



Data Analysis Round

Good Luck and Clear Skies!

General Instructions

1. The **Data Analysis Round** consists of 1 question on the application of analytical skills on astronomical data.
The allocated time for this round is **60 minutes**.
2. The round will be announced to start by the invigilator (Camp Facilitator).
Please **DO NOT** turn over this page before the start of this round.
3. A countdown timer would be shown on the screen. There are no restrictions to the time budget for each question.
4. There is a total of **80** marks allocated. The marks attributed to each question is marked below the problem statement. The problems are not sorted by difficulty.
5. You will be provided working sheets, **1** designated answer sheet and **1** graph paper for your solutions. On **EACH** working sheet, answer sheet and graph paper, write down your **Name, IC Number** and **Question Number**. All answers that are to be evaluated must be written on the sheets provided. You are advised to use separated pages for separate questions.
6. **Cross out** sections that you do not want to be evaluated.
7. Use as many mathematical expressions to help the graders better understand your solutions. The graders may not understand your language. If it is necessary to explain something in words, please use short phrases (if possible in English).
8. You are not allowed to leave your working desk without permission. If you need any assistance (malfunctioning calculator, restroom visits, insufficient or missing sheets, etc.), please put up your hand to signal the invigilator.
9. The round would end once the countdown timer rings. At the end of the round, you must stop writing immediately. Sort and put your working sheets and graph paper in one stack. Put papers you do not want to be graded in another stack. You are allowed to keep this question paper.
10. Please remain seated until your papers are collected. You are allowed to leave once all papers are collected.

Contributors

We kindly thank our problem setter:

- Yap Yong Sheng (University of Cambridge)

1. Faber-Jackson Relation

The astrophysics of galaxy evolution are complicated, and are difficult to predict from first principles. To understand their physical properties and systematics quantitatively, astronomers utilize scaling relations between global properties of galaxies, which present themselves as power laws if highly correlated. In this question, we will examine the Faber-Jackson relation.

A sample of galaxies from the Sloan Digital Sky Survey (SDSS) that are at redshift $z = 0.052$. The velocity dispersions and r-band magnitude of the galaxies are tabulated in the table below.

σ (km/s)	r (mag)	σ (km/s)	r (mag)
93	17.838	98	17.038
124	17.514	142	17.273
95	17.632	144	16.621
92	17.418	93	17.633
115	17.488	144	16.538
158	16.506	103	17.293
124	16.395	136	16.724
113	17.176	129	16.732
117	16.614	141	16.772
144	16.974	132	16.33
145	16.531	117	16.48
152	17.092	134	16.539
93	17.392	139	16.614

- (a) It is conventional to write the Hubble constant as $H_0 = 100 \times h$ km/s/Mpc to express physical quantities without an explicit choice of the Hubble constant (we are still not sure of its value!)

Find the expression to convert the r-band magnitude to the expansion-independent absolute magnitude $M_r - 5 \log(h)$.

[10 marks]

- (b) In the table given in the **Answer Sheet**, evaluate the logarithmic velocity dispersion $\log_{10} \sigma$ and the absolute magnitude $M_r - 5 \log(h)$.

[26 marks]

- (c) On the graph paper provided, plot $M_r - 5 \log(h)$ against $\log_{10} \sigma$. Orient your axes such that dimmer galaxies are to the bottom and brighter galaxies to the top.

Note: If you were not able to find the conversion in part (a), plot r against $\log_{10} \sigma$ instead. Use r to replace $M_r - 5 \log(h)$ in all subsequent questions.

[14 marks]

- (d) The Faber-Jackson relation is a power law scaling between the velocity dispersion of galaxies to their luminosity. It is most commonly expressed in the form

$$L \propto \sigma^\gamma$$

From your plot, estimate the exponent γ in the Faber-Jackson relation and its maximum and minimum uncertainty.

[20 marks]

- (e) Divide the galaxy sample into 3 equally spaced bins in absolute magnitude. Calculate (i) the standard deviation of the velocity dispersion in the mid-range of absolute magnitudes, and (ii) the fractional scatter, i.e. the standard deviation divided by the mean.

[10 marks]

- (f) Draw the extent of the fractional scatter on your graph.

[10 marks]

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