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US VAO Facility for Rapid Transients

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Abstract. The US VAO Facility for Rapid Transients (if funded) will collect and disseminate observations about time-critical astronomical transients, and add annotations and intelligent machine-learning to those observations. The information can be "pushed" to subscribers, who may be either humans or machines that control telescopes. Subscribers can prepare precise "triggers" to decide which events should reach them and their machines, that may be based on the generic event, or on the specific vocabulary of parameters that define a particular type of observation. The system will not be centralized, but rather a set of interoperating nodes with caching. The twin thrusts are automation of process, and discrimination of interesting events.

An important qualitative change is happening in astronomy. The ability to survey large areas of the sky deeply and repeatedly, and to process the data in real time, has opened a whole new field of research: time domain astronomy. The sky is now studied as an ever-changing collection of dynamical phenomena, with moving objects and objects that change in brightness, or appear in an explosive manner. Many of these phenomena can be understood only through time-domain studies, and often require a rapid follow-up using a variety of ground-based telescopes.

Events are Universal: The ideas here apply not just to astronomy, but in other areas of society where events must be followed by rapid, often expensive actions. For example, earthquake early warning systems could shut down elevators, computers, etc, in the seconds between detection and the time the earthquake waves need to propagate. A geiger counter at a homeland security installation scans cargo, and issues events, whose importance is compared with warnings from other sources, and may trigger a manual inspection. A power or data network must respond to reports from multiple sources to detect unusual events, and bring in a human to evaluate. In all cases, it is good to keep the data and those evaluations in a structured manner (*portfolio*).

This facility has been proposed as part of the Virtual Astronomical Observatory, a pending proposal with the US NSF and NASA. We see this "VORapid" facility implementing several components. In each of the following, it is implicit that there will be both a human-facing interface, and a machine-facing (service) interface.

The components are:

- A web-based broker, allowing subscription, with events delivered in near-real time.
- A web-based publishing system, so that authenticated users can inject events.
- An event repository, allowing bulk queries and drill-down.
- An interoperable event broker, conforming to IVOA standards for event handling.

We will first build a prototype system that scales up to many different event streams, and scales to large numbers of events, large numbers of event authors (streams), and large numbers of event subscribers. The new system will work well with amateur astronomers and students, as well as professional astronomers scheduling follow-up on the big NSF-funded telescopes, operated by NOAO and its partners, or on the emerging world-wide robotic telescope networks. Some challenges for the facility will be:

Generality: Many new event streams are coming online or are planned for the future. Thus, it is time to deploy a system that can work with events in general, rather than a custom solution for each survey or spacecraft. The system should encourage adoption of a standard framework and interoperability, avoiding duplication of effort in implementing similar systems.

Subscription: From the web interface, subscribers can arrange to get event packets immediately ("pushed"). Users will build an "alerts" consisting of a trigger and an action. Whenever an event is injected, it is tested against the trigger, and if it passes, then the action occurs. Actions can be messaging (email, IM, robotic telescope), fetching from archives, or running a computation. One objective of VORapid is to encourage robotic follow-up in near real time to catch the most exciting, largely unknown, physics of rapid transients. Once such observations are made, we will encourage submission of that data to VORapid as events, which will be added to the web page for the original event, and of course the follow-up event can be sent to subscribers and other event brokers.

Authoring: Authors of events build semantic content in advance, through an event stream, with description of these events, and semantic definitions of the parameters that will be used to describe each event of the stream. There can also be a template-builder to define the Overview presentation of the event. Streams can be private or public, with access roles according to owner, group, and public. Authors can gain trust by injecting and removing test events in a private stream.

Annotation: Each event will have a web-page, a *portfolio* of data: a collection including spectra, cutouts, etc, from many different surveys and observations. VORapid will integrate multi-sourced heterogeneous data, so long as the event author builds the metadata (event stream) through the web-based authoring interface. The evidence is thus collected, for past evidence of variability, for nearness to a galaxy, for excess infrared flux, and so on, that can help to classify that source. The data will be available not only to human clickers, but also through an Annotator API, which will be called in real time for data mining when the event is injected to VORapid.

Sharing: VORapid will allow events to become part of conversations in both traditional and new social media. One priority will be integration with the Central Bureau for Astronomical Telegrams, the Minor Planet Center, As-

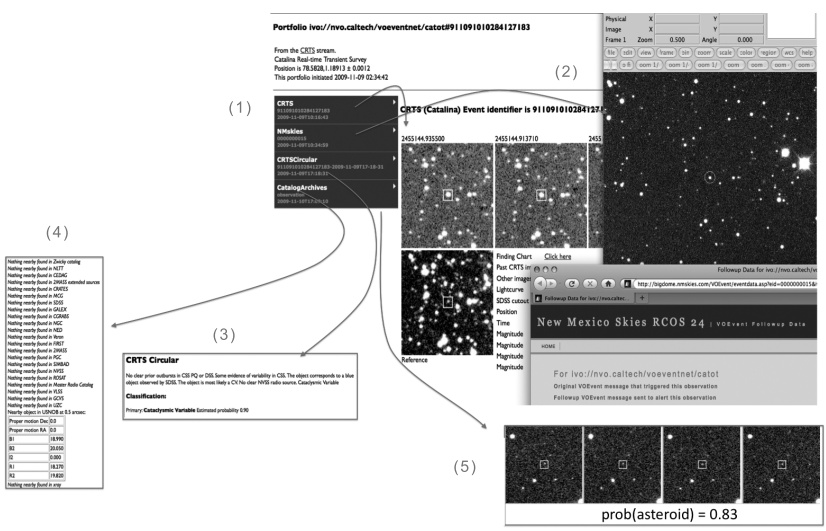

Figure 1. Here is the concept of Portfolio. This example portfolio from Nov 9, 2009, shows several events: (1) the original observations from the CRTS survey (top gray bar), (2) a robotic follow-up observation from the New Mexico Skies observatory 18 minutes later, (3) a human assessment of the meaning of the portfolio, and (4) a collection of archival results. A Portfolio can also contain events from data mining modules, a sort of a computational follow-up, where complex data is reduced to a simple quantity. Here (5) four images are analyzed for motion.

tronomers Telegram, etc. Other media, such as Twitter, Facebook, Second Life, Google Wave, etc, should be used as places for humans and machines to see and comment on events.

Intelligence: Just as an annotator component can get archival images for the event portfolio, so it can analyze data objects already present, for example comparing FITS images to detect motion of a source, or reduction of a spectrum to a single number of interest. These high-level criteria can then be used to trigger action, as with any other parameter in the portfolio.

Finding Events and Streams: We will use the international distributed Registry of the Virtual Observatory to enable publishing and discovery of event streams, so that all interested parties can subscribe to future events and browse past events from that stream. When a new event stream or service is created, its detailed metadata will be written and recorded by the author in a standard way.

Privacy: There should be a detailed access policy, so that people can confidently use VORapid in the early stages of a project, when events are for a small group only. Another way to handle this would be to install the (open-source) VORapid software on an internal network.

Rapid Follow-up: Real-time follow-up observations are crucial to a full understanding of the science of transients. These authors are already collaborating

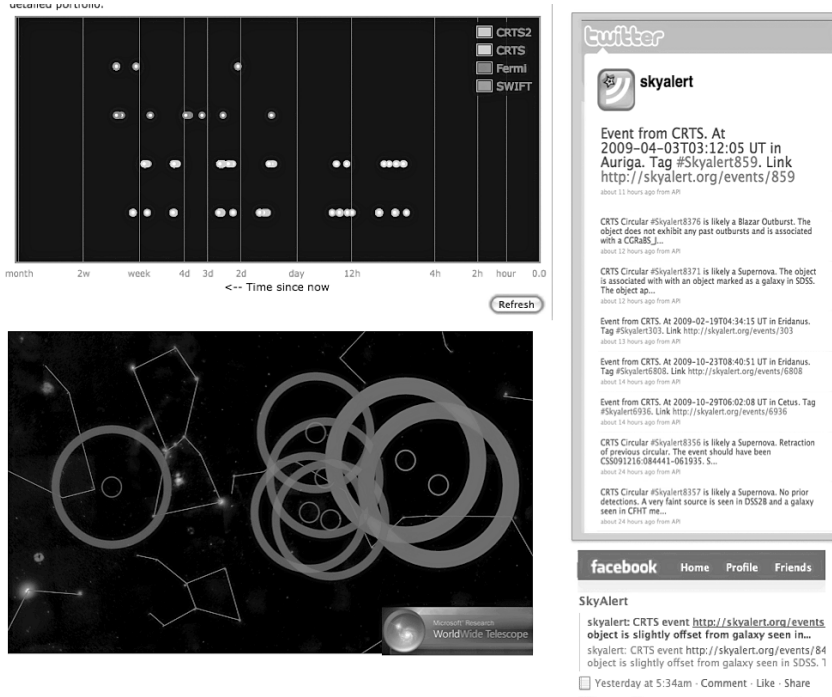

Figure 2. VORapid will have several types of display and outreach. Above left is a display of recent events, with click-through to detailed portfolio. Below left is the full sky with recent events, shown with Microsoft Worldwide Telescope. WWT can show many image surveys, and access NED, Simbad, and other catalog resources. At right are the Twitter and Facebook streams, with detections automatically broadcast from the reduction pipeline, and also the human-built interpretation several hours later.

with event providers, building new collaborations with providers of events, with the amateur astronomy community, and with owners of robotic telescopes.

International Interoperability: VORapid will be part of an emerging international infrastructure of astronomical transients using the VOEvent protocol (Seaman et. al. 2005). There are now many streams and many follow-up facilities, and a general agreement to use the "VOEvent" protocol for representing and communicating astronomical transients.

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References

Seaman, R., et. al, 2005, VOEvent: Sky Event Reporting Metadata
`http://www.ivoa.net/Documents/latest/VOEvent.html`