Lab I

(Topic 6)

Light distribution, velocity dispersion and mass of M87

EXTRAGALACTIC ASTROPHYSICS

November 28, 2022

Timetable

Nov 28 /11:30–14:30h: Presentation, first data analysis, doubts and comments

Dec 7 / 24:00h: Deadline for submissions of PDF reports (goicol@unican.es)

You will work with the isophotes of M87 from the analysis of the optical image **M87_ima1crs.fits**. The file **M87_ima1iso.dat** at MoodleUniCan (within the folder "Data and how to use the isophote package") includes modeled isophotes (fits to ellipses)

NOTE –To answer the questions below, only consider radii *R* (on the 2D sky) that are not affected by seeing, i.e., semi-major axes greater than $3 \times$ FWHM ≈ 15 pixels

Question 1: ISOPHOTES AND BRIGHTNESS PROFILE

(**1a**) In a Figure 1 show real (rough) isophotes of M87 using the software DS9. Is there some anomaly at a radius of about 40 pixels (OJA = optical jet anomaly)? Why does this OJA produce a significant increase in ellipticity and a shift of about –50º in the instrumental position angle? (see slide #37)

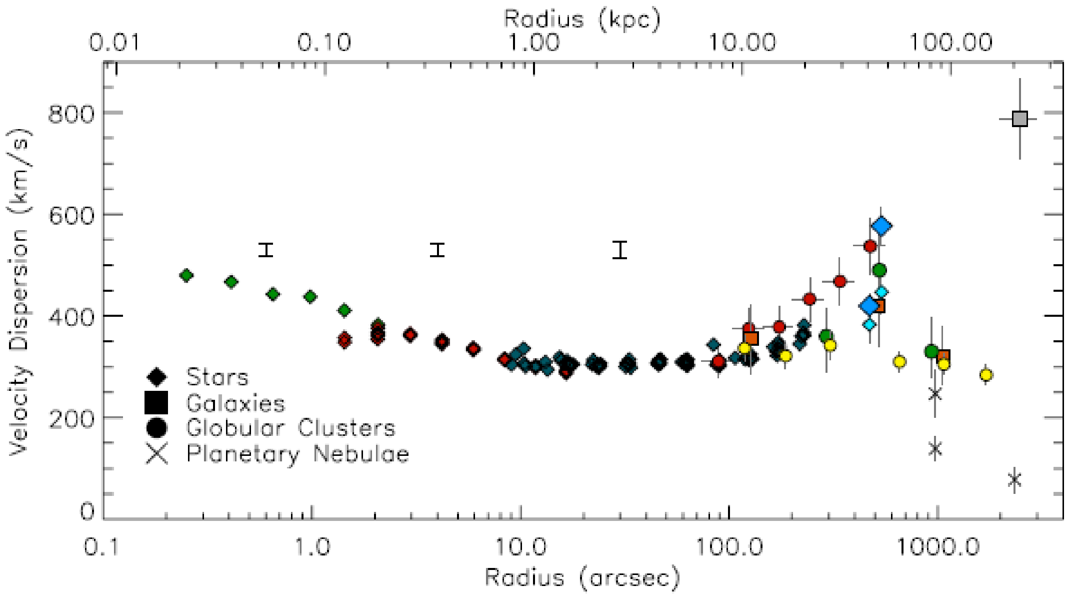
(**1b**) Draw a Figure 2 including the profile of the uncalibrated surface magnitude $\mu(R)$, where R is the semi-major axis (SMA) length in arc second (″). The figure should depict errors $\sigma = (\sigma_{\mu-} + \sigma_{\mu+})/2$, i.e. construct symmetric error bars by averaging the lower and upper magnitude errors, which in general are very similar and likely underestimated (very small values)

(**1c**) Fit a De Vaucouleurs law to the observed profile $\mu(R)$ by minimising the sum of squared deviations between data and model. Neglecting formal errors, the data μ_i can be modelled as a linear law $y = a + b\, x_i$, where $x_i = R_i^{1/4}$. Draw a Figure 3 showing the best fit (least square method) along with the observational data. Are you dealing with a standard elliptical galaxy that follows a De Vaucouleurs law? If you find systematics, try to fit a Sersic law with an arbitrary index n

(**1d**) Determine the best value of the effective radius R_e (in ″) and its standard uncertainty, and compare your results with that in the paper by Liu et al. 2005 (R_e = 108.7″; *The Astronomical Journal* **129**, 2628). Using the distance to M87 (d = 16.4 Mpc; Bird et al. 2010, *Astronomy & Astrophysics* **524**, 71), obtain the radial size R_e in kpc and its standard error

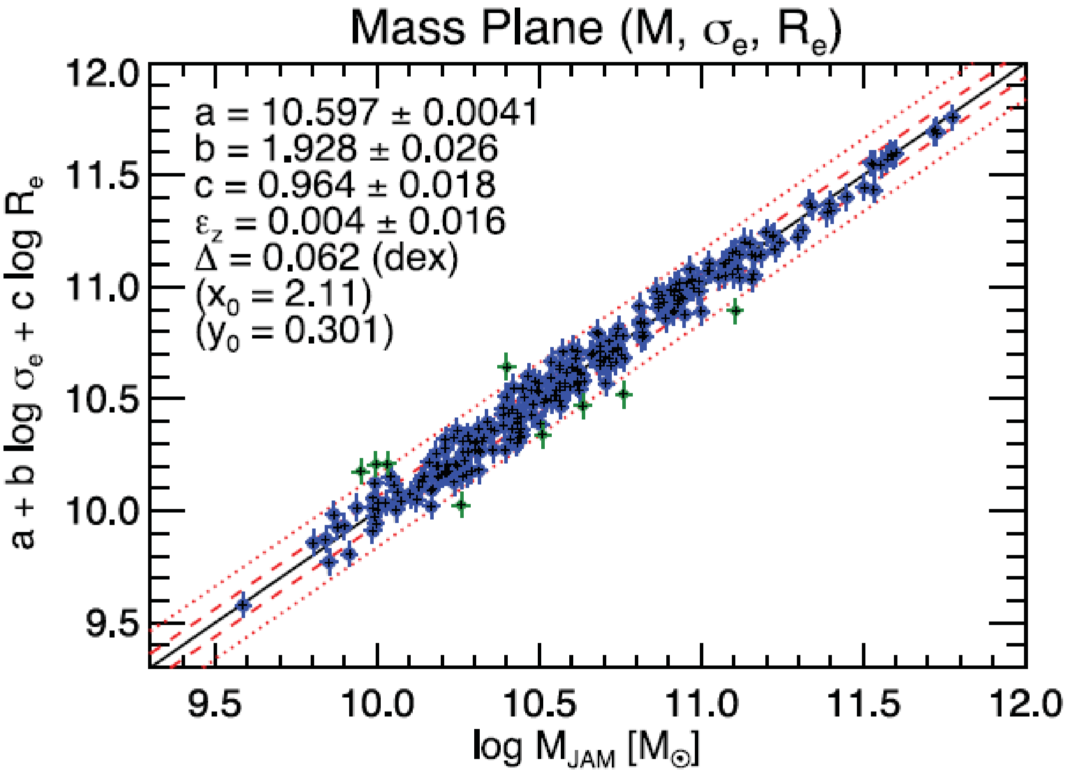
Question 2: VELOCITY DISPERSION, LUMINOSITY AND MASS

(**2a**) Consider the profile of σ(r) for M87 (see here below; Murphy et al. 2014, *The Astrophysical Journal* **785**, A143)



Estimate the visual luminosity of M87 (L_V) and classify it: giant, midsize or dwarf elliptical? Additionally, estimate the stellar mass of the galaxy (M_*) in $M_\odot$, and compare it to that of the Milky Way. Give the M_*/L_V ratio in $M_\odot/L_\odot$

(**2b**) In the paper by Cappellari et al. 2013 (*MNRAS* **432**, 1709), it is included a relationship between $M_{\rm JAM} \approx 2 \times M_{1/2}$ (where $M_{1/2}$ is the total mass within a sphere with radius $r_{1/2}$ enclosing half of the total galaxy light; this quantity refers to 3D distributions instead to projected ones on the 2D sky!) and normalised values of σ_e and R_e (see the attached figure)



The normalised quantities are $\sigma_e = \sigma_e$ (km/s) / 130 km/s and $R_e = R_e$ (kpc) / 2 kpc. Derive the total mass of the galaxy within $r_{1/2} \approx 1.33\ R_e$. Compare this (luminous + dark) mass with that of the Milky Way on a similar radial size. Are you dealing with a massive galaxy?