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Internet Resources for Astronomers Worldwide

George Helou

IPAC, Mail Code 100-22, California Institute of Technology, 1200 E. California Blvd, Pasadena, California 91125, U.S.A. e-mail: gxh@ipac.caltech.edu

Abstract. On today's Internet, resources for astronomical research abound, and are available from wherever a connection is available. These are mostly in the form of freely accessible databases, ranging from literature services to space-mission archives. They offer instant access to the latest published data and papers, and unique opportunities for archival and innovative research. A sampling of such services will be listed, with notes on accessibility from far-flung points on the planet.

1. Overview

Internet-based resources are now an integral part of the research tools of astronomers, just as they are an essential element of international business and information flow. They can also be an invaluable tool for instruction in the sciences at all levels from grade school to college. These resources are unique in that they are readily accessible from wherever an internet connection is possible, and are free of charge in the overwhelming majority of cases.

There is quite a proliferation of these resources today, covering all wavelength ranges from γ-rays to the radio, and all areas of research from planetary science to cosmology. They can be generally assigned to one of three main categories.

- Databases and data services, offering primarily catalogs and sky images from surveys covering part or all of the sky, at any number of wavelengths across the electromagnetic spectrum. Prominent examples are the Digital Palomar Sky Survey data server at NASA's Space Telescope Science Institute (STScI) in the U.S.A. at http://archive.stsci.edu/dss, the Two Micron All-Sky Survey (2MASS) data server at NASA's Infrared Processing and Analysis Center (IPAC), U.S.A. at http://www.ipac.caltech.edu/2mass/overview/access.html, or the variety of catalogs accessible at the Centre de Données de Strasbourg (CDS) in France at http://cdsweb.u-strasbg.fr.

- Data archives from space missions or ground-based observatories, distinguished from the above by their origin as a series of targeted observa-

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tions rather than an unbiased survey. Examples include the Infrared Space Observatory (ISO) archive at ESA's ISO Data Center in Spain at http:/www.iso.vilspa.esa.es, and the collection of mission archives at NASA's High Energy Astrophysics Science Archive Research Center (HEASARC) at http://legacy.gsfc.nasa.gov

- Information services with extensive links to the literature for instance, or to other archives and databases. Examples include the NASA-funded Astrophysics Data System (ADS), for biliographies, at http://adswww.harvard.edu, the NASA/IPAC Extragalactic Database (NED) at IPAC at http://nedwww.ipac.caltech.edu, and the SIMBAD service in Strasbourg, France at http://cdsweb.u-strasbg.fr/Simbad.html.

Most of these services are straightforward to use, and reasonably well documented, so that practising astronomers or physicists ought to be able to obtain what data they seek within a reasonable level of effort. There are a few websites from which one can branch out to a large number of these services, such as the Space Science Data System (SSDS) page at http://ssds.nasa.gov. One example the author is particularly familiar with is the IPAC main page http://www.ipac.caltech.edu, from which one can access services of all three types above, as well as many other similar services around the world. In particular, 2MASS offers a data set with tremendous untapped potential for research and discovery.

2. Access and Exploitation

Access to the Internet and its resources offers instant access to the latest published literature and data. The new paradigm of astronomical research stresses electronic journals and data sets, with the internet itself serving as the library. Journal subscriptions are increasingly paperless, meaning they consist of data access rights to current issues rather than paper copies sent by mail. Back issues of most journals can even be accessed free of charge, including the full detail of their articles. Archives of space and ground-based observatories are placed on-line, and the data are retrievable without need for shipping tapes. The only serious limitation is bandwidth, and this is constantly improving.

Access to these resources presents unique opportunities for archival and creative research, and for training and education. On the research side, it is well known that only a small fraction of the useful science content in data archives gets published in the first two to three years of the data's existence, leaving room for much innovative data analysis and interpretation. In addition, cross-archive comparisons can yield truly exciting results, and even a smaller fraction of these potential results are ever pursued or published. On the training side, exposure of undergraduate students to data sets and archives is an excellent preparation, as well as a motivating force for further education and research. Most of the websites mentioned above include an "education and outreach" section, which can be very valuable as a teaching resource in schools at various levels.

Apart from the direct data and information resources it represents, the Internet is a powerful medium for collaborations in research and education. Unhampered by borders, it can bring together teams of researchers in multiple

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developing countries, or establish bridges between these and their colleagues in industrialized countries.

Some of the data services listed above provide interfaces that are less demanding in terms of technical requirements at the user end, and in terms of required bandwidth. For instance, one can use NED in e-mail mode, or use an interactive interface based on ASCII characters and VT-100 displays, accessible by invoking telnet ned.ipac.caltech.edu. The lower bandwidth requirement is a particularly valuable aspect of such interfaces, and it is a consideration for all users, not just those in developing countries. Feedback to the service providers from all users, regardless of their geographic location, on the value of these less demanding interfaces is important to ensure that the teams providing the services do continue to support them.

3. Conclusions

The Internet has revolutionized many areas of human activity, from business to politics. It has changed dramatically the practice and opportunities of science in industrialized nations, touching equally all aspects from education to research. The Internet has the potential to bring similar changes to science, and more especially astronomy, in developing countries. The only significant threshold is the availability of access to the Internet. Scientists sometimes prefer not to make on-line resources their primary source of research material. Even then, they could ill afford to ignore the Internet as a way to access current literature, data and information in order to place their research in the context of existing knowledge. Just like the sky is there to be observed, the electronic Universe is there to be studied or simply consulted, but definitely not to be ignored.

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Discussion

Corbin remarked that "free library access" for the current year and the two immediately preceding years is usually only available to those whose library has paid the full electronic subscription – which is the same or only a little less than the paper subscription. This is unfortunate for astronomers in most developing countries since it is difficult for them to have access to the current literature, except for the abstracts. Helou agreed that it is still expensive to access the full texts of current articles, because journals operate on a business model. However, the Internet can speed up access, once the subscription is paid and circumvent the delays and hazards to which paper copies shipped by mail are subject.

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