NRAO

an NSF Facility

National Radio Astronomy Observatory

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

ALMA's Contributions to Outflows, Winds and Jets

Al Wootten
North American ALMA Science Center

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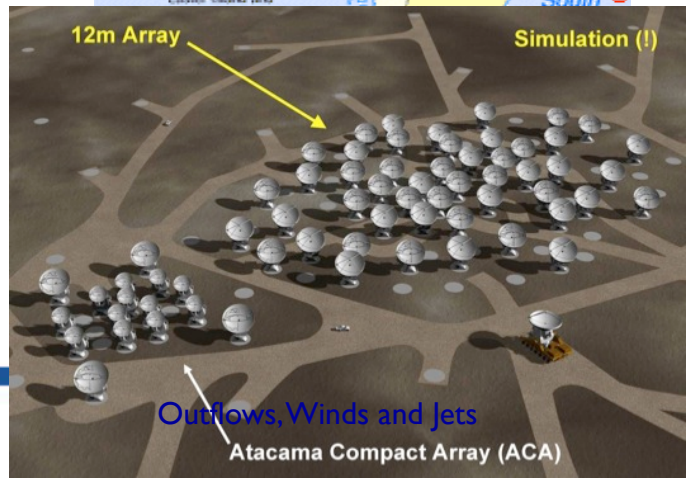
Outline

- Current Status of ALMA

- Capabilities of ALMA for studies of outflows, winds and jets
  - Test data – some results, mostly early with few antennas
  - SV data – no jets, winds, outflow data yet
  - Cycle 0 and beyond – stay tuned
    - Cycle I
    - Development (see tomorrow's discussion)

ALMA Overview

- A global partnership to deliver a transformational millimeter/submillimeter interferometer
  - North America (US, Canada, Taiwan)
  - Europe (ESO)
  - East Asia (Japan, Taiwan)
  - In collaboration with Chile
- 5000m (16,500 Ft) site in Chilean Atacama desert
- Main Array: 50 x 12m antennas
  - + Total Power Array 4 x 12m
  - + Atacama Compact Array (ACA): smaller array of 12 x 7m antennas
- Total shared cost ~1.3 Billion ($US2006)
  - •On budget for completion on time



Operation Support Facility (OSF)
Early 2007, between 1st and 2nd NAASC Workshops

View from East to West

Antenna Vendor Areas
2007

View of Vertex hangar construction

Operations Support

Facility: 9500 ft altitude

15 km from gate on CH23

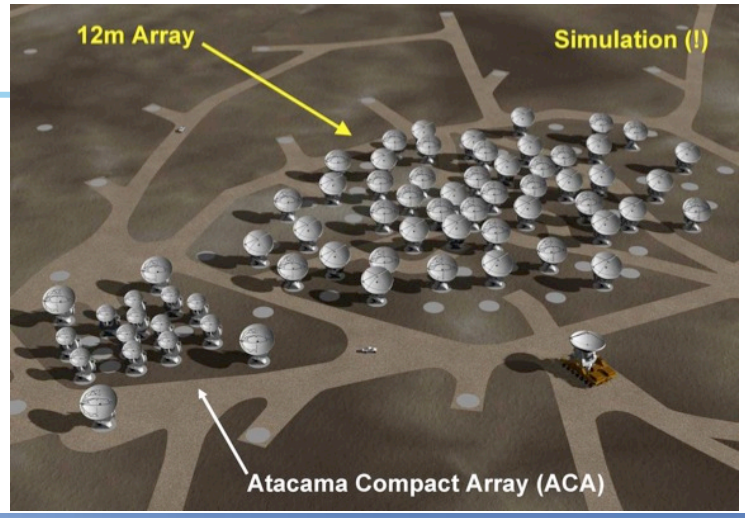
OSF

- Technical Building
  - Completed
  - Warehouse
  - Shops, offices, antenna area
- Camps: House, feed and amuse >500 people
  - ALMA
  - Contractors
- Antenna erection areas
  - VertexRSI (NA)
  - Mitsubishi (JP)
  - Alcatel (EU)
- Temporary Offices

ALMA Overview

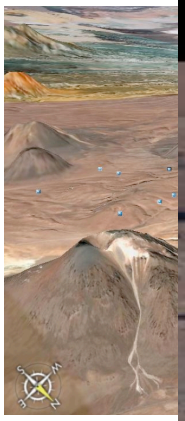
- Baselines up to 15 km (0.015" at 300 GHz) in "zoom lens" configurations
- Sensitive, precision imaging 84 to 950 GHz (3 mm to 315 μm)
- State-of-the-Art low-noise, wide-band SIS receivers (8 GHz bandwidth x 2 polzns)
- Flexible correlators (64 and 16 inputs) with high spectral resolution at wide bandwidth
- Full polarization capabilities
- Estimate .5 TB/day archived

- A resource for ALL astronomers



Array Operations Site: 16400 feet

43 km from [illegible]



m-14km
tenna to TB
r
ls

- Antenna transporter shelter
- Refuge
- No one overnight, few during day

Array Operations Site Technical Building

ALMA in Context

Collecting Area

of Antennas

(# of baselines)

SMA

8 (28)

CARMA

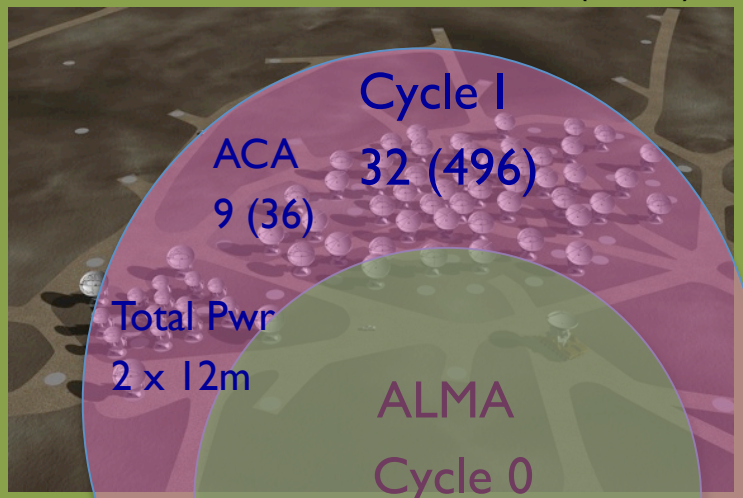
23 (253)

IRAM PdBI

6 (15)

ALMA

Full Science 64 (2016)



Cycle 1

32 (496)

ACA

9 (36)

Total Pwr

2 x 12m

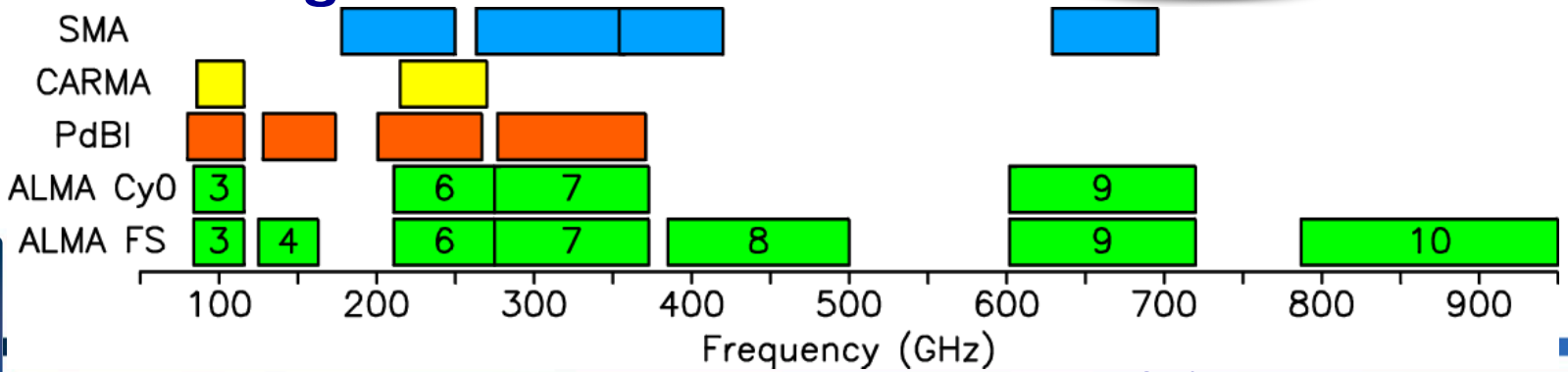
ALMA

Cycle 0

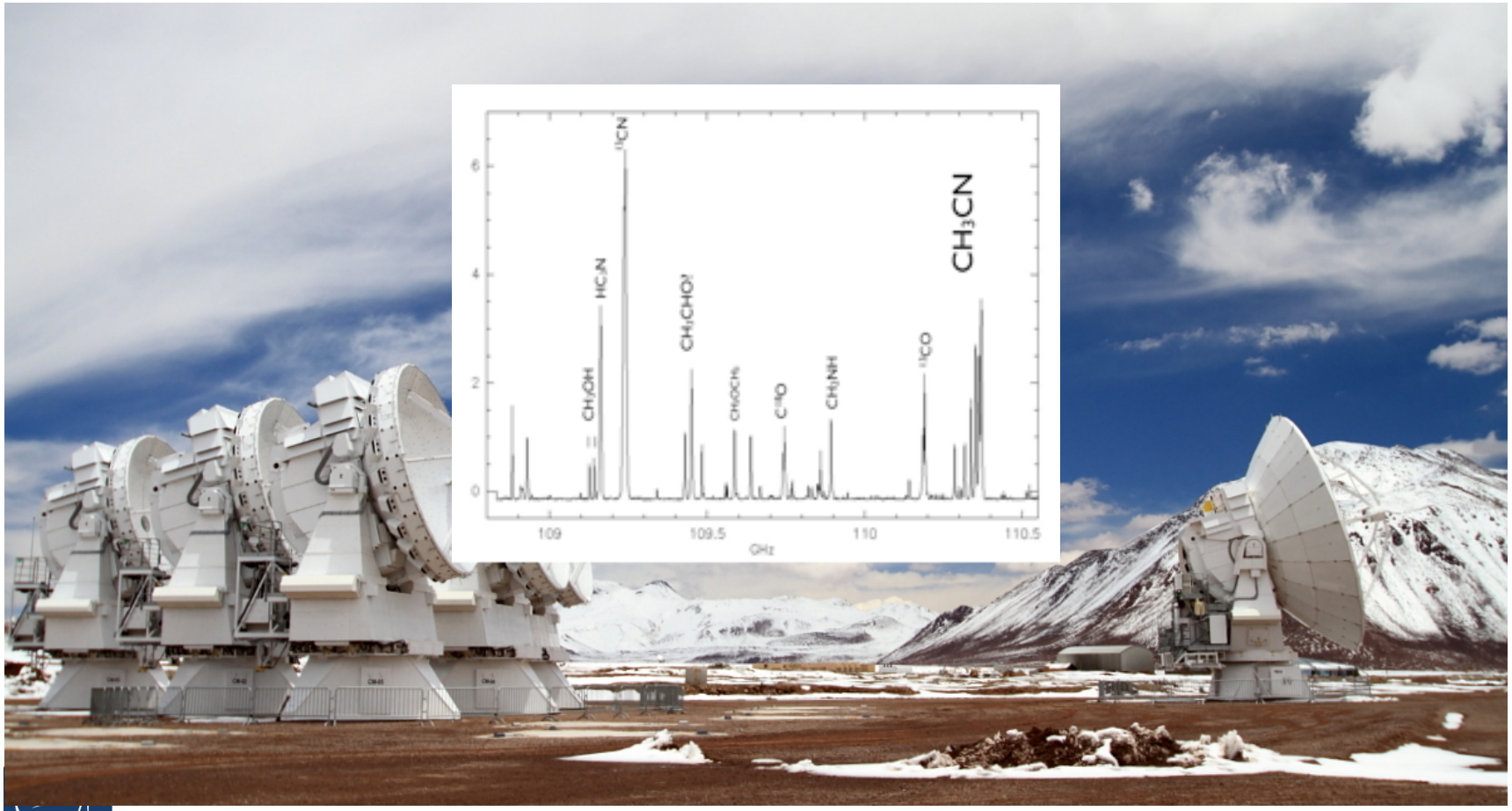
16 (120)

- Sensitivity goes as collecting area
- Image fidelity goes as # of baselines

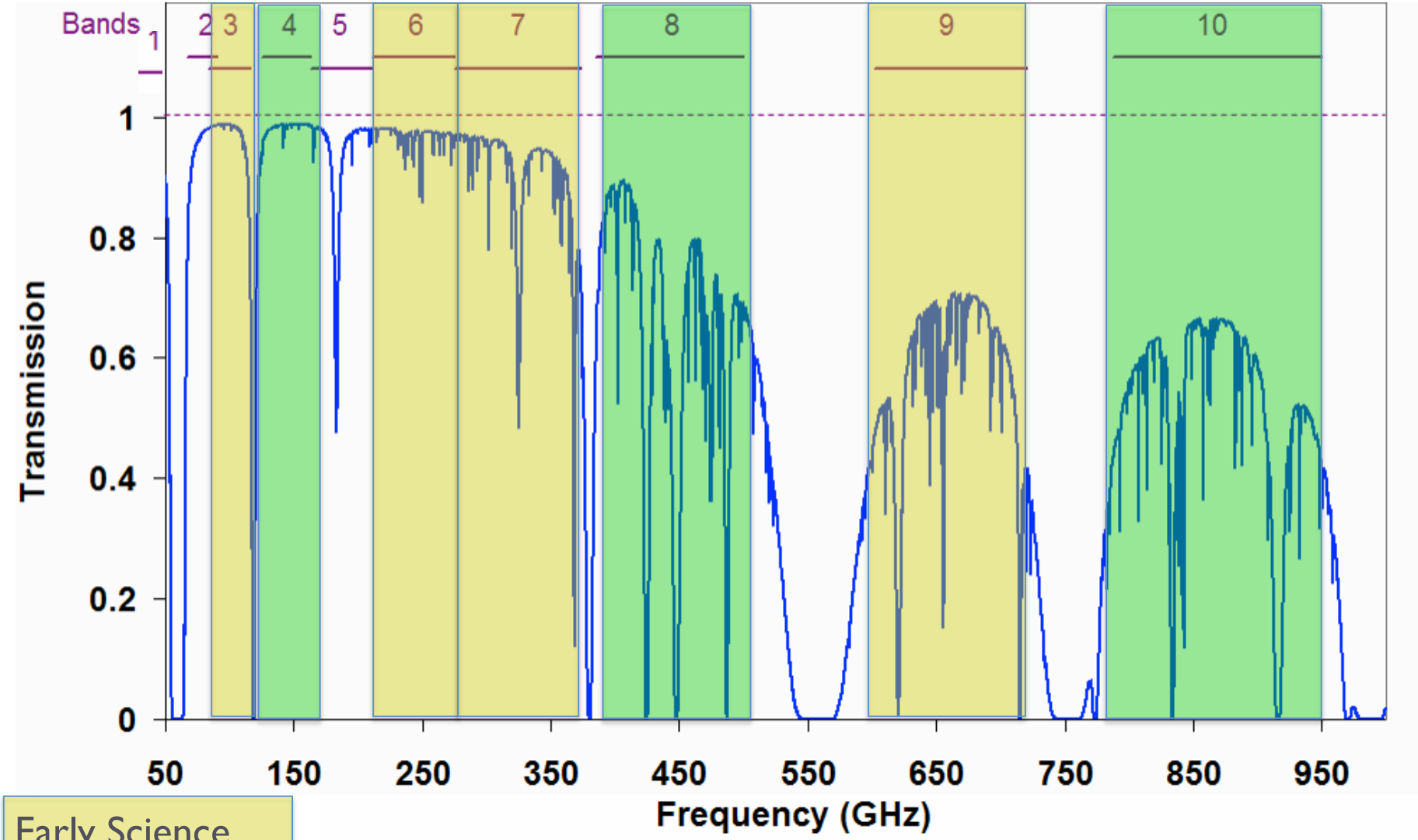
Spectral Coverage



ACA: Short Spacings



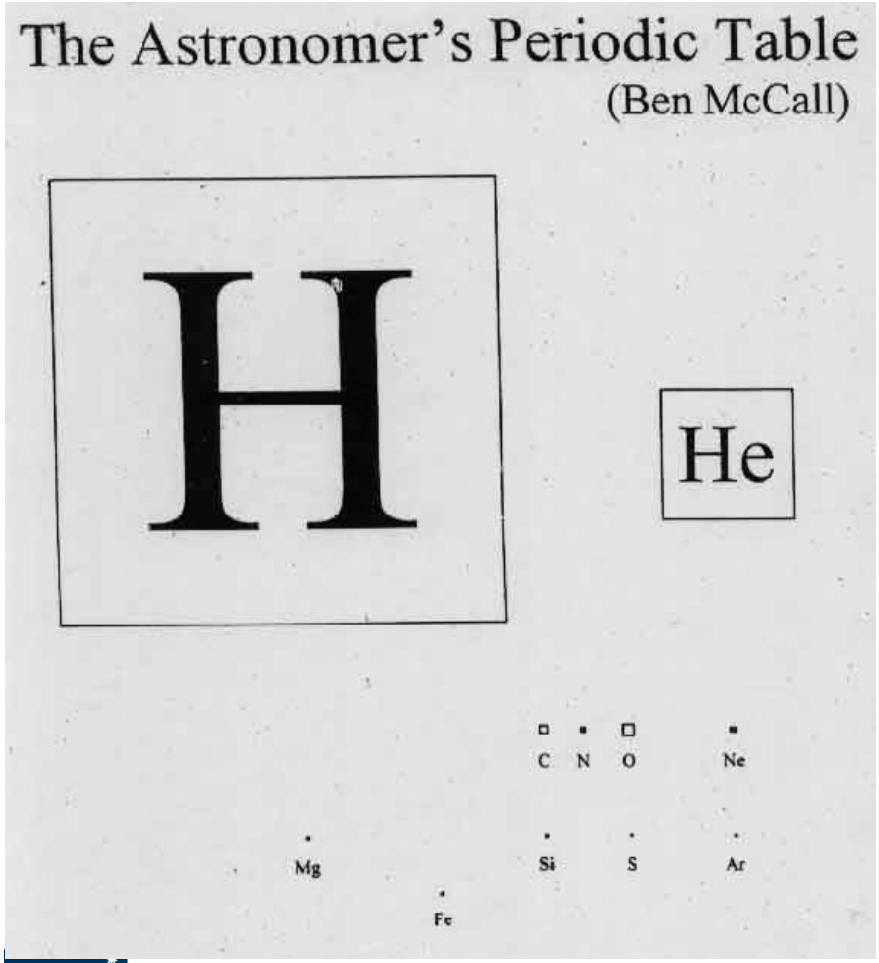
ALMA Receiver Bands



Early Science

Full Operations

The Birth of Chemical Complexity



When chemistry got interesting

(H_3^+, H_2D^+, H_2, HD notwithstanding)

ALMA should be able to monitor the creation of

- O ([O I], [O III], OH, H_2O)
- C ([C I], [C II], CO, CH, CH^+, ^{13}C)
- N ([N II], NH, N_2H^+)

And monitor important isotopes of these elements; many are created as byproducts of the evolution of lower mass stars which begin to pollute the ISM by z~5.5

At high z, spectra are compressed by (1+z).

Sensitivity, Resolution

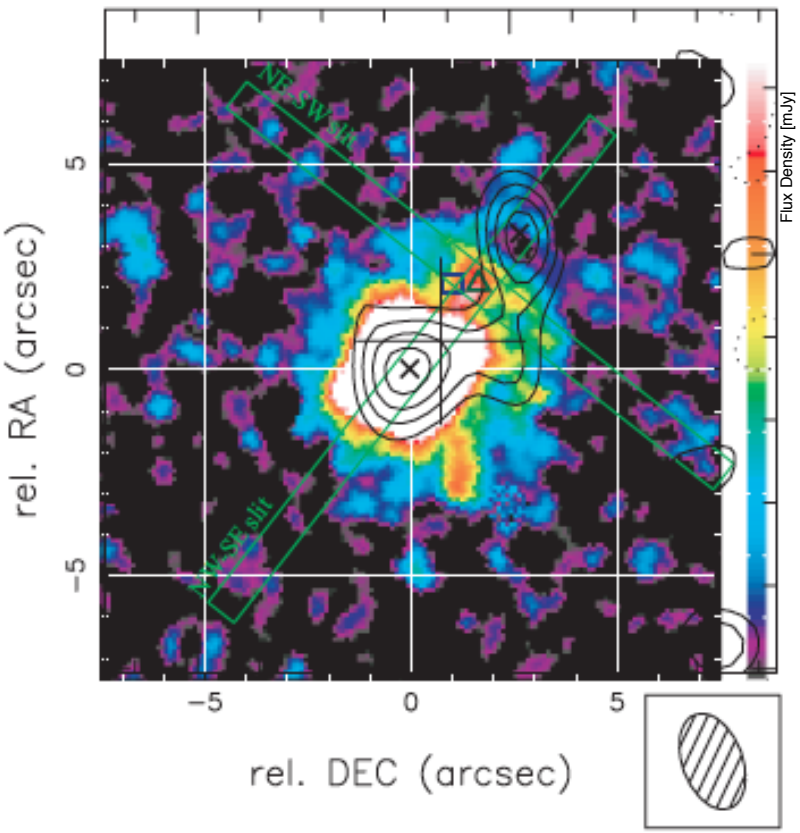
- ALMA can reach 1 mJy/beam in a minute (1 km s^{-1})
- Excellent imaging
  - Atmospheric correction
  - Hundreds of baselines
- 16ms time resolution for interferometric observations
- Provides e.g. possibility of tracking the physical and chemical evolution of shocks accompanying winds, jets and flows

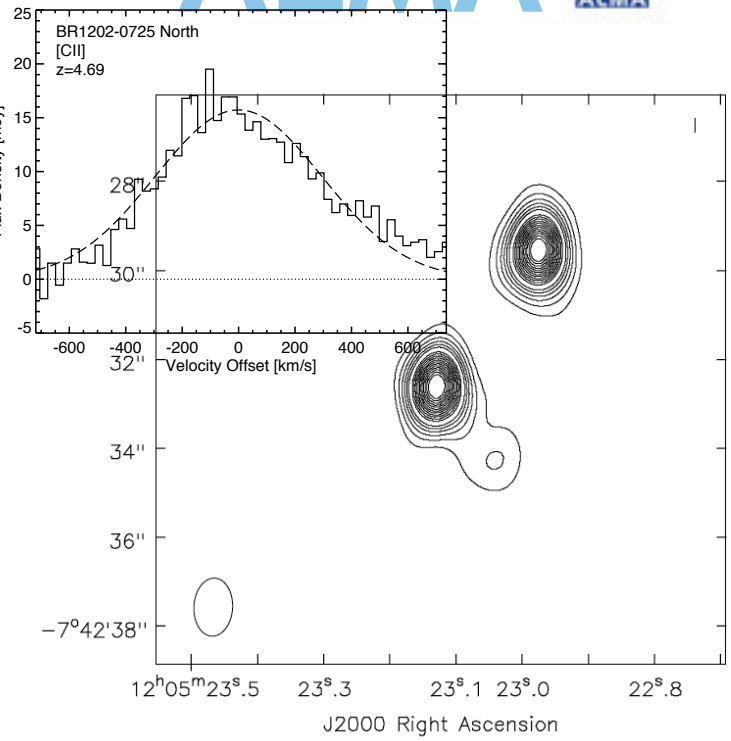
Bottom Line: 30 Sep C0 ES began

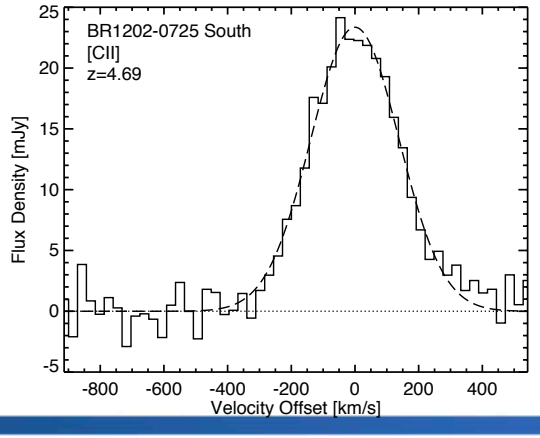
- AOS: 27 antennas, repowering after engineering period
  - 6 are 7m antennas; 21 are transitioning to ES extended
    - Net change of 12
  - 10 (2x7m) at OSF in AIV; 38 'accepted' by project, of 66
  - Capable; some issues with equipment readiness
  - Expect pads for extended configuration by year-end.
- All antennas four bands (42 Front Ends in Chile)
  - Some have B4 (2mm), B8 (.6mm), B5 (1.6mm)
- First datasets: ongoing delivery to PIs
- Planning advanced for Cycle 1

Test D

- Data
  not h
  requi
  data.
- Exam
  BR12
  but is
- 1.5 hr
  obtai
  - S
  - A
  - [C II] agrees with Hi-J CO
  - 3rd source flux 1.4 mJy seen in Subaru image







Data reduction: Wagg

30 Sep Cycle 0 ES

ALMA

- Correlator/Spectral Modes
  - Both ACA and 32 element correlators functioning.
  - Final quadrants of 64 element correlator to be installed Sept 12
  - Imminent CSV demonstration: combination of data
- Scientific Verification Data: Eight Datasets Released (and one datum):
  - 1: **TW Hya: Band 7, high spectral resolution (casaguide).** Band 3, Band 6.
  - 2: **NGC3256: Band 3, low spectral resolution (casaguide).**
  - *3:* **Antennae galaxies: Band 7, high spectral resolution, mosaic (casaguide).** Band 6
  - 4: **M100 Band 3, low spectral resolution.**
  - 5: **SgrA* Band 6, recombination lines.**
  - 6: **Proof of Concept of Response to Targets of Opportunity**: The GRB 110715A (detected)

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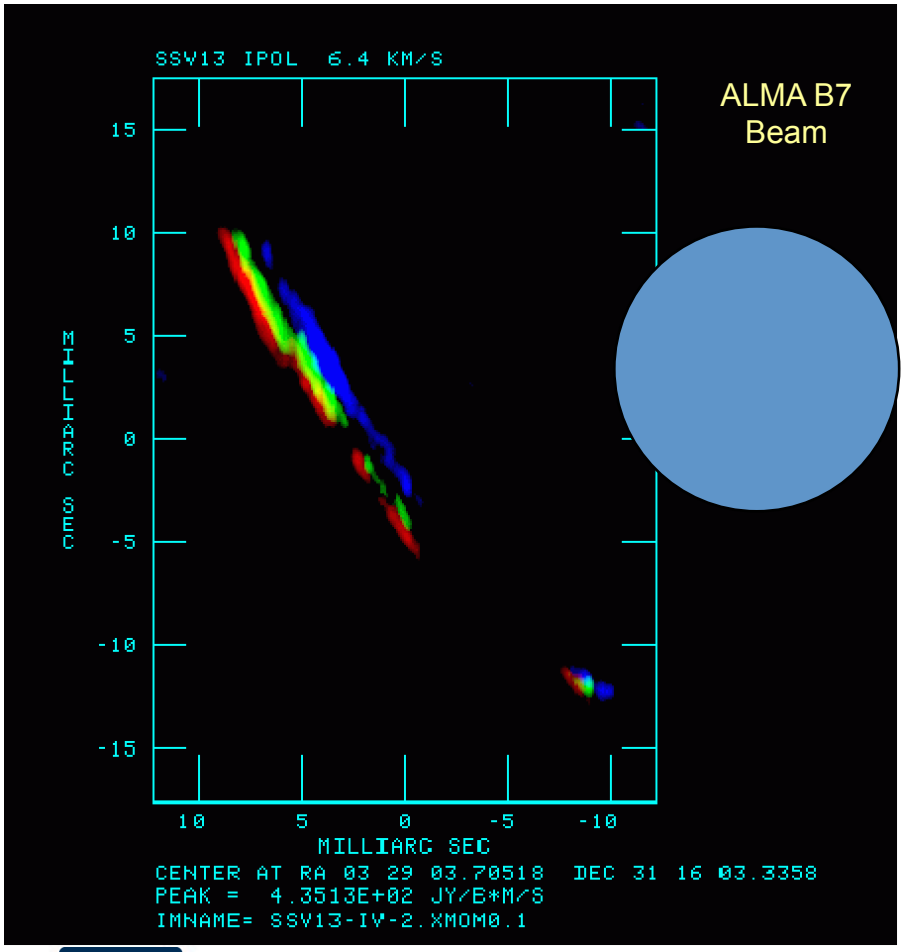
Resolution: Proper Motion, Shock Structure in Dense Clouds



Masers near SVS13; 1mas=0.34AU
Blue Epoch I, Green Epoch III, Blue Epoch IV
Wootten, Marvel, Claussen and Wilking

Winds, jets and outflows interact with local media at shocks; masers can trace these.

Water masers observed over four epochs encompassing 50 days (22 GHz, VLBA). Several of the masers define an arc structure about 5AU in length. This consistently moved at a rate of 0.023 mas/day, or 13.6 km/s. Including the radial velocity offset, a space velocity of 13.7 km/s is calculated at an inclination of 6 degrees from the plane of the sky.

These structures apparently represent water emission from interstellar shocks driven by the outflow from SVS13.

ALMA, VLBA, JVLA can provide images of chemistry in action in shocks such as this.

Key to Understanding Shocks:

High T_B sensitivity at high resolution, 1 min

					Compact		Most Extended	
Band	Frequency	Primary Beam (FOV; ")	Largest Scale (")	Continuum Sensitivity (mJy)	Angular Resolution (")	ΔT_{line} (K)	Angular Resolution (")	ΔT_{line} (K)
Band 1	*31.3 - 45 GHz*							
Band 2	*67 -90 GHz*							
Band 3	*84 - 116 GHz*	*56*	*37*	*0.05*	*3.18*	*0.07*	*0.038*	*482*
Band 4	*125 - 163 GHz*	*48*	*32*	*0.06*	*2.5*	*0.071*	*0.03*	*495*
Band 5	*163 - 211 GHz*	*35*	*23*					
Band 6	*211 - 275 GHz*	*27*	*18*	*0.10*	*1.52*	*0.104*	*0.018*	*709*
Band 7	*275 - 373 GHz*	*18*	*12*	*0.20*	*1.01*	*0.167*	*0.012*	*1128*
Band 8	*385 - 500 GHz*	*12*	*9*	*0.40*	*0.86*	*0.234*	*0.01*	*1569*
Band 9	*602 - 720 GHz*	*9*	*6*	*0.69*	*0.52*	*0.641*	*0.006*	*4305*
Band 10	*787 - 950 GHz*	*7*	*5*	*1.1*	*0.38*	*0.940*	*0.005*	

To be developed in the future. Available for early science.

Looking Forward: Cycle 0 and Cycle 1

- Cycle 0
  - Completion rate of projects is lower than planned
    - 16+ datasets delivered
  - Cycle 0 observing period will be extended until the end of 2012.
    - Time fraction devoted to ES will increase
    - Will allow completion of nearly all Cycle 0 projects
    - May result in completion of some fraction of 'filler' projects
  - This extension will not delay completion of the array.
- Cycle 1
  - Information regarding the capabilities and timeline for ALMA Early Science Cycle 1 to be released April 2012.
  - Deadline is expected to be in July 2012
  - Start of Cycle 1 observations at the beginning of 2013.

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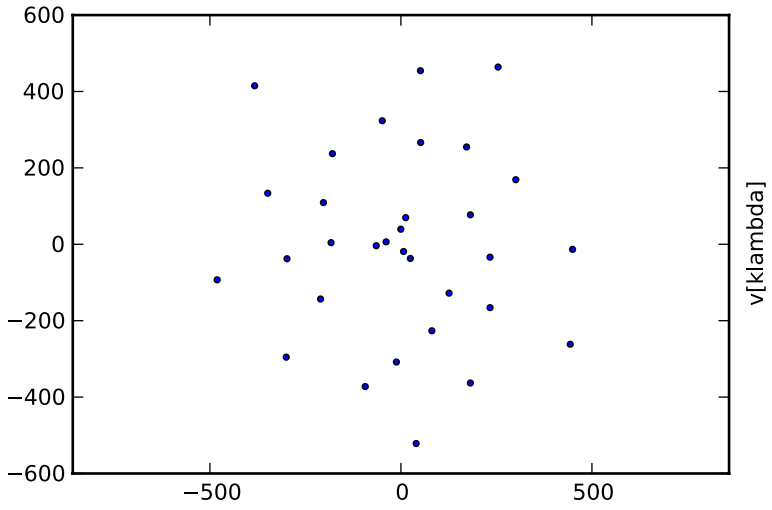

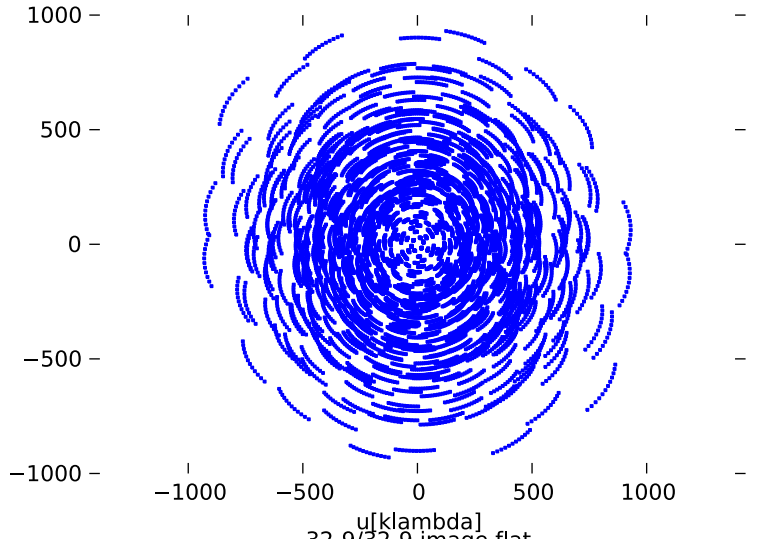

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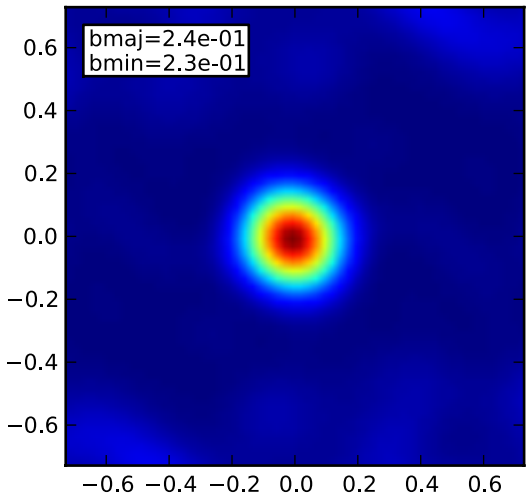

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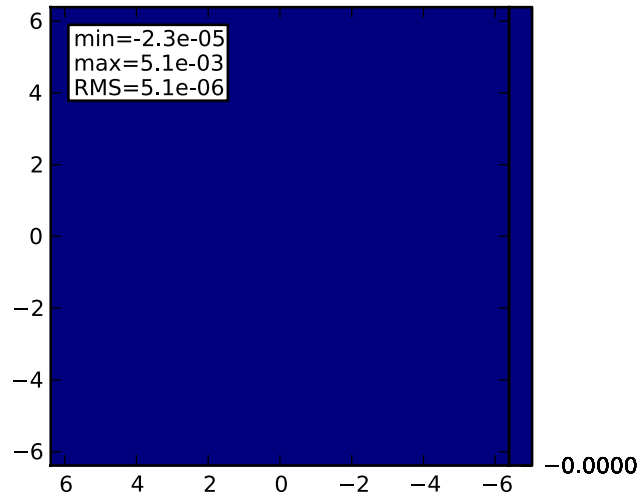
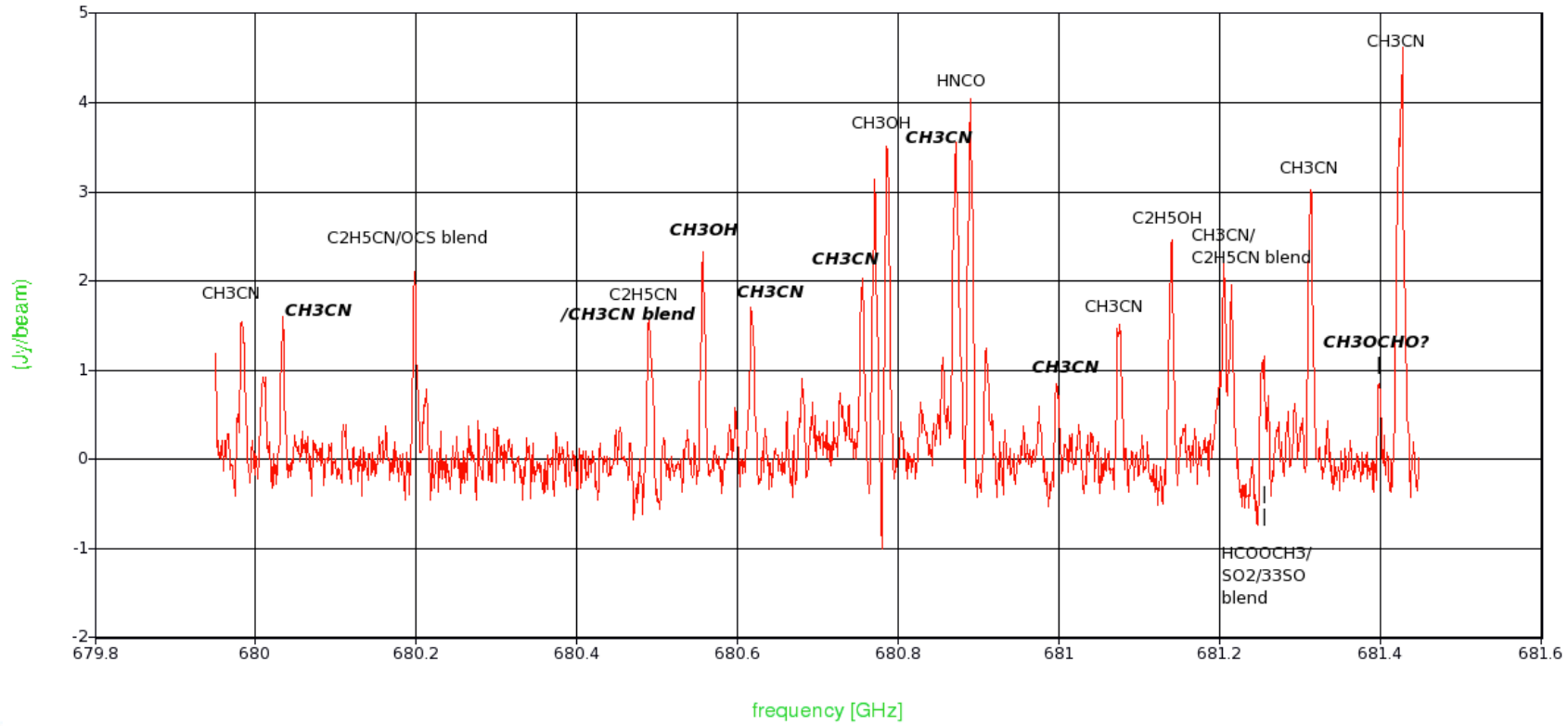


Massive Star Formation: Orion 450µm



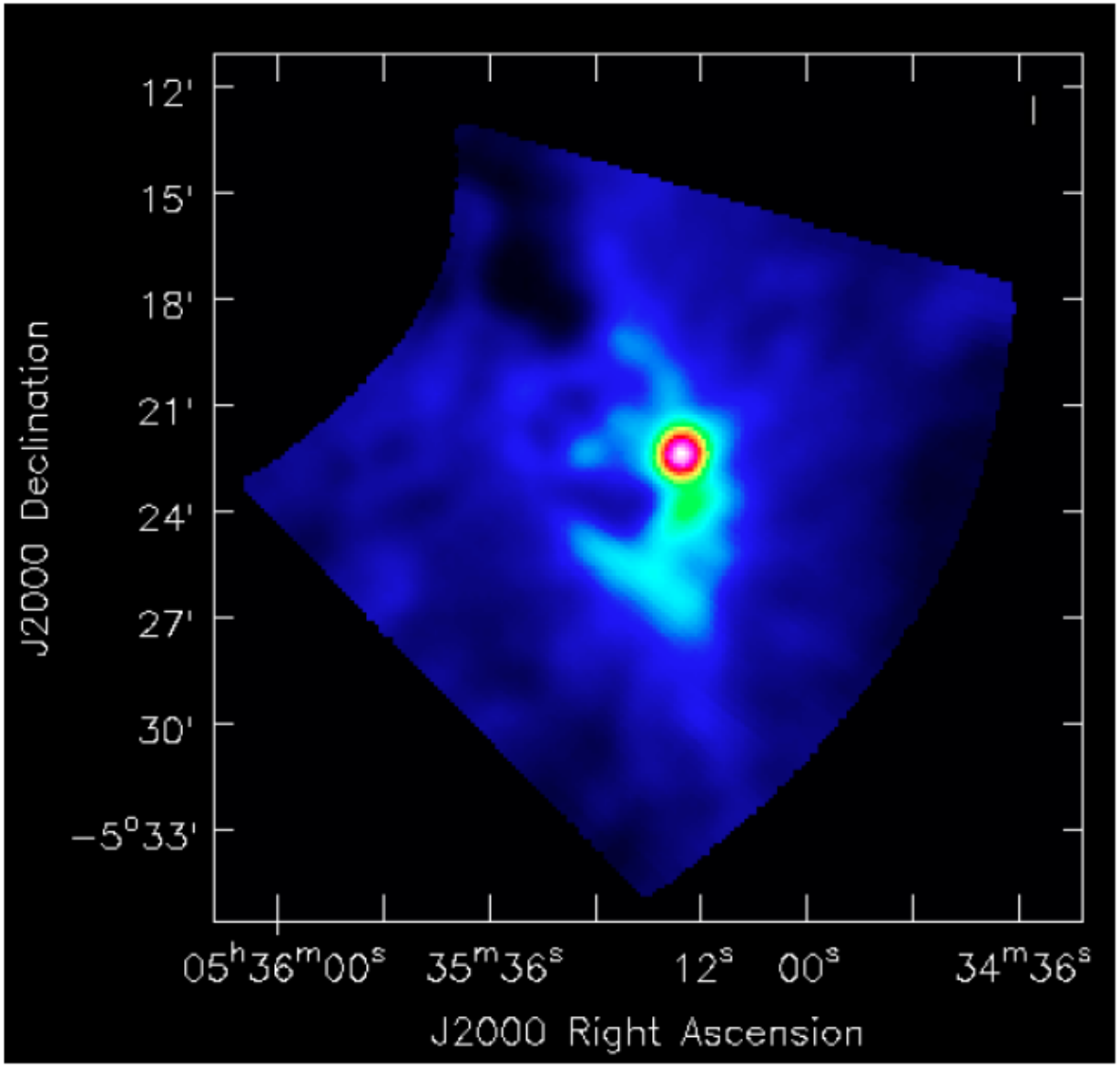
Van Kempen, Impellizzeri

Orion ^{12}CO 1-0

64 row map

Took 52 mins

(of which 34 were on sky and 18 were overheads)



J2000 Right Ascension J2000 Right Ascension

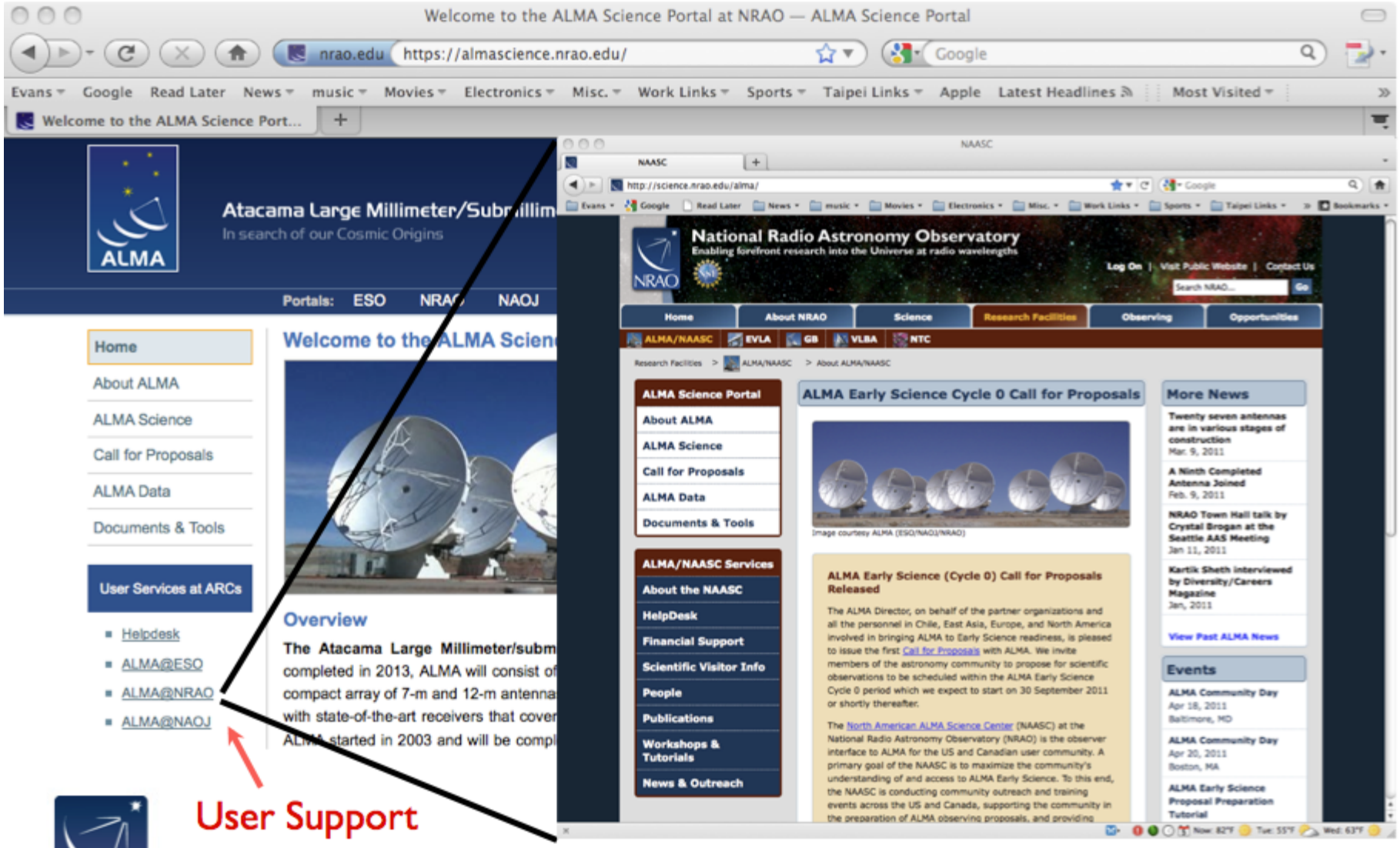
Cycle 1 Capabilities (Proposed)

- Mosaics: 150 pointings/schedule block
- Program considerations
  - Target of Opportunity
  - Director's Discretionary Time
  - Scheduling sharpness only 1-2 weeks
  - No large programs
  - No project transferral to Cycle 2

NRAO User Support

http://almascience.nrao.edu

NAASC



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ALMA

The Atacama Large Millimeter/sub-millimeter Array (ALMA), an international astronomy facility, is a partnership of 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 East Asia by the National Institutes of Natural Sciences (NINS) of Japan 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.

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Outflows, Winds and Jets