

## Grist: Grid-based Data Mining for Astronomy

Joseph C. Jacob, Daniel S. Katz, Craig D. Miller, Harshpreet Walia  
*Jet Propulsion Laboratory, California Institute of Technology,  
Pasadena, CA 91109-8099*

Roy Williams, S. George Djorgovski, Matthew J. Graham, Ashish Mahabal  
*California Institute of Technology, Pasadena, CA 91125*

Jogesh Babu, Daniel E. Vanden Berk  
*The Pennsylvania State University, University Park, PA, 16802*

Robert Nichol  
*ICG, University of Portsmouth, PO1 2EG, UK*

**Abstract.** The Grist project is developing a grid-technology based system as a research environment for astronomy with massive and complex datasets. This knowledge extraction system will consist of a library of distributed grid services controlled by a workflow system, compliant with standards emerging from the grid computing, web services, and virtual observatory communities. This new technology is being used to find high redshift quasars, study peculiar variable objects, search for transients in real time, and fit SDSS QSO spectra to measure black hole masses. Grist services are also a component of the “hyperatlas” project to serve high-resolution multi-wavelength imagery over the Internet. In support of these science and outreach objectives, the Grist framework will provide the enabling fabric to tie together distributed grid services in the areas of data access, federation, mining, subsetting, source extraction, image mosaicking, statistics, and visualization.

### 1. Overview

The Grist<sup>1</sup> project (<http://grist.caltech.edu/>) is enabling astronomers and the public to interact with the grid projects that are being constructed worldwide, and bring to flower the promise of easy, powerful, distributed computing. Our objectives are to understand the role of service-oriented architectures in

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astronomical research, to bring the astronomical community to the grid – particularly TeraGrid, – and to work with the National Virtual Observatory (NVO) to build a library of compute-based web services.

The scientific motivation for Grist derives from creation and mining of wide-area federated images, catalogs, and spectra. An astronomical image collection may include multiple pixel layers covering the same region on the sky, with each layer representing a different waveband, time, instrument, observing condition, etc. The data analysis should combine these multiple observations into a unified understanding of the physical processes in the Universe. The familiar way to do this is to cross-match source lists extracted from different images. However, there is growing interest in another method of federating images that reprojects each image to a common set of pixel planes, then stacks images and detects sources therein. While this has been done for years for small pointing fields, we are using the TeraGrid to perform this processing over wide areas of the sky in a systematic way, using Palomar-Quest<sup>2</sup> (PQ) survey data. We expect this “hyperatlas” approach will enable us to identify much fainter sources than can be detected in any individual image; to detect unusual objects such as transients; and to deeply compare (e.g., using principal component analysis) the large surveys such as SDSS, 2MASS, DPOSS, etc. (Williams et al. 2003).

Grist is helping to build an image-federation pipeline for the Palomar-Quest synoptic sky survey (Djorgovski et al. 2004), with the objectives of mining PQ data to find high redshift quasars, to study peculiar variable objects, and to search for transients in real-time (Mahabal et al. 2004). Our PQ processing pipeline will use the TeraGrid for processing and will comply with widely-accepted data formats and protocols supported by the VO community.

## 2. Service-Oriented Architectures for Astronomy

The Grist project is building web and grid services as well as the enabling workflow fabric to tie together these distributed services in the areas of data federation, mining, source extraction, image mosaicking, coordinate transformations, data subsetting, statistics – histograms, kernel density estimation, and R language utilities exposed by VOSTatistics<sup>3</sup> services (Graham et al. 2004), – and visualization. Composing multiple services into a distributed workflow architecture, as illustrated in Figure 1, with domain experts in different areas deploying and exposing their own services, has a number of distinct advantages, including:

- Proprietary algorithms can be made available to end users without the need to distribute the underlying software.
- Software updates done on the server are immediately available to all users.
- A particular service can be used in different ways as a component of multiple workflows.
- A service may be deployed close to the data source, for efficiency.

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<sup>2</sup><http://www.astro.caltech.edu/pq/>

<sup>3</sup><http://vostat.org/>

Interactive deployment and control of these distributed services will be provided from a workflow manager. We expect to use NVO services for data access – images, catalogs, and spectra – as well as the NVO registry for service discovery.

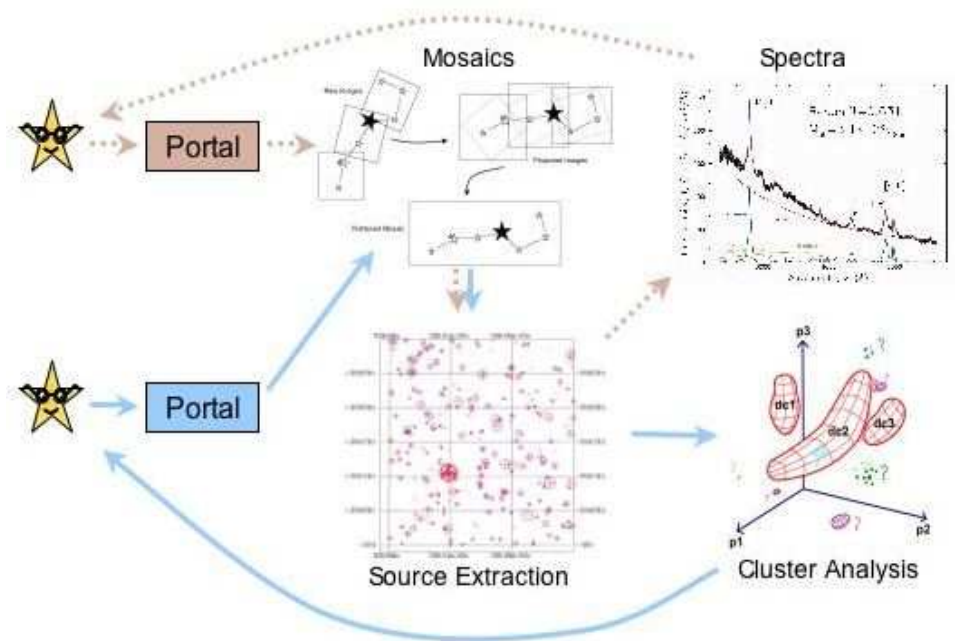


Figure 1. Grist will deploy a library of interoperable services, which may be composed in different ways for astronomical data mining (e.g., two distinct workflows are indicated by the solid and dashed arrows).

### 3. Graduated Security

As described in Section 2., much of the pipeline and mining software for Grist will be built in the form of web services. One of the reasons for building services is to be able to use them from a thin client, such as a web browser. However, for such services to be able to process private data or use high-end computing, there must be strong authentication of the user. The VO and Grid communities are converging around the idea of X.509 certificates as a suitable credential for such authentication. However, most astronomers do not have such a certificate, and we don't want to make them go through the trouble of getting one unless it is truly necessary. Therefore, we are building services with “graduated security”, meaning not only that small requests on public data are available anonymously and simply, but also that large requests on private data can be serviced through the same interface. However in the latter case, a certificate is necessary. Thus the service “proves its usefulness” with a simple learning curve, but requires a credential to be used at full-strength (see illustration in Figure 2).

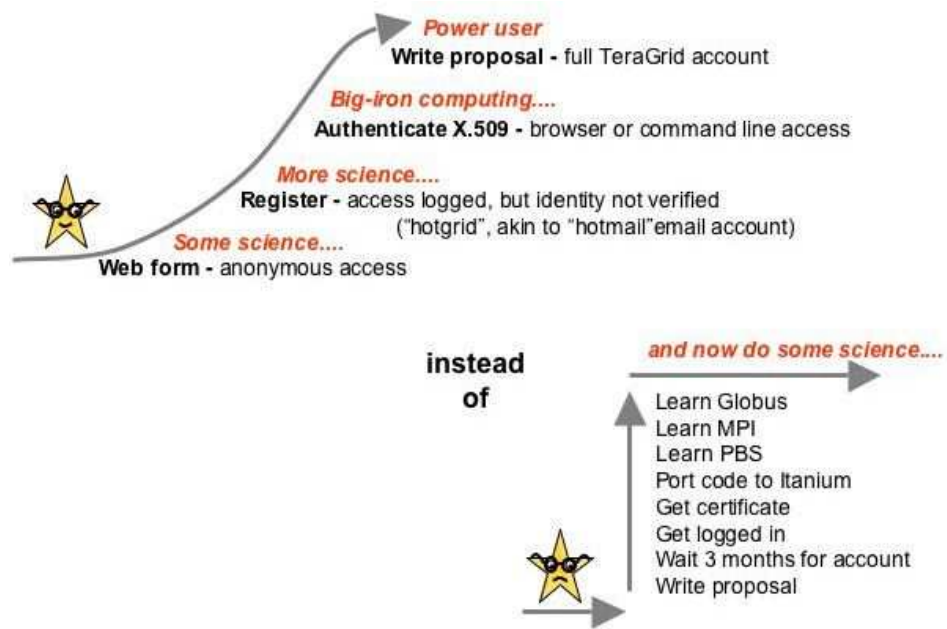


Figure 2. “Graduated security” will shorten the hurdles that stand in the way of scientists who would like to take advantage of the power of computational grids for their research.

#### 4. Palomar-Quest Data Mining

A key science-driven workflow we are constructing is illustrated in the schematic in Figure 3. The primary objectives are to search for high redshift quasars and optical transients in data from the Palomar-Quest sky survey. The pipeline begins by federating multiwavelength datasets, and matching objects detected with the  $z$  filter with catalogs at other frequencies. Cluster analysis performed on the resulting color-color plots (e.g.,  $i-z$  vs.  $z-J$ ) yield new quasar candidates, and outliers may indicate the presence of other objects of interest.

Single epoch transients are indicated by objects that are detected in one filter but not others. An object that is detected in the reddest filter is of special interest since it could be a highly obscured object or a high redshift quasar. For multi-epoch transient search, illustrated in the lower part of Figure 3, we compare new data with a database of past epochs to detect new transients or other variable objects.

As described above, a primary objective of the PQ survey is the fast discovery of new types of transient sources by comparing data taken at different times. Such transients should be immediately re-observed to get maximum scientific impact, so we are experimenting with “dawn processing” on the TeraGrid, meaning that data is streamed from the telescope to the compute facility as it is taken (rather than days later). The pipeline itself is being built with streaming protocols so that unknown transients (e.g., newly identified variables or asteroids) can be examined within hours of observation with a view to broadcasting an email alert to interested parties.

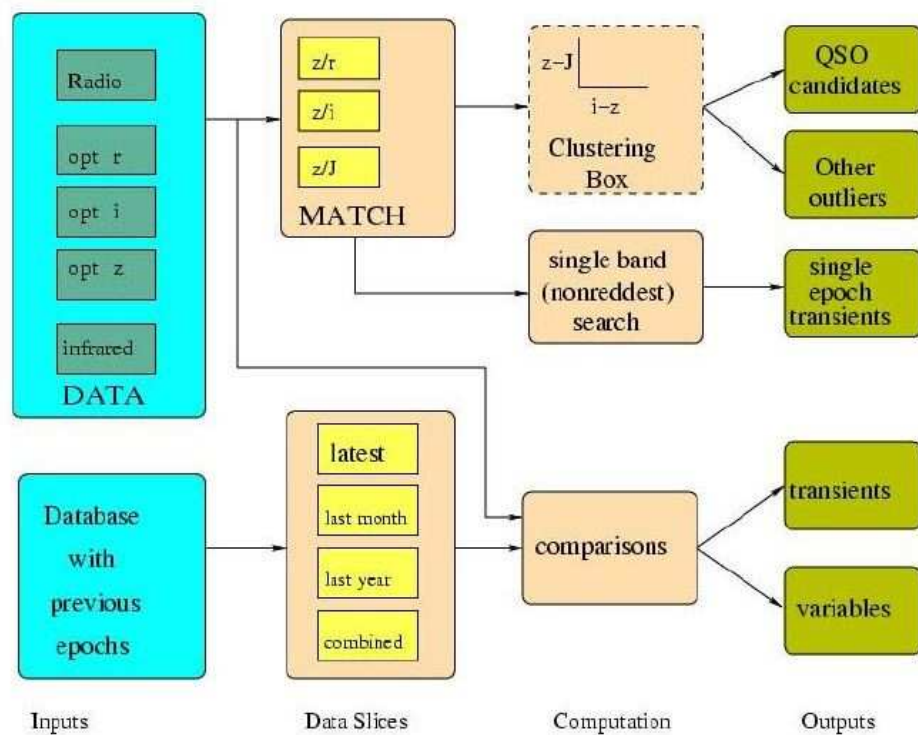


Figure 3. A schematic pipeline to look for quasars, transients and other variables. Combining multi-filter information with multi-epoch datasets through a set of well established techniques will yield a rich set of astronomically interesting objects.

## 5. Summary

Grist is developing a library of interoperable grid services for astronomical data mining on the TeraGrid, compliant with Grid and VO data formats, standards, and protocols. For ease of use, Grist services are built with graduated security, requiring no more formal authentication than is appropriate for a given level of usage. Grist technology is part of a Palomar-Quest data processing pipeline, under construction, to search for high red-shift quasars and optical transients. More information on Grist can be found on our project web site at <http://grist.caltech.edu/>.

## References

- Djorgovski, S. G., et al. 2004, BAAS, 36, 805  
 Graham, M. J., et al. 2004, this volume, [P1.2.7]  
 Mahabal, A., et al. 2004, this volume, [P2.2.7]  
 Williams, R. D., et al. 2004, in ASP Conf. Ser., Vol. 295, ADASS XII, ed. H. E. Payne, R. I. Jedrzejewski, & R. N. Hook (San Francisco: ASP), [O4-3a]