

## Astronomy Sample 2 – Modelling Hubble’s Law

Personal Engagement x/2	Exploration x/6	Analysis x/6	Evaluation x/6	Communication x/4	Total x/24
1	5	4	5	4	19

### Personal Engagement

This criterion assesses the extent to which the student engages with the exploration and makes it his or her own. Personal engagement may be recognized in different attributes and skills. These could include addressing personal interests or showing evidence of independent thinking, creativity or initiative in the designing, implementation or presentation of the investigation.

Mark	Descriptor
1	<p><b>The evidence of personal engagement with the exploration is limited with little independent thinking, initiative or creativity.</b></p> <ul style="list-style-type: none"> <li>There is little evidence of <b>personal input and initiative</b> in the designing, implementation or presentation of the investigation.</li> </ul>
2	<p><b>The evidence of personal engagement with the exploration is clear with significant independent thinking, initiative or creativity.</b></p> <ul style="list-style-type: none"> <li>The justification given for choosing the research question and/or the topic under investigation demonstrates <b>personal significance, interest or curiosity.</b></li> </ul>
<b>Moderator’s Award</b> 1	<p><b>Moderator’s Comment</b></p> <p>The student is clearly interested in this contemporary issue. They demonstrate curiosity in that they consider three interpretations of the same data. However, these interpretations are not original and there is little evidence of initiative in the design or implementation of the investigation, as all the details for the method and data analysis come from established sources.</p>

## Exploration

This criterion assesses the extent to which the student establishes the scientific context for the work, states a clear and focused research question and uses concepts and techniques appropriate to Diploma Programme level. Where appropriate, this criterion also assesses awareness of safety, environmental, and ethical considerations.

Mark	Descriptor
3-4	<ul style="list-style-type: none"> <li>The background information provided for the investigation is mainly appropriate and relevant and aids the understanding of the context of the investigation.</li> </ul>
5-6	<ul style="list-style-type: none"> <li>The topic of the investigation is identified and a relevant and fully focused research question is clearly described.</li> <li>The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.</li> </ul>
<b>Moderator's Award 5</b>	<p><b>Moderator's Comment</b></p> <p>The topic is identified and the research question is described—the best mathematical model for a set of data. The second part of the research question, the implications for using the models for establishing the future of the universe, is interesting but far from being established in the confines of an IA. This investigation is not your typical IA, and perhaps should have been limited to the first question. The method of analysis is entirely appropriate (as it came from a university web site), but the selection of data limits the possible trend lines. The student should have looked at official Hubble-like data to consider the possible graph lines and their corresponding uncertainties. Most of the appropriate factors were considered (given the approach), and the student demonstrates some insightful understanding. The student's hypothesis about less gravitational force causes increased velocity is wrongheaded, and neglects general relativity, space itself expanding and other issues. The hypothesis should have been left out.</p>

## Analysis

This criterion assesses the extent to which the student's report provides evidence that the student has selected, recorded, processed and **interpreted** the data in ways that are relevant to the research question and can support a conclusion.

Mark	Descriptor
3-4	<ul style="list-style-type: none"> <li>The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question.</li> <li>The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced.</li> </ul>
5-6	<ul style="list-style-type: none"> <li>Appropriate and sufficient data processing is carried out with <b>the accuracy</b> required to enable a conclusion to the research question to be drawn that is fully <b>consistent</b> with the experimental data.</li> <li>The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis.</li> </ul>
<b>Moderator's Award 4</b>	<p><b>Moderator's Comment</b></p> <p>The limited data can be seen to beg the question, as appropriate data goes up to 130 Mpc. The limited range can have a number of best-fit lines, as the student shows. The processing is appropriate and errors are appreciated. The three interpretations are understood in great mathematical details (not as much physical detail, though). The R-squared value is a meaningless quantity for this type of investigation. The issue of a correct interpretation is not fully addressed by the different line fits.</p>

## Evaluation

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context.

Mark	Descriptor
3-4	<ul style="list-style-type: none"> <li>A conclusion is described which makes some relevant comparison to the accepted scientific context.</li> <li>The student has <b>described</b> some realistic and relevant suggestions for the improvement and extension of the investigation.</li> </ul>
5-6	<ul style="list-style-type: none"> <li>A detailed conclusion is <b>described and justified</b> which is entirely relevant to the research question and fully supported by the data presented.</li> <li>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are <b>discussed</b> and provide evidence of a clear understanding of the <b>methodological issues</b> involved in establishing the conclusion.</li> </ul>
<b>Moderator's Award</b> <b>5</b>	<p><b>Moderator's Comment</b></p> <p>The student appreciates the three interpretations in both mathematical and physical terms. The research question has been answered with the established linear model, and the student's thoughts here are genuine and impressive. There is no attempt, however, to connect the results with the accepted theory (meaning why Hubble's constant is linear, albeit changing gradient with time). It is a fact that any finite data set has an infinite number of best-fit lines, polynomials and all. Again, the R-squared factors are meaningless in this study. More reflection of the selected data would help. Nonetheless, the student has done a splendid job here.</p>

## Communication

This criterion assesses whether the investigation is presented and reported in a way that supports effective communication of the focus, process and outcomes.

Mark	Descriptor
3-4	<p><b>The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes.</b></p> <ul style="list-style-type: none"> <li>The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way.</li> <li>The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation.</li> <li>The use of subject specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding.</li> </ul>
<b>Moderator's Award</b> <b>4</b>	<p><b>Moderator's Comment</b></p> <p>The report is clear and concise, and minor errors in unit style or missing units do not hamper the intent of the study. The structure is focused and wastes no space; it reads like a textbook. Subject terminology is correct. Graphs are clear and easy to understand.</p>

\*For example, incorrect/missing labelling of graphs, tables, images; use of units, decimal places. For issues of referencing and citations refer to the "Academic honesty" section.