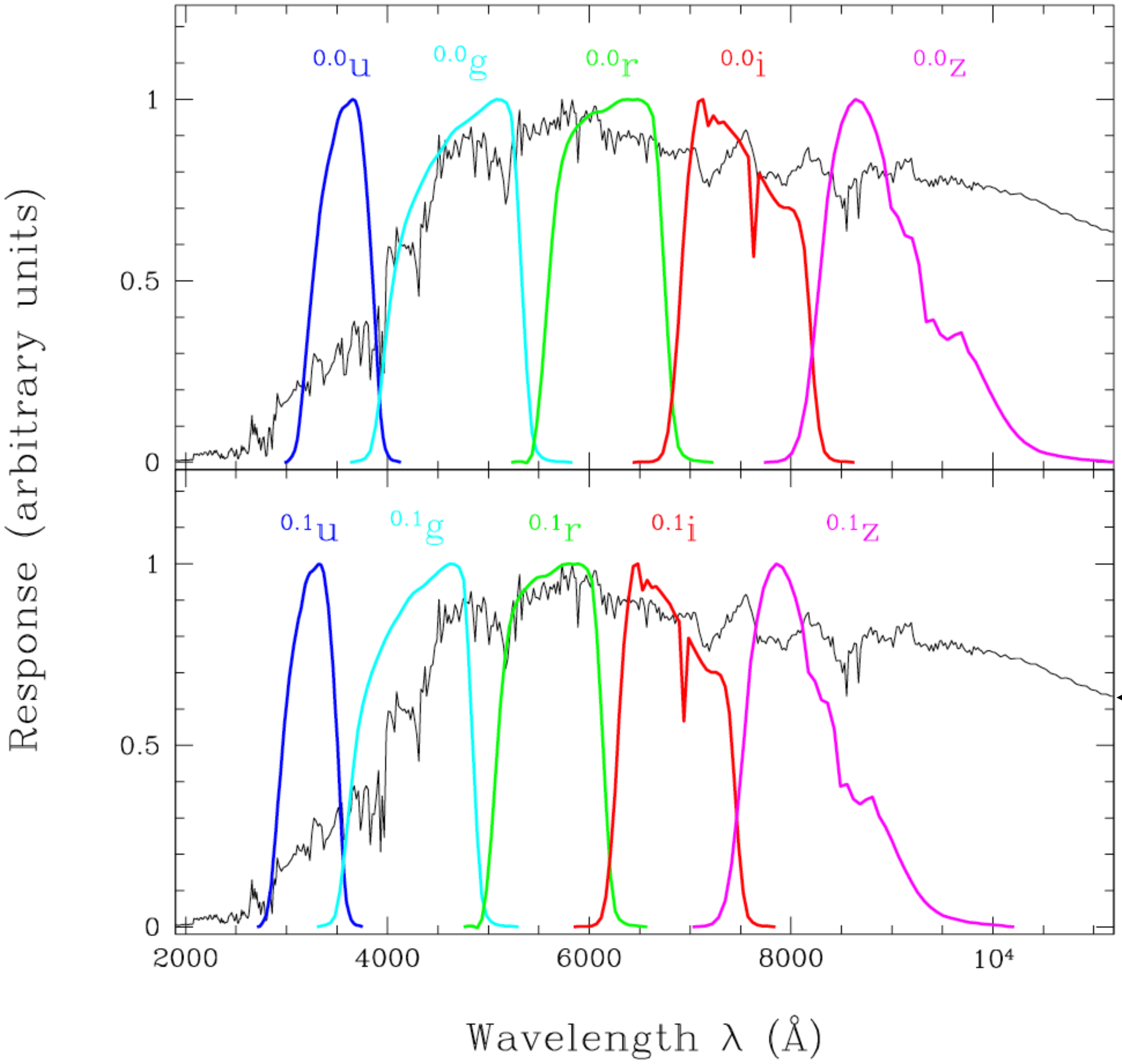
Metcalfe et al. (1996)

FIG. 3 Dots represent the $U' - B' : B' - I'$ colours of galaxies with $B' < 27.5$ mag in the Hubble Deep Field. Primed letters for magnitudes indicate that here we are using the natural HST magnitude system, with the zero point set at an A0V star. The arrows represent detection upper limits, mainly galaxies which are undetected in U'. The $U' - B'$ colours move sharply redwards at $B' - I' \approx 0.8$ due to the Lyman-α forest/Lyman break passing through the U' band. The predicted tracks are the $q_0 = 0.05$ evolutionary models for each morphological type as detailed in Fig. 1 legend, modulated in the case of Sbc/Scd/Sdm types by our assumed internal dust absorption of $A'_U = 0.45$ mag, $A'_B = 0.3$ mag, $A'_I = 0.11$ mag and in the case of all galaxies by the Lyman-α forest absorption. The models used in the $q_0 = 0.5$ case (not shown) show a very similar behaviour, even for the rapidly fading dE type. The $z = 1$ and $z = 2$ labelled positions on the tracks indicate the colours of model E/SO and Sdm galaxies at these redshifts. The remaining symbols show the colours of 45 brighter galaxies with Keck spectroscopic redshifts, and these agree well with the predicted colours for these galaxies. It can also be seen that $U' - B' < 0$ is predicted to correspond to galaxies with $z < 2$, and $U' - B' > 0$ to galaxies with $z > 2$.

Color-color plot with redshifted galaxy tracks



K-corrections



SDSS filters at z=0

K-corrections are necessary to account for the cosmological shifting of a source's spectrum through fixed observational filter bands.

SDSS filters at z=0.1

spectrum of galaxy model

Blanton et al. (2002)

Fig. 2.— Demonstration of the differences between the unshifted SDSS filter system (0.0u , 0.0g , 0.0r , 0.0i , 0.0z) in the top panel and the SDSS filter system shifted by 0. 1 (0.1u , 0.1g , 0.1r , 0.1i , 0.1z) in the bottom panel. Shown for comparison is a 4 Gyr-old instantaneous burst population from an update of the Bruzual A. & Charlot (1993) stellar population synthesis models. The K -corrections between the magnitudes of a galaxy in the unshifted SDSS system observed at redshift z = 0. 1 and the magnitudes of that galaxy in the 0. 1-shifted SDSS system observed at redshift z = 0 are independent of the galaxy's spectral energy distribution (and for AB magnitudes are equal to − 2. 5 log10 (1 + 0. 1) for all bands; Blanton et al. 2002a). This independence on spectral type makes the 0. 1-shifted system a more appropriate system in which to express SDSS results, for which the median redshift is near redshift z = 0. 1.

K-corrections

A correction to the magnitude of an object to account for redshifting of its spectrum.

K-correction

$$K(z,T) = -2.5\log\left[(1+z)\frac{\int_{\lambda_1}^{\lambda_2} S(\lambda) f(\lambda, T)\, d\lambda}{\int_{\lambda_1}^{\lambda_2} S(\lambda) f(\lambda(1+z), T)\, d\lambda}\right]$$

spectral stretching

filter transmission window

change of spectrum through filter window

In passband i

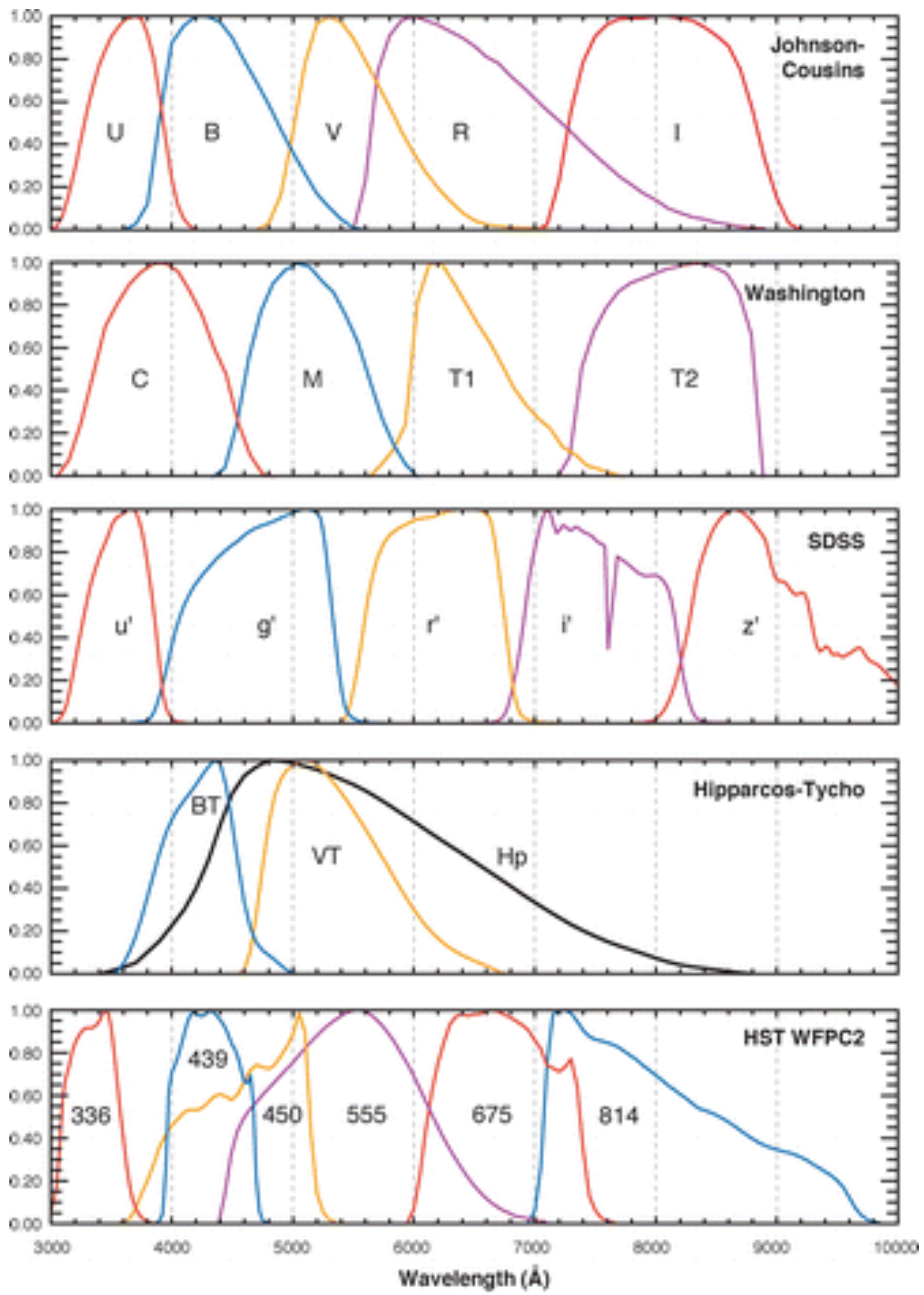
luminosity distance

$$m_i - M_i = 5\log\left(\frac{D_L}{10\ \mathrm{pc}}\right) + A_i + K_i$$

K-correction

distance modulus

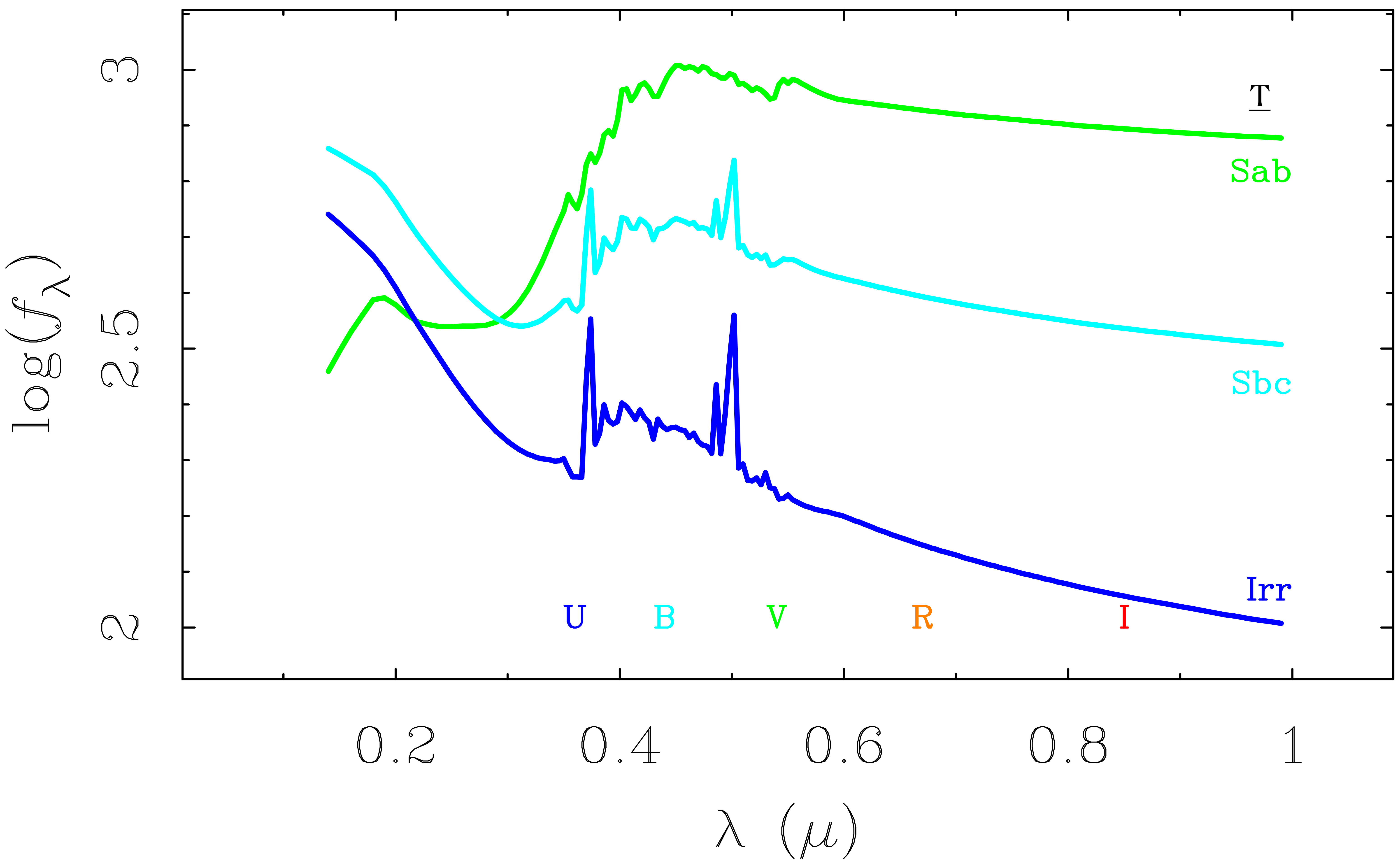
extinction



Bessell, MS. 2005
Annu. Rev. Astron. Astrophys. 43: 293–336

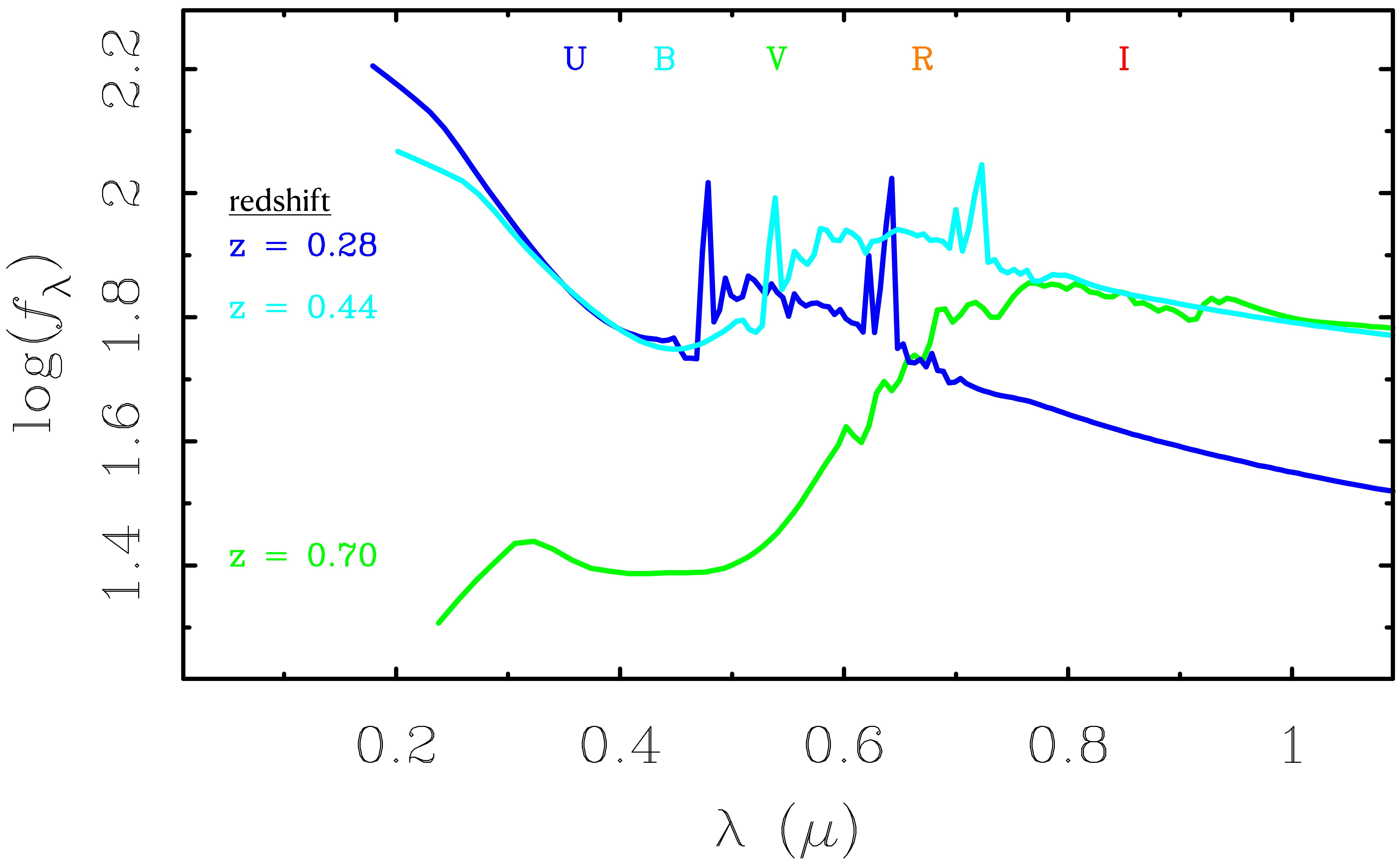
K-corrections

$f(\lambda, T)$



K-corrections

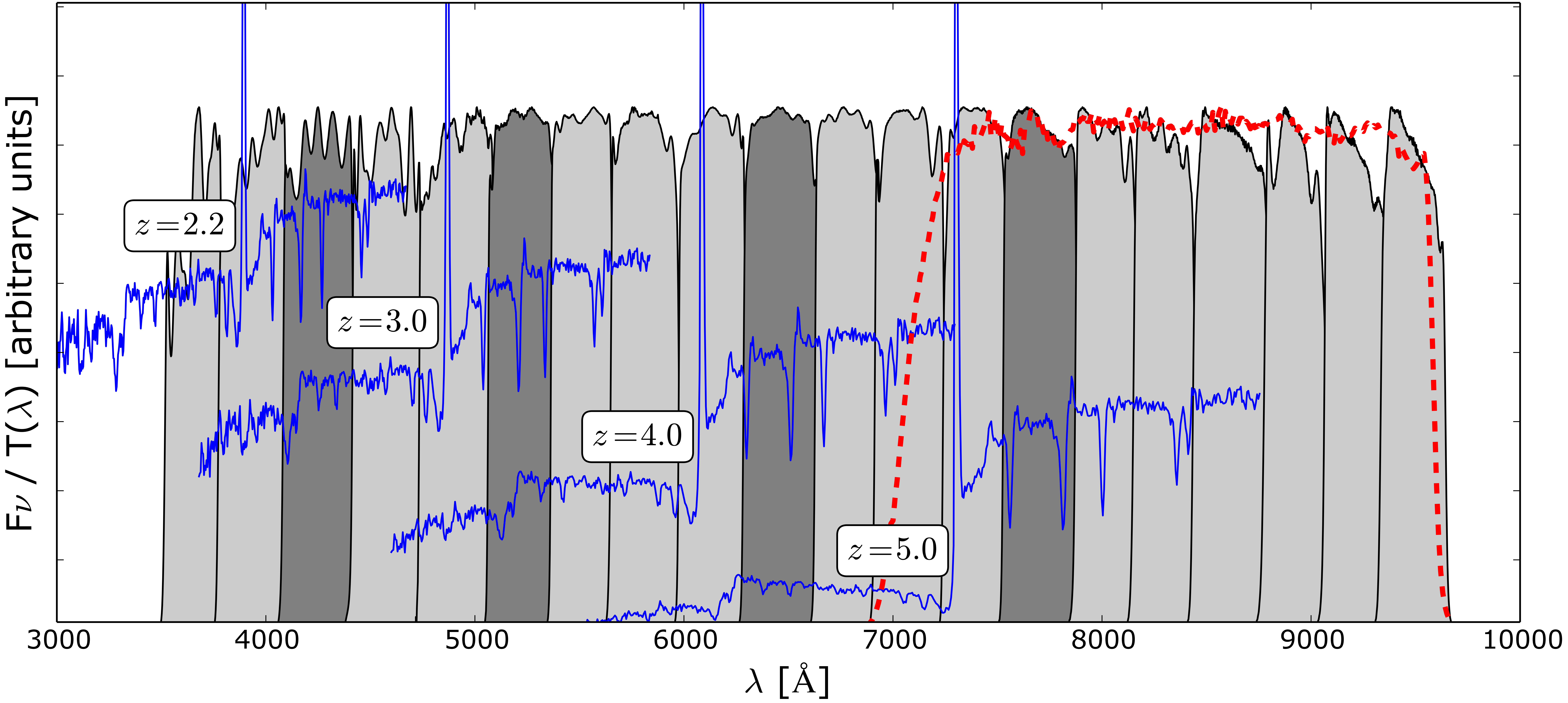
Cosmic expansion causes the source spectrum to shift and stretch.

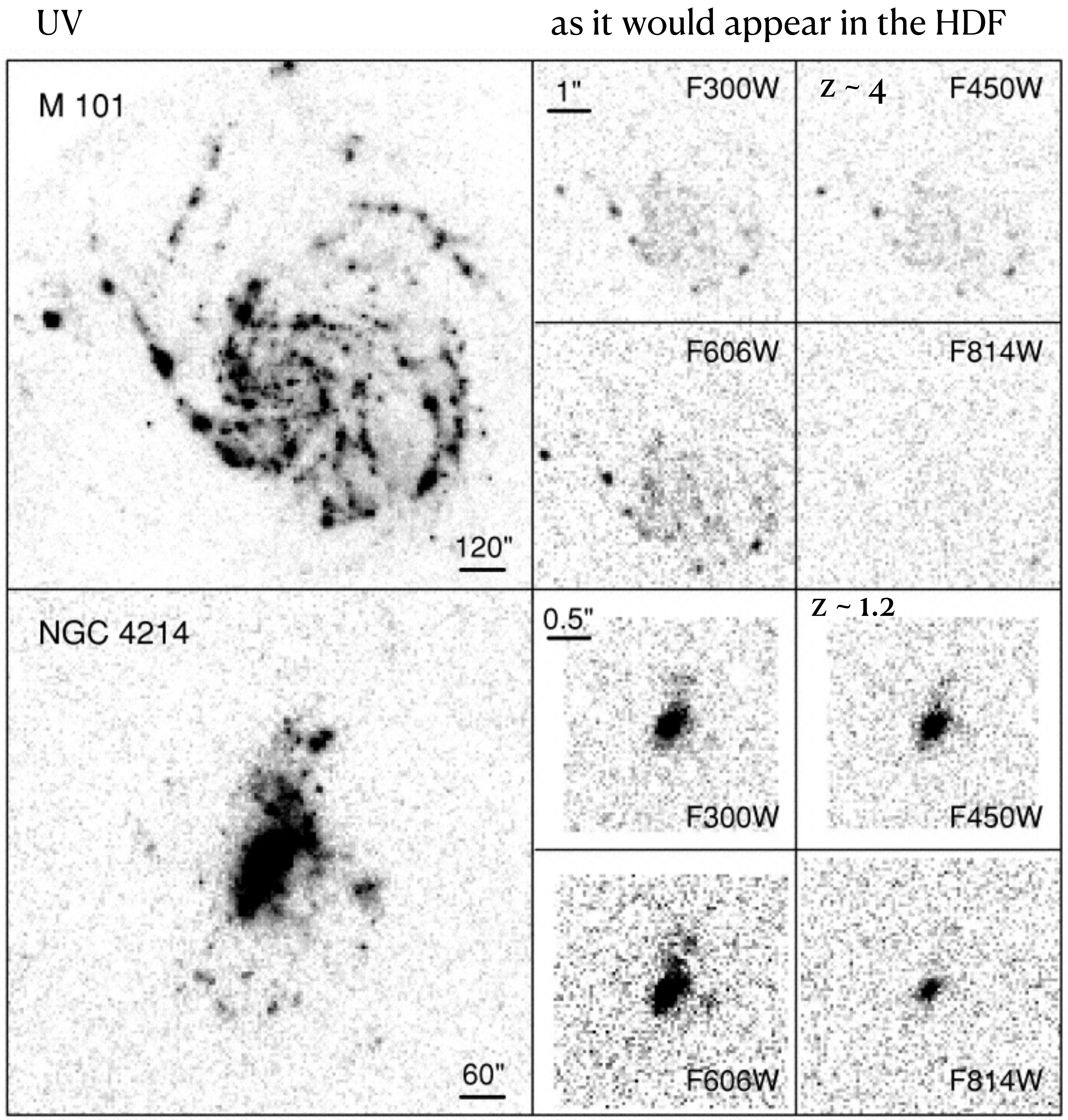


Any given filter provides a fixed window on the moving target of a redshifted spectrum. We observe a bluer part of the spectrum than that which was emitted in the rest frame of the filter.

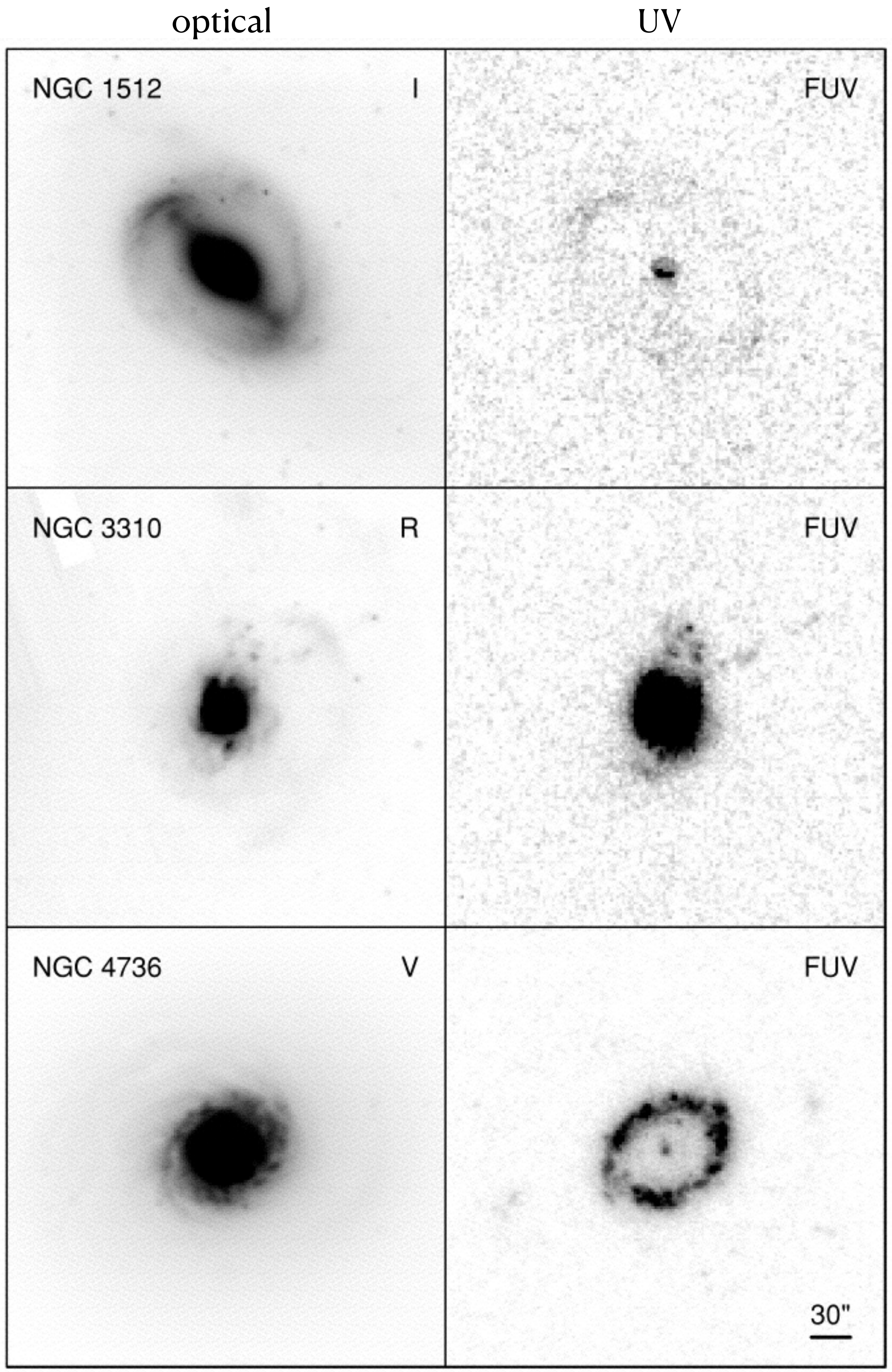
K-corrections

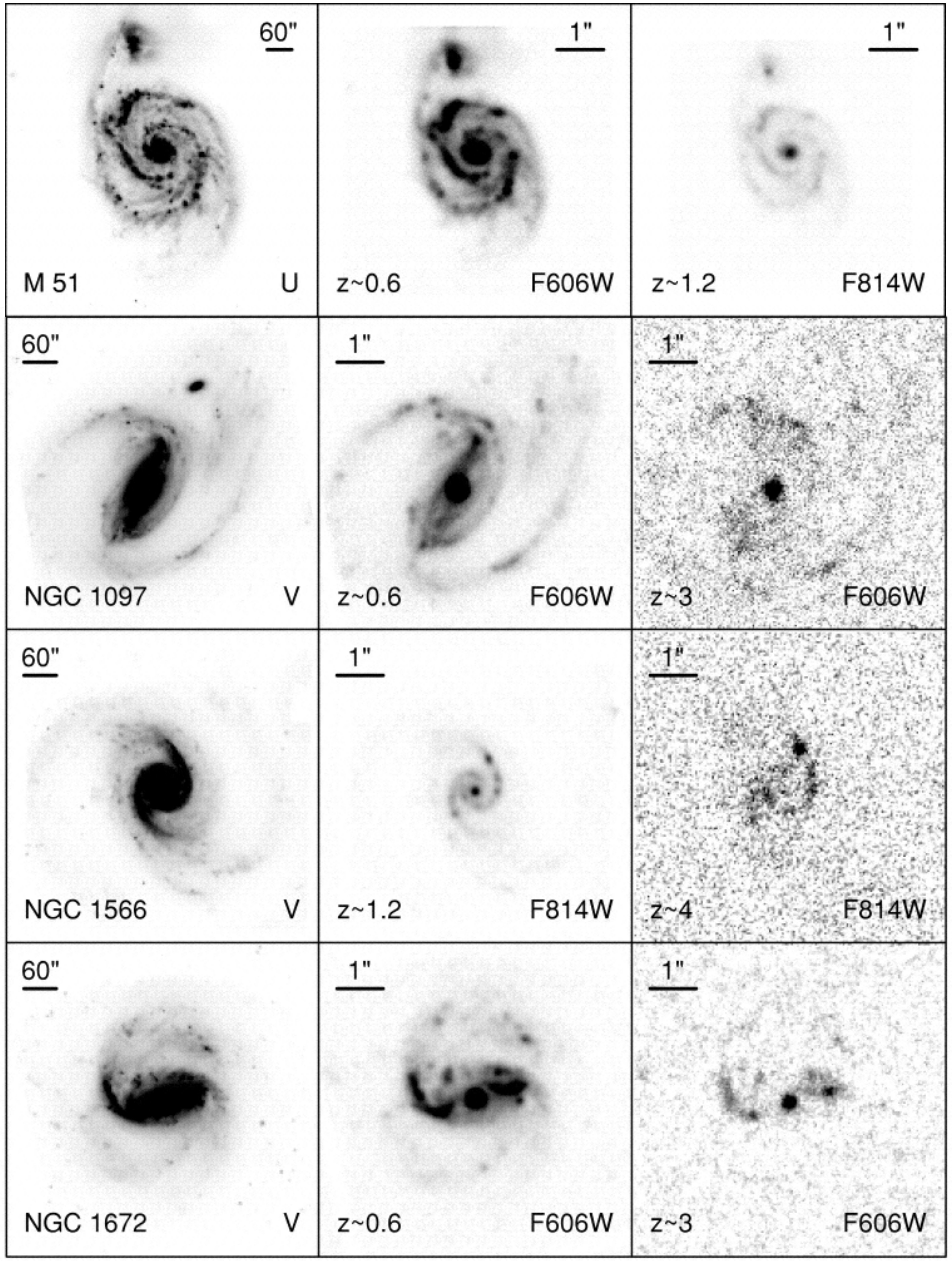
Lots and lots of filters minimizes the assumptions in $f(\lambda, T)$





Kuchinski etal AJ 122 729

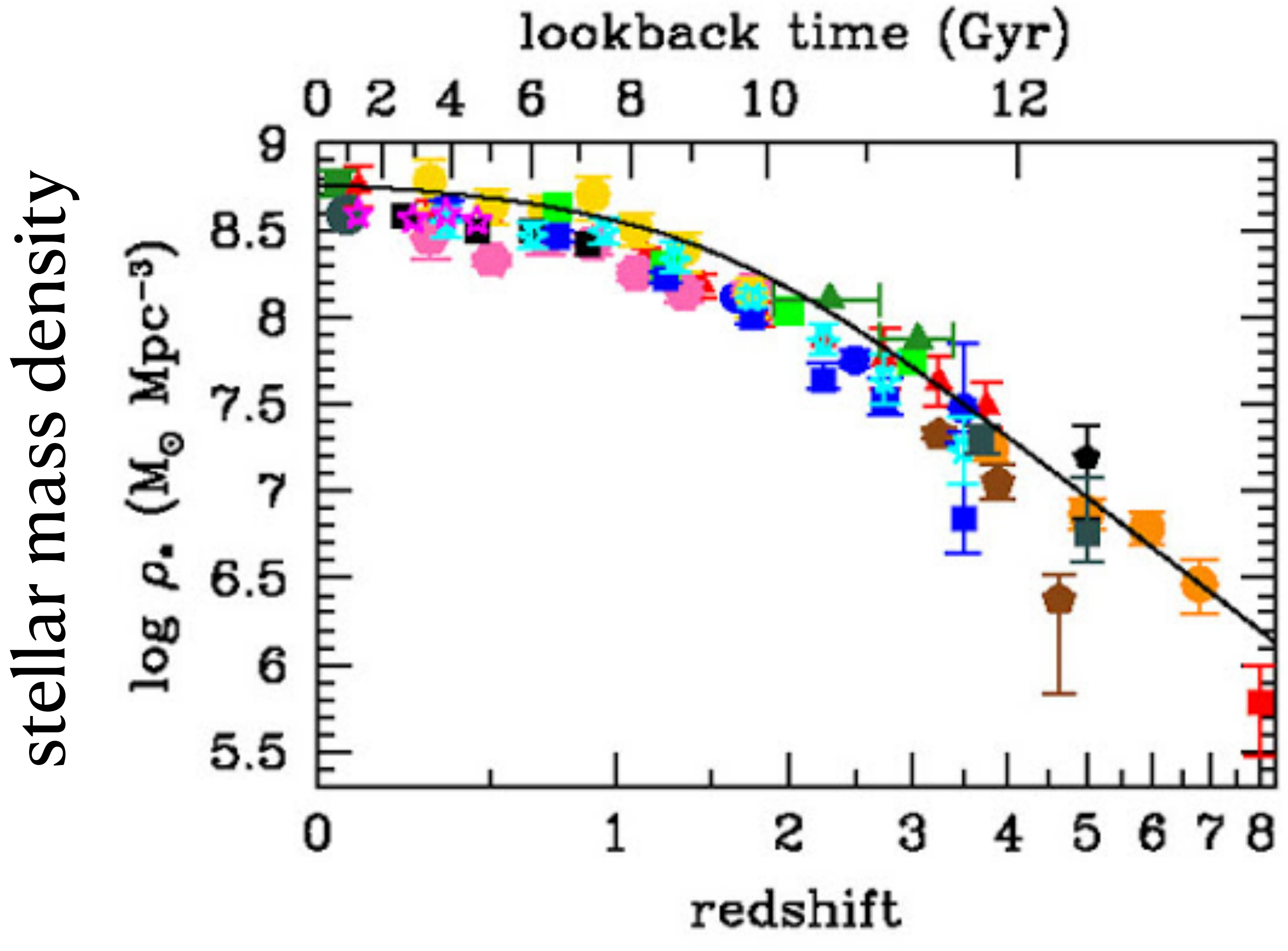


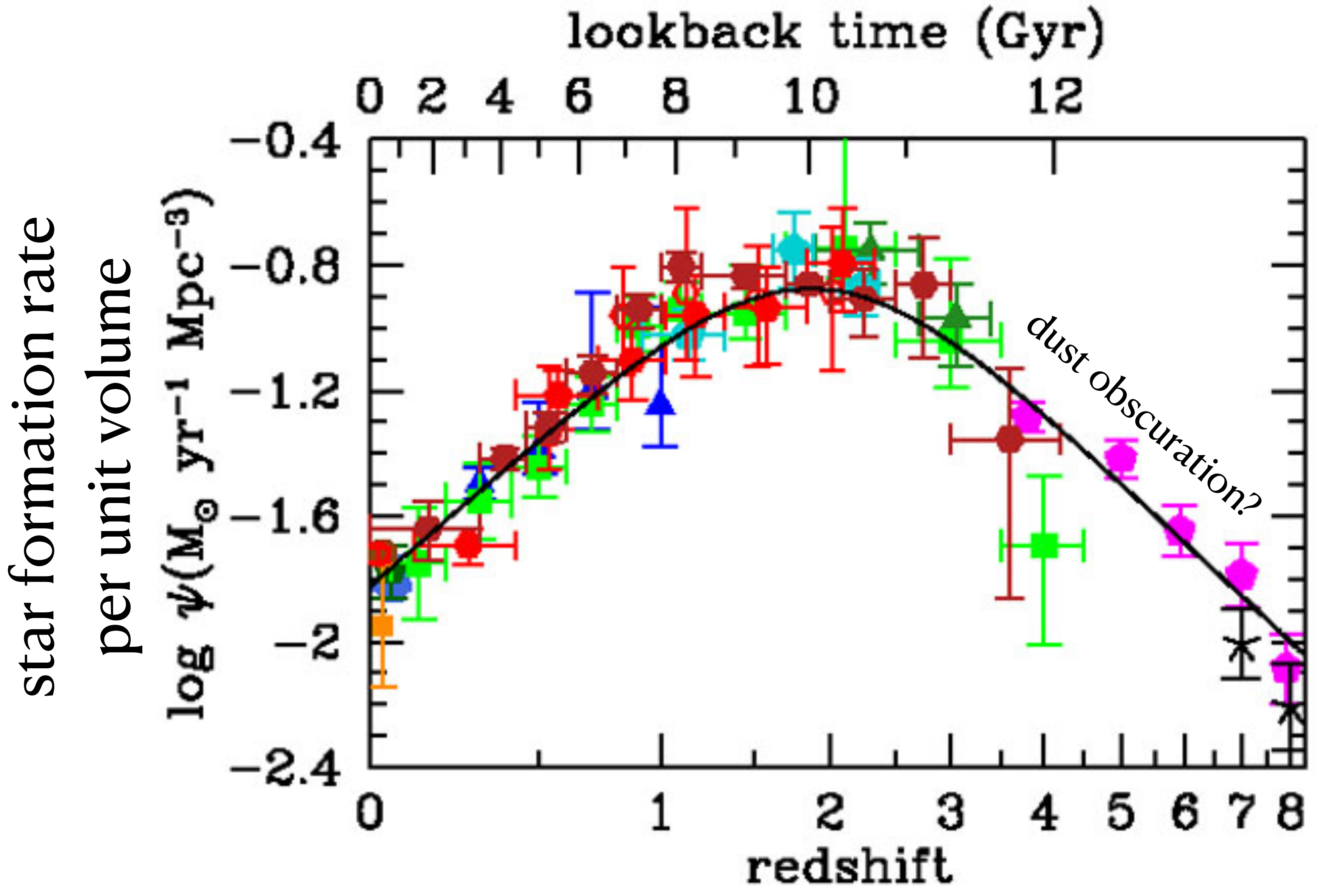


Kuchinski etal AJ 122 729

Integrated stellar mass and star formation rate densities

$$\rho_* = \int_0^t \psi dt'$$





The mass density in stars is small: about 7% of the BBN baryon density

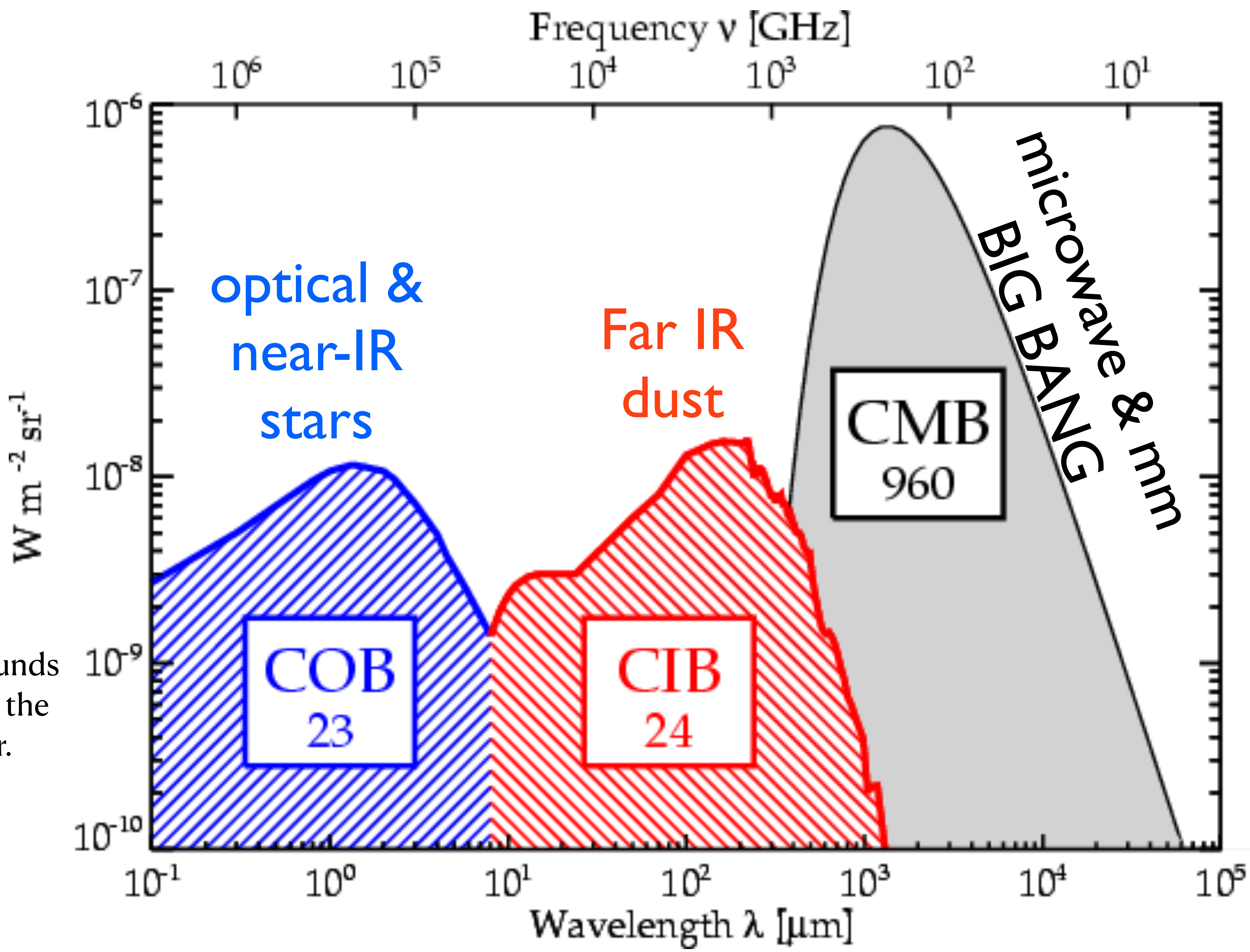
$$\Omega_{*_0} \approx 0.0035$$

The cosmic star formation rate peaked early, around $z \approx 2$ (about 10 Gyr ago).

The star formation rate at high redshift is highly uncertain due to extinction corrections.

Cosmic background radiation: photon energy at all wavelengths over the whole sky

Optical & IR backgrounds is all the light from all the stars and quasars ever.



Twenty times more energy in the CMB than in all the stars added together.

Dust emission is mostly reprocessed starlight: the radiation field warms the interstellar dust, which reradiates in the IR