

Queen Mary Astrophysics MSc
ASTM005 Research Methods in Astronomy
Supplementary Course Notes

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THE RESEARCH LITERATURE

Scientific papers

The main format for distributing new research results is as articles in research journals that are known as scientific *papers*. These journals are used instead of books as the main forum for reporting new research. Papers describe careful, painstaking work in depth. The wording is very precise, detailed and dry.

Papers are subjected to a careful independent checking and verification process called refereeing before they are accepted. This should ensure that the work described in papers is accurate, at least given clearly stated practical constraints on the research carried out.

A paper uses a standard form that consists of: an abstract (a brief summary of the main results); an introduction (an overview of the field, a summary of important previous papers and why the new work has been done); a number of sections describing the new work, the methods and results; a discussion; conclusions; acknowledgements; and references containing the papers cited in the paper.

Previous papers that are referred to in a paper are known as *references*. When a paper is referred to in later papers, these later references to it are known as *citations*. The number of citations a paper gets is often used as a measure of its importance.

Review Volumes

A number of journals are published which contain only reviews. These consist of critical reviews of research fields, with each article discussing a particular detailed subject. These give detailed consideration of past research papers. Examples are the *Annual Review of Astronomy and Astrophysics*, and the *Annual Review of Earth and Planetary Sciences*.

Conference Proceedings

Major international academic conferences often produce a book-sized volume containing summaries of the proceedings. They often include some very useful reviews of particular fields. There are many short write ups of recent research based on conference talks or poster papers. However, the material in proceedings is usually not subjected to the same level of independent checks as journal papers.

Textbooks

Textbooks present overviews of broad fields. They are mostly concerned with standard background material, rather than cutting-edge developments. They give limited coverage of research issues.

Examples of astronomical journals

Astronomical Journal
Astronomy and Astrophysics
Astrophysical Journal
Icarus
Monthly Notices of the Royal Astronomical Society

High-profile general scientific journals

Nature
Science

Where to Access the Research Literature

Paper versions

Academic journals, review volumes, conference proceedings and textbooks are available in printed form in selected university libraries. These subscriptions to these printed versions are expensive. The Queen Mary, University of London, library stocks a wide range of these publications on the first floor.

Journal websites

The development of the web has transformed access to research literature. All journals have websites with electronic copies of journal articles as HTML pages, as PDF files, and as postscript format files. A subscription is generally needed to be able to access recent editions, although the Athens systems can provide access to the academic community. University library subscriptions generally provide access to electronic copies for users in those institutions. We have access to a wide range of journals over the web from inside Queen Mary, University of London.

The NASA ADS

A fundamentally important web resource is the NASA Astrophysics Data System (ADS) based in Harvard at <http://adswww.harvard.edu/> (with mirrors available in Nottingham and Strasbourg among other places). This provides an enormous database of research papers in astronomy and related sciences, including full references, author lists, titles and even abstracts. It is easy to search for papers by particular authors within specified publication dates, or alternatively, papers that have particular words and phrases in their titles or abstracts. Each recent paper in a major journal that is listed in the ADS has a link to a copy on the journal's web page. This makes the astronomical literature very easy to access.

Even better still is the set of scans of research journals published up to 1996. The ADS has digitised all front-rank astronomical research journals up to this date. In the case of the Monthly Notices this means that there are scans of each page dating back to the 1820s!

The astro-ph preprint archive

Advance copies of research papers that have been accepted for publication in journals are issued as *preprints* to provide an early release of information. Astrophysics preprints are deposited in the astro-ph archive available over the web at

<http://www.arxiv.org/archive/astro-ph> (with a U.K. mirror available in Southampton at <http://uk.arxiv.org/archive/astro-ph>). This provides free access to research results, without the need for the expensive subscriptions required by journals.

These are numbered by a numerical sequence in each month of each year. The first preprint deposited in October 2005 (the 10th month of 2005) was astro-ph/0510001. There is free access for depositing material, which means that there is a wide variation in the quality of the material deposited. This ranges from papers that have passed the rigorous checks of journals, through conference proceedings articles, to a small number of private reports that would never be accepted for publication in a journal.

FINDING INFORMATION ON GENERAL SCIENTIFIC ISSUES

There are several places we can look for information when we have a particular question on an astronomical subject. The most important of these are:

- the web,
- textbooks,
- the research literature (available in printed form and over the web).

Which of these we use will depend on the question and its depth. The starting point for searching for information is to define the question behind the search: you will need a clearly defined objective before starting the search.

Obtaining Information from the Web

The web contains a vast amount of information of varying quality. It can be excellent for general information and up-to-date results. It can be good for reviews of a subject or field. Some useful directories of astronomical websites exist. One example is our own list of internet astronomy resources on the website of the Queen Mary Astronomy Unit (<http://www.maths.qmul.ac.uk/Astronomy/about/links/>).

The quality of the material on the web ranges from excellent to complete rubbish, and judging the quality is essential to using web resources properly. Important factors in assessing the reliability are:

- **Where** does it appear? Websites of reputable organisations, such as research institutes, are likely to have information written by experts in their fields and to have been checked by other scientists. Therefore we might expect information on the websites of the European Space Agency, NASA and the European Southern Observatory, for example, to be reasonably reliable. We might doubt the reliability of material on the websites of organisations we have not heard of before.

- **Who** wrote the information? Was it written by an experienced scientist? If so we might have reason to believe it to be reasonably reliable. Was it written by a journalist. If so, the material might be reasonably reliable if it was written by a specialised science journalist, much less so by someone with only casual experience of a field. Might the material have been written by someone who knows little about the field? Even worse, might it have been written by a crank who sounds opinions without having taken the trouble to read and understand the background of the subject?

- **When** was it written? Is the material current or out of date? Does this matter for the case you are interested in?

Textbooks

University libraries have a broad range of textbooks. These are excellent for summaries of broad, general subjects that are well-understood. However, they rarely consider current research activities.

The research literature

The NASA Astrophysics Data System (see above) provides an easy, quick tool for finding research papers. The astronomy query form allows the database to be searched for papers matching particular criteria. If you have a reference to a particular paper that you want to chase up, typing some of the author names and the year of publication into the query form will quickly find the paper (remember to click the “and” option if more than one author is specified, and to put the year of publication in both date boxes).

More general queries of the database can be made by typing important words in the title or abstract boxes (selecting the correct option between “or” and “and”). However, this can often produce very large numbers of papers.

HOW TO WRITE A RESEARCH PAPER

Writing Style

Research papers must be written in a precise, accurate, detailed, but quite brief, style. A passive voice is usually adopted, stating that “The analysis was done using the IRAF software package” rather than “We did the analysis using the IRAF software package”. References to other papers and publications are used regularly. Full credit must be given to other people if their work is used. If you need to state the details of a method, refer to a publication where it has already been described, rather than repeat the description at length.

Authors of research papers need to justify in writing the decisions they have made. For example, why data were taken from one particular source than from another, why one method was preferred over another, or why previously published results from one author are preferred to those from another. Conclusions should be discussed accurately and honestly: care must be taken not to overinterpret results because you favour one particular outcome over another. The text should be phrased carefully to avoid making unjustifiable or unwarranted claims, for example by stating “Given the evidence from the available statistical samples, it is likely that ...” rather than claiming that something is definitely true if there is still a little uncertainty about it.

What to Write

At the outset, an author has to be clear about the objective: why and what is to be told. This is an *essential* starting point.

If ideas are set out haphazardly, they will have little impact on readers and will be ignored. There must be a clear structure to the paper and at its most simple it is: beginning, middle and end.

Prompts for Reading an Article

What is being done? What is described?

What is new?

What is important? Why?

Are there any caveats?

What is next?

What is new?

What do I need to find out about?

Beginning

Title: A good, clear title will orientate the reader. A title that gives too little detail will not differentiate the paper from others on related subjects. If the title is too detailed there is a risk that the reader will be overwhelmed with information.

Abstract (Summary): The abstract provides a summary of the paper and its results. It should be sufficient for a reader to tell whether the paper is of interest to them and is worth reading in detail. It must be descriptive and informative.

Introduction: The Introduction should provide the context of the research study. It will review the field and summarise what has previously been discovered. It will say why the new results are important. It will provide a summary of the paper and explain the structure of the paper. The Introduction usually forms Section 1 of the paper.

The Middle Ground

This is where the main part of the work is presented. It must have a logical structure and be broken down sensibly into sections and subsections. The basic data or method might form one section. Another section might present the analysis of data and another would present the results. Another section might then present a discussion of the results.

The way the paper is broken down into various sections will depend on the work described, as will the number of sections used.

The End

Conclusions: The main results can be summarised in the Conclusions section. It should specify the limitations on the quality of the work, for example those imposed by too little computing time, by too little observing time, by a lack of suitable instrumentation, and by an inadequate understanding of important parameters that are used in the analysis. The Conclusions will also state future perspectives, such as possible future work and recommendations for how future research should be carried out.

Acknowledgements: A short section can thank people who have helped with the work who are not actually authors. It can thank financial sponsors (e.g. a research council). It can state that certain public databases or software were used.

References: The References or Bibliography section gives the full references for the publications cited in the paper. Individual journals are often abbreviated in a journal's own style.

The structure can be summarised as “IMRD”: Introduction, Method, Results, Discussion.

Illustrations and tables are crucially important. They can provide information that cannot be stated easily in words. Graphs are particularly important in understanding results. Tables can list important numerical results.

How to Publish a Research Paper

Getting a scientific paper published in a journal involves going through a procedure consisting of several distinct stages. The standard procedure is summarised here.

(1) The first stage involves writing a first version of the paper and agreeing its contents with all the authors. Great care must be taken to ensure that the wording is correct, it is clearly written, precise and accurate. The article must be logically laid out. The format of the paper must conform to the journal's own standards. The article is usually typeset using the LaTeX word processing package, using a style file supplied by the journal's publishers. LaTeX allows equations to be incorporated into the text relatively easily, while also allowing figures (i.e. graphs and illustrations) and tables to be included. The body of the paper is contained in a single LaTeX .tex computer file with figures in separate data files (usually in a format known as encapsulated postscript format). Journals usually also accept papers in Microsoft Word format or printed on paper. LaTeX has the advantage that it produces a version suitable for distribution in a consistent form, while LaTeX style files allow the draft version to follow the formatting style of the research journal.

(2) The paper is then submitted to the journal, usually electronically using a web form, by e-mail or by FTP. It is then considered by the journal's Editorial Board, which will decide whether the paper appears appropriate for the journal in terms of style and scientific content: some papers are rejected at this stage. The Editorial Board will select an expert referee to review the paper. The journal will then approach the referee and if the referee is prepared to consider the paper, a copy will be sent to him/her. The referee will study the paper in detail and will send a *referee's report* back to the journal's Editorial Board. The report will state whether the paper is any good and why. It will include an assessment of whether the paper is suitable for publication. The referee may decide that the paper is not suitable for publication and will reject the paper outright. The report will make a detailed critique, section by section, subsection by subsection, which may be many pages long. The report will judge whether the paper makes appropriate references to other research work. It will specify what changes need to be made to the paper to make it suitable for publication.

The main part of the referee's report is then sent to the authors. The name of the referee is not disclosed to the authors unless the referee requests that it is: this is *anonymous refereeing*. The authors therefore receive a set of detail criticisms of their work from another scientist, who is unnamed, and who might even be a competitor of theirs.

(3) The authors will respond to the referee's comments by revising the paper and making detailed responses to each of the referee's points, provided of course that the referee has recommended that the paper is suitable for publication after revisions. This often requires much extra work. The analysis often has to be redone.

The revised paper and the response to the referee's comments are then sent back to the journal. The journal forwards them to the referee for further consideration. The referee decides whether the paper is now suitable for publication. This process continues iteratively until the referee recommends that journal can publish the paper.

(4) The authors often issue a preprint once the paper has been accepted for publication. Today this usually means depositing the preprint in the astro-ph archive (<http://www.arxiv.org/archive/astro-ph>). Some authors, however, choose to submit a copy of their paper at the time it is first submitted, a slightly controversial practice.

(5) The publisher of the journal will send proofs to the authors for checking. This is an early form of the version of the paper that will appear in the printed journal. The publisher will also send a bill to the authors for page charges, if the journal is one that demands that authors pay to publish. Some journals do not charge authors for publishing (and therefore those journals are more expensive for libraries to buy).

(6) The paper is finally published.

This process involves *peer review*: another researcher reviews the work of the authors. It provides the quality control that is critical in ensuring that scientific papers reach a basic standard of reliability. The process should ensure that published papers make a significant contribution to research and that the results are correct, or as near to being correct as is possible given the practical limitations on resources/facilities.

The time from submission to publication can vary from a few months to two years. Some modes of publishing are quick: for example short papers (2–4 pages in length) in the *Astrophysical Journal Letters*, or letters in *Astronomy and Astrophysics*. Longer papers in main journals are slower. The high-profile journal *Nature* uses two independent referees: both must be enthusiastic for a paper to be accepted for publication.

WRITING RESEARCH REVIEWS

Reviews of the research literature provide an overview of the current state of knowledge in some particular field. Reviews are published in dedicated review journals, such as the *Annual Review of Astronomy and Astrophysics* and the *Annual Review of Earth and Planetary Sciences*. Conference proceedings often contain reviews, but some authors sometimes tilt these towards their own work. The proceedings of summer and winter schools often contain useful reviews. Some journals, such as *Nature*, carry occasional review articles.

Review articles need to be balanced. They must try to be fair and impartial. They must try to treat all authors fairly. An author must study all relevant research papers. This means reading the abstracts of many papers, scanning through papers of some moderate relevance to the subject of the review, and reading all papers of importance thoroughly.

Writing a review therefore requires a lot of hard work. The NASA Astrophysics Data System is invaluable. SIMBAD can be used to find papers that refer to individual astronomical objects (individual stars, nebulae or galaxies). The NASA Extragalactic Database is invaluable for subjects outside our Galaxy.

To start a review, an author should establish the most important papers in their subject. Introductions of papers can be very helpful in this. The author must of course determine what has been done in the field. But equally, the author should find out what has not been done and establish why: perhaps the work would be too difficult theoretically, perhaps it would require an impractical amount of observing time, or perhaps the necessary instruments do not exist. The author must refer to individual studies by referencing published papers.

There will be conflicting results in many cases. Different, incompatible results will be found in one paper compared with another. There may be different opinions in the research community, with different camps. The author might reflect their own opinions, but must try to be *impartial*.

WRITING MSC REPORTS

The style required for Astrophysics MSc reports at Queen Mary involves a detailed literature review, plus sections detailing any additional new research. Some MSc dissertations provide only a literature review.

Typically, the MSc report will have an introductory chapter which will give the background to the field, the history, an explanation why it is important, and a discussion of its relevance to astrophysics and science in general. The second might follow the style of a textbook, explaining basic, well-understood concepts.

The main literature review will present a detailed review of the literature. It will go far beyond textbook level, dealing with concepts that may be controversial and which are not well understood. It will refer to important papers and give their main results. It will show how the field has developed over time. Differing opinions will be given. It must be a critical review, detailing deficiencies in current knowledge. It will also discuss the deficiencies in individual papers. The review might present detailed discussions of some important recent papers, stating the limitations of those papers. The MSc student should understand why the authors of these papers have not gone further than they did, and what future research could be done and how.

Research sections of the dissertation should follow the style of research papers described earlier. Research methods should be described in detail.

The assessment of an MSc dissertation looks for intelligence, a balanced approach and an in-depth knowledge of the research literature.