ALMA (Atacama Large Millimetre/ Submillimetre Array)

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ALMA Board & ALMA Budget Committee

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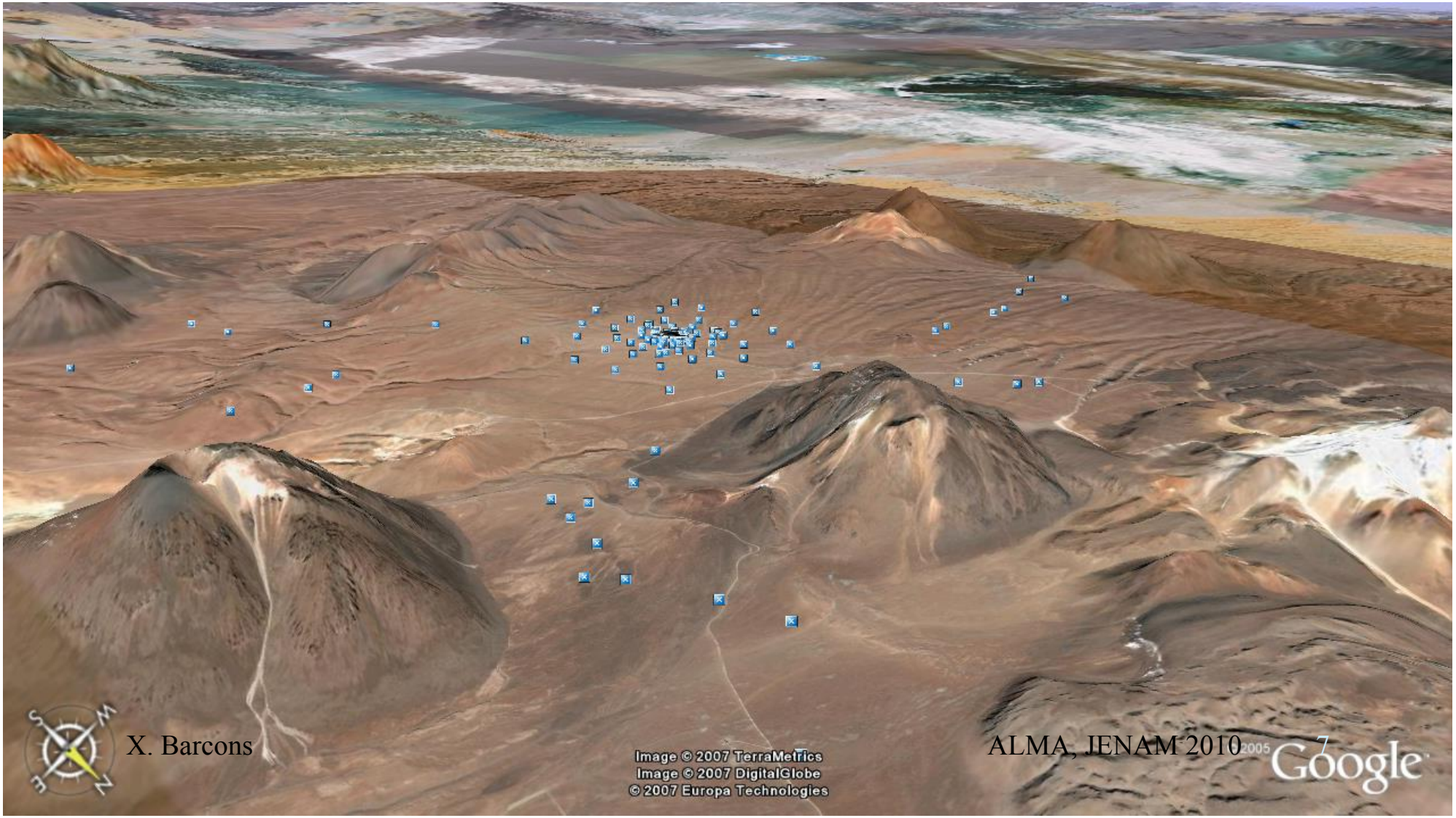
What is ALMA

- ALMA is a large sub/millimetre observatory in construction phase (Atacama desert, Chile)
- When finished it will be the world's largest interferometer for millimetre and sub-millimetre wavelengths
- Three sites:
  - Array Operations Site (AOS), llano de Chajnantor (5100 m)
  - Operations Support Facility (OSF), near San Pedro de Atacama (2900m)
  - Santiago Central Office (SCO)
- First large ground-based "global" scientific infrastructure.

Location of ALMA


AOS (5000m)
OSF (2900m)
San Pedro de Atacama (2400m),
Atacama desert, Northern Chile

Google-Earth view of site with antennas in the most extended configuration – baselines to 16km



ALMA Santiago Central Office (in ESO premises)

Moved there 1/9/2010

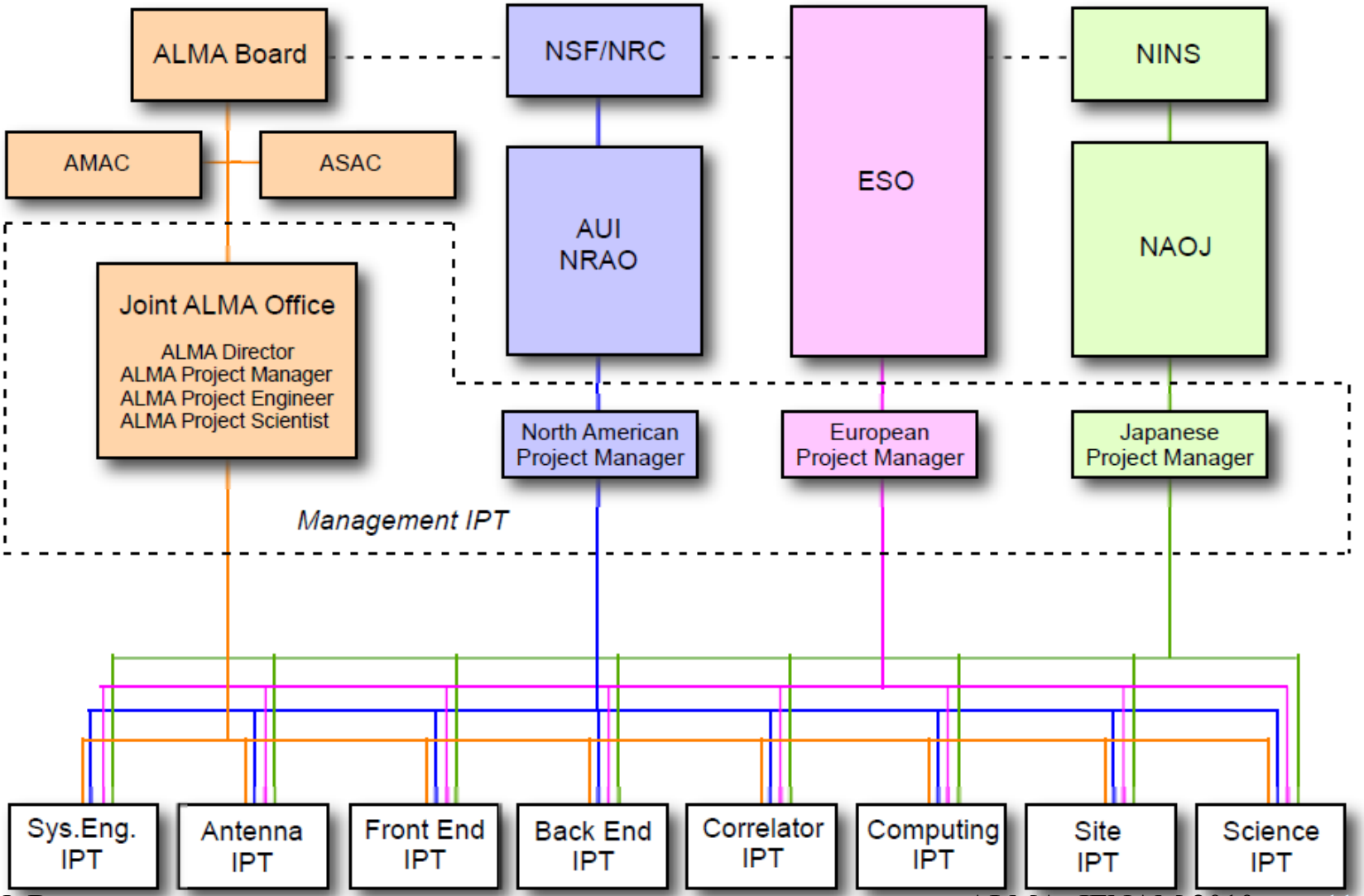
ALMA as an international partnership

- ALMA is a collaboration between
  - ESO – Europe (14 member states of ESO)
  - NRAO – North America (USA, Canada), and
  - NAOJ – East Asia (Japan, Taiwan),
  - In collaboration with the Republic of Chile
- Hardware and software is developed and built across the three partner regions
- In Chile, the *Joint ALMA Observatory* (JAO) commissions and operates ALMA
- ALMA costs ~1.2 billion €, shared among the partners

ALMA formal definition

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership among Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and in Japan by the National Institutes of Natural Sciences (NINS) in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI) and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

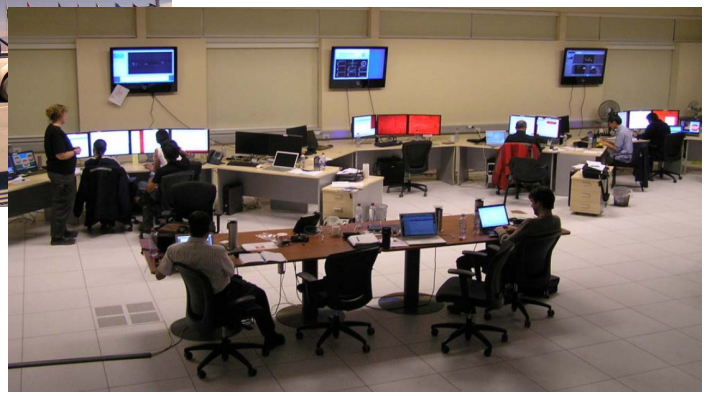
ALMA Management Structure



ALMA Infrastructure

- OSF – Operations Support Facility (2900m)
  - Operations Base: control room (operating)
  - Antenna integration (ongoing)
  - AIV (Assembly,Integration & Verification)
  - Technical Building etc.: Labs, maintenance,
  - Residencia (being designed), dormitories etc
- AOS – Array Operations Site (5000m)
  - 66 antennas, 192 antenna stations (done)
  - Technical Building: correlator, LO reference (done)
- SCO – Santiago Central Office
  - "Home base" of ALMA (occupied 1 Sep 2010)

Array Operations Site (AOS) and Operations Support Facility (OSF)



X. Barcons

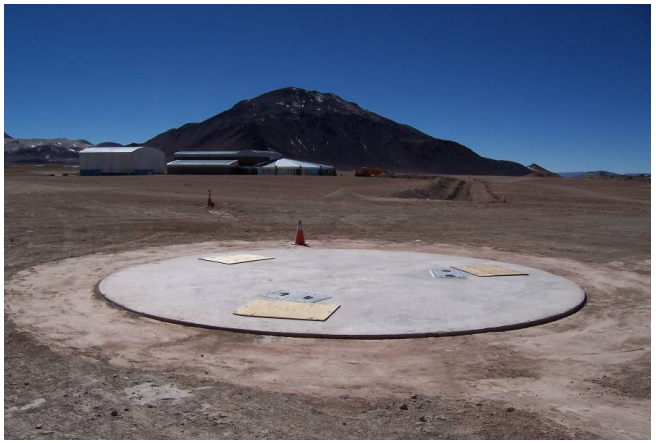
ALMA OSF (2900m)

- Antenna integration in three work areas
- Technical building, canteen, bedrooms, etc.
- About 500 people at the Operations Support Facility (OSF)

Technical building (AOS)

Antenna stations

- There are 192 antenna stations at 5000m to allow different configurations
- They are being equipped with high-precision inserts (=interface to the antenna)
- Cabling in progress



Digital correlator in the AOS TB

Other ALMA site infrastructure

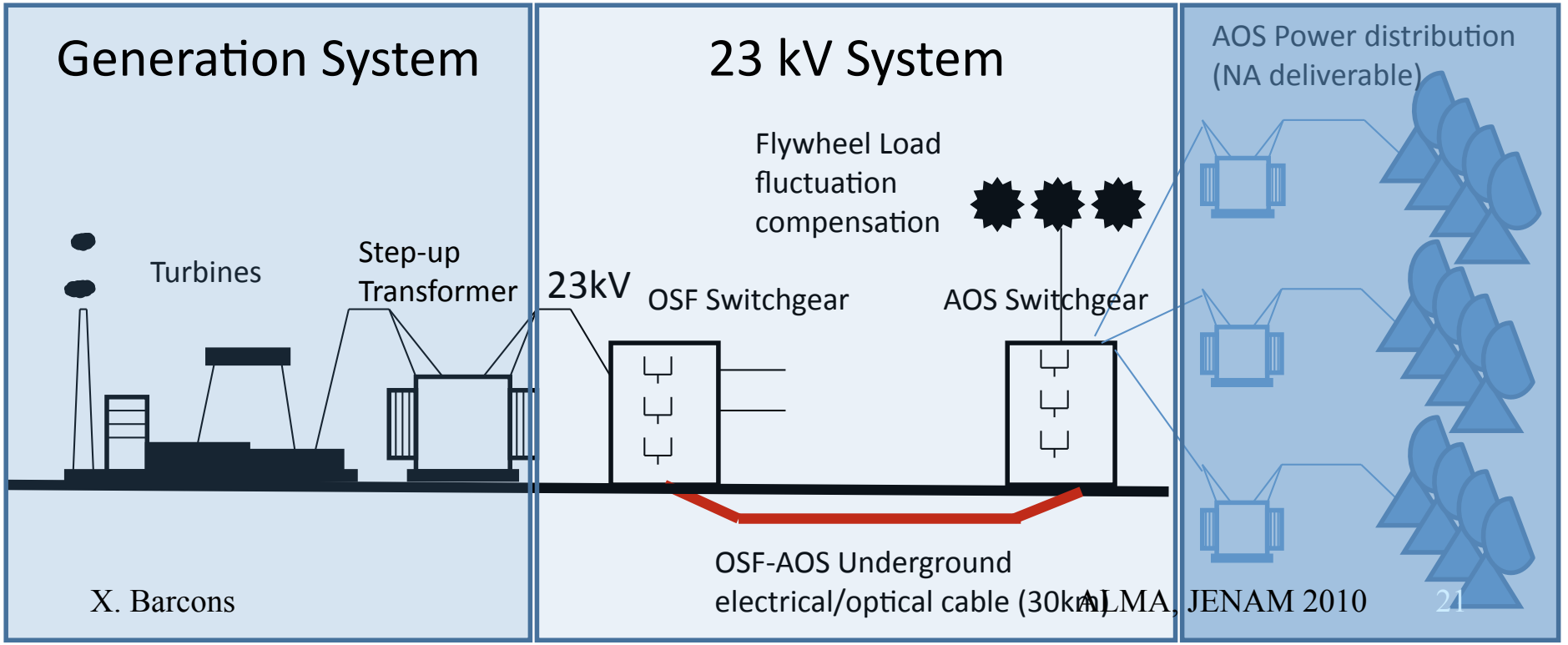
- Roads from Chilean Highway 23 to OSF and AOS
  - 14 km from highway to OSF
  - 29 km from OSF to AOS
  - Roads are done – surface improvement being finalised

- Power supply
  - ALMA needs 7 MW of electrical power
  - To be generated at the OSF – Multi fuel generators
  - Transmitted to AOS (29 km) via 23 kV line
  - Power supply includes "fly wheel" system
  - Looking into sustainable energy for the future (windmills inefficient though)

Access to ALMA

ALMA Power Supply

- Needs: 7 MW (peak), 4 MW (average)
- Power generation at OSF via (multi-fuel) turbine
- Transmission to AOS via 23 kV system
- Special feature: fly wheel system
- Total cost of power system > 30M EUR



What is the ALMA observatory made of

- Europe/North America: 2 x 25 dishes with 12m diameter. Baselines from ~15 m to 16 km
- ALMA Compact Array (ACA) provided by East Asia
  - 12 x 7 m dishes in compact configurations
  - 4 x 12 m dishes primarily for total-power
- Low-noise, wide-band, dual polarization receivers
- Digital correlator giving wide range of spectral resolutions
- Software (dynamic scheduling, imaging, pipelines)
- Will eventually provide sensitive, precision imaging between 30 and 950 GHz in 10 bands
  - 350 GHz continuum sensitivity: about 1 mJy in one second
  - Angular resolution will reach ~0.05 arcsec at 100 GHz

Antenna types in ALMA

North America
(Vertex)

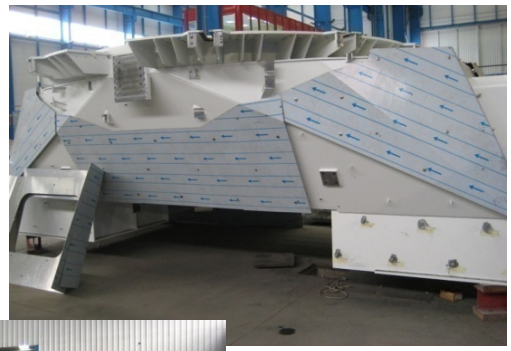
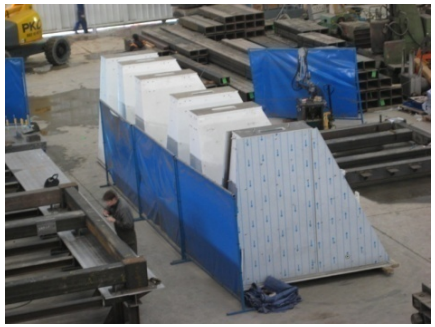
Europe
(AEM)

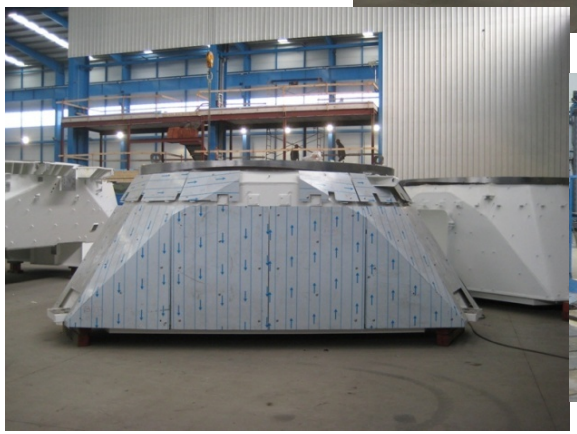
East Asia
(MELCO)

First (Japanese) antenna to 5000m

Antenna Production Line in Europe
Antenna mount



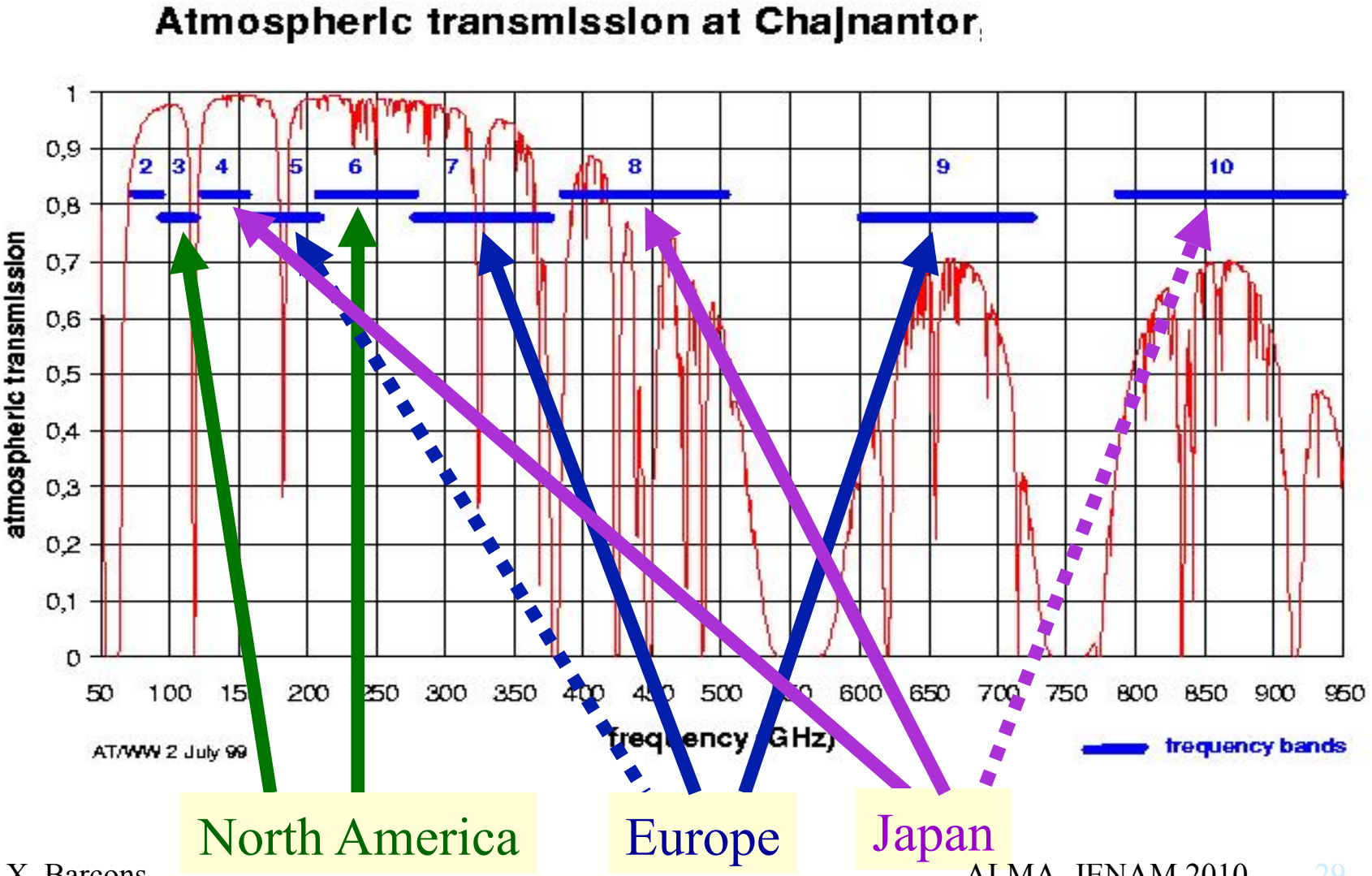



Antenna pre-assembly (OSF)

Assembly of AEM antennas (OSF)

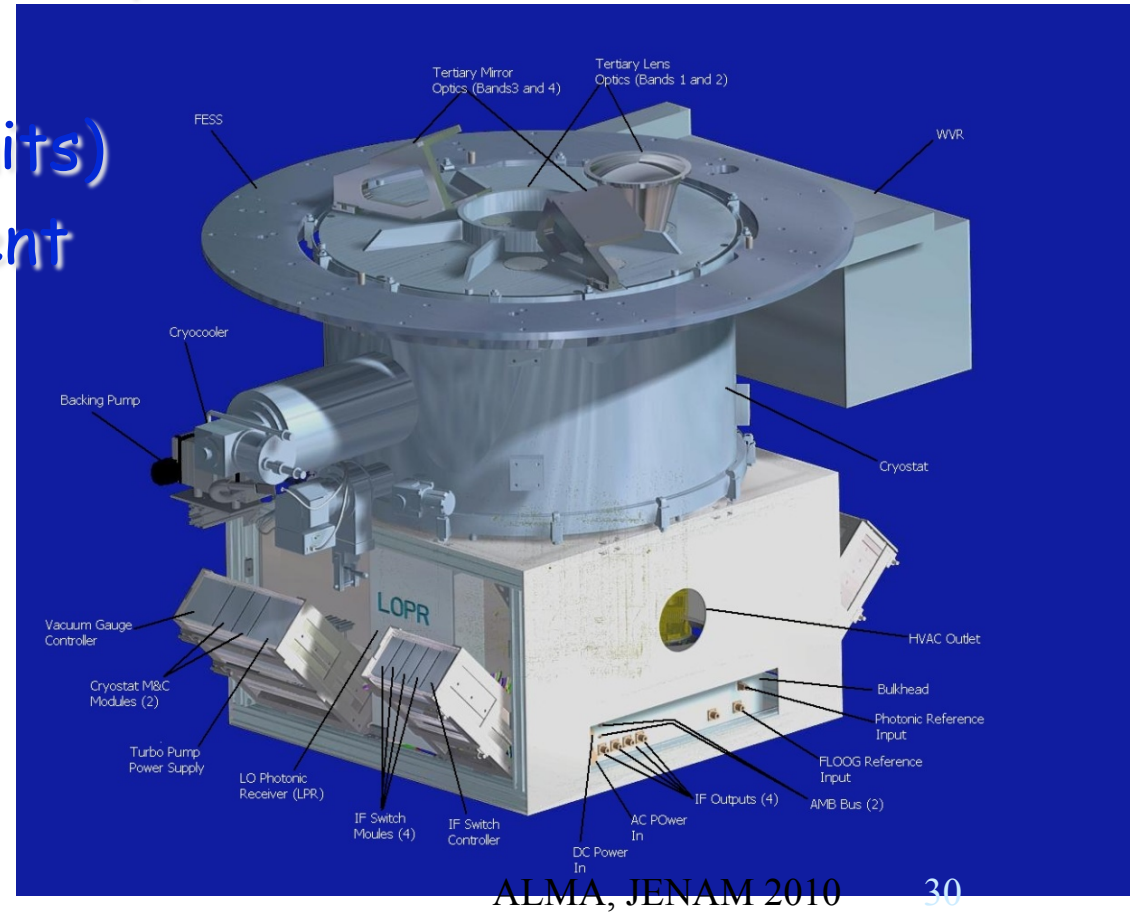
European Antenna #2

ALMA Frequency Bands

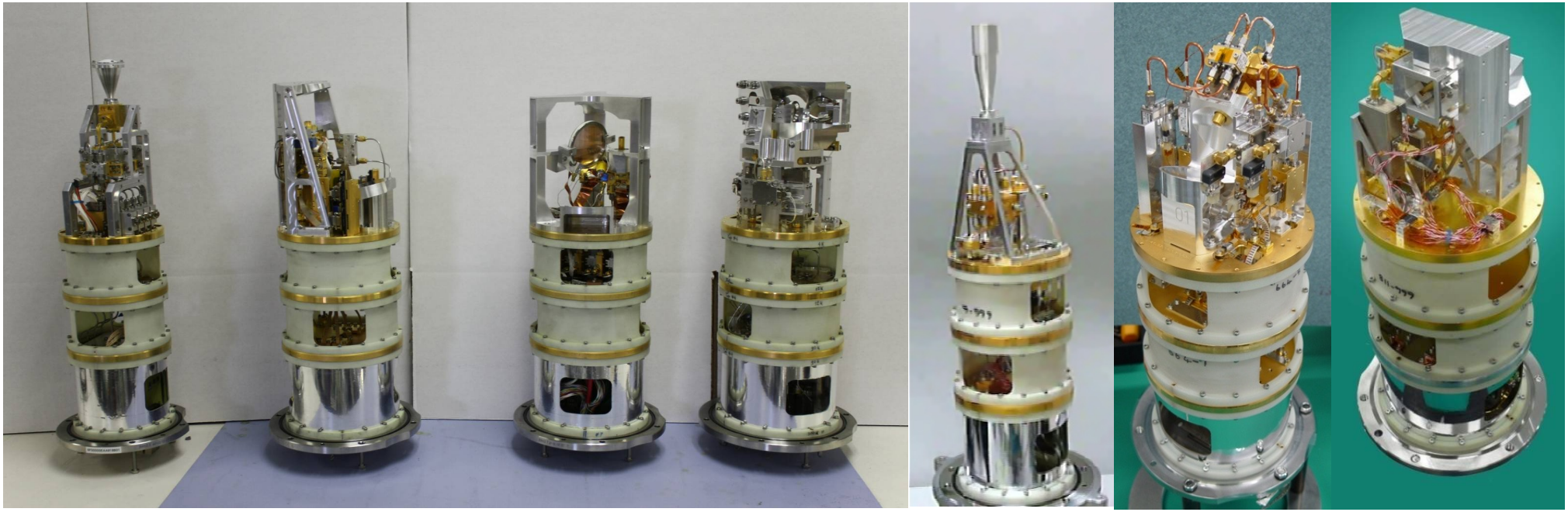


Front End Assemblies

- 10 bands from 30 GHz to 950 GHz in one cryostat
- Bands 3, 4, 6, 7, 8, and 9 in production
- Band 10 prototyping
- Band 5 EU funded (6 units)
- Band 1 under development



Receiver Cartridges



Band 3	Band 6	Band 7	Band 9	Band 4	Band 8	Band 10
HIA	NRAO	IRAM	NOVA	NAOJ	NAOJ	NAOJ

ALMA Front End integration

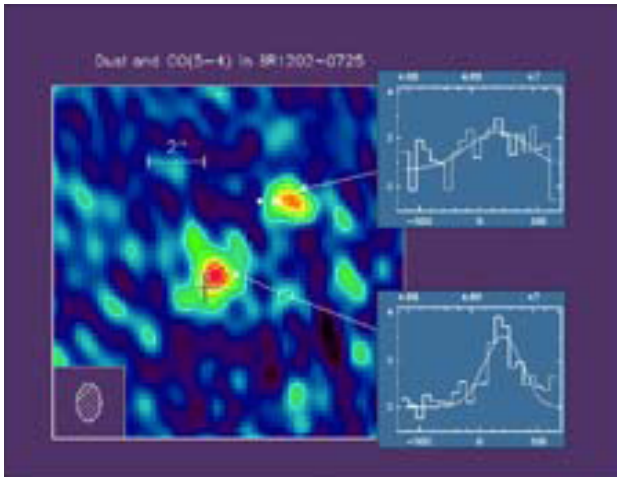
- Three Front End Integration Centers
  - RAL (UK)
  - NRAO (USA)
  - ARL (Taiwan)
- Integration of 26 subsystems/components from all ALMA partners
- Integration and testing ongoing, 10 front ends delivered to Chile (August 2010).

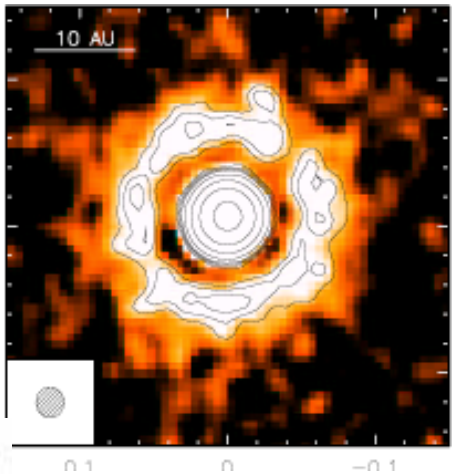
ALMA Science

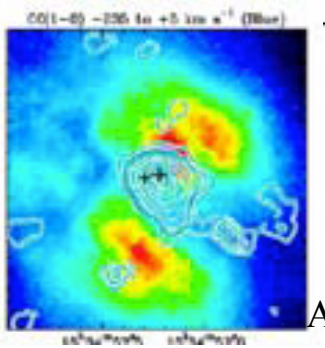
- Two main themes:
  - Formation and origin of high-z galaxies (cold ISM)
  - Birth of stars and planetary systems
- Can penetrate into highly obscured regions (A_V>100)
- Combination of superb angular resolution (0.01" to 0.1") and sensitivity (>10 IRAM-NOEMA at mm wavelengths)
- Targets:
  - Continuum: cold dust
  - Lines: Molecular transitions

ALMA Top Level Science Goals

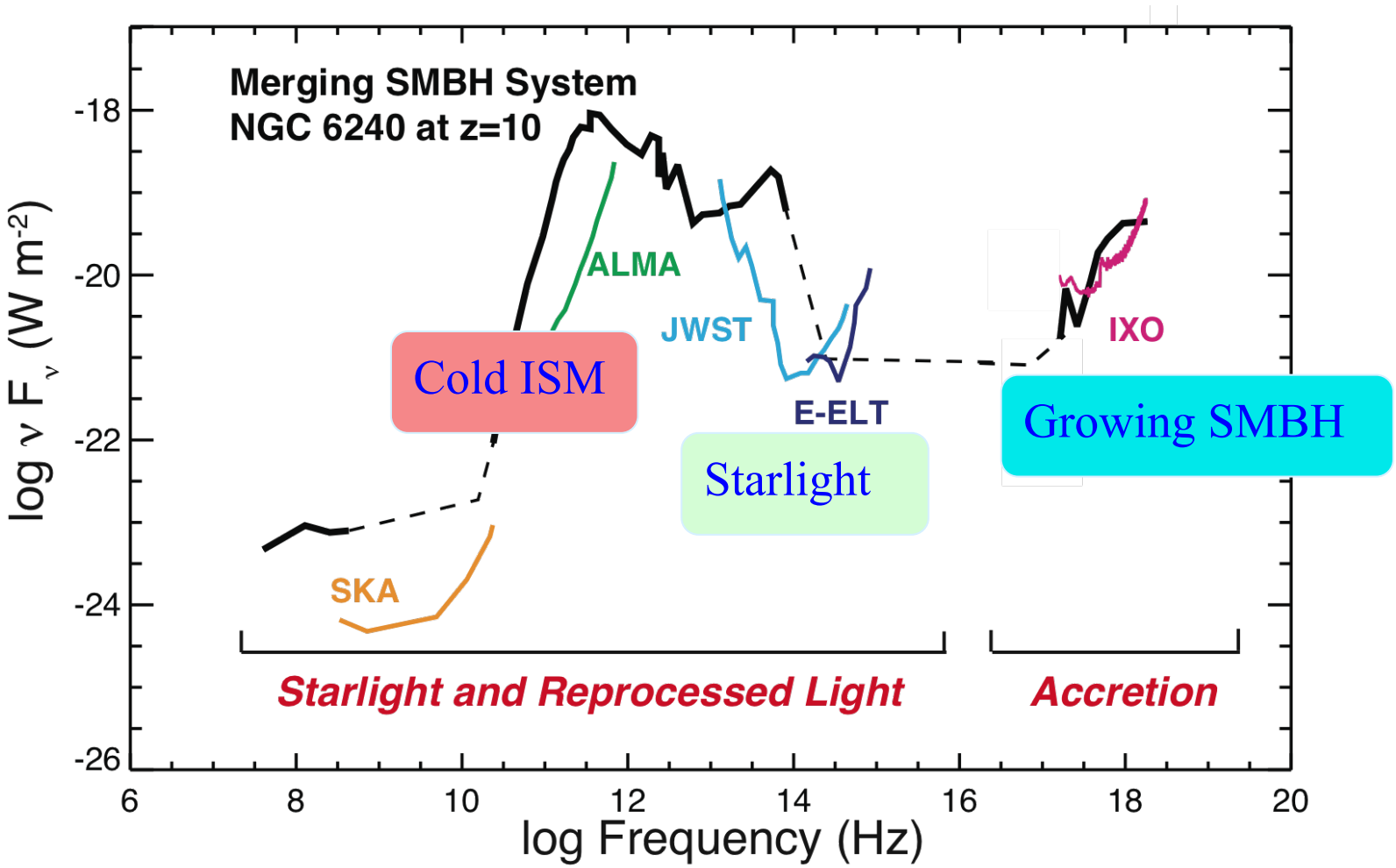
1. Detect and map CO and [C II] in a Milky Way galaxy at z=3 in less than 24 hours of observation
2. Map dust emission and gas kinematics in protoplanetary disks
3. Provide high fidelity imaging in the (sub)millimeter at 0.1 arcsec resolution





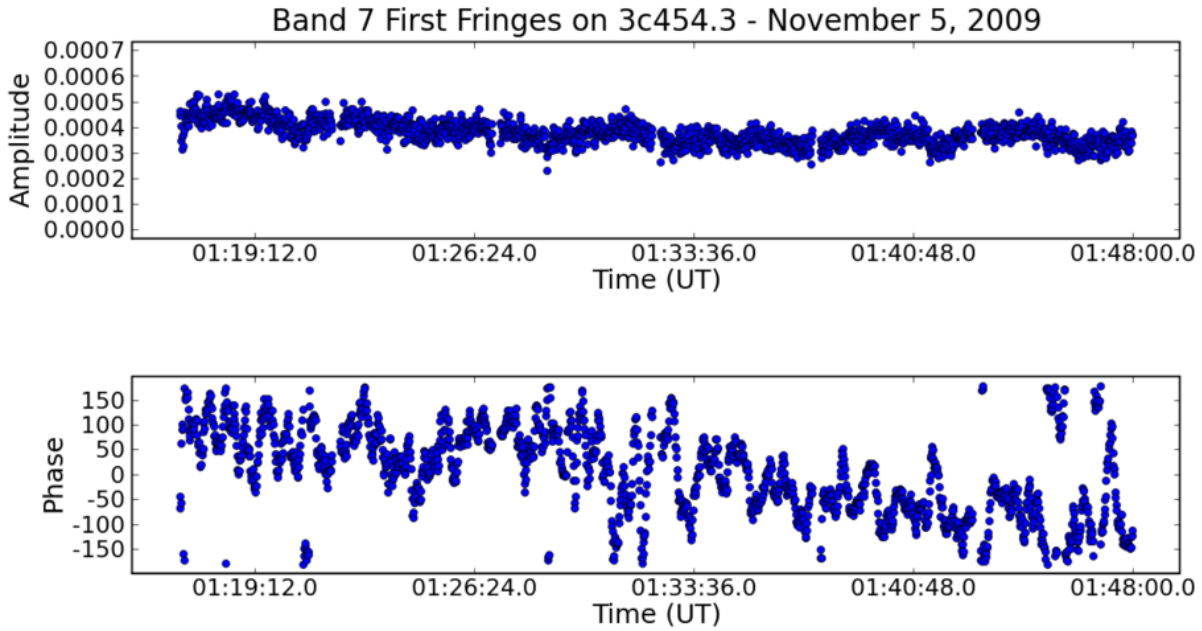


The multi-λ view of high-z galaxies



First fringes at the high site

- Beginning of November 09 the first fringes were observed at the AOS with bands 3, 6, and 7
- Later in Nov first fringes were observed with Band 9

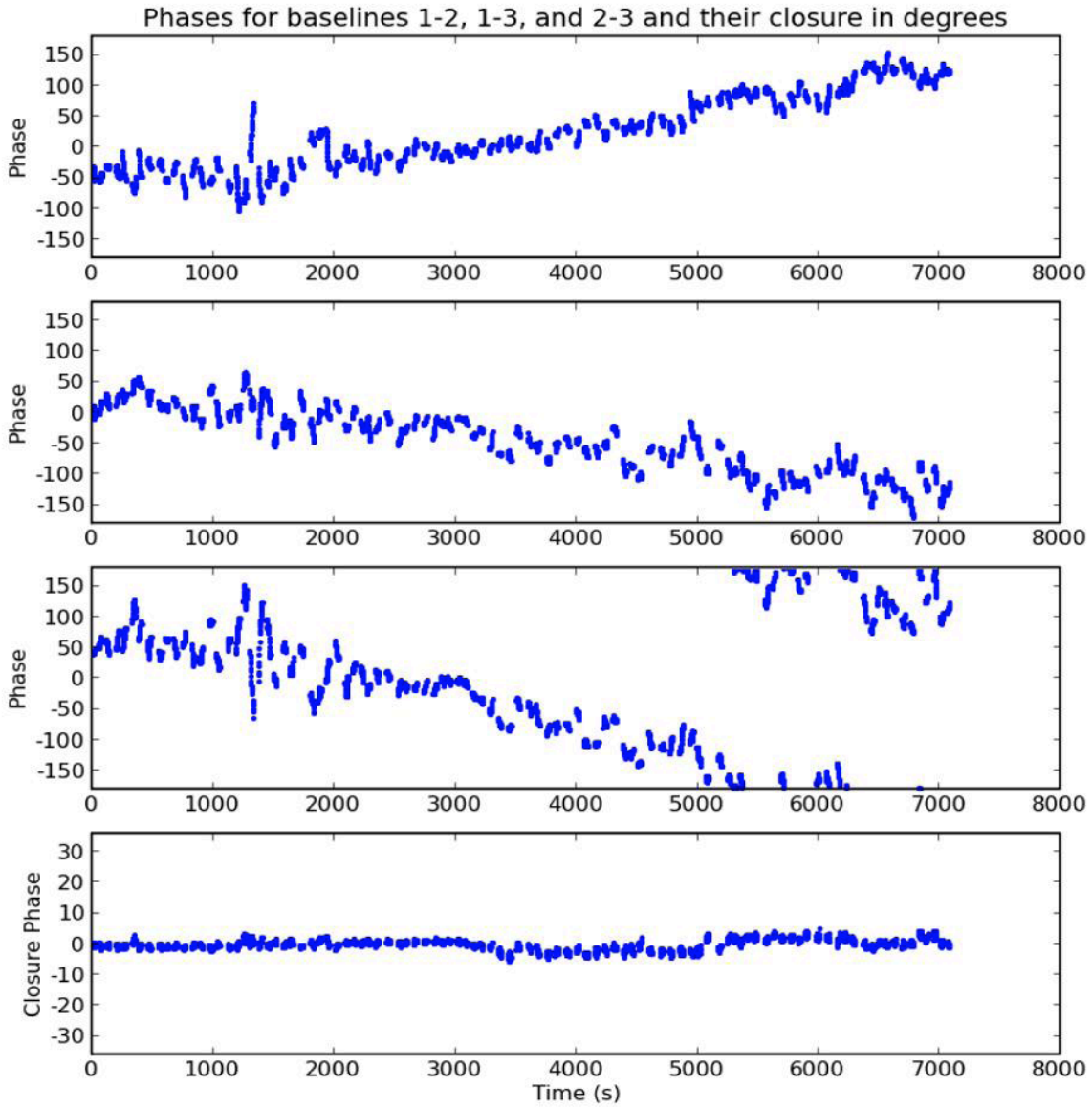


Phase closure with 3 antennas at AOS (Nov 09)

- Commissioning & Science Verification started 22/1/2010

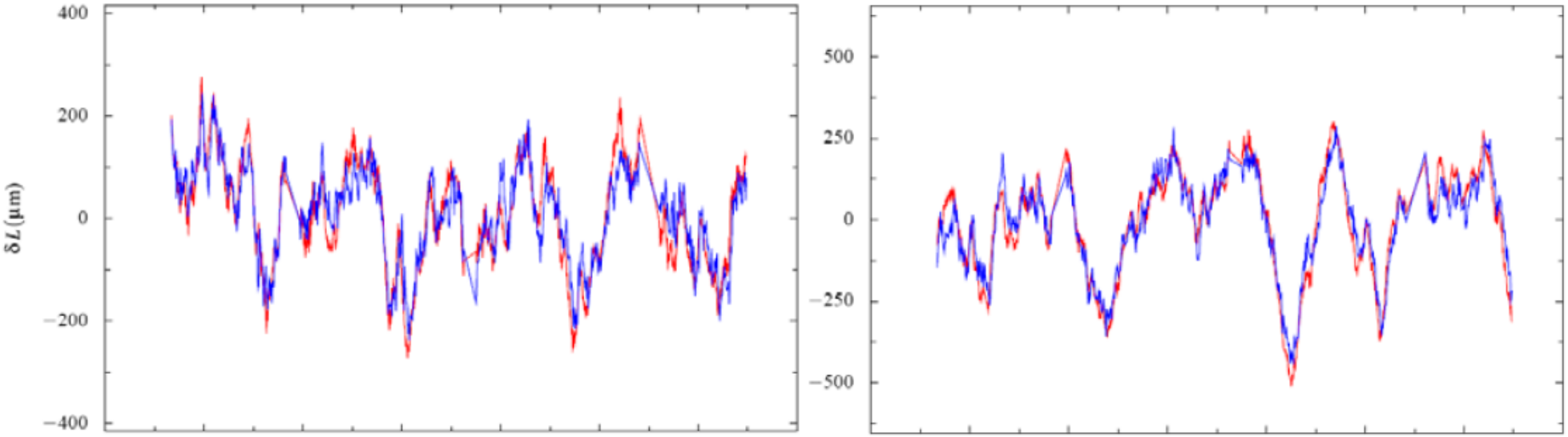
Phase closure at work

VWR phase correction works well under good weather condtions



Phase correction using Water Vapour Radiometers

- Initial testing of phase correction using the WVRs
- Graph shows ~20 min of data on two baselines (red = interferometer phase, blue = estimated WVR correction)



ALMA Schedule

- Commissioning and Science Verification (CSV) started January 2010
- Call for Early Science proposals possibly by end of 2010
  - Readiness review in October/November 2010
  - Start of Early science ~8 months later
- Long-term schedule dominated by delivery of Front-Ends and Antennas
  - Inauguration (50 antennas, 4 bands) late 2012
  - Complete array 2013
- ALMA development plan starting

A few personal thoughts

- Fascinating project (site, high-tech, science)
- Remarkable cultural differences between partners
- Complex managerial structure, based on functional (as opposed to organic) role
- Every single component is technologically challenging: mechanics, civil work, electronics, electricity, software.
- Every other aspect is also challenging: life in the desert, language, time zone differences, tension between JAO and regions, etc.
- Great opportunity for scientists and engineers, but also to prove that global big projects are possible.