5. The local Universe I

- Schneider
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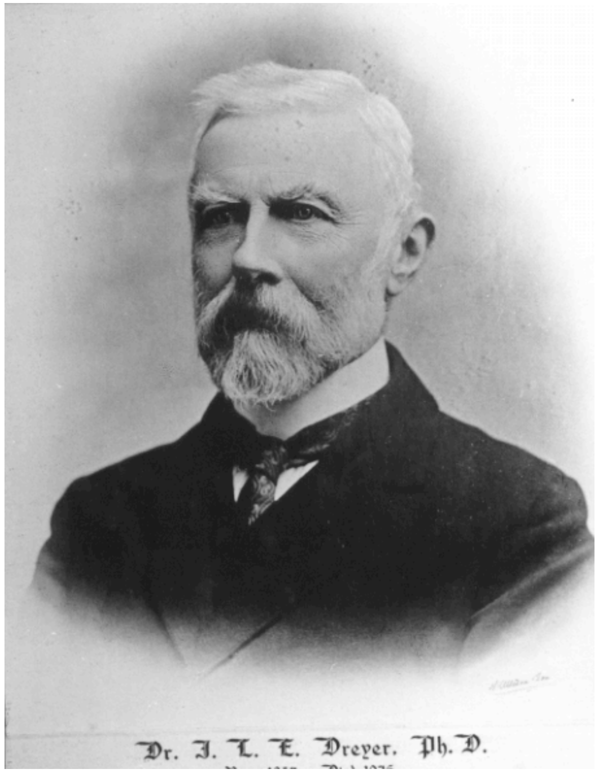
Section 3: Introduction: some history

First galaxy catalogues



Messier (1730-1817) compiled his "*Catalogue des Nébuleuses et des Amas d'Étoiles*" ("Catalogue of Nebulae and Star Clusters"). It contained 103 objects, among which M31

John Dreyer's (1852-1926) contribution was the monumental *New General Catalogue of Nebulae and Clusters of Stars.* It contained nearly 8000 objects

1920: *Great debate* on the nature of galaxies between Slipher and in Curtis.
Are the nebulae in or outside our galaxy?

Vesto Melvin Slipher (1875 - 1969) demonstrated that galaxies rotate

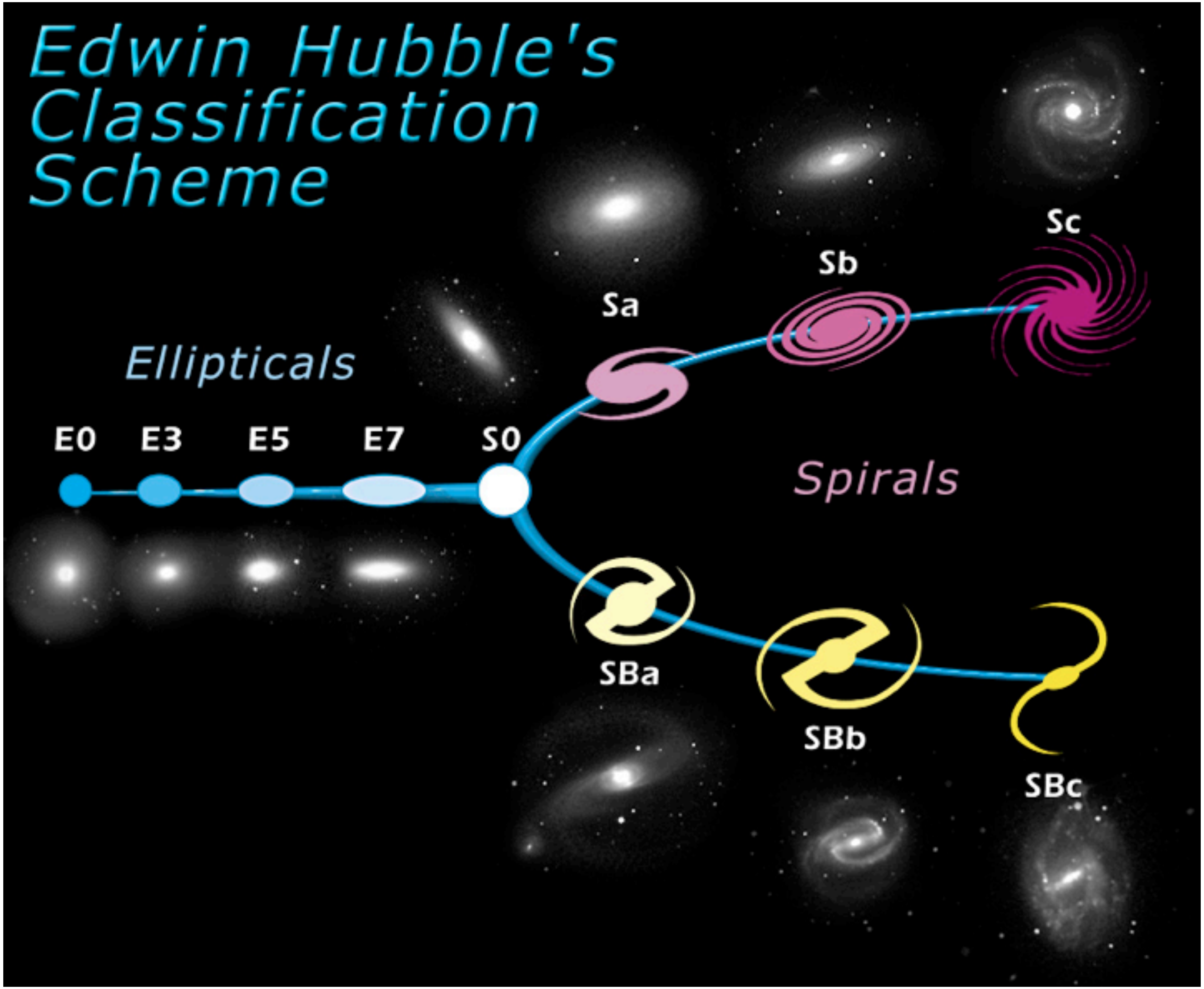
Edwin Hubble

1925:

Period luminosity relation for Cepheids in andromeda:

M31 at a distance of 285 kpc (factor 3 too small)

Section 3.1 Classification

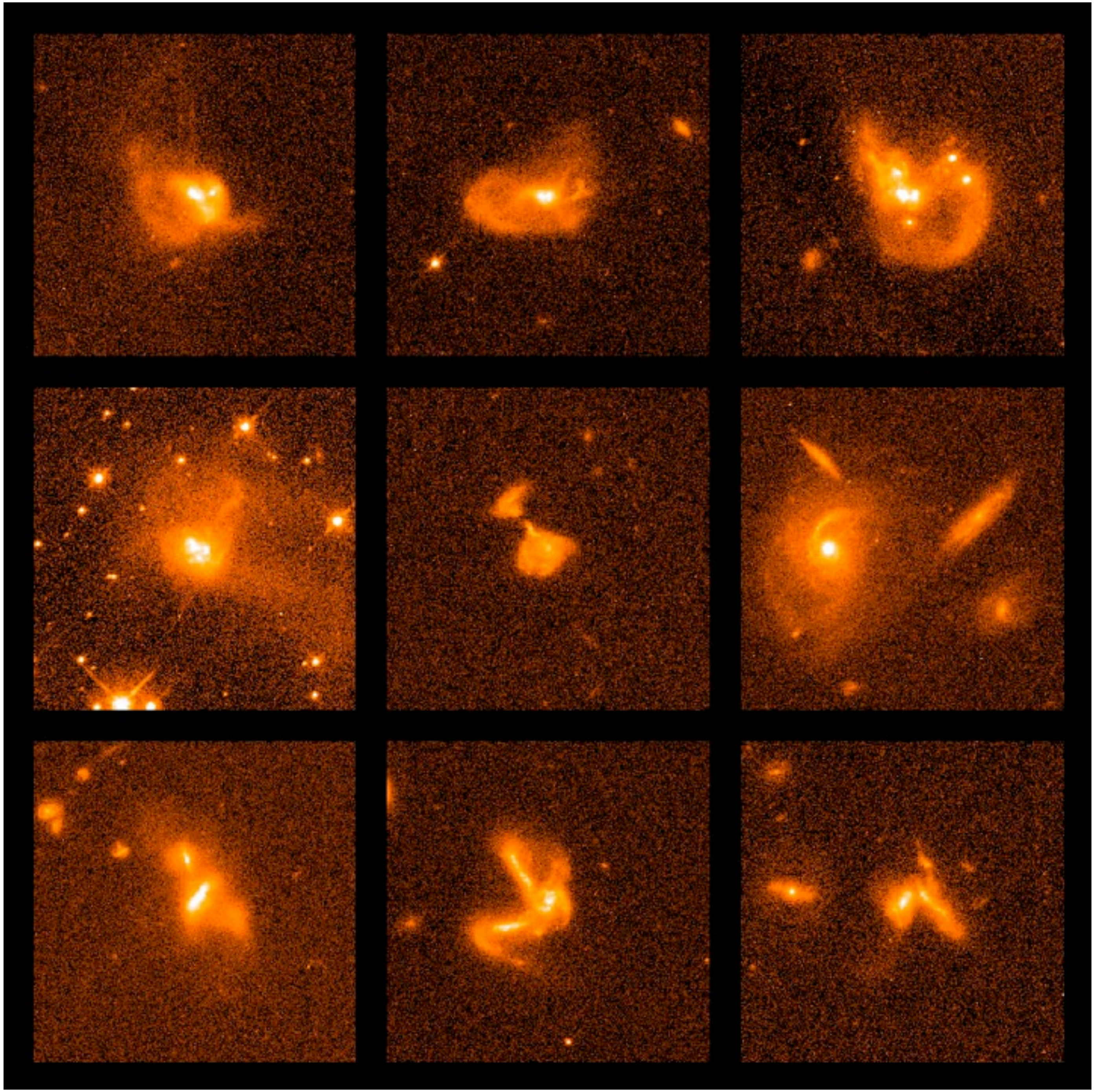

Edwin Hubble's
Classification
Scheme
Ellipticals
E0
E3
E5
E7
S0
Sa
Sb
Sc
Spirals
SBa
SBb
SBc

LMC - Irr I

M82 - Irr II

The S0 or lenticular galaxy NGC 3115

3.1.2 Other Types of Galaxies



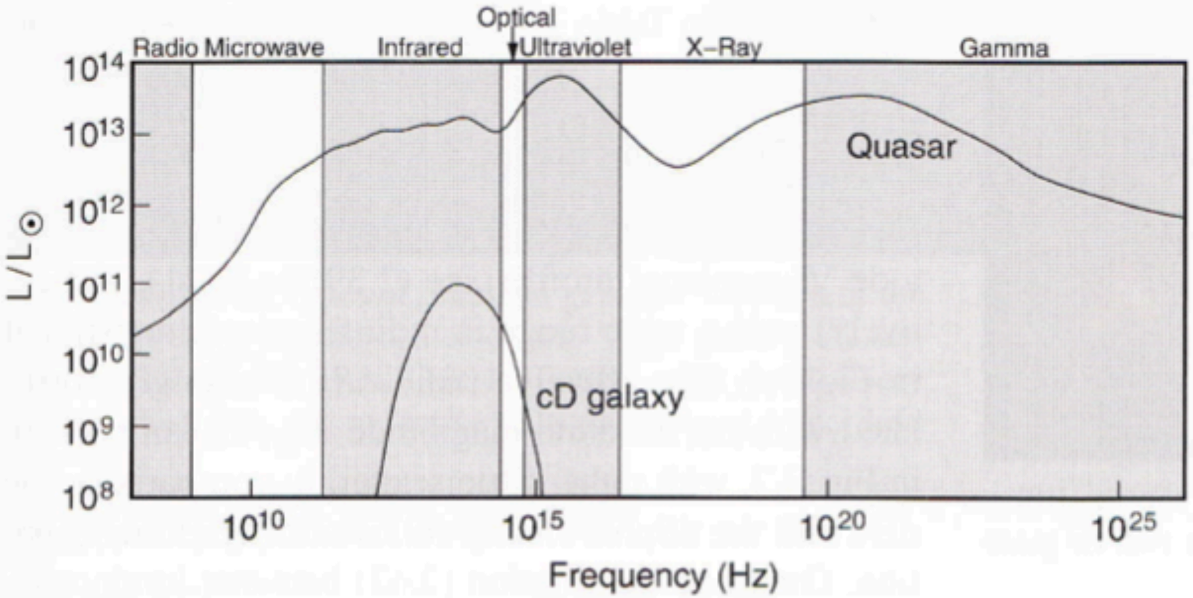


Fig. 3.3. The spectrum of a quasar (3C273) in comparison to that of an elliptical galaxy. While the radiation from the elliptical is concentrated in a narrow range spanning less than two decades in frequency, the emission from the quasar is observed over the full range of the electromagnetic spectrum, and the energy per logarithmic frequency interval is roughly constant. This demonstrates that the light from the quasar cannot be interpreted as a superposition of stellar spectra, but instead has to be generated by completely different sources and by different radiation mechanisms

– Section 3.2.1-3.2.3 Elliptical galaxies

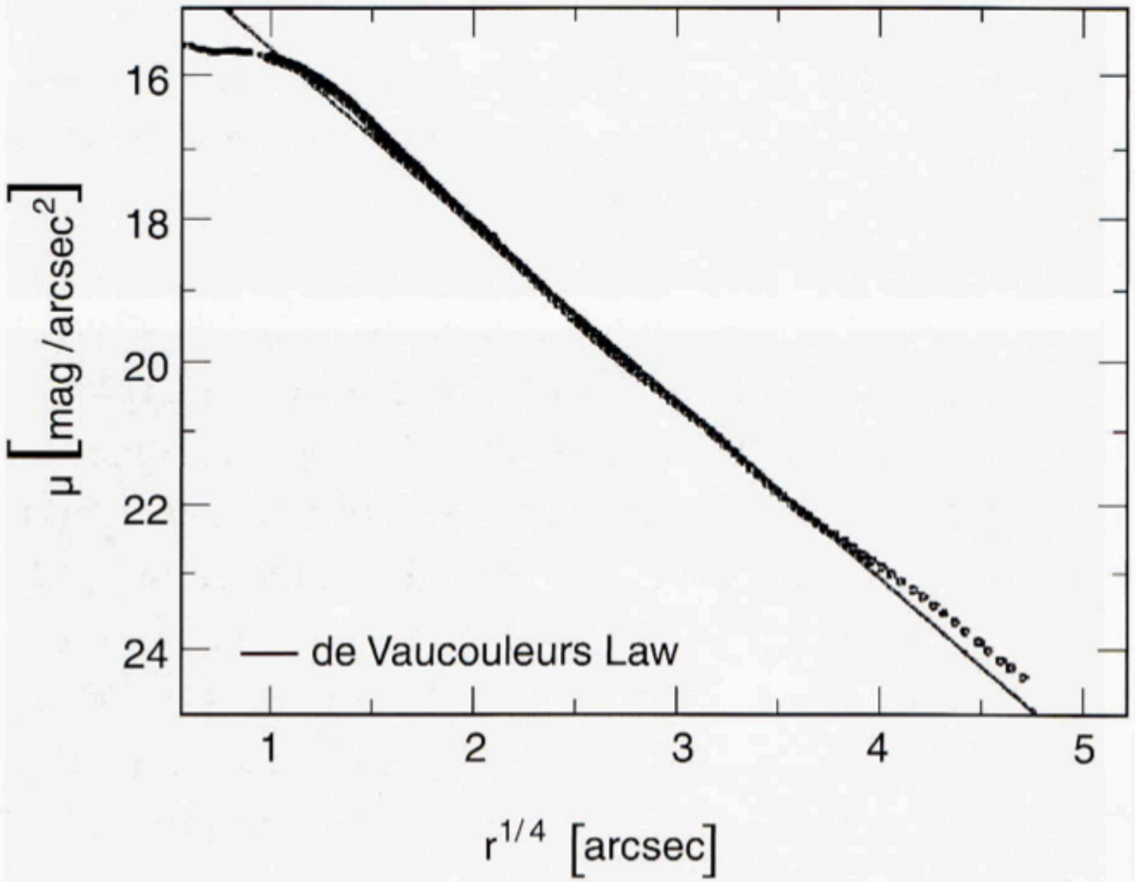
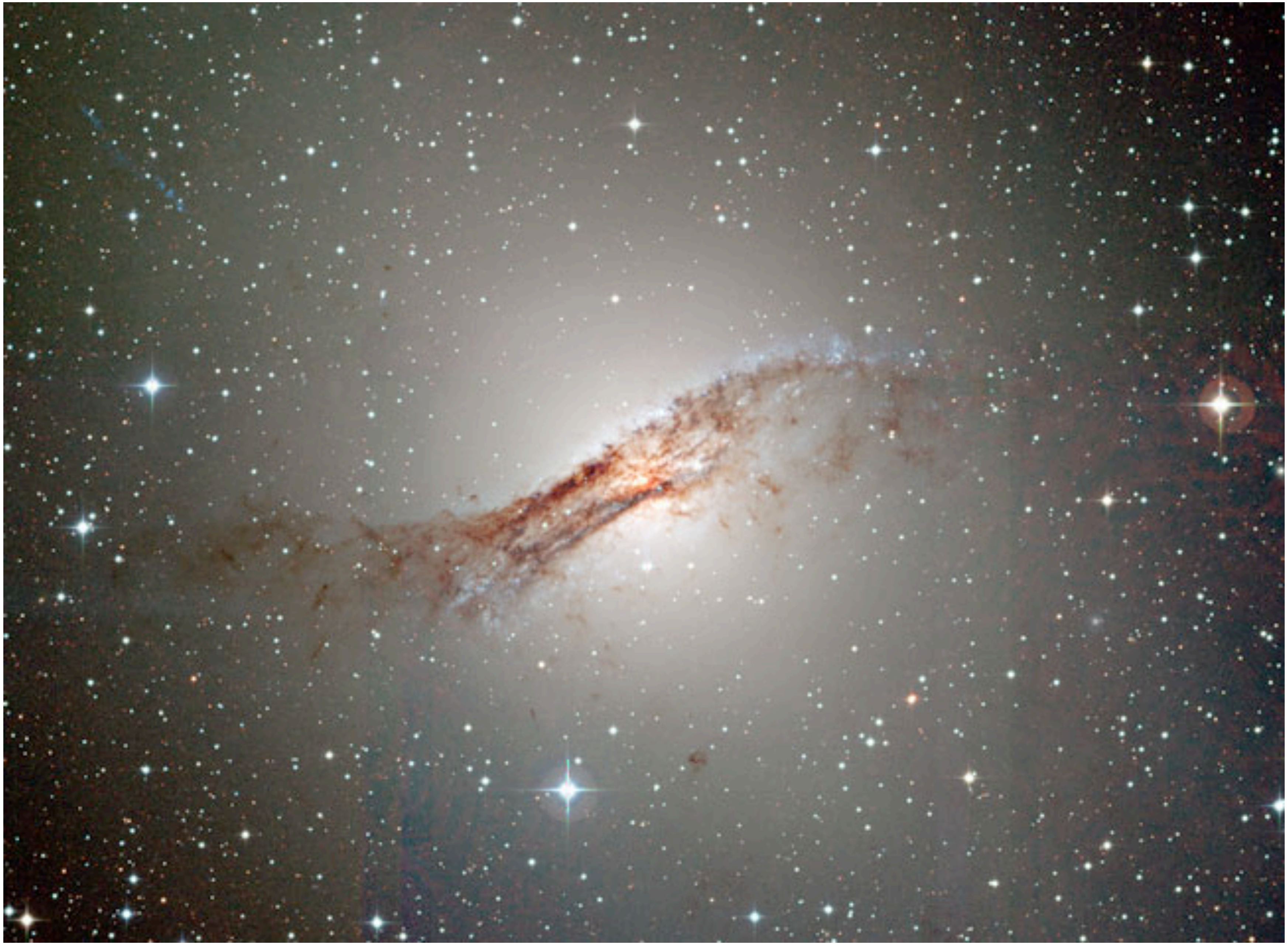
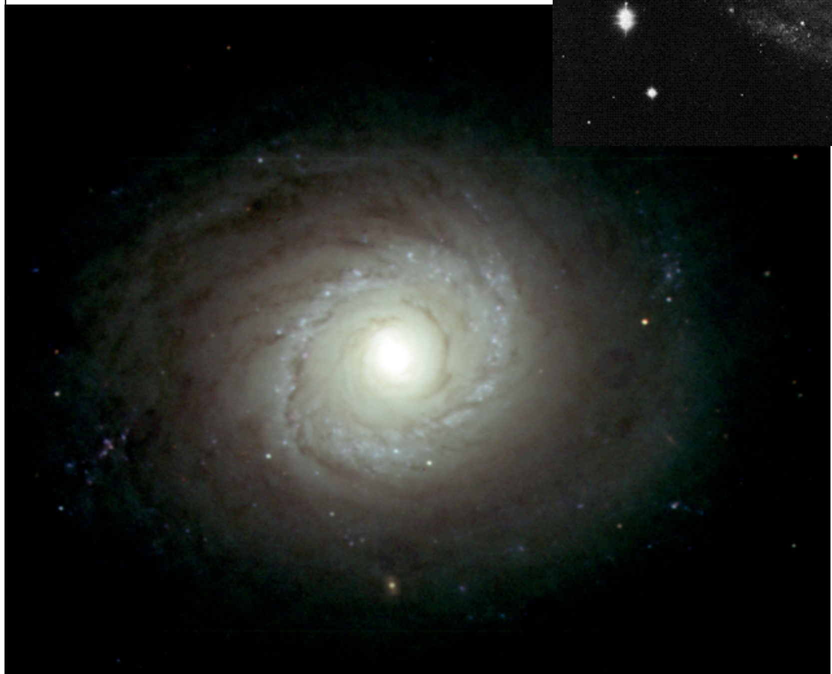
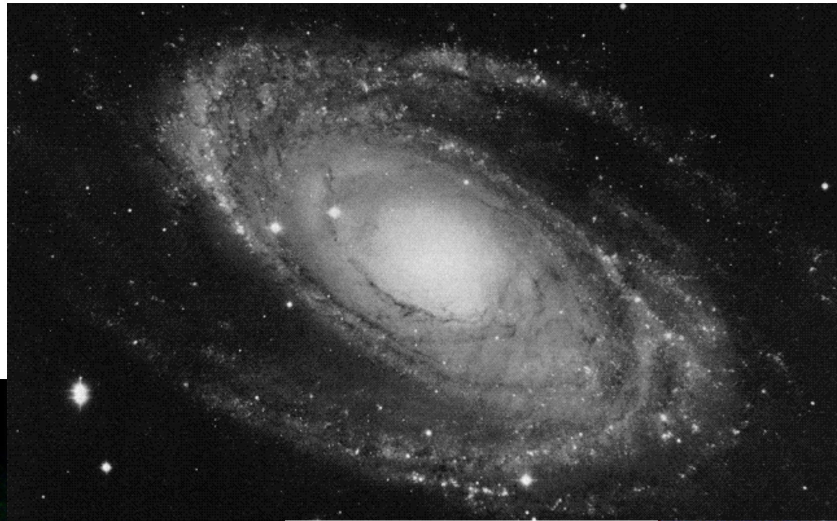


Fig. 3.6. Surface brightness profile of the galaxy NGC 4472, fitted by a de Vaucouleurs profile. The de Vaucouleurs profile describes a linear relation between the logarithm of the intensity (i.e., linear on a magnitude scale) and $r^{1/4}$; for this reason, it is also called an $r^{1/4}$-law

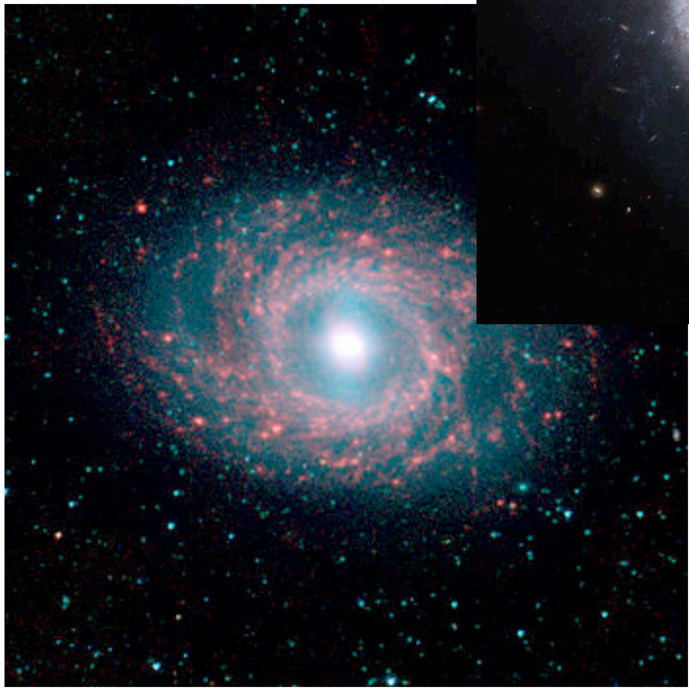


– Section 3.3 Spiral galaxies





M94 - Sa　　　M81 - Sb　　　M101 - Sc



M95 - SBa NGC 1300 - SBb NGC 7741 - SBc

Brightness profile spiral galaxies

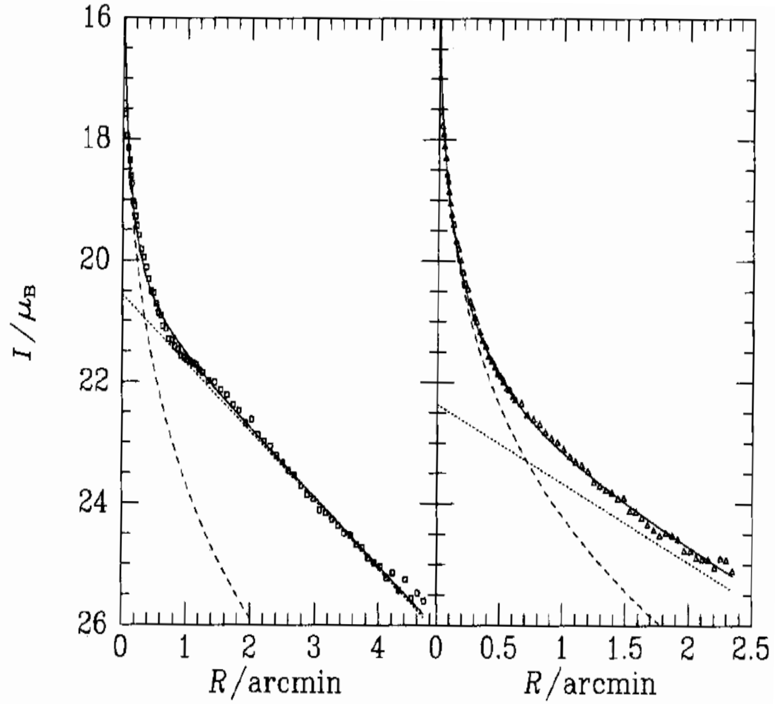


Figure 4.48 Fits to the surface-brightness profiles of NGC 2841 (left) and NGC 3898 (right). The dotted curves show the exponential fits to the disks and the dashed curves show the $R^{1/4}$ fits to the bulges; the full curves show the sums of these components. [From data published in Boroson (1981)]

In general, the brightness profile of spirals galaxies can be modelled as the sum of

(i) an exponential disk for the outer regions

$I(R) = I_0 \exp(-R/R_d)$, where R_d is the disk scale-length.

(ii) an $r^{1/4}$ law to the bulge

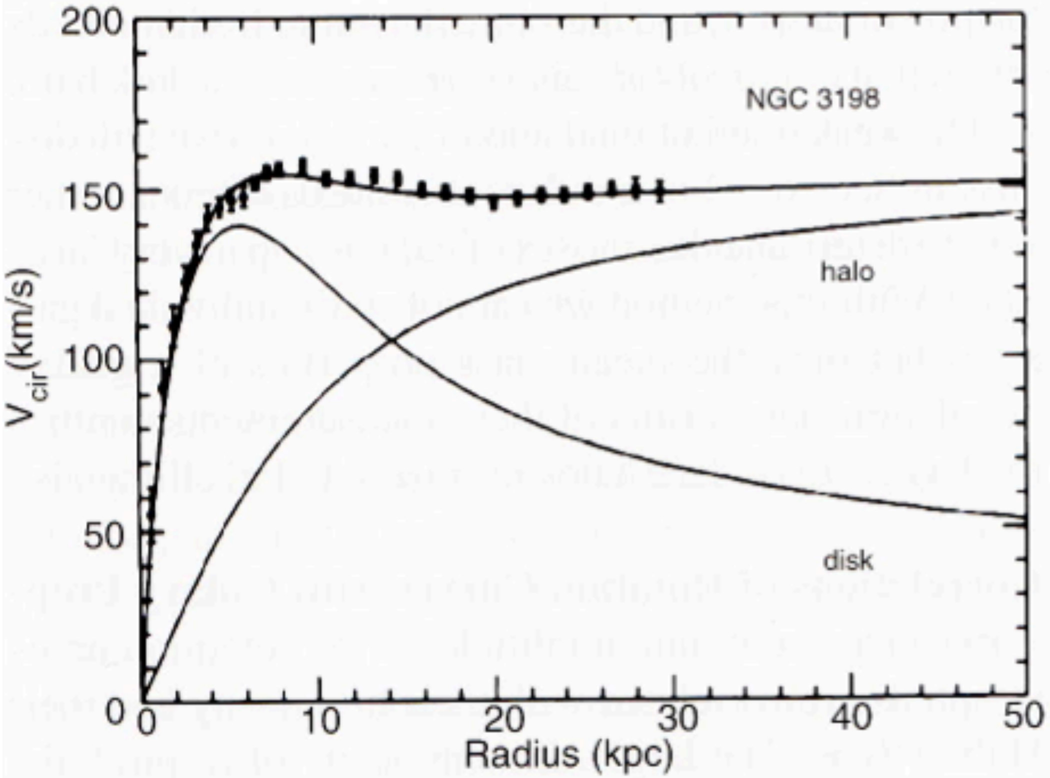


Fig. 3.16. The flat rotation curves of spiral galaxies cannot be explained by visible matter alone. The example of NGC 3198 demonstrates the rotation curve which would be expected from the visible matter alone (curve labeled "disk"). To explain the observed rotation curve, a dark matter component has to be present (curve labeled "halo"). However, the decomposition into disk and halo mass is not unambiguous because for it to be so it would be necessary to know the mass-to-light ratio of the disk. In the case considered here, a "maximum disk" was assumed, i.e., it was assumed that the innermost part of the rotation curve is produced solely by the visible matter in the disk

– Section 3.4.1-3.4.3 Scaling relations

3.3 Spiral galaxies and the Tully-Fisher relaxation

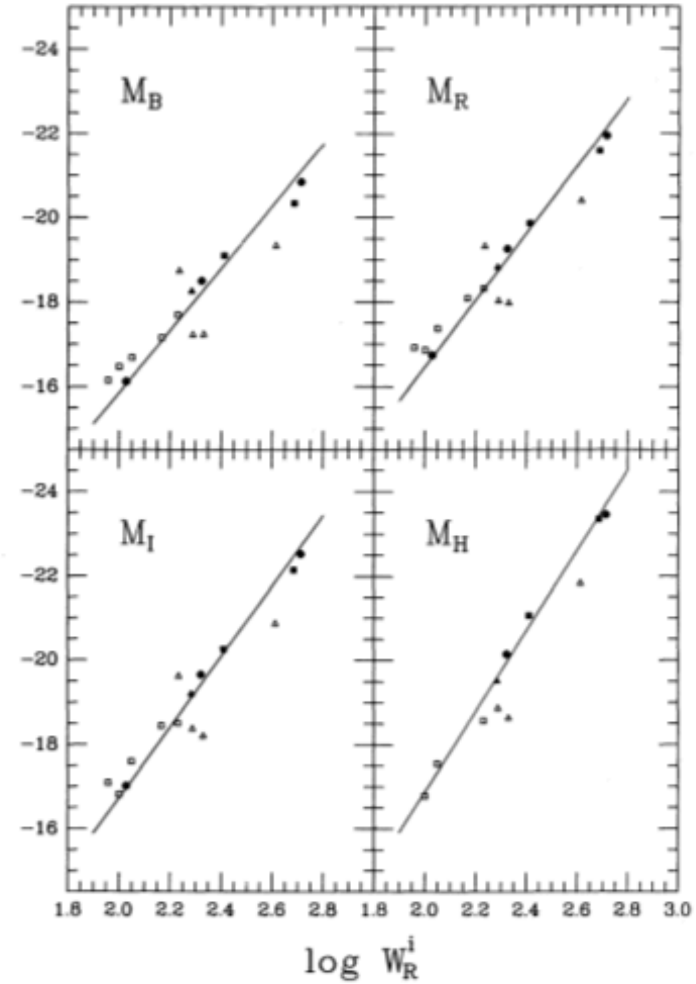


FIG. 1.—The TF relations for the members of the Local (*points*), Sculptor (*triangles*), and M81 (*squares*) groups. The filled symbols represent galaxies with individual distance determinations using Cepheids, RR Lyraes, and/or planetary nebulae. Open symbols represent systems assigned a mean group distance. Note the significant line-of-sight depth for the Sculptor Group. The solid line in each panel is the result of a least-squares fit to similar data for galaxies in the Ursa Major Cluster (Pierce & Tully 1988, 1991) minimizing the residuals in line width. The zero point was established from the six systems with individual distance determinations (i.e., the solid points).

Schneider p.106
Pierce and Tully, ApJ 387, 47

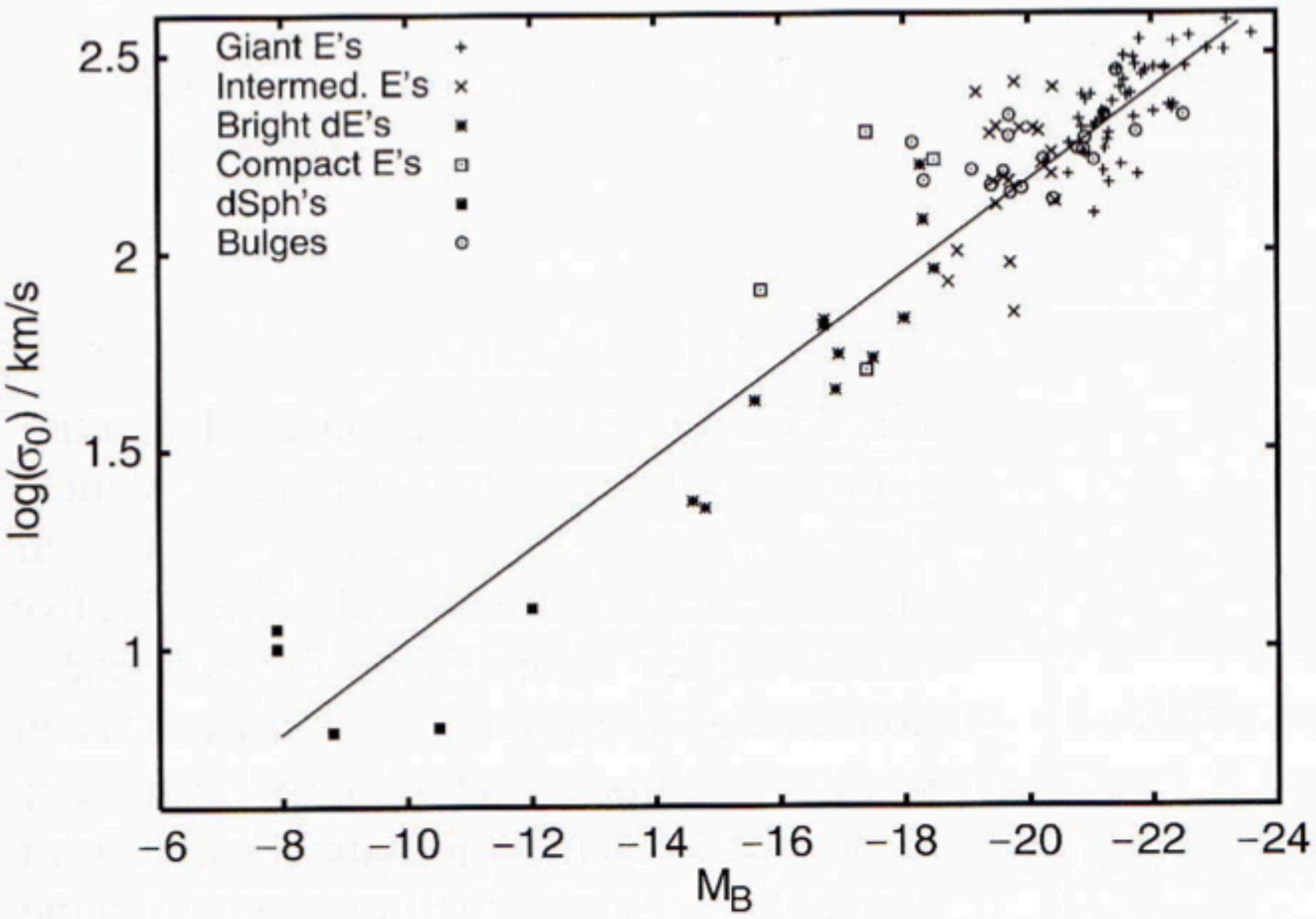


Fig. 3.22. The Faber–Jackson relation expresses a relation between the velocity dispersion and the luminosity of elliptical galaxies. It can be derived from the virial theorem

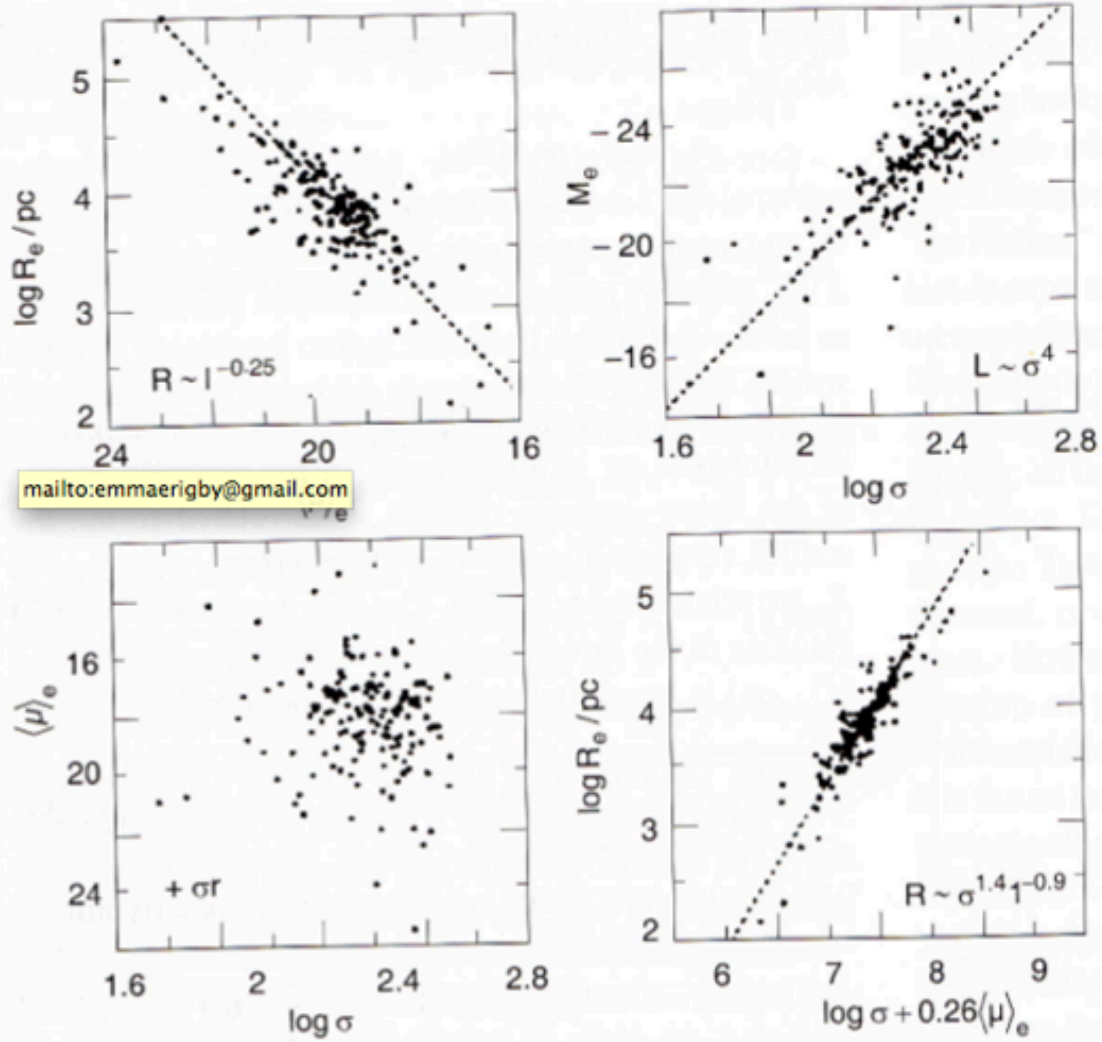


Fig. 3.23. Projections of the fundamental plane onto different two-parameter planes. Upper left: the relation between radius and mean surface brightness within the effective radius. Upper right: Faber–Jackson relation. Lower left: the relation between mean surface brightness and velocity dispersion shows the fundamental plane viewed from above. Lower right: the fundamental plane viewed from the side – the linear relation between radius and a combination of surface brightness and velocity dispersion

3.7 Luminosity Function of Galaxies

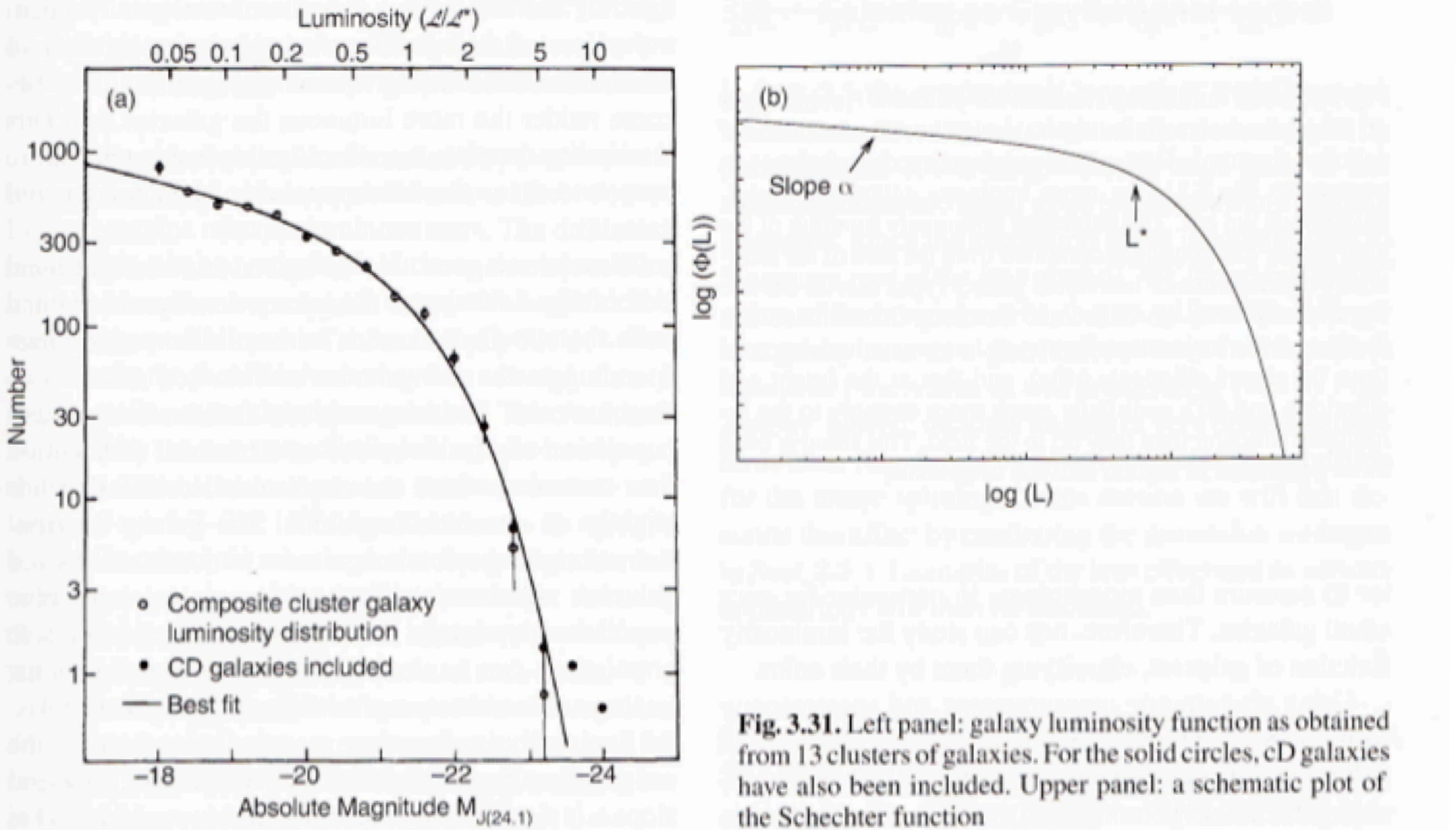


Fig. 3.31. Left panel: galaxy luminosity function as obtained from 13 clusters of galaxies. For the solid circles, cD galaxies have also been included. Upper panel: a schematic plot of the Schechter function

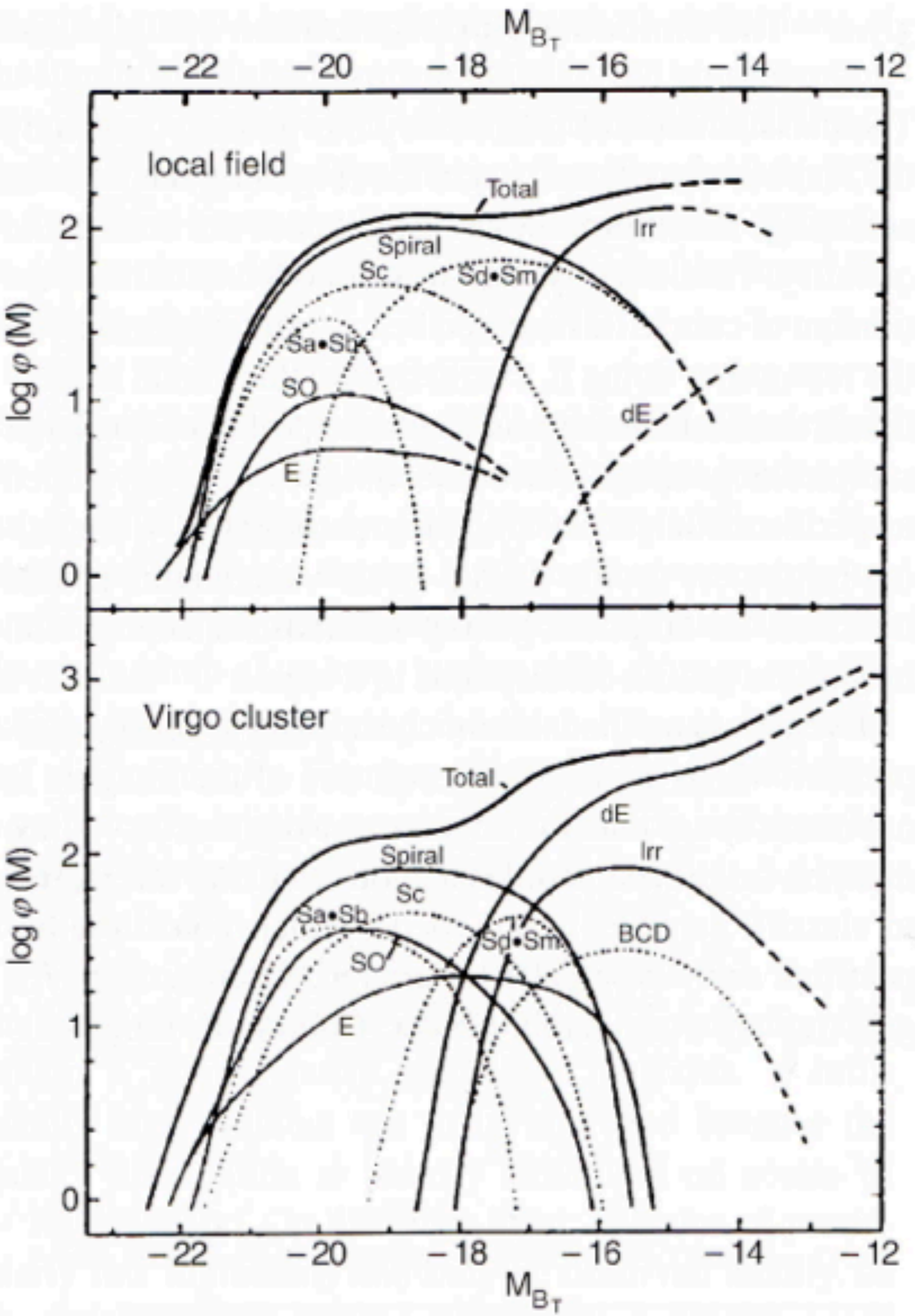
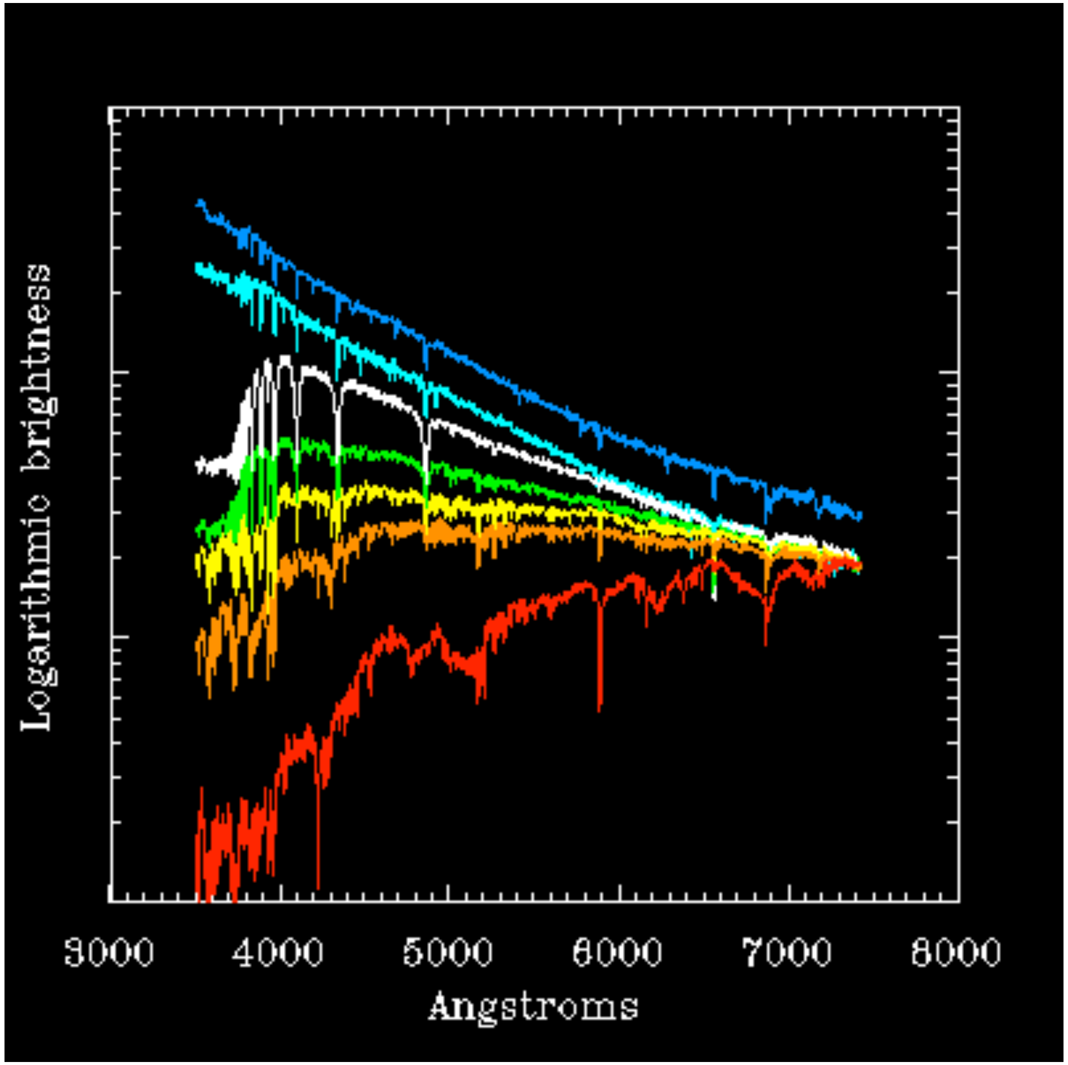


Fig. 3.32. The luminosity function for different Hubble types of field galaxies (top) and galaxies in the Virgo Cluster of galaxies (bottom). Dashed curves denote extrapolations. In contrast to Fig. 3.31, the more luminous galaxies are plotted towards the left. The Schechter luminosity function of the total galaxy distribution is compiled from the sum of the luminosity distributions of individual galaxy types that all deviate significantly from the Schechter function. One can see that in clusters the major contribution at faint magnitudes comes from the dwarf ellipticals (dEs), and that at the bright end ellipticals and S0's contribute much more strongly to the luminosity function than they do in the field. This trend is even more prominent in regular clusters of galaxies

3.9 Population synthesis

Stellar spectra I



Stellar spectra I

O stars are the hottest, with temperatures from about 20,000K up to more than 100,000K. These stars have few absorption lines, generally due to helium. These stars burn out in a few million years.

- **B** stars have temperatures between about 10,000 and 20,000K. They are noticeably blue.
- **A** stars have strong absorption lines of Hydrogen. Temperatures are about 8000-10,000K. They appear white.
- **F** stars are slightly hotter than the Sun. Absorption lines of metals appear
- **G** stars have temperatures between 5000 and 6000K. They appear yellow. Our Sun is a G star and lives for 10 Gyr
- **K** stars appear orange. Temperatures are 3000-5000K.
- **M** stars are the coolest stars. They are so cool (2000-3000K) that molecules, including water, carbon monoxide, Vanadium Oxide and Titanium oxide are visible.

$$\text{Ages} \approx \frac{10\,\mathrm{Gyr}}{(M/M_\odot)^3}$$

info: http://www.astro.sunysb.edu/fwalter/AST101/spt.html

- Most stars are called **main sequence stars** or **dwarfs**. These are stars which are burning Hydrogen stably. O dwarfs are about 50 times as massive as the Sun, and a million times as bright; M dwarfs may be as small as a tenth the mass of the sun and one ten-thousandth as bright. Stars which have used up their core hydrogen and are beginning to burn out expand into **subgiants**, **giants**, and **super giants**. Later they may become **white dwarfs**. These categories are called **luminosity classes**. Note that there is no such thing as a normal star.

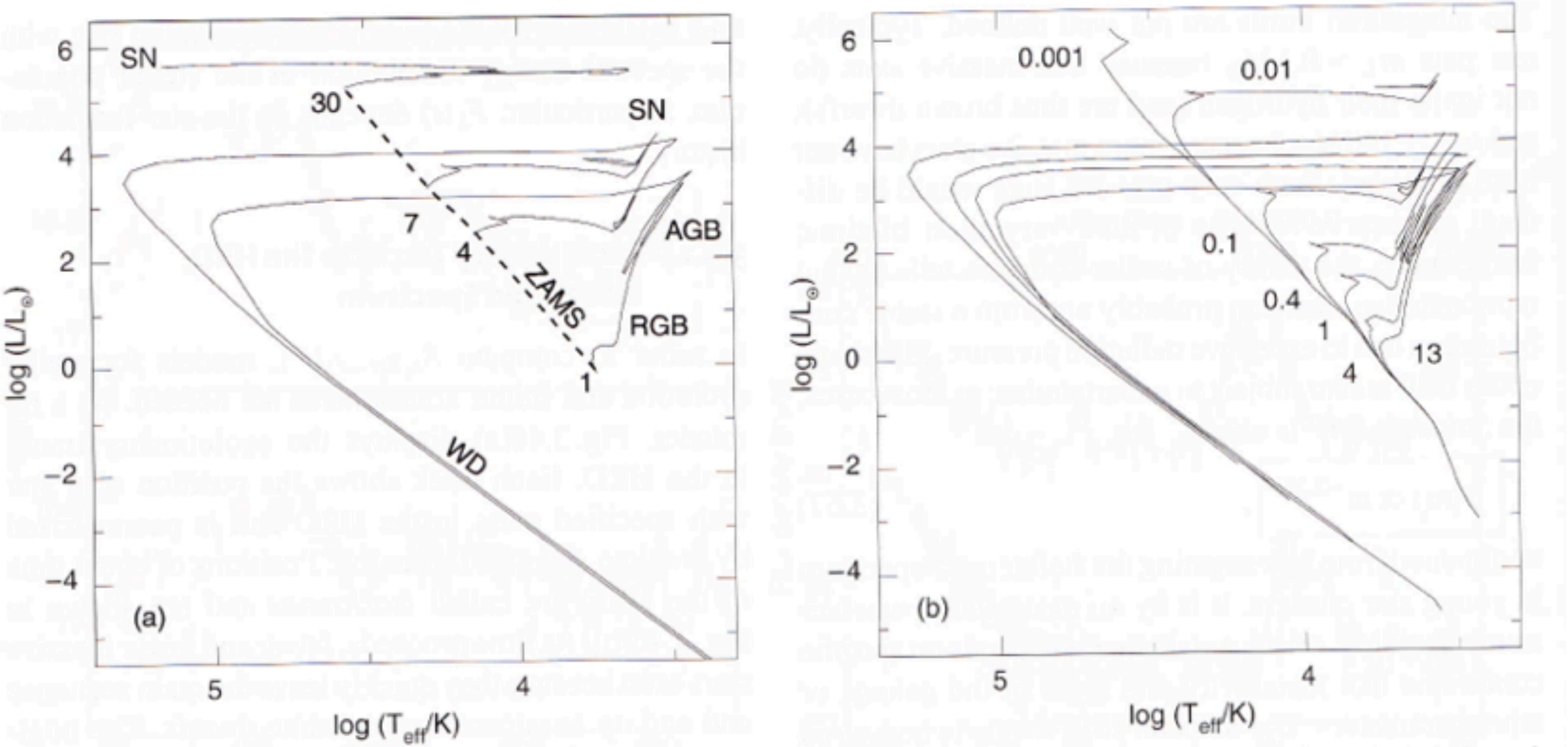


Fig. 3.46. a) Evolutionary tracks in the HRD for stars of different masses, as indicated by the numbers near the tracks (in units of $M_\odot$). The ZAMS (zero age main sequence) is the place of birth in the HRD; evolution moves stars away from the main sequence. Depending on the mass, they explode as a core-collapse SN (for $M \geq 8M_\odot$) or end as a white dwarf (WD). Prior to this, they move along the red giant branch (RGB) and the asymptotic giant branch (AGB). **b)** Isochrones at different times, indicated in units of 10^9 years. The upper main sequence is quickly depopulated by the rapid evolution of massive stars, whereas the red giant branch is populated over time

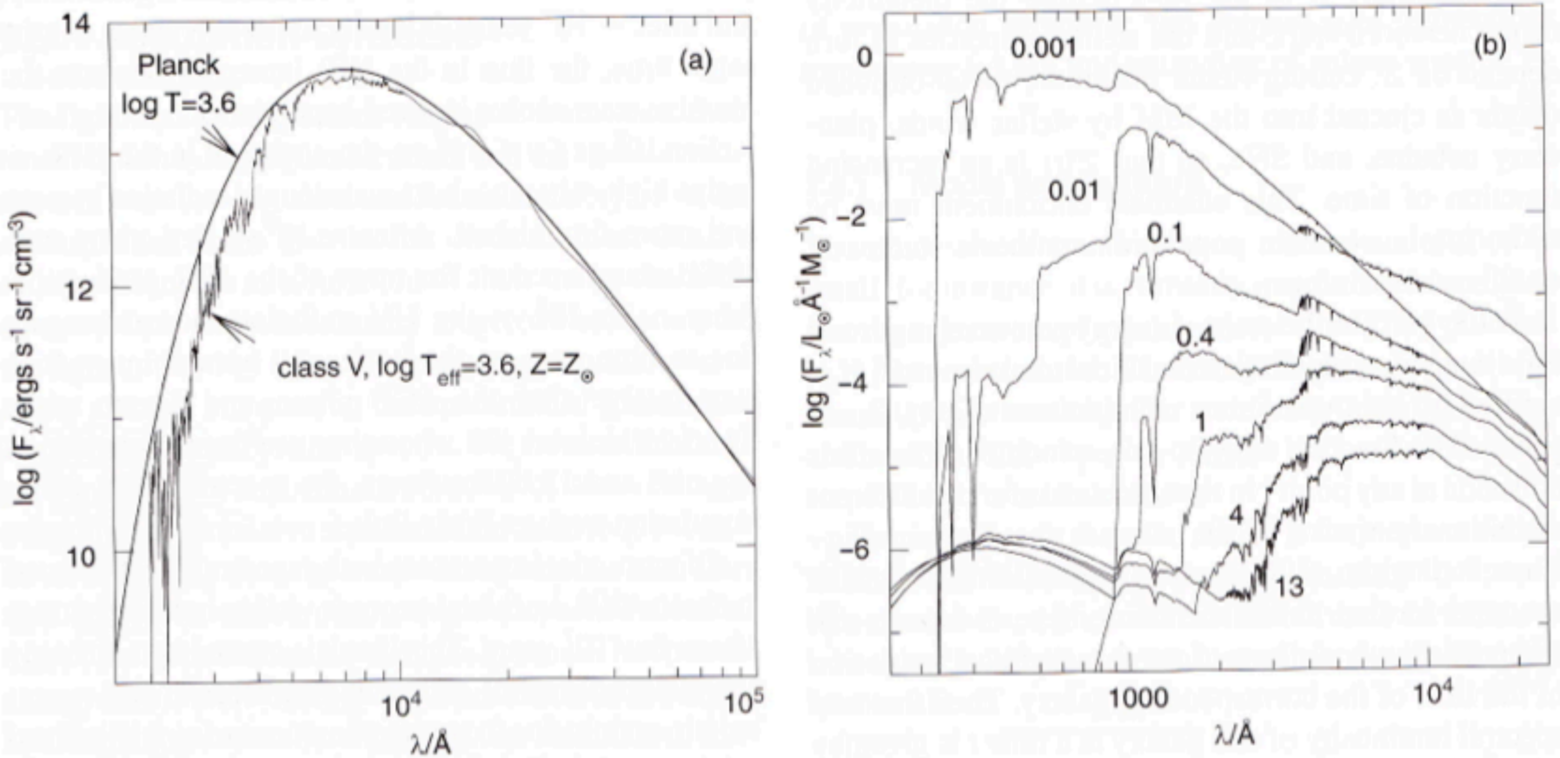


Fig. 3.47. a) Comparison of the spectrum of a main-sequence star with a blackbody spectrum of equal effective temperature. The opacity of the stellar atmosphere causes clear deviations from the Planck spectrum in the UV/optical. **b**) Spectrum of a stellar population with solar metallicity that was instantaneously born a time t ago; t is given in units of 10^9 years

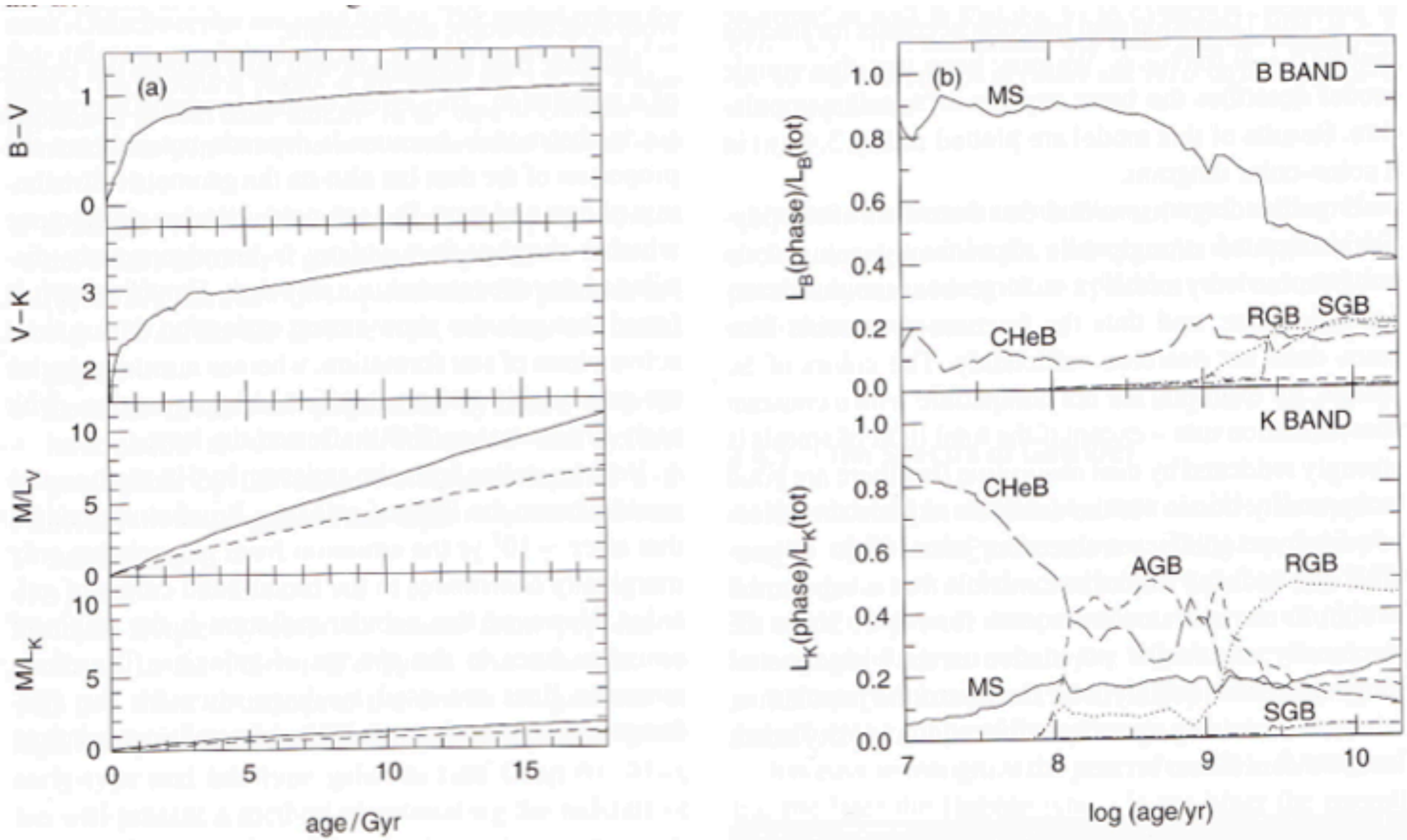


Fig. 3.48. a) For the same stellar population as in Fig. 3.47(b), the upper two graphs show the colors $B-V$ and $V-K$ as a function of age. The lower two graphs show the mass-to-light ratio M/L in two color bands in Solar units. The solid curves show the total M/L (i.e., including the mass that is later returned into the ISM), whereas the dashed curves show the M/L of the stars itself. **b)** The fraction of B- (top) and K-luminosity (bottom) contributed by stars in their different phases of stellar evolution (CHeB: core helium burning stars; SGB: subgiant branch)

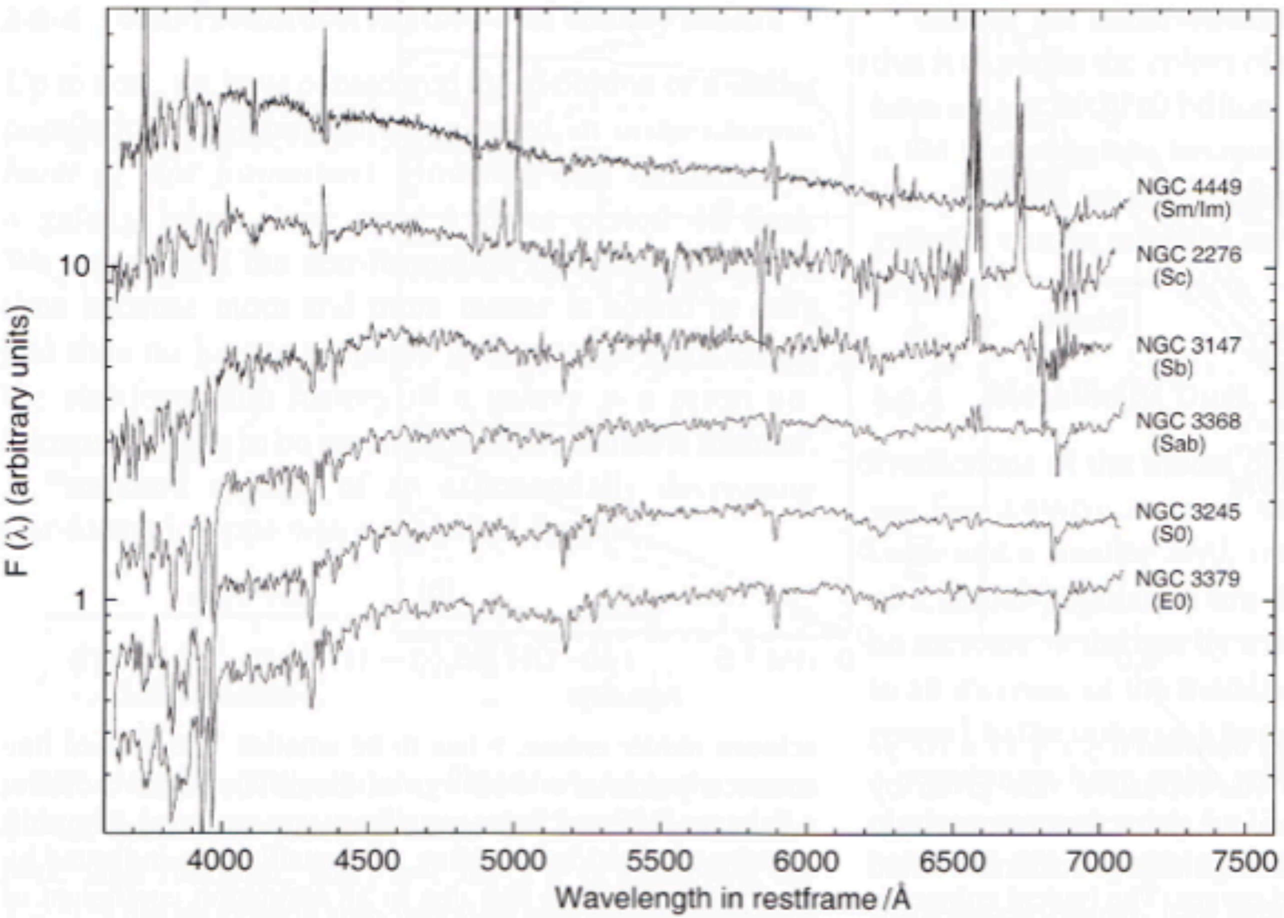


Fig. 3.50. Spectra of galaxies of different types, where the spectral flux is plotted logarithmically in arbitrary units. The spectra are ordered according to the Hubble sequence, with early types at the bottom and late-type spectra at the top

5. Homework

1. What is the galaxy type of the Milky Way ?

2. Why do we classify the Magellanic Clouds not as ellipticals ? They don't have spiral arms.

3. How do you recognize mergers ?

4. Given a galaxy with an exponential profile $I(R) = I_0 \exp(-R/R_d)$
   - what is the total amount of light emitted ? (Express in terms of I_0 and R_d.)
   - what is the half light radius ? (i.e., the radius in which half the light is emitted)

5. For a Salpeter IMF (page 133), what fraction of the stars are formed with a mass more then 50 solar mass, and what fraction less then 0.5 solar mass?

6. See page 108 of Schneider. Show how the mass to light ratio increases slowly with mass (eq. 3.27) starting with the virial theorem as given and following the line of arguments also as given.