The Atacama Large Millimeter/Submillimeter Array: ALMA

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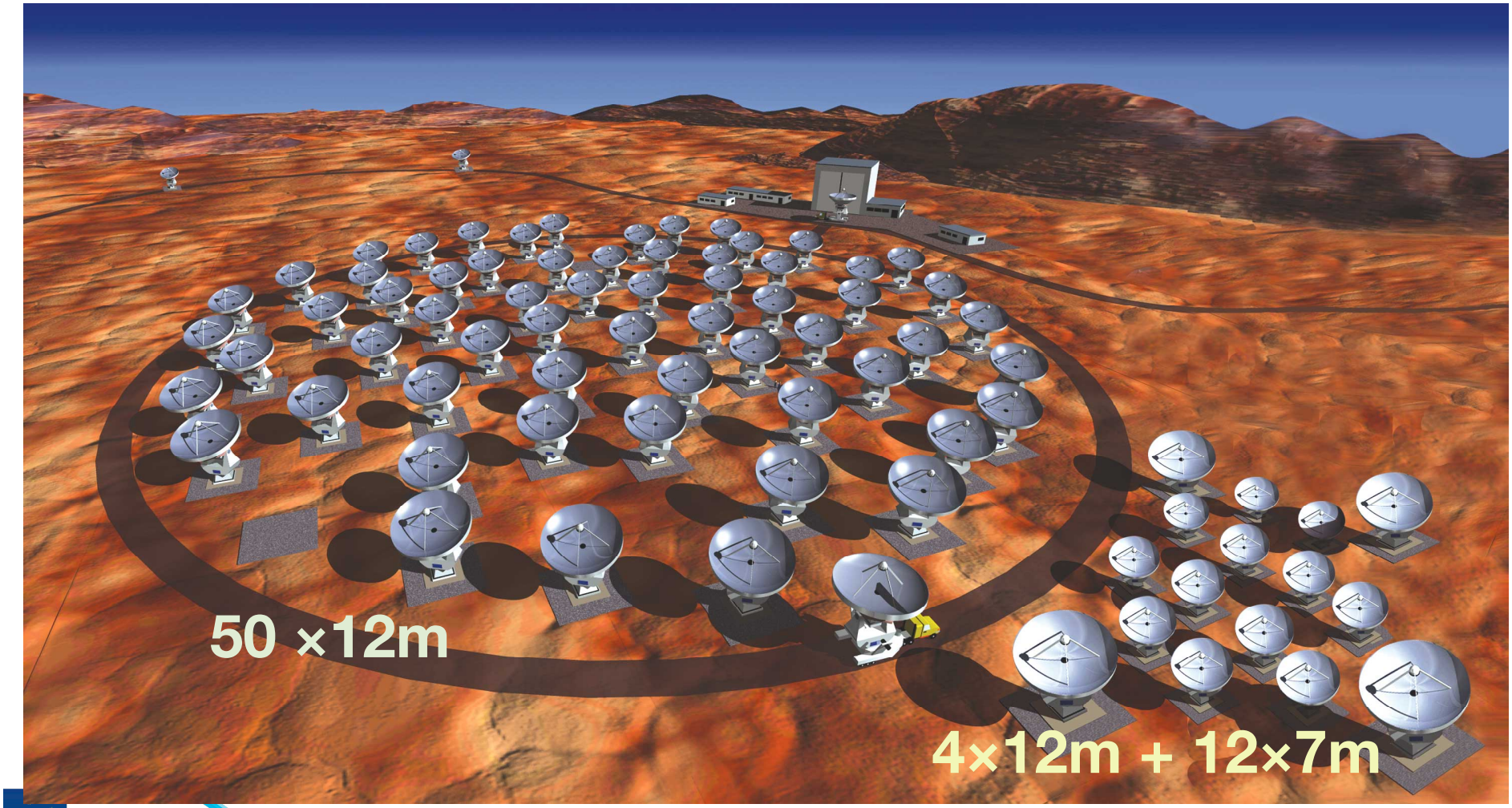
What is ALMA?

- ALMA = Atacama Large Millimeter/submillimeter Array
- ALMA is an interferometer for millimetre and submillimetre astronomy
- The main scientific objectives are the origins of galaxies and the origins of stars and planets
- ALMA will be 10-100 more sensitive and have 10-100 times better angular resolution than existing instruments
- ALMA is built and operated by Europe (ESO), North-America (NRAO) and East-Asia (NAOJ)

ALMA main array + Atacama Compact Array

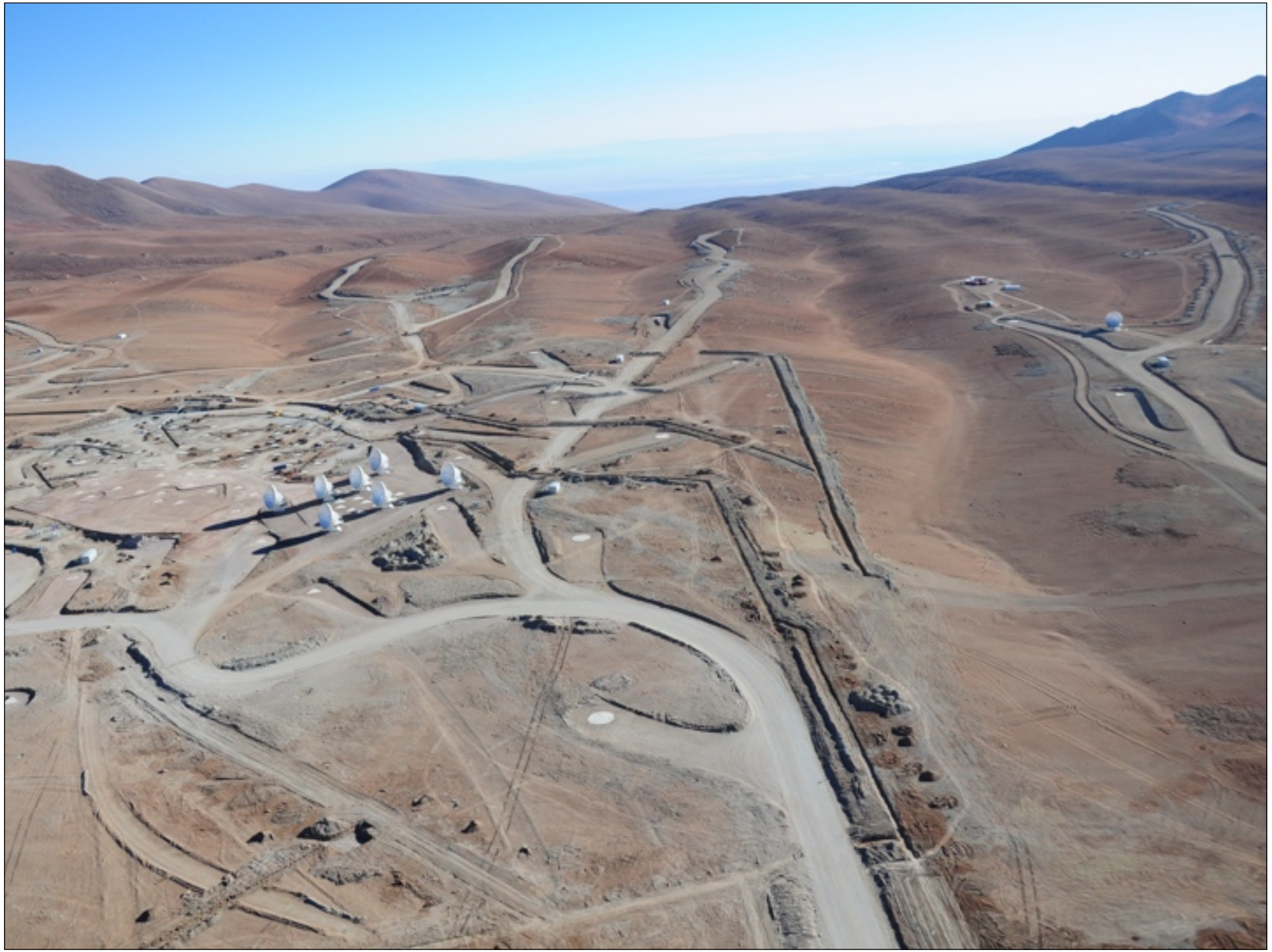


ALMA parameters

- **Baselines up to 14.7 km** (0.005” at 650 GHz) in “zoom lens” configurations
- Full coverage of **all atmospheric bands up to 1 THz**
- **50 12-m antennas** (25 “European” and 25 “North American”)
- **Short spacings essential** for mapping extended sources/mosaics
  - 4 12-m antennas provide total power measurements
  - ALMA Compact Array (ACA) adds 12 7-m antennas
- State of the art **low-noise, wide-band receivers** (8 GHz bandwidth)
- **Flexible correlator** with high spectral resolution at wide bandwidth
- **Full polarization** capabilities
- Estimate up to **1 TB/day** to be archived
- ***A resource for ALL astronomers***

Location

- Atacama desert in Northern Chile
  - Chajnantor plain at 5000 m (AOS)
- Latitude = -23 degrees
- APEX also located on Chajnantor
- Operations base at 2900 m (OSF)

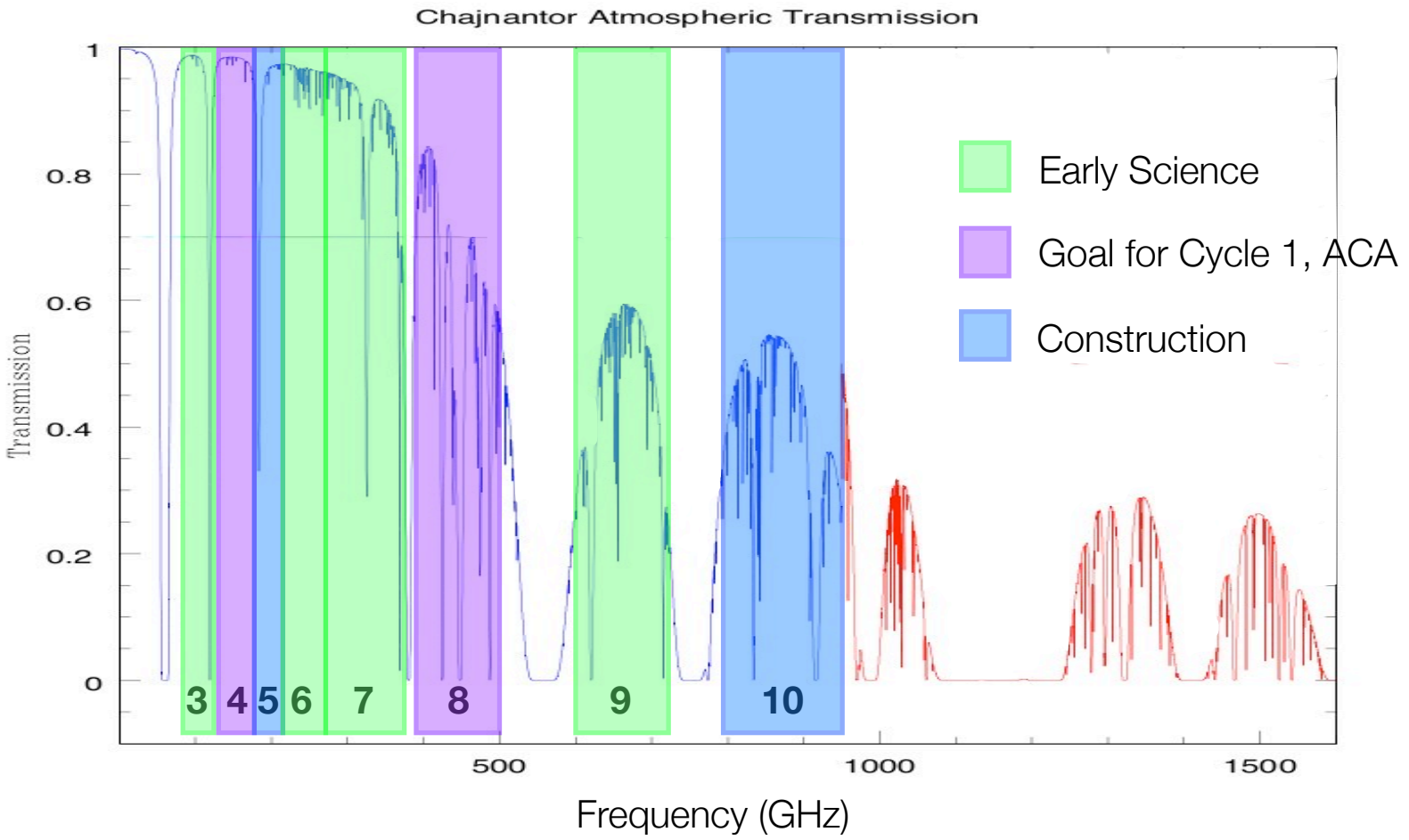


ALMA Science

- Detect line emission from CO or CII in a Milky Way type galaxy at $z = 3$, in 24 hours.
- Image the gas kinematics in protostars and protoplanetary disks around young Sun-like stars at a distance of 150 pc
- Provide precise images at an angular resolution of 0.1 arcsec

- *ALMA will be 10-100 more sensitive and have 10-100 times better angular resolution than existing instruments*

ALMA bands and transparancy

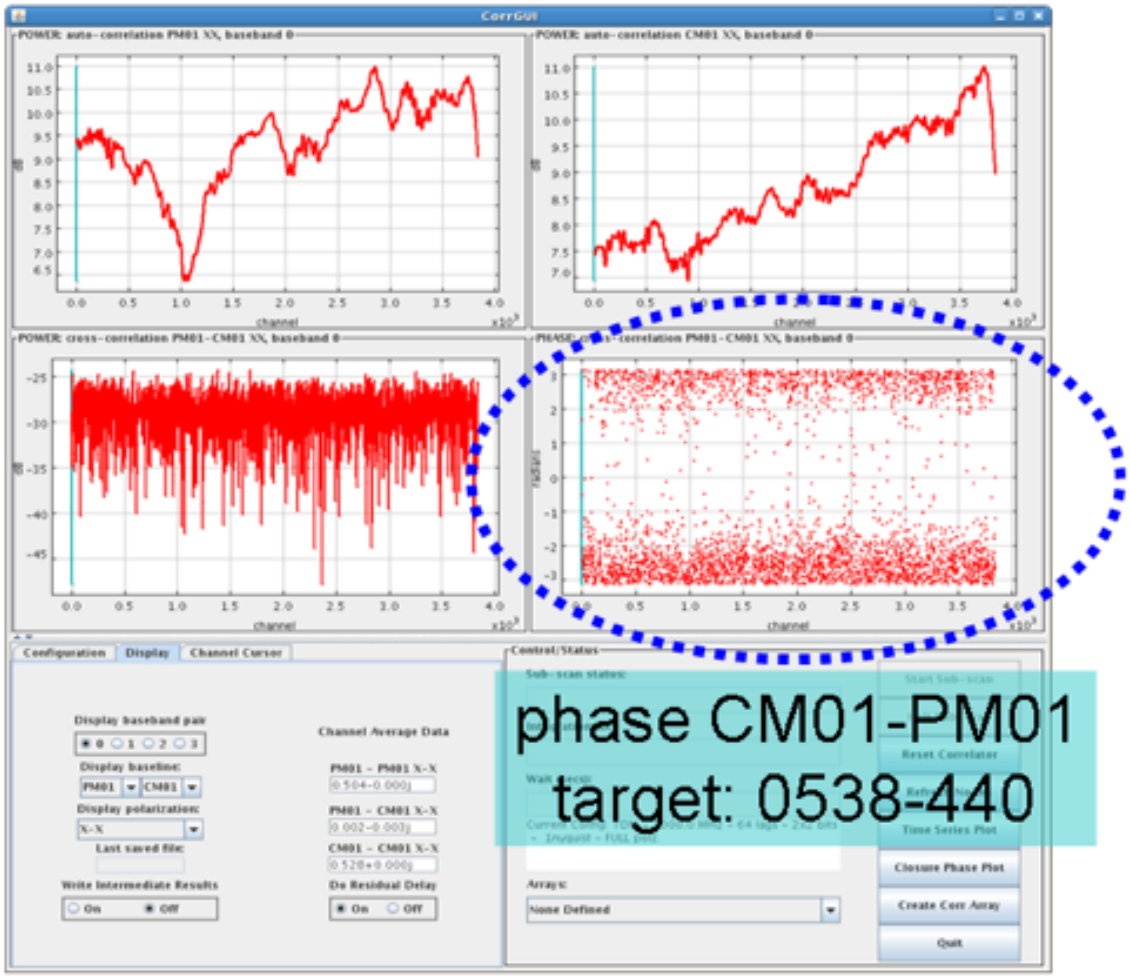


Status of antennas

- **20 antennas** at 5000m site
- **European antennas**:
  - Two European antennas at the high site
  - Third European antenna going up soon
  - Two more accepted this year
- **First 7m antenna** arrived at the high site. First fringes achieved
- **First fringes with 16 antennas** achieved
- Antenna **acceptance rate** is now 2 per month
- Moving antennas into the compact **Early Science Configuration**


First 7m antenna arrived at the high site

First fringe with ACA 7m antenna at AOS



2011/9/2 8:20 UT


European antennas at the low site

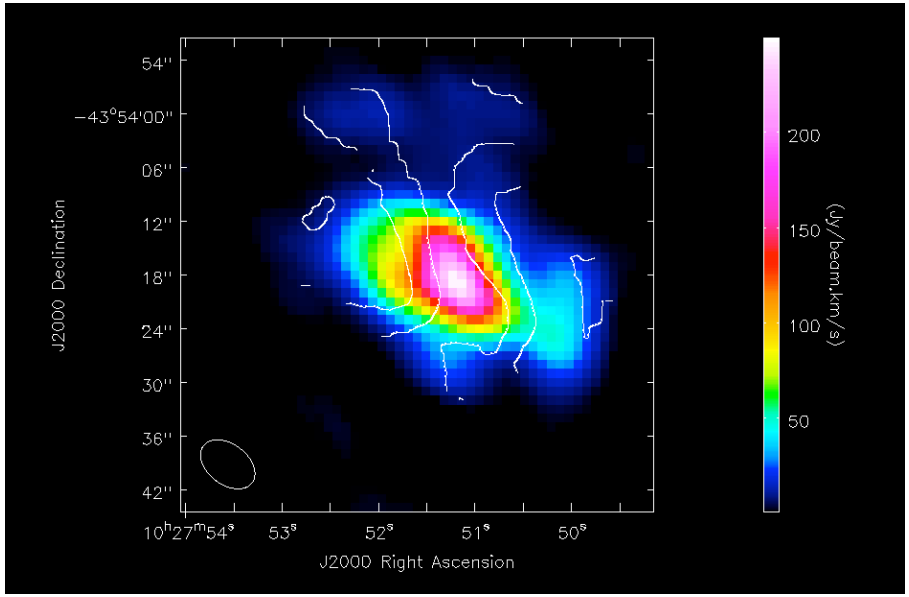
ALMA **Science verification** data

- **Data are available** from the Science Portal: ***http://almascience.eso.org/***
  - NGC 3256 (band 3)
  - TWHya (Band 7)
  - Antenae galaxies (Band 7)
- **Data reduction guides** (casaguides) are also included
- More data coming soon:
  - More TWHya
  - SgrA*
  - M100

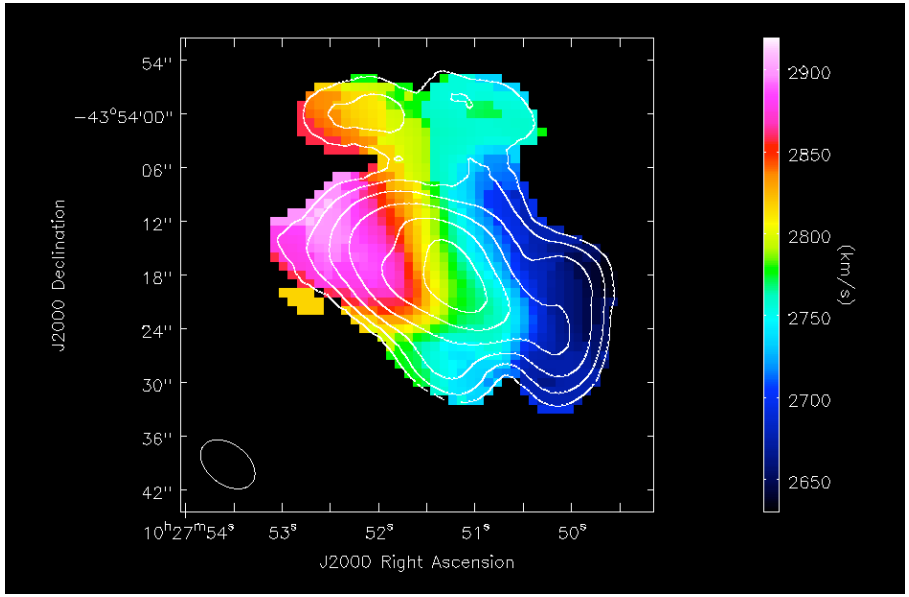
ALMA Science Verification: NGC 3256

- Band 3 observations of the CO(1-0) line in NGC 3256
- 8 antennas were used, total integration time ~4hours
- NGC3256 is a very bright infrared galaxy
- Reference data from the SMA can be found in Sakamoto et al.
- This is a nice data set to test your data reduction skills. The full calibration and imaging can be done on a regular desktop or laptop computer

ALMA Science Verification: NGC 3256



CO(1-0) map



CO(1-0) velocity field

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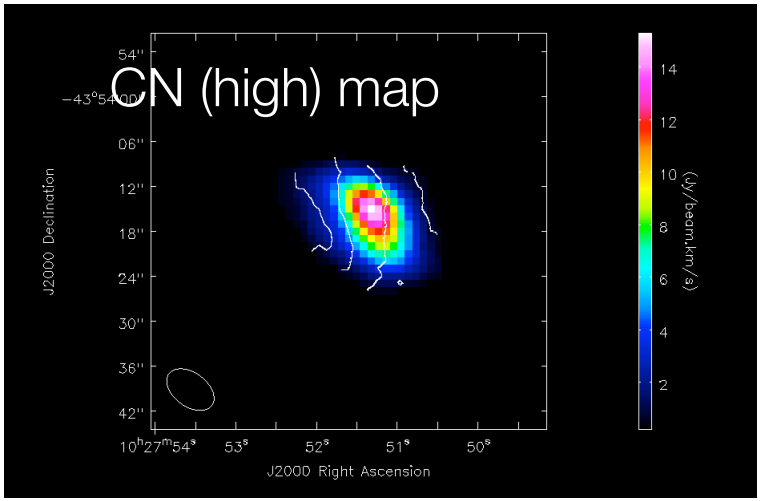
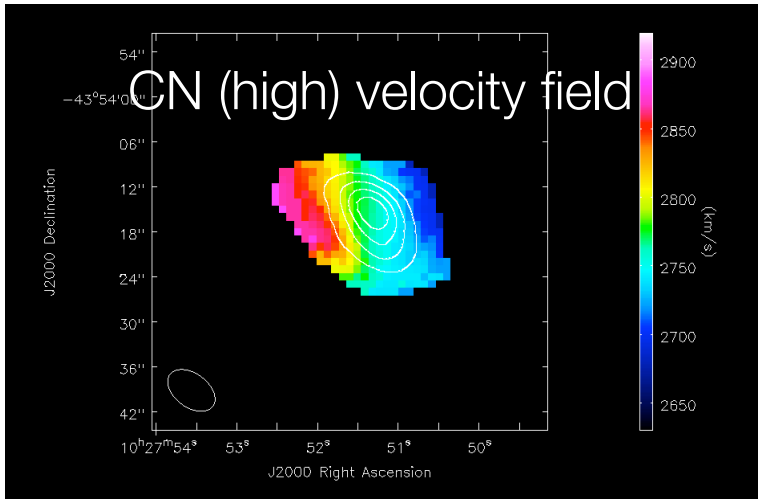
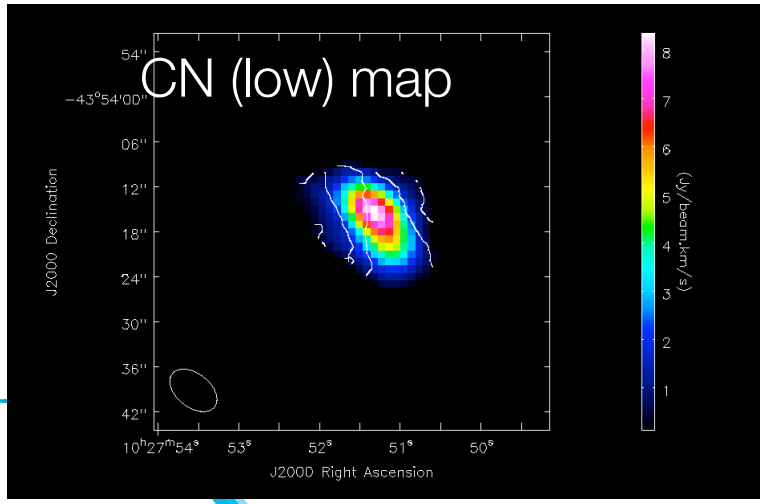
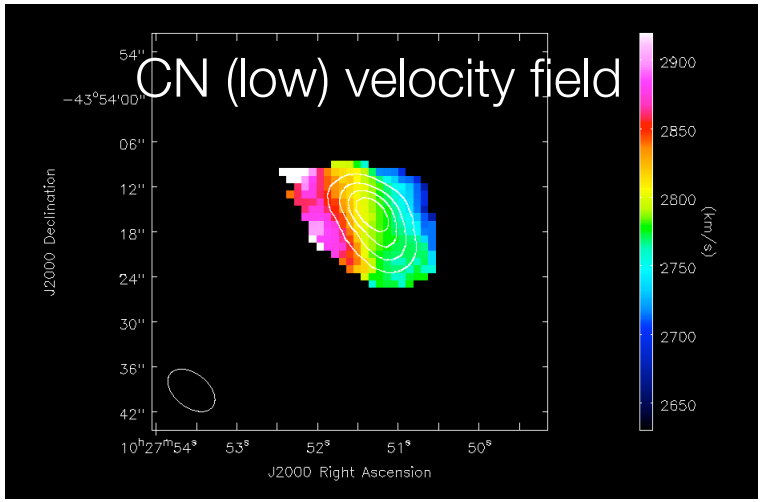
ALMA Science Verification: NGC 3256



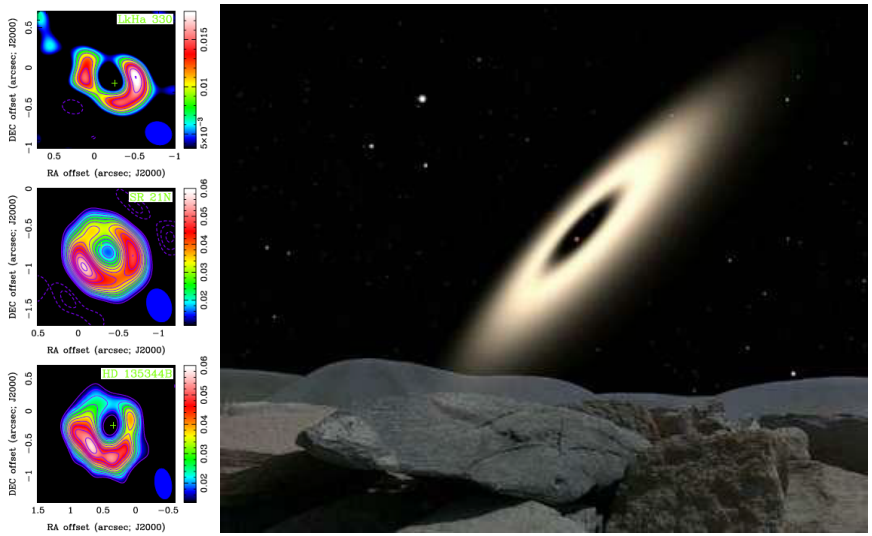


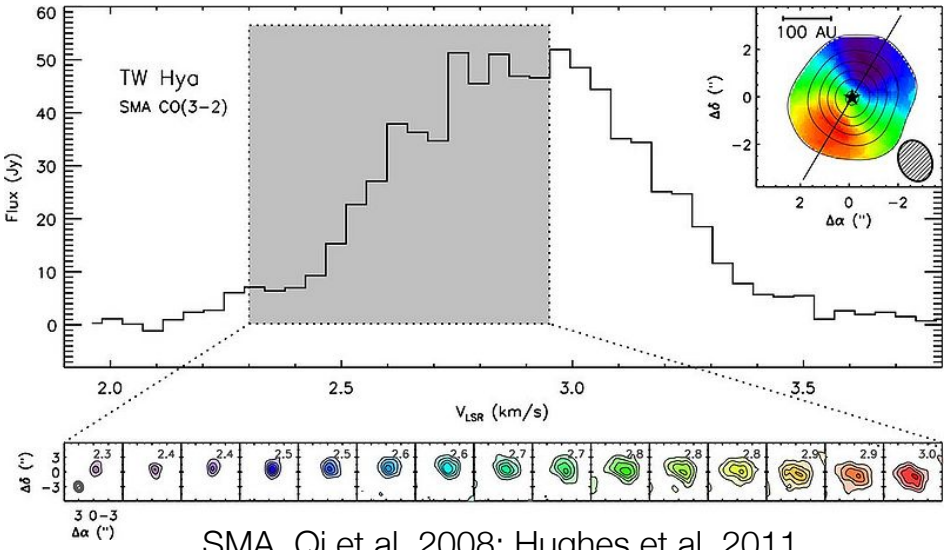




ALMA Science Verification: TWHya

- TW Hya: classical T Tauri star
  - Age of 10 Myr
  - Distance 51 ± 4 pc
  - Actively accreting
- Images at various wavelengths reveal an optically thick dust disk
  - Nearly face-on
  - Diameter ~300 AU
- TW Hya is the Rosetta Stone for Transition Disks





SMA, Qi et al. 2008; Hughes et al. 2011

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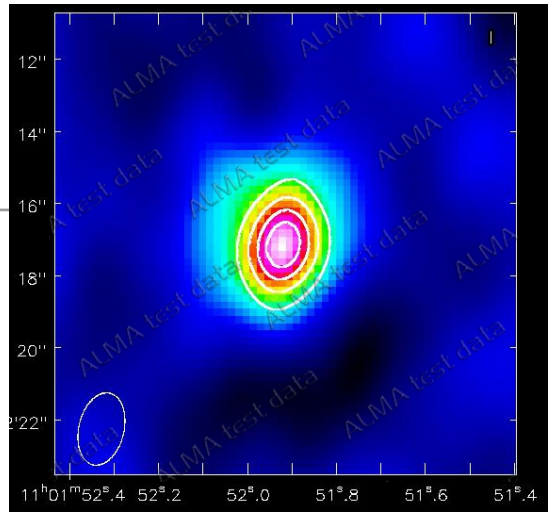
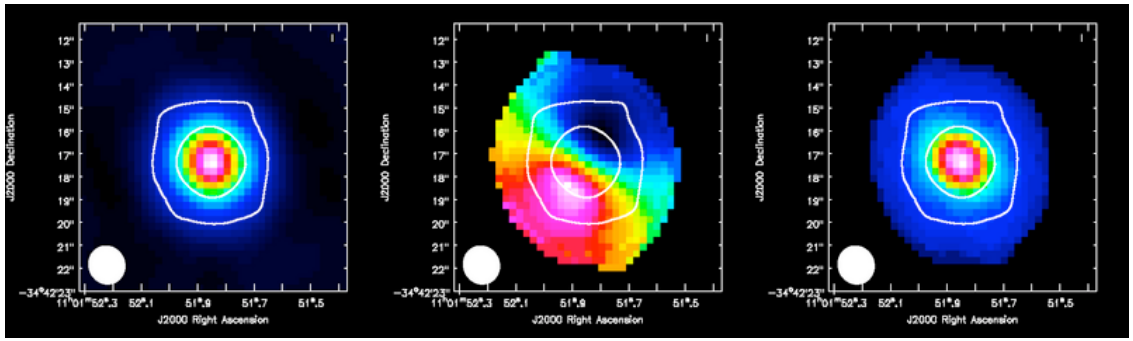
ALMA Science Verification: TWHya

- Band 7, total time 4.5 hours
- 9 antennas but one was flagged

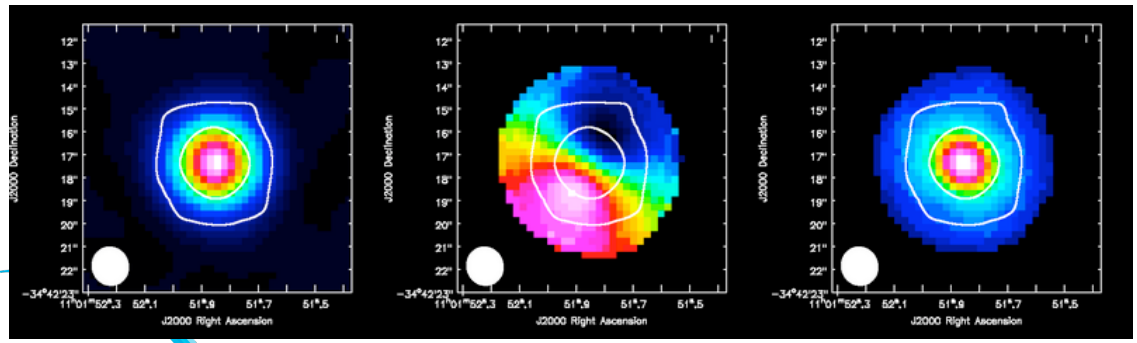


Continuum

Intensity Velocity Field Velocity dispersion



CO(3-2)



HCO+(4-3)

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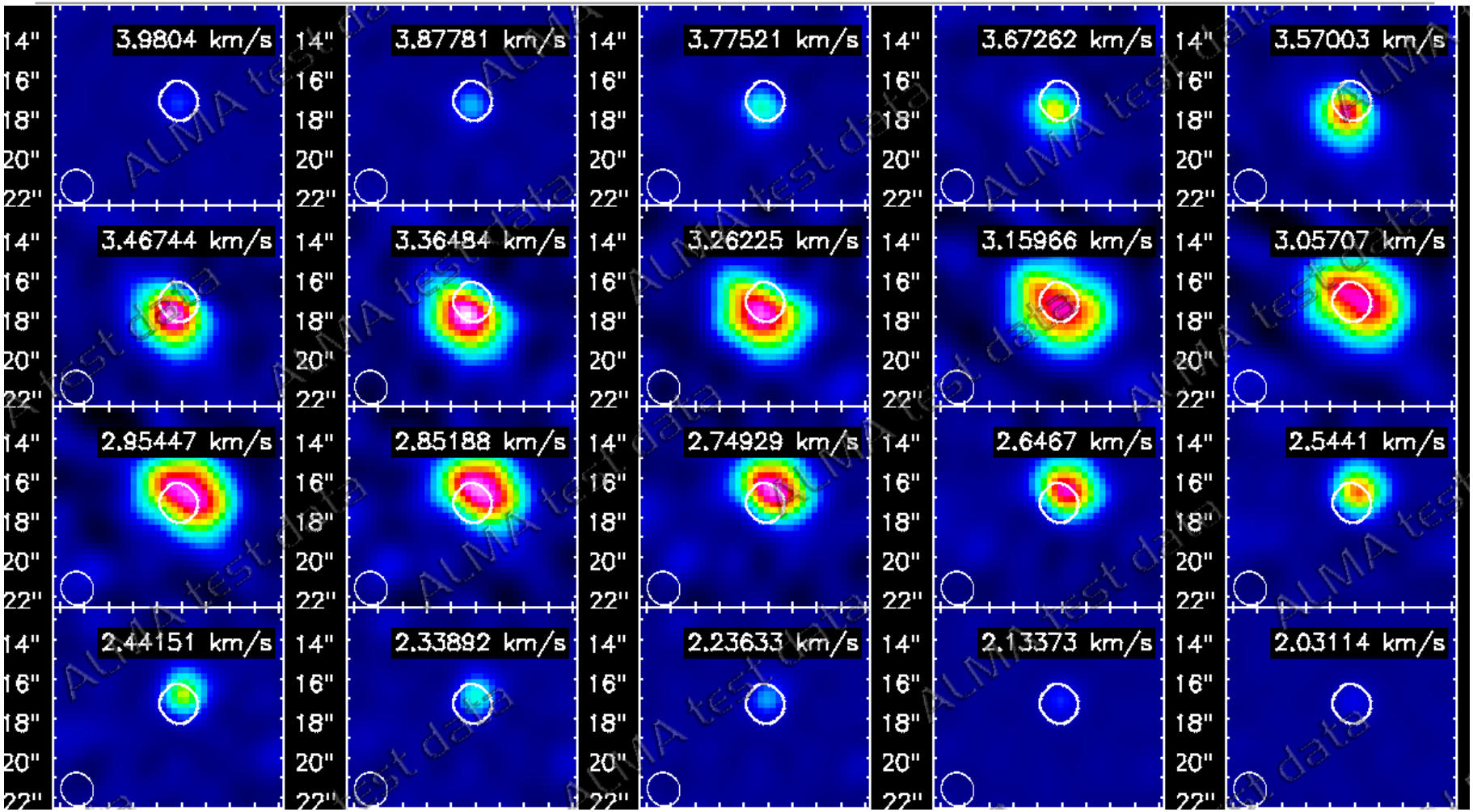
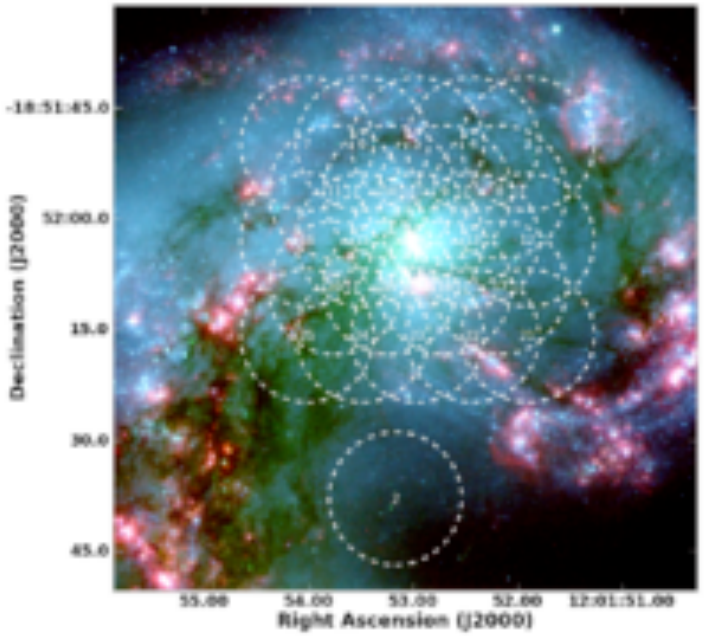
ALMA Science Verification: TWHya

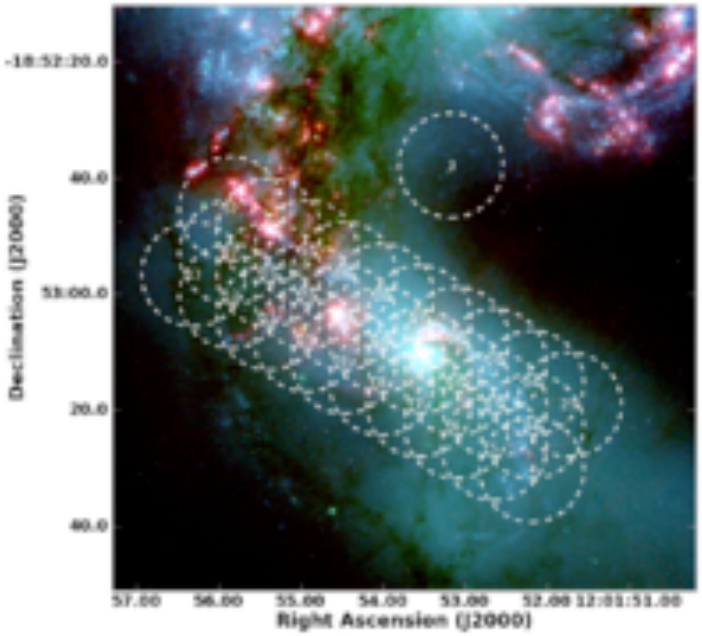


Molecular emission is more extended. Rotation of disk clearly seen.

ALMA Science Verification: Antennae galaxies

- Nearby (22 Mpc) pair of merging galaxies
- ALMA band 7: CO(3-2)
- First ALMA mosaics: one south, one north





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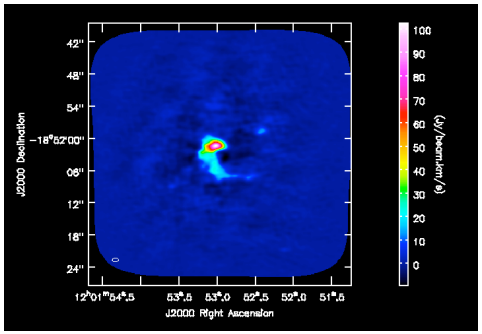
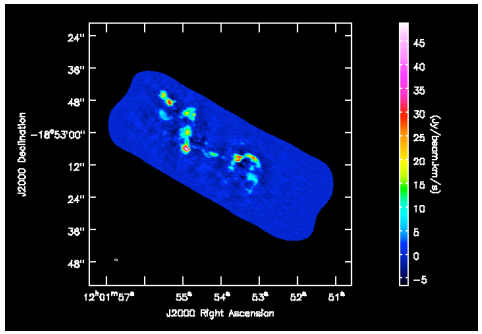
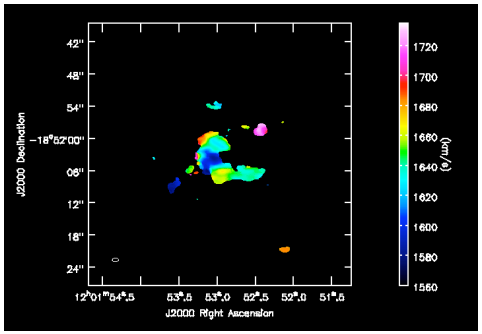
ALMA Science Verification: Antennae galaxies

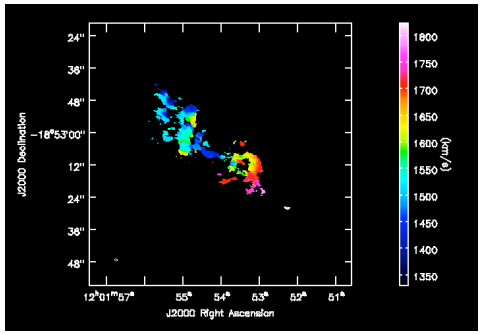
Intensity



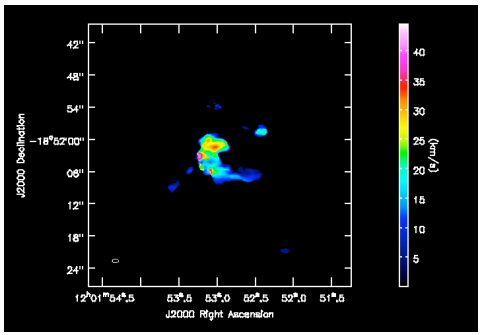


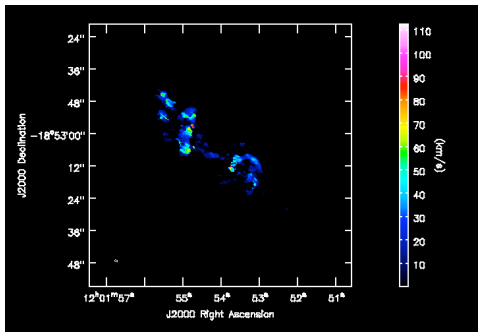
Velocity Field





Velocity dispersion





North

South

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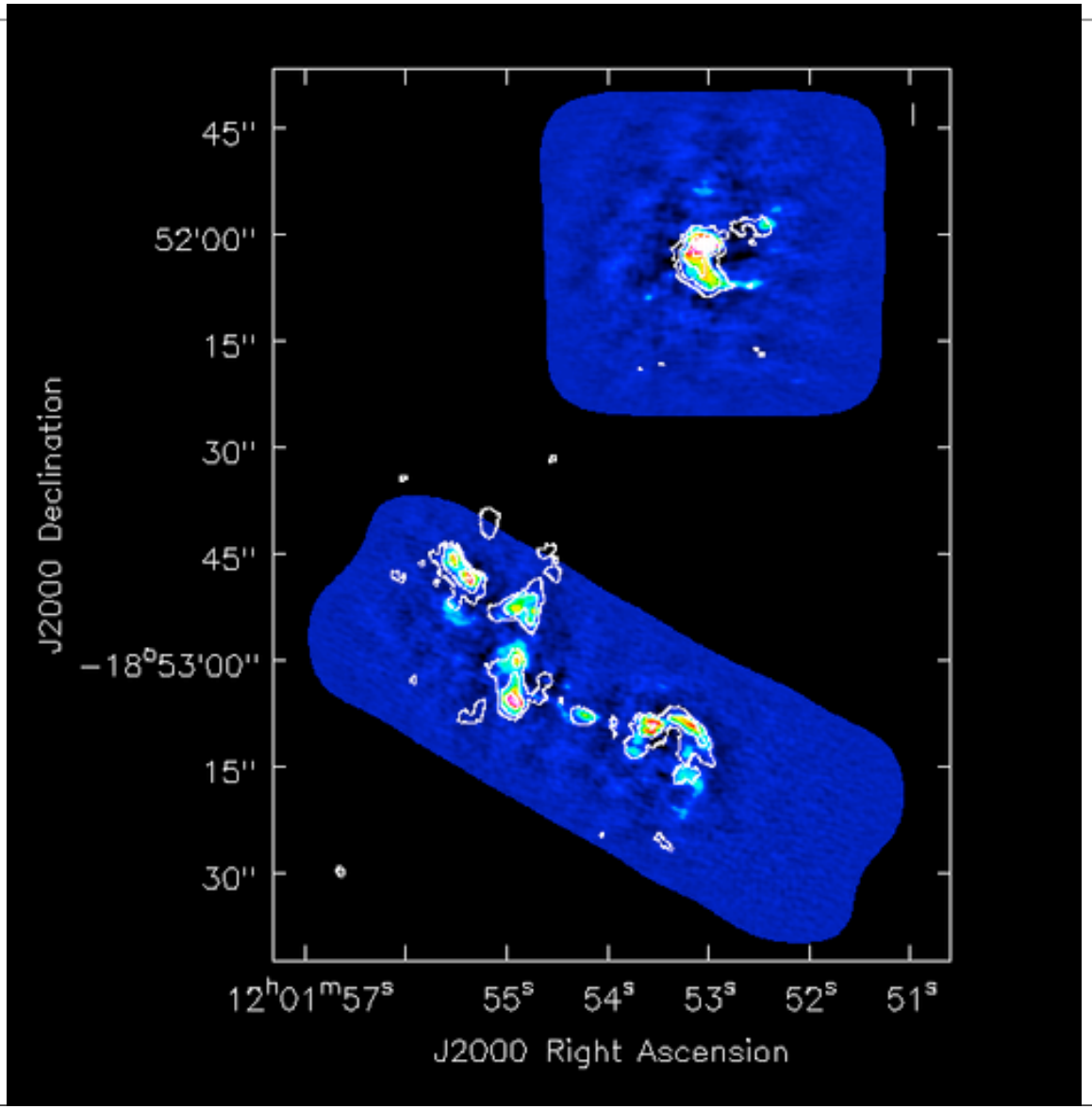
ALMA Science Verification: Antennae galaxies

Colors: ALMA SV CO (3-2) data

Contours: SMA CO (3-2) data (Ueda, Iono, Petitpas et al.)



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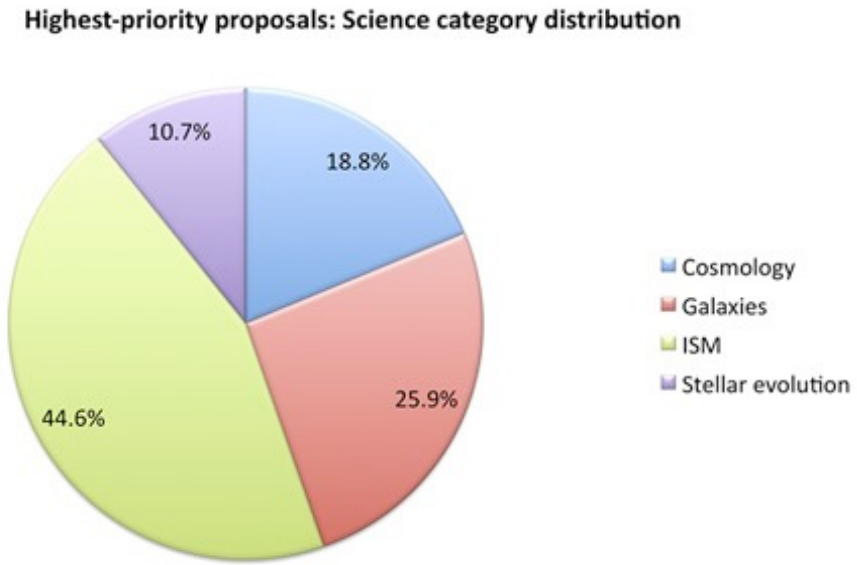
ALMA Cycle 0

- First proposal deadline June 2011
- 919 proposals received
- 16 antennas, two configurations, four bands (3, 6, 7, 9)
- 112 ‘highest-priority projects’
- Observations start ~30 September



ALMA Cycle 1

- **Proposal deadline**: probably late March 2012
- **Observing period**: August 2012 to April 2013
- ~60% of time available for science observing
- Target: **32 main-array** antennas (12m) and **6 ACA** antennas (7m)
- No discrete configurations, but expanding and contracting
  - **Maximum baseline lengths** will be between **150m and 750m**
  - PIs will apply for a required resolution and largest angular scale

All of this: TBC!

ALMA Cycle 1 capabilities

All of this: TBC!

- **Correlator modes** and **spectral set-up**:
  - Independent settings of bandwidth for each baseband
- **Zero spacing**:
  - Spectral mode, possibly continuum mode
- **Receiver bands**:
  - bands 3, 6, 7 and 9, possibly bands 4 and 8 for the ACA
- **Mosaics**:
  - Up to 150 pointings
- **Polarization**:
  - Probably continuum observations only
- **Solar observing**:
  - no solar filters, no calibrations (morphology information only)

ALMA Cycle 1

- **Programs:**
  - Standard, ToO, DDT
  - Time critical with scheduling fuzziness of 1-2 weeks
  - No Large Programs
- **Limitations**:
  - Maximum number of source per project
  - Maximum number of spectral setups per project

All of this: TBC!

High-level **concepts for ALMA science operations**

- Observations **only in service observing mode** with flexible (dynamic) scheduling
- Observations **24h/day** interrupted by maintenance periods
- All observations executed in the form of **scheduling blocks** (SBs)
- Default output: **reliable images**, calibrated and imaged using the data reduction pipeline
- The Joint ALMA Observatory (JAO) is responsible for the **data product quality**
- All science and calibration raw data are captured and **archived**