# ESO Public Surveys

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

Magda Arnaboldi, Nausicaa Delmotte, Dimitri Gadotti, Michael Hilker, Gaitee Hussain, Laura Mascetti, Alberto Micol, Monika Petr-Gotzens, Marina Rejkuba, Jörg Retzlaff , and Rob Ivison, Bruno Leibundgut, Martino Romaniello

# 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

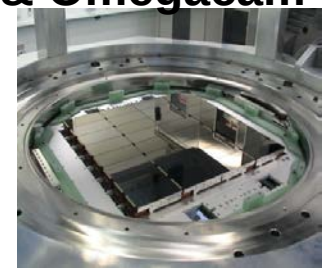
# Motivation & Policies

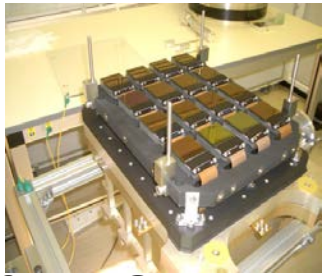
- Since 2010, ESO operates dedicated telescopes for surveys: VST and VISTA. Also FLAMES@UT2, UVES@UT2, VIMOS@UT3, EFOSC/SOFI@NTT spectrographs are supporting survey projects
- Future: Next Generation Transit Surveys (NGTS) started operations in 01.04.2016 & data products delivery on 01.04.2018. Two additional wide field spectrographs – MOONS and 4MOST in 2020-2021
- 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).

# On-going Public Surveys

http://www.eso.org/sci/observing/PublicSurveys/sciencePublicSurveys.html

- 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

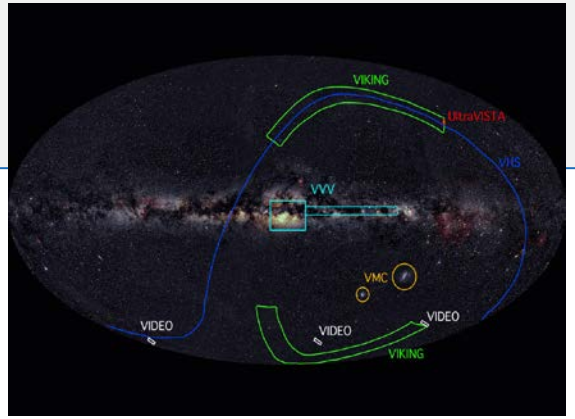



FLAMES@UT2
VIMOS@UT3

EFOSC&SOFI
@NTT

# VISTA PS

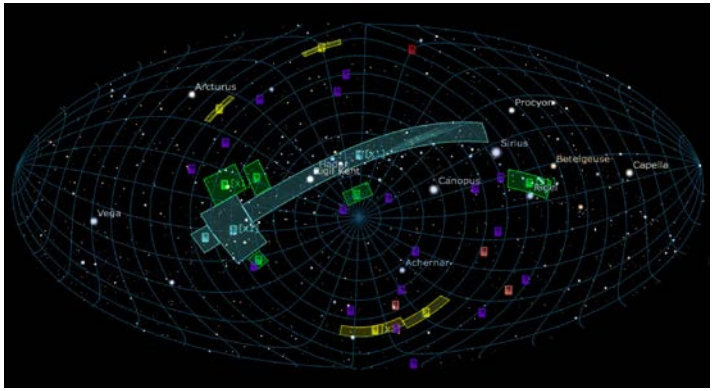



- First cycle of VISTA surveys started operations
- on April 2010.
- Current assessment is that they will all be completed in P100 – 570 hrs remaining

| Survey ID and home page | Science topic | Area (deg$^2$) | Filters | Magnitude limits | Observing time completed (hrs) to Oct. 1st 2017 |
|---|---|---|---|---|---|
| Ultra-VISTA http://home.strw.leidenuniv.nl/~ultravista/ | Deep high-z | 1.7 deep<br>0.73 ultra deep | Y J H Ks<br>NB118 | 25.7 25.5 25.1 24.5<br>26.7 26.6 26.1 25.6 26.0 | 1809 |
| VHS http://www.ast.cam.ac.uk/~rgm/vhs/ | Whole sky | 17800 | Y J H Ks | 21.2 21.1 20.6 20.0 | 4519 |
| VIDEO http://www-astro.physics.ox.ac.uk/~video | Deep high-z | 12 | Z Y J H Ks | 25.7 24.6 24.5 24.0 23.5 | 1876 |
| VVV http://vvvsurvey.org/ | Galactic MW | 560 | Z Y J H Ks | 21.9 21.1 20.2 18.2 18.1 | 2157/Completed |
| VIKING http://www.astro-wise.org/projects/VIKING/ | Extragalactic | 1500 | Z Y J H Ks | 23.1 22.3 22.1 21.5 21.2 | 2410 |
| VMC http://star.herts.ac.uk/~mcioni/vmc/ | Resolved SFH | 180 | Y J Ks | 21.9 21.4 20.3 | 1779 |

# VISTA PS

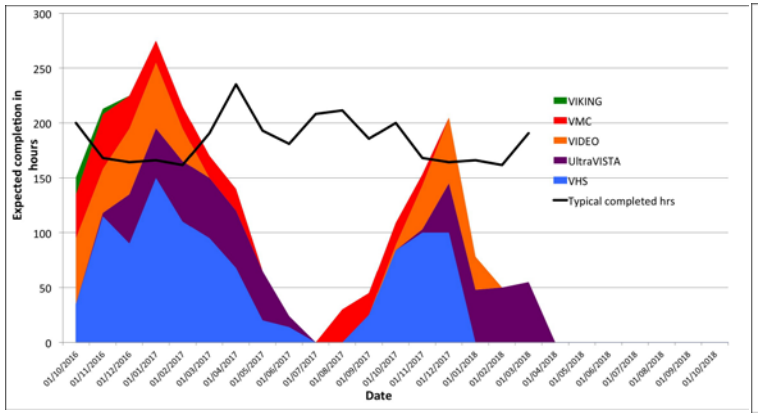
- **Second cycle of VISTA surveys, ESO call in 2015**
- **13 Loi submitted by the community, oversubscription > 2**
- **7 proposals selected; started operations in April 2017**

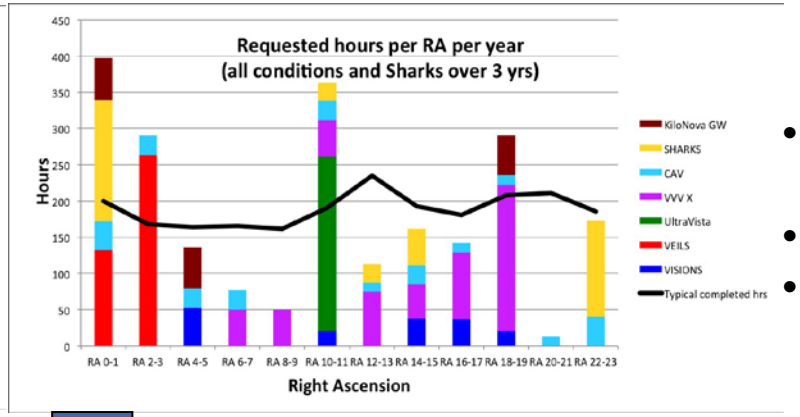



| Name P.I. | Short Title | Filters | Tot. Time (hrs) | Area ($deg^{2}$) |
|---|---|---|---|---|
| GW; N. Tanvir | Kilonova counterparts to Gravitational wave sources | Y J Ks | 420 | 300 |
| UltraVISTA; J. Dunlop | Completing the legacy of UltraVISTA | J H Ks | 756 | 0.75 |
| VVVX; D. Minniti | Extending VVV to higher Gal lat. | J H Ks | 1900 | 1700 |
| VEILS; M. Banerji | VISTA Extragalactic Infrared Survey | J Ks | 1180 | 9 |
| CAV; M. Nonino | Clusters at VIRCAM | Y J Ks | 560 | 30 |
| VISIONS; J. Alves | VISTA star formation atlas | J H Ks | 553 | 550 |
| SHARKS;I. Oteo | Southern Herschel-Atlas Regions K-band survey | Ks | 1200 | 300 |

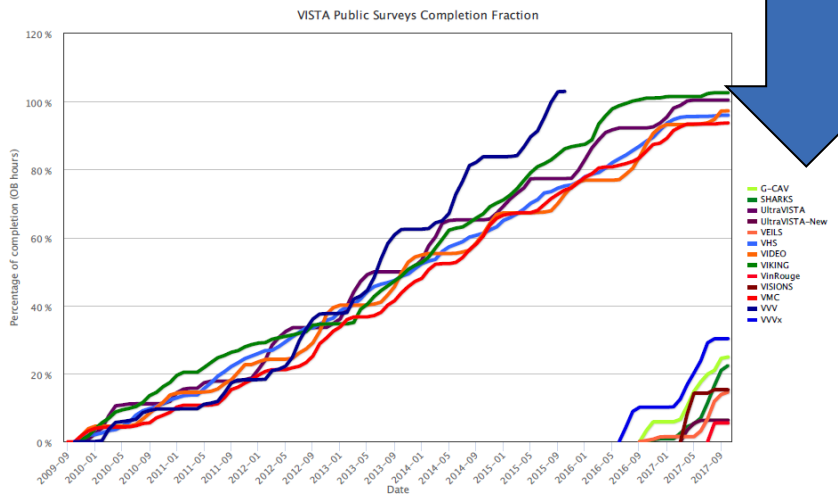
# Lessons learnt and time domain

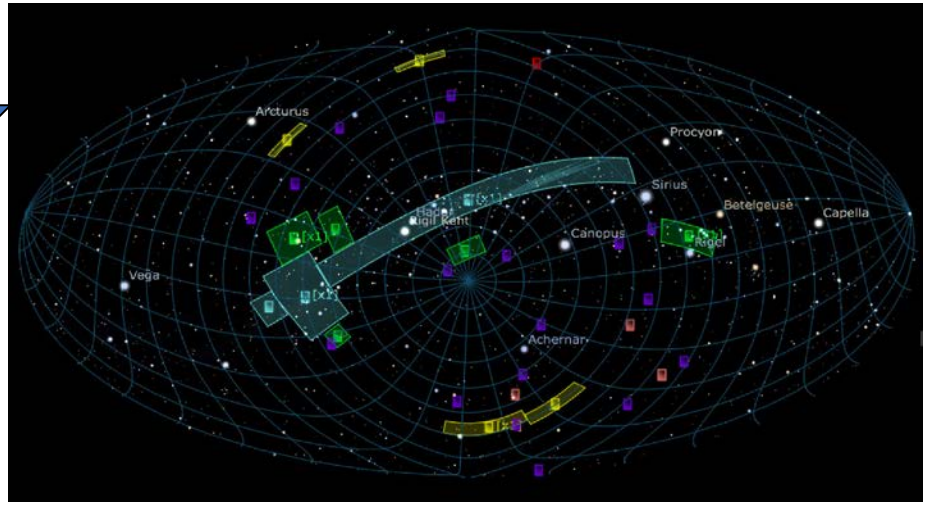
VISTA 1st cycle surveys reaching completion in P100!



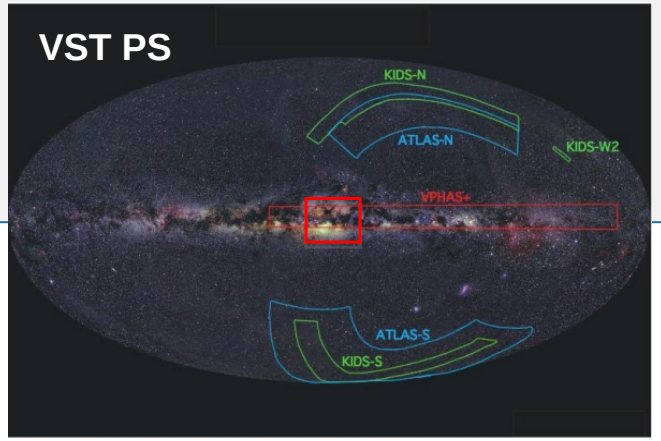

- **Compreh. science program;**
- **complementing obs. constraints**
- **Obs overheads**
- **Exploitation of the time domain universe**



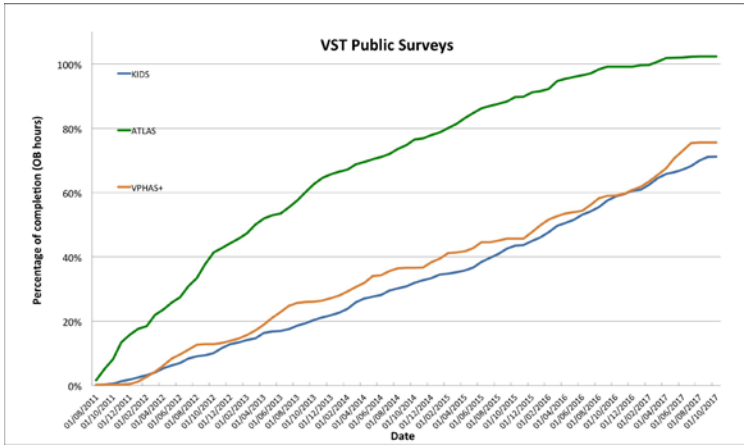

Arnaboldi et al. [2017Msngr.168...15A]

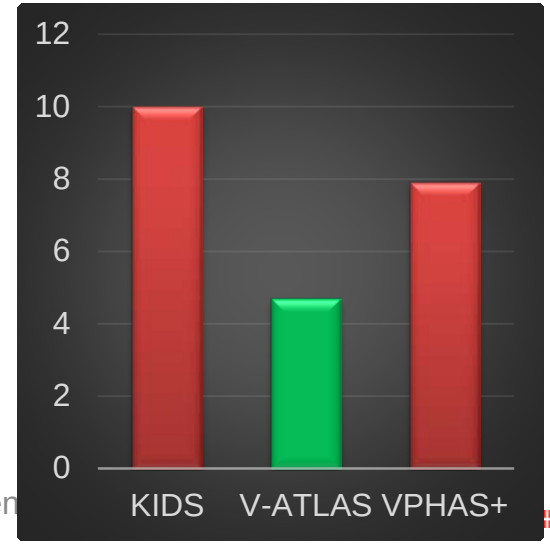
# VST PS




**The VST surveys started operations on October 2011**

| Survey ID and home page | Science topic | Area deg$^2$ | Filters | Magnitude limits | Observing time completed (hrs) to Oct 1st 2017 |
|---|---|---|---|---|---|
| KIDS http://kids.strw.leidenuniv.nl/ | Extragalactic | 1500 | u' g' r' I' | 24.1 24.6 24.4 23.4 | 2297 |
| ATLAS http://astro.dur.ac.uk/Cosmology/vstatlas/ | Wide area/BAO | 4000 | u' g' r' I' z | 22.0 22.2 22.2 21.3 20.5 | 1422 |
| VPHAS+ http://www.vphas.eu | Stellar astrophysics | 2000 | U' g' Hα r' I' | 21.8 22.5 21.6 22.5 21.8 | 985 |



# Spectroscopic Surveys

- **Gaia ESO**: this survey targets $10^5$ stars distributed ar… components of the Milky Way (MW) and in 100 open clust… …ynergy with the Gaia satellite survey. It provides the ph… …and abundances for the stellar populations in the MW. C… …on FLAMES/ UVES@UT2, current 5th year of operations. T… …mes from the imaging surveys VHS and VVV, among others. (http://w… …eso.eu/ )

Galactic MW, stellar evolution

- **PESSTO:** spectroscopic follow-up of ab… …ies in an unbiased sample of nearby galaxies to understa… …upernovae explosion. Started in 01/2012 on EFOSC/SO… …nd 5th year of operations. (http://www.pessto.org/ )

SuperNovae physics

- **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 C… fields, CDF South and UDS. Goal is to measure metallicities and… …onized gas in these systems. 914 hours allocated on VI… …andels.inaf.it )

- **LEGA-C:** study of 3000 ga… …the COSMOS field in the redshift range 0.6 < z< 1.0. Unde… …ies grow in mass through measurements of their dynamical masses, … ages and metallicities. 1010 hours allocated on VIMOS@UT3. (http://www.mpia.de/home/legac/index.html )

Galaxy evolution, Cosmology

# Spectroscopic Surveys

- **Gaia ESO**: this survey targets $10^5$ stars distributed among the major components of the Milky Way (MW) and in 100 open clust… a strong synergy with the Gaia satellite survey. It provides the ph… and abundances for the stellar populations in the MW. Started … 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/ )

Completed

- **PESSTO:** spectroscopic follow-up of ab… ndidates in an unbiased sample of nearby galaxies to understand… supernovae explosion. Started in 01/2012 on EFOSC/SOFU@NTT … on 5th year of operations. (http://www.pessto.org/ )

Completed

- **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 C… ELS fields, CDF South and UDS. Goal is to measure metallicities and … he ionized gas in these systems. 914 hours allocated on VI… …ndels.inaf.it )

To be completed in P101

- **LEGA-C:** study of 3000 ga… the COSMOS field in the redshift range 0.6 < z< 1.0. Understa… …ies grow in mass through measurements of their dynamical masses, ste… ages and metallicities. 1010 hours allocated on VIMOS@UT3. (http://www.mpia.de/home/legac/index.html )

# Summary distributed operations

- 2nd cycle of the VISTA surveys started in 04/2017; ESO is currently managing 20 PS projects
- Phase1 and Phase2 completed for 21800 hrs of telescope science operations; delivery&pub. of raw and science data products ongoing
- Publication of > 50 TB of science data products through the ESO SAF via Phase 3 http://www.eso.org/sci/observing/phase3/data_releases.html
- 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

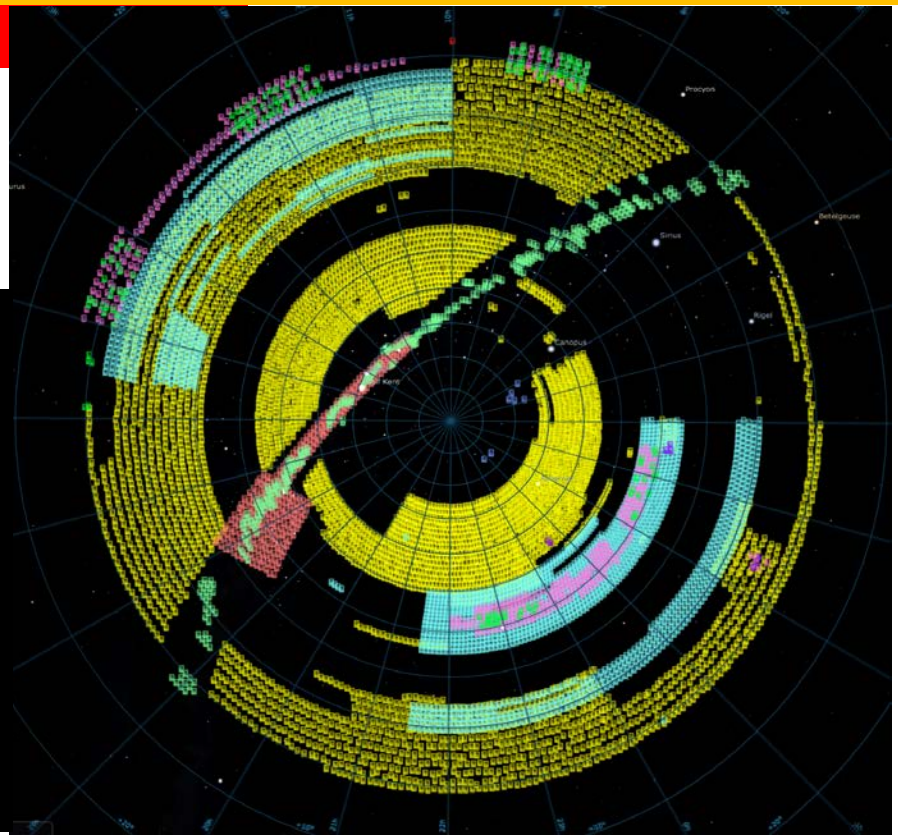
# Impact of ESO PS


**Ref. Publications: 5**
**21% from archive p**

http://telbib.eso.org

**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



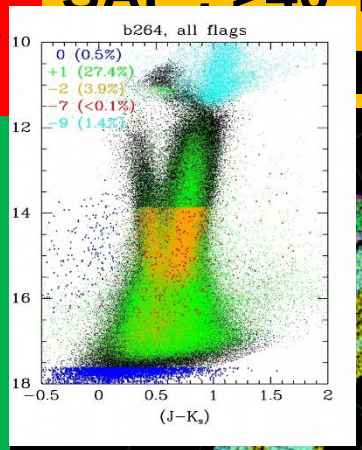
# Impact of ESO PS

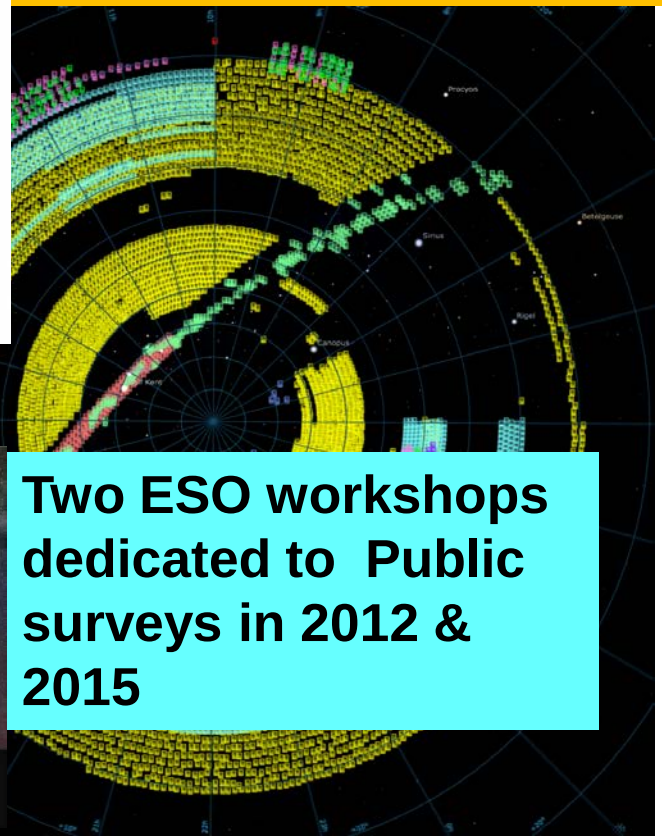

**Ref. Publications: 3**
**21% from archive**

http://telbib.eso.org

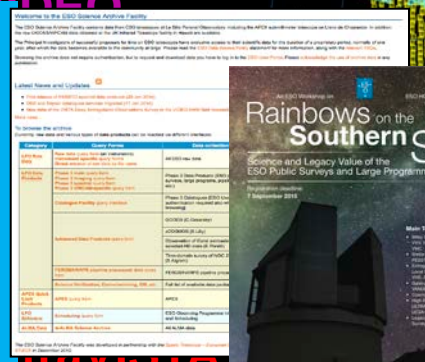
**All PS have published data product releases through ESO SAF : >40 TB, 270k+ files, > 30k**
**pt./NIR: 4336/9445 deg²**

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



**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

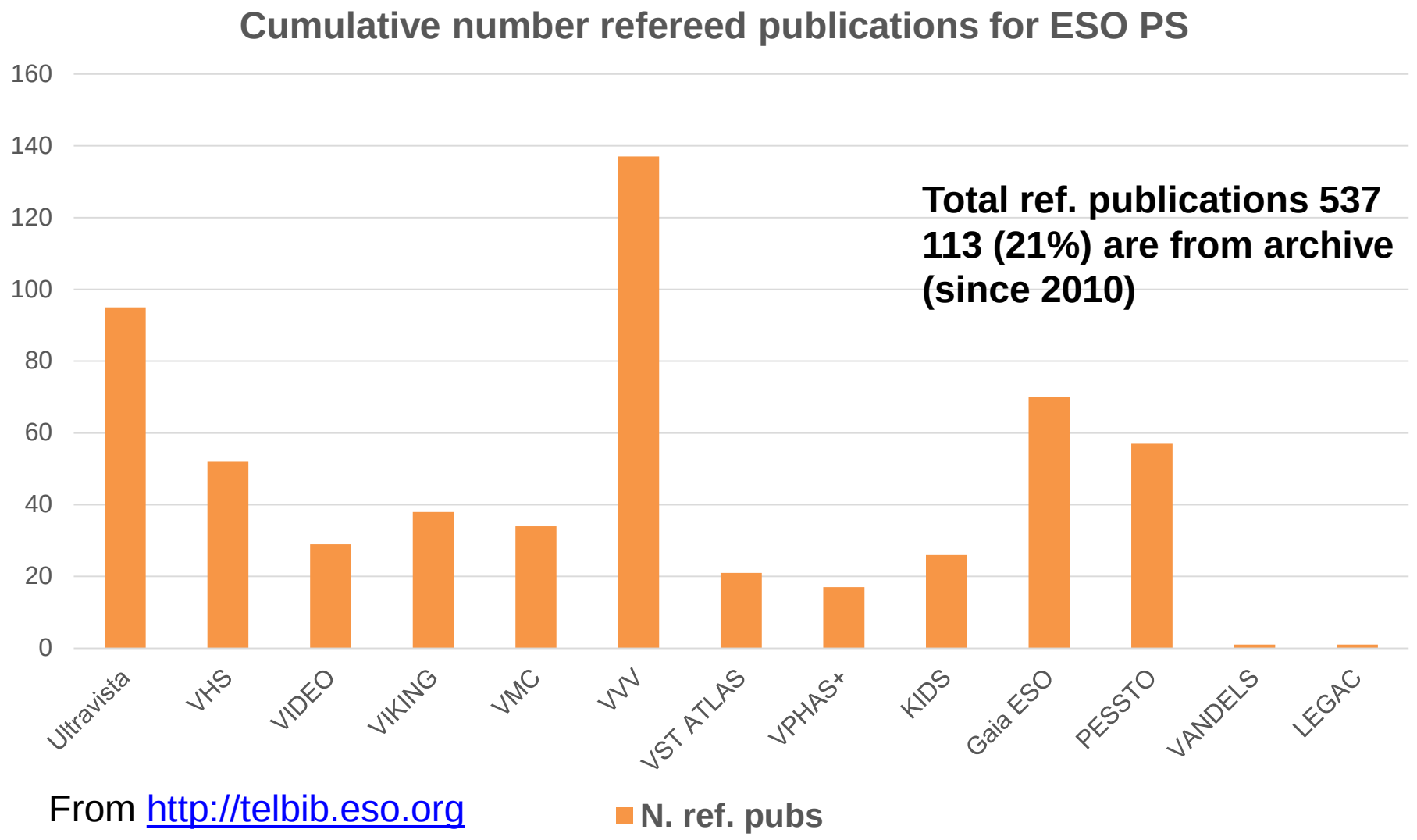





**Two ESO workshops dedicated to Public surveys in 2012 & 2015**

▪VIDEO
▪ATLAS

# Impact of ESO PS



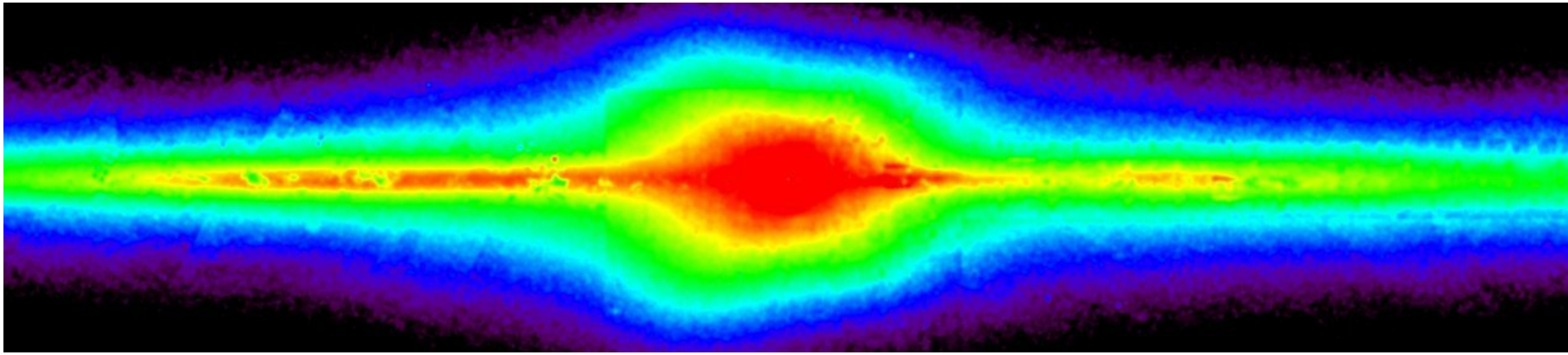

From http://telbib.eso.org

From VISTA 1st Cycle

# MILKY WAY AND LOCAL UNIVERSE

# Impact of ESO PS

## The structure of the Milky Way outside the Bulge(*)



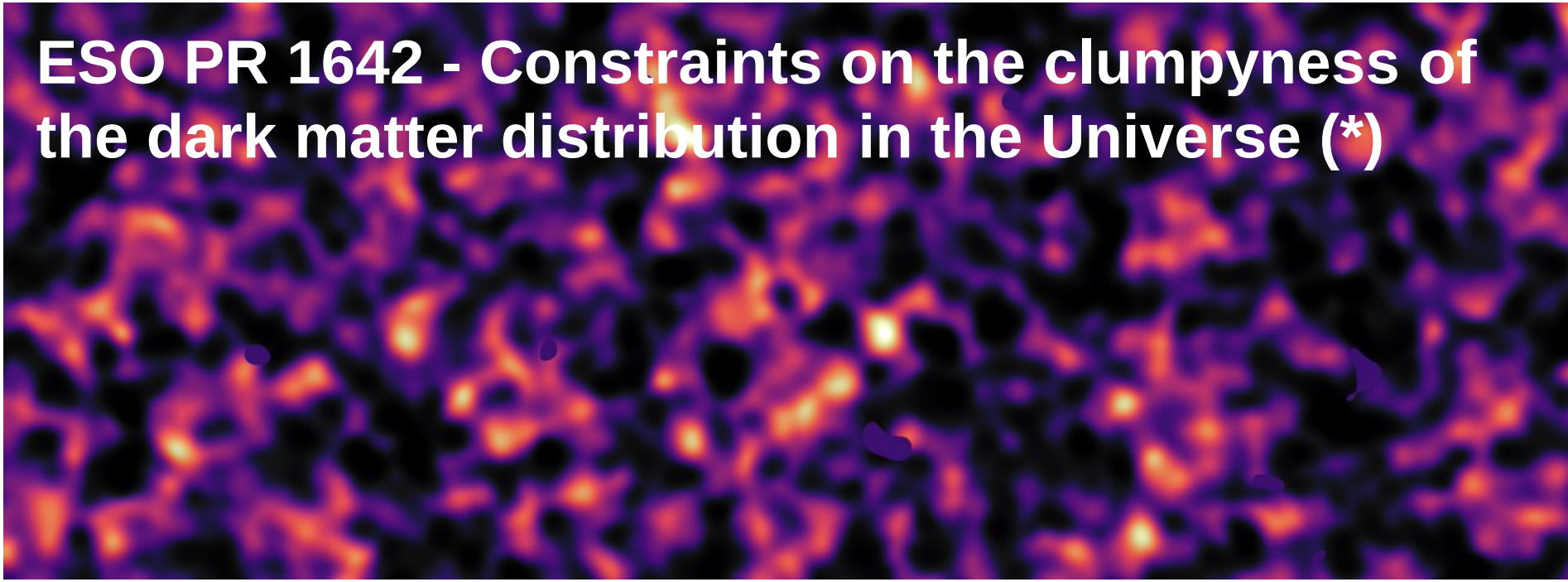
This image shows the surface density of stars in the Milky Way as seen from the Sun, taken from four different surveys (UKIDSS, VVV, 2MASS, and GLIMPSE) and corrected for extinction. The bulge is the thicker region near the center; it is asymmetric because it is barred. The asymmetry in the disk towards the left of the image is due to the thinner long bar outside the bulge. Wegg, Gerhard & Portail 2015, MNRAS, 450, 4050

* MPE PR http://www.mpe.mpg.de/6333402/News_20150521

From the VST surveys

# COSMOLOGY

# Impact of ESO PS




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

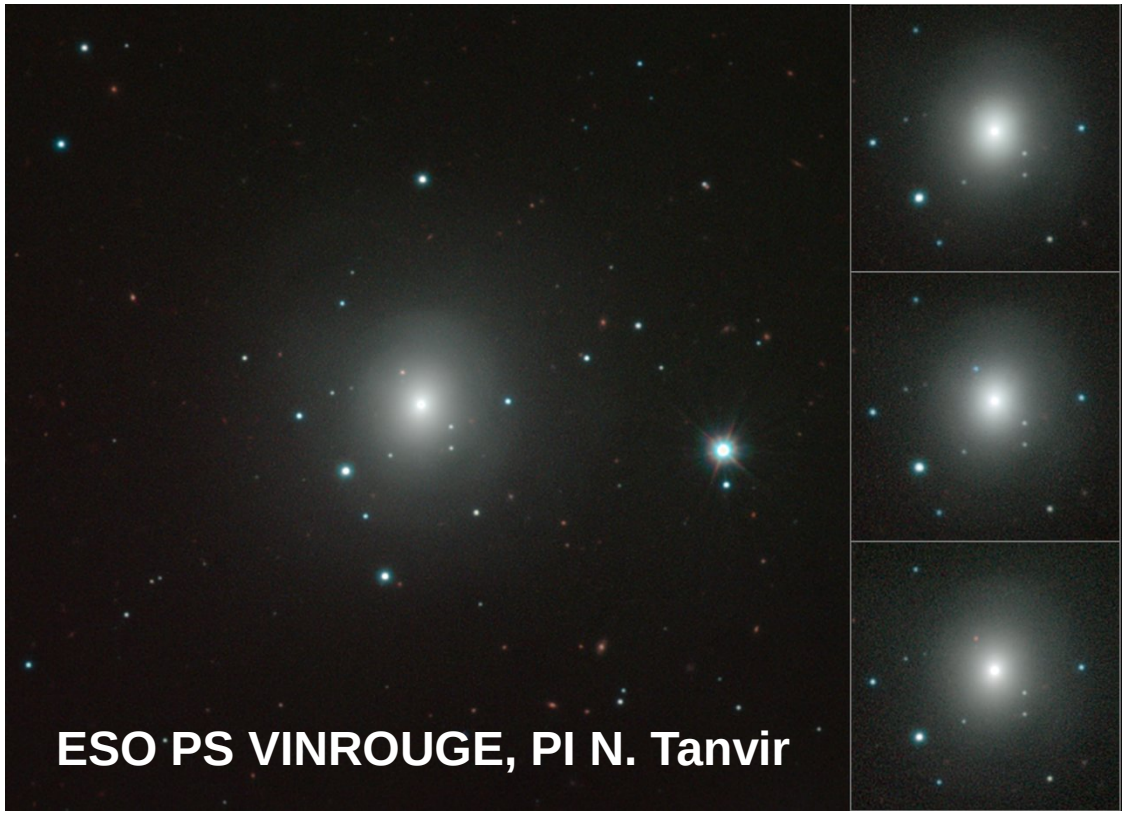
From the VISTA 2nd cycle & Public Spectroscopic Surveys

# GRAVITATIONAL WAVE ALERTS AND EM COUNTERPARTS

# IMPACT of ESO PS

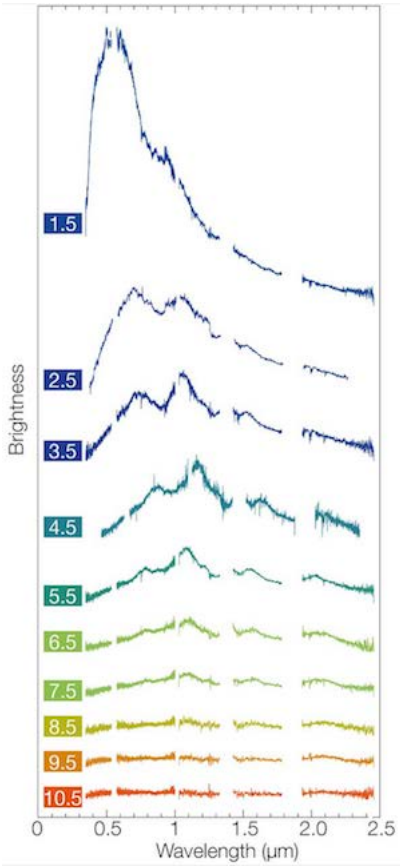
## ESO PR 1733 - ESO Telescopes Observe First Light from Gravitational Wave Source

**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.**

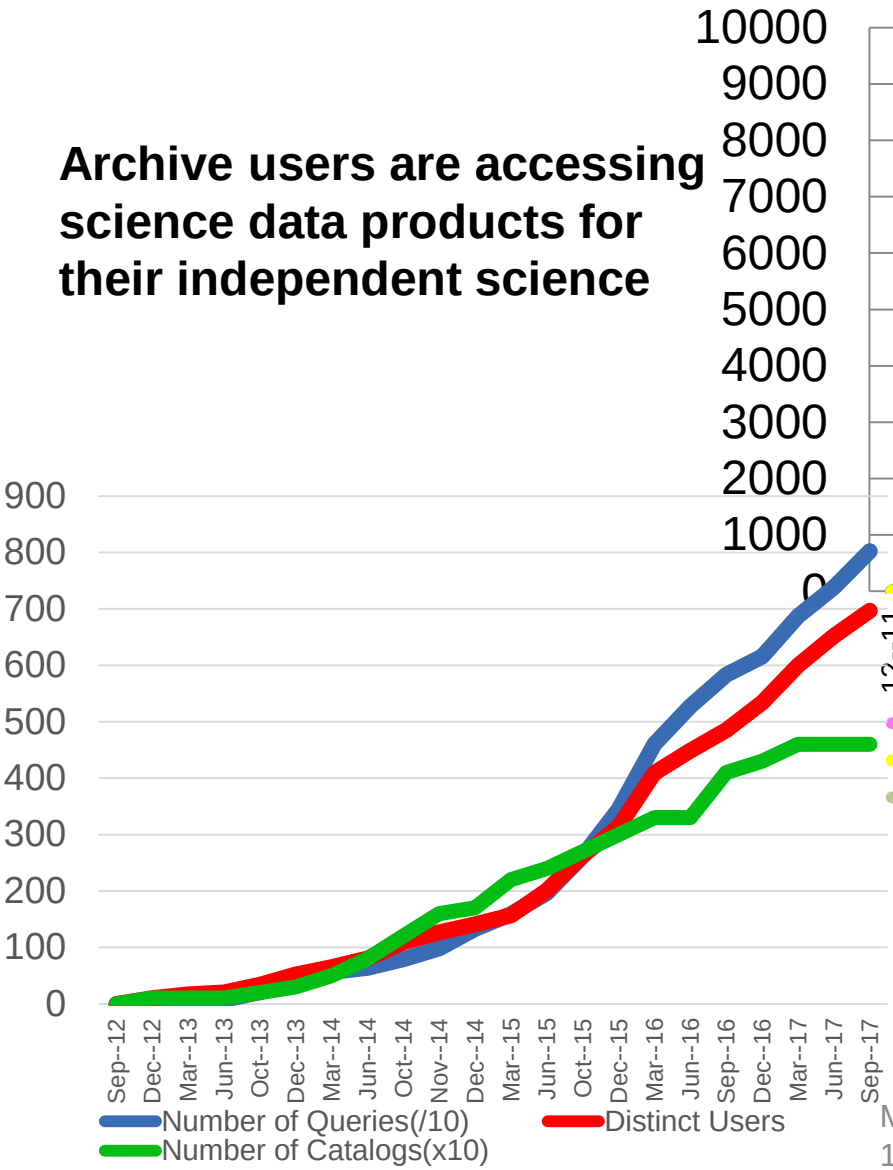
*ESO/Pian et al./Smartt & ePESSTO*

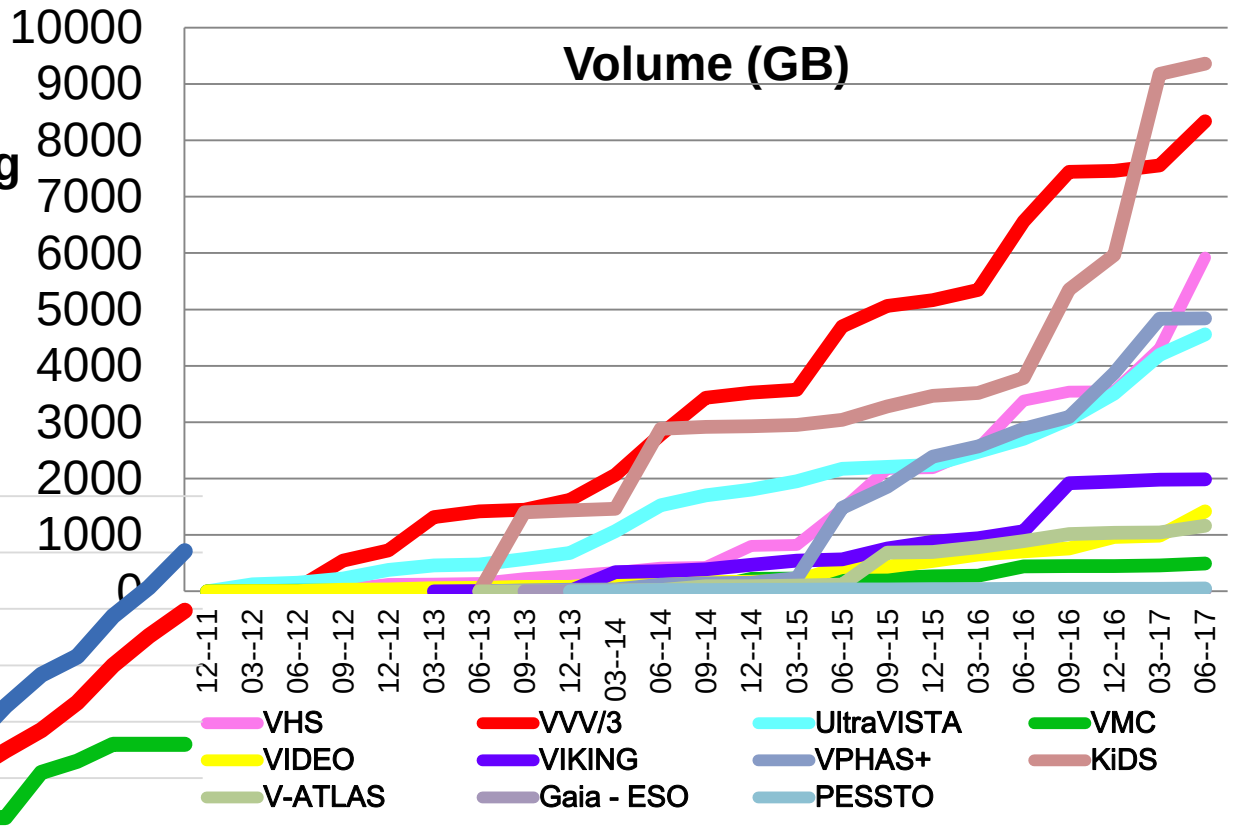


# Returns for the community

http://archive.eso.org/wdb/wdb/adp/phase3_main/form

**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**

# Conclusions

- 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


- We would like to thank our La Silla Paranal colleagues, for their work and support to the science operations of the ESO Public Surveys.
- We wish to acknowledge our colleagues from the ESO Department of Engineering for their support in developing the tools required for carrying out Phase1, Phase 2 and Phase 3 for the ESO Public Surveys, and the ESO library team for the careful monitoring of the refereed publications.
- We wish to thank the PIs of the Public Surveys and their collaborators, including the data centers at CASU, WFAU and TERAPIX, for their hard work and support to ESO mission.