CRTS and the VOEvent Networks

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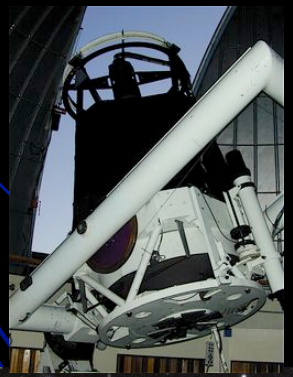
The Catalina Surveys

- Catalina Real-time Transient Survey (CRTS) is a Caltech operated transient survey that started in Nov 2007 using from the Catalina Sky Survey (CSS).

- CSS is an NEO survey that began operation in March 2004.

- CSS operates three telescopes.

Two in Tucson AZ (0.7m+1.5m), one in Siding Spring, Aus (0.5m).

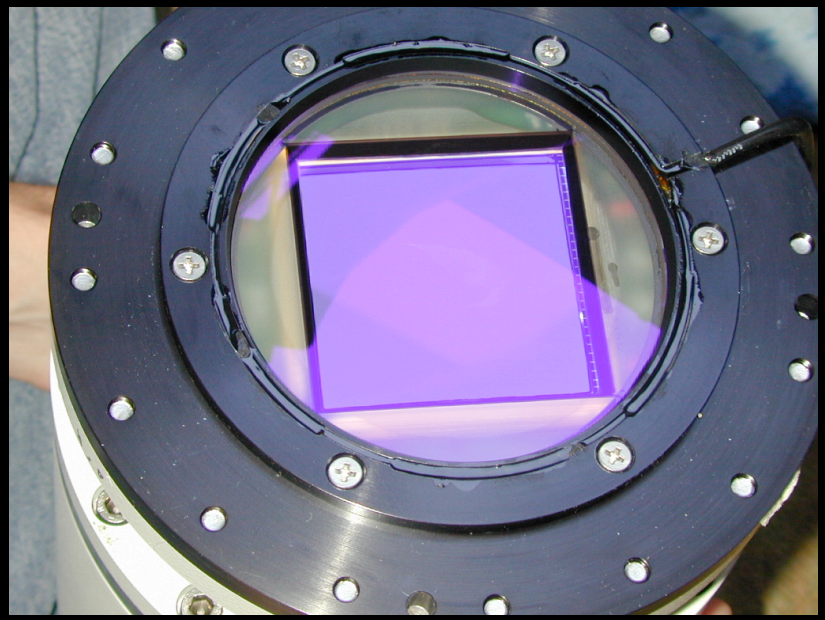




CRTS Catalina Real-Time Transient Survey

Catalina Sky Survey

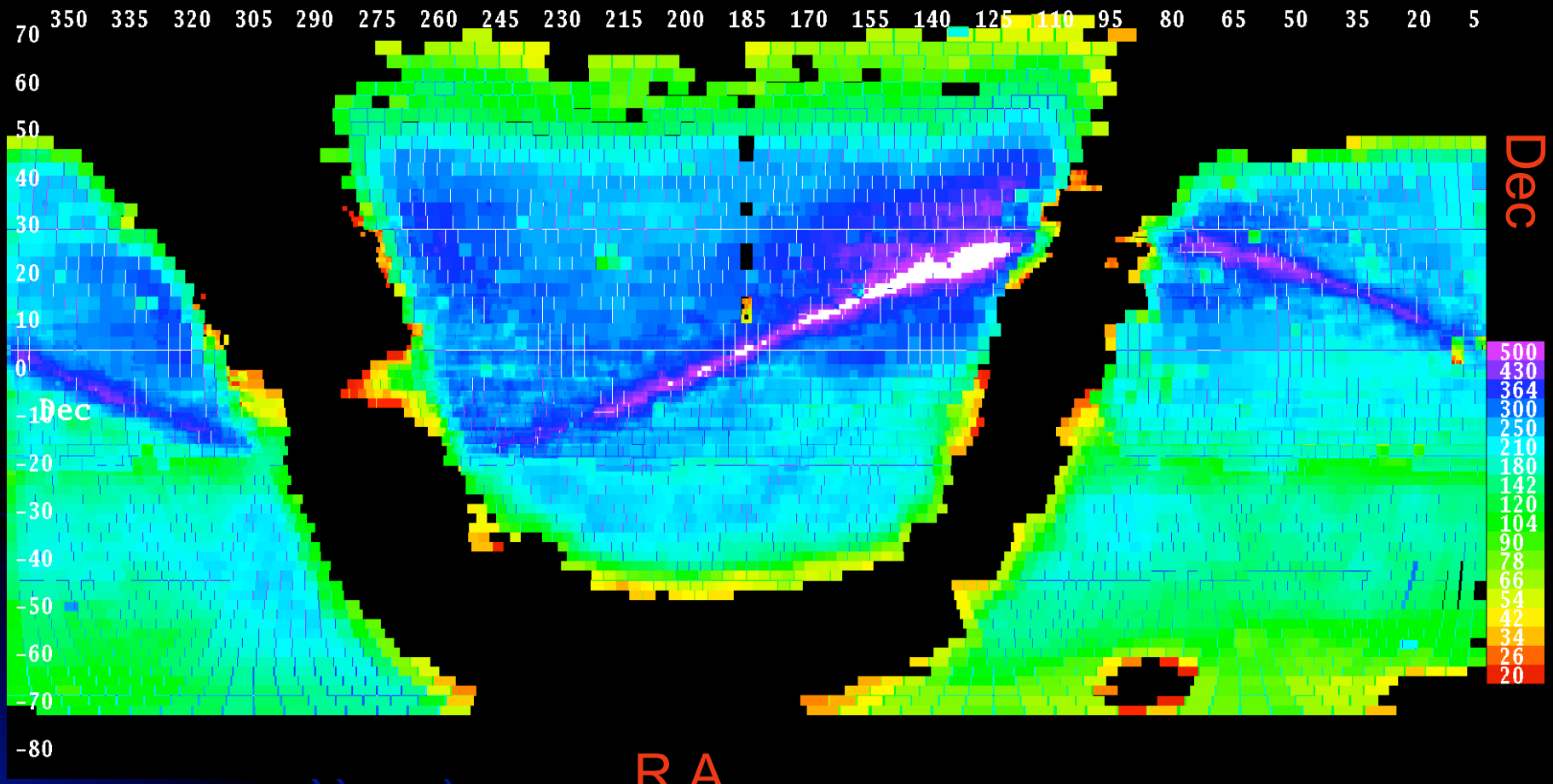
Observations

- All observations are taken clear.
- Observations 21 days/lunation.
- 4 visits per field over 30mins.
- Covers 2000 deg^2/night
- Total 30,000 deg^2.
- At mags of V=19 to 22.
- Each camera 4k x 4k.



Catalina Sky Survey

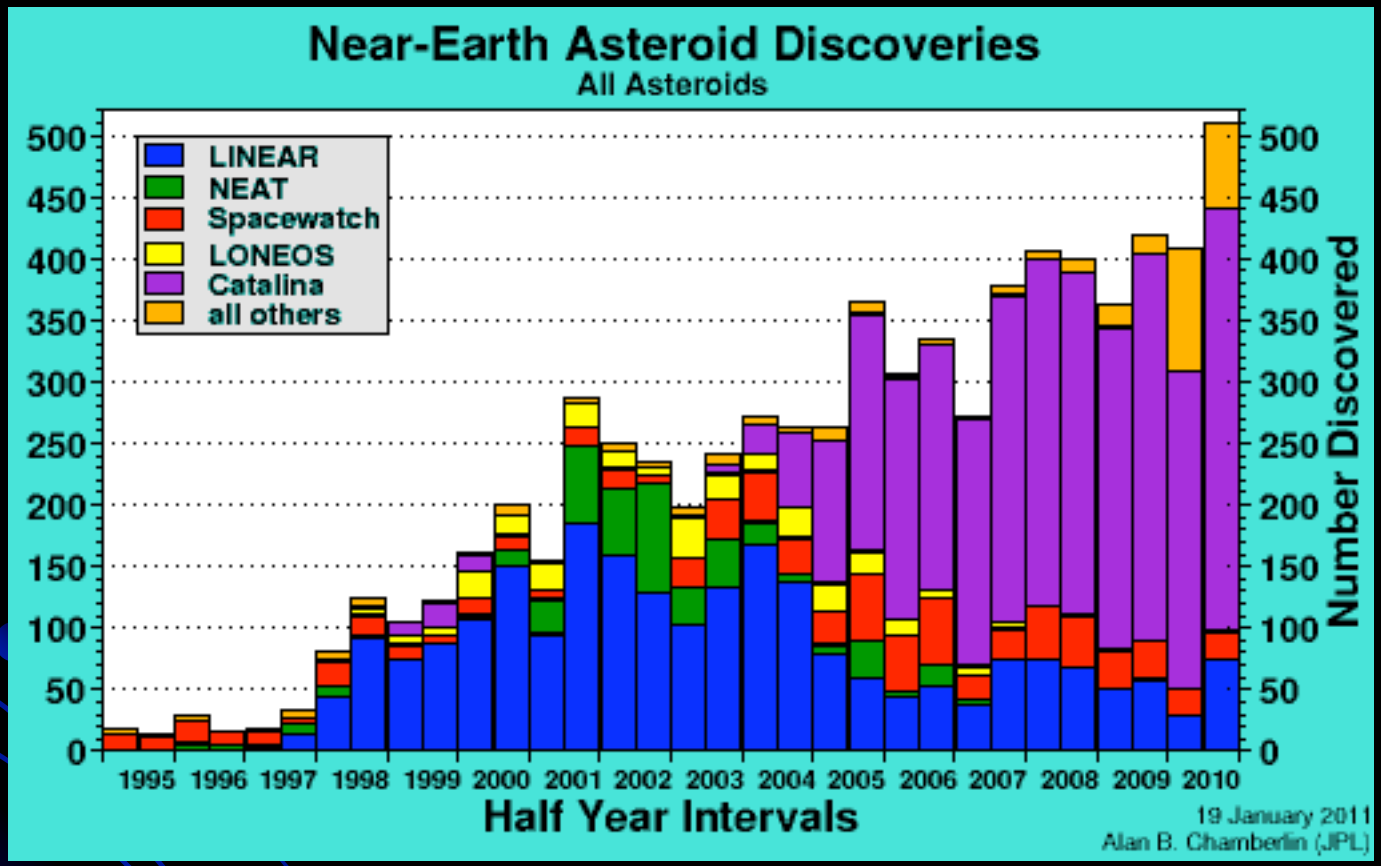
Catalina Sky Coverage



CSS fields with > 20 observations.

Catalina Sky Survey

Catalina Sky Survey Discoveries



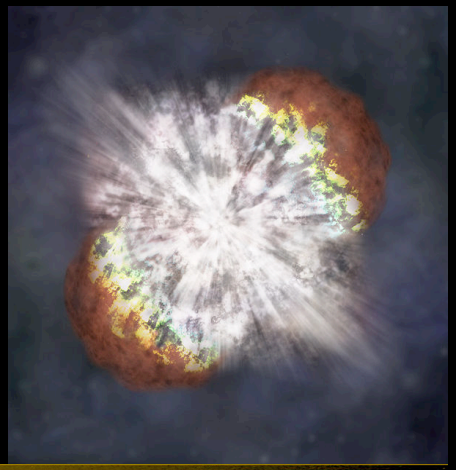
Catalina Sky Survey

Catalina Transient Survey

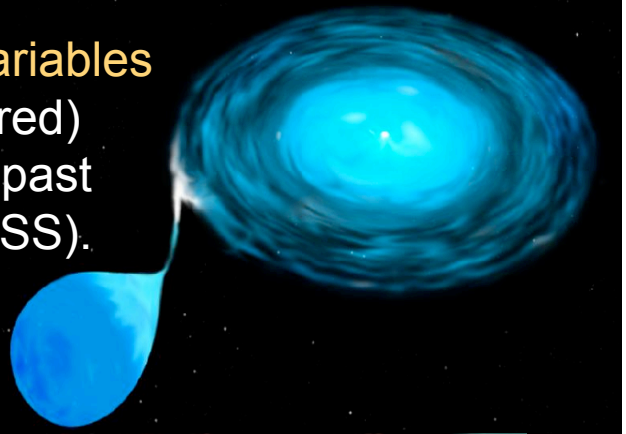
- The CRTS survey searches for highly varying (>1 mag) astronomical sources ("optical transients").
- Transient detection has run for three and a half years.
  3.5 yrs 0.7m telescope, 1.5 yr 1.5m, 11 mths 0.5m.
- Transients are found based on catalog comparisons
  - CSS coadds, USNO-B, PQ, SDSS.
- Same pipeline base code runs on data from all three CSS telescopes.
- All data is fully processed within minutes of observation.
- Discovery rate is ~ 1 OT /10^6 measurements.
- Discoveries are made public instantly using VOEvent standard to enable rapid follow-up.

CRTS Transients

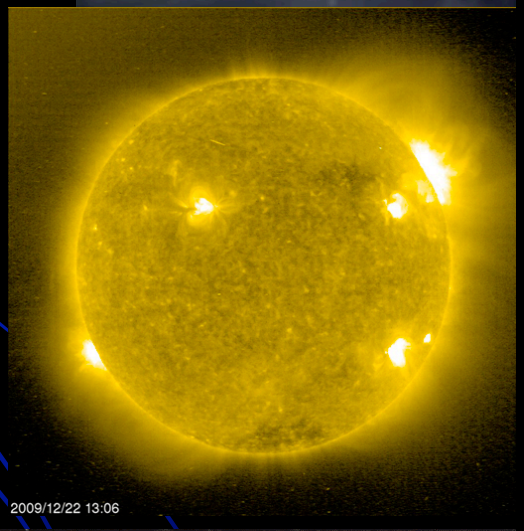
Supernovae
(> 700 discovered)
2009+2010 twice number published by any other group (PTF, PanSTARRS, LOSS, etc.).



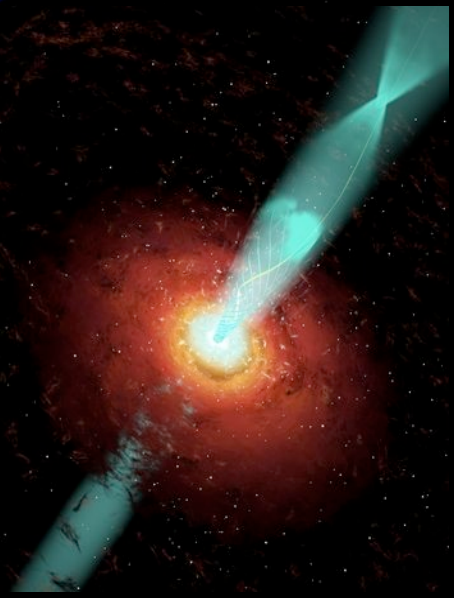
Cataclysmic Variables
(> 500 discovered)
More than any past survey (eg. SDSS).



UV Ceti stars
(flare stars)
~100 discovered



Blazars
~120 discovered



CRTS Catalina Real-Time Transient Survey

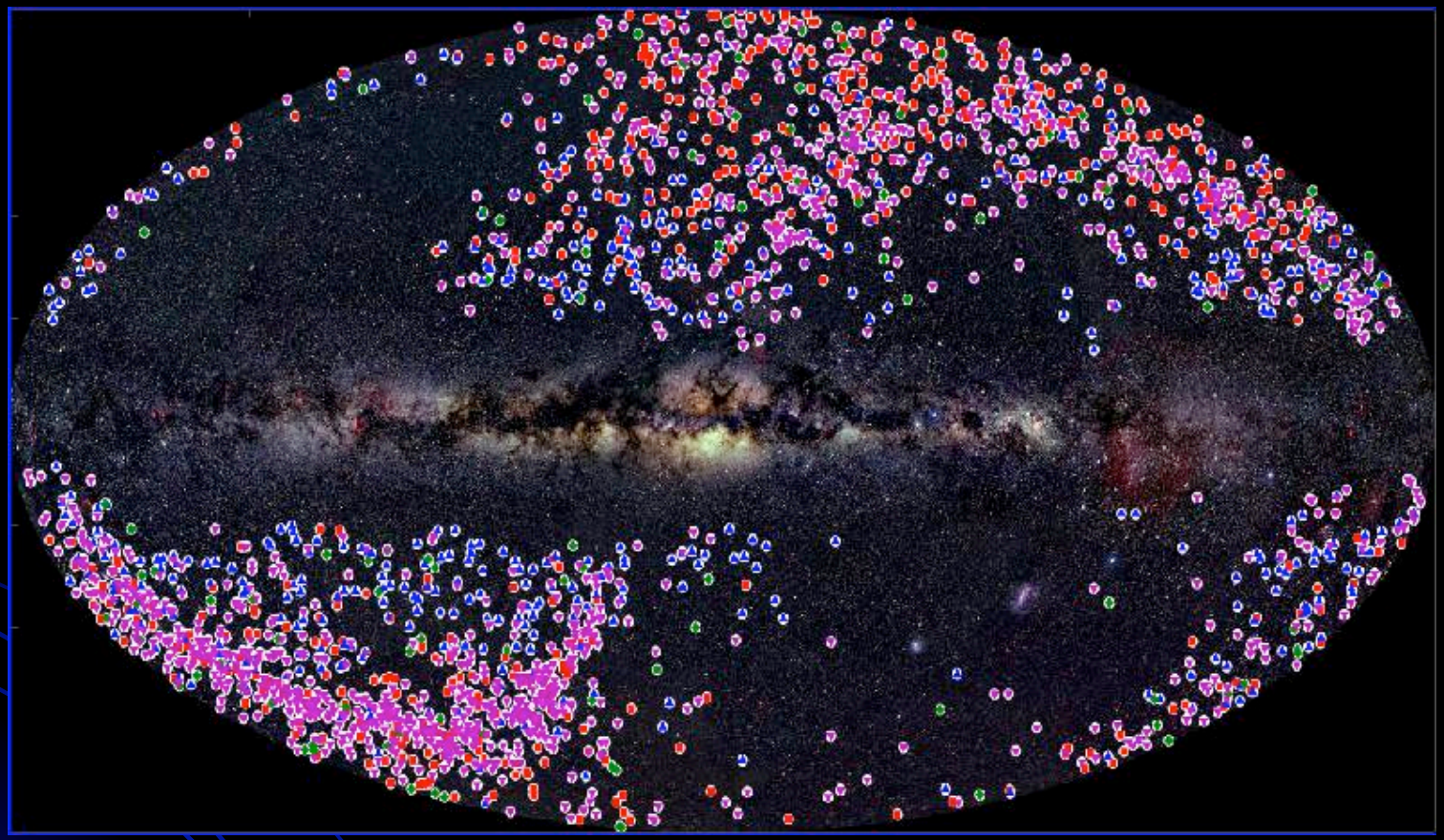
100's other transient sources

- Variable stars (LPV, RR Lyrae)
- Active Galactic Nuclei
- Young Stellar Objects (FU Ori, T Tauri)
- High Proper Motion stars
- Classical Novae (CSS081007)
- Pair Instability SNe? (SN 2009jh & SN 2007bi).
- Tidal disruption events (archival)
- Luminous Blue Variables

- Transient wish list:

  Microlensing events, Type .Ia SN, other new transient types.

Discovery Locations



Red=SN, Blue = CV, Green=Blazar, Magenta=Other

CRTS Catalina Real-Time Transient Survey

Event follow-up

Supervised follow-up strategy:

Photometry first

- P60, NMSU, DAO, CSS 1m (June 2011)

Spectroscopy only for transients appearing unusual
(avoid common SN like Ia's based on colour normal luminosities) .

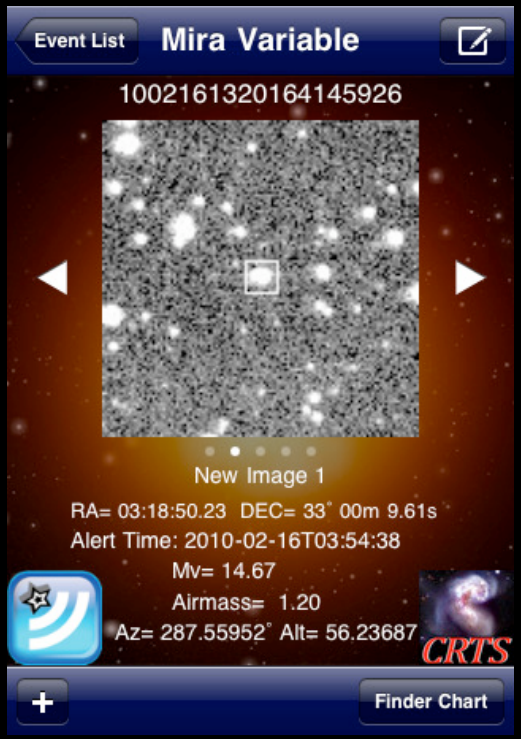
- Gemini N+S, Keck, P200, SMARTS, IGO, MDM.

External follow-up:

- Foster follow-up of other transients by open publication and collaboration.

Discovery Notification

- Three layers of event distribution.
  1) Real-time discovery (mins)
     - VOEvents
  2) Human classified (mins-hrs)
     - Event portfolios
     - HTML, iPhone, Circulars, Twitter
  3) Events of interest (mins-days)
     - Portfolios + follow-up
     - ATel, CBAT, VSNET



LSST/CRTS iPhone app

CRTS Catalina Real-Time Transient Survey

Classified Events

Evaluation of past information Including:
light curves, images, colours, nearby sources (eg. x-ray, radio, galaxies) -> classification.
Info on classification also published as VOEvents to SkyAlert.org.

CSS ID	RA (J2000)	Dec (J2000)	Date	Mag	CSS images	SDSS	Others	Followed	Last	LC	Classifica
CSS100219:102916+273911 √	157.31642	27.65305	20100219	19.86	1002191260514135892 √	yes	13589 √	no	2010-02-19	13589 √	SN SDSS mag 22,0
CSS100219:045646+060456 √	74.19340	6.08221	20100219	15.44	1002191070274109660 √	no √	10966 √	no	2010-02-19	10966 √	CV mag 20,5
CSS100219:040700+005244 √	61.74923	0.87886	20100219	13.83	1002191010224113664 √	yes	11366 √	no	2010-02-19	11366 √	CV mag 18,0 J0406+0052
CSS100219:032652+011513	51.71540	1.25368	20100219	17.80	1002191010194118882	no √	11888	no	2010-02-19	11888	CV SDSS mag 18,5
CSS100219:094851-121632	147.21382	-12.27551	20100219	16.37	1002190120524132212	no √	13221	no	2010-02-19	13221	CV? mag 21
CSS100218:043829+004016	69.62126	0.67108	20100218	16.70	1002181010254112737	yes	11273	no	2010-02-18	11273	CV mag 19,3
CSS100217:102913+404220	157.30232	40.70548	20100217	16.02	1002171400444123118	yes	12311	no	2010-02-17	12311	AGN/SN mag 17,7
CSS100217:111053+370948	167.71951	37.16321	20100217	19.34	1002171380484109521	yes	10952	no	2010-02-17	10952	SN SDSS mag 21,5
CSS100217:124326+360245	190.86010	36.04578	20100217	19.46	1002171350574139609	yes	13960	no	2010-02-17	13960	AGN SDSS mag 20,9
CSS100217:122946+355830	187.44038	35.97487	20100217	19.69	1002171350564137559	yes	13755	no	2010-02-17	13755	AGN SDSS mag 21,4
CSS100217:112713+341752 √	171.80587	34.29767	20100217	18.95	1002171350514109348 √	yes	10934 √	no	2010-02-17	10934 √	SN SDSS mag 21,3
CSS100217:111001+362503 √	167.50408	36.41747	20100217	19.36	1002171350504148201 √	yes	14820 √	no	2010-02-17	14820 √	SN? SDSS mag >22,5
CSS100217:125357+324908 √	193.48585	32.81886	20100217	19.89	1002171320604132045 √	yes	13204 √	no	2010-02-17	13204 √	AGN/CV SDSS mag 20,8
CSS100217:124243+325205 √	190.68031	32.86799	20100217	19.96	1002171320594132636 √	yes	13263 √	no	2010-02-17	13263 √	SN SDSS mag 21
CSS100217:124506+273813 √	191.27512	27.63701	20100217	19.36	1002171260624141001 √	yes	14100 √	no	2010-02-17	14100 √	AGN SDSS mag 21,0
CSS100217:144559+200820 √	221.49433	20.13901	20100217	19.18	1002171210754109063 √	yes	10906 √	no	2010-02-17	10906 √	AGN SDSS mag 20,4

http://crts.caltech.edu

Publication

- CRTS Circulars (> 1500)

twitter.com/skyalert

- Astronomer's Telegrams (> 60)

  www.astronomerstelegram.org

- CBETS (> 90)

www.cfa.harvard.edu/iau/cbet/RecentCBETs.html

- VSNET Alerts (> 100)

www.kusastro.kyoto-u.ac.jp/vsnet/

- Journals (>20, mostly collaborative)

crts.caltech.edu/pub.html

CRTS Summary

- CRTS has discovered:

~3500 unique optical transients:

(>700 SNe, >500 CVs, >120 Blazars, >100 Flare stars, ~500 High amp vars, AGN, HPM stars).

- CRTS discoveries are all made public immediately (cf. PTF, PanSTARRS).

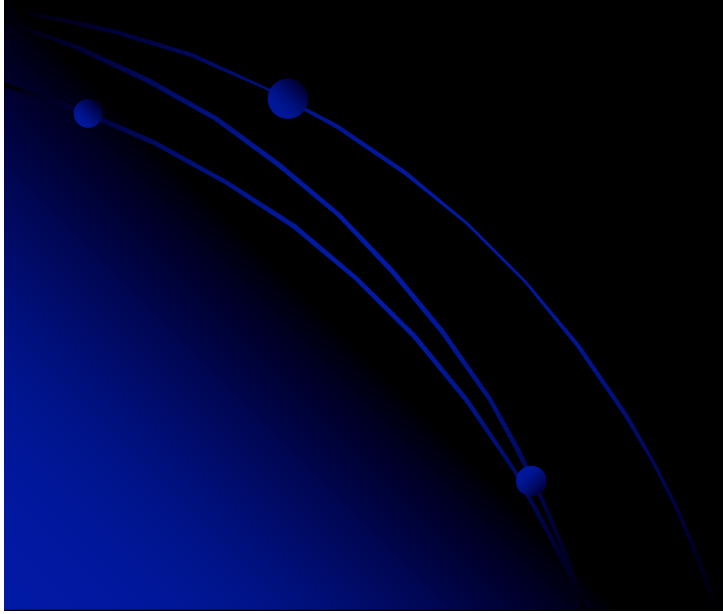
- CRTS is making all past CSS survey data public.

(500 million objects, 80 billion photometry points)

http://crts.caltech.edu/

CRTS is supported by NSF Grant No. AST-0909182

Alerting the World



The VOEvent Network

The VOEvent standard was introduced in 2005 to produce an open generalized method for alerting robotic and human users about astronomical events from diverse range of current and future transient surveys (SKA, LSST, LOFAR, PQ, Swift, Fermi…).

In order to transport these VOEvents the VOEventNet project was begun. This project has been replaced by the SkyAlert project.

VOEvents

- Standardized structured xml data packets.

A basic VOEvent contains:

```
<VOEvent>
   <Who> Author Data </Who>
   <What> Parameters Measured <What>
  <WhereWhen> Coords and Time </WhereWhen>
  <How> Instrument Setup </How>
  <Why> Reason for Alert </Why>
</VOEvent>
```

VOEvent Example


```
<voe:VOEvent xsi:schemaLocation="http://www.ivoa.net/xml/VOEvent/v1.1 http://www.ivoa.net/xml/VOEvent/VOEvent-v1.1.xsd" version="1.1"
ivorn="ivo://nvo.caltech/voeventnet/catot#110405001085416013 3" role="observation">
<Description>Candidate new Transient</Description>
<Who>
<AuthorIVORN>ivo://nvo.caltech/voeventnet</AuthorIVORN>
<Author>
<shortName>LPL and Caltech</shortName>
<contactName>
Andrew Drake (for the Catalina Real-time Transient Survey)
</contactName>
<contactEmail>ajd@cacr.caltech.edu</contactEmail>
</Author>
<Date>2011-04-05T11:15:13</Date>
</Who>
<Citations>
<EventIVORN cite="supersedes"/>
</Citations>
<What>
<Group name="Asteroid params">
</Group>
<Group name="First Detection params">
<Param unit="mag" value="17.702600" ucd="phot.mag;em.opt.R4" name="magnitude"/>
</Group>
<WhereWhen>
<ObsDataLocation>
<ObservatoryLocation xlink:href="ivo://STClib/Observatories#TOPOCEN" xlink:type="simple" id="TOPOCEN"/>
<ObservationLocation>
<AstroCoordSystem xlink:href="ivo://STClib/CoordSys#UTC-FK5-TOPO/" xlink:type="simple" id="UTC-FK5-TOPO"/>
<AstroCoords coord_system_id="UTC-FK5-TOPO">
<Time unit="s">
<TimeInstant>
<ISOTime>2011-04-05T11:04:44</ISOTime>
</TimeInstant>
</Time>
<Position2D unit="deg">
<Name1>RA</Name1>
<Name2>Dec</Name2>
<Value2>
<C1>237.6261300</C1>
<C2>-0.2381300</C2>
</Value2>
<Error2Radius>0.0012</Error2Radius>
</Position2D>
</AstroCoords>
</ObservationLocation>
</ObsDataLocation>
</WhereWhen>
<How>
<Reference type="url" uri="http://crts.caltech.edu"/>
<Description>
Transient discovered by the Catalina Real-time Transient Survey. Mt. Bigelow, Catalina Mountains Schmidt Telescope
</Description>
</How>
<Why>
<Inference probability="0.1">
<Concept>Newly discovered Transient</Concept>
</Inference>
</Why>
</voe:VOEvent>
```

Transporting Events

Two Methods:

Jabber IM (via JEP-060):
secure, reliable, scalable,
native xml, open.

VTCP:
Simple, closed network.

Both require custom software.

Event Transport

VOEvent network running Jabber servers (Ejabberd or Openfire):

Caltech
LIGO (x2)
MOA
LSST
SVOM

Event Services

Connection to Jabber servers.

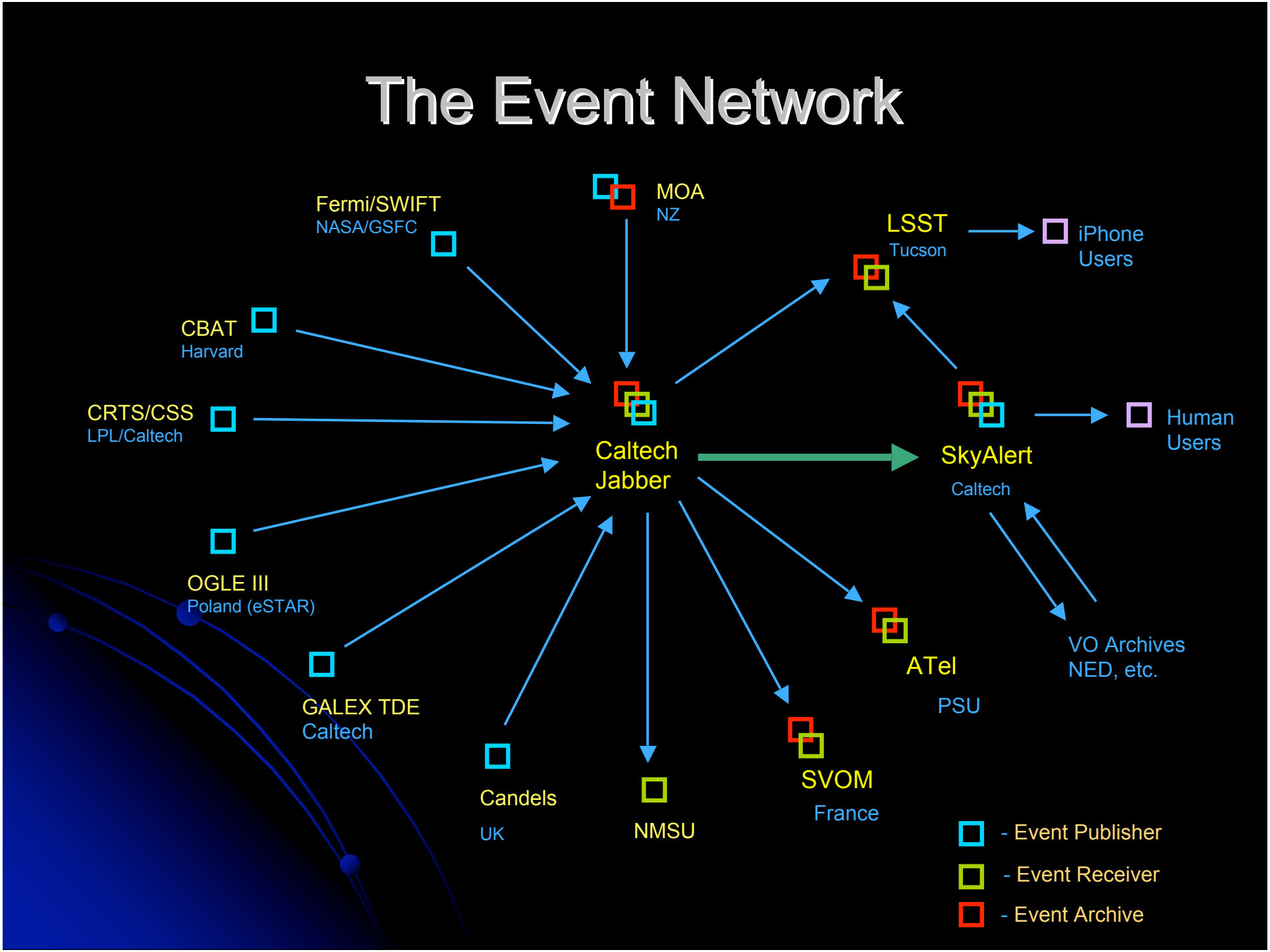
Require custom clients that understand PubSub XMPP xml stanza.

Clients are available in Java, C, Perl, Python.

PubSub

- Server mediates connections.
- Publishers send data to node.
- Core protocols include end-to-end signing and object encription via TLS and SSL.
- Servers can keep record of sent events.
- Affiliations to, subscribe, publish, purge items, config a node, delete a node.
- Users can be publishers, subscribers, or blocked.
- Message nodes can be discovered by clients.
- subscription can be open, list, authorized.

The Event Network



SkyAlert

Skyalert.org

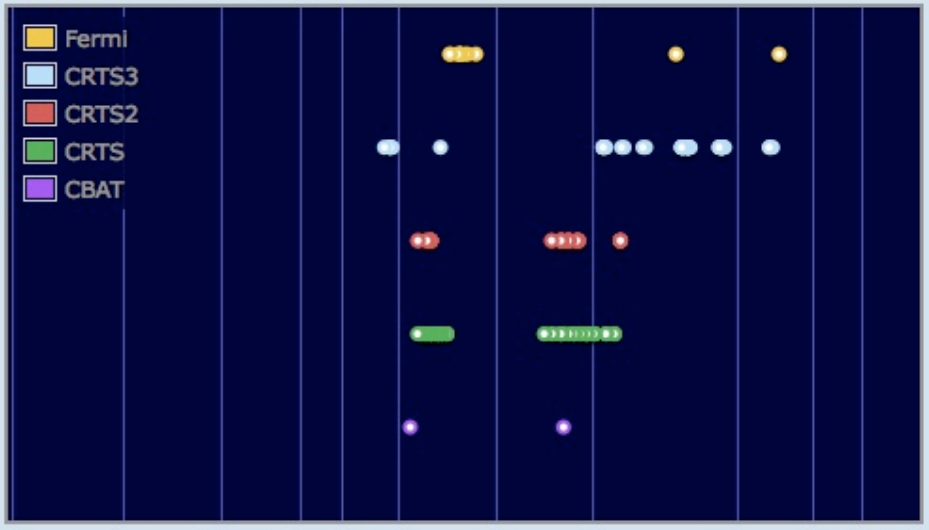
Sponsored by the National Science Foundation

Browse Event Streams | Browse Skyalert Feeds | **my** Feeds and Alerts

Log in here, or register here

Recent Events

In the picture below, time is measured with "right now" at the right. Ages of recent events -- the last 200 received -- are shown by stream. Click on an event to bring up a new window with detailed portfolio.



<-- Time since now (2011/04/05 2:22 PDT)

About Skyalert

SkyAlert collects and distributes astronomical **events** in near-real time. Each event belongs to a **stream** of events that come from a common source, with a common vocabulary of parameters for each event. You can browse event streams and the events themselves, at the links below. You can set up "alerts" which decide which events you find interesting, that comes with an Atom feed of those that pass the selection. You get only the events you want -- no more, no less.

- Skyalert News
- Feeds of interesting astronomical events
- Browse event streams that skyalert is monitoring
- Recent events as a table
- Recent events with WorldWide Telescope
- Recent events Facebook page
- Recent events with Twitter
- Build a custom feed

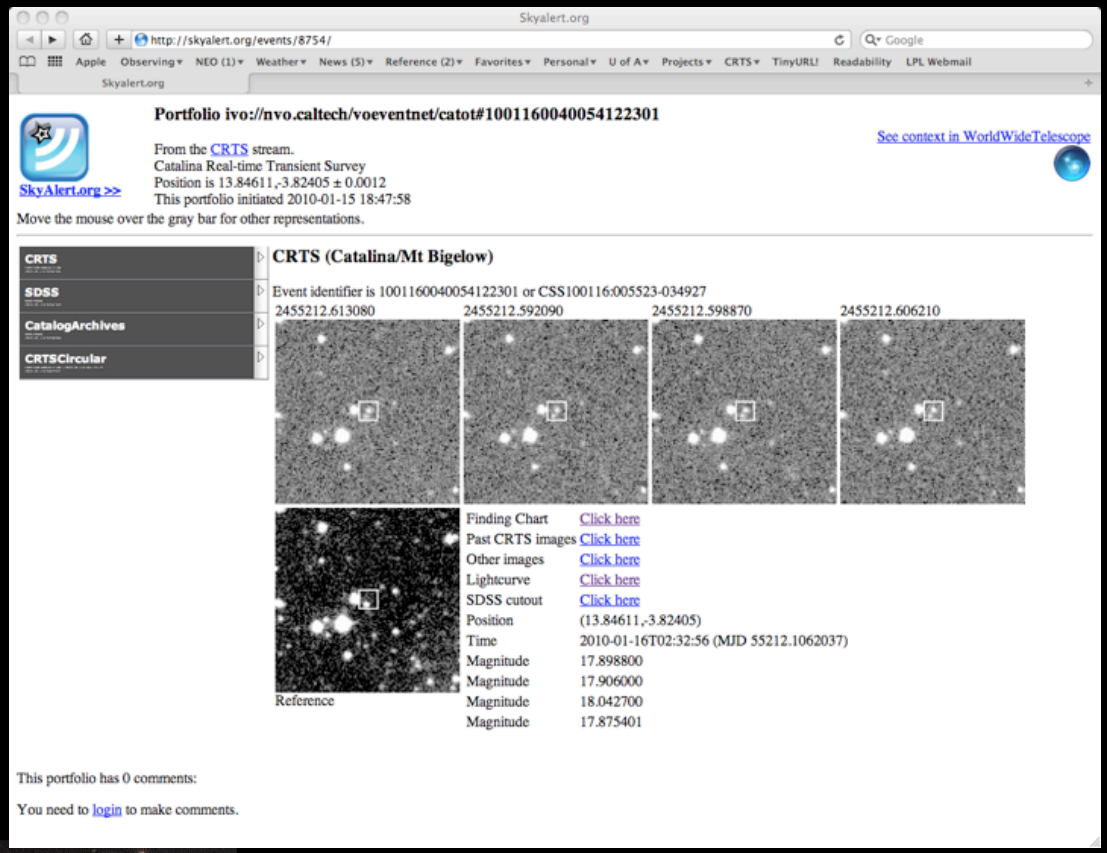
Events at SkyAlert

Current Event Streams:

CRTS (OTs)
CSS (NEOs)
MOA (Microlensing)
CBAT (SN, Novae)
OGLE (Microlensing)
GALEX (UV transients)
Fermi (GRB, etc.)
SWIFT (GRBs)
HST_MCT (Candels SNe)
AAVSO (CVs, Novae)

CRTS + SkyAlert

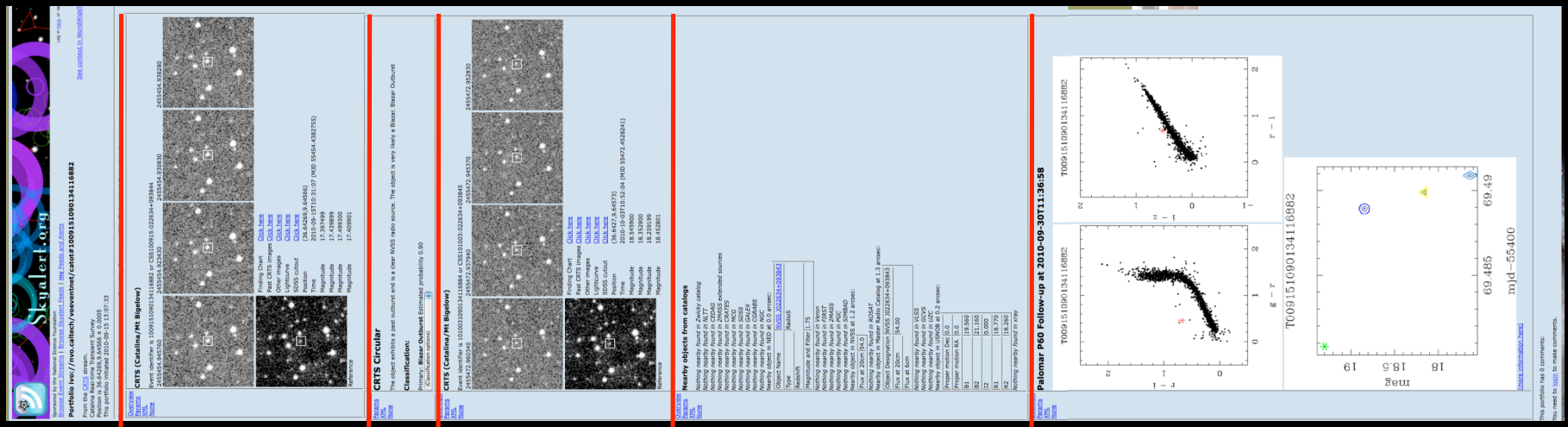
Discovery data -> VOEvent xml. Notices published over VOEventNet to SkyAlert, etc.
Automated discovery agents create a portfolio from VO services (SIMBAD, NED, etc.) & catalogs (SDSS, NVSS, etc.)



CRTS Catalina Real-Time Transient Survey

http://skyalert.org

SkyAlert Portfolios



First observation

Later observation

Is it in the archive
yes: NED and SIMBAD

Telescopic followup

Classification as blazar outburst

Data from many sources
joined to initial event
Computer can understand it
and make selection

More info about VOEvent

http://hotwireduniverse.org

Free download!

Table of Contents

Since time domain astronomy is a moving target, planning is already underway for a 2nd editio