

What is VOEvent?

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We present the essence of VOEvent. The subsequent sections in this chapter describe advanced features for representing complex data structures and time series. VOEvent is an evolving standard [1] maintained and extended by a living community, the IVOA VOEvent working group [2]. These two links bear emphasis:

Standard:

<http://ivoa.net/Documents/latest/VOEvent.html>

Community:

<http://voevent.org>

Why VOEvent?

Humans have pondered the import of changes within the “eternal” sky for thousands of years. Astronomers have studied the dynamic universe since Tycho Brahe discovered his “Stella Nova” (since promoted to the ranks of the supernova) in 1572 [3]. Reports of celestial events were among the first telegrams sent over the newly laid transatlantic cable in 1866.

VOEvent seeks to combine the rich semantics of astronomical telegrams (for example CBAT [4], MPC [5], ATel [6] and many more), with the instant delivery of the Gamma-ray bursts Coordinates Network (GCN) [7], while building on modern software standards of the International Virtual Observatory Alliance (IVOA) [8].

Rather than supplanting the roles of prior alert publishers, VOEvent offers a path forward to a common interoperating transient alert infrastructure. Every snapshot of the sky may contain the signatures of multiple diverse time varying phenomena of interest to many stakeholders for disparate investigations. Separating the technology for reporting supernovae, for instance, from that for reports of solar system objects, variables stars, gamma-ray bursts and so forth has served to obscure the resulting science and to complicate observational logistics. Software systems have been needlessly duplicated.

The VOEvent XML Schema

VOEvent is an IVOA Recommendation – that is, it has been adopted as an international standard. As with many other IVOA standards, VOEvent is based on XML, the Extensible Markup Language [9]. XML is ubiquitous in worldwide web technologies and simply provides a structured way to build a nested hierarchy of elements, to attach attributes to those elements, and to assign values to each. An additional constraint on many IVOA standards, including VOEvent, is a *schema* to apply rules on the arrangement and numbers of each element and attribute and on their allowed values. XML Schema [10] can be an often-entertaining technology for the designers of a standard. Providing a battle-hardened VOEvent schema [11] is a priority of the VOEvent v2.0 development effort. A well-crafted schema permits the validation of documents (in this case VOEvent messages, also referred to as “packets”) against the requirements of the standard, and can even be used to automatically create software to parse such messages.

IVOA Recommendations are *normative* – that is, they have the final word on the rules for Virtual Observatory formats and protocols. But it is the VOEvent schema where the rubber meets the road. As a practical matter, the schema enforces the rules. The alternative is for a standard to be defined by a particular software implementation. The limitation with the latter notion is that it ties a user, a project, or an organization to that software package through a roller coaster of operating system updates and

external project life cycles. We will not describe the subtleties of schema usage further, but it is important to know that a VOEvent schema exists to capture the format's rules. The one fact to remember should you find yourself speaking to a fussy programmer is that *schema* is singular. The plural is *schemata*.

The <VOEvent> Element

The one required element in any VOEvent message naturally enough is <VOEvent>. XML elements are surrounded by angle brackets (“<” and “>”) as with the more familiar HTML tags. This is not the place to describe all the ins-and-outs of XML usage – many references exist online or on computer bookshelves. Suffice it to say that the <VOEvent> element has three attributes, *ivorn*, *role*, and *version*. The usage of the version is relatively self-explanatory. The role attribute permits, for instance, distinguishing a test message from an actual celestial alert.

The funny word, *IVORN*, refers to an International Virtual Observatory Resource Name [12]. This is the identifier that distinguishes one celestial transient alert message from another. The format resembles other types of web addresses, for example:

`ivo://my.observatory#message17`

The first part of the IVORN represents the publisher. The second part (after the “#”), identifies the specific message. For further details about IVORNs (or any other issue in this section) please consult appendix 5.1, the working draft of v2.0 of the VOEvent standard. Always remember that the current normative standard is available at:

<http://ivoa.net/Documents/latest/VOEvent.html>

The VOEvent schema controls how the elements of the standard can nest. In general a VOEvent packet may contain exactly one copy, or otherwise no copy, of each of the six major elements described below:

- <who> – *Author information*
- <what> – *Event characterization*
- <wherewhen> – *Targeting for follow-up observations*
- <how> – *Instrumental setup*
- <why> – *Scientific inferences*
- <citations> – *Threads of empirical investigation*

In addition, each of the major elements can contain <Description> elements for human-readable content and <Reference> elements to point to external content.

The <Who> Element

The nesting rules of XML do not enforce a particular order for elements on the same hierarchical level. We discuss the <who> element first, but a message's elements may be reordered without changing their meaning. The <who> element is used to provide curation metadata describing the origin of the observational information in the VOEvent message. This may include a description of the *Author* and *Publisher* and a publication date (and time) for the particular message. The words have their typical usage here – the Author is responsible for the scientific content of the message, while the Publisher is responsible for the numerous logistics associated with distributing the message.

While detailed curation information may be written to individual messages, it is more likely that an <AuthorIVORN> sub-element will be used to reference a registered resource record describing an Author who may publish numerous VOEvent messages. Similarly, information about the Publisher is usually implicit in each message's own IVORN, an attribute of the <VOEvent> element. See section 4.2 for more information about using the IVOA Registry to locate virtual resources.

The <What> Element

The work of describing the actual celestial phenomena falls to the <what> element. Something happened in the sky. What was it? At its most basic, the <what> element contains one-or-more <Param> sub-elements. A <Param> associates the name of a quantity with its value, for example:

```
<Param name="mag" value="13" ucd="phot.mag;em.opt.R" />
```

IVOA Unified Content Descriptors (UCDs) are discussed further in section 4.3 and in [13]. Parameter attributes may also include `units`, and <Param> elements may be nested inside <Group> elements to provide simple data structures. More advanced usage is described in sections 2.2 and 2.3.

The <WhereWhen> Element

While the <what> element describes the dependent variables of some observation (or set of observations), the <wherewhen> element describes the independent variables to indicate where and when the phenomena were observed. More generally, <wherewhen> provides targeting information for follow-up observations. Spatial and temporal coordinate systems are tied together in astronomy, and so they are tied together in the IVOA and VOEvent. Details are in section 3.4 of the IVOA VOEvent Recommendation [1] and in the document “Space-Time Coordinate Metadata for the Virtual Observatory” (STC) [14].

A key aspect of celestial coordinates is that fundamentally the location of the observer must be provided in addition to the location of the astronomical object or phenomena that are being studied. STC provides a list of <AstroCoordSystem> defaults that tames some of this inherent complexity.

The <How> Element

The <How> element is where a project can provide information describing the instrument that was used to make the observation in question. A list of <Reference> elements can be provided, linking to external RTML (Remote Telescope Markup Language) documents that describe the instrument. Please consult the RTML documentation [15].

The <Why> Element

VOEvent can be viewed as a language for conducting discussions of scientific investigations. Phenomena are discovered, described, and announced. Communities of like-minded individuals (or robotic facilities) receive these alerts and conduct follow-up observations resulting in follow-up VOEvent messages. The intent of this empirical conversation is to understand the physics and cosmic history underlying the observed phenomena. The <why> element provides a facility for the scientific assessment resulting from this conceptual *mangling* [16].

The <why> element itself allows two attributes – a measure of the **importance** of the VOEvent alert, and an estimate of when the implicit call for follow-up observations **expires**. Within the <why> element are a list of <Concept> and <Name> elements to associate the phenomena with known classes of phenomena or with specific astronomical objects. These may be grouped using the <Inference> element which has attributes asserting a **probability** that the inference is correct and associating a description of the **relation** between the VOEvent alert and the <Concept> or <Name> elements within.

VOEvent <Citations>

The final major ingredient to a VOEvent message is the <Citations> element. As described under <why>, alert messages often result in follow-up observations that are themselves expressed as VOEvent messages. The <Citations> element permits associating each message with others earlier in the particular empirical chain [17], via a list of <EventIVORN> elements referring to the earlier message identifiers.

Each <EventIVORN> must also have a `cite` attribute describing whether the current message is a **followup** of the cited message, or rather is a **retraction** or **supersedes** the previous message. By superseding

previous messages, chains of follow-ups can be split or merged should it later be discovered that they describe different (or rather identical) phenomena.

The VOEvent Network Architecture

VOEvent is *transport neutral*, that is, a celestial transient alert might well be delivered via an unofficial channel (one could puckishly suggest a fortune cookie or carrier pigeon) and still result in important scientific discoveries and follow-up observations. However, it was recognized immediately that creating the VOEvent standard and developing a reliable distribution mechanism went hand-in-glove.

Numerous project-tied systems have been prototyped, developed, and deployed, for example, VOEventNet [18], VO-GCN [19], eSTAR [20], and SkyAlert [21]. The key is that separate implementations are interoperable, for example, events from VO-GCN flow to SkyAlert. Even more importantly, interoperability will permit current facilities to evolve into the celestial transient alert networks of tomorrow. Figure 1 shows one possible model of how VOEvent-based transient alert messages from the Large Synoptic Survey Telescope (LSST) [22] will flow from the telescope on Cerro Pachon in Chile to data centers in both hemispheres and onward to the larger VOEventNet.

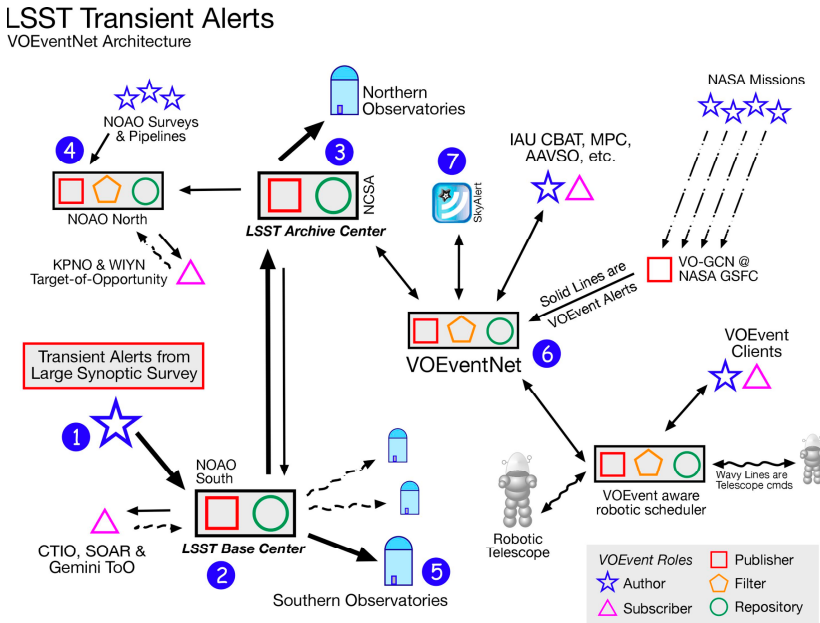


Figure 1. Proposed architecture for LSST transient alerts.

benefit from different arrangements of network the basic sequence is numbered in Figure 1:

1. Celestial transient alerts are generated by the LSST pipeline
2. Alerts are published via a registered VOEvent broker
3. The full feed of messages is sent to the LSST Archive Center
4. Regional data centers also receive all alerts
5. Most LSST follow-up observations will occur in the south
6. VOEventNet streams and features are available to LSST
7. Users connect via general purpose alert services like SkyAlert

References

[1] Latest IVOA VOEvent standard
<http://www.ivoa.net/Documents/latest/VOEvent.html>

[2] IVOA VOEvent Working Group
<http://voevent.org>

- [3] Tycho Brahe, *De Stella Nova*, 1573
<http://www.texts.dnlb.dk/DeNovaStella/Index.html> (in Danish)
- [4] CBAT: IAU Central Bureau for Astronomical Telegrams
<http://www.cbat.eps.harvard.edu/index.html>
- [5] MPC: IAU Minor Planet Center
<http://www.minorplanetcenter.org/iau/mpc.html>
- [6] ATel: The Astronomer's Telegram
<http://www.astronomerstelegam.org>
- [7] GCN: The Gamma-ray bursts Coordinates Network
<http://gcn.gsfc.nasa.gov>
- [8] IVOA: International Virtual Observatory Alliance
<http://www.ivoa.net>
- [9] XML: Extensible Markup Language
<http://www.w3.org/XML>
- [10] XML Schema
<http://www.w3.org/XML/Schema>
- [11] VOEvent Schema (version 1.1)
<http://www.ivoa.net/xml/VOEvent/VOEvent-v1.1.xsd>
- [12] IVORN: IVOA Resource Names
<http://www.ivoa.net/cgi-bin/twiki/bin/view/IVOA/ResourceNameSemantics>
- [13] UCD: IVOA Uniform Content Descriptors
<http://www.ivoa.net/Documents/latest/UCD.html>
- [14] STC: IVOA Space-Time Coordinates Metadata
<http://www.ivoa.net/Documents/latest/STC.html>
- [15] RTML: Remote Telescope Markup Language
<http://www.uni-sw.gwdg.de/~hessman/RTML>, or
<http://monet.uni-goettingen.de/twiki/bin/view/RTML> (twiki)
- [16] Andrew Pickering, *The Mangle of Practice*, U. of Chicago Press, 1995.
- [17] R. Seaman, *Thread safe astronomy*, AN v329 n3 p237, March 2008.
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<http://voeventnet.caltech.edu>
- [19] VO-GCN: VOEvent-compliant GCN
http://www.cacr.caltech.edu/hotwired2/program/presentations/HTU2_VOGCN_Barthelmy.pdf
- [20] eSTAR: eScience Telescopes for Astronomical Research
<http://www.estar.org.uk>
- [21] SkyAlert
<http://www.skyalert.org>
- [22] LSST: Large Synoptic Survey Telescope
<http://www.lsst.org>