ESO Public Surveys

Lessons Learnt from the VISTA Cycle 1 Surveys and the Start of Cycle 2

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Outline

- Motivation & Policies – Public Surveys as examples of distributed science operations
- On-going ESO Public Surveys
  - VISTA first & second cycle
  - Lesson learnt and time domain universe
  - VST surveys & Spectroscopic Surveys
- Scientific impact
- Returns for the community
- Conclusions
- Acknowledgments
Since 2010, ESO operates dedicated telescopes for surveys: VST and VISTA. Also FLAMES@UT2, UVES@UT2, VIMOS@UT3, EFOSC/SOFI@NTT spectrographs are supporting survey projects.


ESO public surveys: such scheme implements a partnership between ESO and its community for distributed science operations.

- ESO organize calls, support telescope operations, delivery of raw data, data standard authority and publication of products through the archive, organization of peer reviews – activities coordinated by the ESO Survey Team
- Community define the science projects, observing strategy & observations, final scientific QC and delivery of science data products.

The ESO Science Archive Facility (SAF; http://archive.eso.org/cms.html) is the primary point of publication/availability of the survey products (as per ESO Council Meeting 104, 17–18 December 2004).
Public Surveys in a nut-shell

- Legacy value for astronomical community at large
- Very large programmes (>2 years); very diversified observing strategies
- Synergy between optical and NIR imaging, from 0.33 to 2.15 micron
- Spectroscopic follow-up of sources; multiplexing capabilities (FoV ~ 10 arcmin) to single slit; Spec_res 10^4 to ~1000.
- All raw observations are immediately public
- Survey teams commit to deliver reduced images/spectra and catalogues within ~yearly releases
First cycle of VISTA surveys started operations on April 2010. Current assessment is that they will all be completed in P100 – 570 hrs remaining.

<table>
<thead>
<tr>
<th>Survey ID and home page</th>
<th>Science topic</th>
<th>Area (deg²)</th>
<th>Filters</th>
<th>Magnitude limits</th>
<th>Observing time completed (hrs) to Oct. 1st 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-VISTA [link]</td>
<td>Deep high-z</td>
<td>1.7 deep 0.73 ultra deep</td>
<td>Y J H Ks NB118</td>
<td>25.7 25.5 25.1 24.5 26.7 26.6 26.1 25.6 26.0</td>
<td>1809</td>
</tr>
<tr>
<td>VHS [link]</td>
<td>Whole sky</td>
<td>17800</td>
<td>Y J H Ks</td>
<td>21.2 21.1 20.6 20.0</td>
<td>4519</td>
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<tr>
<td>VIDEO [link]</td>
<td>Deep high-z</td>
<td>12</td>
<td>Z Y J H Ks</td>
<td>25.7 24.6 24.5 24.0 23.5</td>
<td>1876</td>
</tr>
<tr>
<td>VIKING [link]</td>
<td>Extragalactic</td>
<td>1500</td>
<td>Z Y J H Ks</td>
<td>23.1 22.3 22.1 21.5 21.2</td>
<td>2410</td>
</tr>
<tr>
<td>VMC [link]</td>
<td>Resolved SFH</td>
<td>180</td>
<td>Y J Ks</td>
<td>21.9 21.4 20.3</td>
<td>1779</td>
</tr>
</tbody>
</table>

VISTA PS

First cycle of VISTA surveys started operations on April 2010. Current assessment is that they will all be completed in P100 – 570 hrs remaining.
VISTA PS

- Second cycle of VISTA surveys, ESO call in 2015
- 13 Loi submitted by the community, oversubscription > 2
- 7 proposals selected; started operations in April 2017

<table>
<thead>
<tr>
<th>Name P.I.</th>
<th>Short Title</th>
<th>Filters</th>
<th>Tot. Time (hrs)</th>
<th>Area (deg²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW; N. Tanvir</td>
<td>Kilonova counterparts to Gravitational wave sources</td>
<td>Y J Ks</td>
<td>420</td>
<td>300</td>
</tr>
<tr>
<td>UltraVISTA; J. Dunlop</td>
<td>Completing the legacy of UltraVISTA</td>
<td>J H Ks</td>
<td>756</td>
<td>0.75</td>
</tr>
<tr>
<td>VVVX; D. Minniti</td>
<td>Extending VVV to higher Gal lat.</td>
<td>J H Ks</td>
<td>1900</td>
<td>1700</td>
</tr>
<tr>
<td>VEILS; M. Banerji</td>
<td>VISTA Extragalactic Infrared Survey</td>
<td>J Ks</td>
<td>1180</td>
<td>9</td>
</tr>
<tr>
<td>CAV; M. Nonino</td>
<td>Clusters at VIRCAM</td>
<td>Y J Ks</td>
<td>560</td>
<td>30</td>
</tr>
<tr>
<td>VISIONS; J. Alves</td>
<td>VISTA star formation atlas</td>
<td>J H Ks</td>
<td>553</td>
<td>550</td>
</tr>
<tr>
<td>SHARKS; I. Oteo</td>
<td>Southern Herschel-Atlas Regions K-band survey</td>
<td>Ks</td>
<td>1200</td>
<td>300</td>
</tr>
</tbody>
</table>
Lessons learnt and time domain

VISTA 1st cycle surveys reaching completion in P100!

- Compreh. science program;
- complementing obs. constraints
- Obs overheads
- Exploitation of the time domain universe

Arnaboldi et al. 2017Msngr.168...15A
The VST surveys started operations on October 2011

<table>
<thead>
<tr>
<th>Survey ID and home page</th>
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<th>Area deg$^2$</th>
<th>Filters</th>
<th>Magnitude limits</th>
<th>Observing time completed (hrs) to Oct 1$^{st}$ 2017</th>
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<td>KIDS</td>
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<td>1500</td>
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<td>24.1 24.6 24.4 23.4</td>
<td>2297</td>
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<tr>
<td>ATLAS</td>
<td>Wide area/BAO</td>
<td>4000</td>
<td>u’ g’ r’ I’ z</td>
<td>22.0 22.2 22.2 21.3 20.5</td>
<td>1422</td>
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<tr>
<td><a href="http://astro.dur.ac.uk/Cosmology/vstalas/">http://astro.dur.ac.uk/Cosmology/vstalas/</a></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VPHAS+</td>
<td>Stellar astrophysics</td>
<td>2000</td>
<td>U’ g’ Hα r’ I’</td>
<td>21.8 22.5 21.6 22.5 21.8</td>
<td>985</td>
</tr>
<tr>
<td><a href="http://www.vphas.eu">http://www.vphas.eu</a></td>
<td></td>
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</tbody>
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The graph shows the percentage of completion of VST Public Surveys over time, with KIDS leading in percentage of completion.
Spectroscopic Surveys

- **Gaia ESO**: this survey targets $10^5$ stars distributed among the various components of the Milky Way (MW) and in 100 open clusters. It has a strong synergy with the Gaia satellite survey. It provides the phase space structure and abundances for the stellar populations in the MW. Started in 01/2012 on FLAMES/UVES@UT2, current 5th year of operations. Target selection comes from the imaging surveys VHS and VVV, among others. ([http://www.gaia-eso.eu/](http://www.gaia-eso.eu/))

- **PESSTO**: spectroscopic follow-up of about 150 SN candidates in an unbiased sample of nearby galaxies to understand the physics of supernovae explosion. Started in 01/2012 on EFOSC/SOFU@NTT, current 5th year of operations. ([http://www.pessto.org/](http://www.pessto.org/))

- **VANDELS**: study of the star forming galaxies in the redshift range $2.5 < z < 7.0$ and passive galaxies in the redshift range $1.5 < z < 2.5$, in the two CANDELS fields, CDF South and UDS. Goal is to measure metallicities and kinematics of the ionized gas in these systems. 914 hours allocated on VIMOS@UT3. ([http://vandels.inaf.it](http://vandels.inaf.it))

- **LEGA-C**: study of 3000 early-type galaxies in the COSMOS field in the redshift range $0.6 < z < 1.0$. Understood how galaxies grow in mass through measurements of their dynamical masses, stellar ages and metallicities. 1010 hours allocated on VIMOS@UT3. ([http://www.mpia.de/home/legac/index.html](http://www.mpia.de/home/legac/index.html))
Spectroscopic Surveys

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2nd cycle of the VISTA surveys started in 04/2017; ESO is currently managing 20 PS projects

Phase 1 and Phase 2 completed for 21800 hrs of telescope science operations; delivery & publication of raw and science data products ongoing


Science data are served co-jointly with ESO in house processed products – latest addition MUSE, MUSE deep and PIONIER NIR interferometry data

Talks by Maschetti on Phase 3/Data audit and Retzlaff on Archive Science Project
Impact of ESO PS

All PS have published data product releases through ESO SAF: >40 TB, 270k+ files, > 30k spectra; Opt./NIR: 4336/9445 deg²

- VPHAS+
- VIDEO
- VVV
- VHS
- KiDS
- VIKING,
- VMC - blue
- UltraVISTA
- ATLAS
Impact of ESO PS

Ref. Publications: 337 total, 21% from archive
http://telbib.eso.org

Catalogues with aperture matched magnitudes in all relevant bands, lights curves, spectral time series
http://www.eso.org/qi

All PS have published data
product releases through ESO
SAF : >40 TB, 270k+ files, > 30k spectra; Opt./NIR: 4336/9445 deg^2

- VPHAS+
- VIDEO
- VVV
- VHS
- KiDS
- VIKING
- VMC - blue
- UltraVISTA
- ATLAS

Building a community
>2300 unique users of science ready data...and counting!
~9 requests per user;~30% of these users are new to ESO, having not applied for time

Two ESO workshops dedicated to Public surveys in 2012 & 2015

M. Arnaboldi - ESO/ESA workshop - Distributed Science Operations
18.10.2017
Impact of ESO PS

Cumulative number refereed publications for ESO PS

Total ref. publications 537
113 (21%) are from archive (since 2010)

From http://telbib.eso.org

M. Arnaboldi - ESO/ESA workshop - Distributed Science Operations
18.10.2017
From VISTA 1st Cycle

MILKY WAY AND LOCAL UNIVERSE
The structure of the Milky Way outside the Bulge(*)

This image shows the surface density of stars in the Milky Way as seen from the Sun, taken from four different surveys (UKIDSS, VVV, 2MASS, and GLIMPSE) and corrected for extinction. The bulge is the thicker region near the center; it is asymmetric because it is barred. The asymmetry in the disk towards the left of the image is due to the thinner long bar outside the bulge.


* MPE PR http://www.mpe.mpg.de/6333402/News_20150521
From the VST surveys

COSMOLOGY
Dark matter may be less dense and more smoothly distributed throughout space than previously thought. An international team used data from the Kilo Degree Survey (KiDS, PI Kujken) to study how the light from about 15 million distant galaxies was affected by the gravitational influence of matter on the largest scales in the Universe. The results appear to be in disagreement with earlier results from the Planck satellite. (*) Hildebrandt et al. 2017, MNRAS,465,1454
From the VISTA 2nd cycle & Public Spectroscopic Surveys

GRAVITATIONAL WAVE ALERTS AND EM COUNTERPARTS
IMPACT of ESO PS

ESO PR 1733 - ESO Telescopes Observe First Light from Gravitational Wave Source

Mosaic of VISTA images of NGC 4993 showing changing kilonova

Montage of X-shooter spectra showing changes in the kilonova in NGC 4993 over 12 days.

ESO/Pian et al./Smartt & ePESSTO
Archive users are accessing science data products for their independent science

On average users carry out eleven independent queries for catalog records via the ESO catalog query
Distributed science operations are key to the success of surveys in observational astronomy.

Projects such as these are characterized by large investments in "survey systems" that include dedicated telescopes and instruments, a large community of astronomers involved in the science projects and large networks for the data distribution.

The scientific success of survey projects includes the legacy values of the science products that become available through the archives for further scientific analysis by the community.

**ESO Public Surveys** are examples of effective implementations of such systems, and empower the community at large to discover the Universe, in the spirit of the IAU statement “The Universe: yours to discover”
Acknowledgements

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We wish to acknowledge our colleagues from the ESO Department of Engineering for their support in developing the tools required for carrying out Phase 1, Phase 2 and Phase 3 for the ESO Public Surveys, and the ESO library team for the careful monitoring of the refereed publications.

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