A brief history of Serbian involvement in LSST
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Andrevlje, May 30 2022

Outline

Rubin observatory, CS Telescope

History of Serbian involvement

STG in kind kontribution

Future

Modern observational methods in astronomy and astrophysics in the next decade (or few)

Large telescopes (8-40m): faint objects especially spectroscopy

Telescopes above the atmosphere: high angular resolution, other wavelength regions (X-ray, radio, infrared ...)

Large Sky Surveys – new way of doing astronomy using digital sensor technology, information technology, automated data processing and data distribution

Most data are available through databases and/or VO

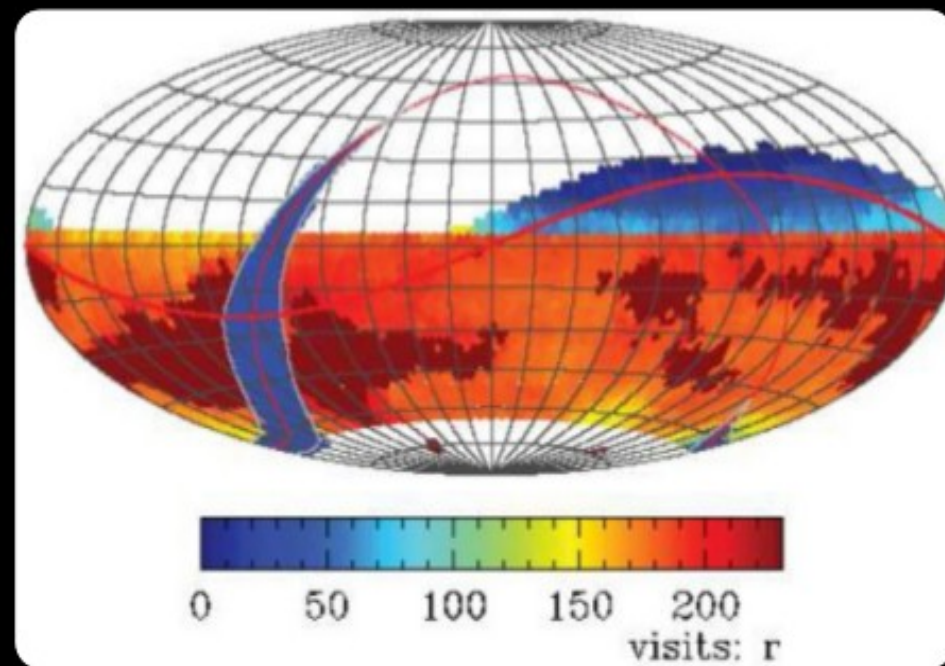# LSST: A Deep, Wide, Fast, Optical Sky Survey

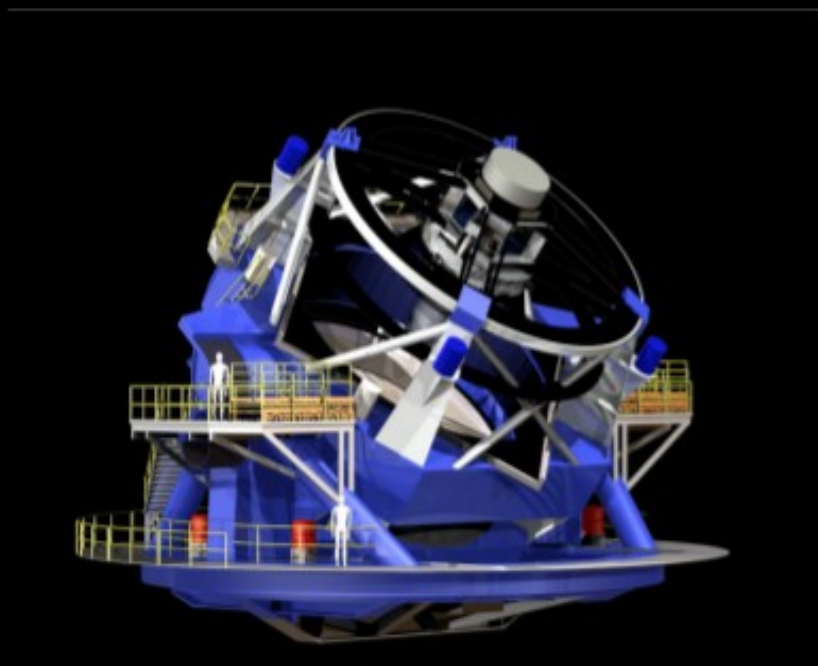8.4m telescope   18000+ deg^2 10mas astrom.   r<24.5 (<27.5@10yr)

ugrizy   0.5-1% photometry

3.2Gpix camera   30sec exp/4sec rd   15TB/night   37 B objects

Imaging the visible sky, once every 3 days, for 10 years (825 revisits)

LSST Science Themes

- Dark matter, dark energy, cosmology (spatial distribution of galaxies, gravitational lensing, supernovae, quasars)

- Time domain (cosmic explosions, variable stars)

- The Solar System structure (asteroids)

- The Milky Way structure (stars)

These drivers not only require similar hardware and software systems, but also motivate a uniform cadence: **about 90% of time will be spent on a uniform survey**

A Dedicated Survey Telescope

- The LSST is an integrated survey system. The Observatory, Telescope, Camera and Data Management system are all built to support the LSST survey. There's no PI mode, proposals, or time.

- **The ultimate deliverable of LSST is not the telescope, nor the instruments; it is the <u>fully reduced data</u>.**

  - All science will be come from survey catalogs and images
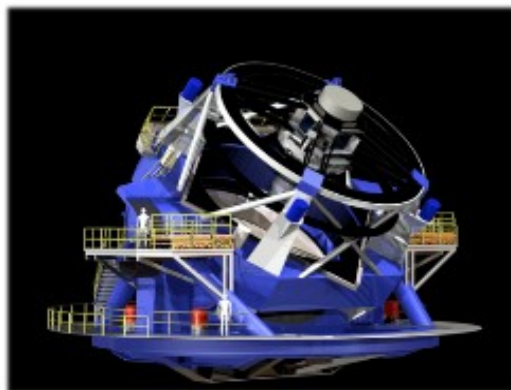
Telescope ➔ Images ➔ Catalogs

Table 4: Level 2 Catalog Object Table

Name	Type	Unit	Description
psRadecTai	double	time	Point source model: Time at which the object was at position radec.
psPm	float[2]	mas/yr	Point source model: Proper motion vector.
psParallax	float	mas	Point source model: Parallax.
psFlux	float[ugrizy]	nmgy	Point source model fluxes[58].
psCov	float[66]	various	Point-source model covariance matrix[59].
psLnL	float		Natural log likelihood of the observed data given the point source model.
bdRadec	double[2]	degrees	B+D model[60]: (α, δ) position of the object at time radecTai in each band.

LSST@Europe: The Path to Science – IfA, Cambridge, UK – September 9-12th, 2013.

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Open Data, Open Source: A Community Resource

- LSST data, including images and catalogs, will be available with <u>no proprietary period</u> to the astronomical community of the <u>**United States, Chile, and International Partners**</u>

- Alerts to variable sources ("transient alerts") will be <u>**available world-wide within 60 seconds**</u>, using standard protocols

- LSST <u>**data processing stack will be free software**</u> (licensed under the GPL, v3-or-later)

- **All science will be done by the community (not the Project!), using LSST's data products**

# LSST is a Public/Private, Interagency Project

- The National Science Foundation:
  - Support for the telescope and site facility construction, the data management system, and the education and public outreach components.
  - Funded under the Major Research Equipment and Facility Construction (MREFC) line. Total *not to exceed* cost is $473M.
  - Prime contractor for this effort is the Associated Universities for Research in Astronomy (AURA), which also manages the National Optical Astronomy Observatory (NOAO), the Space Telescope Science Institute (STScI), and other facilities.

- The Department of Energy:
  - Support for the camera fabrication.
  - Funded as a Major Item of Equipment (MIE), through the Office of High Energy Physics in the Office of Science. Total *estimated* cost is $165M. *Cost will be baselined at CD-2.*
  - SLAC National Accelerator Laboratory is the lead DOE lab for the LSSTcam project.

- Private Support:
  - Key donors include the Lisa and Charles Simonyi Fund for Arts and Sciences, Bill Gates, Richard Caris, the W.M. Keck Foundation, Research Corporation for Science Advancement, Wayne Rosing and Dorothy Largay, Eric and Wendy Schmidt, and Edgar Smith.
  - Total Support has been ~ $40M.
  - Funded development of the primary/tertiary mirror, the secondary mirror blank, preliminary site preparation, as well as early sensor studies and some data management activities.
  - Responsible organization is the Large Synoptic Survey Telescope Corporation.
  - Key assets will be transferred to AURA for use in construction.

Statistical analysis of a massive LSST dataset

- **A large (100 PB) database and sophisticated analysis tools:** for each of 20 billion objects there will be about 1000 measurements (each with a few dozen measured parameters)

Data mining and knowledge discovery
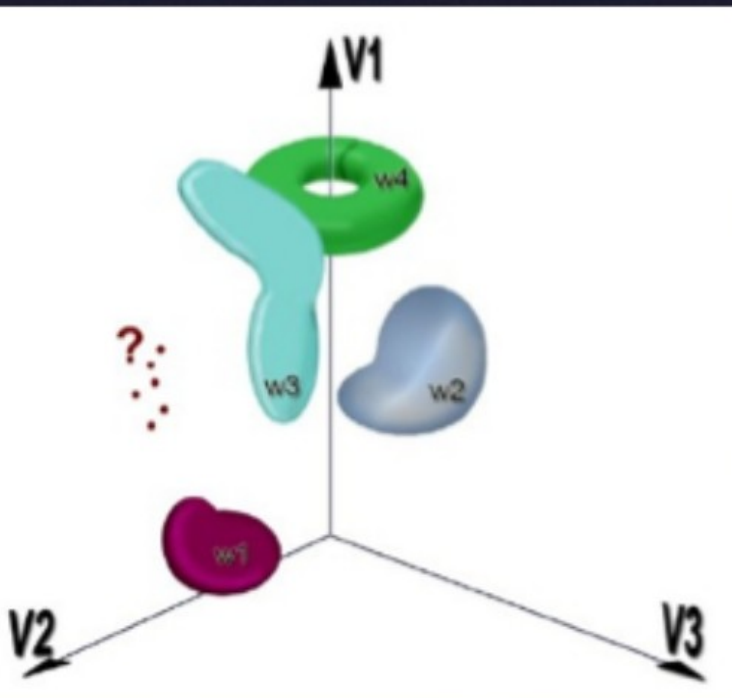
- 10,000-D space with 20 billion points
- Characterization of known objects
- Classification of new populations
- Discoveries of unusual objects

Clustering, classification, outliers

SKY MAPPERS

Outside the United States and Chile, 68 institutions within 26 nations say they will pay to access the enormous data set expected from the Large Synoptic Survey Telescope (LSST).

16 United Kingdom

10 China

LSST at Cerro Pachón in Chile

Host countries (unlimited access) ■
Countries with 1 ■ 2–4 ■ >4 ■ participating institutions
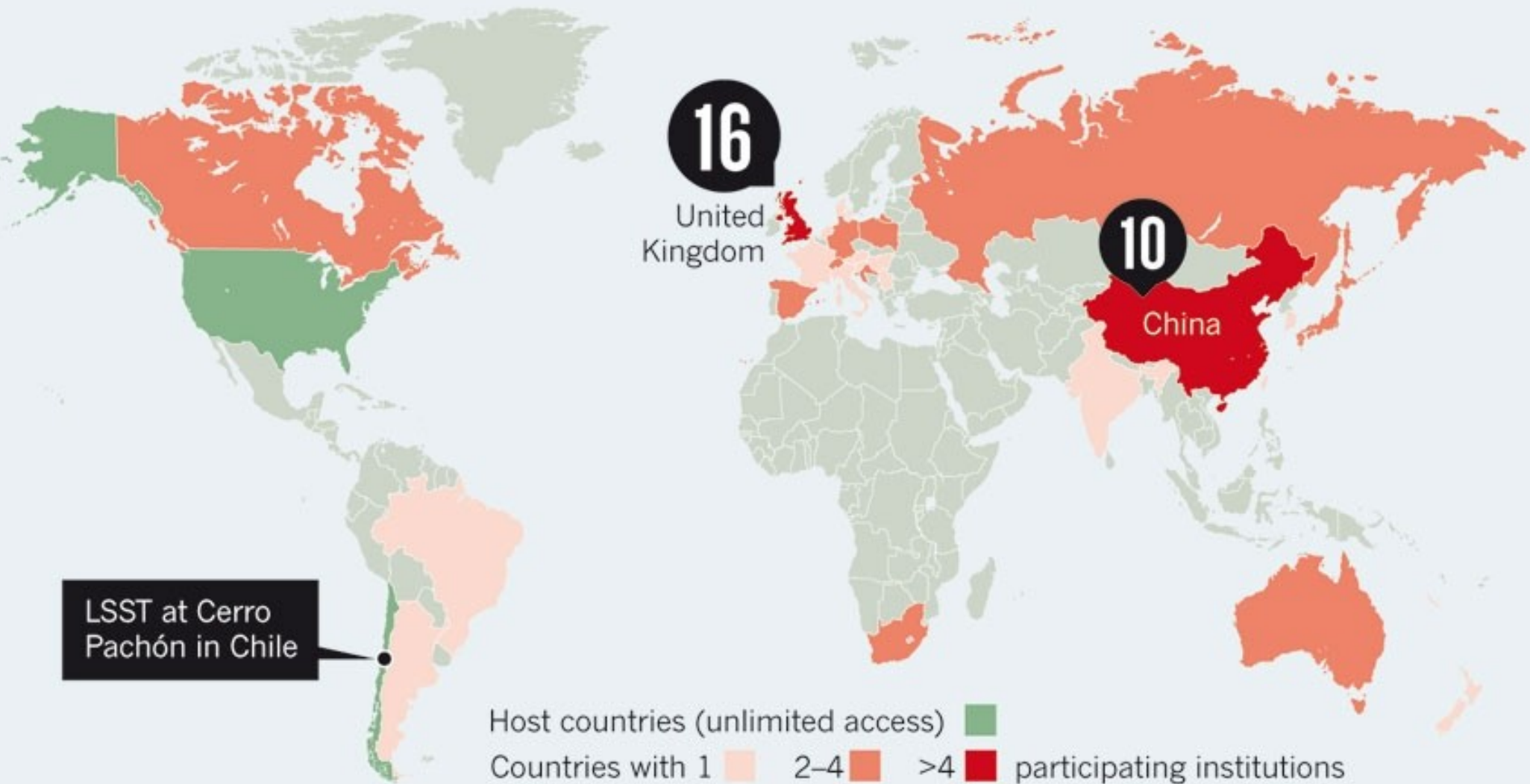
Eric Hand, Cosmic survey finds global appeal Nature 487, 284 (19 July 2012)

Integrated Project Schedule
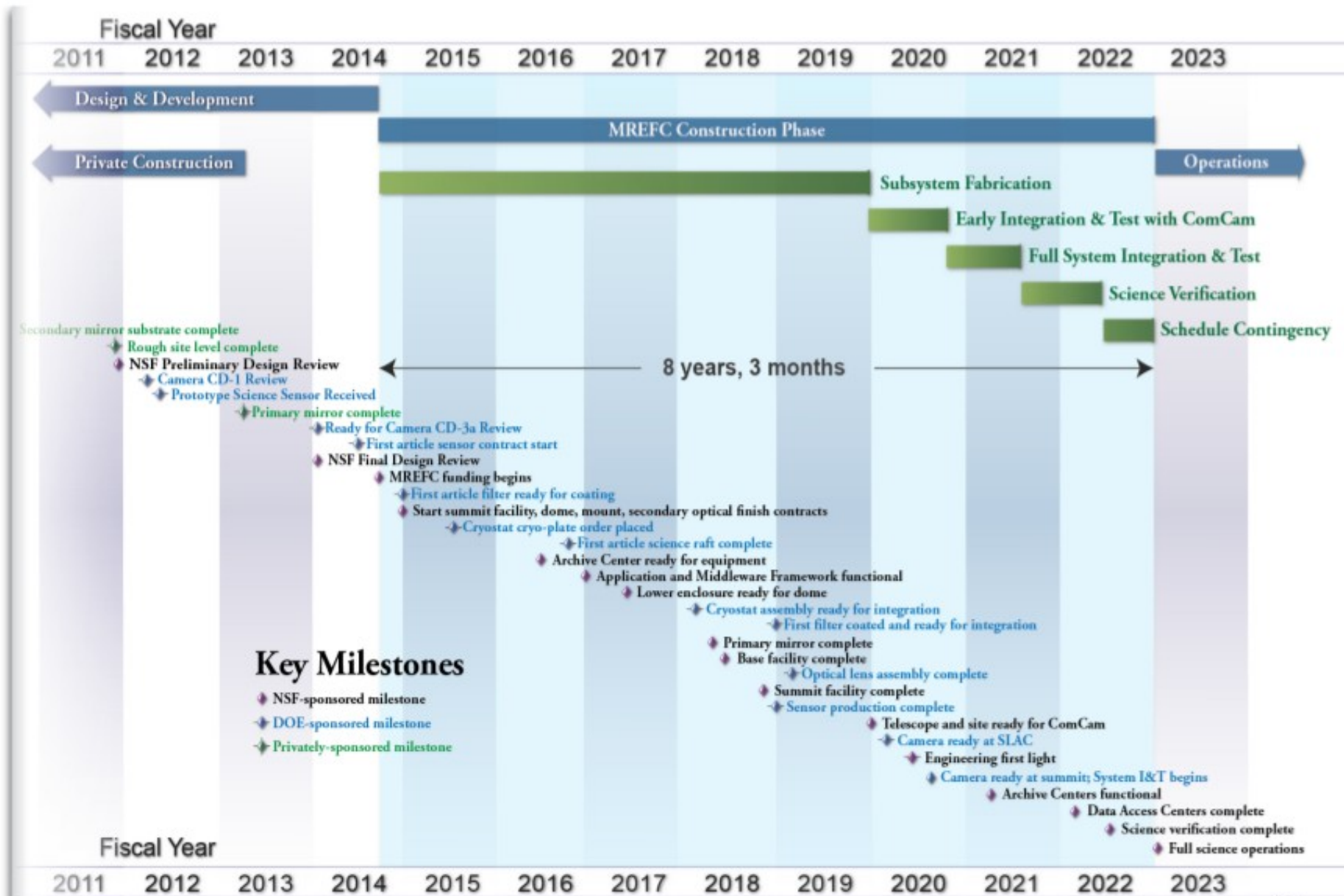
The top 10 "celebratory achievements"

- **Very similar to project <u>milestones</u>, but** using a different name <u>to:</u> i) avoid confusion with PM, and ii) to raise a glass of beverage every time we meet them!
- We plan to **publish forecast** (not baseline) dates **on monthly cadence**:
  - TMA and Dome contracts substantially complete: **July 2022**
  - EPO complete: **September 2022**
  - LSSTCam shipped from SLAC to Chile: **April 2023**
  - Telescope ready for integrated optical testing: **May 2023**
  - ComCam: Engineering First Light: **June 2023**
  - LSSTCam ready for I&T at the telescope: **July 2023**
  - LSSTCam: System First Light: **October 2023**
  - Science Pipelines ready for Science Verification Surveys: **November 2023**
  - Commissioning Science Verification Surveys completed: **March 2024**
  - Operations Readiness Review completed: **March 2024** (4 months of schedule contingency)

Still months of uncertainty in first light dates, but we will get there!

LSST Project and Community Workshop
Tucson, AZ August 14-19 2016

Serbian Astronomy

Two main institutions: AOB and DAFMBU

AOB (129 years old) ~20 PhD's + students

old instruments, new ones...

DAFMBU ~10 PhD's + students

UNS,UNis UKG, IPB (1-2 PhD's)

Interest of SA in LSST

Variable phenomena

Variable stars

AGN variability

Gravitational micro-lensing

SNR & Planetary nebulae

Small solar system bodies (orbits, elements...)

Development of astroinformatics

Development of algorithms, software...

Science...

Serbian involvement in LSST

Before the results of decadal survey were announced we applied for funds to join the LSST (through III44002)

300kEuro granted (from EIB loan – Call for capital equipement) ID8885 p.301 paper copy / p. 185 document on PIU site

Important NSF review (If you are so good do you have an International interest Yes at the moment France and Serbia

LOI has been submitted (and appreciated!)

MOA's are signed November 2013 – standard contribution & in kind

Serbian involvement in LSST key dates/events

2009 started informal queries

2010 submitted proposal Astroinformatics with significant LSST part

2011 funds granted (300k) LOI submitted

2013 MOI signed

2014 AlertSim agreed as in-kind contribution of STG to LSST

2015 first simulated alerts generated

2016 LSST@Europe2; AlertSim in the LSST codebase(github)

2019 change of LSST/Rubin policy toward international contributors;

2020 new round of proposals for in-kind contribution

2021 Two groups from Belgrade :2 PI's SER-STG(for work already done) and 8 PI;s for SER-SAG AGN group

Serbian involvement in LSST key dates/events

Unfortunately AOB refused in 2013 to sign MOI and it lost 300kEuro

NanoCenter acted as proxy

We were embedded in LSST Simulation group which was dismantled areound 2017 when R&D was distributed toward

We were initiators COST TD1403 Big data in sky and Earth observations

We participated (gave talks) at many conferences – EWAS2017, LSST@Europe, LSST AHM, JTM PCW , TD1403

Organized many meetings

AlertSim Serbian in kind contribution

- NSF rules ...

  - everything for the construction has to be budgeted

  - if some part is outsourced for example to us and savings are made – it has to be offset from the budget – so no luck there

  - Solution – we do some work toward early operation phase which at the moment is not critical (another rule what can be outsourced)

- We agreed that alert simulator would be the best choice

Level 1 Data Products: Time Domain

- **Real-time image differencing as observing unfolds each night**

- Detection performed on image differenced against a deep template
- Measurement performed on the difference image and direct image
- Associated with pre-existing observations and stored in a database

- *Result: Alerts transmitted within 60 seconds of observing, enabling rapid follow-up*
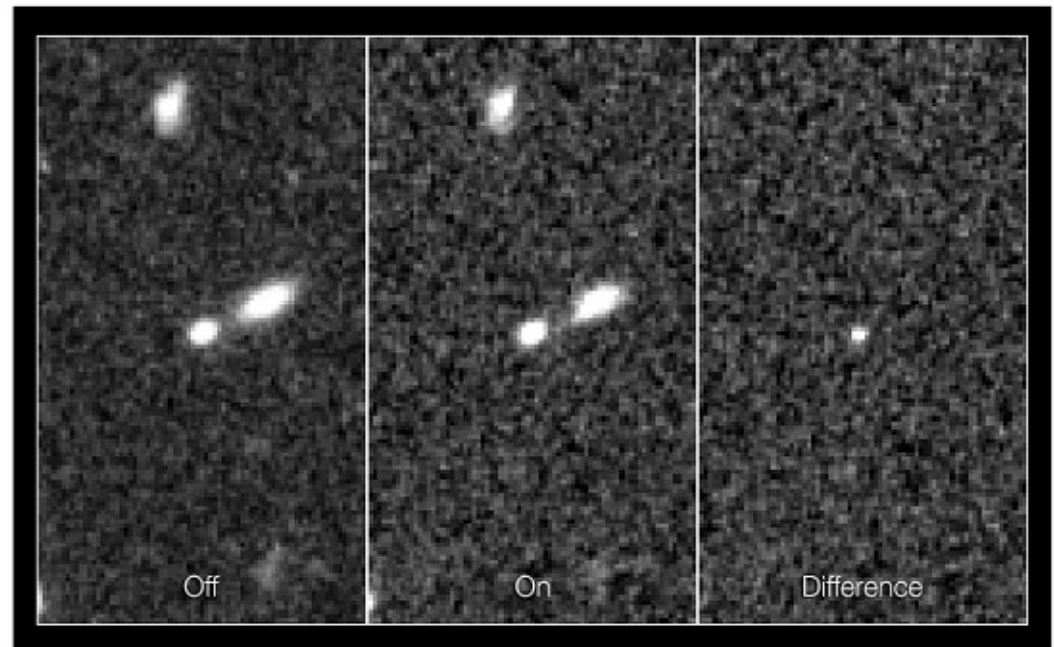
- *Also: time-domain from direct imaging (Level 2)*

CANDELS (http://www.spacetelescope.org/images/heic1306d/)

LSST@Europe: The Path to Science – IfA, Cambridge, UK – September 9-12th, 2013.

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- **LSST computing is sized for 10M alerts/night (average), 10k/visit (average), 40k/visit (peak)**
  - Dedicated networking for moving data from Chile to the US
  - Dedicated image processing clusters
  - New image differencing pipelines with improved algorithms

- **Will measure and *transmit with each alert*:**
  - position
  - flux, size, and shape
  - light curves in all bands (up to a ~year; stretch: all)
  - variability characterization (eg., low-order light-curve moments, probability the object is variable)
  - cut-outs centered on the object (template, difference image)

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AlertSim Serbian in kind contribution

10M alert * 0.1Mb=1Tb/night = max 2-4 alert streams

It has been anticipated that there is a need :

- for software to validate and assess the performance of external brokers(CEP Engines)

- For capability for continuous validation and troubleshooting and monitor broker/CEP engine performance

- For helpdesk and technical personnel to assist in troubleshooting external broker connectivity/ functionality issues.

AlertSim Serbian in kind contribution

- We coordinate details with LSST data management and Simulation group

- J.Aleksić & V. Vujčić are doing the work as part of their thesis work (DAFMBU & FOS)

- There is potential for involvement of more software engineers 2-3 persons/year

- We will develop simultaneously our own CEP engine...
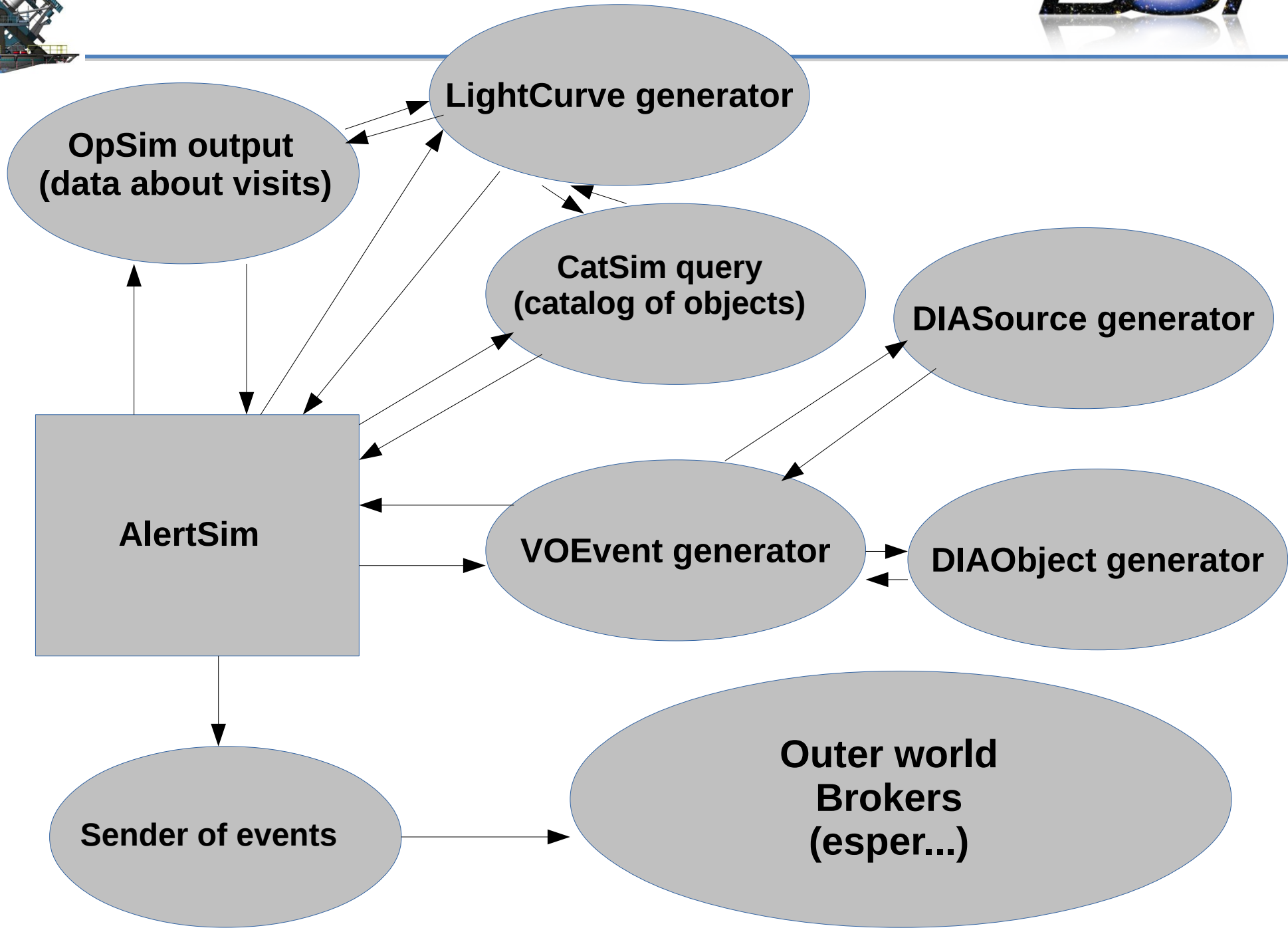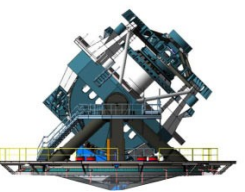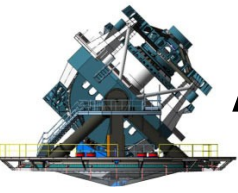
AlertSim – production version

- As of November 2016 AlertSim is included in the LSST Simulation codebase

- To achieve that we developed battery of tests

- Problem is that AlertSim depends on many connections and some users might not have access to databases (detecting such cases and handling them took longer that we hoped)

- Any changes in Simulation/DM-Stack packages influencing AlertSim are detected and code is adjusted accordingly (mainly by developers introducing those changes)

AlertSim - service

- Basic idea is to provide brokers (Antares etc.) heads up playground

- (we had to calculate too many light curves for Antares...)

- Django based (experience with VAMDC!)

- Easily adaptable for machine queries (requests)!

- Simple form to fill to choose:

  - ip address and port

  - Different local or remote opsim databases

  - Diferent catsim tables

  - Parameters for querying databases

AlertSim - service

- History calculated from opsim and variability mixin inside catsim (slow, problems with single magnitude...)

- Pack history(ical light curves) in diasource chunks (or emit complete diasources)

- Necessary connection to UW databases (is it wise to have it as a service??)

- For how long we want service to run?

- Note that we connect mainly to the stellar stuff – galaxies &sso in the future

- **AlertSim and DM end-to-end simulations**

AlertSim – demo of service

- Control parameters

- We use RRLyrae/allstars

- sending and receiving xml

- Esper

- python example_parser.py -c "allstars" -r "1.75" -oc "(night between 21 and 210 and fieldra between 1.3 and 1.5 and fielddec between -0.32 and -0.01 and filter like 'r')" -cc "rmag between 10 and 30 and varParamStr not like 'None' " -ip 147.91.240.29 --no_header

darko@servo9.aob.rs:~ <2>

zzz False
zzz False
zzz False
zzz False
zzz False
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zzz False
zzz False
Number of events from this visit : 52. Time from first to last event 68.148956 o
r 1.310557 per event
zzz False
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zzz False

Variable Objects <@servo2>

veljko@servo2:...space/voevent-test

ename":"rrly_lc/RRab/1895734_per.txt", "tStartMjd":3.348832344077652e+004}, "var
MethodName":"applyRRly"}
        [java] 20:46:21,195 INFO [VOEventListener] Lyrae!
        [java] 20:46:21,195 INFO [VOEventListener] true_positive! ra: 1.502853 dec
: -0.102618 delta_u: 0.969320
        [java] TPCount: 1151   FPCount: 0   FNCount: 95
        [java] Completeness: 0.923756   Contamination: 0.000000   {"pars":{"fil
ename":"rrly_lc/RRab/359035_per.txt", "tStartMjd":3.346232030145854e+004}, "varM
ethodName":"applyRRly"}
        [java] 20:46:24,218 INFO [VOEventListener] Lyrae!
        [java] 20:46:24,218 INFO [VOEventListener] true_positive! ra: 1.509062 dec
: -0.107374 delta_u: 1.379028
        [java] TPCount: 1152   FPCount: 0   FNCount: 95
        [java] Completeness: 0.923817   Contamination: 0.000000   {"pars":{"fil
ename":"rrly_lc/RRc/2233809_per.txt", "tStartMjd":3.360160548803787e+004}, "varM
ethodName":"applyRRly"}
        [java] 20:46:24,239 INFO [VOEventListener] Lyrae!
        [java] 20:46:24,239 INFO [VOEventListener] true_positive! ra: 1.510099 dec
: -0.100660 delta_u: 1.326530
        [java] TPCount: 1153   FPCount: 0   FNCount: 95
        [java] Completeness: 0.923878   Contamination: 0.000000   {"pars":{"fil
ename":"rrly_lc/RRab/2993853_per.txt", "tStartMjd":3.349017733880840e+004}, "var
MethodName":"applyRRly"}

simsuser@gateway3:~

darko@servo9:~> ssh servo3
Password:
Password:
Read from socket failed: Connection reset by peer
darko@servo9:~> ssh servo3
Password:
Last failed login: Tue Feb 23 19:57:53 CET 2016 from 75-144-26-73-sfba-ca.h
mcastbusiness.net on ssh:notty
There was 1 failed login attempt since the last successful login.
Last login: Tue Feb 23 19:56:17 2016 from 75-144-26-73-sfba-ca.hfc.comcast
ss.net
Have a lot of fun...
darko@servo3:~> ssh -L 51433:fatboy-private.phys.washington.edu:1433 simsu
teway.astro.washington.edu
bind: Address already in use
channel_setup_fwd_listener: cannot listen to port: 51433
Could not request local forwarding.
Last login: Mon Feb 22 02:09:10 2016 from servo3.aob.rs
[simsuser@gateway3 ~]$

Window 1 (top left): darko@servo9.aob.rs:~ <2>

```
zzz False
zzz False
zzz False
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zzz False
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zzz False
```

Window 2 (top right): Variable Objects <@servo2>

Window 3 (bottom left): veljko@servo2:...space/voevent-test

```
ename":"rrly_lc/RRab/4133965_per.txt", "tStartMjd":3.335797781497854e+004}, "var
MethodName":"applyRRly"}
     [java] 22:24:33,562 INFO  [VOEventListener] Lyrae!
     [java] 22:24:33,562 INFO  [VOEventListener] true_positive! ra: 1.414480 dec
: -0.065079 delta_u: 0.925091
     [java] TPCount: 3942      FPCount: 0      FNCount: 307
     [java] Completeness: 0.927748     Contamination: 0.000000     {"pars":{"fil
ename":"rrly_lc/RRc/2779194_per.txt", "tStartMjd":3.364375507515414e+004}, "varM
ethodName":"applyRRly"}
     [java] 22:24:36,615 INFO  [VOEventListener] Lyrae!
     [java] 22:24:36,615 INFO  [VOEventListener] true_positive! ra: 1.383113 dec
: -0.052930 delta_u: 1.146334
     [java] TPCount: 3943      FPCount: 0      FNCount: 307
     [java] Completeness: 0.927765     Contamination: 0.000000     {"pars":{"fil
ename":"rrly_lc/RRab/1652999_per.txt", "tStartMjd":3.350036413919062e+004}, "var
MethodName":"applyRRly"}
     [java] 22:24:36,658 INFO  [VOEventListener] Lyrae!
     [java] 22:24:36,658 INFO  [VOEventListener] true_positive! ra: 1.407050 dec
: -0.059686 delta_u: 0.684207
     [java] TPCount: 3944      FPCount: 0      FNCount: 307
     [java] Completeness: 0.927782     Contamination: 0.000000     {"pars":{"fil
ename":"rrly_lc/RRab/2369144_per.txt", "tStartMjd":3.344179155453762e+004}, "var
MethodName":"applyRRly"}
```

Window 4 (bottom right): darko@servo9.aob.rs:~ <5>

```
darko@servo9:~> ssh servo3
Password:
Password:
Read from socket failed: Connection reset by peer
darko@servo9:~> ssh servo3
Password:
Last failed login: Tue Feb 23 19:57:53 CET 2016 from 75-144-26-73-sfba-ca.hfc.co
mcastbusiness.net on ssh:notty
There was 1 failed login attempt since the last successful login.
Last login: Tue Feb 23 19:56:17 2016 from 75-144-26-73-sfba-ca.hfc.comcastbusine
ss.net
Have a lot of fun...
darko@servo3:~> ssh -L 51433:fatboy-private.phys.washington.edu:1433 simsuser@ga
teway.astro.washington.edu
bind: Address already in use
channel_setup_fwd_listener: cannot listen to port: 51433
Could not request local forwarding.
Last login: Mon Feb 22 02:09:10 2016 from servo3.aob.rs
[simsuser@gateway3 ~]$ Write failed: Broken pipe
darko@servo9:~>
```

Desktop

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elp

Q Sear

EMIT VOEVENT STREAM FROM ALERTSIM

Opsim table:

output_opsim3_61

Catsim table:

All stars

Opsim constraint:

dra between 1.3 and 1.5 and fielddec between -0.32 and -0

Catsim constraint:

rmag between 10 and 30 and varParamStr not like 'None'

Radius:

1.75

Maintained by Darko Jevremović. Questions or Comments?
Click here to send an email.

```
[java]                    </Time>
[java]                    <Position2D>
[java]                        <Value2>
[java]                            <C1>1.290246</C1> <!-- RA -->
[java]                            <C2>-0.132507</C2> <!-- Dec -->
[java]                        </Value2>
[java]                        <Error2Radius>0.010000</Error2Radius>
[java]                    </Position2D>
[java]                </AstroCoords>
[java]            </ObservationLocation>
[java]        </ObsDataLocation>
[java]    </WhereWhen>
[java]    <Citations>
[java]        <EventIVORN cite="followup">ivo:lsst.org/resource#89474</EventIVORN>
[java]        <EventIVORN cite="followup">ivo:lsst.org/resource#89475</EventIVORN>
[java]    </Citations>
[java]    <Description></Description>
[java] </voe:VOEvent>
[java]
[java] 10:40:20,770 INFO  [VOEventListener] Lyrae!
```

sstsw/m
and 30
ght be
.32 and

LSST Impact

Early involvement in LSST means that we have all relevant information and documentation to be able to explore & efficiently use data from the onset of survey

- There is possibility to do some interesting work during commissioning ComCam or even earlier

- There is plenty of room for collaborations with people from statistics, math, CS, software engineering, physics (dark energy), big data science, visualization

- COST1403 Big Data in Sky and Earth Observations

Future

Why I was talking about our involvement with Rubin/LSST and what that has to do with A&M

The main reason is our other project (VAMDC) and that we might want to implement some ideas from it i

Namely we will be dealing (similar to VAMDC) with heterogeneous distributed databases of follow-up observations

We will really need good registry of data sets and ways to access them so experience with VAMDC will be crucial

Possibility to use some of VAMDC codebase as part of development of future service

VO->VAMDC->Rubin