

Vincent van Gogh Starry Night Painting

Hvězdná noc, 1889

Struktura a kinematika galaxií (F7567)

Bruno Jungwiert



Astronomical
Institute
of the Czech Academy
of Sciences

- II. Hubbleova a de Vaucouleursova klasifikace***
- III. Příčky a prstence v diskových galaxiích***

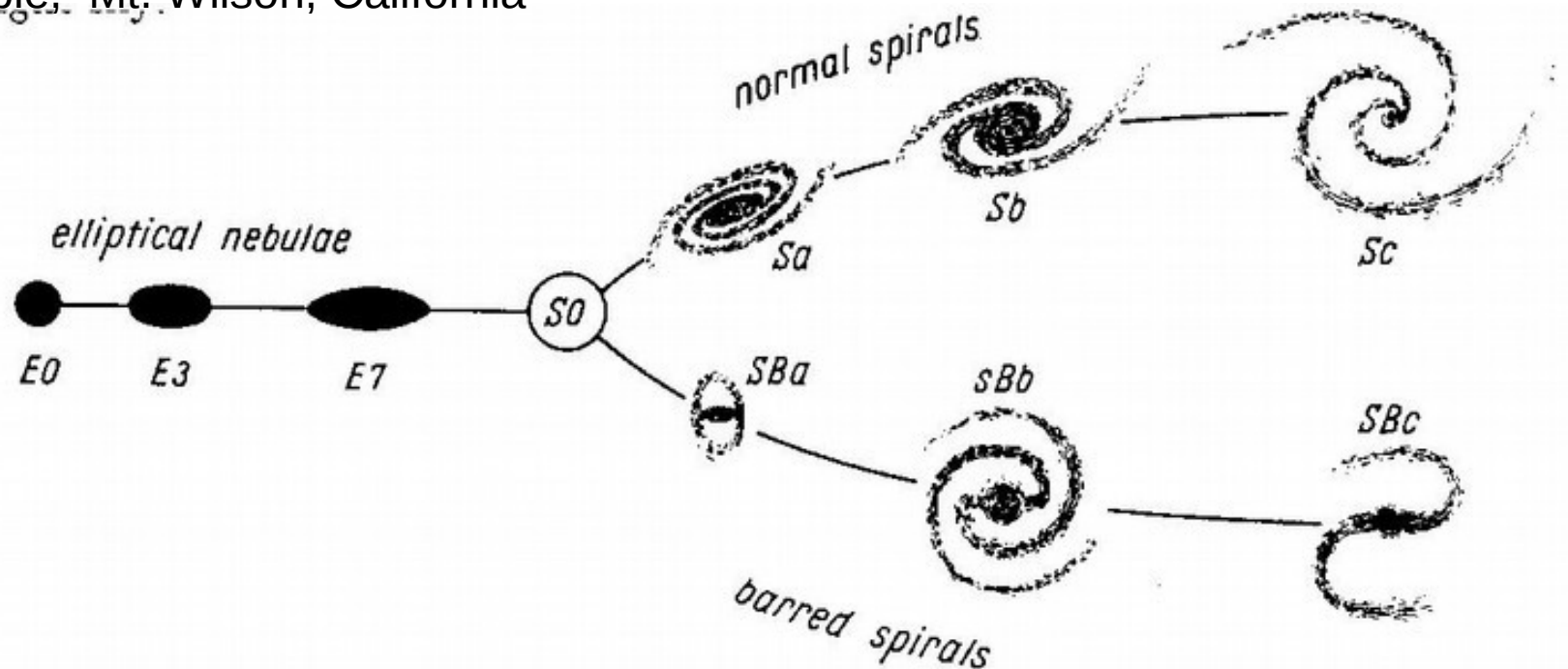
1920-1924: Spiral nebulae (galaxies) and the „Great Debate” questions:

- 1) Are they made of stars or gas?
- 2) Are they inside or outside of our own Galaxy? If outside, how far?
- 3) How big is our Galaxy? 30,000 l.y.? 300,000 l.y.?

1924: Two important discoveries are made by Edwin Hubble:

- 1) some individual stars (**Cepheids**) resolved in nearby “spiral nebulae”
 - 2) distances to these stars, and thus to their host galaxies, estimated
- => conclusions: “spiral nebulae” are made of stars; they are independent *stellar islands far beyond the outskirts of our own Galaxy*

1926-1936: The Hubble Sequence (The Hubble classification of galaxies = the first classification of galaxy morphologies)
Edwin P. Hubble, Mt. Wilson, California



from: G. de Vaucouleurs, Classification and Morphology of External Galaxies, Handbuch der Physik, 1959, Vol. 53, pp. 275-310

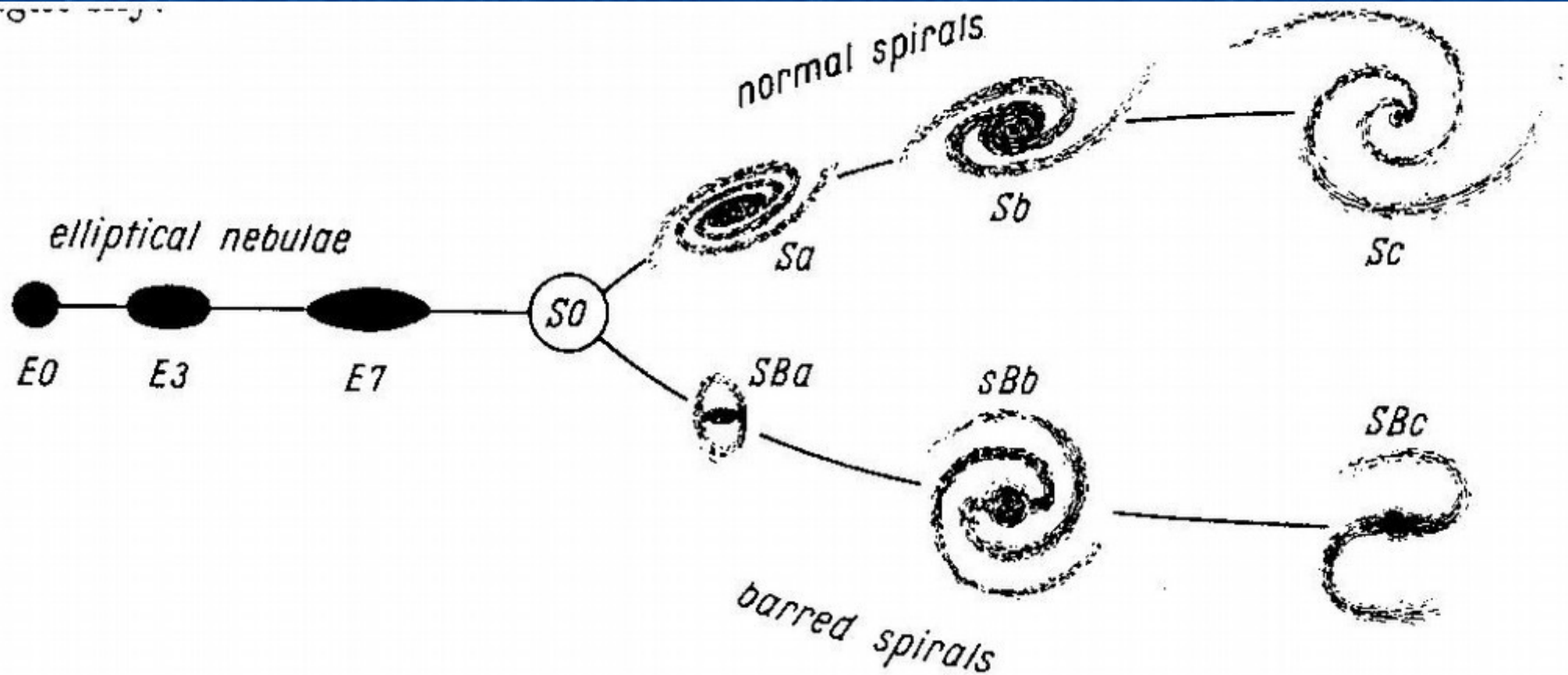
<http://nedwww.ipac.caltech.edu/level5/Dev/frames.html>

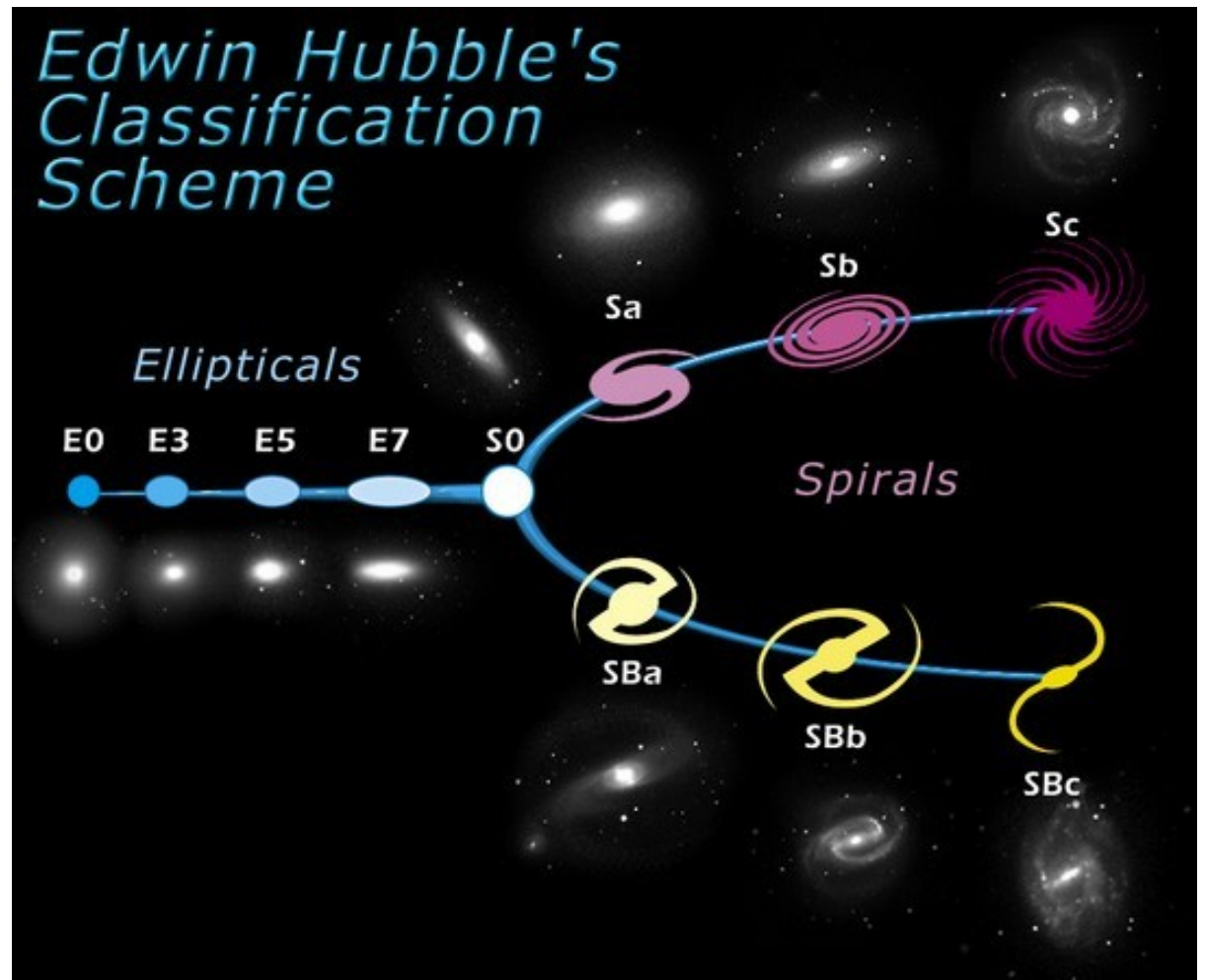
The Hubble tuning fork (1925, Mt. Wilson)

Elliptical (E), lenticular (S0), normal spiral (S), barred spiral (SB) and irregular galaxies (I)

E sub-types: E0 – E7, $n = 10(1 - b/a)$

S and SB sub-types: Sa, Sb, Sc and SBa, SBb, SBc





Edwin P. Hubble
(1889 - 1953)

Galaxies are classified by their morphology as:

- elliptical galaxies (ellipticals) (E)
- lenticular galaxies (lenticulars) (S0)
- spiral galaxies (spirals)
 - divided into: normal spirals (S)
 - barred spirals (SB)

Note: The Hubble classification does not include **dwarf galaxies** that dominate the galaxy counts (they are subdivided into dwarf irregular, dwarf elliptical, dwarf spheroidal and ultra-faint dwarf galaxies).



Hooker telescope (100-inch mirror) Mt. Wilson, California

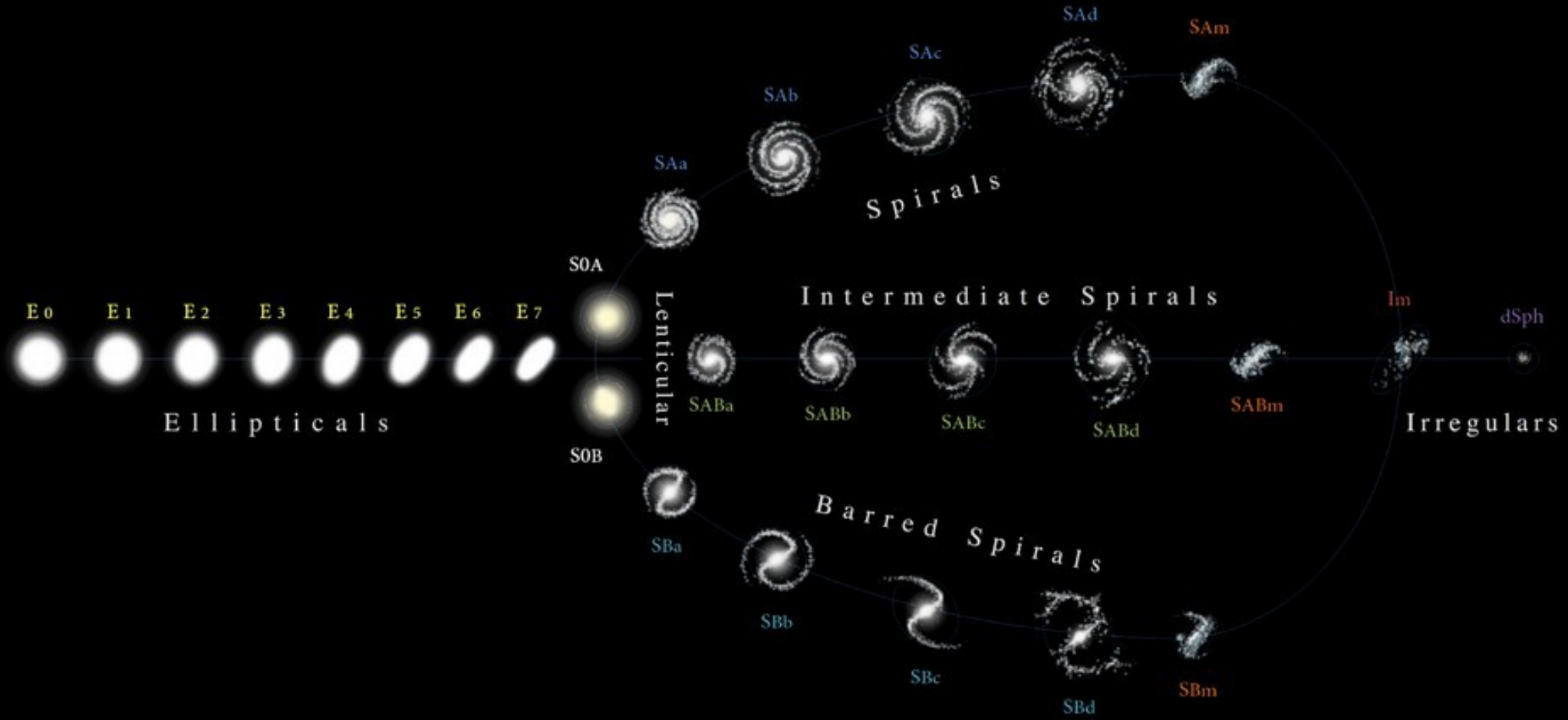
Fundamental discoveries:

- nature of spiral nebulae: **galaxies**
- speeds of galaxies: **expansion of the Universe**



Revised Hubble classification (de Vaucouleurs, 1959)

HUBBLE-DE VAUCOULEURS DIAGRAM





Spiral Galaxy Messier 83
(FORS / VLT)

ESO PR Photo 24b/05 (August 10, 2005)



Spiral Galaxy NGC 4565
(FORS / VLT)

ESO PR Photo 24a/05 (August 10, 2005)



AAT 60

elliptical galaxies,
normal spiral galaxies,
barred spiral galaxies

face-on views
edge-views



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AAT 55



The Sombrero Galaxy (VLT ANTU + FORS1)

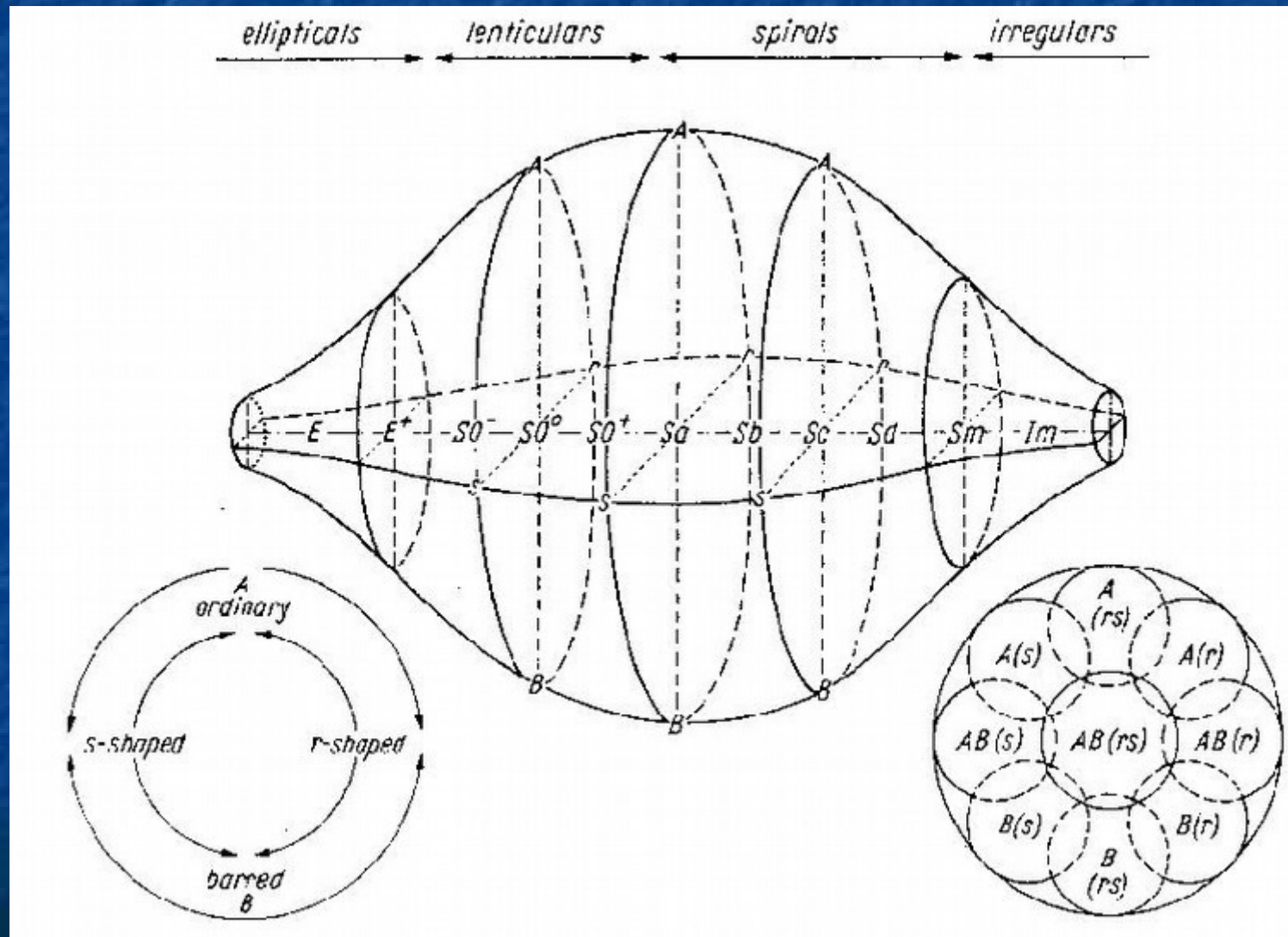
ESO PR Photo 07a/00 (22 February 2000)

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The de Vaucouleurs classification (1959, 1964)

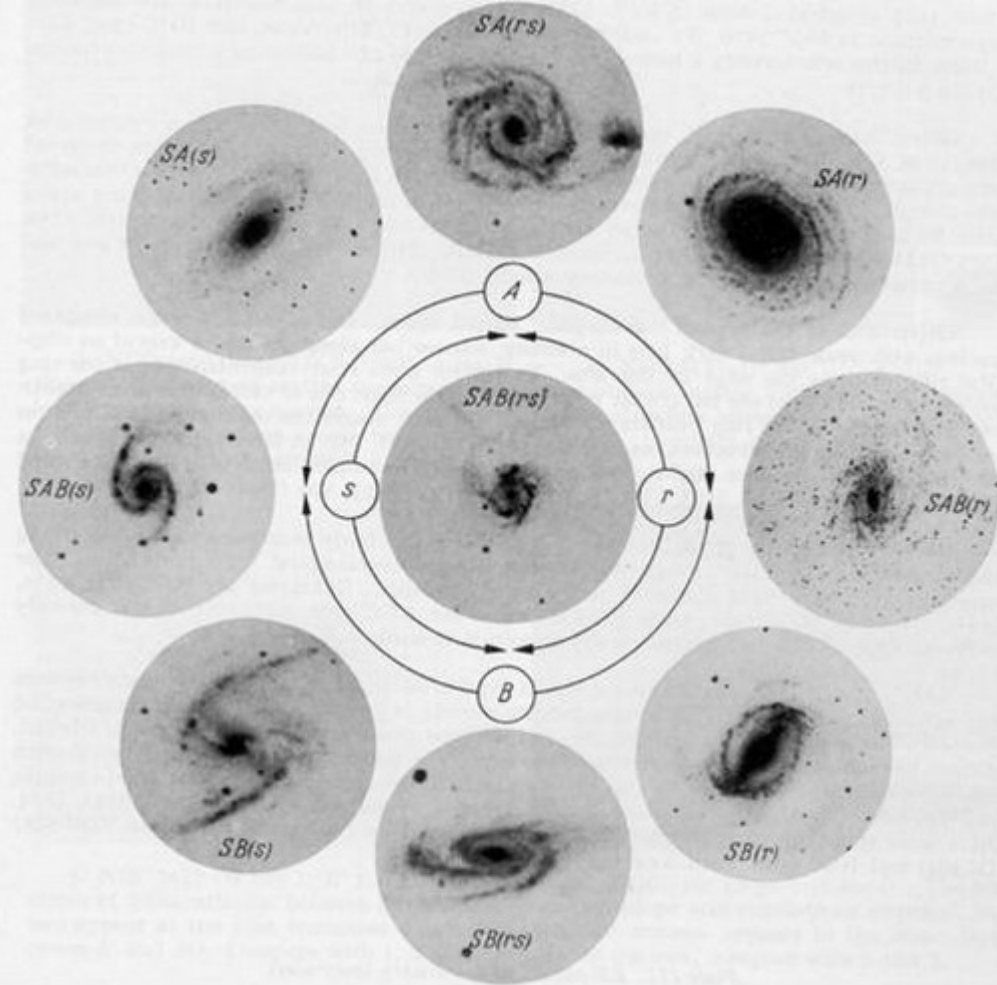
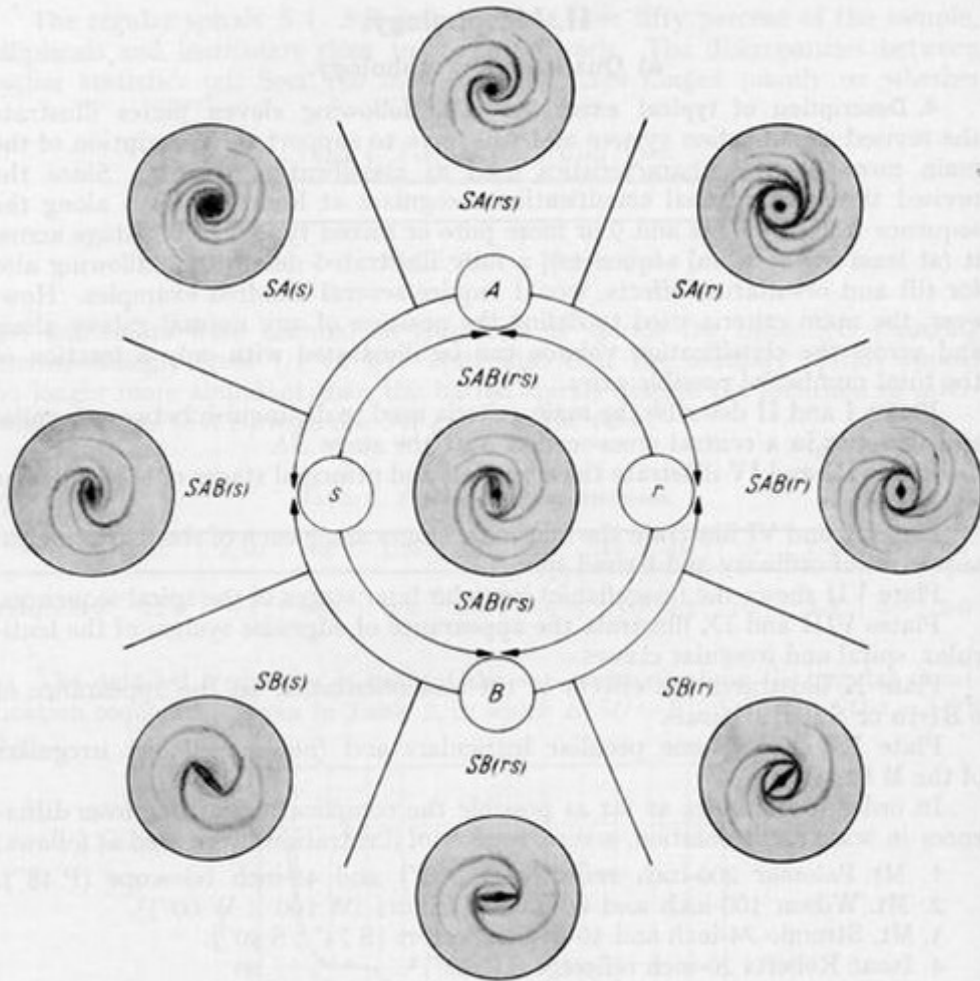
- classes E, S0, S, Im
- families A (unbarred), AB (weakly barred), B (barred)
- varieties s (inner spiral structure), r (inner ring), rs (inner pseudo-ring)



from: G. de Vaucouleurs, Classification and Morphology of External Galaxies, Handbuch der Physik, 1959, Vol. 53, pp. 275-310

<http://nedwww.ipac.caltech.edu/level5/Dev/frames.html>

De Vaucouleurs (1959)



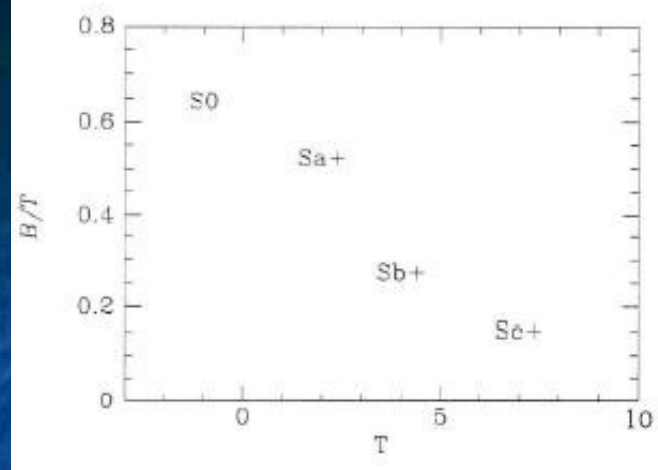
from: G. de Vaucouleurs, Classification and Morphology of External Galaxies, Handbuch der Physik, 1959, Vol. 53, pp. 275-310

<http://nedwww.ipac.caltech.edu/level5/Dev/frames.html>

Bulges

M 104 SA(s)a
 NGC 4565 SA(s)b?

B/D – bulge-to-disk ratio
 $B/T = B/(B+D)$ – bulge-to-total luminosity ratio



(zdroj: Binney & Merrifield, Galactic Astronomy, kapitola IV)

Figure 4.51 The later the Hubble stage T of a disk galaxy, the smaller is its bulge fraction B/T . The plotted values are means. In individual values scatter significant about these means. [From data published in Kent (1985)]

SA(s)a



The Sombrero Galaxy (VLT ANTU + FORS1)



SA(s)b



Spiral Galaxy NGC 4565 (FORS / VLT)



Bars (příčky)

> 2/3 diskových galaxií mají příčku viditelnou v optickém oboru

typ SA: galaxie bez příčky ~1/3
typ SAB: galaxie se „slabou“ příčkou ~1/3
typ SB: galaxie se „silnou“ příčkou ~1/3

v blízké infračervené oblasti je frekvence příček > 80%

SAB(s)c



Spiral Galaxy Messier 83
(FORS / VLT)

SAB(rs)cd



Spiral Galaxy NGC 7424
(VLT MELIPAL + VIMOS)

SB(r'l)b



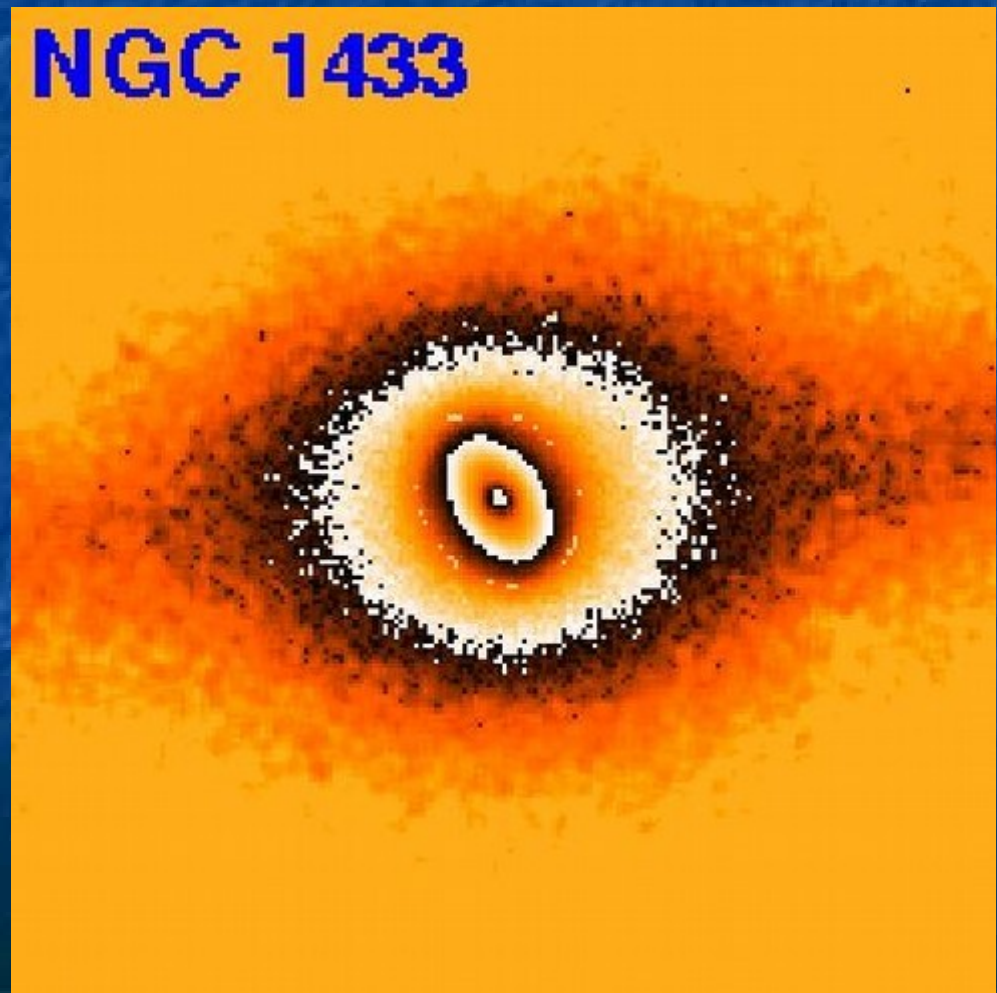
Spiral Galaxy NGC 1097
(VLT MELIPAL + VIMOS)

Dvojpríčky (double bars, bars-in-bars)
Nukleární příčky (nuclear bars, baby bars)

Double bar in NGC 1433 (R'_1 SB(rs)ab)

(B band, Buta & Combes 1996)

(H band, JCA, 1997)



Prstence (rings) a pseudo-prstence (pseudo-rings) v diskových galaxiích

označení:

- | | prstence | pseudo-prstence |
|--------------------|---------------|-------------------|
| - vnější (outer): | R, R_1, R_2 | R', R'_1, R'_2 |
| - vnitřní (inner): | r | rs (nebo r') |
| - nukleární: | nr | nr' |

Příklady vnějších a vnitřních prstenců

NGC 7020 (Buta & Combes 1996)
(R)SA(r)0⁺



The Colossal Cosmic Eye NGC 1350
(FORS/VLT)

ESO PR Photo 31a/05 (September 27, 2005)



(R'₁)SB(r)ab (Sy)

(R'₂)SAB(r)b



Spiral Galaxy ESO 269-57
(VLT ANTU + FORS1)

ESO PR Photo 26a/99 (30 April 1999)



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Nukleární prstenec v NGC 1097

SB(r'l, nr)b



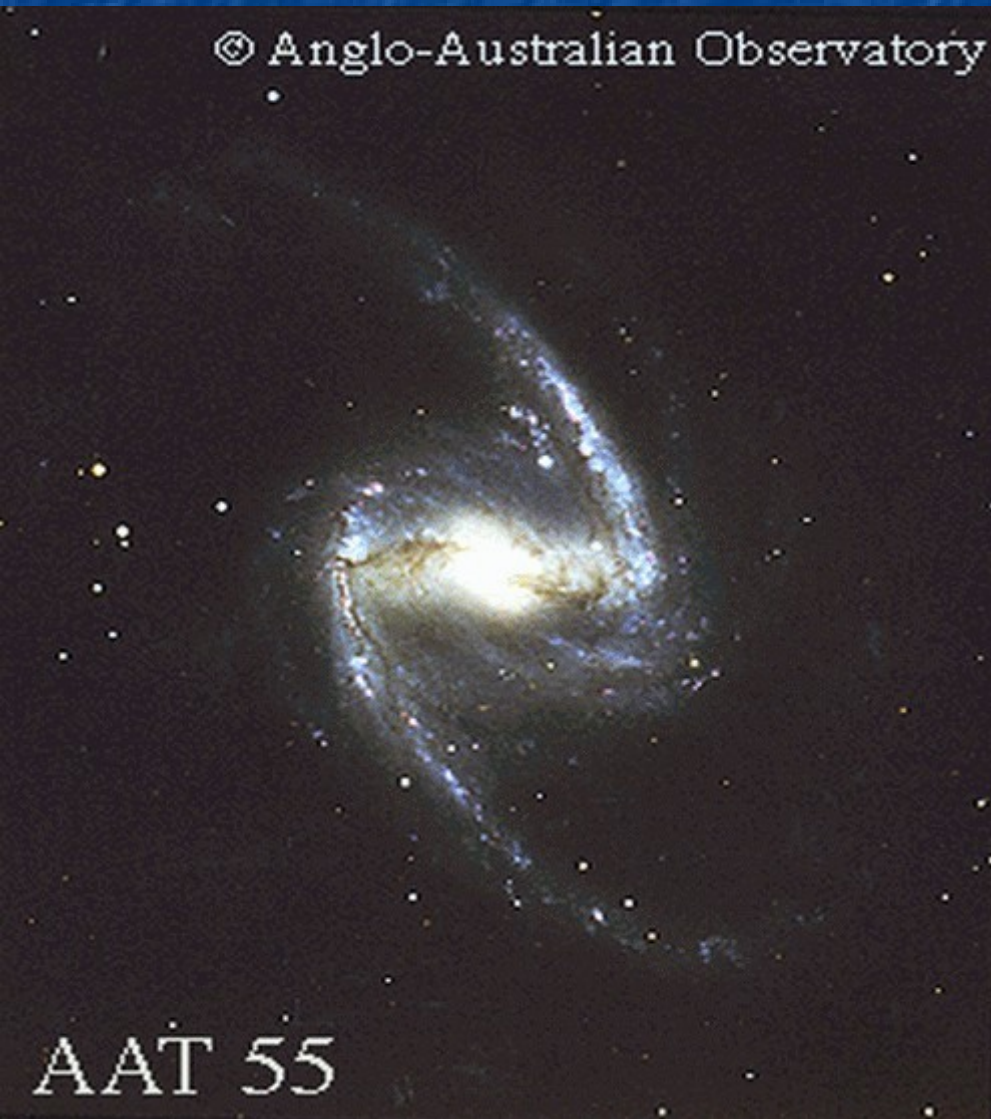
Spiral Galaxy NGC 1097
(VLT MELIPAL + VIMOS)



The Centre of the Active Galaxy NGC 1097
(NACO/VLT)

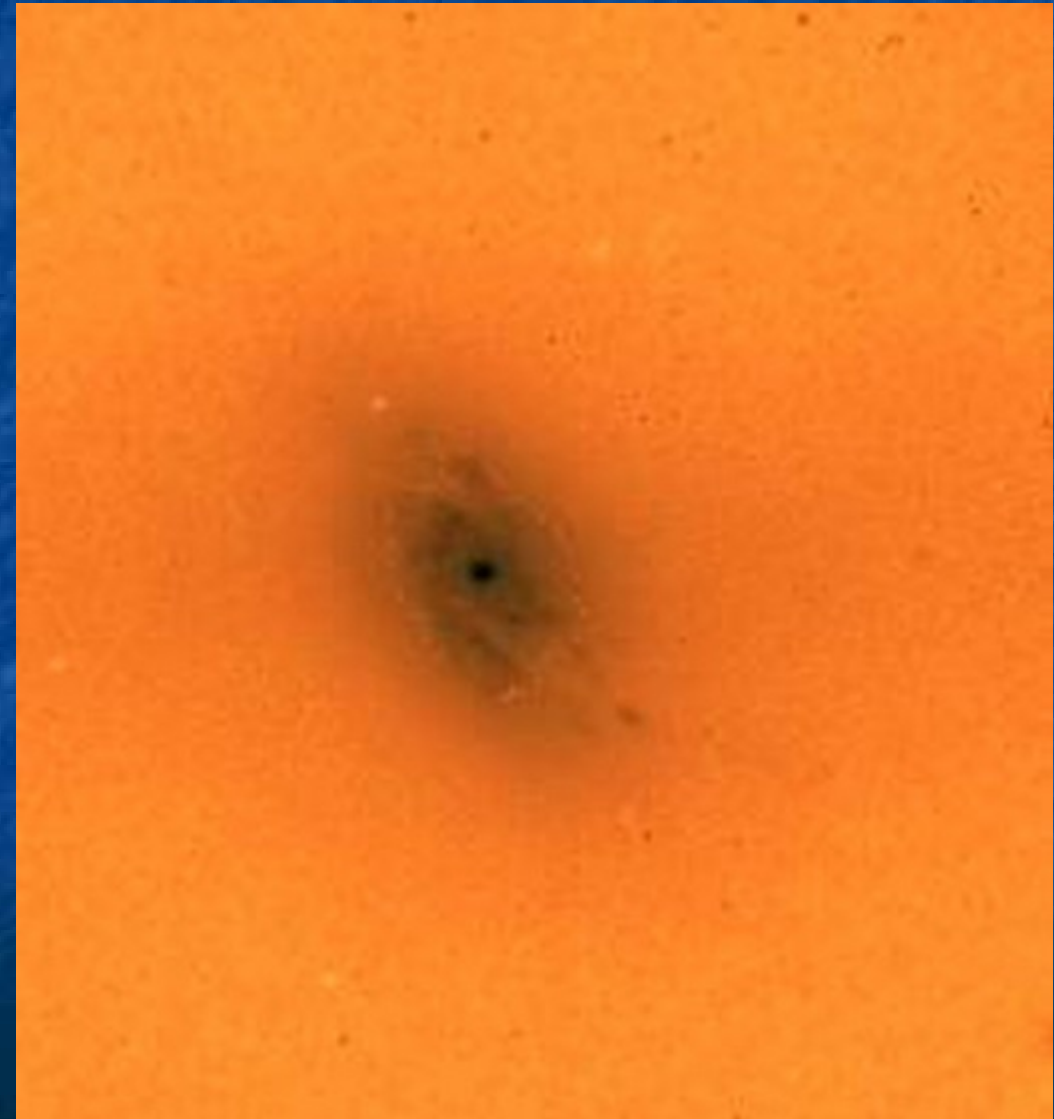
Nukleární spirály

NGC 1365, SB(s)b
optical image



near-IR image (H-band)

(different scale; from JCA, 1997)



Normal (unbarred) spiral galaxies (Hubble type SA)



M81 (Bode's galaxy) (SAab)

M94 (SAab)



NGC 891 (SAb)



M64 (Black eye) (SAab)

M104 (Sombrero) (SAa)



Normal (unbarred) spiral galaxies (Hubble type SA)



M88 (SAb)



M51 (Whirlpool galaxy) (SAbc)



M74 (Phantom) (SAc)

NGC 4565 (Needle



M63 (Sunflower galaxy) (SAbc)



M33 (Triangulum) (SAcd)



Normal (unbarred) spiral galaxies (Hubble type SA)



M81 (Bode's galaxy) (SAab)

M94 (SAab)



NGC 891 (SAb)



M64 (Black eye) (SAab)

M104 (Sombrero) (SAa)



Weakly barred spiral galaxies (Hubble type SAB)



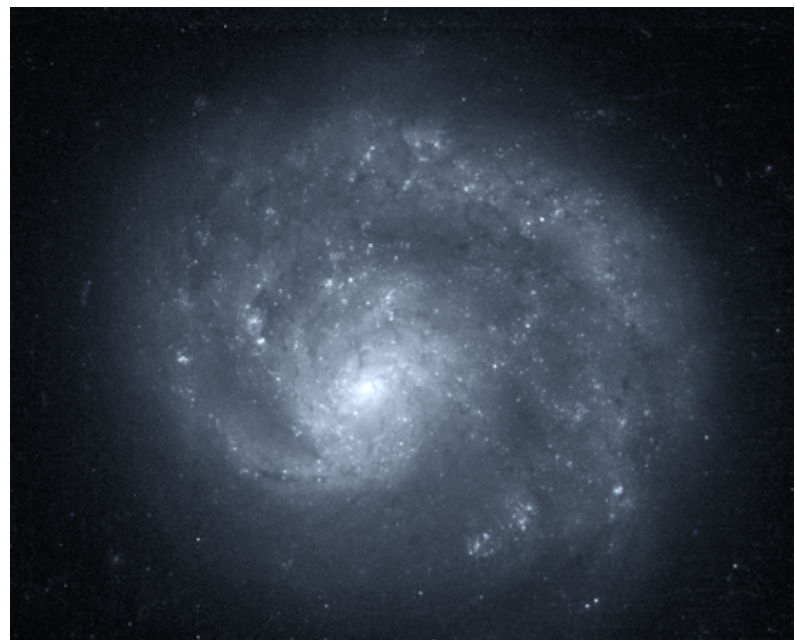
M90 (SABab)

M96 (SABab)



M61 (SABbc)

M101 (Pinwheel) (SABcd)



NGC 4625 (SABm)

M83 (Southern pinwheel) (SABc)



Strongly barred spiral galaxies (Hubble type SB)



M91 (SBb)



NGC 1365 (SBb)



NGC 1097 (SBb)

NGC 1300 (SBbc)



NGC 2903 (SBd)





Credit: NASA/ESA, HST, HLA
Processing and Copyright: Steve R Cooper

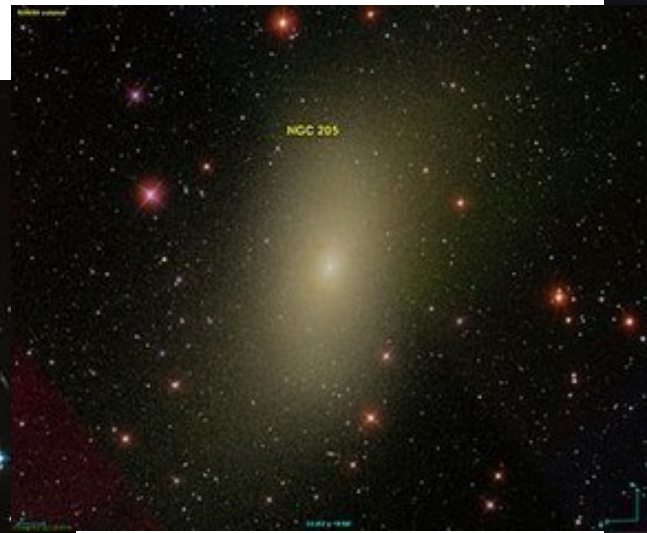
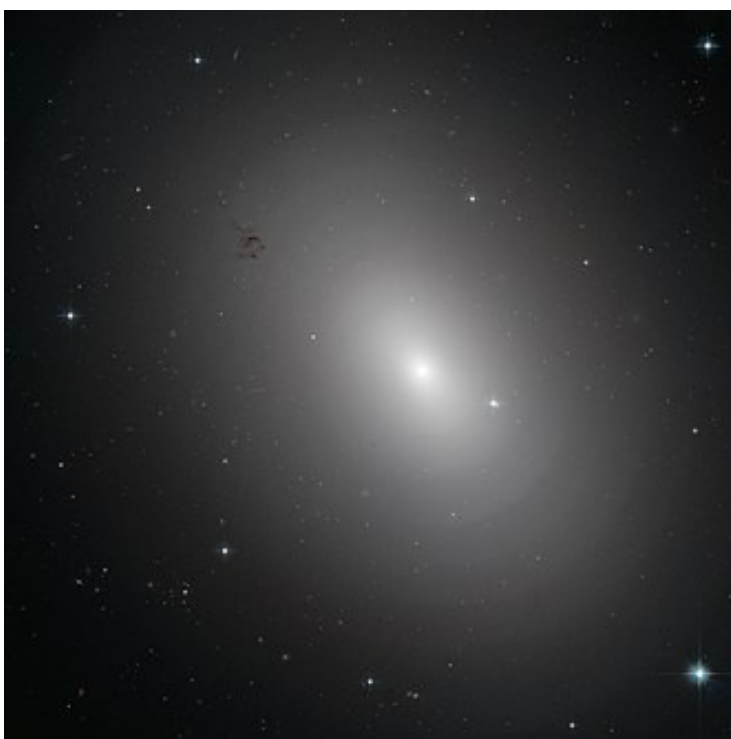
<http://apod.nasa.gov/apod/ap160913.html>

NGC 1672: Barred Spiral Galaxy from Hubble

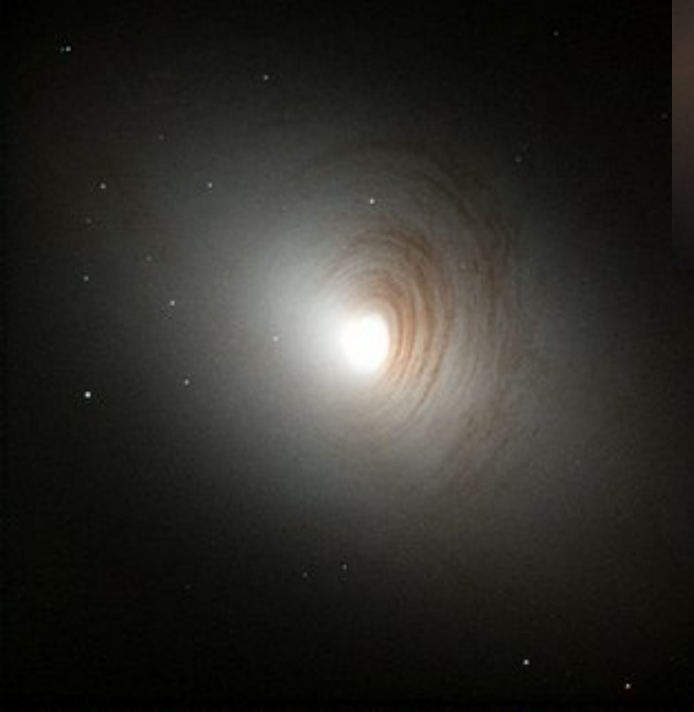
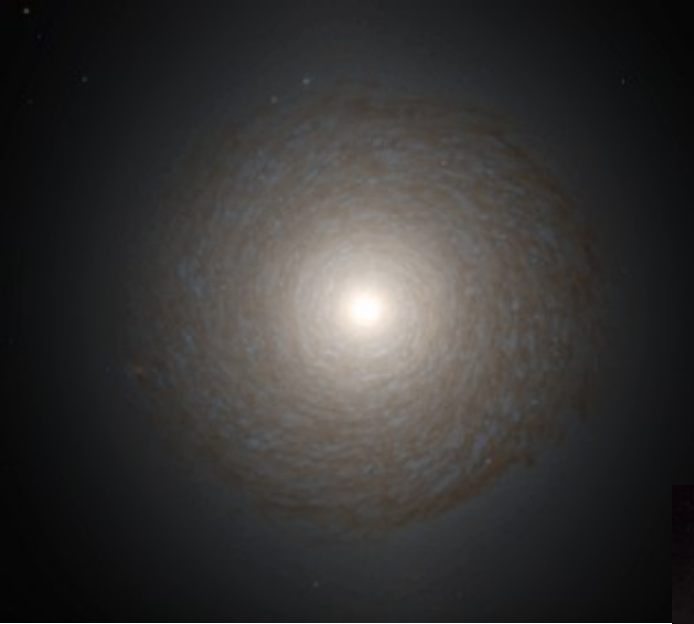
Image Credit: Hubble Legacy Archive, NASA, ESA; Processing & Copyright: Steve Cooper

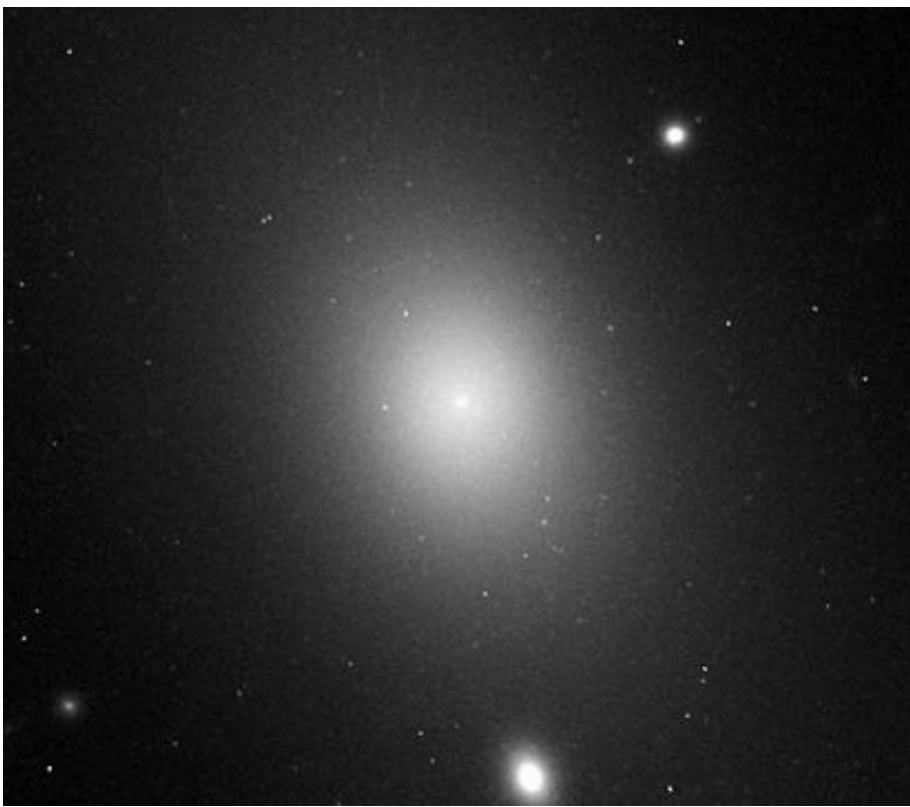
Explanation: Many spiral galaxies have bars across their centers. Even our own Milky Way Galaxy is thought to have a modest central bar. Prominently barred spiral galaxy NGC 1672, featured here, was captured in spectacular detail in an image taken by the orbiting Hubble Space Telescope. Visible are dark filamentary dust lanes, young clusters of bright blue stars, red emission nebulas of glowing hydrogen gas, a long bright bar of stars across the center, and a bright active nucleus that likely houses a supermassive black hole. Light takes about 60 million years to reach us from NGC 1672, which spans about 75,000 light years across. NGC 1672, which appears toward the constellation of the Dolphinfish (Dorado), is being studied to find out how a spiral bar contributes to star formation in a galaxy's central regions.

Elliptical galaxies (Hubble type E)



Lenticular galaxies (Hubble type S0)





The largest known galaxy: *IC 1101*

a supergiant *lenticular galaxy*
(Hubble type S0)

size: 5 million light years across
(25 times the Milky Way disk)

distance: 1.2 billion l.y. (redshift: 0.08)

number of stars: 100 trillion (10^{14})
(500 x more than the Milky Way Galaxy)

For the first time observed in 1790 by
William Herschel



The smallest known galaxy: *Segue 2*

a *dwarf spheroidal galaxy* (dSph),
member of the Local Group

size: 200 light years

distance: 110,000 light years

number of stars: 3,000

Discovered in 2009