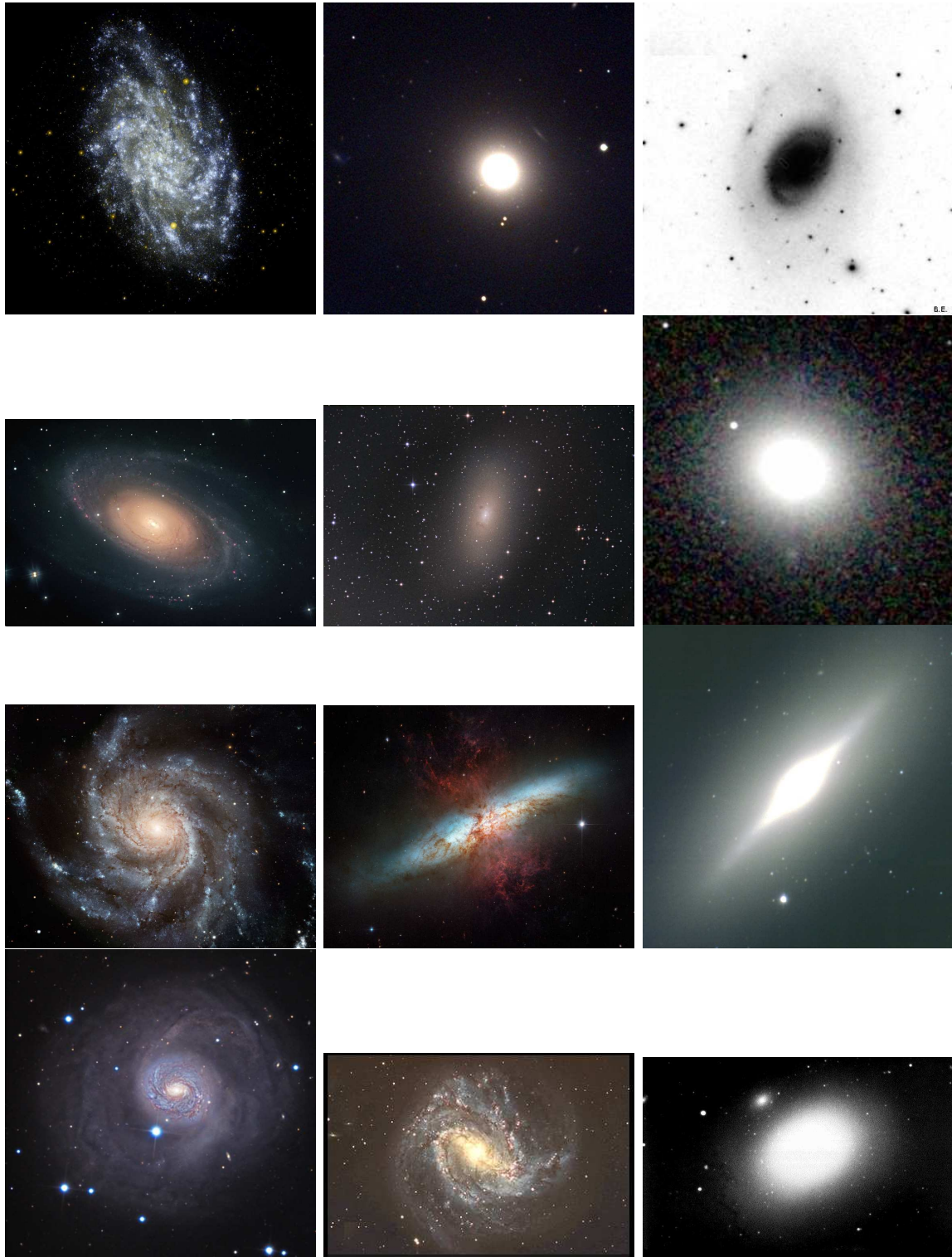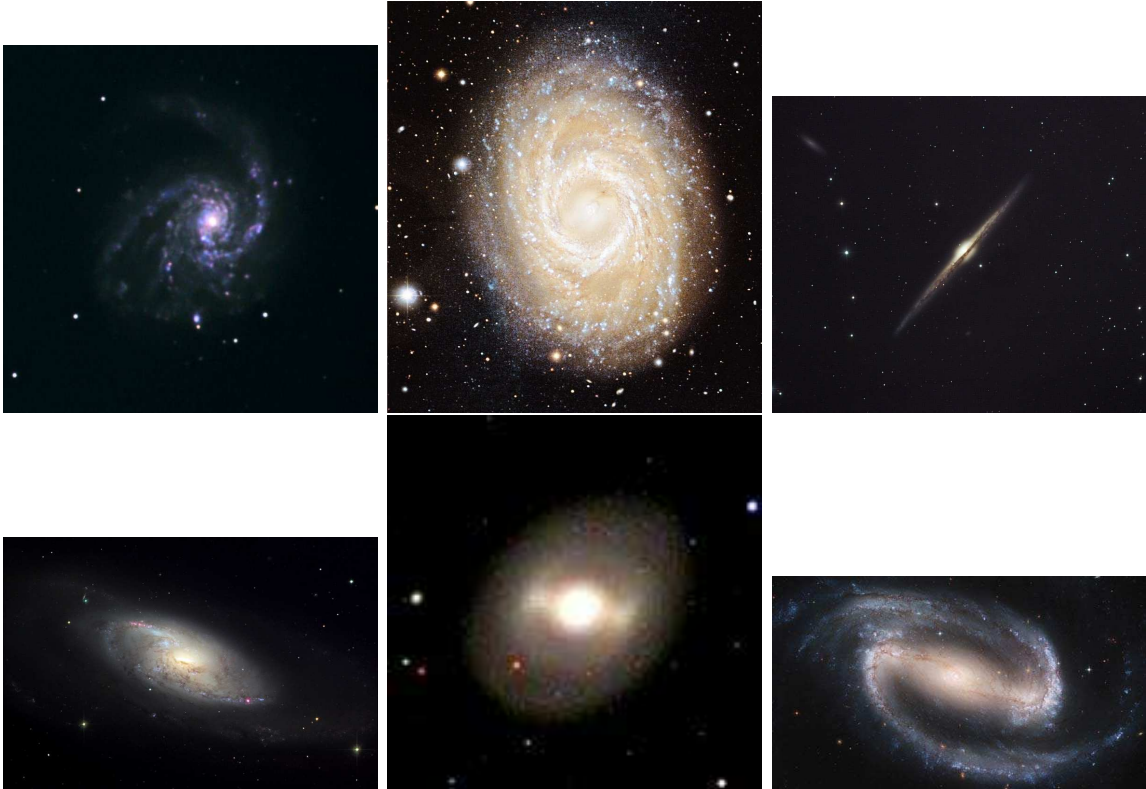## Problem set #7

**Problem 1**   *Galaxy classification*

Classify the following galaxies:

Problem 2   *Inclination angles of spiral galaxies*

Spiral galaxies can be observed under different inclination angles i, where $i = 0$ describes a "face-on" perspective and $i = \pi/2$ describes an "edge-on" perspective. How do the inclination angles i of spiral galaxies distribute if the galaxies are oriented randomly in space?
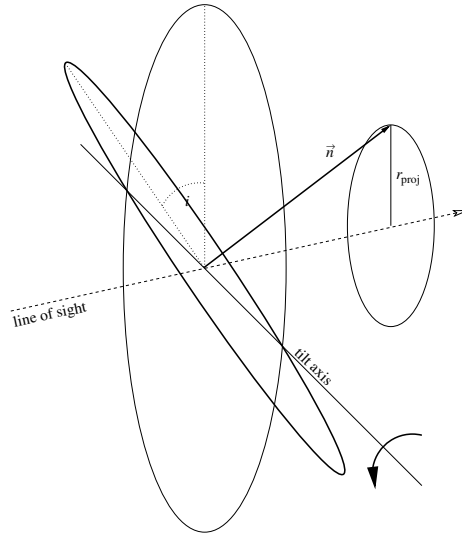
(a) First assume a disc which can be tilted with respect to an axis ("tilt axis" in the figure) perpendicular to the line of sight. (This axis is assumed to be fixed in space.) How are the inclination angles i distributed in this case, if i can take values from 0 to $\pi/2$? Derive the normalized distribution function $p(i)$ so that $\int_0^{\pi/2} p(i)\,\mathrm{d}i = 1$.

(b) Allowing different tilt axes gives an additional degree of freedom. To calculate the true distribution of the inclination angles it is convenient to use the normal vector $\vec{n}$ of the disc surface and to distribute the end of the vectors uniformly over the surface of a sphere. Convince yourself that the probability $p(i)$ of an inclination angle i must be proportional to the circumference of the circle on the sphere touched by the normal vector $\vec{n}$. Estimate for which i the probability must be highest and lowest.

(c) Find the functional dependence of the radius $r_{\mathrm{proj}}(i)$ of this circle by plotting r_{proj} against i. Can this be described by a mathematical function? From this derive the true normalized distribution function $p(i)$ of the inclination angle i.

Problem 3   *Hubble sequence*

Galaxies show a huge variety of shapes and forms. The first attempts to bring some order to this diversity were based on optical imaging, and thus most classical classification schemes are based on the visual appearance of the galaxies. The basis for the morphological classification remains until today the Hubble sequence of galaxies, published by Edwin Hubble in 1936.

Illustrate the Hubble sequence schematically. Explain the morphological types present in the original Hubble sequence. What are late-type and early-type galaxies and why did Hubble name them thus? Which other classifications have been added later (for example by de Vaucouleurs 1974, Sandage 1975, and Kormendy 1982) and why was that necessary? (*Hint:* explain what Sab, Sbc, r, R, and l stand for in galaxy classifications.) What are the problems with this kind of classification system?