



# The ESO Science Archive Facility & its content

## The scientific legacy from the ESO public surveys

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*Presented by Magda Arnaboldi*

*On behalf of the ESO survey team, Back-end operation department and  
User support department*





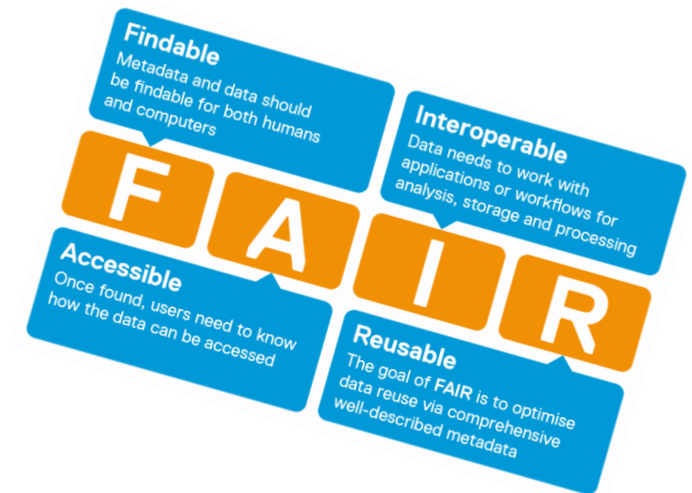
- **Outline**

- **The ESO Science Archive Facility**
- **Why carrying out ESO Phase 3 for your data**
- **Archive & Public surveys' stats**

# Modern Science Archives

## *FAIR principle*

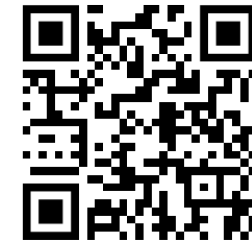
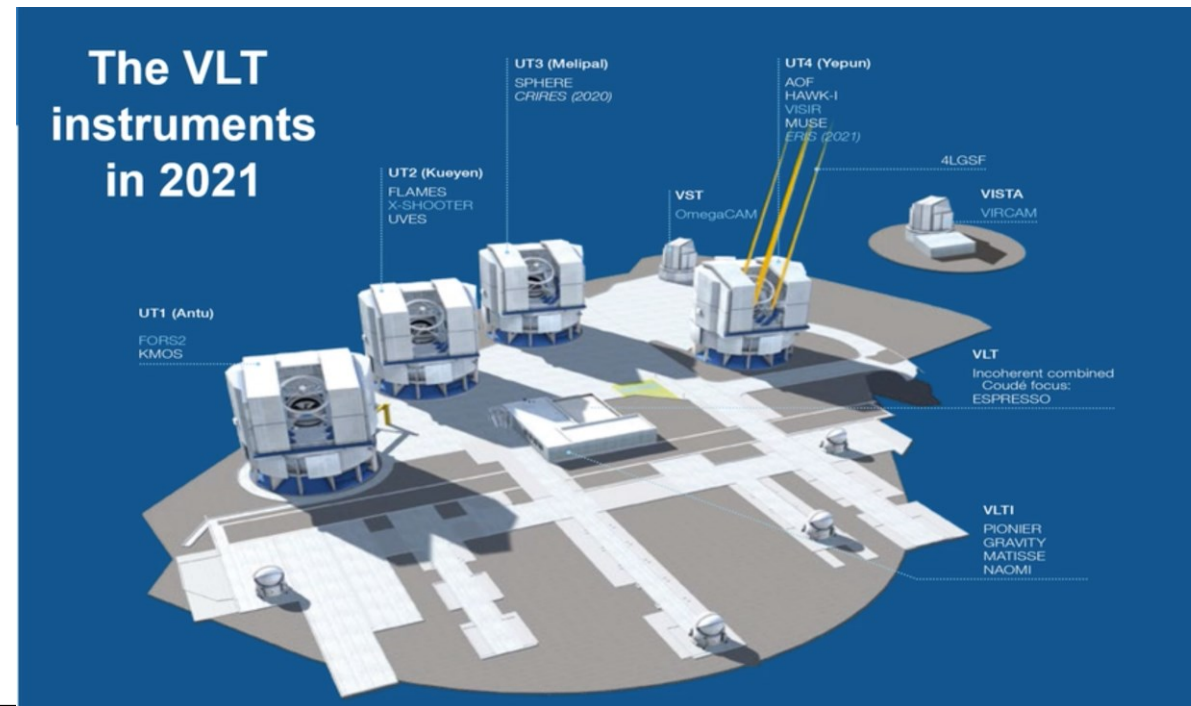
- Help maximize the scientific return of astronomical facilities
- Favorable cost-benefit ratio
- Multi-wavelength, multi-messenger astronomy
- Reproducibility
- Time variability
- Support for scientists from developing countries
- Citizen-science
- Outreach



# The ESO Science Archive

The Science Archive is **the** access point to data from the La Silla Paranal Observatory, including ELT

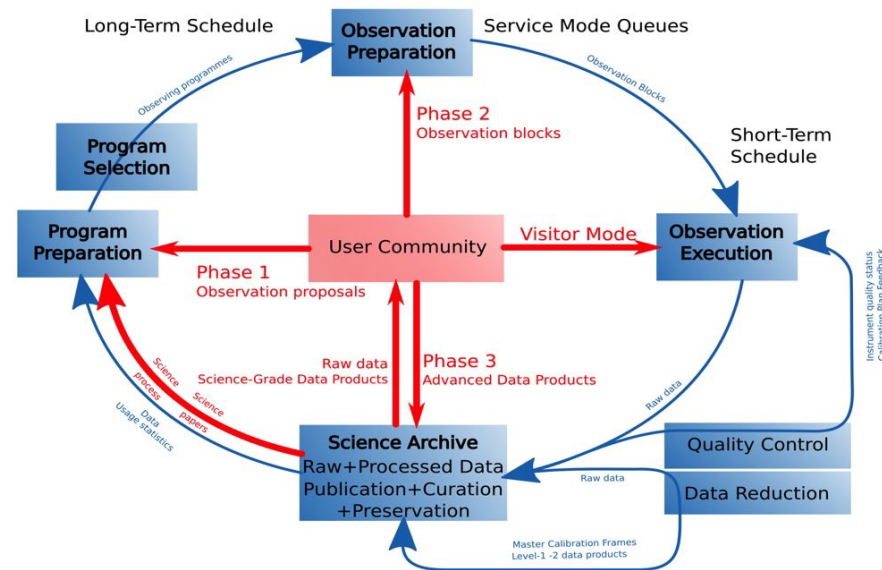
# archive.eso.org



# Archive Science at ESO

“The telescopes are operated to optimize scientific excellence, to maximize the scientific return of ESO by undertaking observations that have the potential to yield significant scientific advancements, and to exploit synergies between them as well as with other facilities. **The telescopes are operated within an end-to-end process which starts with proposal solicitation and ends with data preservation and publication [...] ESO supports an open data policy**”

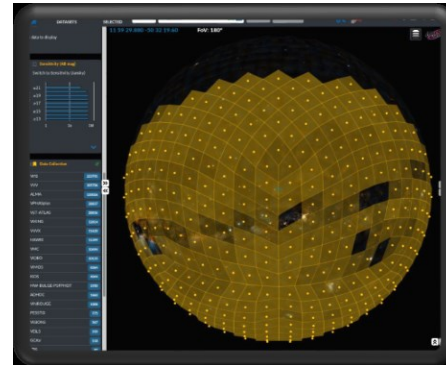
ESO Optical/Infrared Telescopes Science Operations Policies, **2020**, Cou-1847



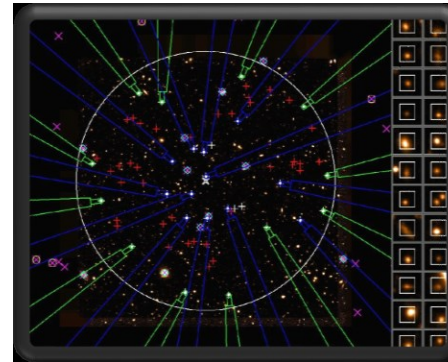
# Science data content: 20 years of science data



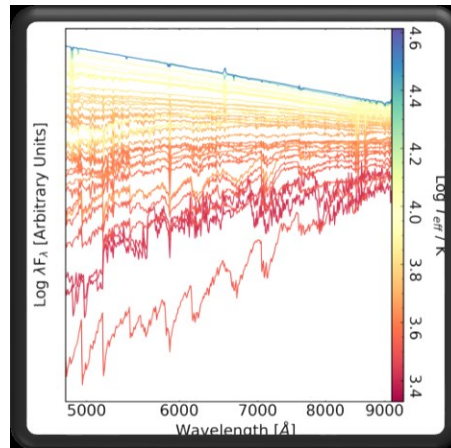
VISTA HEMSIPHERE SURVEY



KMOS datacubes



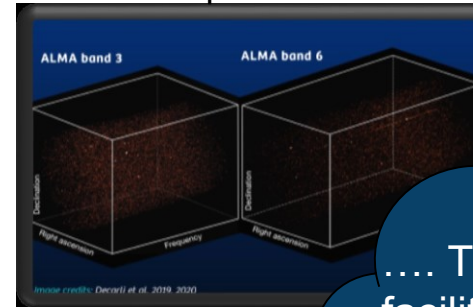
MUSE standard stars



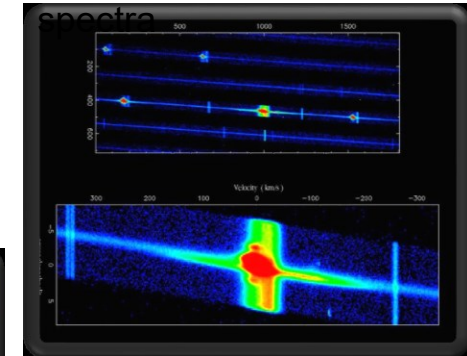
MUSE deep field



ALMA deep field



UVES reprocessed spectra



.... The largest telescope facility ever: the ESO archive.. (Carretta & Bragaglia 2018A&A...614A.109C )



# Archive operations

The bedrock upon which everything else stands

Data In- and outflow

- Total holdings: 1.2 PB in 50M files
- Metadata: 50B header keywords
- Nightly inflow of raw data: ~300 GB
- Daily outflow of data: ~500 GB

Anonymous access: 2018

Revamped Download Portal: 2020

Available products when browsing for raw data: since 2021

The screenshot shows the ESO Science Archive Facility website. At the top, there are navigation links for Public, Science, User Portal, Intranet, Contact, Site Map, and a search bar. Below the navigation is a 'Welcome to the ESO Science Archive Facility' message. A central navigation menu highlights 'Raw Data', 'Programmatic', 'Catalogue Facility', and 'Community Forum'. Below this is a 'Latest News and Updates' section with several news items. At the bottom, there is a table titled 'To browse the archive' with columns for Category, Access Point, Data collection, Data Type, and Events.

Category	Access Point	Data collection	Data Type	Events
LPO Raw Data	Raw data query form (all instruments) Instrument specific query forms Direct retrieval of raw data by file name	All ESO raw data	Various	Many La Silla Par...
LPO Processed Data	Science Portal (Processed Data) Type specific query forms (generic, spectral, imaging, VISTA) Direct retrieval of reduced data by file name	Processed data (ESO public surveys, ESO pipeline-reduced products, Large programs: GOODS, COSMOS, etc.)	Imaging, Spectroscopy, Catalogs, etc.	Various
Other processed data products	Catalogue Facility query interface	Catalogues (ESO User Portal authentication required)	Catalogues	Various
HARP's Preliminary pipeline processed data query form	HARP's Preliminary pipeline processed data query form	HARP's Preliminary and calibration pipeline processed data	Spectroscopy	HARP's Preliminary calibration filters (above), FEROS in the Phase 3 stars
Other Advanced Data Products (available only as downloadable packages, no query form)	Science Verification, Commissioning, EIK, etc. (no query form)	Various (30 Doradus, Carol, Galilei, etc.)	Spectroscopy imaging	FEROS WFI
APEX Check Look Products	APEX query form	Full list of available data packages	Various	Many
LPO Schedule	Scheduling query form	ESO Observing Programme information and Scheduling	Heterodyne, Extender	ARTAMIS, CHAMP, SIAACA, DESPA
ALMA Data	ALMA Science Archive	All ALMA data	Cube	ALMA

As PI/co-I of an ESO programme, one can access raw data via archive web interfaces or directly from User portal services



# Archive Content



## Raw data



- Science data generally with a proprietary period of 12 months
- Calibrations immediately public

## Processed data

- Access rights inherited from raw data
- Generated in-house (w/ exceptions)
- Quality-controlled mass processing by instrument (mode) with ESO pipelines
- **14 streams** (of which 2 contributed)

## Contributed by the community

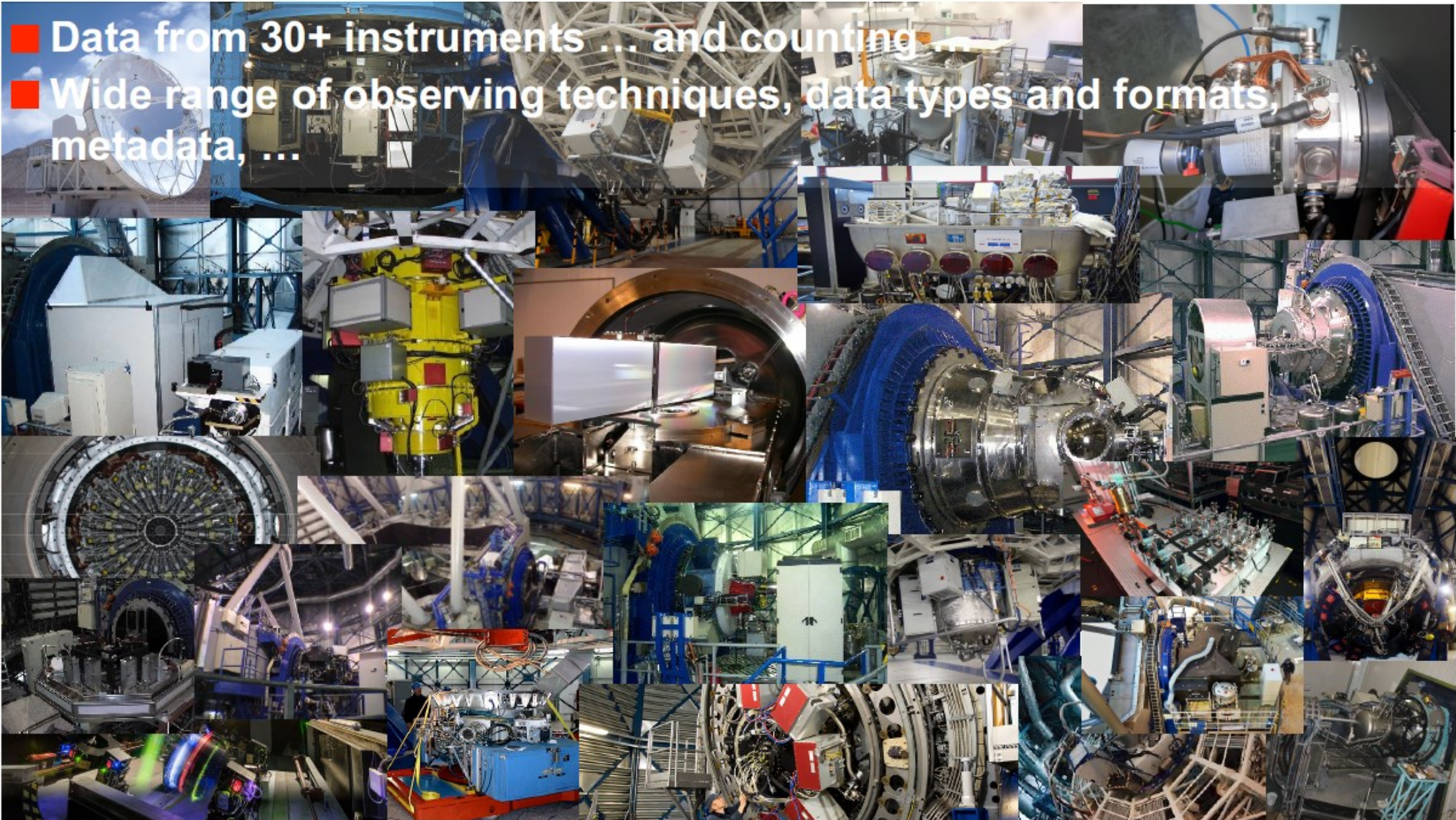
- Focused on specific projects
- Curation via the Phase 3 process
- Large Programmes, Public Surveys and Hosted Telescopes are mandated to return data
- Voluntary contributions and collaborations
- **65 collections**

[DOIs for traceability and recognition of data providers \(link\)](#)

... and their metadata







■ Data from 30+ instruments ... and counting

■ Wide range of observing techniques, data types and formats, metadata, ...



# Ways to access the data content...



## Graphical interfaces (web) => Raw: basic query functionalities

- Processed data: the ESO Science Archive Portal - Visual exploration based on properties of the data (SNR, wave coverage and resolution, depth, ...)
- Catalogues

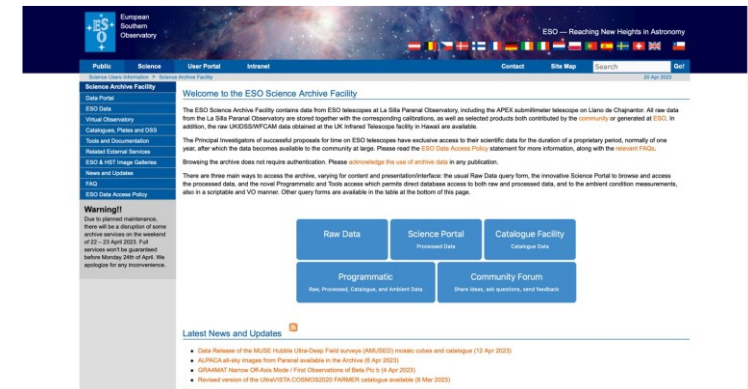


## Programmatic/tools => The full power and complexity of direct database access

- Via VO protocols
- We are currently re-writing the ESO package in *astropy.astroquery* as middle layer
- Access from Virtual Observatory tools: Aladin, TOPCAT, ...



## Community Forum



# Archive interfaces

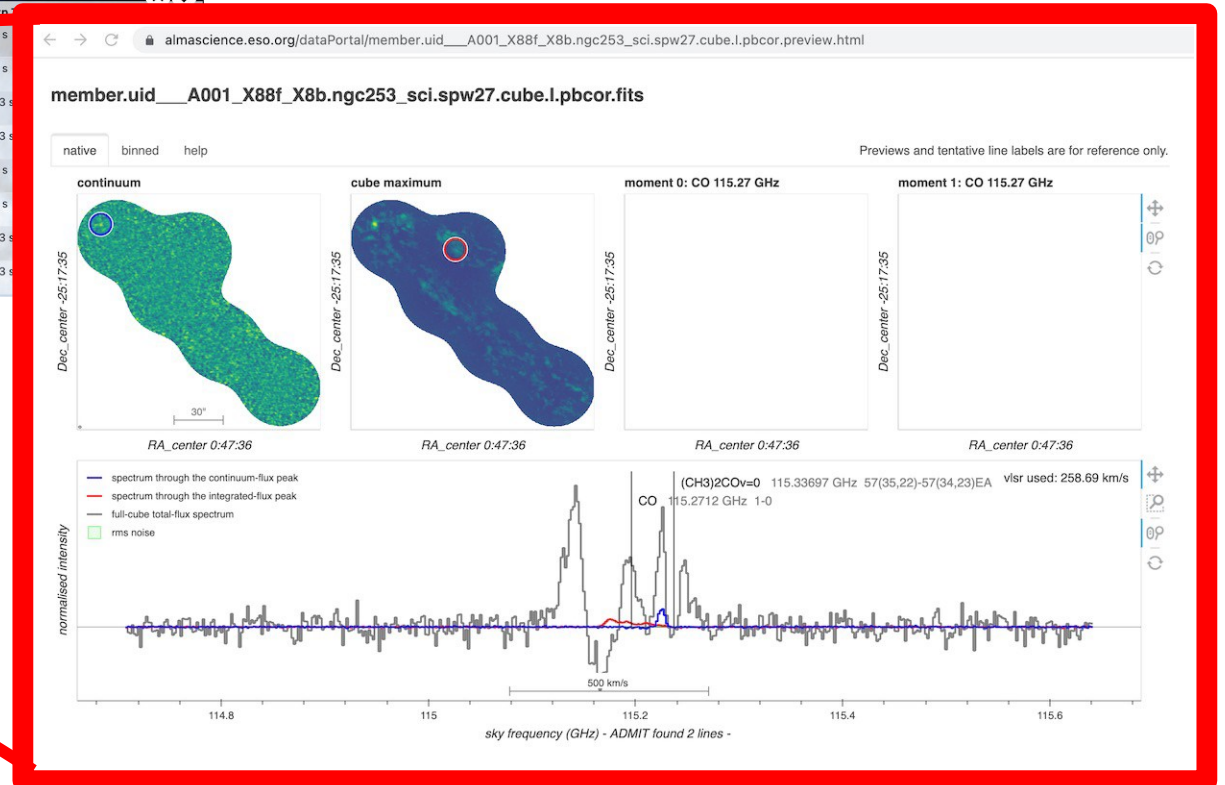
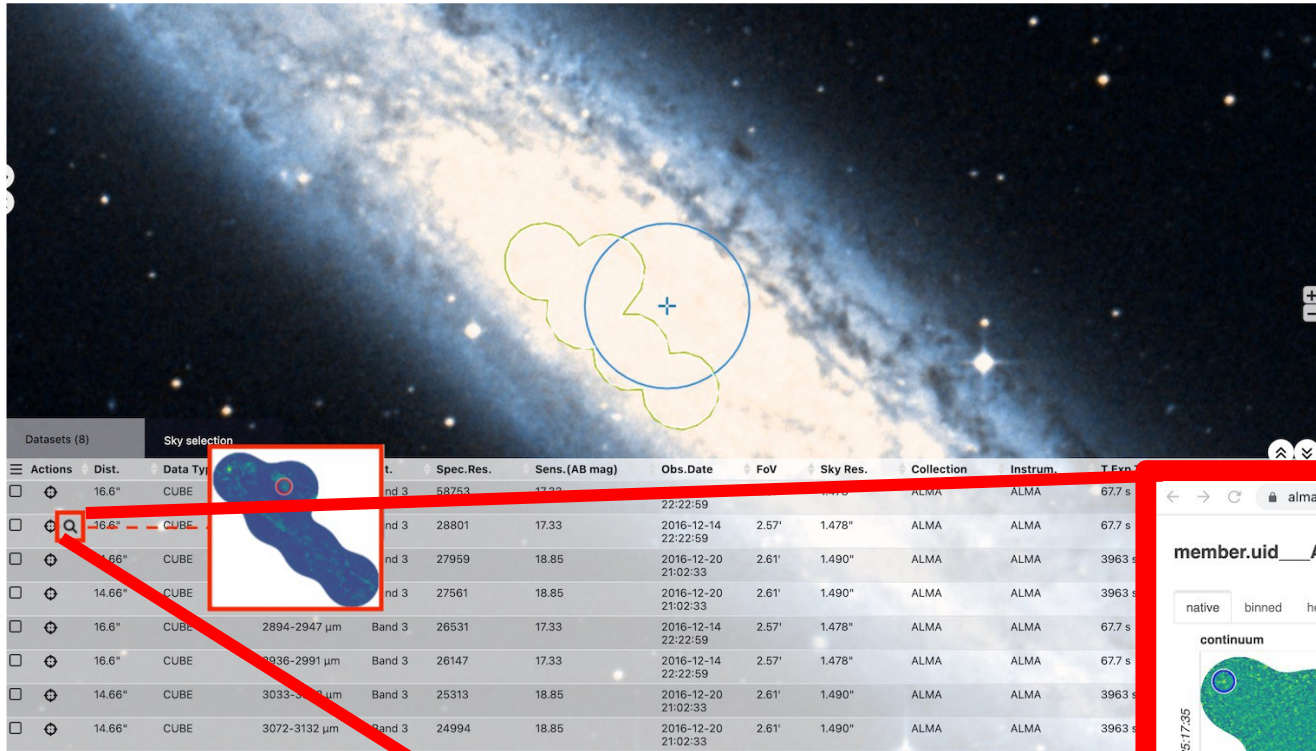


WHALE GALAXY [ALMA + VIRCAM + OMEGACAM]

Data Type	Count
<input type="checkbox"/> SPECTRUM	2005743
<input type="checkbox"/> IMAGE	854303
<input type="checkbox"/> CATALOG	544467
<input type="checkbox"/> CUBE	433080
<input type="checkbox"/> VISIBILITY	3792

# Integration of ALMA previews

<https://www.eso.org/sci/publications/announcements/sciann17605.html>







# The era of multi-\* Astronomy

Multi-wavelength, multi-facility, multi-messenger

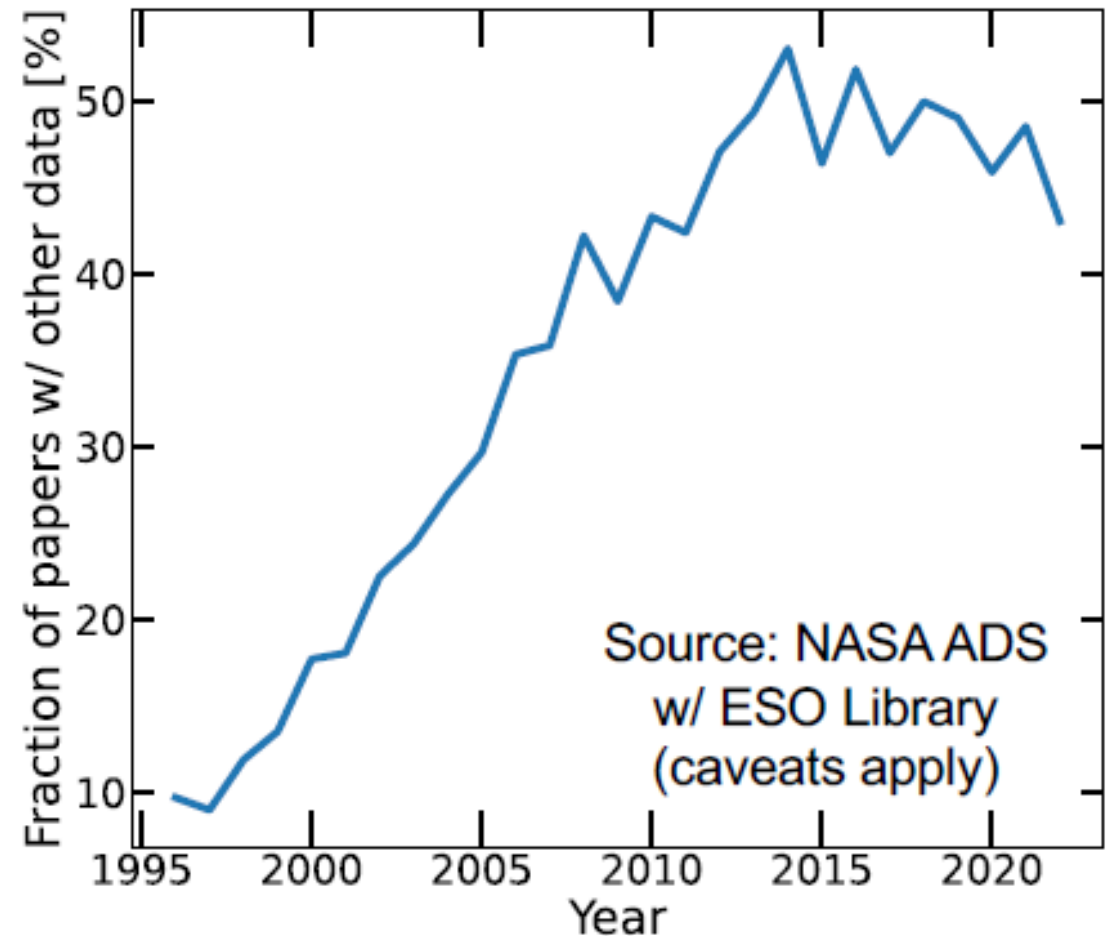
About 50% of LPO papers use data from other facilities

Sharing and combining data across facilities is crucial

Astronomy as a discipline is well placed in this respect

- As a culture
- In practice with the Virtual Observatory
- More on the impact of the ESO science archive in the

Messenger



# Archive interfaces: VO inside

The ESO Web and Programmatic interfaces use:

- ADQL
- Aladin Lite
- DataLink
- HiPS
- ObsCore
- SAMP
- SODA
- SSA
- STC-S (point, circle, polygon, multi-polygon)
- TAP (DALI, VOSI, UWS, UCD, UTYPE, ...)
- TOPCAT
- VOTable
- Pyvo
- ...



■ Catalogue query interface

■ When using the ESO Science Archive, you are using the VO





**Interested in more ESO data?  
Are you curious to know more?  
The archive demo is available on  
*youtube*. Check it out here**





**- Why carrying out ESO Phase 3 for your data**



# Archive data content - II

The data must be trusted

- Fundamental for any uses, especially for legacy

That is, understood and documented

- So that users can assess whether and how to use the data
- It does *not* mean perfect (whatever that might mean)

Data stewardship and curation

- Phase 3: publication & auditing process which enable archive data releases for completeness, compliance and consistency; Release Description
- Quality Control: compliance w/ observing constraints (QC0); master calibrations, individual science exposures (QC1); final science quality, stacks, data aid algorithm enhancement and development (QC2)

# Why engaging in Phase3

High visibility of the published data the ESO archive

- Data releases advertised in the ESO newsletter
- Data releases advertised in the ESO newsletter
- **\*\*DOIs are minted/available for P3 data collections since 12.05.2022\*\***
- Leadership

Long term preservation

Increase

Importance

Cross

**Ensure re-use of data by building trust  
Enhance browsing, discoverability &  
legacy value**

→ multi-wavelength/multi-instrument/time domain science



# Why engaging in Phase3 (cont.)



## Digital Object Identifiers (DOIs) for Data Collections in the ESO Science Archive

This page lists the Digital Object Identifiers (DOIs) for Data Collections in the ESO Science Archive. In this case astronomical data.

If you use data from one or more of the collections listed below in publications, please cite the [policy](#):

Based on data obtained from the ESO Science Archive Facility with DOI(s): <https://doi.org/>.  
(Please substitute NNN with the correct number from the doi column in the table below)

Collection Name	DOI	Collection
081.C-0827	<a href="https://doi.org/10.18727/archive/6">https://doi.org/10.18727/archive/6</a>	Cold dust in the barred galaxy M83
092.A-0472	<a href="https://doi.org/10.18727/archive/7">https://doi.org/10.18727/archive/7</a>	Ultra-Deep Ks-band imaging of the HST Frontier Field
096.B-0054	<a href="https://doi.org/10.18727/archive/8">https://doi.org/10.18727/archive/8</a>	Kinematics of local thick discs
195.B-0283	<a href="https://doi.org/10.18727/archive/9">https://doi.org/10.18727/archive/9</a>	The fingerprint of a galactic nucleus: a 0.2"-resolution image

<https://archive.eso.org/wdb/wdb/doi/collections/query>

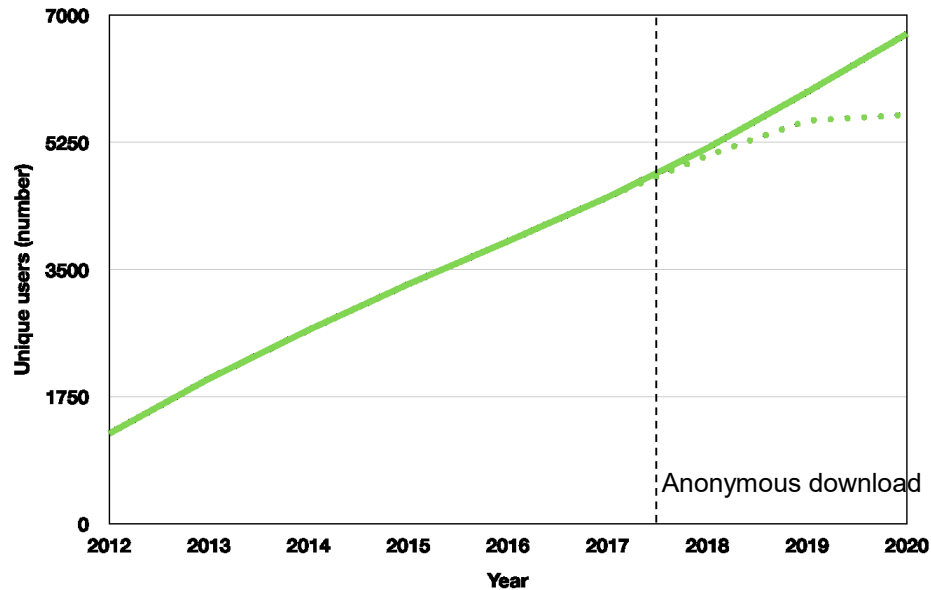


# - Archive & ESO public surveys' stats\*

\*Heartfelt thanks to Uta and the Library team!

# Archive stats

## Archive users

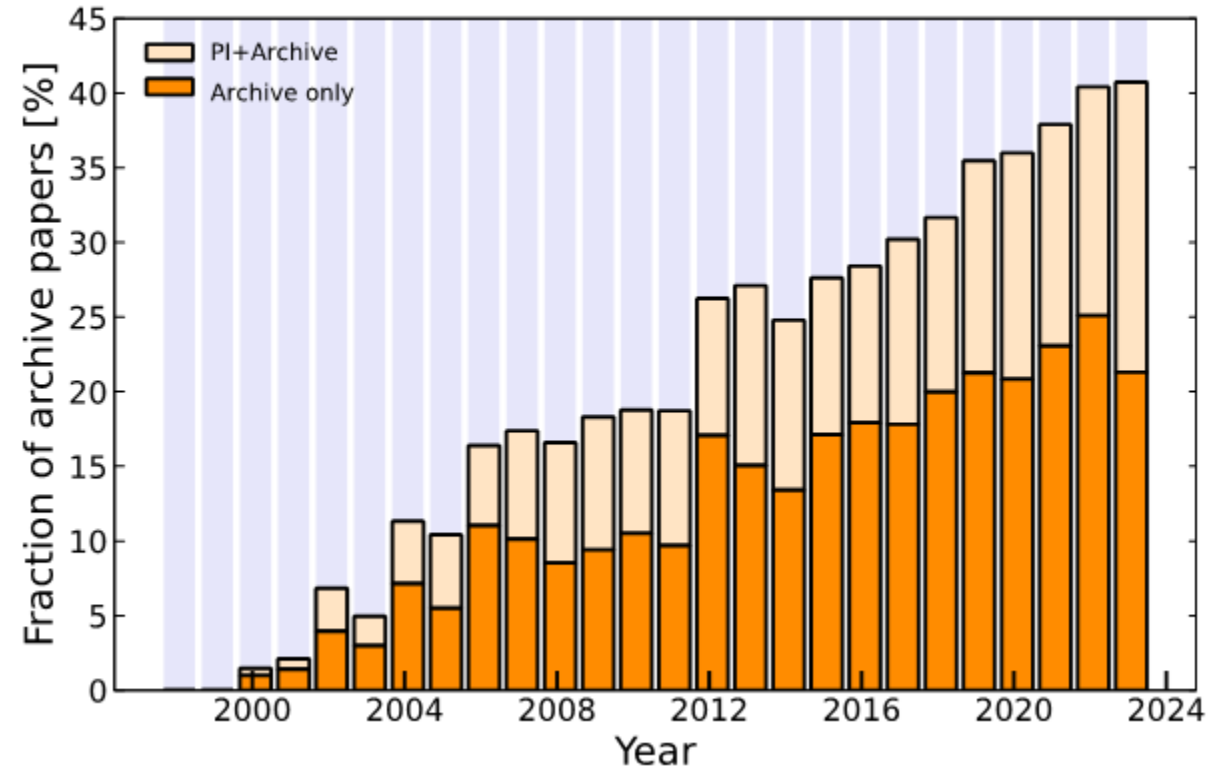


About 30% of the archive users are otherwise new to ESO

Early-career scientist particularly active with the archive

## VLT archive refereed papers

Source: telbib.eso.org



Wide variations among instruments

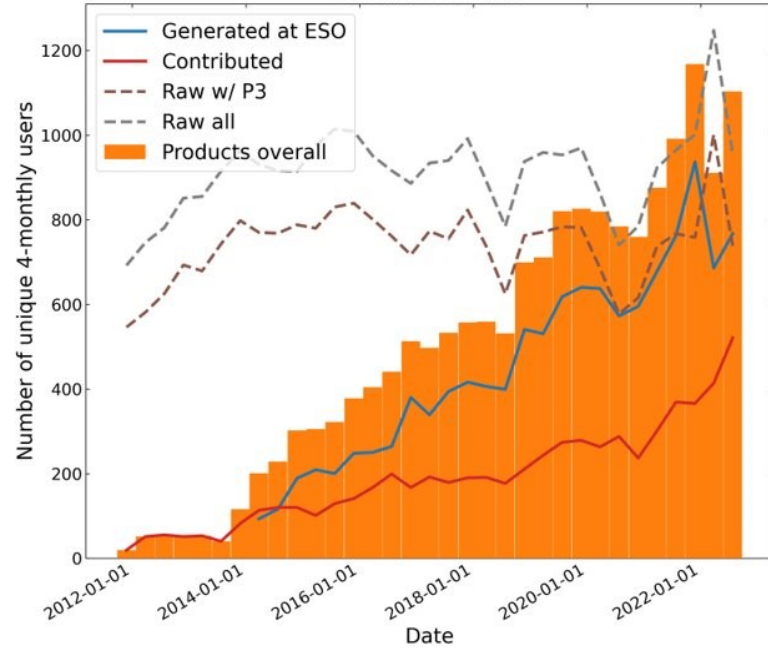
- UVES, HARPS: >50%



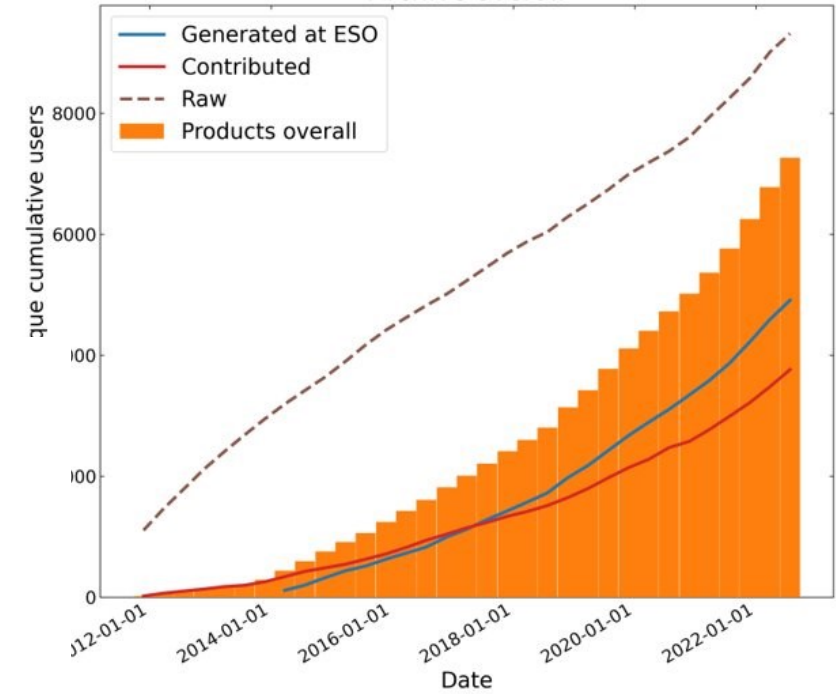


# Archive stats

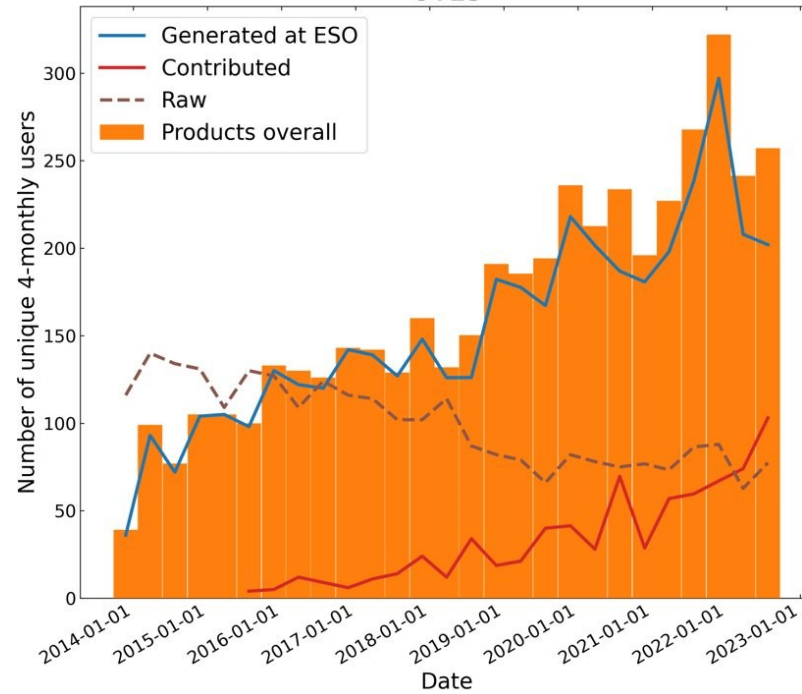
Archive overall



Archive overall

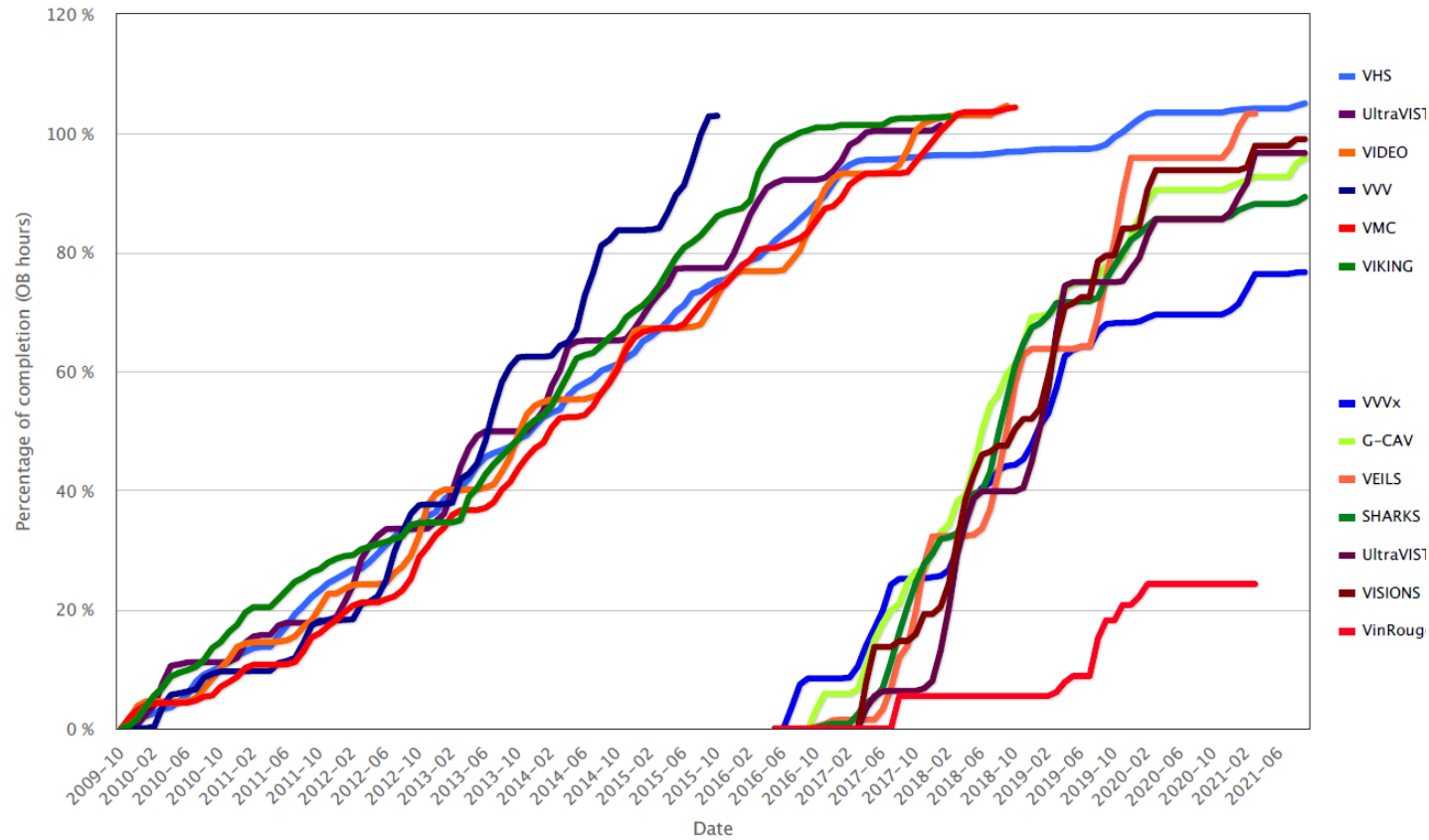


UVES

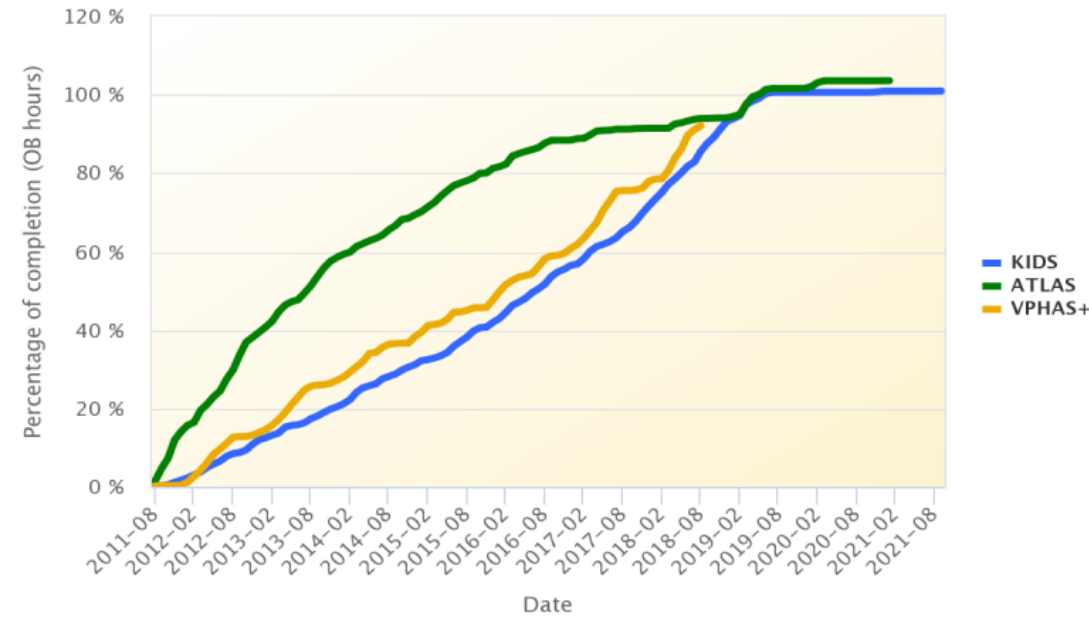


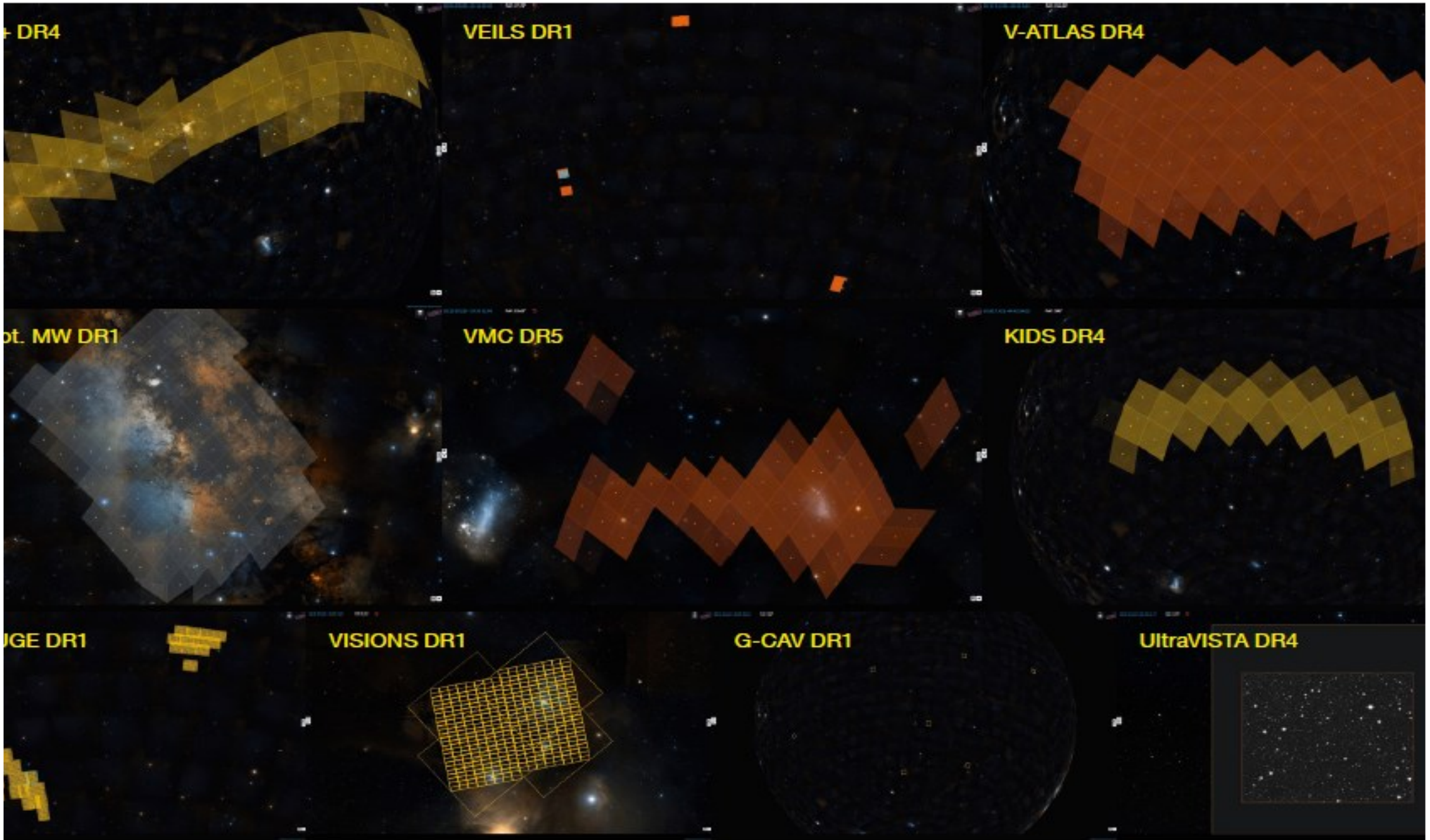
# Data acquisition for ESO imaging surveys

VISTA Public Surveys Completion Fraction



VST Public Surveys Completion Fraction





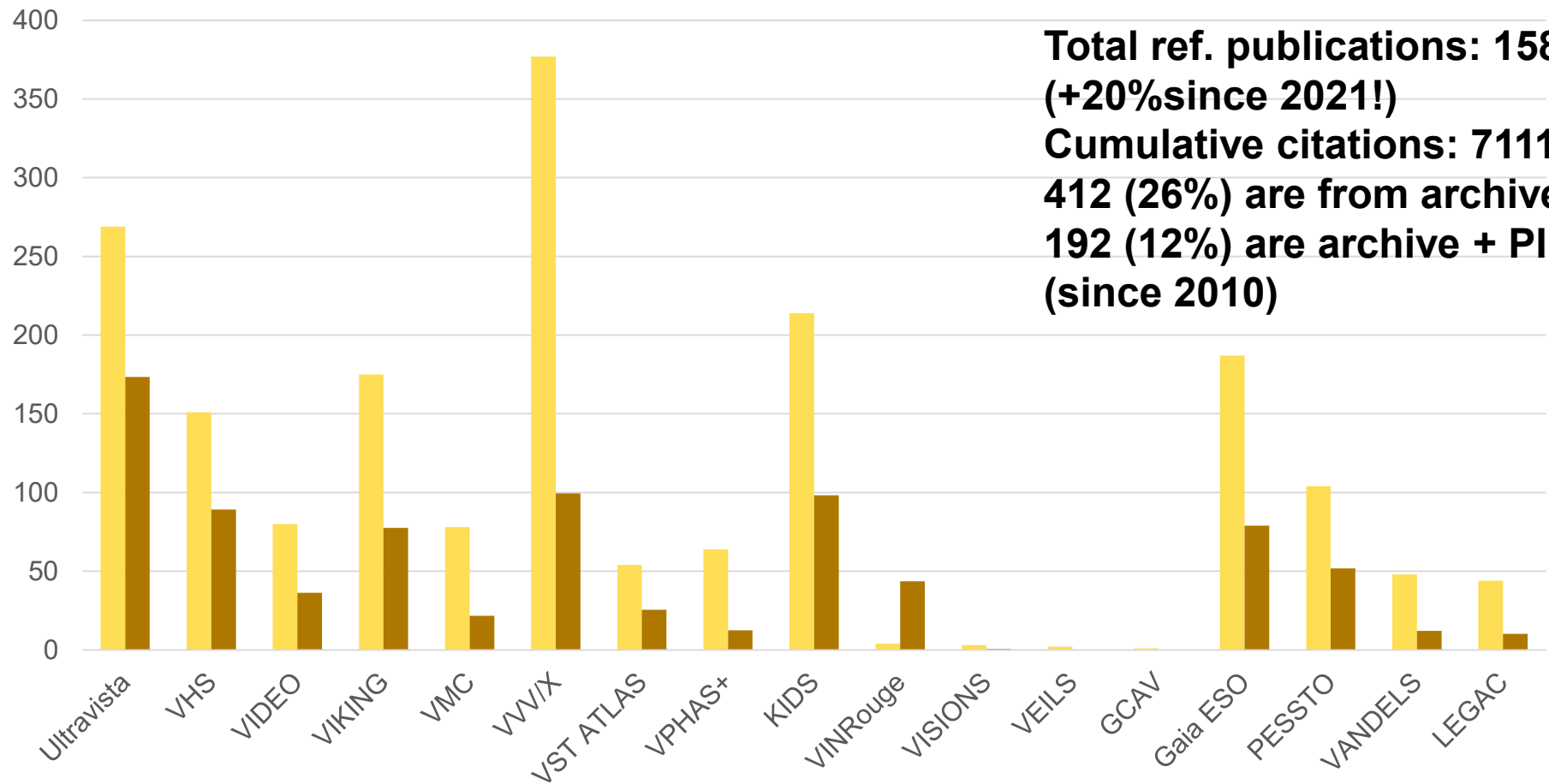
# Planned DRs in 2023-2024



ID	Data Products	#
VISIONS	Images and catalogs	DR3.0
VMC	Images and final catalogs (multi epoch, psf)	DR7.0
VEILS	Images and catalogs (variability)	DR2.0
GCAV	Images and catalogs	DR4.0 (final!)
UltraVISTA	Catalogs (COSMOS2020) and deep images	DR6.0
KIDS	Images and final catalogs	DR5.0 (final, coming soon!)
ATLAS	Images and final catalogs (including ugr in the 700 deg <sup>2</sup> NGC Dec<-20deg area)	DR5.0 (final!)
VVVX	images and proper motion catalogue (VIRAC 2.0)	DR3.0
VHS	Images and final catalogs	DR6.0 (final)
VPHAS+	Images and final catalogs	DR3.0 (final)

# Impact of ESO PS

Cumulative number refereed publications for ESO PS



**Total ref. publications: 1584**  
**(+20% since 2021!)**  
**Cumulative citations: 71110**  
**412 (26%) are from archive**  
**192 (12%) are archive + PI**  
**(since 2010)**

From <http://telbib.eso.org>

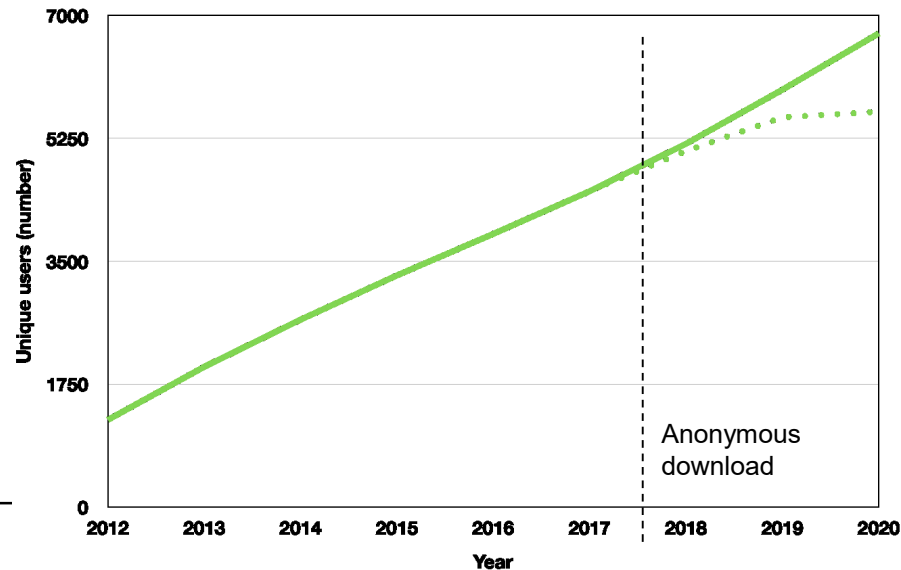
■ N. ref. pubs ■ N. Citation/100



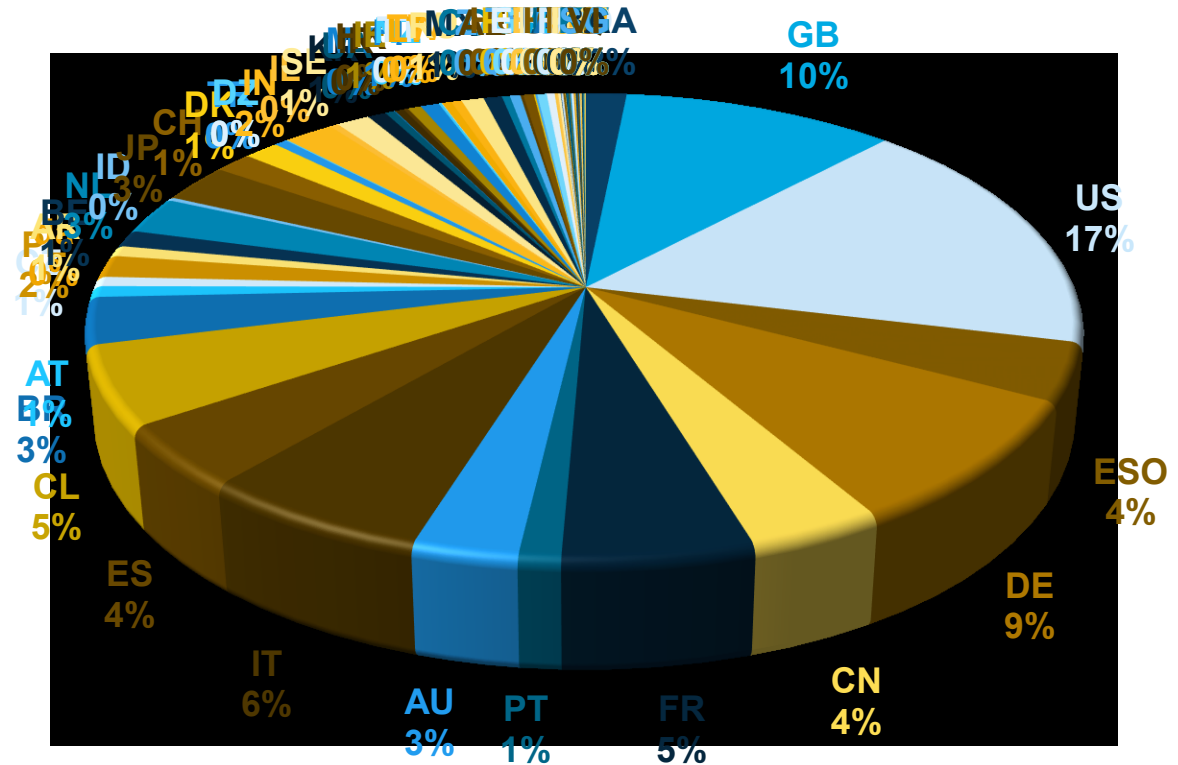
# Countries and account IDs

N. distinct account ids(*)	4862
N. distinct countries	100
N. distinct ips	25495

ESO science archive products accessed by 7000+ users from 100 countries!

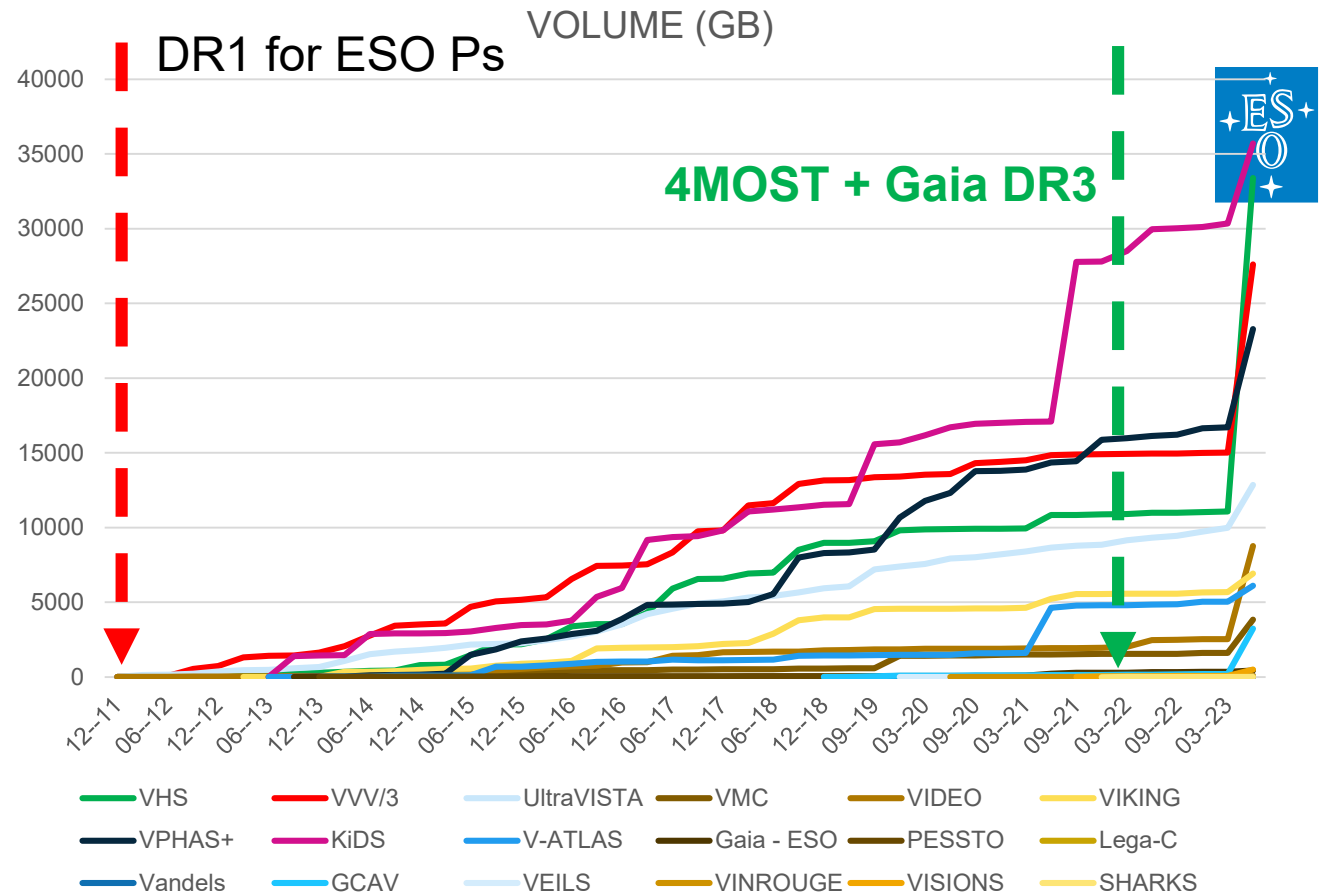
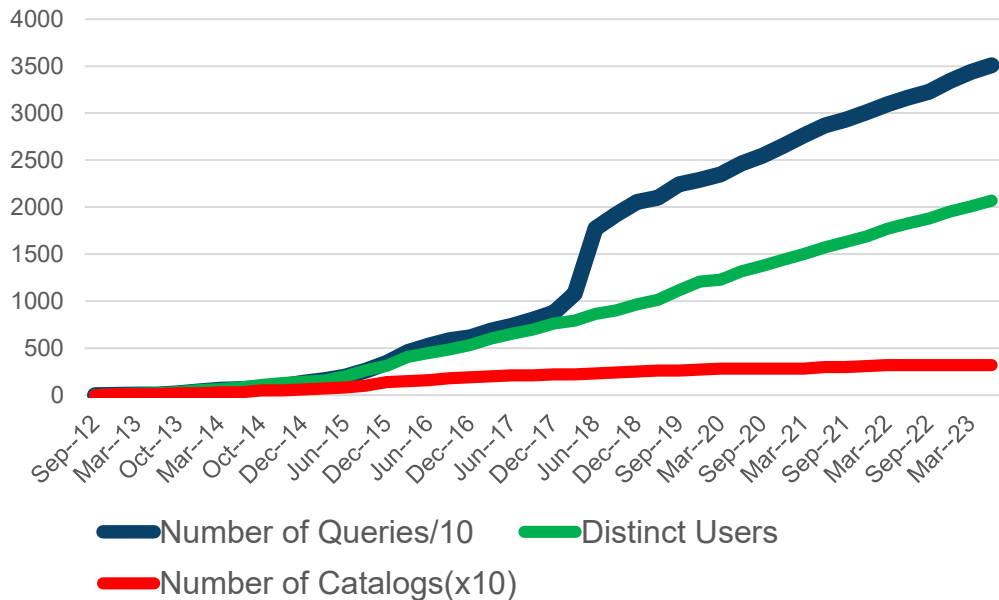


## # DISTINCT ACCOUNT IDS



**Archive users are accessing science data products for their independent science**

**Catalogue facility  
Number of queries and distinct users**



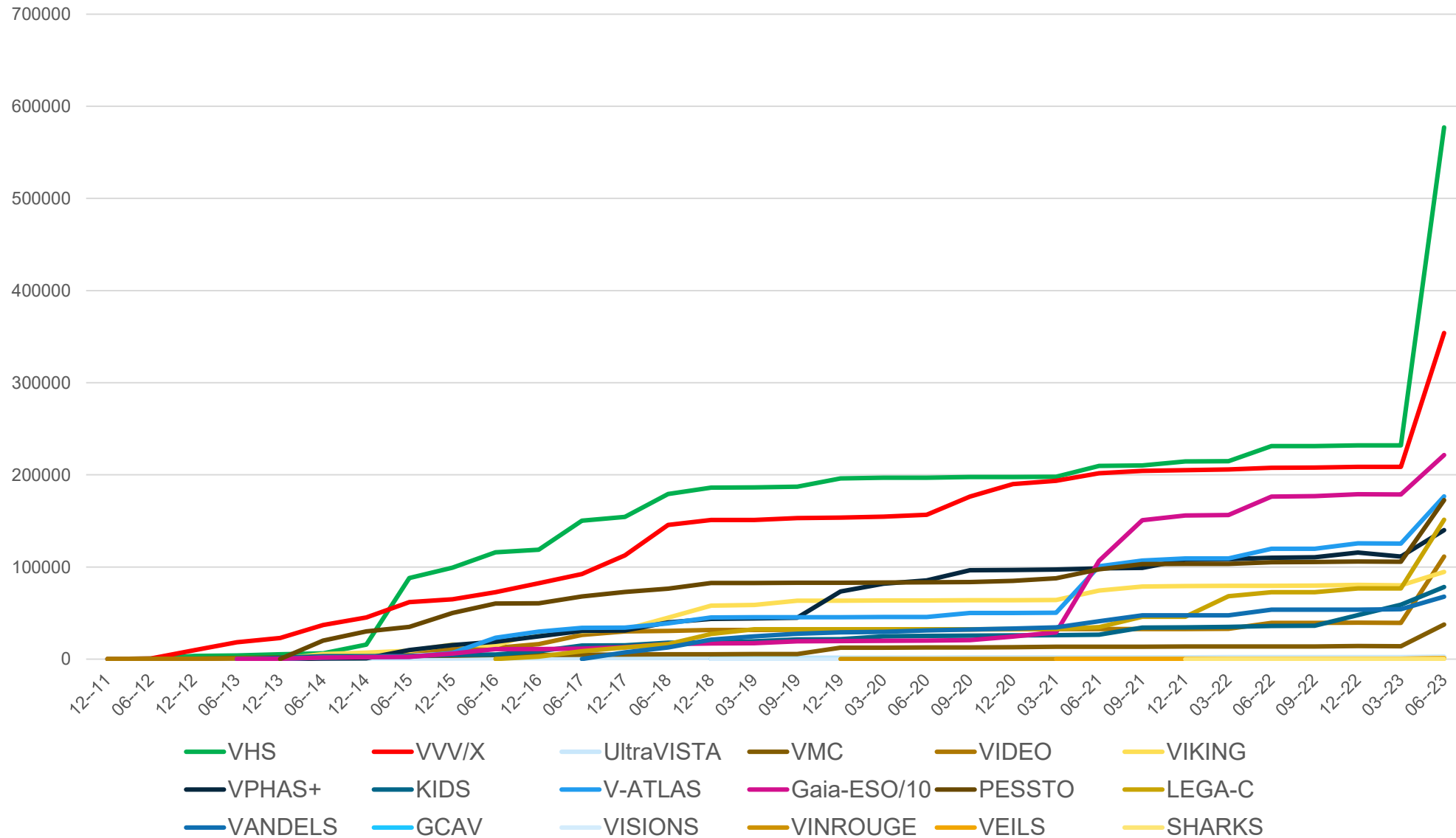
**On average users carry out **\*\*18\*\*** independent queries for catalog records via the ESO catalog query interface**

Since 062018,  $5.0 \times 10^5$  invocations\*/2300 users for catalogues@ESO via programmatic access interface of SAF

\*Aladin, topcat, sql queries



# Number of files downloaded

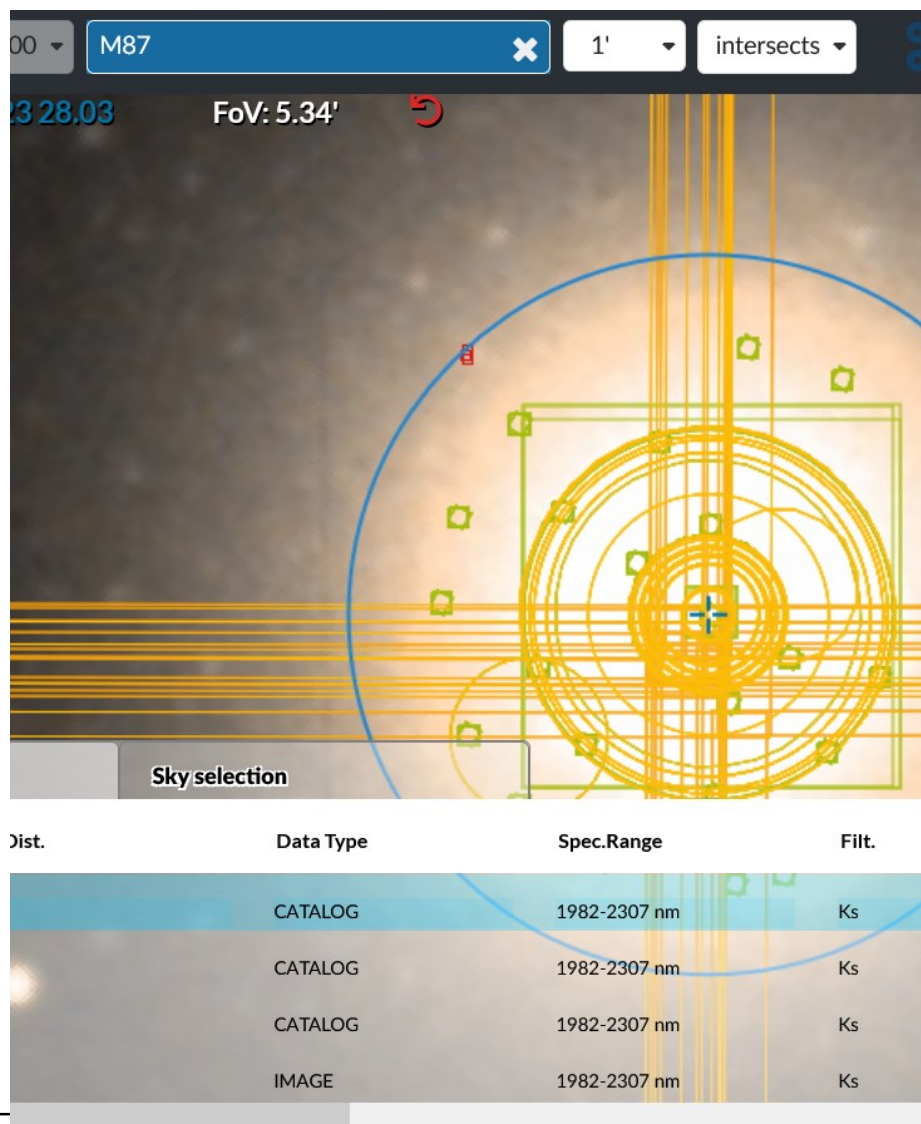




## Forward look

- 4MOST public surveys starting in 2025 !
- ELT

# archive.eso.org



The screenshot shows the ESO Archive search interface for the object M87. The search criteria are set to a 1' radius and the 'intersects' filter. The field of view (FoV) is 5.34'. The interface displays a sky map with a blue circle representing the search area and a green square representing the object's position. Below the map, a table lists the search results.

Dist.	Data Type	Spec.Range	Filt.
	CATALOG	1982-2307 nm	Ks
	CATALOG	1982-2307 nm	Ks
	CATALOG	1982-2307 nm	Ks
	IMAGE	1982-2307 nm	Ks

Would you like to see your data published in the ESO archive? Talk to us [asg@eso.org](mailto:asg@eso.org)

Interested to come and visit us in ESO Garching? Have a look here [ESO - Policy Scientific Visitors Garching](#)



# Questions?

Thanks to

- ESO Back-End Operations Department (AOG, ASG, SDP, QC) and DMO
- ESO DFI for software development of P3 infrastructure + web interfaces, Archive infrastructure + web interfaces (interactive/programmatic)
- ESO Pipeline group
- ESO LPO science operations
- External data providers (Pis of ESO PSs/LPs and their teams, Data Centres – CASU, WFAU, TERAPIX, Astrowise, NGTS, Grenoble, SPHERE, etc...)
- CDS

# Thanks!



