Euclid Data Processing

Martin Kümmel,
on behalf of the ***Euclid Consortium***

LMU

LUDWIG-MAXIMILIANS-UNIVERSTITÄT MÜNCHEN

Faculty of Physics
Chair for Cosmology and Structure Formation

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Euclid Consortium (May '18)

- 16 countries;
- 225 institutes/labs
- 1545 full members
- Long term project (already 200 alumni)
- Yearly Euclid Mission Conference with ~400 participants;

Science Goals of Euclid

- Determine the expansion of the Universe at various cosmic ages;
- Understand the nature of the expanding Universe;
- Explore the nature and properties of dark energy, dark matter and gravity
- **Two experiments:**
  - **Weak lensing analysis (Baryonic Acoustic Oscillations);**
  - **Galaxy clustering (Redshift Space Distortion);**
- Redshifts are required:
  - From NISP slitless spectroscopy;
  - From photo-z;
- (Legacy science);

Euclid Satellite

Telescope	1.2m Korsch, 3 mirror anastigmat., f=24.5m				
Instrument	**VIS**	**NISP**			
Field-of-View	0.787x0.709 deg^2	0.763x0.722 deg^2			
Capability	Visual Imaging	NIR Imaging Photometry			NIR Spectroscopy
Wavelength range	550-900 nm	Y (920-1146 nm)	J (1146-1372 nm)	H (1372-2000 nm)	1100-2000 nm $3x10^{-16}$erg $cm^{-2}s^{-1}$
Detector Technology	36 arrays 4k x 4k CCD	16 arrays 2k x 2k NIR sensitive HgCdTe detectors			
Pixel Size/FWHM	0.1" / 0.2”	0.3 " / 0.3”			0.3 "/
Spectr. Res.	-	-			R=250

Launch: December 2021

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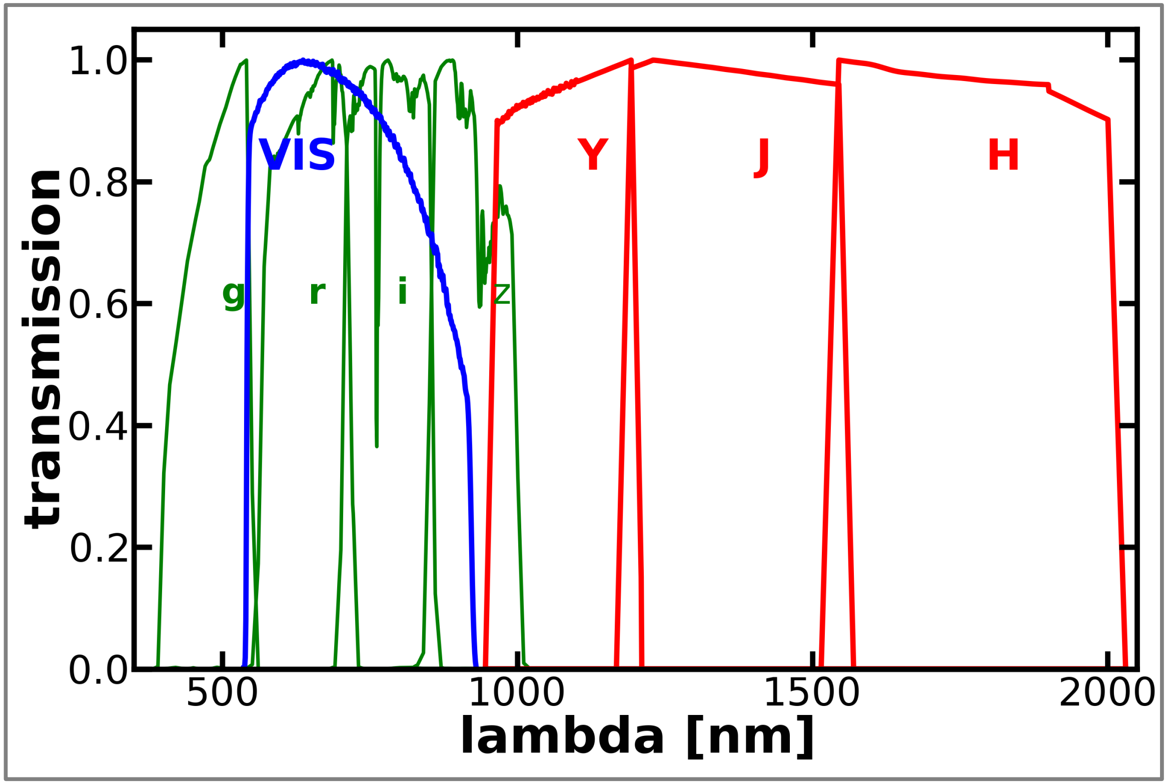
Euclid Filters

- **VIS:** weak lensing
- **NIR:** photo-z
- Ground based (photo-z): *griz*



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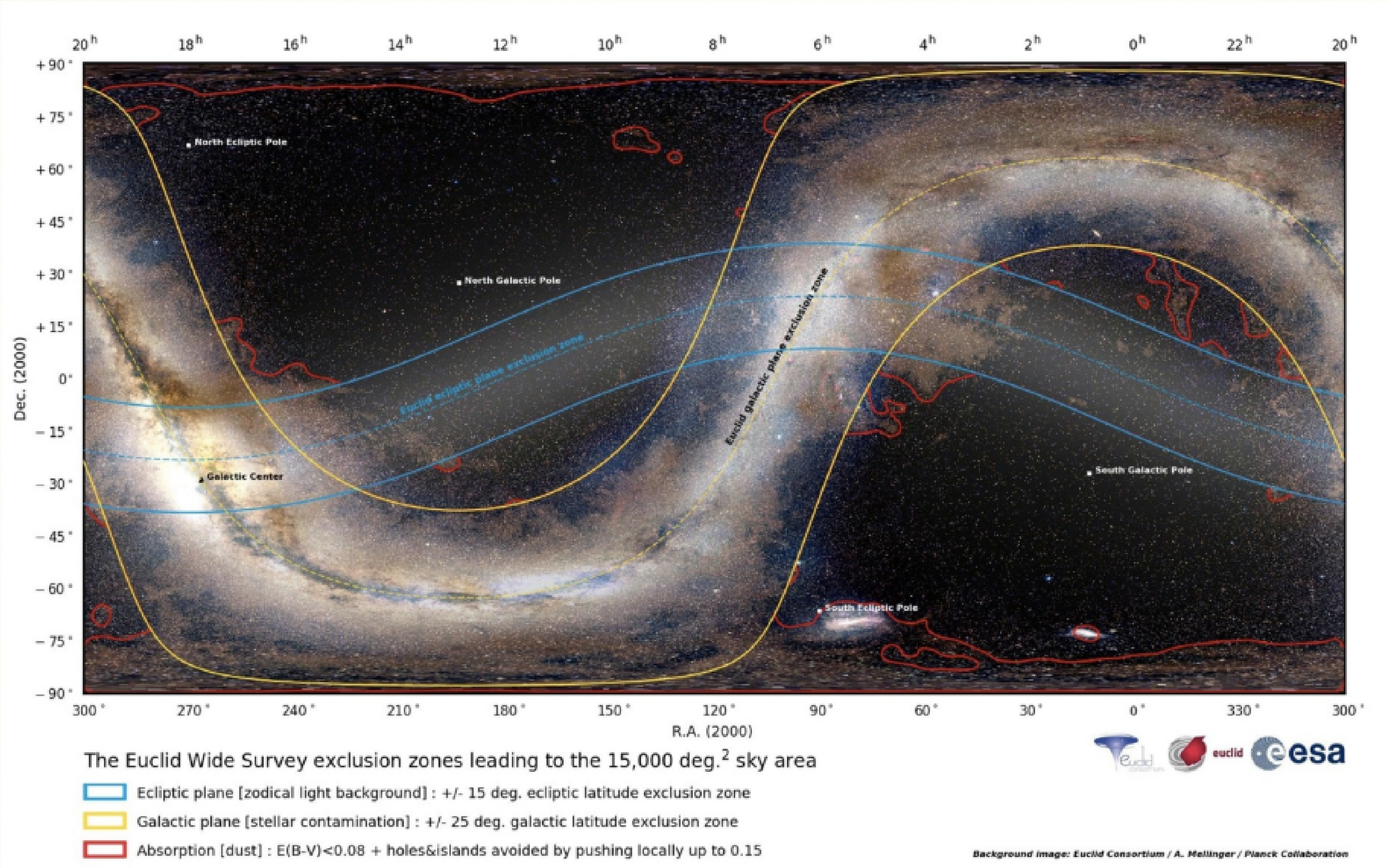
Euclid Survey(s)

- Wide Survey:
  - 15,000 deg^2
  - VIS: 24.5 mag (10σ)
  - Y/J/H: 24.0 mag (5σ)
  - *g/r/i/z* = 25.2/24.8/24.0/24.0mag (10σ)
- Deep Survey:
  - 2x20deg^2 (EDF-North and EDF-South)
  - VIS: 26.5 mag (10σ)
  - Y/J/H: 26.0 mag (5σ)
  - *g/r/i/z* = 27.2/26.8/26.0/26.0mag (10σ)
- NIR self-calibration field;
- Photo-z calibration field;

Euclid Surveys



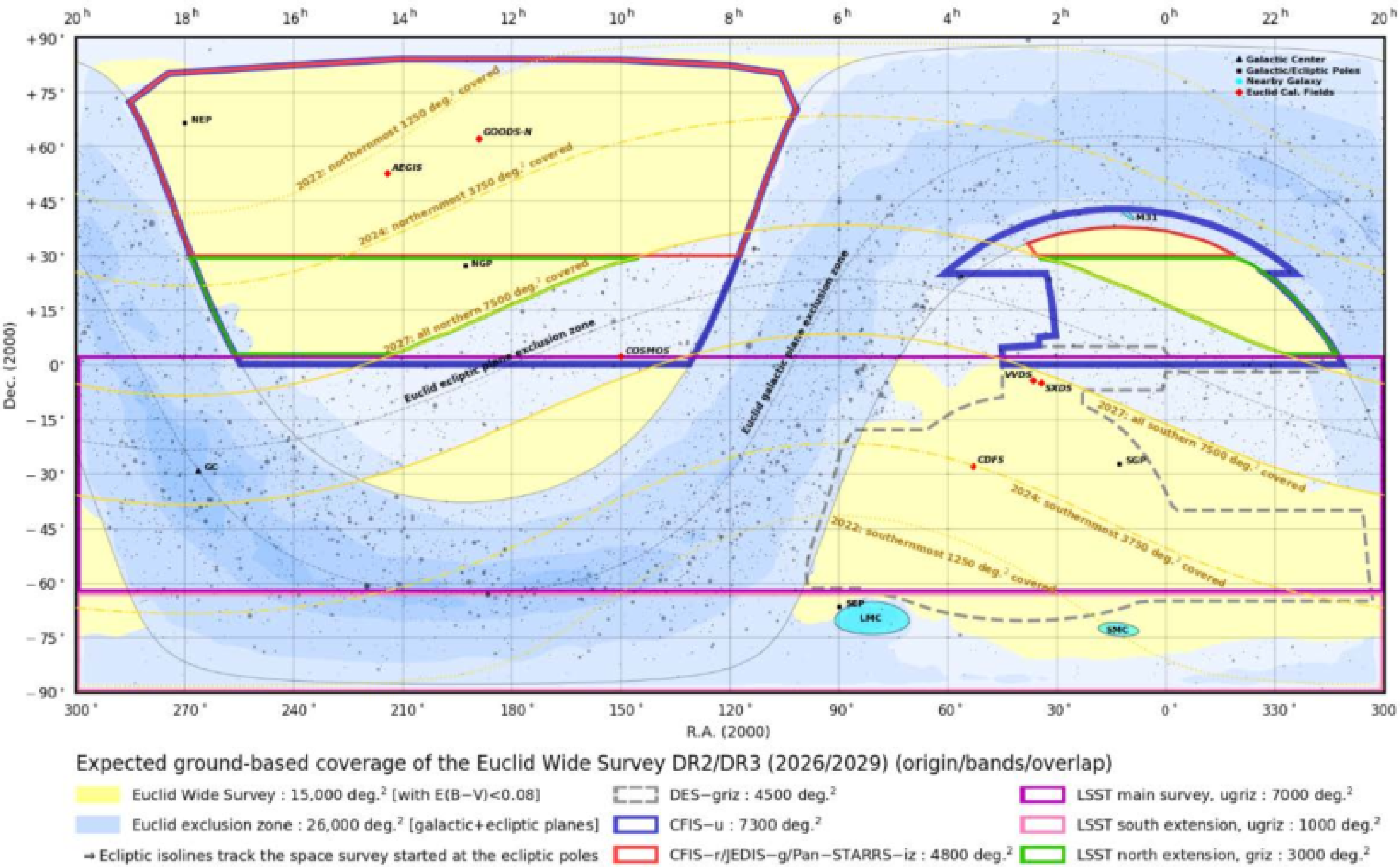
Map produced by J. C. Cuillandre, showing exclusion regions due to extinction

External Surveys: photometric

- Dark Energy Survey (**DES**): *griz,* south;
- Kilo Degree Survey (**KiDS**): *ugriz,* south;
- CFHT survey **CFIS**: *ur*, north
- **JPAS** survey: *g*, north;
- **PAN-STARRS 1 / 2**: *iz*, north, (MoU to be signed);
- **LSST**: *ugrizy*, south and north (partially), negotiations are going on;

For photometric redshifts!

External Surveys: photometric



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External Surveys: spectroscopic

- For photometric redshift calibration;
- Goal: unbiased spectroscopy;
- Dedicated programs in the North (Keck) and South (VLT);
- Grantecan (GTC) spectroscopy started;
- Call to the community to collect spectra (https://www.isdc.unige.ch/euclid/call-for-spectroscopic-data.html or A. Galametz audrey.galametz@unige.ch)

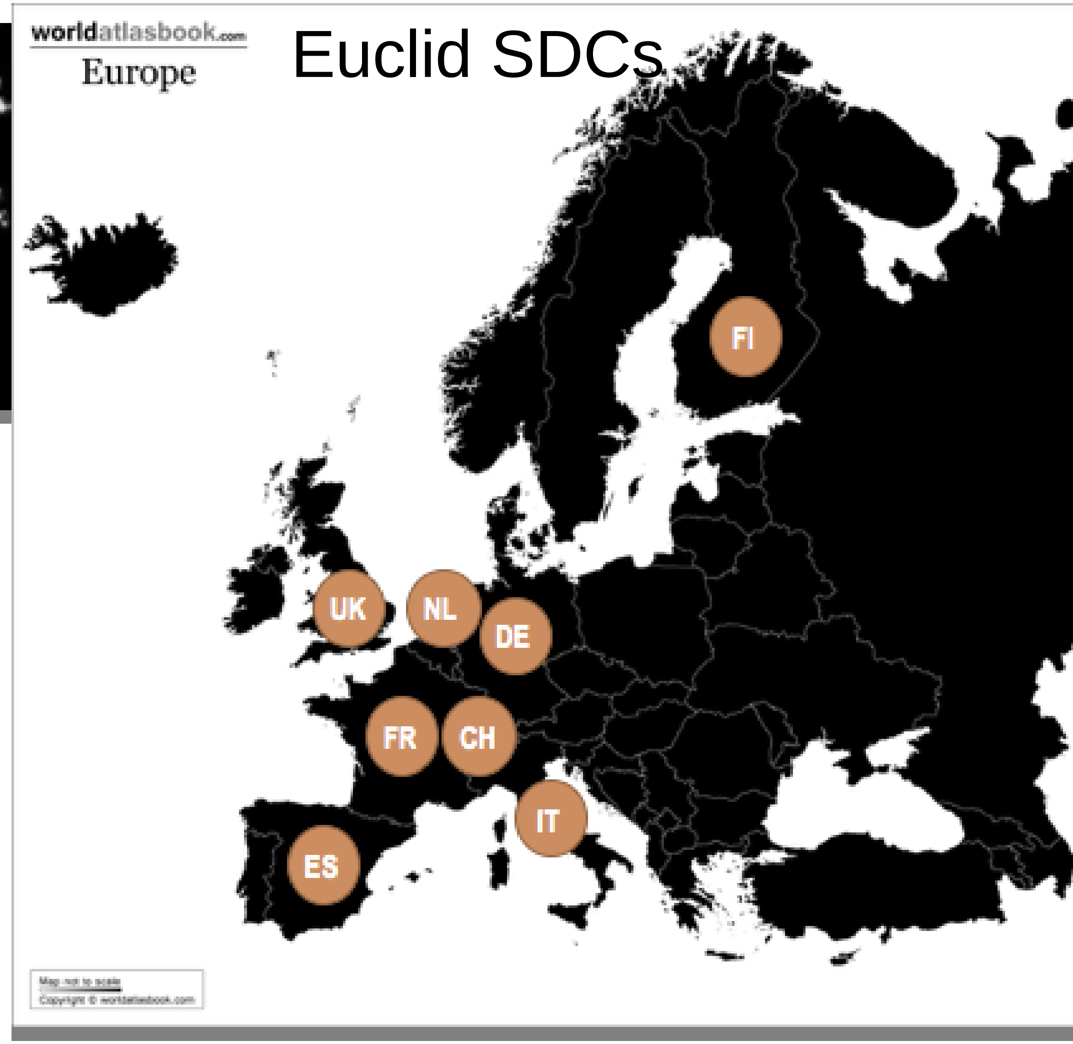
Science Ground Segment (SGS)

- Science Working Groups (SWG's):
  - Cover Weak Lensing/Cluster/Galaxy Clustering/Strong Lensing/Cosmology
  - Set the requirements for the data reduction;
  - Do the scientific analysis;
  - Write papers;
- Organizational Units (OU's):
  - Find data reduction methods;
  - Develop (at least) prototype code;
  - Design and implement the Pipeline Function;
- Science Data Centers (SDC's):
  - Euclidize software;
  - Optimize software to production level;
  - Run the Pipeline Functions;
- Euclid Archive System (EAS):
  - Hosts the data and metadata;
  - Controls the processing;
  - Data delivery;

Organizational Units (OU's)

- OU-SIM: simulations for all instruments;
- “Instrument oriented” OU's:
  - OU-VIS: for VIS data;
  - OU-NIR: for NIR photometry;
  - OU-SIR: for NIR spectroscopy;
  - OU-EXT: for ground based photometry (subdivided);
- OU-MER: object detection, photometry, morphology;
- “Science oriented” OU's:
  - OU-PHZ: photometric redshifts;
  - OU-SPE: spectroscopic redshifts;
  - OU-SHE: weak lensing;
- OU-LE3: cores science analysis;

Science Data Centers



Science Data Centers (cont.)

- Each major contributor has one SDC;
- Different organizations (dedicated hardware, general computing center, ...)
- Classical server hardware;
- No GPU's (due to heterogeneity);
- Every SDC must be able to run every Euclid code (... except EXT legacy code);
- SDC-DE:
  - Part of the Max-Planck-Gesellschaft computing center;
  - Dedicated hardware;
  - 1st generation cluster with 648 cores already retired;
  - 2nd generation cluster with ~300 cores, 600 TB storage running;
  - During survey processing: 6000 cores;

Processing / Software development

- Processing:
  - In Virtual Machines (VM), CENTOS7 based;
  - Defined set of libraries available;
  - Latest VM with CVFMS (→ automatic upgrading);
  - Continuous software deployment;
- Software development:
  - C++11 and python3;
  - Few (non-C++/python3) legacy code;
  - CMake based build system;
  - Git/github;
  - Not many fundamental libraries;

Available libs/applications

- boost
- Breathe
- cMake
- cppCheck
- Cppunit
- Doxygen
- Ds9
- pyFFTW
- Scikit-learn
- Elements
- EuclidEnv
- Euclid DM Bindings
- Eclipse
- FV
- gcovr
- Git
- GSL
- Healpix-C++

- swig
- wcslib
- Xerces
- libpng
- libcairo2
- libreadline6
- GoogleTest
- Sphinx
- Fitsio
- Healpy
- Astropy
- lxml
- matplotlib
- NumPy
- PyEphem
- PyQt
- SciPy

- Python
- Log4cpp
- pylint
- PyTest
- python-coverage
- PyXB
- RATS
- Six
- SonarQube
- Subversion
- valgrind
- vera++
- Kcachegrind
- CCfits
- CFitsIO
- Eigen
- FFTW

Science Challenges

- What to do without real data → use simulations!
- Simulations:
  - True Universe catalogs;
  - Star catalog (including double stars);
  - Very very detailed instrument models;
- Science Challenges:
  - Increase in area;
  - Increase in processing depth;
  - Increase in level of detail;
- Goal: end-to-end processing over entire survey area!
- Central for pipeline validation and performance validation

Science Challenges (cont.)

Scientific Challenge #1: Simulators challenge	Produce samples of Euclid FoV (0,7°) of VIS/NIR/SIR simulated images and spectroscopy images consistent with a single input catalogue (galaxies, stars), instrument model, cosmic rays injected into the simulation code.
Scientific Challenge #2: SIM/ VIS/NIR/SIR	Produce VIS/NIR/SIR output data products which are consistent with the Data Model: calibrated exposures, stacks, masks, catalogues, 1D spectra, 2D spectra (detection of transients not needed, level Q not needed).
Scientific Challenge #3: VIS/ NIR/EXT/MER	Production of a merged catalogue of sources (each source has a single ID). **Now planning to use data products in Science Archive demo (SAS)**
Scientific Challenge #4: VIS/ NIR/SIR/EXT/MER/SHE	Production of galaxy shape measurement and VIS PSF model refinement KOM in Jan 2018
Scientific Challenge #5: VIS/ NIR/SIR/EXT/MER/PHZ	Production of photometric redshifts measurement and PDF. KOM in Jan 2018
Scientific Challenge #6: VIS/ NIR/SIR/EXT/MER/SPE	Production of spectroscopic redshifts measurement. KOM in Jan 2018
Scientific Challenge #7: VIS/ NIR/SIR/EXT/MER/ SPE /PHZ/ SHE	Update pipeline releases to meet more consistent requirements coverage w.r.t. the previous challenges
scientific challenge #8: VIS/ NIR/SIR/EXT/MER/SPE / PHZ/ SHE/LE3 (LE3)	Quality of LE3 data products shall be challenged according to the corresponding scientific requirements

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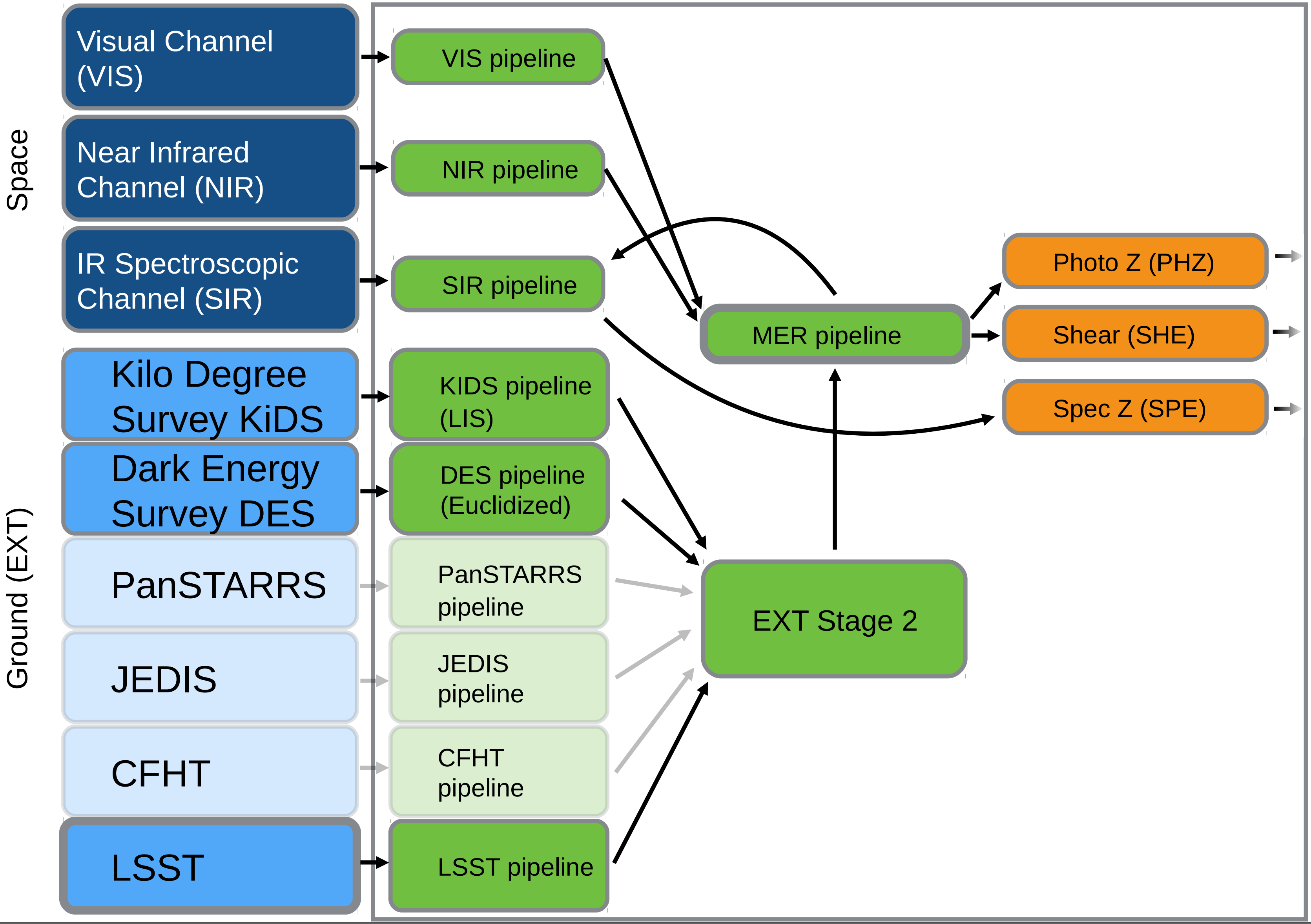
Science Challenge 4/5/6: Overview



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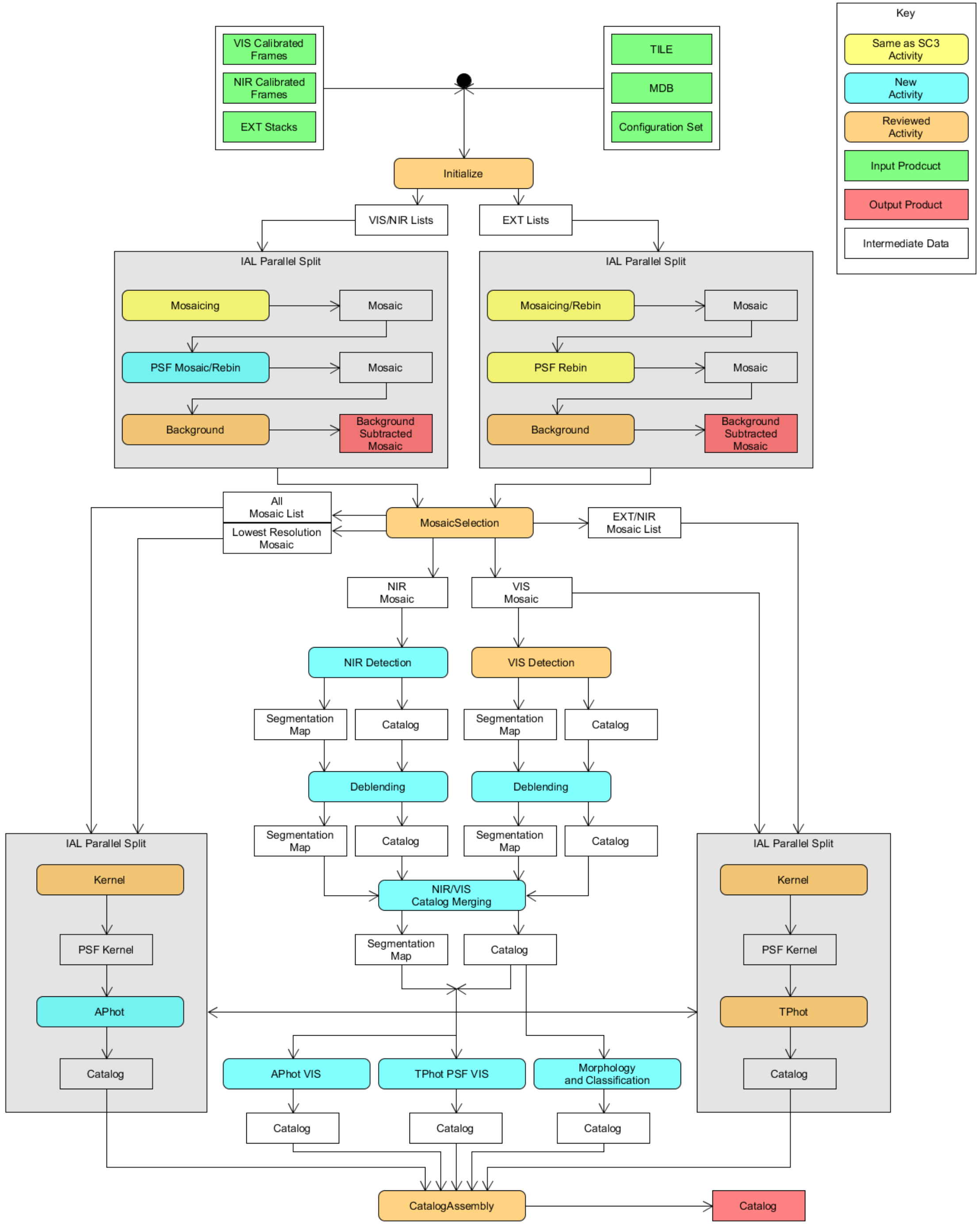
OU-MER pipeline

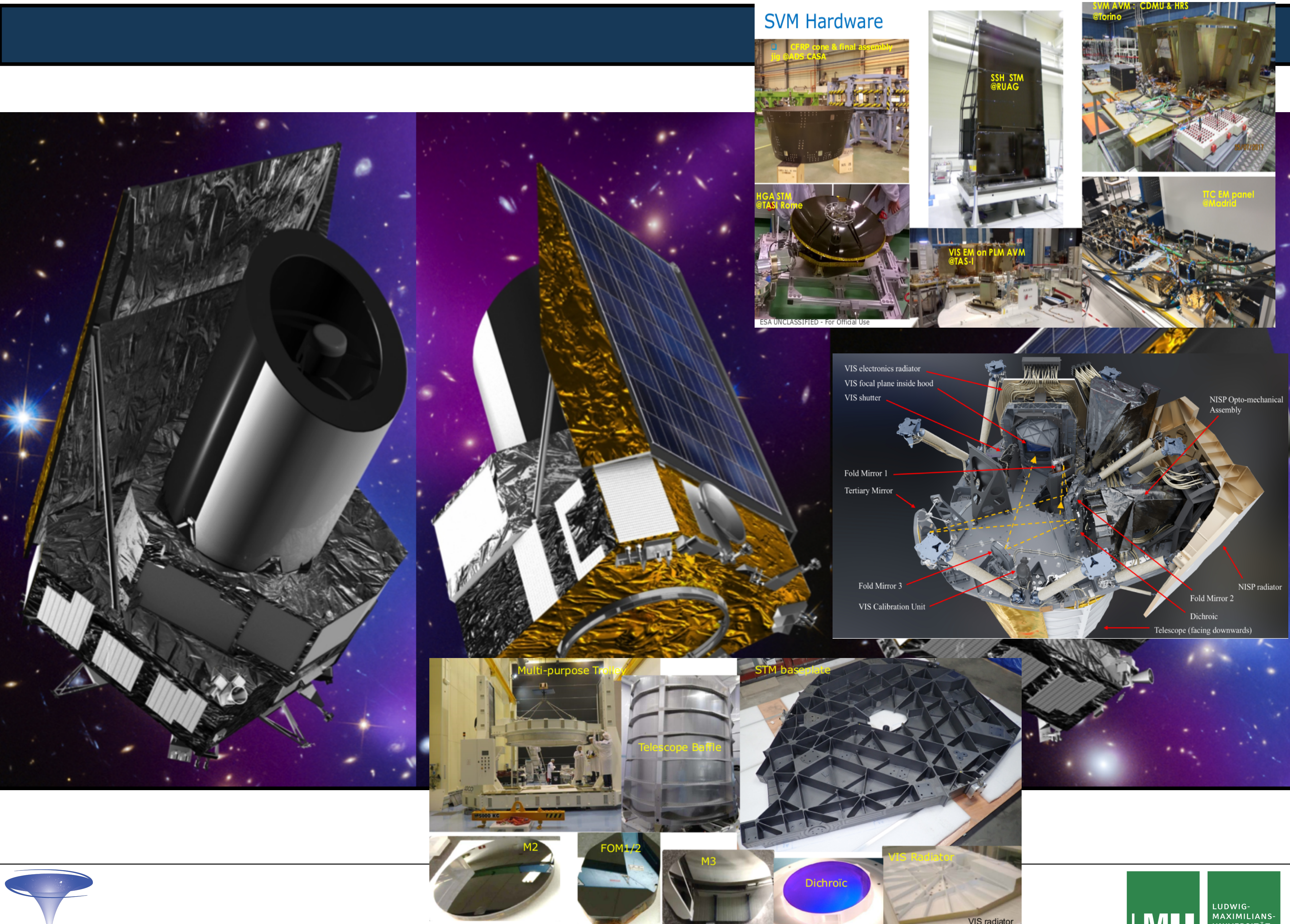
Flow diagram of the MER pipeline



Aster

Euclid and the VO

- Will be heavily used on the user side of the archive;
- Tools that are/will be used:
  - TAP+ service interface;
  - UWS job management;
  - ESASky;
  - CDS Aladin Lite;
  - VOSpace Browser;
  - SAMP;
  - HIPS?


SVM Hardware
CFRP cone & final assembly jig @ADS CASA
SSH STM @RUAG
SVM AVM : CDMU & HRS @Torino
HGA STM @TASI Rome
VIS EM on PLM AVM @TAS-I
TTC EM panel @Madrid
ESA UNCLASSIFIED - For Official Use
VIS electronics radiator
VIS focal plane inside hood
VIS shutter
Fold Mirror 1
Tertiary Mirror
Fold Mirror 3
VIS Calibration Unit
NISP Opto-mechanical Assembly
NISP radiator
Fold Mirror 2
Dichroic
Telescope (facing downwards)
Multi-purpose Trolley
Telescope Baffle
STM baseplate
M2
FOM1/2
M3
Dichroïc
VIS Radiator
VIS radiator