

Arecibo and the Virtual Observatory

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Abstract

The United States Virtual Observatory was established in 2001 to provide worldwide access to data acquired by U.S. observatories, including Arecibo Observatory at the National Astronomy and Ionosphere Center in Puerto Rico. Arecibo's 7-element L-band Feed Array (ALFA) is being used to survey line and continuum radiation over large areas of the 21cm-wavelength sky. Two surveys were the focus of this project: the Galactic interstellar medium HI 21cm line survey (GALFA) and the Arecibo Galaxy Environment HI Survey (AGES). Both surveys are producing large volumes of data in "cubes" of intensity as a function of right ascension, declination, and line-of-sight Doppler velocity. An essential objective of both GALFA and AGES is to make the data available over the World Wide Web. This will require a user interface that returns the appropriate cube for a given set of coordinates, or computes a new cube on the fly covering a desired coordinate range. To implement this service, computationally efficient processing and serving methods are required. This presentation will discuss the current methods used for remote data access as well as new methods that can be used to analyze data cubes online with web tools.

Defining the Problem

A primary goal of both the AGES and GALFA surveys is to make the data available to users on the World Wide Web through the Virtual Observatory. The US-VO gives scientists the option to:

1. Upload spectra and 2D images into repositories
 - Require data to be in fits or VOTable format
2. Register archives with the VO.
 - VOTable format is preferable but not required
 - Does not fully support 3D data

It also has a number of programs used to analyze data in VOTable format. **The US Virtual Observatory does have plans to implement standards regarding data cubes which are not yet in place.** The only option is to serve the data cubes from a remote host and register the coordinates with the Virtual Observatory. This presented a number of problems:

- How to Index and allow users to Search Data Cubes
- What sort of computer hardware will be needed to serve data?
- What types of services does Arecibo want to offer?
 - 3D cut out?
 - 2D projection?
 - Allow the User to specify any data range?

Data Cube Query

To allow users to search for a given coordinate (RA, DEC, Velocity) in a data cube the coordinates of each data cube were entered into a database. The data cubes are indexed by their center point. MySQL was used to create and query the databases. Perl searches for a cube whose center point is within 1.499 degrees of the user's coordinate.

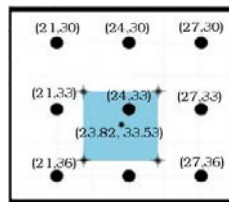


Figure 4 Data Cube coordinate search

Future Considerations

Potentially while returning the correct url for downloading the correct data cube more options for cube manipulation could be presented to the end-user.

ALFA, GALFA and AGES

The Arecibo L-Band Feed Array (ALFA) is a seven feed system that can be used for wide sky surveys with very high sensitivity which was all but impossible in the past. The system makes use of the 305 meter radio telescope at Arecibo Observatory in Puerto Rico, currently the largest radio telescope in the world. The ability to do surveys using telescopes in the past has been limited due to a small field of view. However, ALFA, which is made up of a cluster of seven cooled dual-polarization feeds, a fiber-optical transmission system, and digital back-end signal processors and operates around 1.4 GHz, is well suited to take on large-scale deep surveys.

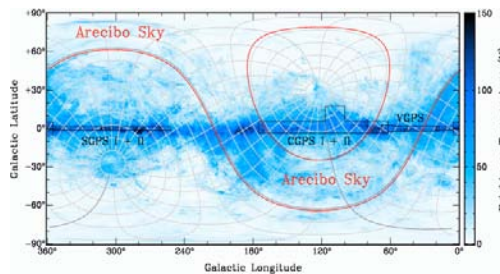


Figure 1 Image of Arecibo sky and range of ALFA

Two of the surveys which currently make use of ALFA are the Galactic interstellar medium HI 21cm line survey (GALFA) and the Arecibo Galaxy Environment HI Survey (AGES). Both surveys are producing large volumes of data in "cubes" of intensity as a function of right ascension, declination, and line-of-sight doppler velocity.

References/Support: ¹Kalbera et al. and S.Gibson ²J.R. Graham et al. "The Performance and Scientific Rationale for an Infrared Imaging Fourier Transform Spectrograph on a Large Space Telescope"

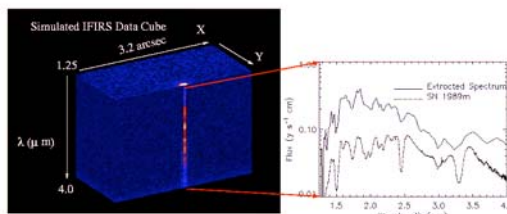


Figure 2: A data "cube" is a method of storing data of intensity values in a 3 dimensional (or higher) array. AGES and GALFA are both producing a large number of data cubes that are as large as 5 gigabytes in size. The coordinates are indexed by their right ascension, declination and line-of-sight doppler velocity.

Common Gateway Interface (CGI)

After a user submits a coordinate via the web interface a series of processes happens:

1. The command is forwarded to a CGI program written in Perl.
2. The CGI program queries the MySQL database searching for the data cube which contains the given coordinate.
3. The correct cube along with the cube's location on the server is returned on a new website to the user.

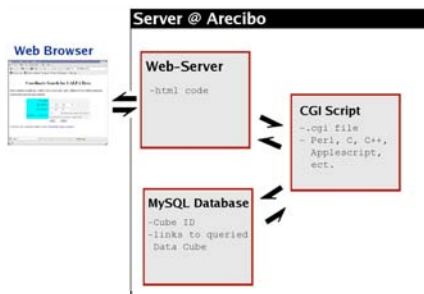


Figure 3 Data transfer between Server at Arecibo and a remote user

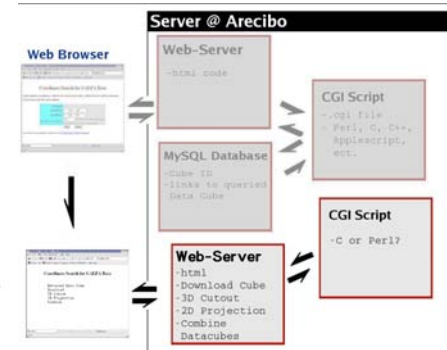


Figure 5 After correct Data Cube is located more options for Data query could be available.

Analyzing Data Cubes on the fly

There are a number of services that one could wish to provide for end-users.

- 3D cut out
 - Allow users to cut out a specific data range on the fly from a larger cube
- 2D projections
 - Collapse one dimension of a 3D data cube to a 2D intensity array
- 2D cut out, 1D cutout
 - Similar to a 3D cutout, one or two dimensions are one unit in length
- Unlimited data range query
 - Combine smaller data cubes and then cutout a user specified coordinate range.

Programs
Mirage, Aladin

Summary

The Virtual Observatory allows users to register their 3D data; better standards are being developed to allow users to search data using a three dimensional coordinate system. GALFA and AGES surveys plan on implementing these services. The development of the Virtual Observatory will be a great benefit to scientists, educators and students.