Advanced Data Products at ESO
(the challenge of photometric calibration
of ESO archival data)

P.Rosati (ESO)
with special thanks to:
J.Retzlaff, C.Rite, R.Slijkhuis, B.Vandame, N.Delmotte (DMO/ADP),
M.Nonino (TS)

ESO Calibration Workshop - Jan 24, 2007

ESO Science Archive Facility (SAF)

- ESO operates one of the world's largest astronomical archive, the Science Archive Facility (SAF)

- The VO System Dept. @ESO was created in Nov 2004 with the aim of transforming the SAF into a powerful scientific resource for the ESO and world-wide community

- **Key project**: Populate the SAF with an increasing number of Advanced Data Products (ADP), i.e. science ready calibrated data (both imaging and spectra), and a larger volume of intermediate-level data products
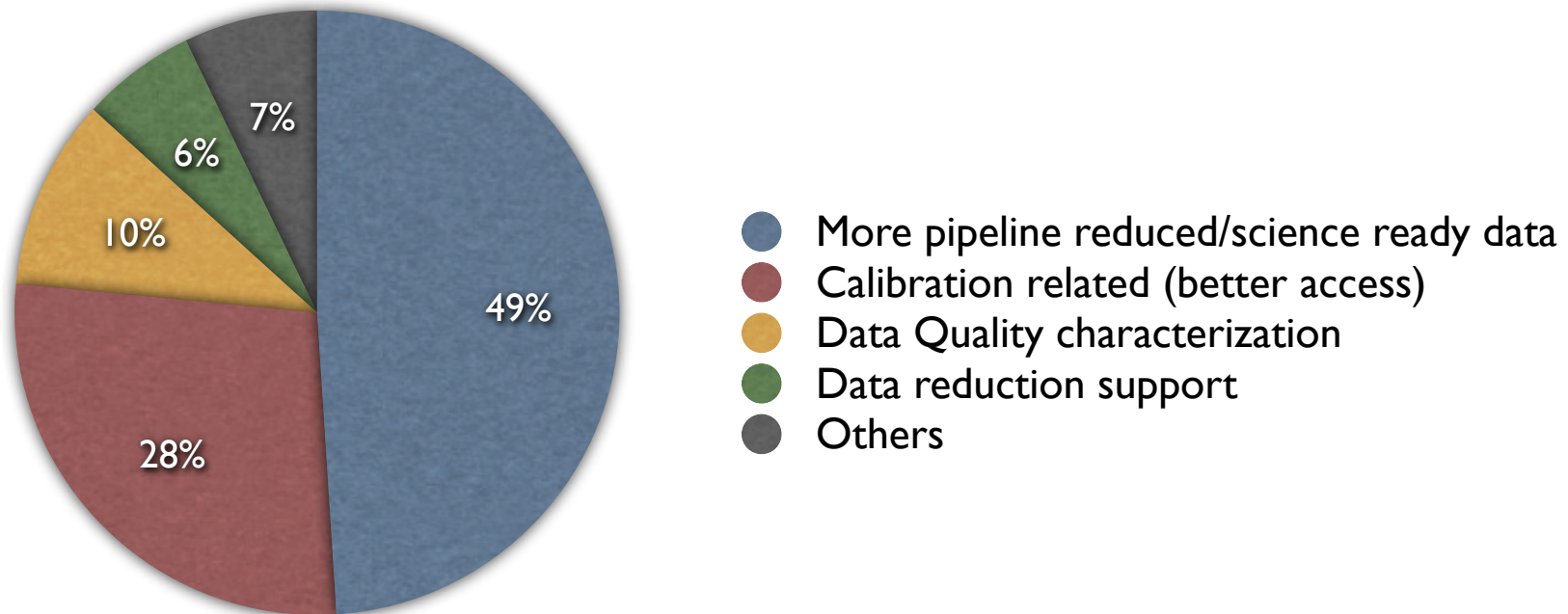 Motivations:

  1) an increasing demand from the community to access high-level data products in the SAF

  2) ADP significantly boost scientific productivity of the SAF

  3) A prompt scientific exploitation of the VO infrastructures heavily relies on the availability of large volumes of ADP

ESO Science Archive: user top-wish-list
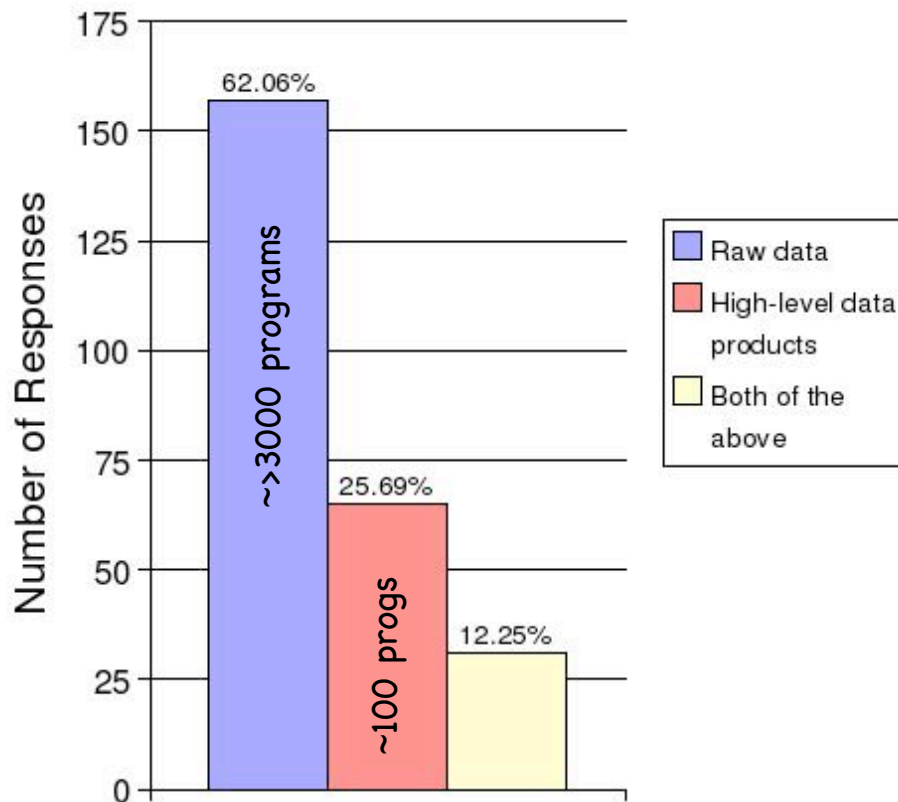
Science related needs of Archive Users

- More pipeline reduced/science ready data
- Calibration related (better access)
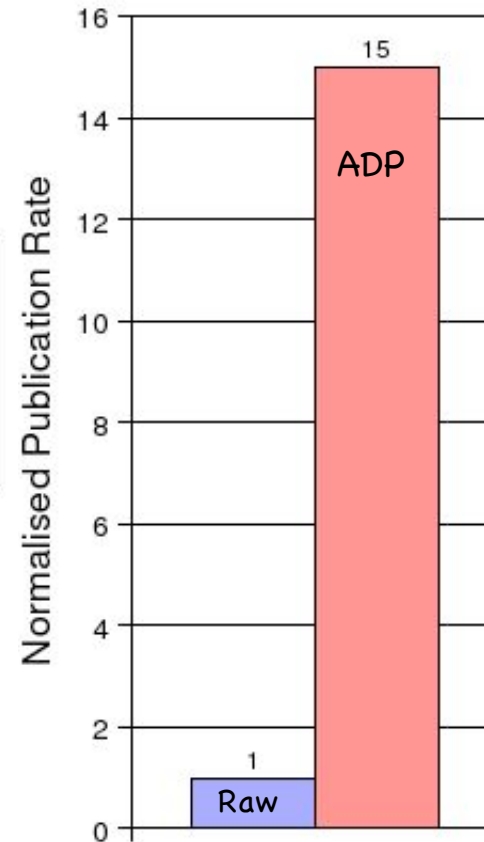- Data Quality characterization
- Data reduction support
- Others

ESO Science Archive: scientific exploitation

Publication rate/potential of archival data for <u>non PIs/coIs</u>:
nature of the data

Legend:
- Raw data
- High-level data products
- Both of the above

Left chart labels:
- 62.06% (~>3000 programs)
- 25.69% (~100 progs)
- 12.25%

Y-axis: Number of Responses

Right chart:
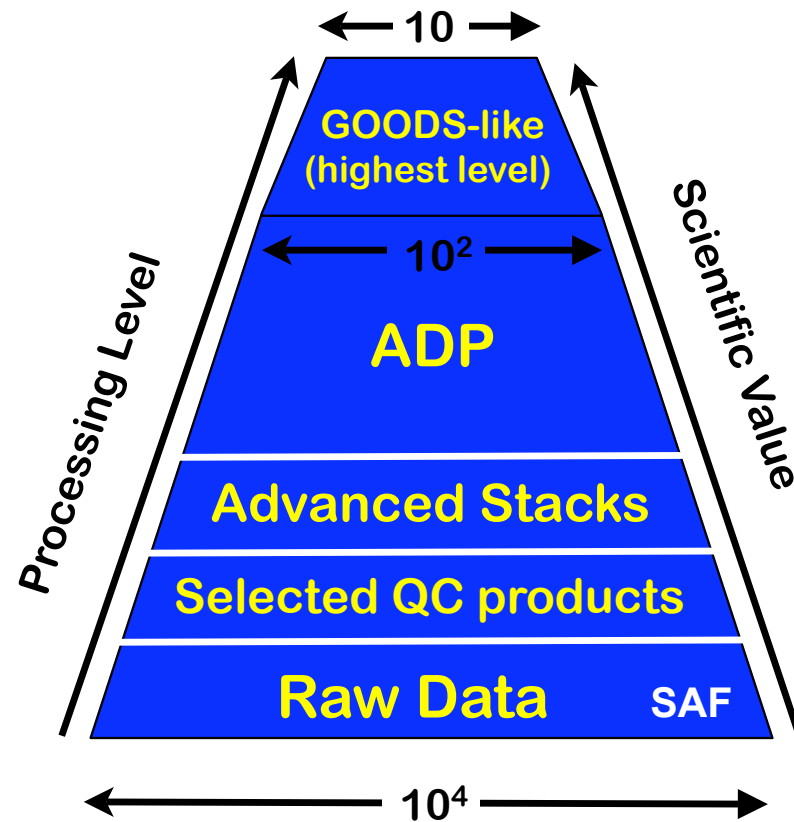- ADP: 15
- Raw: 1

Y-axis: Normalised Publication Rate

- Similar results are found from HST data

The Challenge of Advanced Data Products
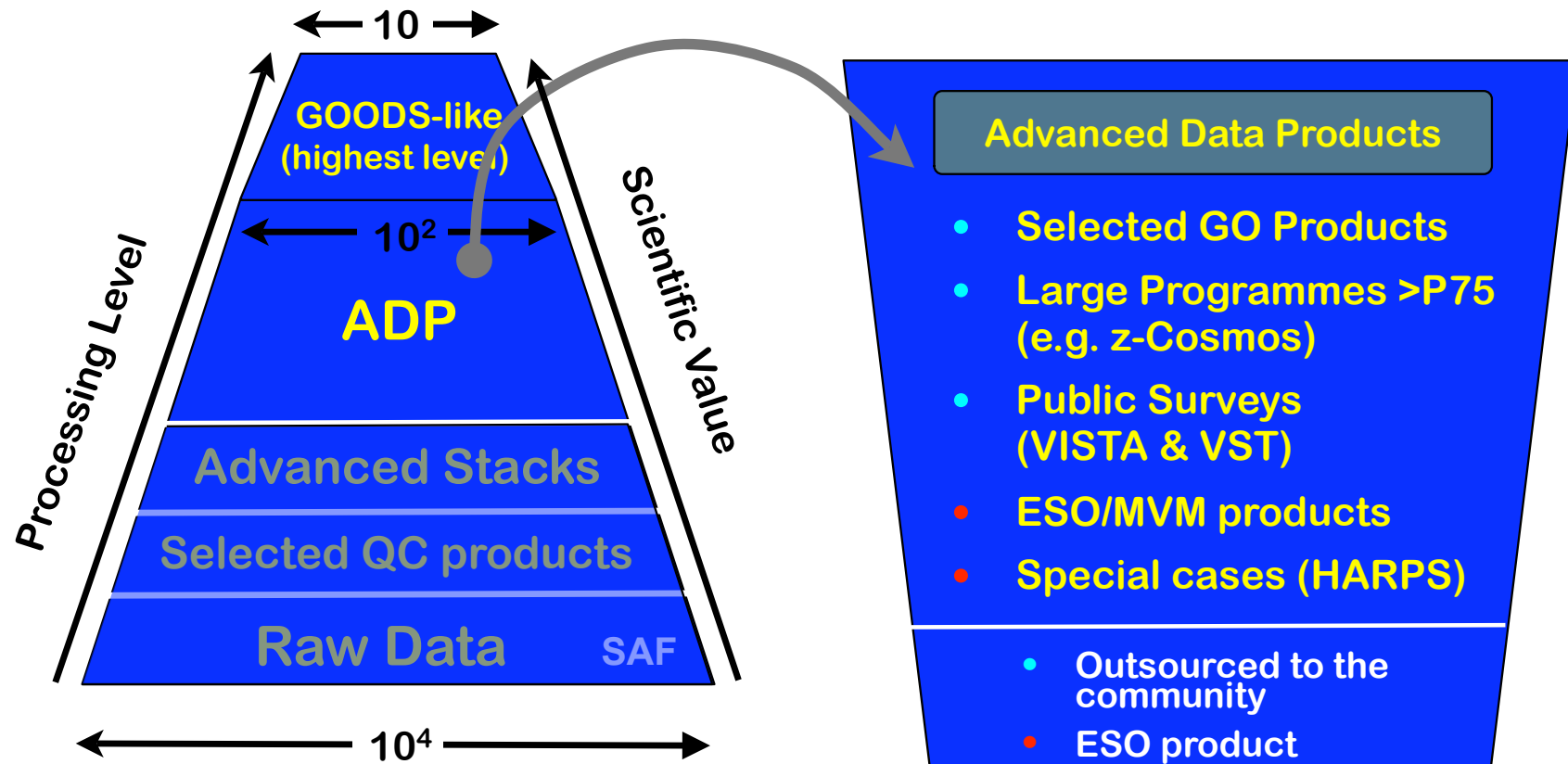
- The creation of a large number High Level Science Data Products from <u>ground-based Archives</u> is <u>very</u> challenging:
  - Photometric calibration, large number of instruments/ modes, non-homogeneous observing conditions/strategies
  - Even harder for MOS spectroscopy, but feasible for 3D spectroscopy

- On-going ground-based efforts deal solely with (public) surveys, e.g.: NOAO, CFHLS, UKIDSS, SLOAN (also spec), ...

- For space observatories, the task of producing HLSDPs from generic archival programs is easier. On-going efforts include HST, Chandra, XMM, ISO, Spitzer, etc. with plans to publish data products with VO standards

- First efforts have focused on **Large Programs and Surveys** to face the complexity and volume of the data sets and to guarantee their legacy value
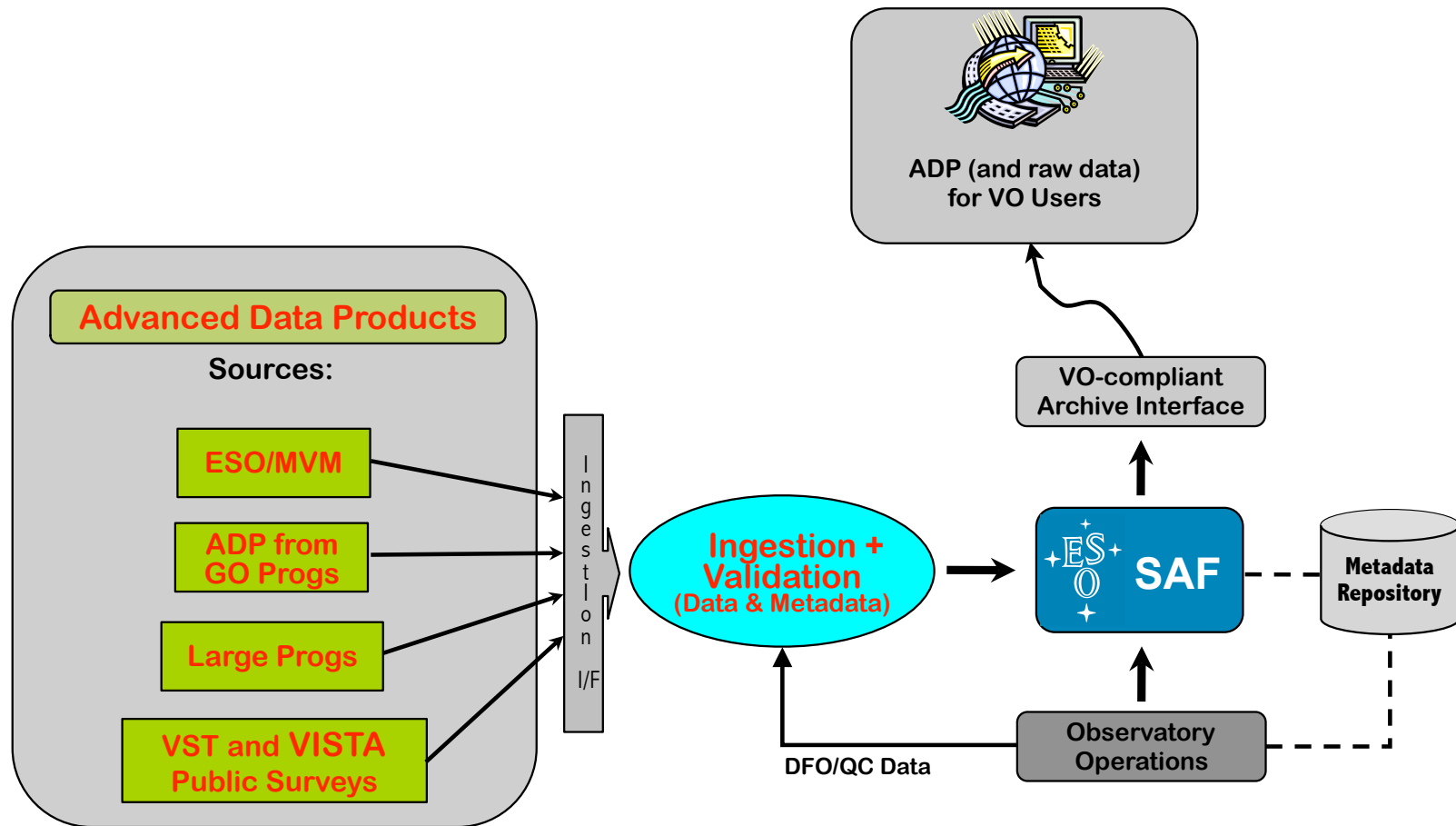
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Data Products Hierarchy @ESO

Data Products Hierarchy @ESO
sources of ADPs

10

GOODS-like
(highest level)

10^2

ADP

Processing Level

Scientific Value

Advanced Stacks

Selected QC products

Raw Data   SAF

10^4

Advanced Data Products

- **Selected GO Products**
- **Large Programmes >P75 (e.g. z-Cosmos)**
- **Public Surveys (VISTA & VST)**
- **ESO/MVM products**
- **Special cases (HARPS)**

- **Outsourced to the community**
- **ESO product**

Publishing ESO ADP in the ESO Archive and VO

ADP (and raw data) for VO Users

Advanced Data Products

Sources:

ESO/MVM

ADP from GO Progs

Large Progs

VST and VISTA Public Surveys

Ingestion I/F

Ingestion + Validation (Data & Metadata)

VO-compliant Archive Interface

SAF

Metadata Repository

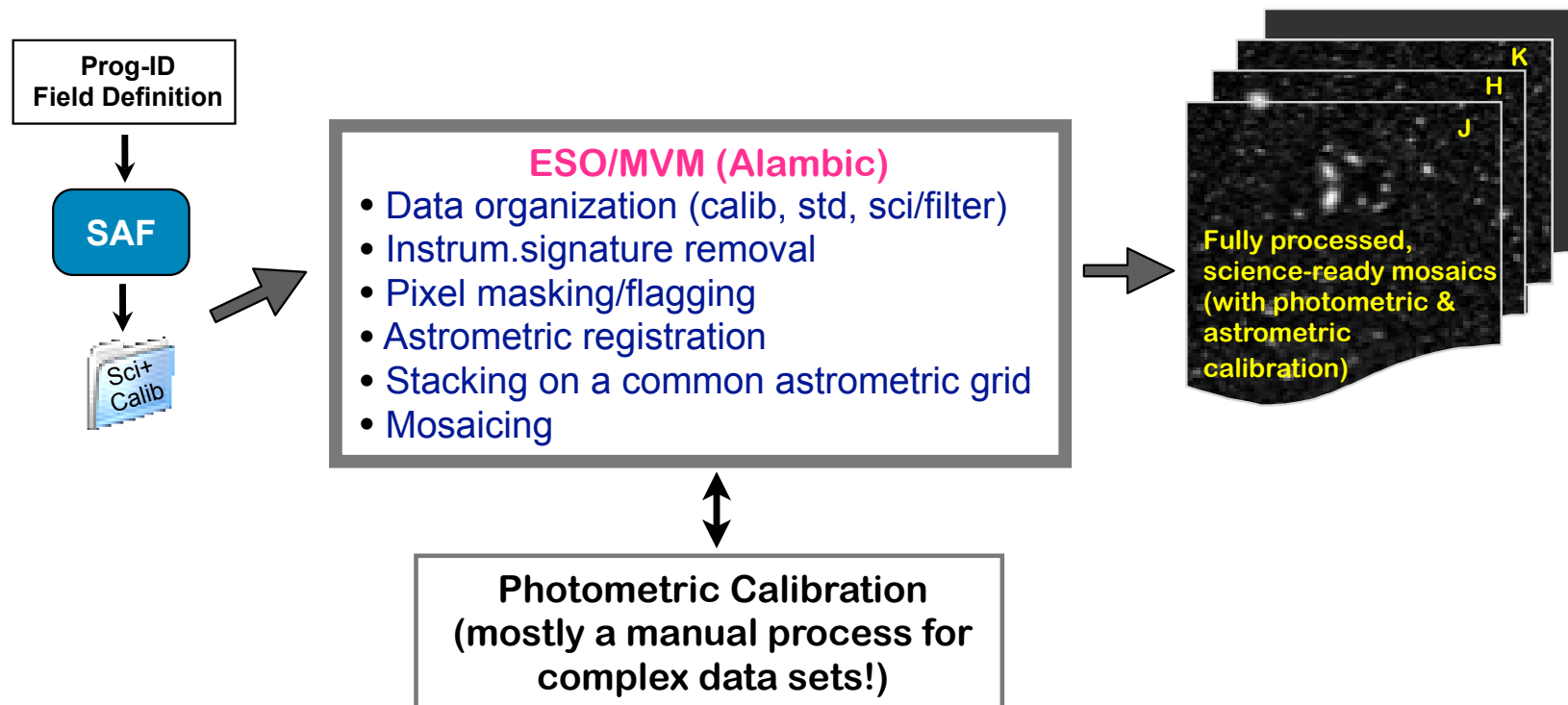**Observatory Operations**

DFO/QC Data

ADP workflow

Science Requirements for ESO produced ADP

- Final products: fully processed, <u>full stack and mosaic</u> of entire imaging data set + associated weight maps

- <u>Astrometric accuracy:</u>
  0.1 arcsec rms, homogeneous across the entire imaging area (limited by the astrometric accuracy of reference catalog) → easy with MVM data reduction system

- <u>Photometric accuracy:</u> always better than 0.05 mag.
  Driver: photometric redshift accuracy, SED fitting, CMDs
  Goal: 1–3 % in optical and 2–4% in near-IR,
  <u>homogeneous across mosaics</u> → challenging, it takes 99% of the time of the entire process (unless there is a reference photometric catalog, e.g. 2MASS)

Creating Advanced Data Products with ESO/MVM

- **ESO/MVM** (Multi-Vision Model): end-to-end, high-throughput image reduction system, originally developed by B.Vandame as part of the EIS project

- Seamless processing of optical & near-IR data (WFI, ISAAC, SOFI, VIMOS, FORS2,..)

  ➡ **the work of months is typically reduced to one day !**

- Major intellectual investment over 10 yrs: 171,000 lines of code (SExtractor: 30,000)

Prog-ID Field Definition

SAF

Sci+ Calib

ESO/MVM (Alambic)
- Data organization (calib, std, sci/filter)
- Instrum.signature removal
- Pixel masking/flagging
- Astrometric registration
- Stacking on a common astrometric grid
- Mosaicing

Fully processed, science-ready mosaics (with photometric & astrometric calibration)

K

H

J

Photometric Calibration (mostly a manual process for complex data sets!)

# GOODS/ISAAC ADP Data Release
(v1.5 June 05, v2.0 Jan 07)

- Part of the GOODS/ESO Public Programme in CDFS (PI: Cesarsky)

- New v2.0 final release soon. Deepest large nearIR field carried out to date
  - 160 arcmin^2 in J,H,K, 127 arcmin^2 H (J,H,K: 25.5, 25, 25 AB mag lim at 5σ)

- Fully processed and calibrated mosaics with ESO/MVM data reduction system (~50,000 raw frames ➔ 160 final science-ready frames). A few % accuracy of photometric calibration

- Intensive use by the worldwide community: it complements HST and Spitzer data for galaxy evolution studies out to z~7

- Large number of papers/projects based on this high-quality data set

- Scientific value greatly enhanced by many spectroscopic surveys: ⇒ thousands of reduced 1D spectra being ingested as ADP into SAF
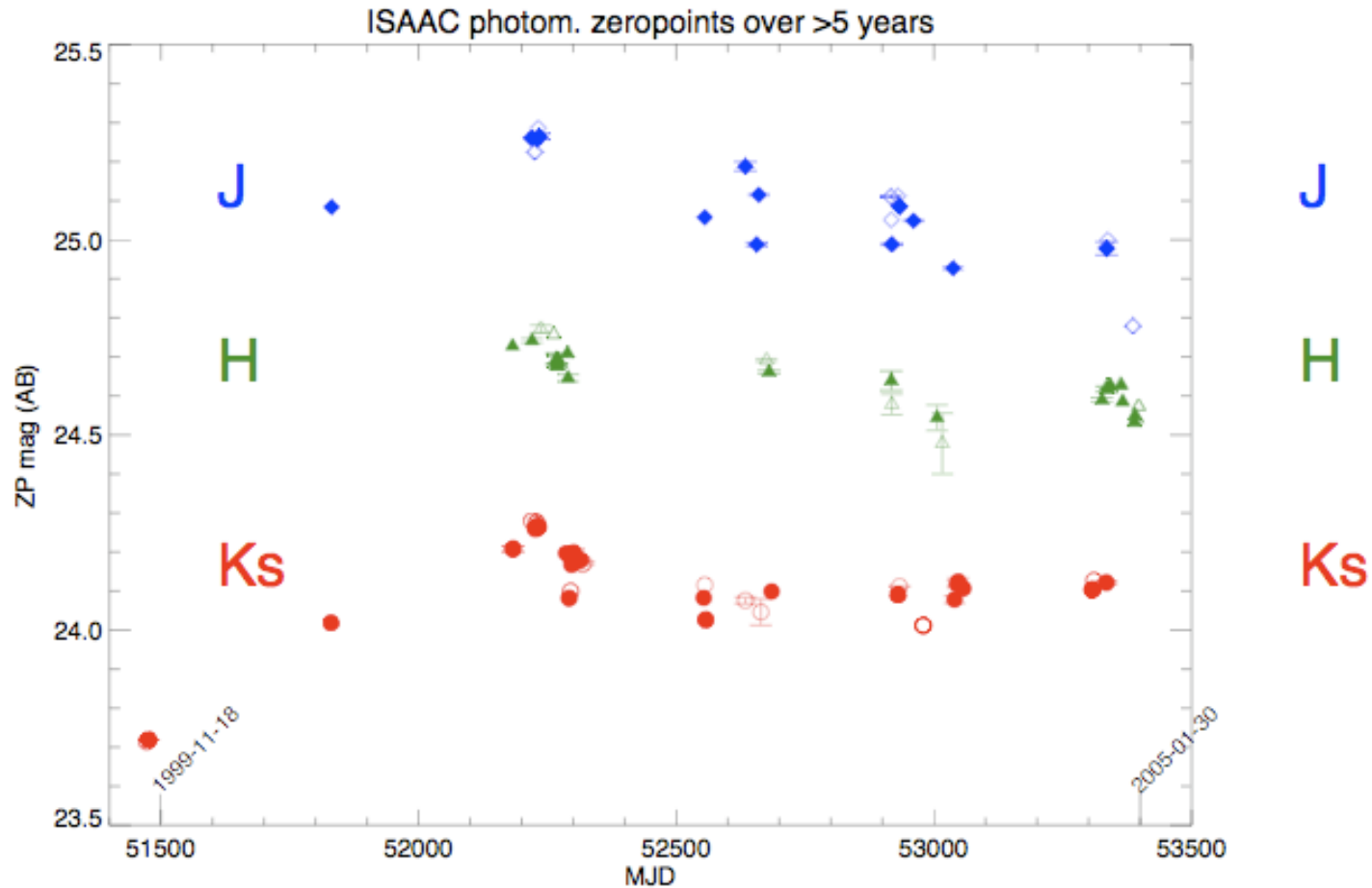
The challenge of photometric calibration

Rescaling zero points in a given field observed over several years...

Example for 3 fields/filter
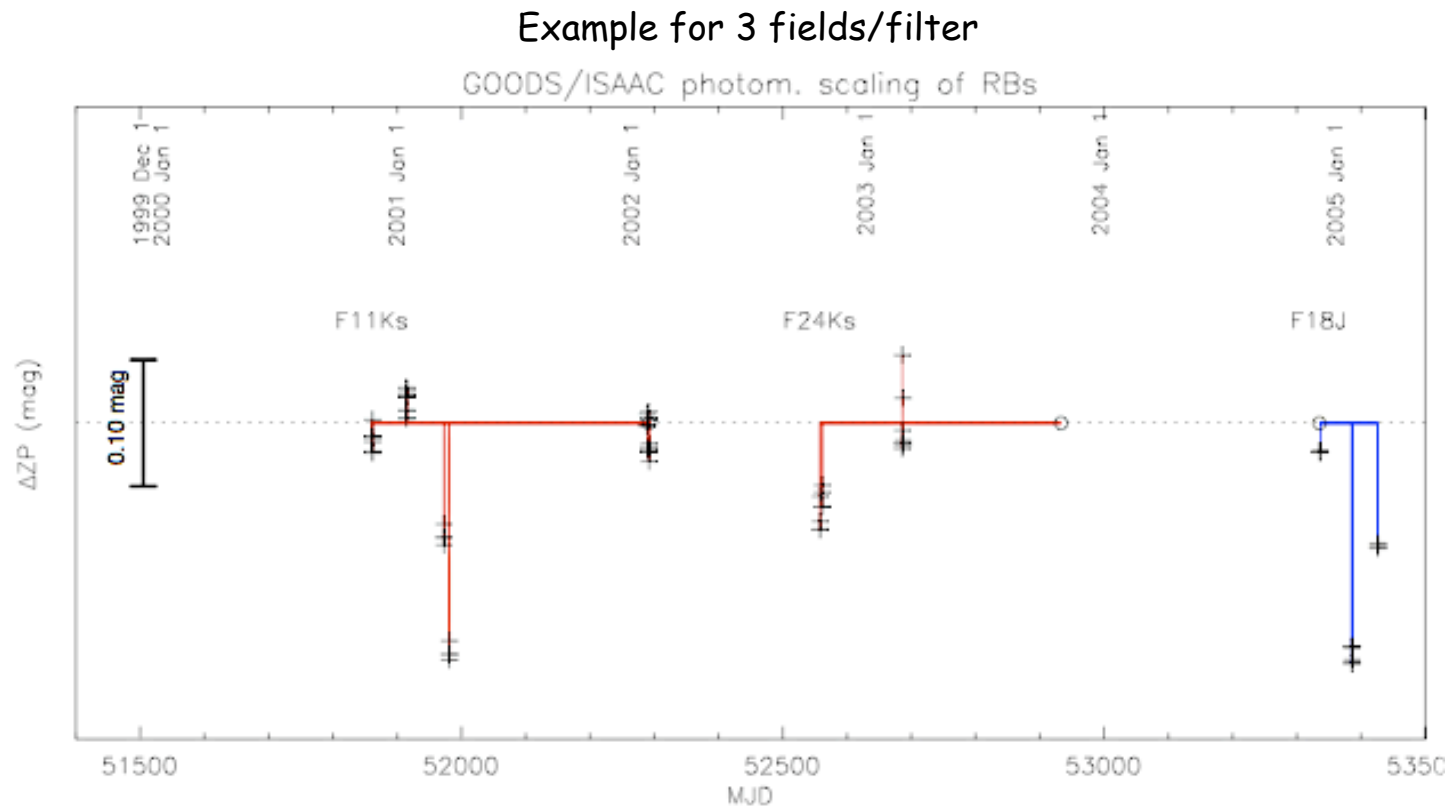
This has to be done for 26 tiles in J, 26 in Ks, and 24 in H !

The challenge of photometric calibration

"Reference zero points" for the GOODS/ISAAC survey

ISAAC photom. zeropoints over >5 years

A few % accuracy across the whole mosaic is only reached using
SOFI imaging (+ 2MASS) to suppress tile-to-tile differences

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Illumination correction:
## a weak link in the photometric calibration process...

ISAAC (J,H,Ks)

2.5%

6%

10%
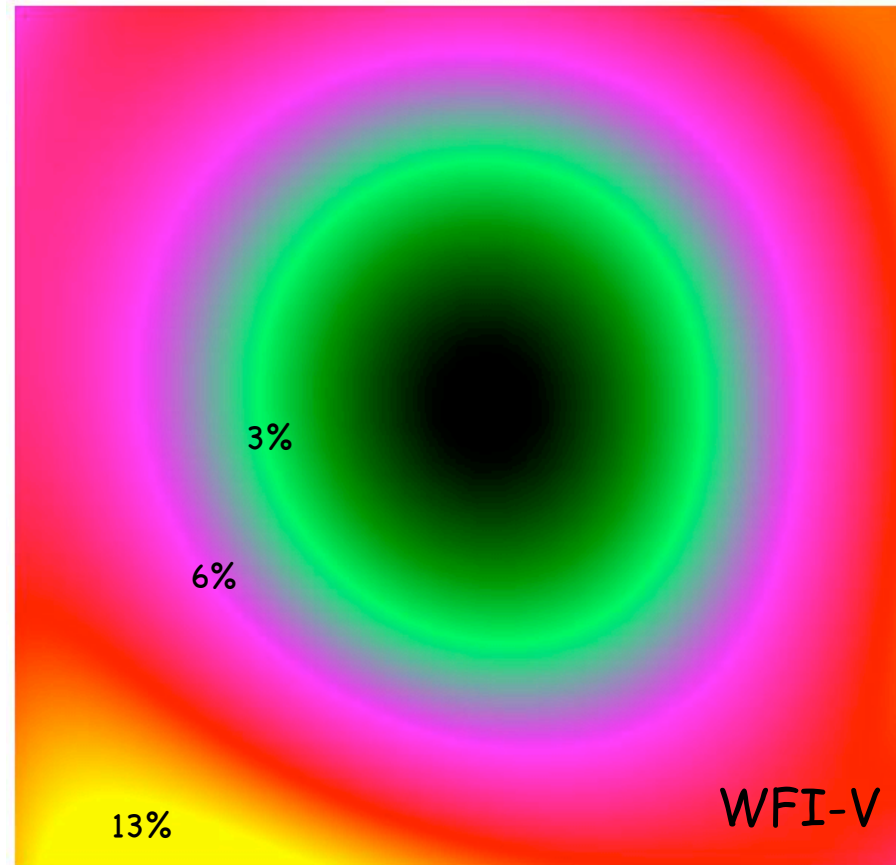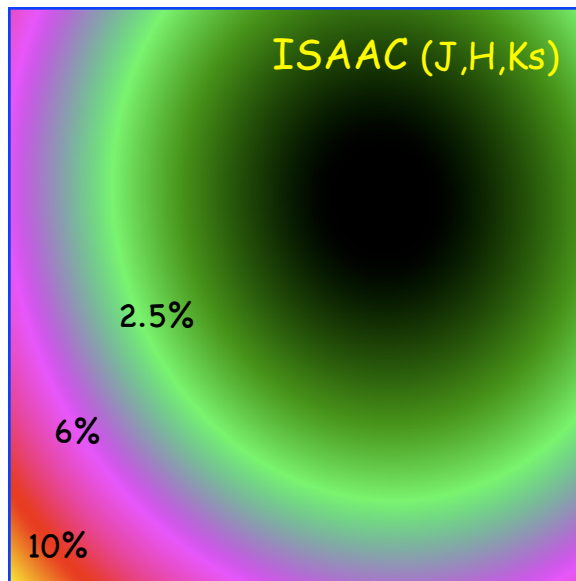
- No adequate calib data to build reliable Illumination maps
- No good monitor of time-dependence
- Need specific Ill-Maps OBs to run monthly for each instrument/filter
- Just relative photom needed: dense star fields better than dithered stds fields

3%

6%

13%

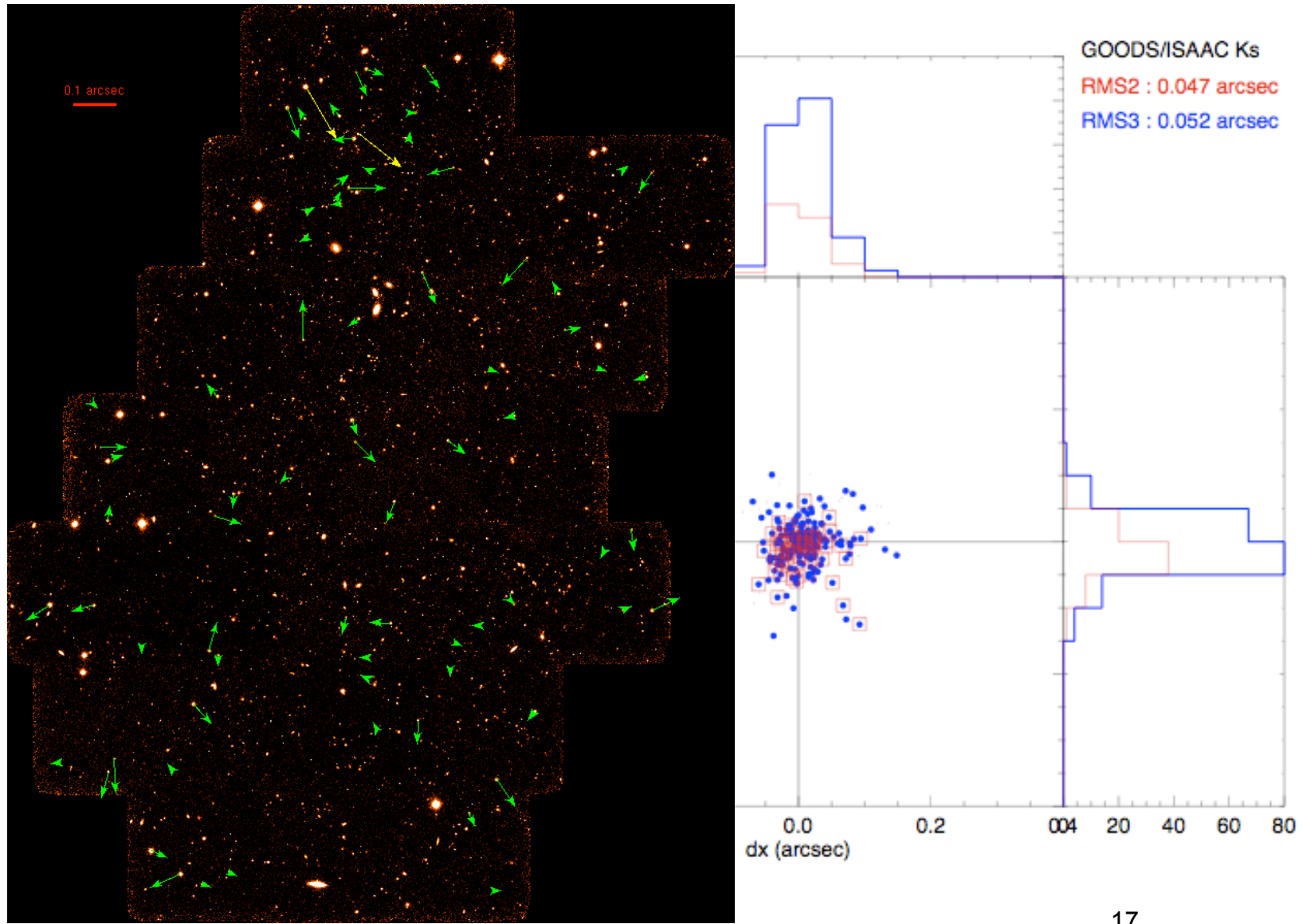WFI-V

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<u>Very</u> accurate sky-subtraction…

3-step masking to improve photometry at very faint level ($<5\sigma$)
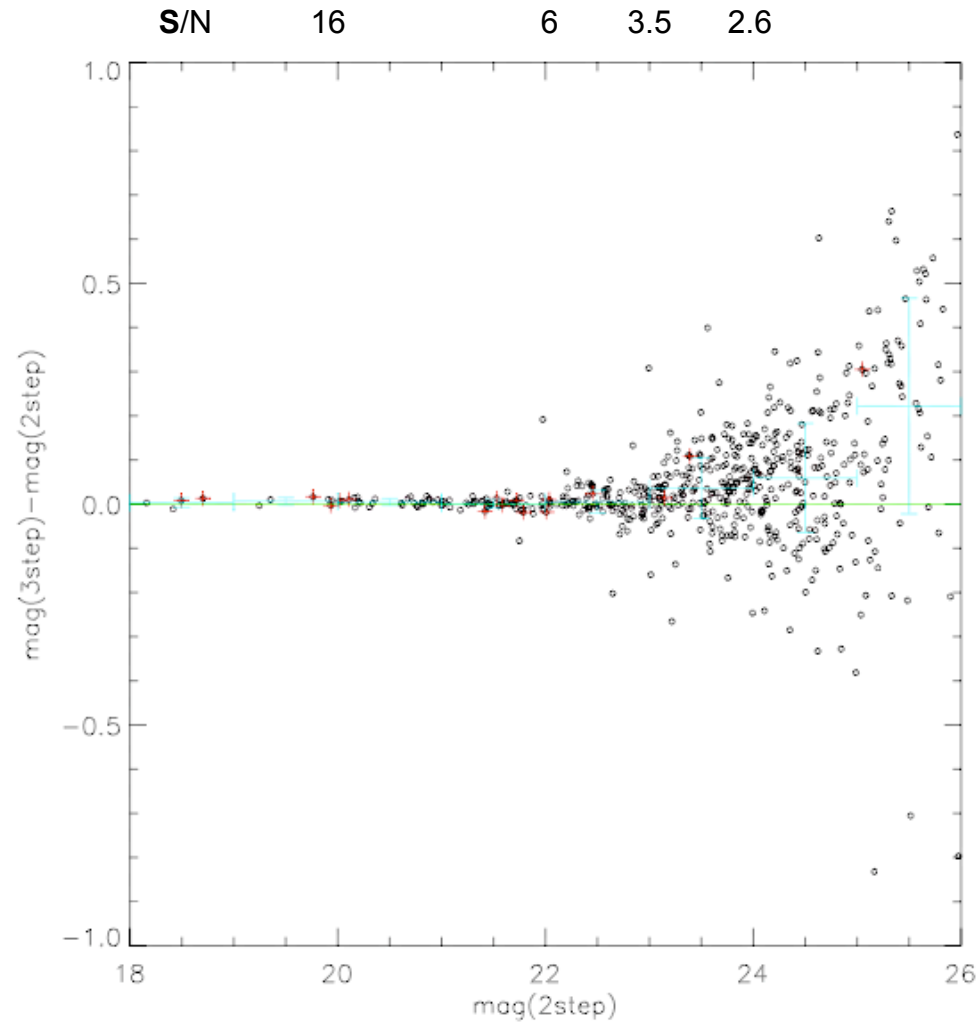
The UDF case
Deepest ISAAC image ever
26 hrs in Ks - 0.5" seeing
26 ABmag (5σ limit)
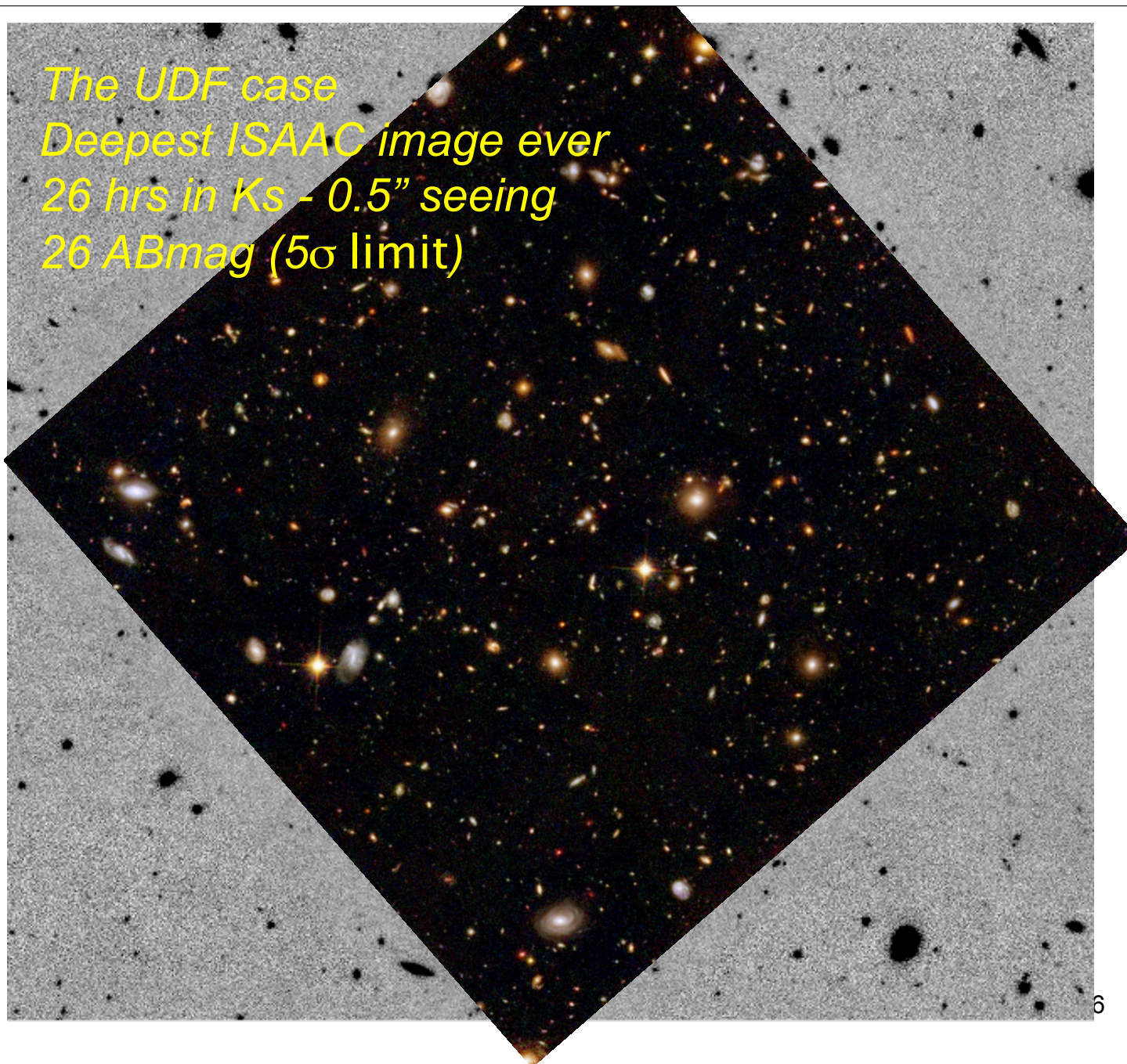
Astrometric accuracy

CDFS VIMOS-U
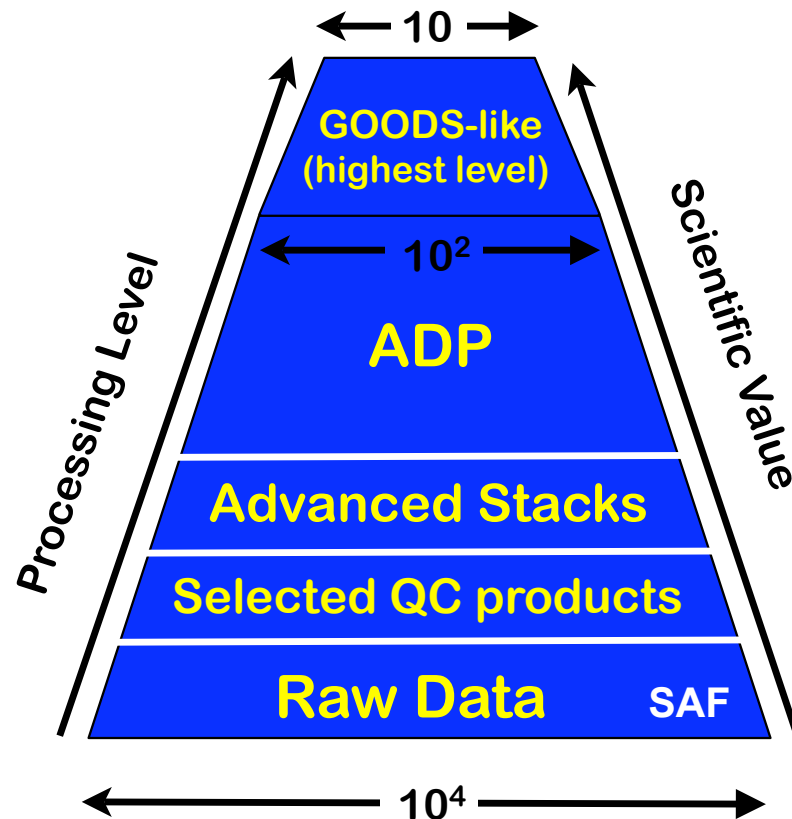
- FoV: 25x30' – 0.9" seeing

- Depth: 29 AB_{mag}

- Input images: 150

- ZP error <0.05 mag

30 Doradus

- 2x2 WFI mosaic

- B, V, OIII, H$_\alpha$

- FoV: 1 deg^2

- Input images: 300

- Non-photometric conditions (need external calibration)

- Release date: Dec 18, 06

How can we populate the Archive with more high-level imaging data products ?

➡ Accuracy of photometric calibration sets the volume of ADP which can be produced from the SAF with a given amount of resources (if there only was no atmosphere..)

➡ by relaxing this requirements we could populate the SAF with a large number of high–level DPs, e.g.:

ESO/MVM can be used to gradually scan the entire Archive (imaging instruments) to produce
<u>Advanced Stacks:</u>
combined images on a common astrometric grid per night/runID/ target/filter + reduced standards.
ZPs from QC or left to the users

Lessons learned (user perspective) how can we even do better ?

- **Standard Calibration plan could be upgraded,** <u>without extra-resources and overheads</u>, to allow a significant improvement in (spectro)photometric calibration of archival data

  ➡ more structured selection of stds (possibly twice a night), to allow better determination of extinction and color terms

  ➡ ~monthly execution of Calib OBs for Illumination Corrections (not really 2nd order corrections to instrumental signature)

- **More emphasis on modeling the atmosphere** (along with the instrument)

- **Calibration Proposals are needed** (see HST): using <u>new and archival</u> data (shifting the burden to the community) to

  ✓ provide instrument modeling for a large suites of instruments/modes

  ✓ provide post-calibration (e.g. with smaller La Silla telescopes)