25 Years Working on ESO Automatic Data Reduction Pipelines: Lessons Learned

Andrea Modigliani[1] Contact: amodigli@eso.org

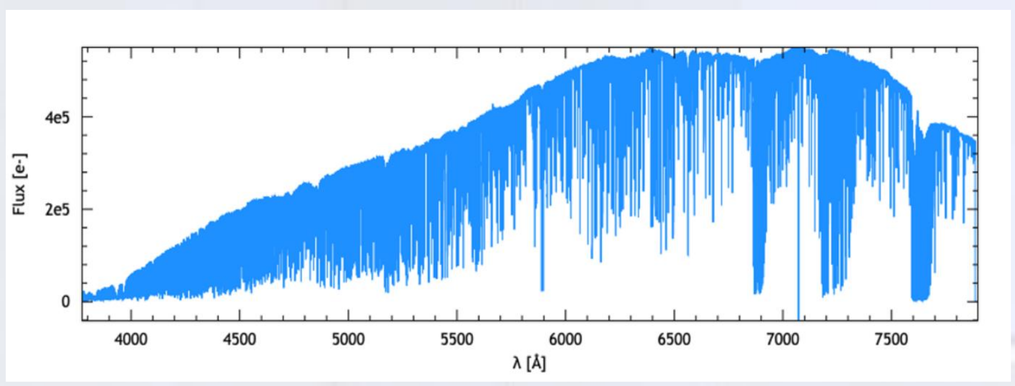
1: ESO

Thanks to all contributions from ESO's pipeline, contractors, science data quality, Paranal Operations, and instrument consortia teams for 25 years of collaboration in building, maintaining, and improving ESO pipelines

This contribution reflects on 25 years of experience developing and maintaining automatic data reduction pipelines and related software at the European Southern Observatory (ESO). Over this period, the technology landscape has evolved from early MIDAS-based tools to systems built on the Common Pipeline Library (CPL) and the High-level Data Reduction Library (HDRL), and more recently toward Python-based frameworks such as PyCPL and PyHDRL. Originally designed and implemented as quick-look tools to support Very Large Telescope (VLT) operations, the pipelines later evolved to address the broader needs of the user community by generating science-ready data products. This evolution naturally involved a larger group of stakeholders in verification, validation, and further development. Despite changes in technology and an improved review process using multiple milestones and the involvement of multiple stakeholders, many core challenges and design principles have remained consistent throughout the projects' life cycles, from establishing close collaboration with consortia delivering initial versions, to continuous cooperation with all stakeholders through design, implementation, commissioning, and long-term operations. Key lessons concern the importance of full commitment and valuing complementary contributions from all participants, identifying and prioritizing areas for improvement, and adopting modular, reusable, and sustainable software architectures with well-defined interfaces between scientific and engineering teams. This poster summarizes these lessons and how they have shaped the evolution of ESO's pipeline ecosystem, offering guidance for future projects in astronomical data reduction and analysis.

Introduction

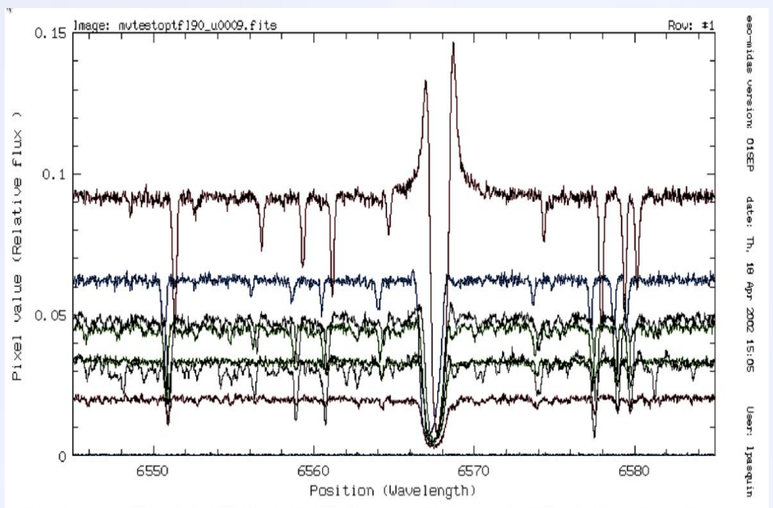
ESO data reduction pipelines and operational tools evolved over the last three decades to address ever stringent operational and user community requirements. Still a few conditions remain important:
Proper consortium deliveries aligned with ESO standards
Systematic **testing** and verification at each project milestone
Collaboration across ESO and consortia for quality and maintainability



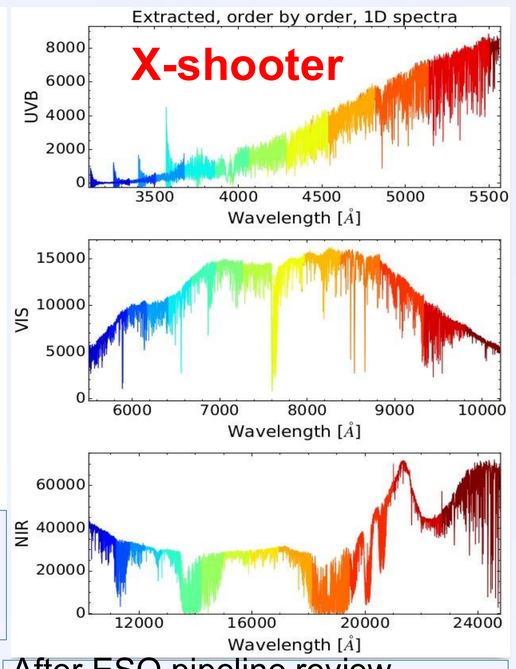
Wavelength calibrated spectrum of Tau Cet in UHR. 2021A&A...645A..96P

ESO development & review cycle Europe

Phase A: instrument proposed and defined.
SAR: System Architecture Review. Check definition, system interfaces.
PDR: Preliminary Design Review. System requirements & early design.
FDR: Final Design Review. Detailed design, ready for implementation.
TRR: Technical Readiness Review: are we ready for PAE?
PAE: Preliminary Acceptance Europe. Verification and final acceptance.



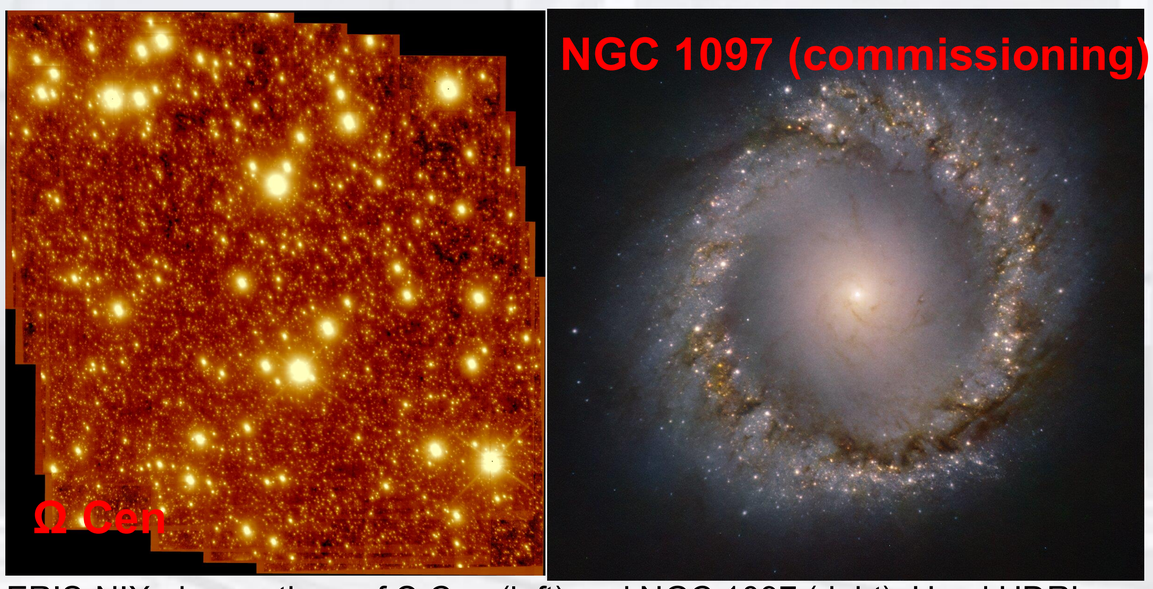
Ω Cen: FLAMES-UVES 1st light, MIDAS pipeline later ported to CPL. 2004Msngr.118....8M
Public pipeline used for ESO-GAIA survey.



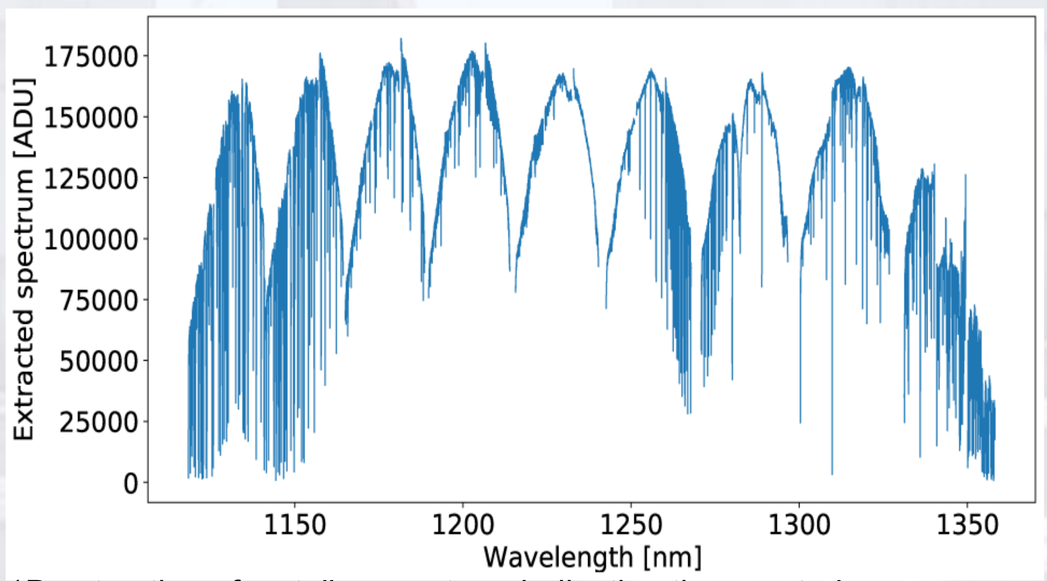
After ESO pipeline review, products science grade, phase3 format. Used in X-shooter spectral library.
2020A&A...634A.133G

ESO development & review cycle Cile

AIV: Assembly & integration of the instrument.
Commissioning: all systems are commissioned on several runs.
SV: Science Verifications. Instrument performance verified on Sky.
Start of Operations.
PAC: Preliminary Acceptance Chile. The instrument is accepted by the observatory.

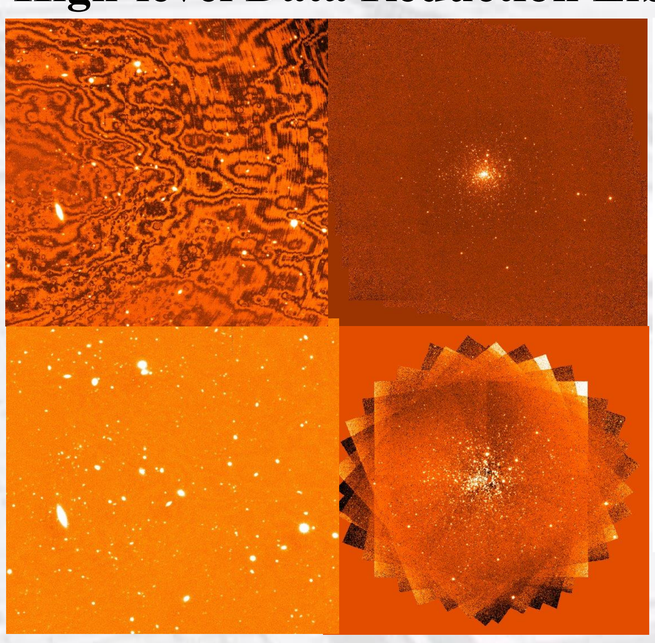


ERIS-NIX observations of Ω Cen (left) and NGC 1097 (right). Used HDRL resampling

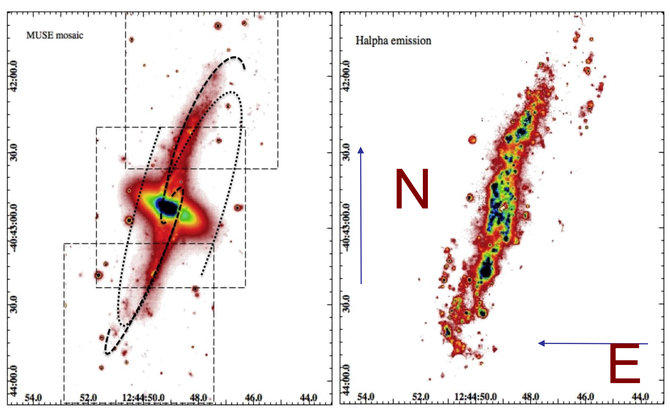


1D extraction of a stellar spectrum indicating the spectral coverage achieved for a single wavelength setting, here J1228. 2023A&A...671A..24D

High-level Data Reduction Library



HDRL: fringe correction (left). Image resampling (right)



Left: MUSE mosaic of NGC 4650 A , SDSS r-band. Right: Ha emission from MUSE data. 2015A&A...583A..48I

Lessons learned

- To obtain very good quality of data reduction pipeline are important:
- Strong collaboration between consortia and ESO staff
- Collect feedback from all stakeholders: engineers, algorithm experts, quality control staff, operations, scientists
- Early problems detection and prioritization before milestone reviews
- Robust and maintainable code, verified on several platforms
- Both robustness and quality are essential
- Collaboration across ESO teams essential to share workload, improve quality, and enhance both stakeholders & user satisfaction.

References:

CPL 2004ASPC..314..392B , **ESO Reflex.** 2013A&A...559A..96F, **HDRL.** 2015ASPC..495