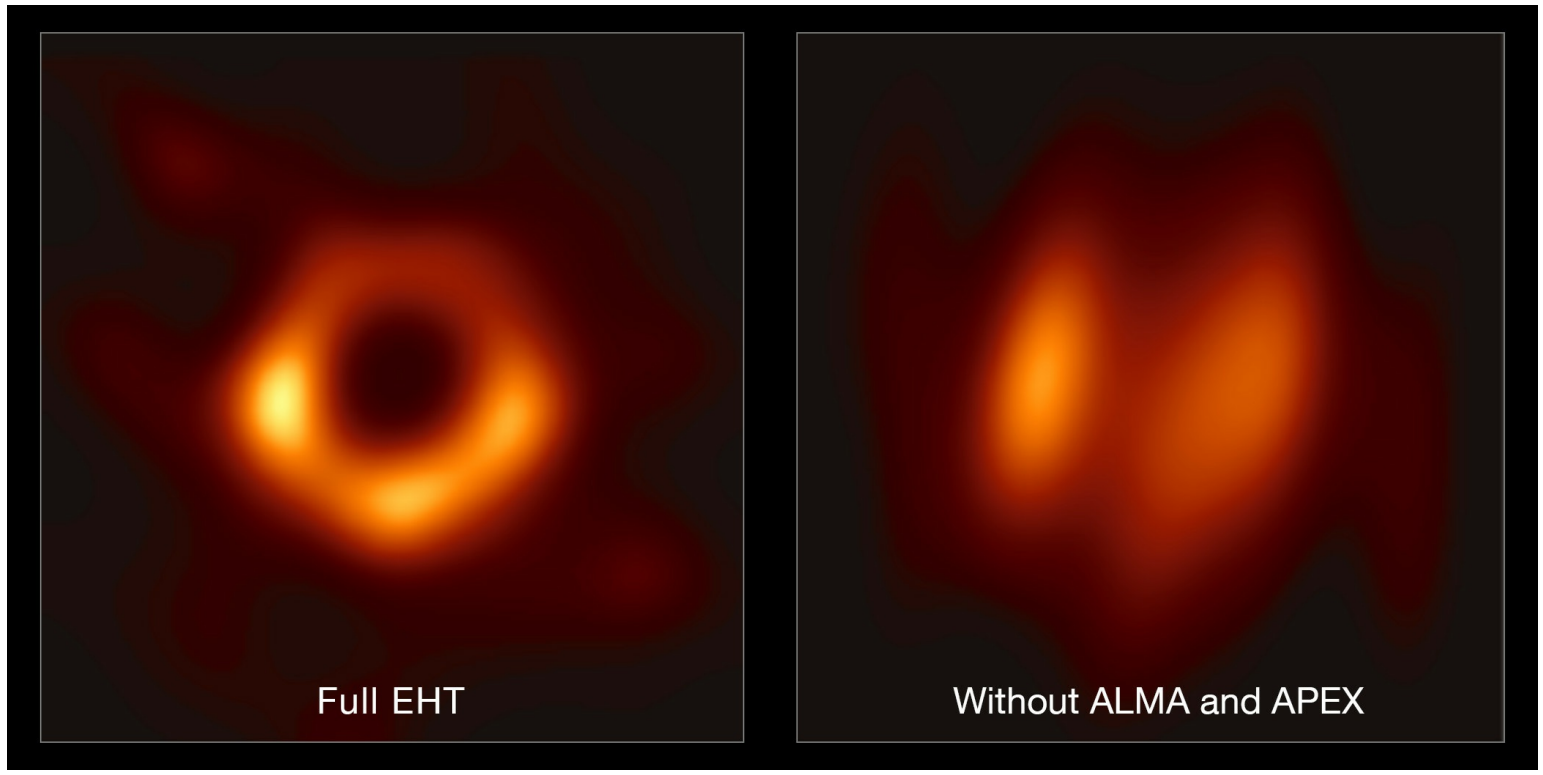
ALMA-EU Development Projects and Studies

Ciska Kemper
European ALMA Programme Scientist

The 42 μas shadow of the black hole in M87

The Event Horizon Telescope Collaboration (2019a-f)

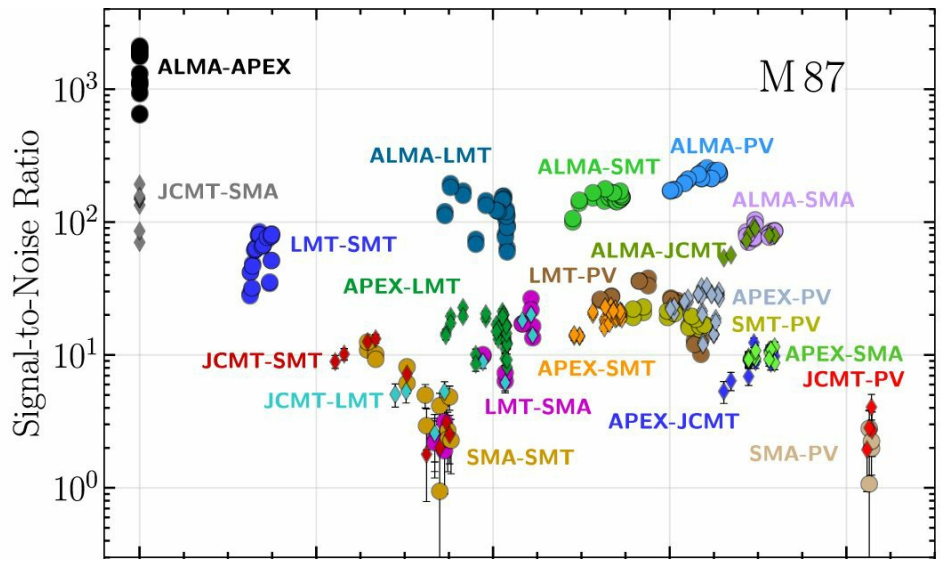
ALMA and APEX were crucial

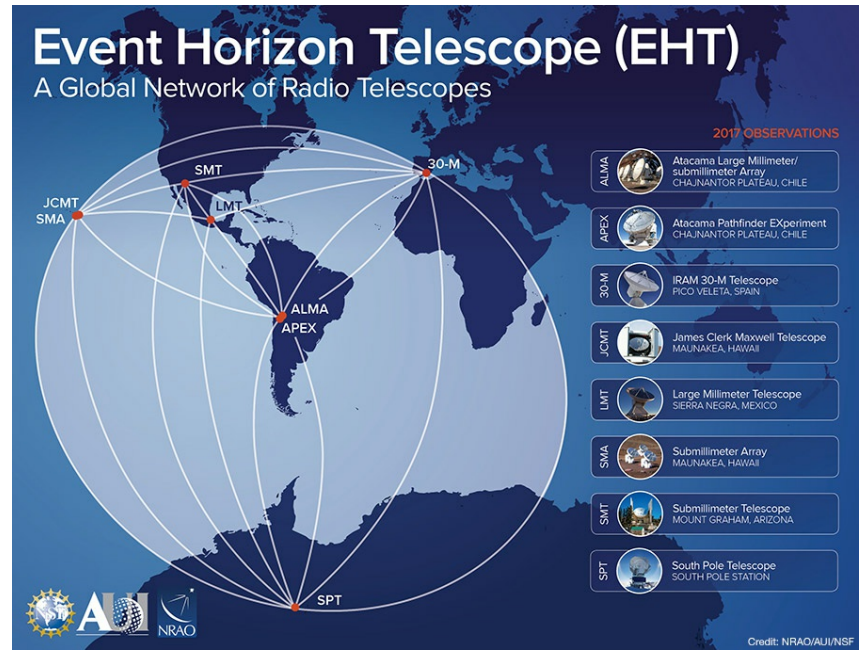


The contribution of ALMA and APEX

- Collecting area
- Phase calibration

(EHT Collab. 2019c)





Imaging protoplanetary disks

DSHARP

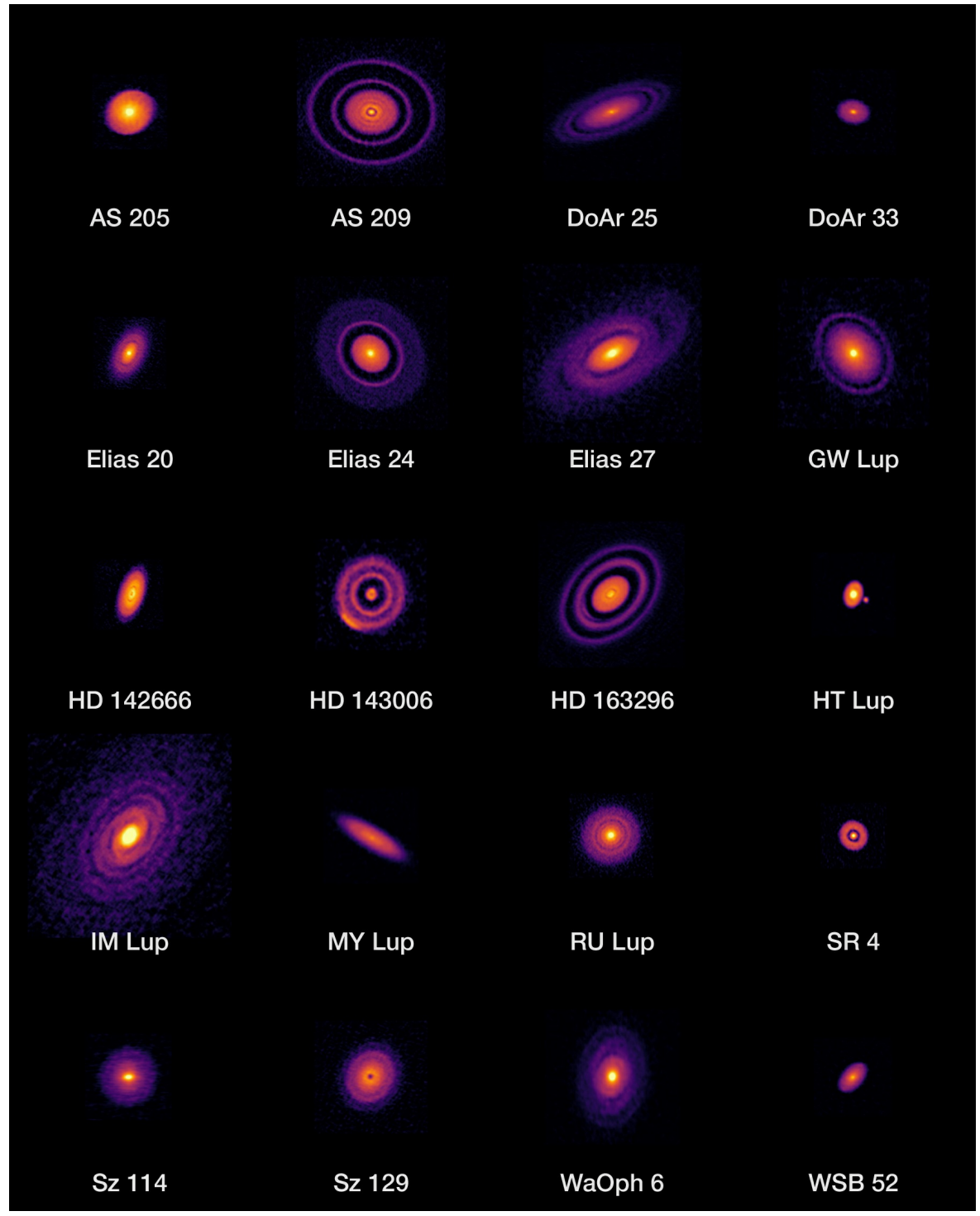
10 papers in Dec 2018

PIs:

S. Andrews, A. Isella,
L. Perez, C. Dullemond

Cycle 4 LP

Band 6 continuum
(1.25 mm)



Evaluation top level science goals

Capabilities to reach the top-level science goals, that were set when ALMA was being planned/under construction, are now in existence

Level I science goals:

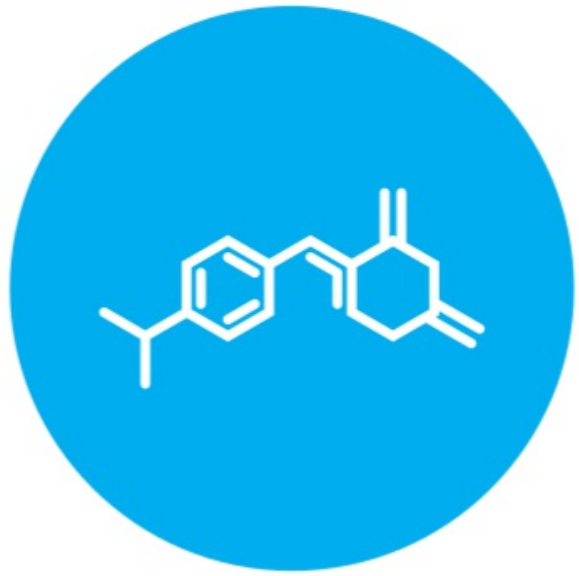
- Detect CO or C+ at z=3 in a normal galaxy in less than 24 hours of observation
- Image gas kinematics in protoplanetary disks at 150 pc and detect tidal gaps created by planets
- Precise imaging at 0.1" angular resolution

2030 Roadmap and implementation

New Fundamental Science Drivers

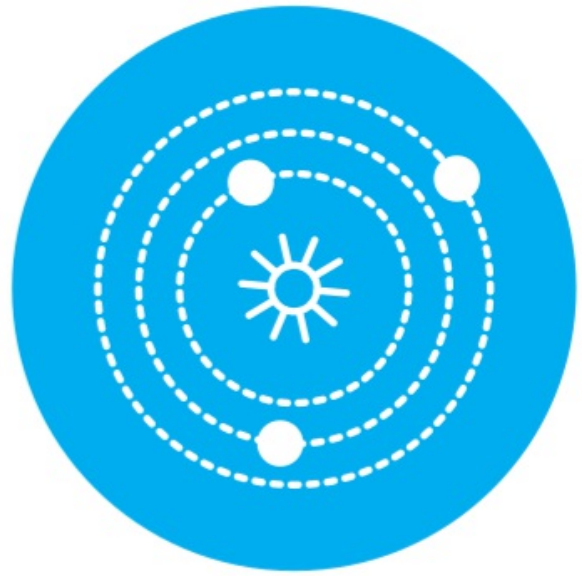
ORIGINS OF GALAXIES

Trace the cosmic evolution of key elements from the first galaxies (z>10) through the peak of star formation (z=2–4) by detecting their cooling lines, both atomic ([CII], [OIII]) and molecular (CO), and dust continuum, at a rate of 1-2 galaxies per hour.



ORIGINS OF CHEMICAL COMPLEXITY

Trace the evolution from simple to complex organic molecules through the process of star and planet formation down to solar system scales (~10-100 au) by performing full-band frequency scans at a rate of 2-4 protostars per day.



ORIGINS OF PLANETS

Image protoplanetary disks in nearby (150 pc) star formation regions to resolve the Earth forming zone (~ 1 au) in the dust continuum at wavelengths shorter than 1mm, enabling detection of the tidal gaps and inner holes created by planets undergoing formation.

2030 ALMA Development Roadmap priorities

- Broaden the receiver IF bandwidth by at least a factor 2; upgrade associated electronics and correlator
- Receiver upgrades
  - 200-425 GHz (Band 6, 7, 8)
  - <200 GHz
  - >425 GHz
- Long term capabilities of the ALMA archive
- Studies on future development paths
  - Extending the max. baseline by a factor of 2-3
  - Focal plane arrays

ALMA System Requirements

Team tasked with formulating requirements for subsystems in order to implement the 2030 Roadmap. Led by Nick Whyborn, to be replaced with S. Asayama, EU members are Gie Han Tan and Neil Phillips.

Status: just getting started, first status report to AMT in May 2019

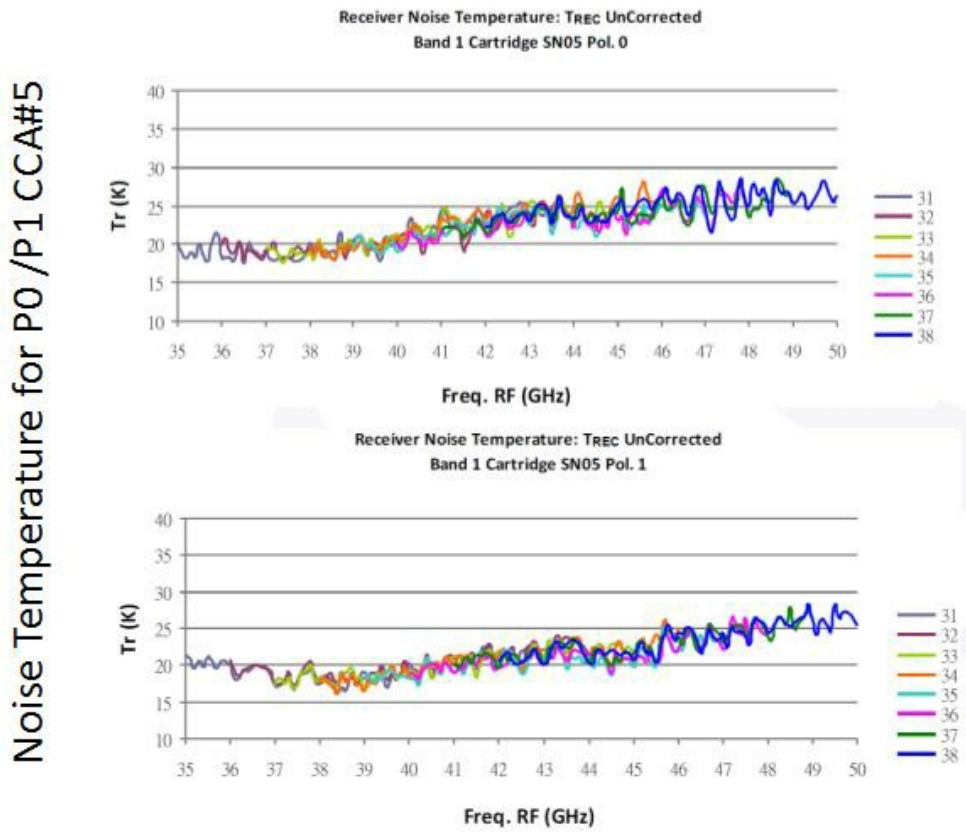
Key decision: balancing bandwidth with receiver noise

Metric: Chose between options such that the observing time for a set of mixed proposals (single line, multiple line, continuum) is minimized

Updated

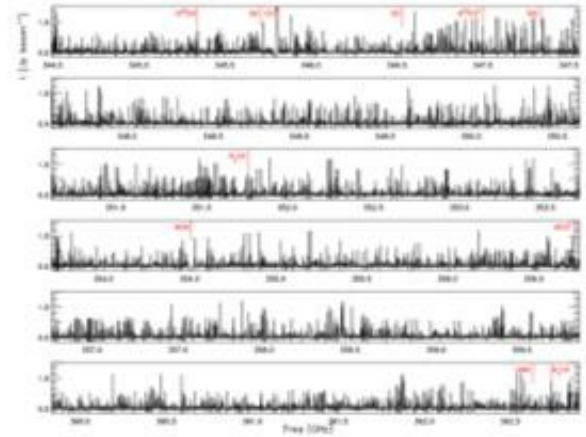
Band 1 Receiver (led by ASIAA)

- Band 1 activities re-started with the target to hold the MRR and full production in 2019
- 16 CCA/WCA integrated and tested by ASIAA



Acting on ALMA2030 vision

- Expanding ALMA's processed bandwidth
  - ***Correlator Upgrade Project (CUP)*** The Correlator Upgrade Project (CUP) will significantly enhance the spectral capabilities of the ALMA 12-m array correlator and allow for processing of twice the instantaneous bandwidth compared to what is presently possible.The CUP has been split into two phases, based on technology readiness:
  - Phase 1 – 8 times more channels per baseband
    - All changes happen in the correlator and downstream to handle increased data rate
    - 4x4 bit sampling (all but 4GHz bands): the spectral sensitivity improves by 12.2%.This is equivalent to adding 6 antennas to a 48-antenna array!
  - Phase 2 – Double the total bandwidth
    - With changes to the digitizers, tunable filter bank cards
- Phase 1 of the CUP was passed PDR Feb 28-March 1, 2018 and received ALMA Board approval for construction in April. It will be deployed in Cycle 11



PILS was executed in Band 7, 18 executions Post Phase 1 CUP provides 4x larger bandwidth at the same spectral resolution; would take 1/3 the time.

Two Projects began during FY2018.

Correlator Upgrade Project

Project Delays

- Correlator Upgrade system upgrade delayed by at least 6 months; delay in science release is TBD (6 to 12 months)
  - Original Commissioning: March 2023 – Cycle 10
  - Updated Commissioning: Cycle 11 (dates to be negotiated post-CDMR)
- Major drivers:
  - High technical risk in ASIC design → prototype of Correlator Card prior to ASIC production
    - Addressed in updated schedule
  - Slow rate of hiring digital engineers into project
    - New engineer arriving in March 2019
  - Uncertainty of Hardware-in-the-Loop Simulator (HiLS) availability for OSF testing
    - Detailed plan in process

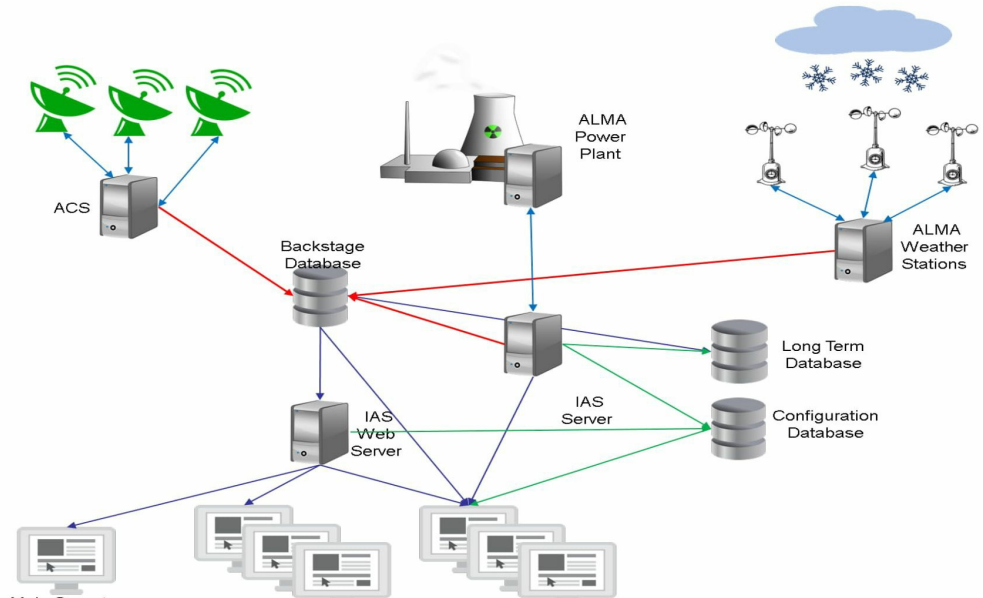
Development projects in ALMA-Europe

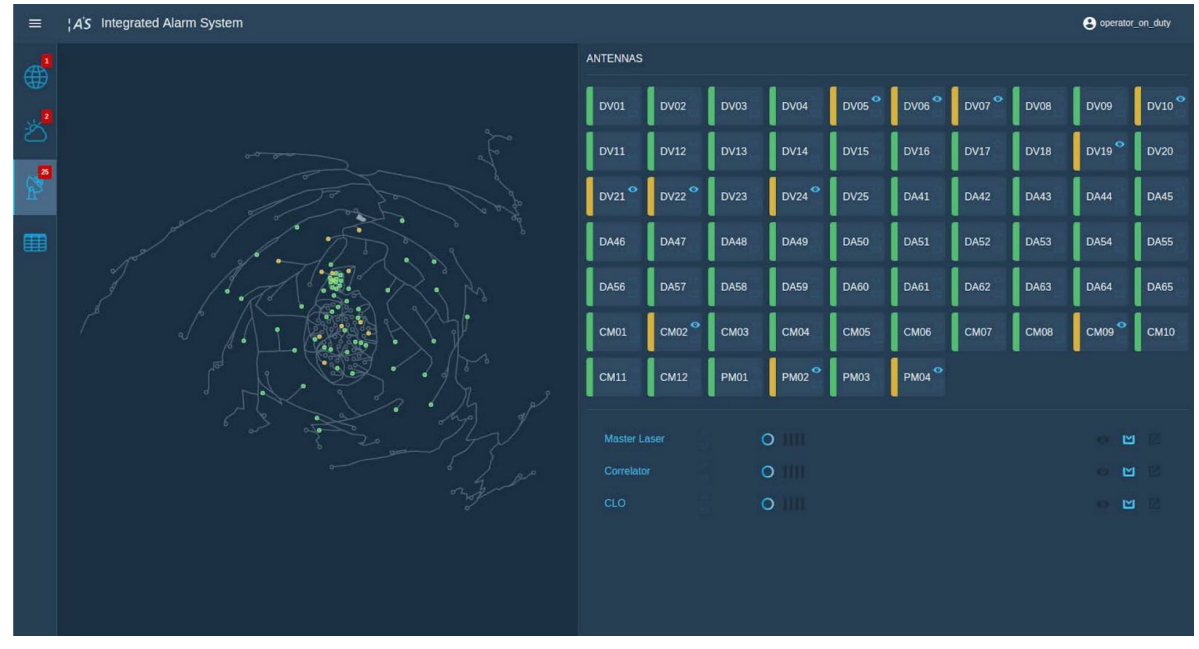
- Integrated alarm system (finished)
- Band 2 (see presentation Pavel Yagoubov)
- Involvement in Correlator Upgrade Project (CUP)
- ARI-L (starting)

In addition to obtaining ESO approval (via recommendation ESAC/STC), all development projects have to be approved by the ALMA board, or by the ALMA director (for projects < 250 kEUR), via recommendation by ASAC

Development project: Integrated Alarm System

- Software tool to monitor abnormal situations on site
  - Improve operator situational awareness
  - Quick identification of root cause of a problem
  - Reduce downtime
- Accepted by ALMA with some conditions (April 2019)





Development project: Correlator Upgrade Project (CUP)

The correlator upgrade is an ALMA-wide project

ESO will contribute with the following software:

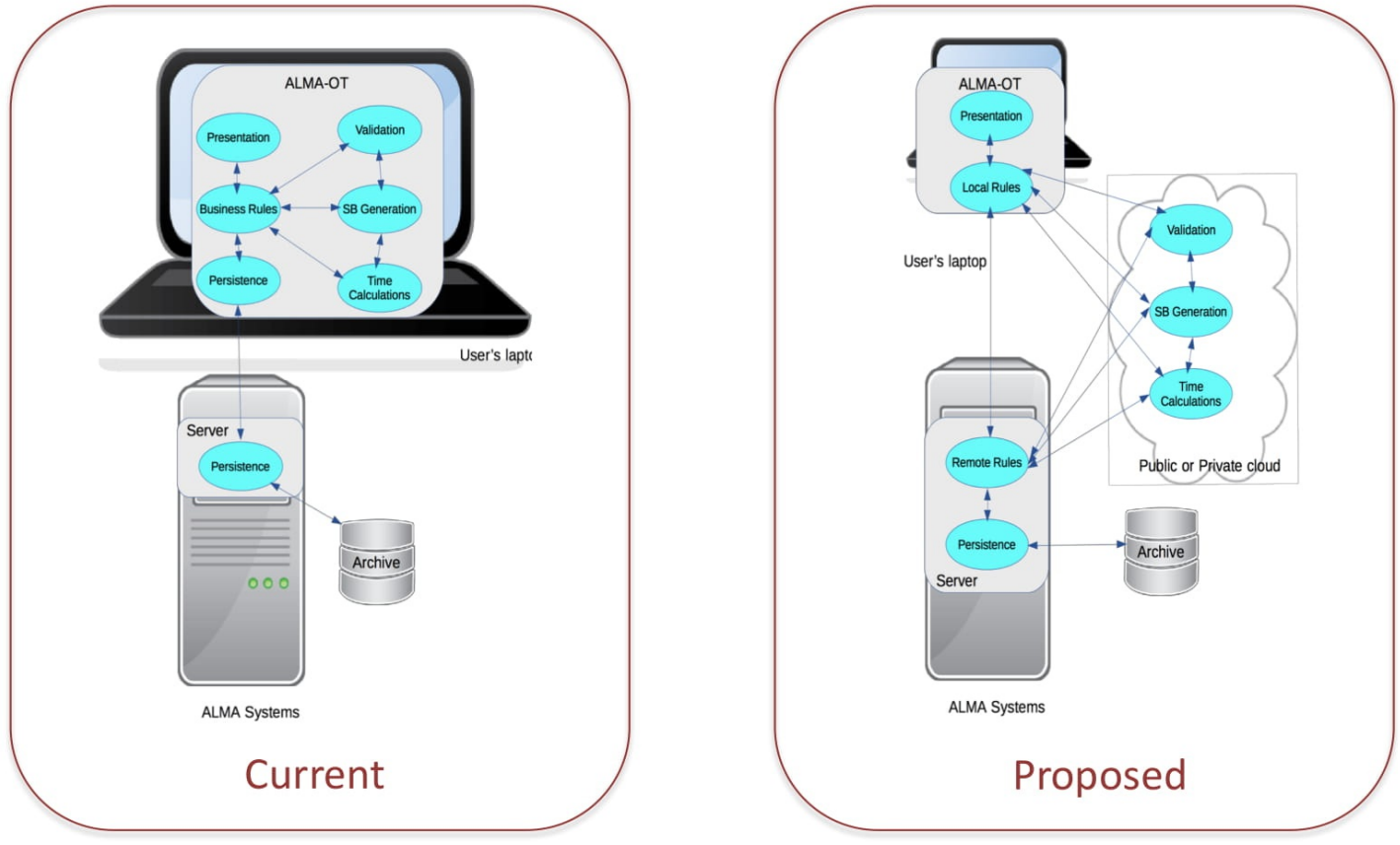
- OT upgrade
  - ➢ Most likely as part of the new OT development (TBC)
- Telcal and archive upgrades
  - ➢ Required because of increased data rate and volume

These software upgrades will not be started before 2021, according to the current deployment schedule

A web-based OT

The OT will be web-based, similar to other modern observing tools, in use with e.g. NRAO

Architecture



CPU-intensive tasks are moved to the "cloud" where they can be

a) Scaled to meet demand
b) Made available to other ALMA subsystems/as stand-alone applications

ESAC Meeting - Feb 2019

OT upgrade timeline

The OT upgrade development study is expected to evolved into a new development project

- Study report review: July 2019
  - ➢ Detailed project implementation timeline, cost and plan being developed as part of the study
  - ➢ New technologies will be validated
- Development project proposal: Aug 2019
- ESAC/ASAC discussion: Sept/Oct 2019
- Aim for adoption as Development project in Nov 2019 (subject to change)
- Start project: Q1/2 2020 (subject to change)

ARI-L

Additional Representatitve Images for Legacy (ARI-L)

PI: Marcella Massardi (INAF)

Goal: to process 70% of 3476 MOUs from cycles 2-4

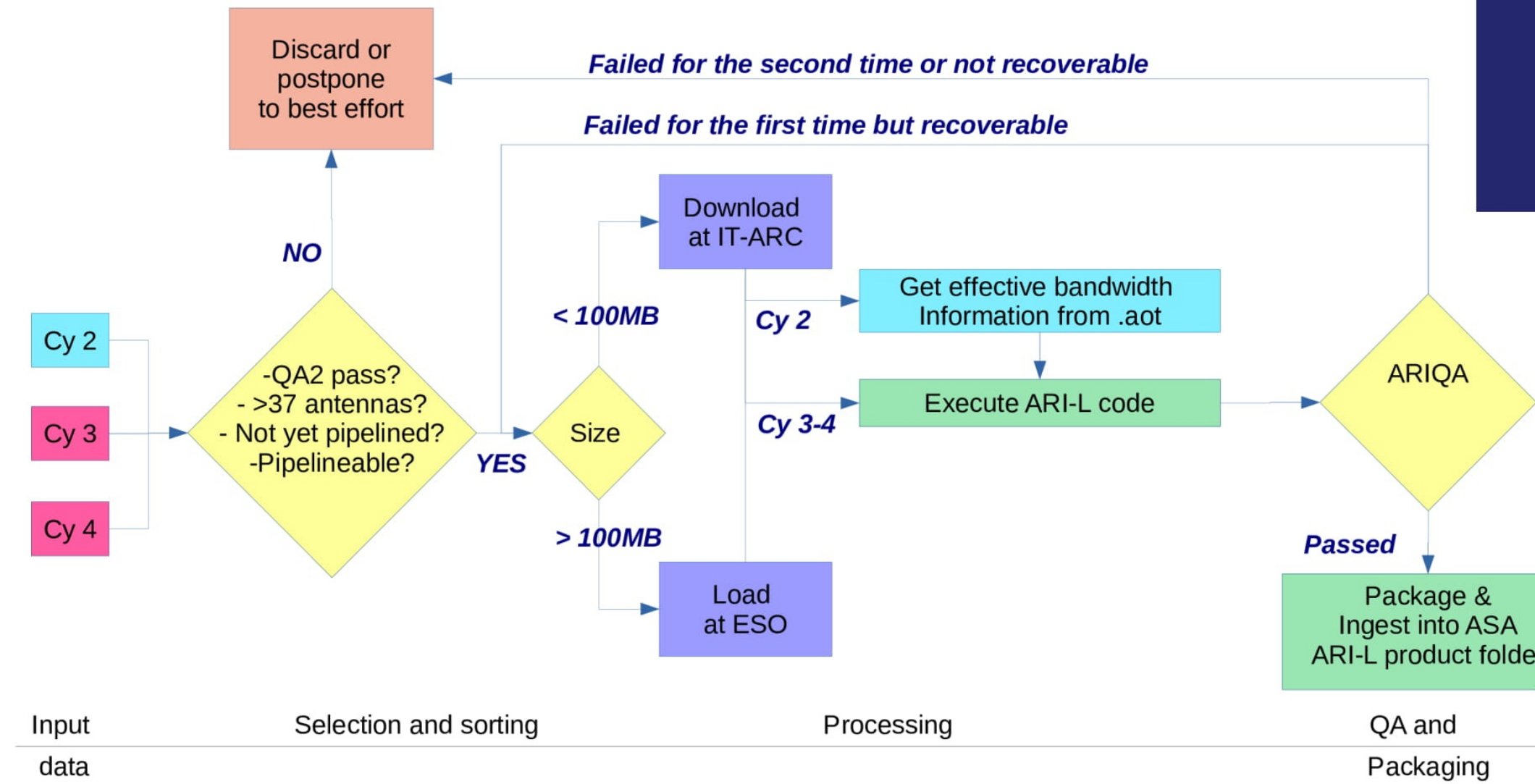
Dec 2018: ARI-L approved by ALMA director

Spring 2019 (T0): Kick-off and start processing

T0+6 months: Documentation published and website operative

T0+3 years: Finish project

THE ARI-L DEVELOPMENT PROJECT : WORKFLOW



The ARI-L processing will be run at ESO and at the IT-ARC site to minimize download issues, selecting only pipeline processable datasets (no TP, solar, polarization, VLBI).
A QA procedure will certify the products before ingesting them into the ASA.
Cycle 0 and 1 cannot be processed with the current pipeline without particular cares and have been postponed to future efforts.

ALMA Development studies

- Develop new ideas within the region
  - Studies may lead to new development projects or explore new ideas
- Highly successful program
  - Leverage on external expertise and funding opportunities
  - Limited ESO-internal complementary studies
- Running on 3-year cycles
  - Last call was issued in 2016
  - 17 proposals, 9 funded after internal evaluation and discussion with ESAC/STC
  - Next call for 2019: CfP end of May, deadline early Sept.
  - Full list at: http://www.eso.org/sci/facilities/alma/development-studies.html

ALMA Development studies

- Development studies run for about 2-3 years
- Closely monitored by ESO
  - Kick off meeting, mid-term review, final review
  - Reporting at these meeting, as well as intermediate points
  - Conclusion: feasibility as a development project

- Development projects
  - Require a detailed proposal and budget for which study is essential
  - Recommendation by ASAC
  - Approval by ALMA board (or ALMA director for <250 kEUR)

ALMA Development studies

- ALMA Development studies funded by ESO
  - Develop technology and study ideas for upgrades/development projects
  - Mostly executed by institutes in the member states
- Receiver development
  - Synergy with APEX: Band 7, Band 9 upgrades
  - Components for new Band 2 receiver
- Digital signal processing
  - Digitizers and correlator upgrades
- Software
  - Archive, observing tool, tuning algorithms, imaging

Status of studies from the 2016 call

PI (institute)	Title	Status
Massardi (INAF)	ALMA Re-imaging	Finished; self-funded
Bridger (STFC)	Next generation observing tool	2nd half
Villa (INAF)	Band 2+3 passive components	2nd half
Fuller (Manchester)	Band 2+3 LNAs	2nd half
Baryshev (NOVA)	Digital Frond End Working Group	2nd half
Quertier (Bordeaux)	16 GHz wide digitizers	2nd half
Belitsky (GARD)	SIS technology for wideband 2SB (band 7)	Halfway
Hesper (NOVA)	Advanced tuning algorithms	Halfway
Maercker (Onsala) + Wedemeyer (Oslo)	High cadence Solar imaging	Started Q4 2018
Baryshev (NOVA)	Band 9 upgrade to 2SB	Started Q1 2019

New call for ESO ALMA Development studies

- We have issued a new call for ESO ALMA Development studies at the end of May 2019
- Focus on the priorities of the ALMA 2030 roadmap
- Deadline: 2 September 2019