ALMA: Atacama Large MM/Submm Array

Status and Overview

Crystal Brogan

(NRAO/North American ALMA Science Center)

Atacama Large Millimeter/submillimeter Array

Expanded Very Large Array

Robert C. Byrd Green Bank Telescope

Very Long Baseline Array

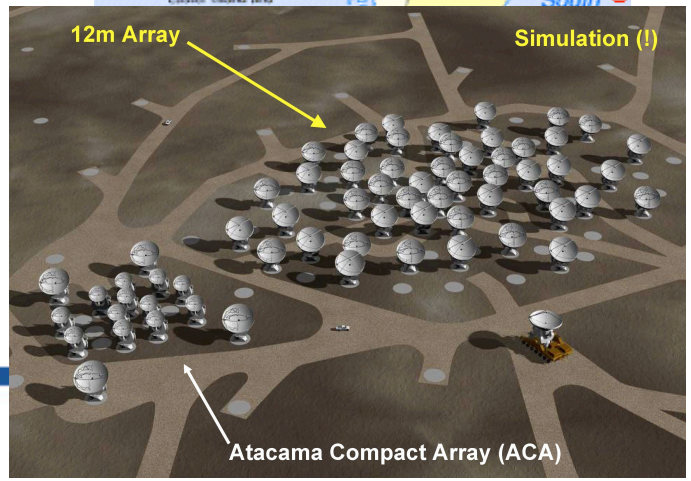
Associated Universities, Inc.

NSF

NRAO

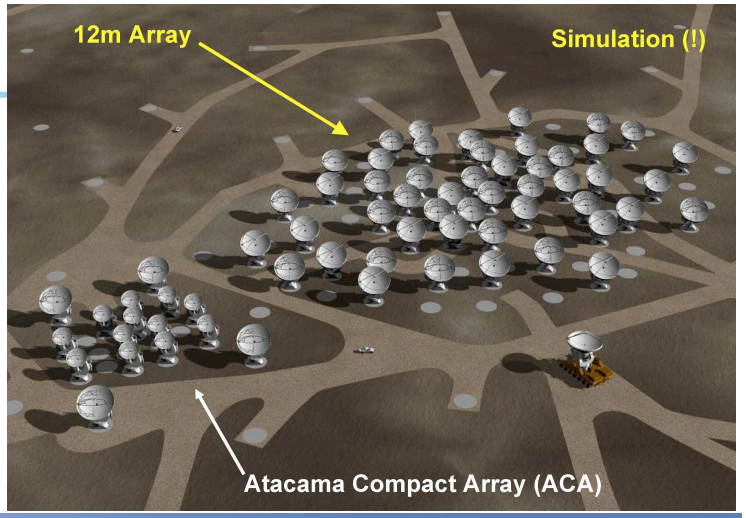
The Atacama Large MM/Submm Array : ALMA

- 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)



ALMA in a Nutshell

- 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 receivers (8 GHz bandwidth)
- Flexible correlator with high spectral resolution at wide bandwidth
- Full polarization capabilities
- Estimate 1 TB/day to be archived



ALMA will be 10-100 times more sensitive and have 10-100 times better angular resolution compared to current millimeter interferometers

- A resource for ALL astronomers

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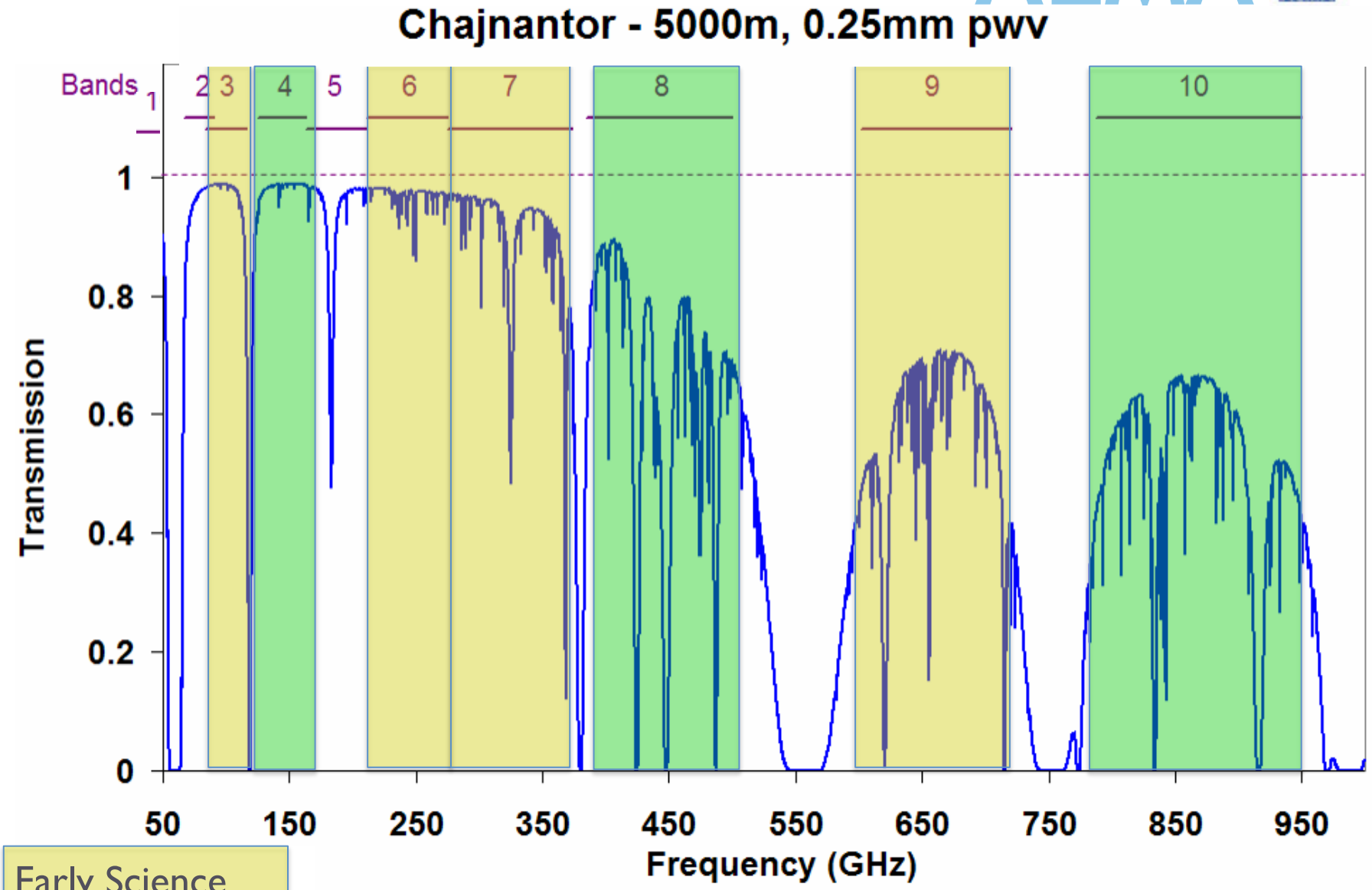
Receiver Bands



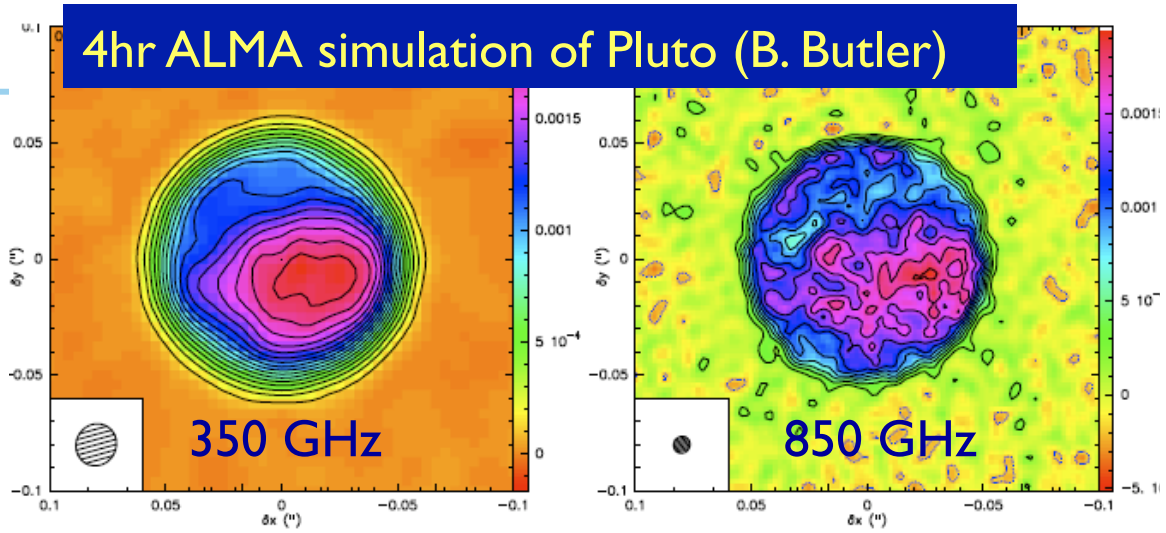
Early Science

Full Operations

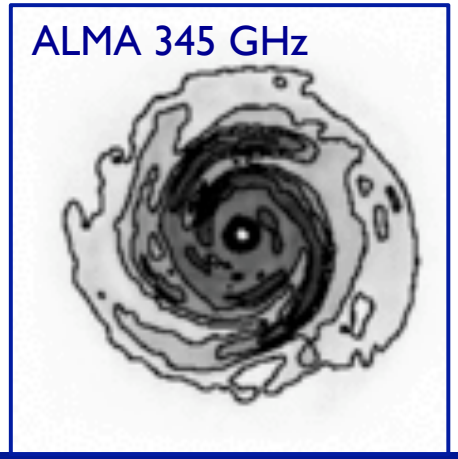
Breadth of Full Science: Galactic

- Exploring the Solar System from the sun to minor planets and moons

- Revealing disks and forming protoplanets around nearby stars



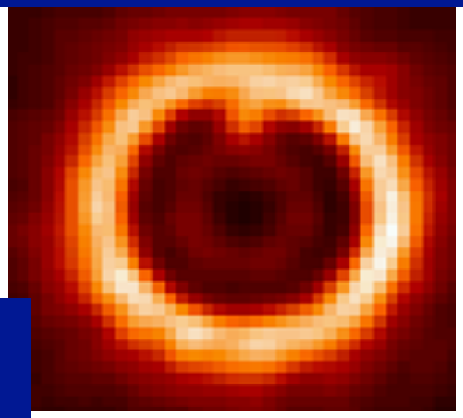
4hr ALMA simulation of Pluto (B. Butler)

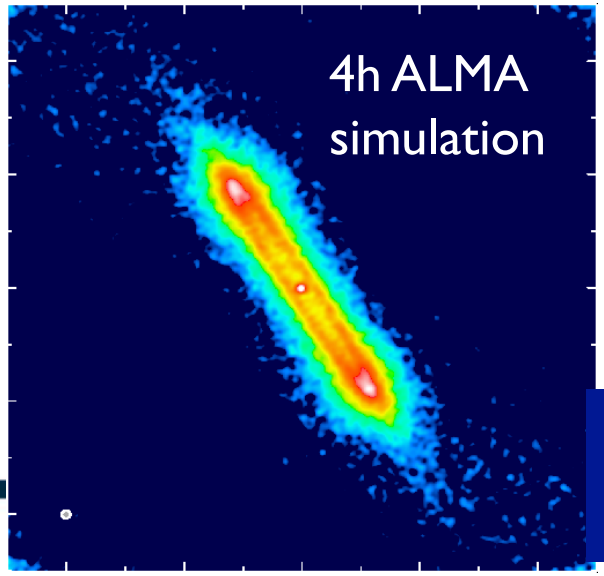


ALMA 345 GHz

Simulation of dust opacity in a face-on circumstellar disk at 50 pc (Cossins et al. 2010)

ALMA 950 GHz simulation of dust from forming protoplanet at 100 pc (Wolf & D'Angelo)



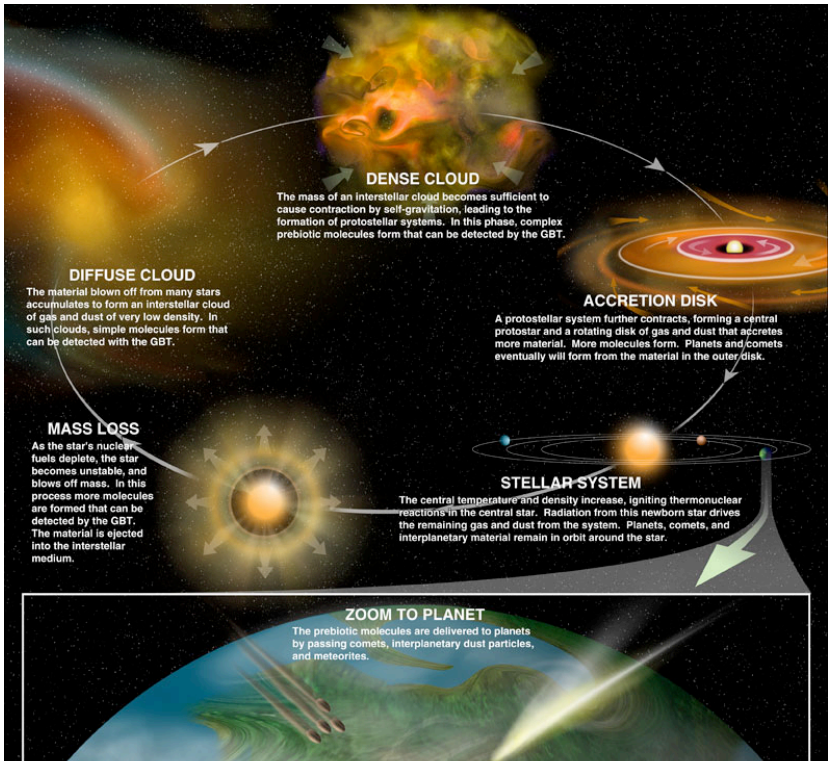


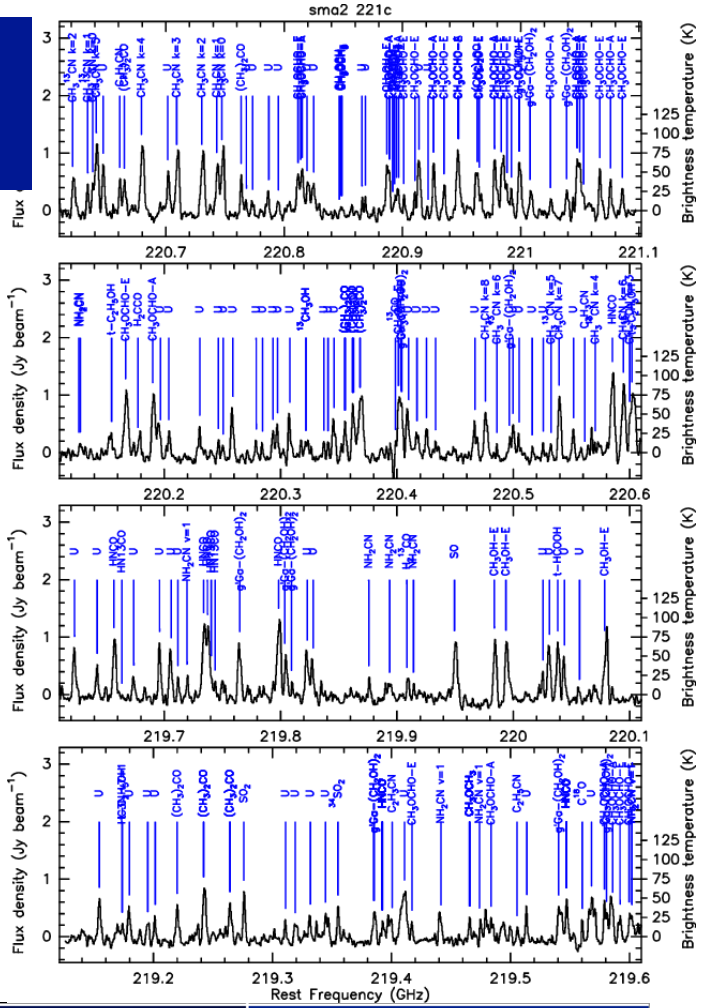
Simulation of dust in Beta Pictoris debris disk using model by Chris Stark (D.Wilner)

Breadth of Full Science: Galactic

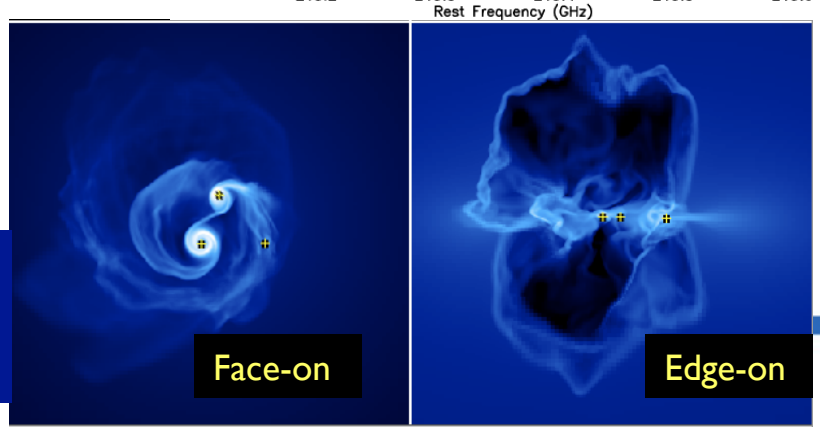
Line forest from massive protostar (SMA; Brogan et al. in prep).

- The life cycle of molecular gas and chemistry





- Resolving the accretion process(es) of massive protostellar and cluster formation



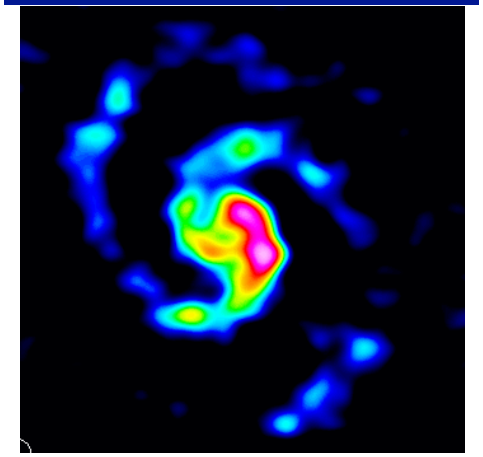
Theoretical simulation of massive star formation with 10 AU resolution (Krumholz et al. 2009)

Breadth of Full Science: Extragalactic

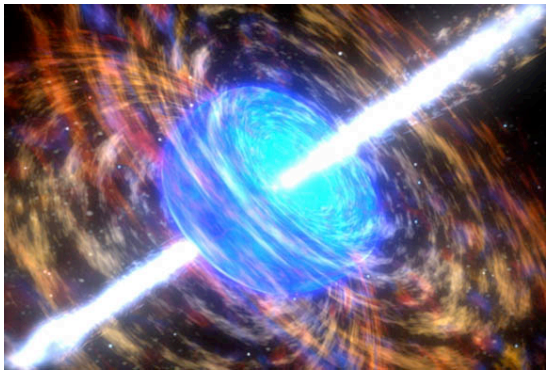
ALMA

- Detailed imaging of dust and gas in nearby galaxies

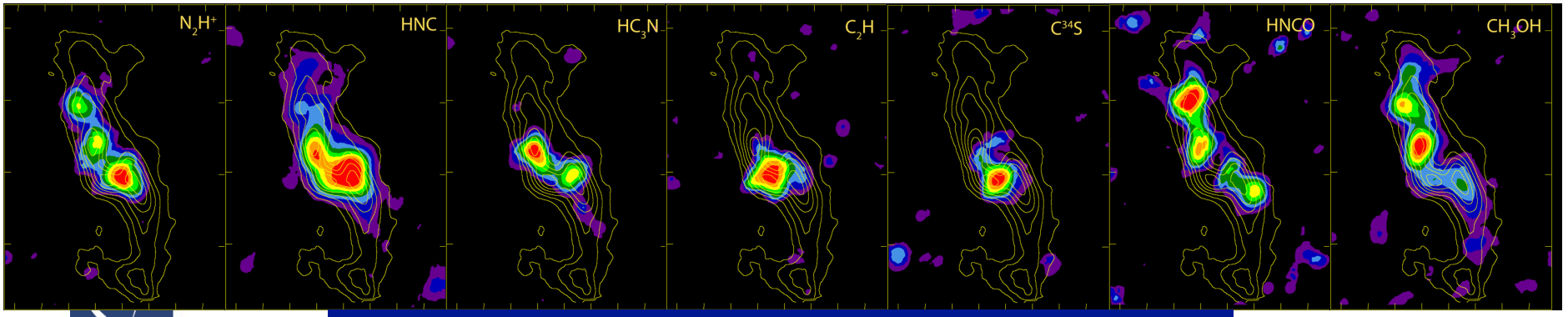
4 hr CASA Simulation of M51 at z=0.1 in CO(1-0)



- Probing the nature of AGN, black holes, GRBs and other transient phenomena



N_2H^+ HNC HC_3N C_2H $C^{34}S$ HNCO CH_3OH



IC 342 with OVRO at 3 mm (Meier & Turner 2005); with ALMA chemical census of all nearby galaxies possible

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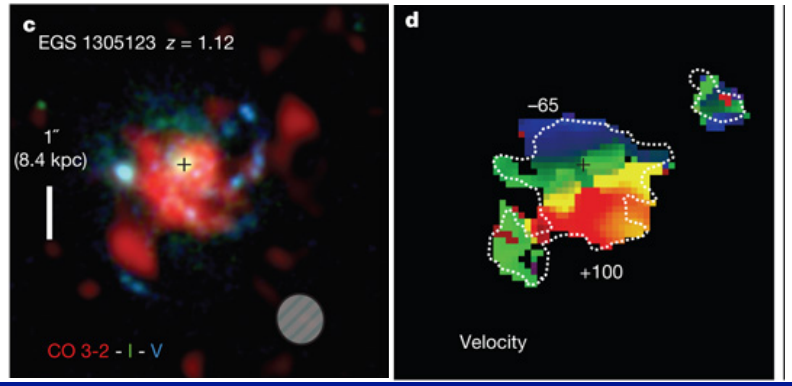
Breadth of Full Science: Extragalactic

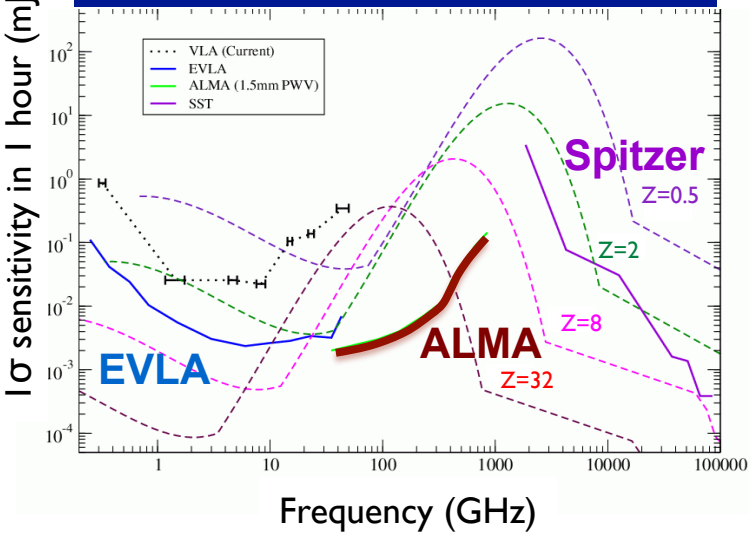
ALMA

- Imaging dust and gas from high redshift galaxies

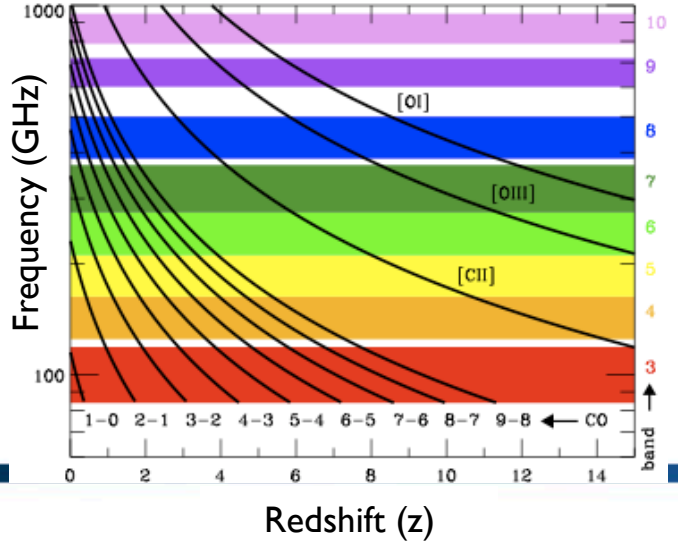


CO(3-2) with PdBI in 20 hours at Z=1.1 (Tacconi et al. 2010); full ALMA in a few hours

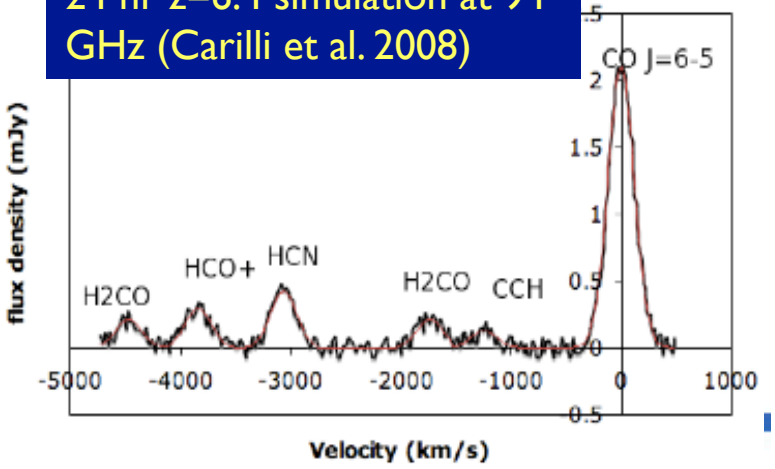
Detect dust continuum from high-z galaxies as easily as those at z~0.5



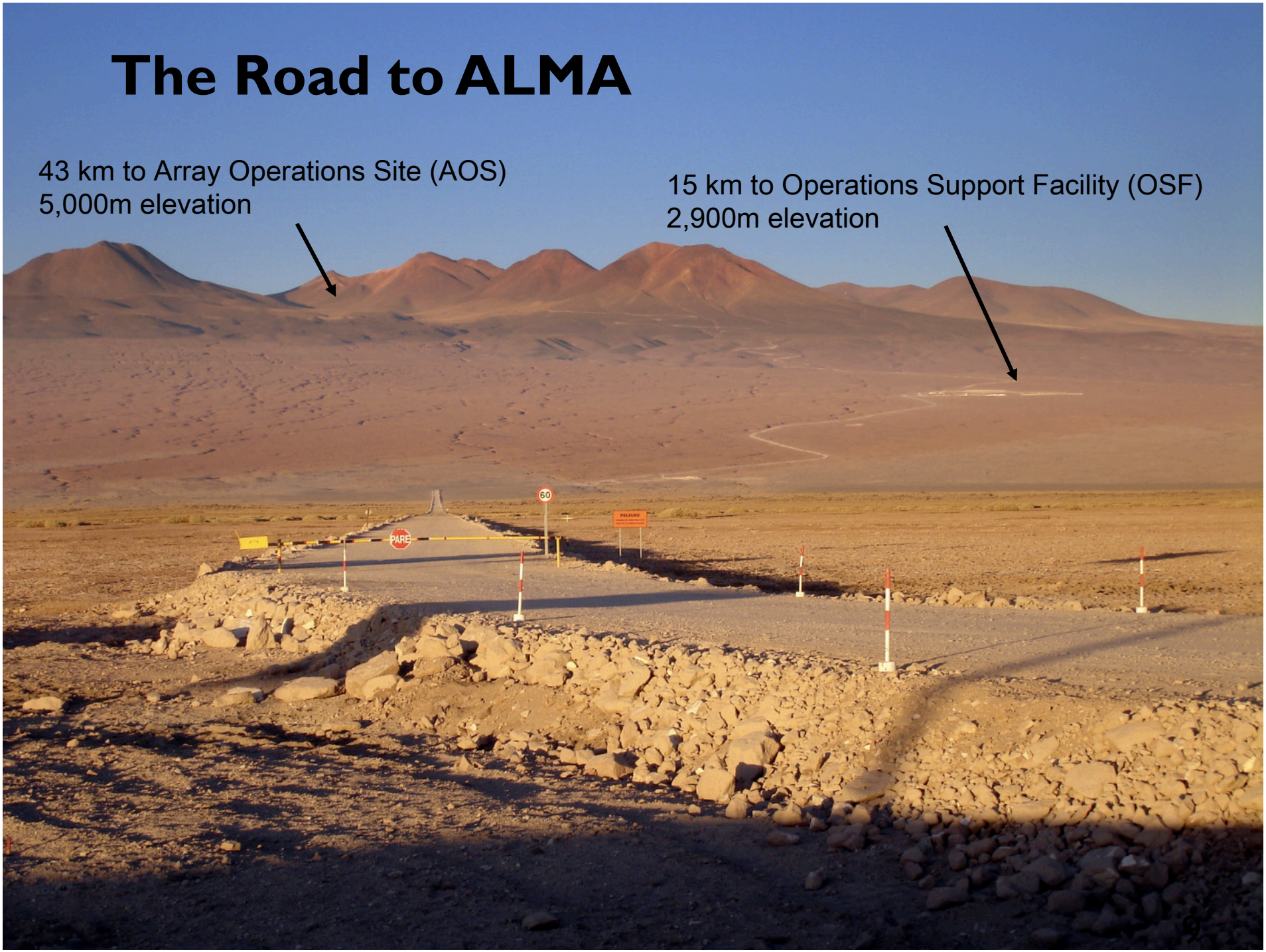
Nearly continuous coverage of important lines as a function of redshift (Maiolino 2008)



24 hr z=6.4 simulation at 94 GHz (Carilli et al. 2008)



The Road to ALMA



Operations Support Facilty (2900m level)

ALMA

Melco, (EA), antenna

Vertex, (NA), assembly

and AEM, (EU)

Contractors camp

There are now >27 antennas in various stages of completion

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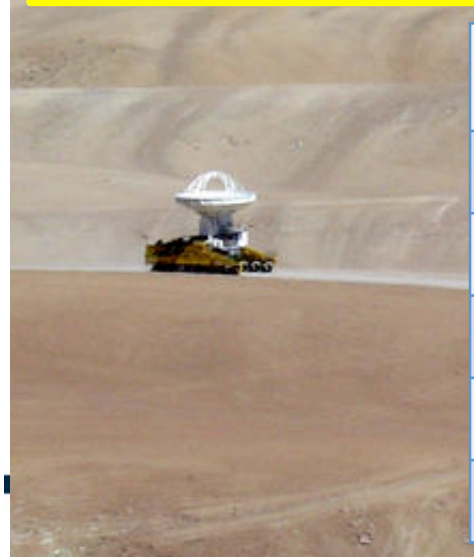
Progress at the Array Operations Site at 5000m ➔ the "high site"

AOS Technical Building - completed 2008

Home of the ALMA 12-m and ACA correlators

Move of the ninth antenna to high site on December 12, 2010



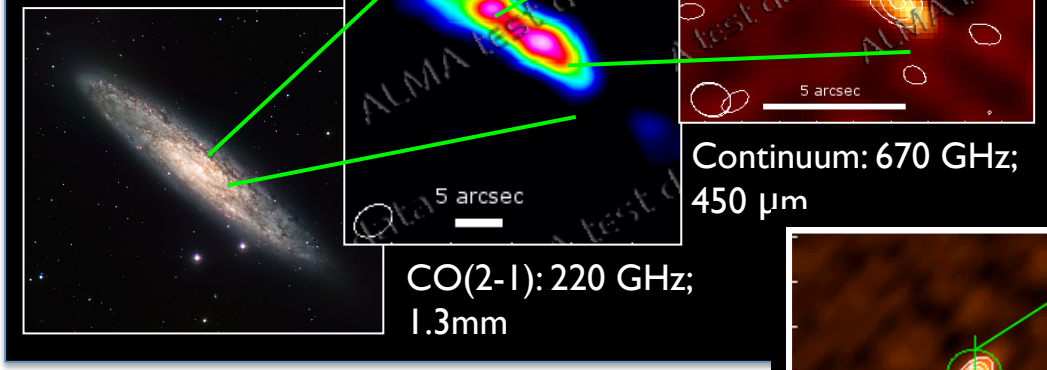
ALMA Timeline

All Last Year (2010)	Commissioning (began Late 2009)
March 31 2011	**1st call for Early Science Proposals**
3rd Quarter 2011	Early Science observing begins
Late 2012	Pipeline images for standard modes
Late 2013	Baseline ALMA construction complete

Commissioning: Stunning Test Images

ALMA

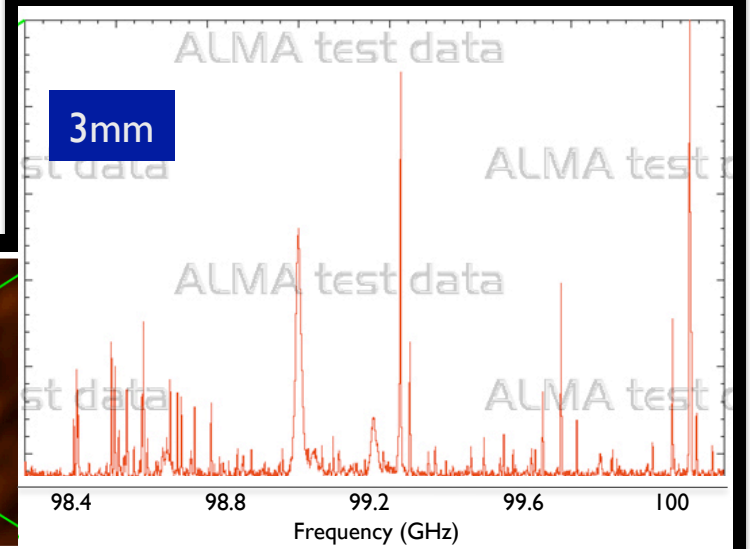
The heart of a star forming galaxy: NGC253

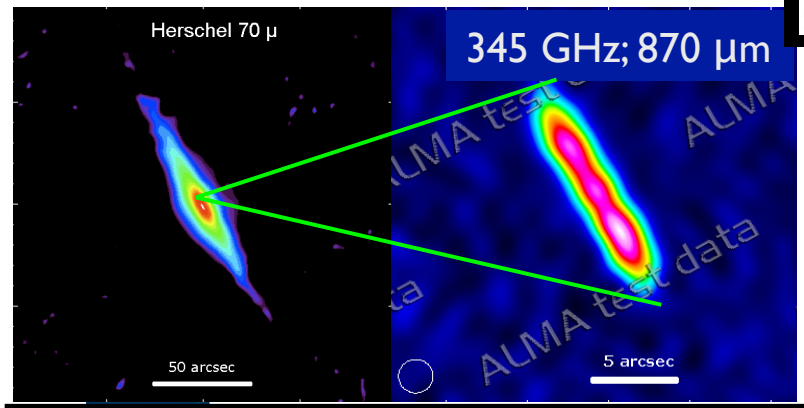


Continuum: 670 GHz; 450 μm

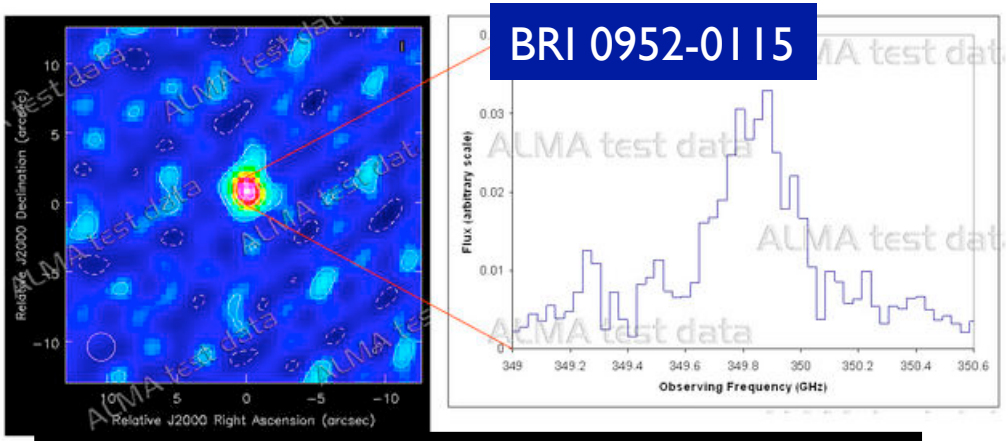
CO(2-1): 220 GHz; 1.3mm

Spectral line forest from a Galactic massive protostar



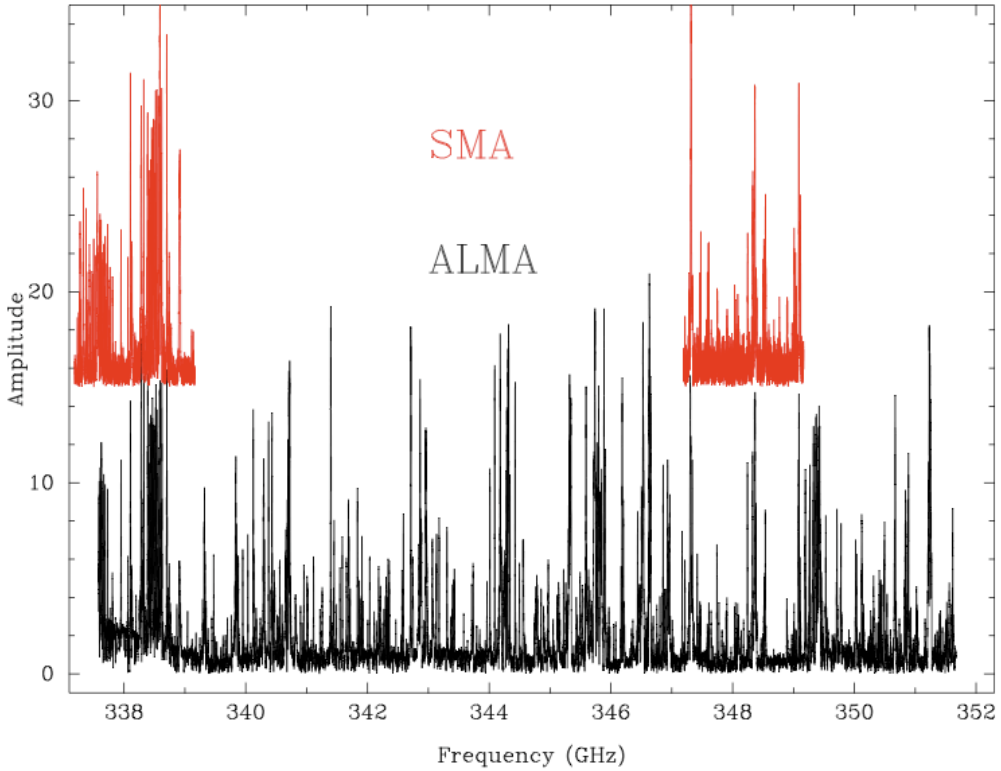


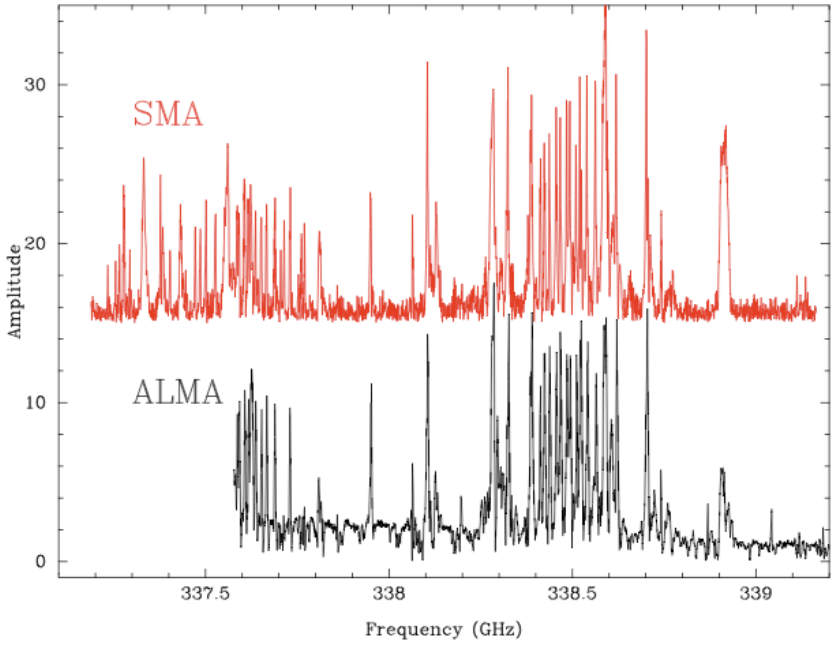
Dust continuum of the potentially planet forming debris disk: Beta Pictoris



Ionized Carbon (CII @ 158 μm) at z=4.43

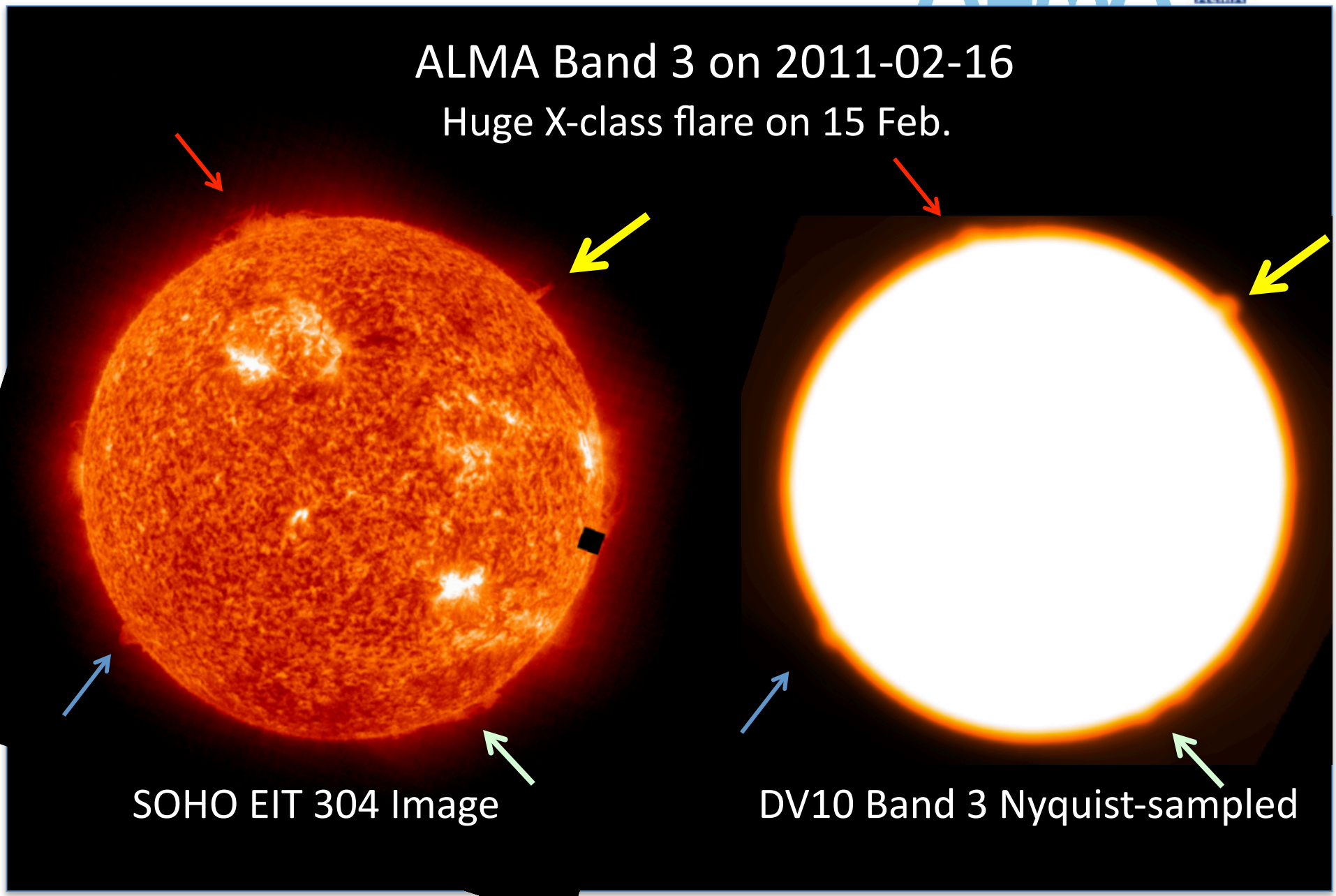
Towards Science Verification: Orion Band 7 test data





- See ALMA solicitation for Science Verification (SV) ideas http://www.almaobservatory.org/en/announcements-events/251-alma-scientif
- First SV data will be released near the call
- SV will continue throughout commissioning process

Single Dish Progress: The Sun



ALMA 1st Call March 31

At least:

- 16 antennas
- 4 Receiver bands 3, 6, 7, 9 ➔ 100, 230, 345, 670 GHz ➔ 3, 1.3, 0.8, 0.45 mm
- Expect 2 configurations: max baselines of ~125m and ~400m
  - @ 450 μm (670 GHz) resolutions of ~0.7" or ~0.2"
- Range of correlator modes: up to 4 spectral windows and 8 GHz bandwidth
  - @ 870 μm (345 GHz) 0.007 to 27 km/s channels with bandwidths 200 to 7500 km/s

➢ Additional capabilities **may** be announced with the call (limited mosaicing)

Process:

- Due date June 30, observing begins Fall 2011
- Observing will span 9 months, with ~600 hours available
- Off-line data reduction necessary
- User support from ALMA Regional Centers ARCs


How will It Work?

ALMA

- Single international proposal review: Science panels rank science, Uber panel adjusts for partner shares. Process Spitzer/HST – like
  - Chair of committee will be Neal Evans
  - Four Science Areas
  - A (best efforts), B (if time allows), C (filler), and will not be observed
- Proposals submitted using "Observing Tool" (OT) – Phase I
  - Technical Assessments by ALMA staff. If necessary modifications would lead to proposal falling outside call parameters, it will be deemed infeasible
- For approved projects Scheduling Blocks created using OT – Phase II
  - You will not ask for time (or tracks) instead you ask for a sensitivity. Observing Tool (OT) estimates time which is used for planning.
- Array will be dynamically scheduled. Highest ranked project for current weather will be observed. During Cycle 0 process will be manual.
- Total project time will likely be built up from a number of discrete observations

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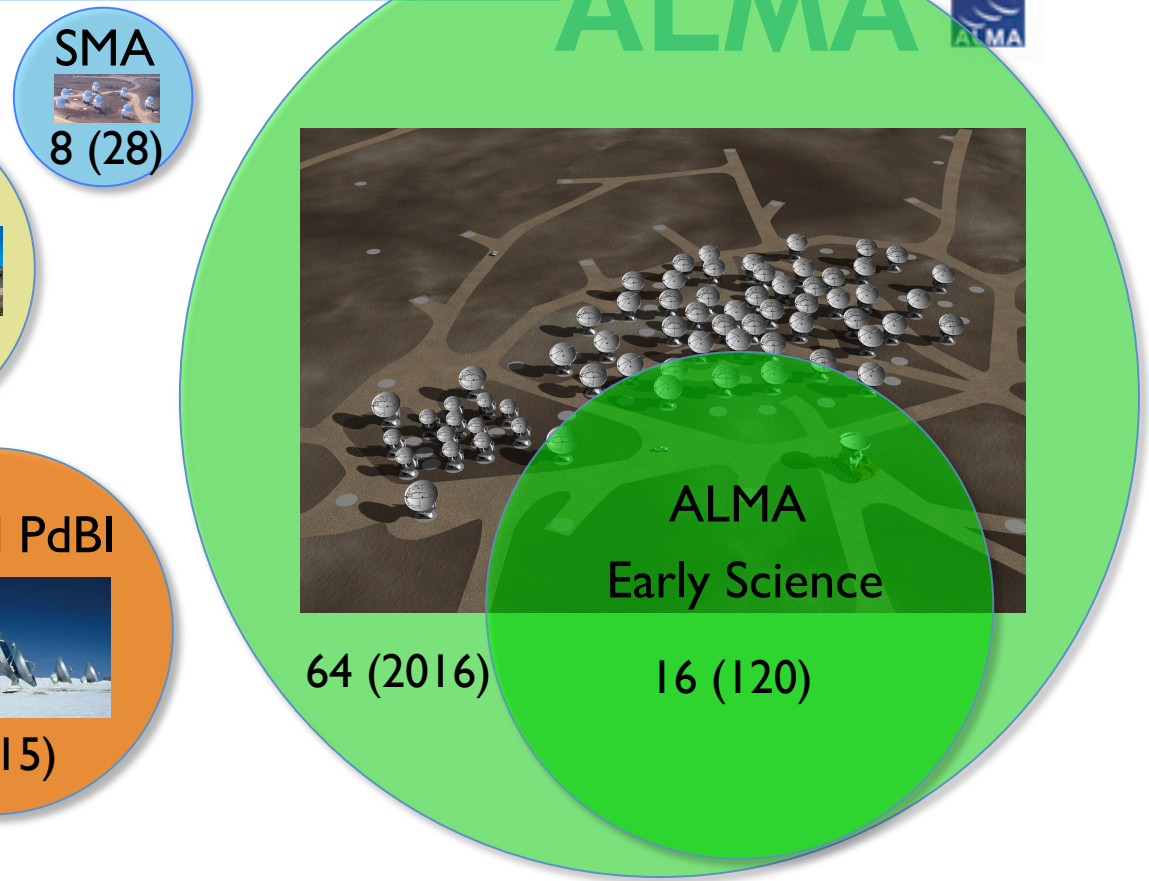
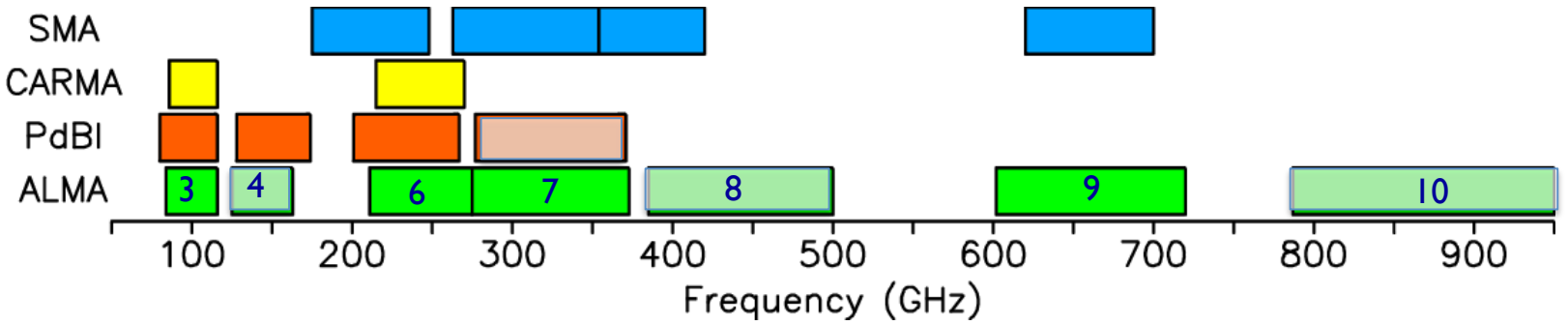
Comparison

Collecting Area



- Sensitivity goes as collecting area
- Imaging complexity goes as # of baselines

Spectral Coverage

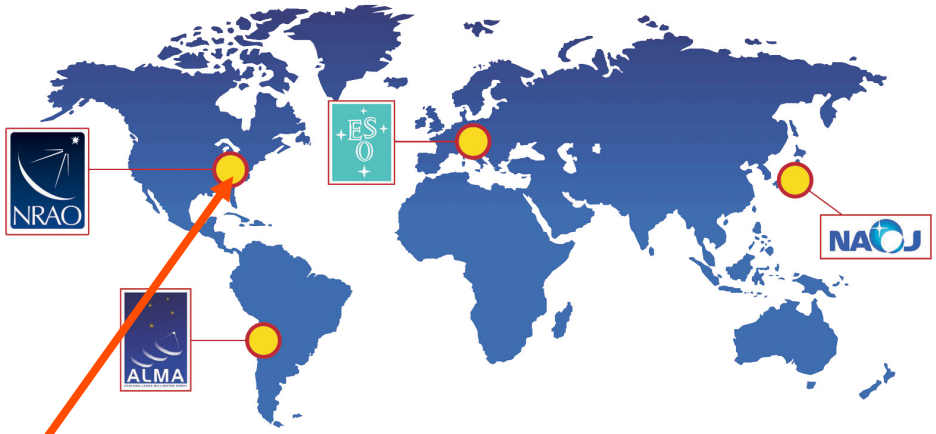


Science Support

- Three ALMA Regional Centers: ARCs
  - NA: Charlottesville, VA, USA
  - EU: Garching, Germany
  - EA: Mitaka, Japan

- North American ARC: US - Canada (7.25%) partnership for core support

- North American ALMA Science Center (NAASC) encompasses NA ARC and includes partnership with Taiwan



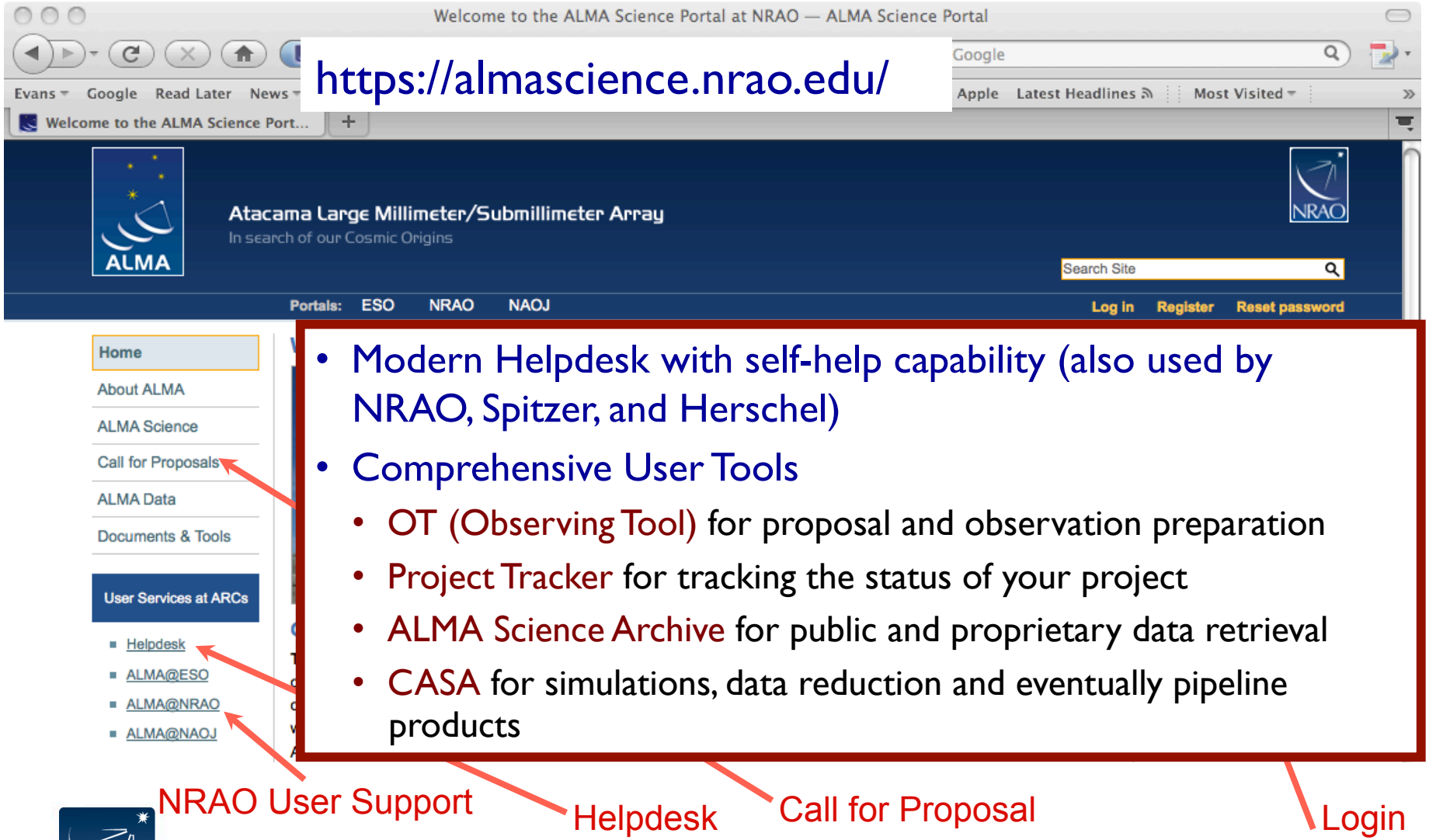
NAASC: One-stop shopping for:

- Proposal Help and Submission
- Observation preparation
- Data archive
- Data processing
- Community outreach

NAASC in Charlottesville, VA

What do you need to know?

ALMA



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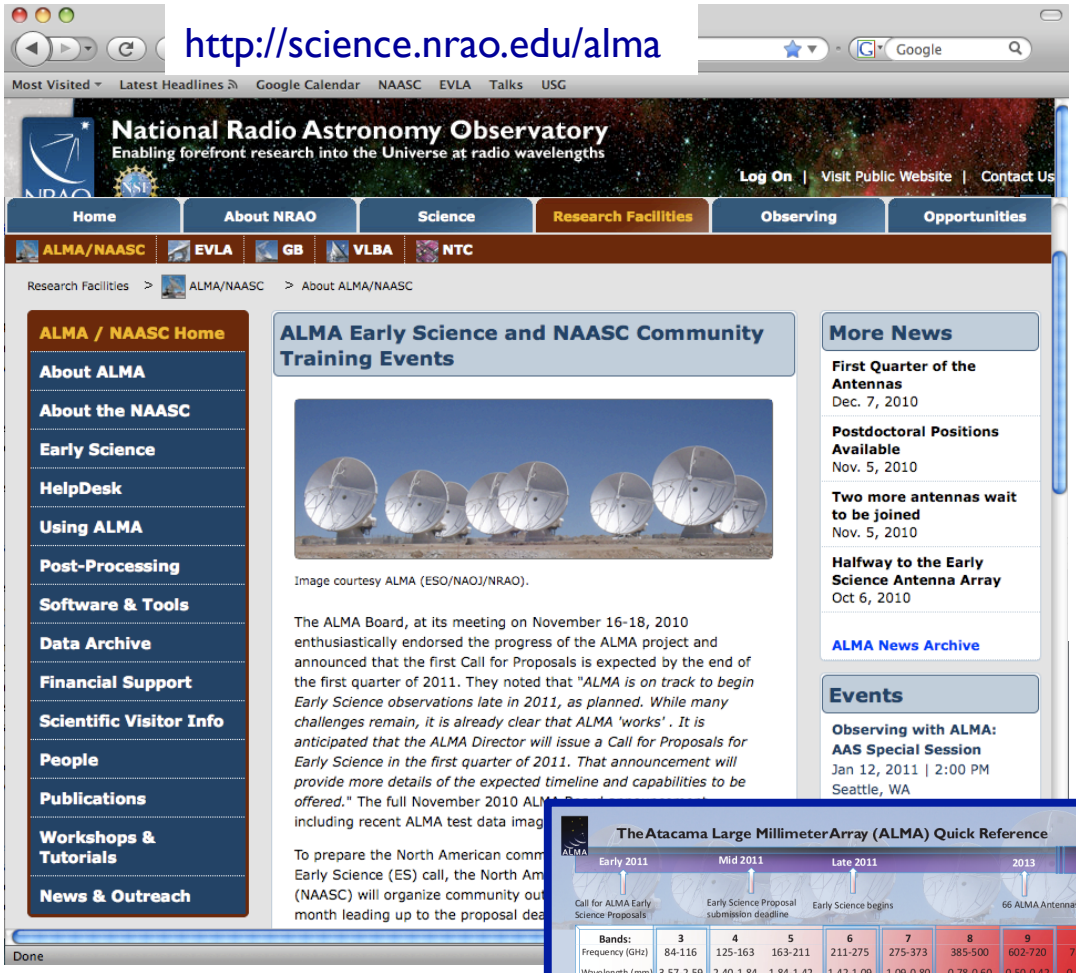
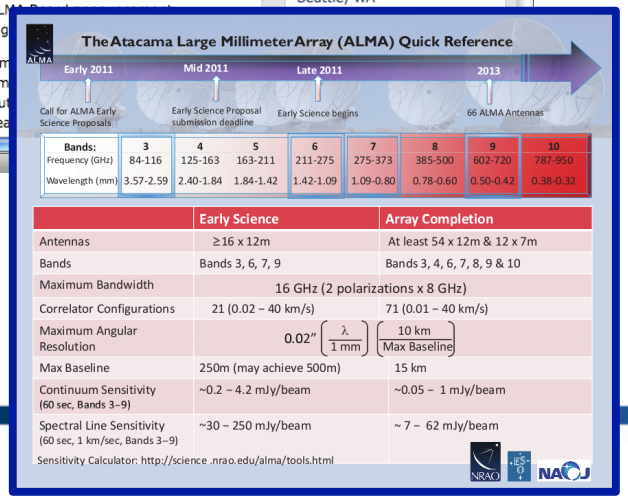
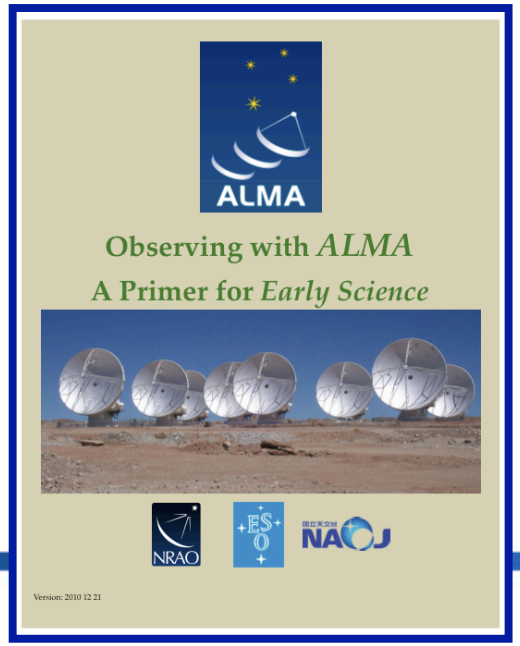
NAASC User Support

ALMA

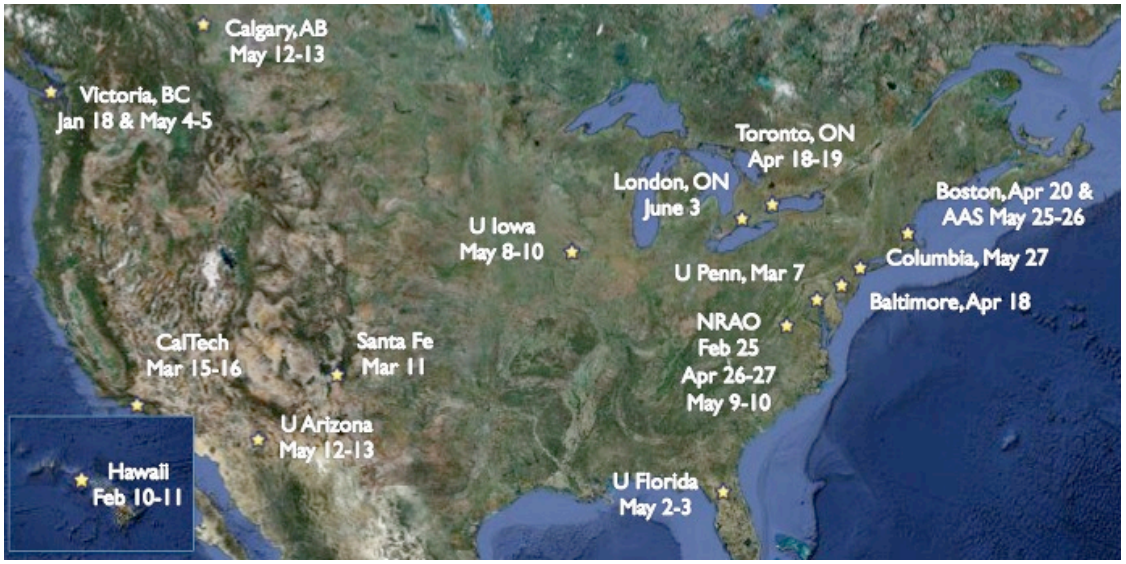




- Additional NAASC community support programs
  - Science workshops and tutorials
  - Face-2-Face visitor support
  - Publication page charge support
  - Post-docs and students

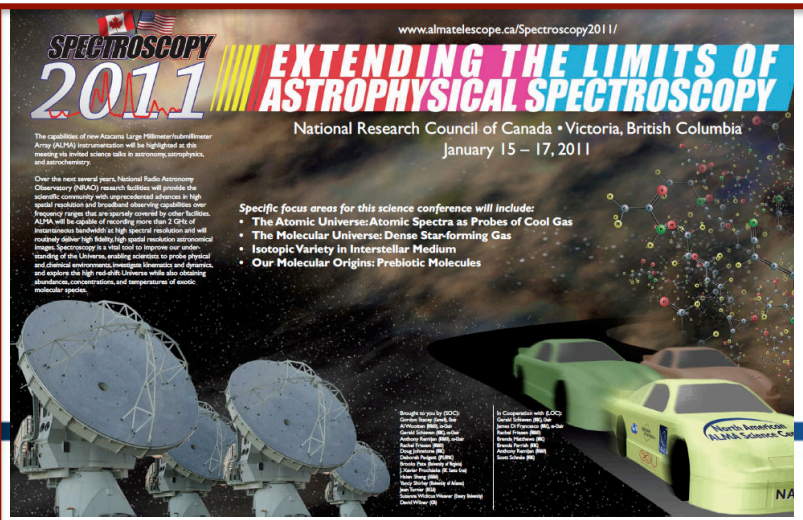


Upcoming NAASC Supported Workshops & Tutorials



- ES Community days ongoing across US
- After June 30 deadline, we will begin planning ALMA data reduction workshops

➔http://science.nrao.edu/alma/community1.shtml



Science Workshops

- 5th annual meeting Jan. 2011
- Announcement soon for next year's meeting

Summary

- Amazing scientific promise
- Tremendous progress in construction: 10 antennas at high site
- 1st Call for Early Science March 31,
  - already more collecting area and spectral coverage than current arrays
- Many training events coming up and proposals for ALMA community days being accepted
- One-Stop for community support at NAASC

Info common across project { http://almascience.nrao.edu/

NAASC specific programs { http://science.nrao.edu/alma/

www.almaobservatory.org

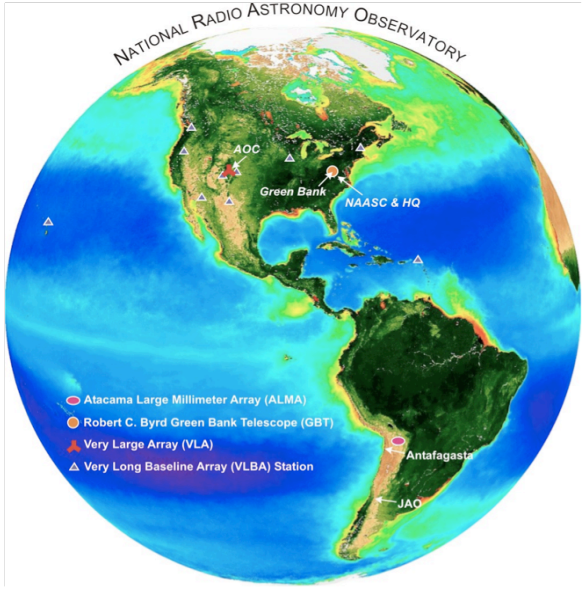
The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership among Europe, Japan and North America, in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere,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

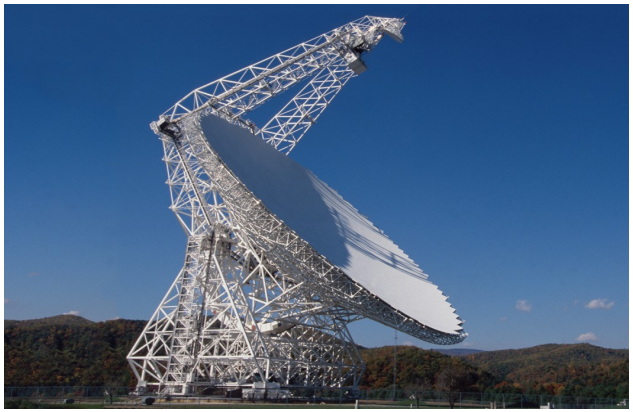
NRAO Beyond ALMA

3 Other Cutting-Edge Facilities That Complement ALMA

EVLA

GBT



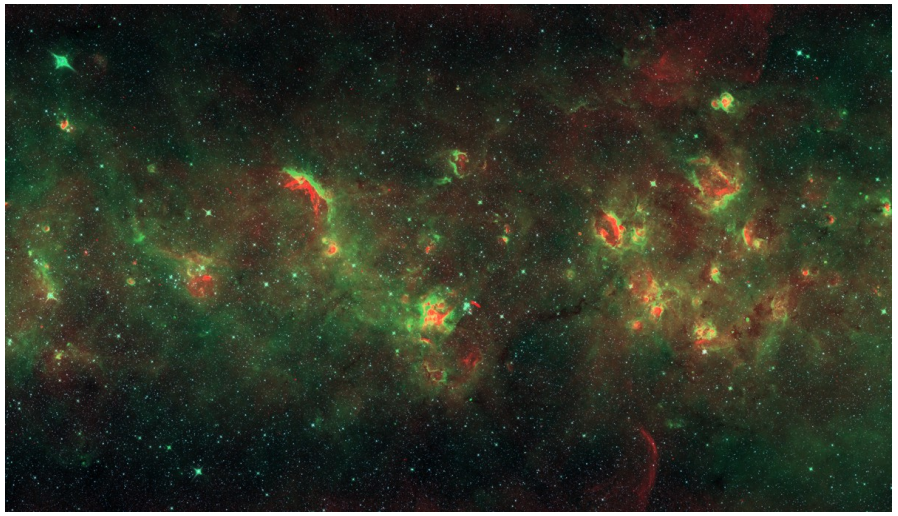


VLBA

ALMA

Expanded Very Large Array

- **The EVLA Era is here!**
- Continuous **spectral coverage** 1-50 GHz (λ 0.6-30 cm)
- **Powerful new WIDAR correlator** (built by Canada)
- 8 GHz **bandwidth:** 10X VLA continuum **sensitivity**
- **Early Science underway since March 2010**



Overall EVLA Performance Goals

- Providing orders of magnitude improvements in performance!

Parameter	VLA	EVLA	Factor
Continuum Sensitivity (1-σ, 1 hr.)	30 μJy	3 μJy	**10**
Maximum BW in each polarization	0.1 GHz	8 GHz	**80**
# of frequency channels at max. BW	16	16,384	**1024**
Maximum number of freq. channels	512	4,194,304	**8192**
Coarsest frequency resolution	50 MHz	2 MHz	**25**
Finest frequency resolution	381 Hz	0.12 Hz	**3180**
# of full-polarization spectral windows	2	64	**32**
(Log) Frequency Coverage (1 – 50 GHz)	22%	100%	**5**

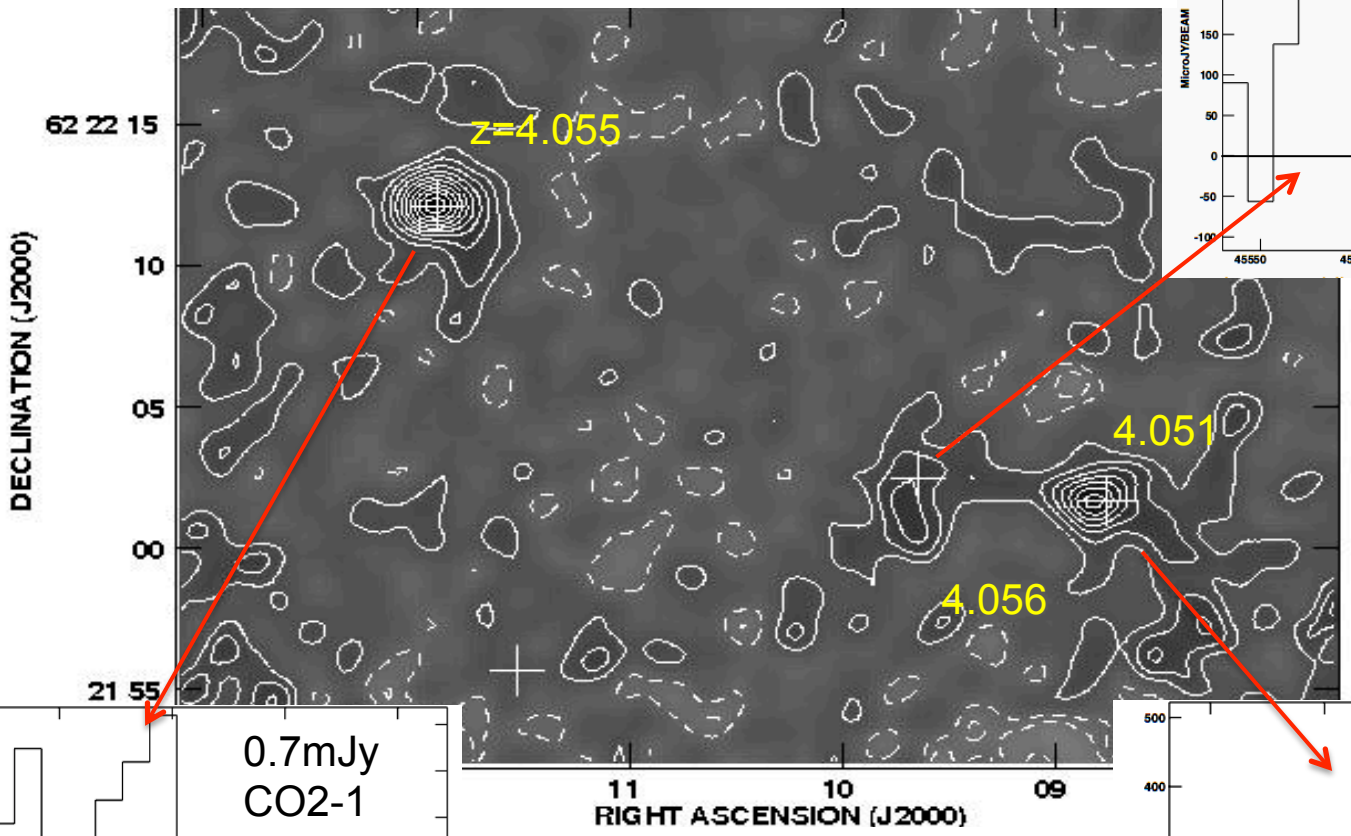
EVLA Milestones

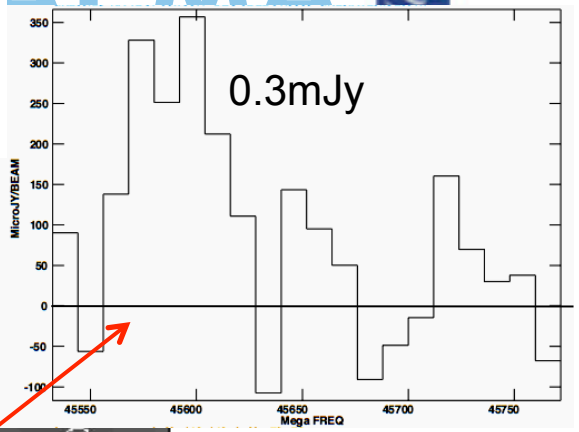
- All antennas now converted to EVLA standards.
- VLA correlator shut down January 2010.
- New 'WIDAR' correlator began operations March 2010.
- EVLA 'early science' OSRO and RSRO programs began March 2010, and will continue through 2012.
- Receiver implementation completed end of 2012.
- Full bandwidth (8 GHz/polarization) available in 2012.

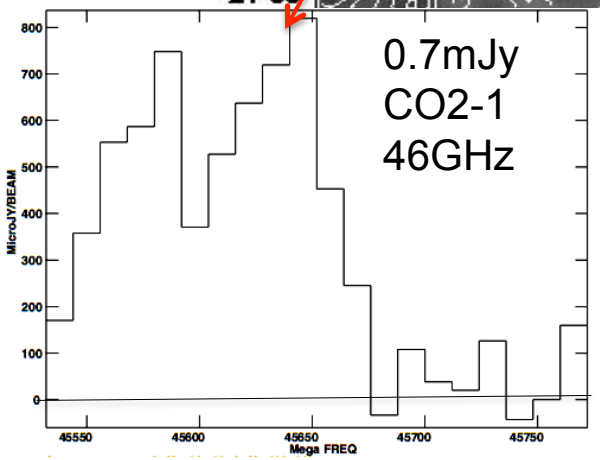
Evolving Universe – high z early galaxies.

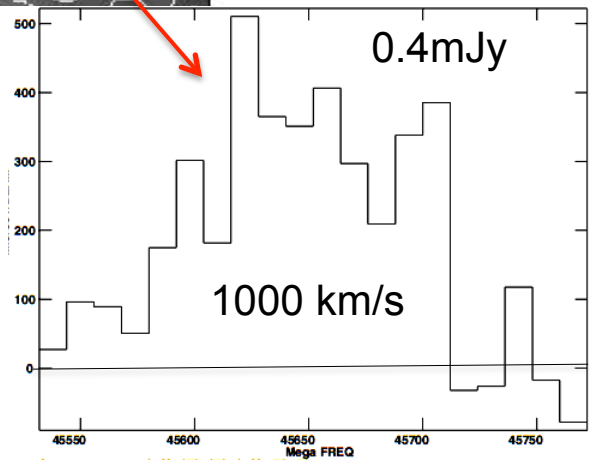
GN20 molecule-rich proto-cluster at z=4 (Daddi)

CO 2-1 in 3 submm galaxies, all in 256 MHz BW





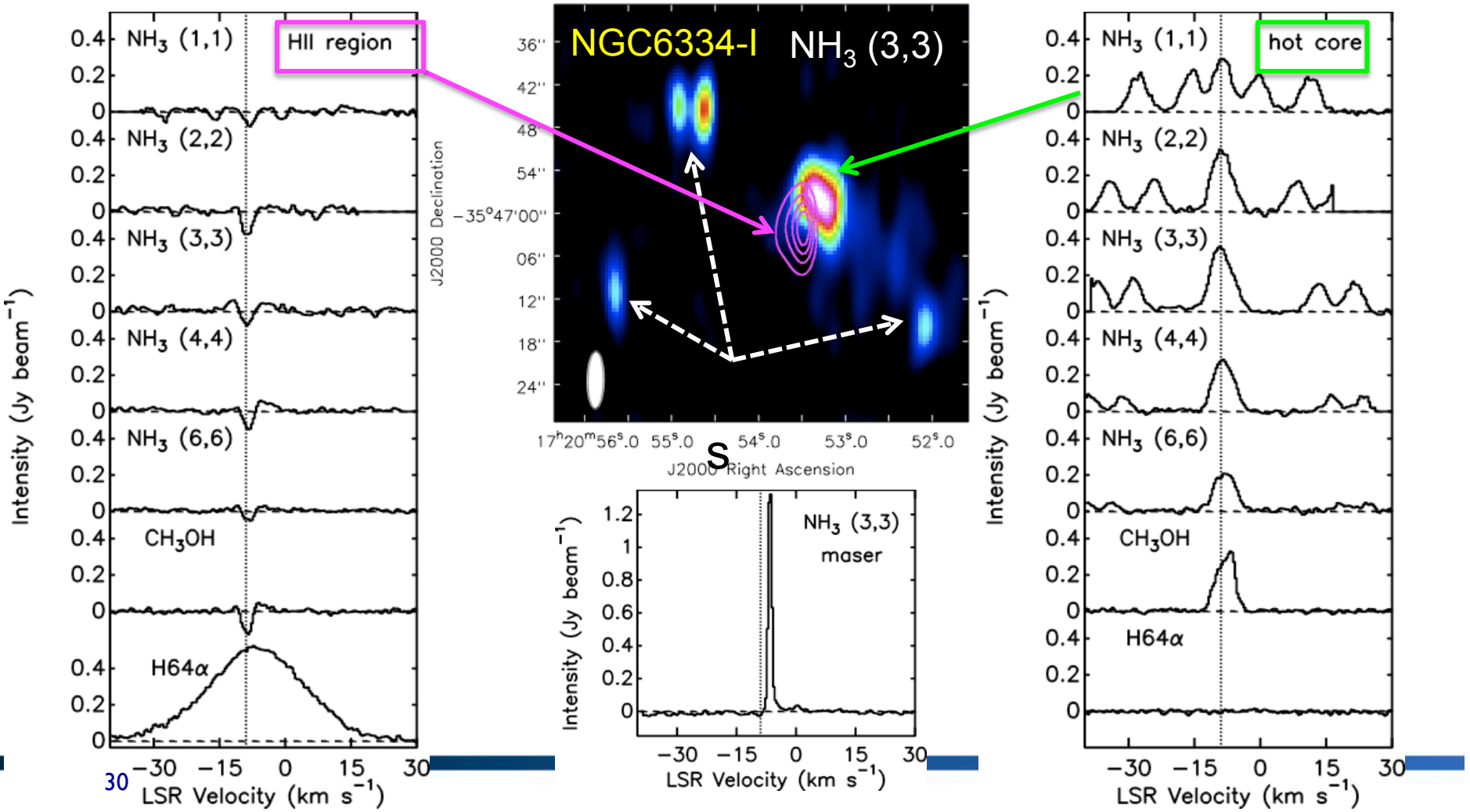




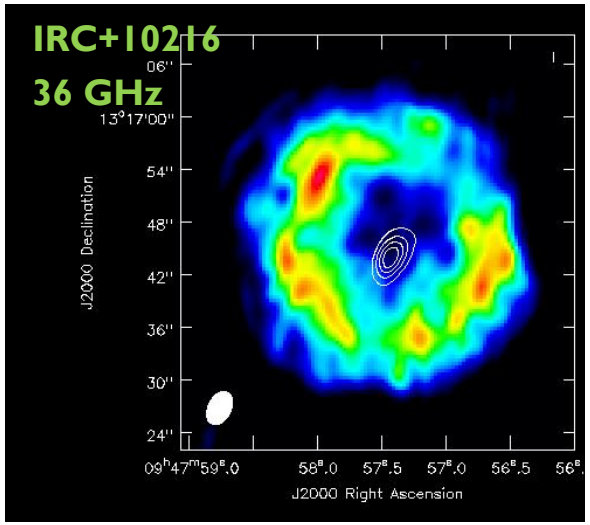
- SFR ~ 10^3 M_o/year
- M_{gas} ~ 10^{11} M_o
- Early, clustered massive galaxy formation

EVLA K-band: massive young stellar objects in NGC6334-I

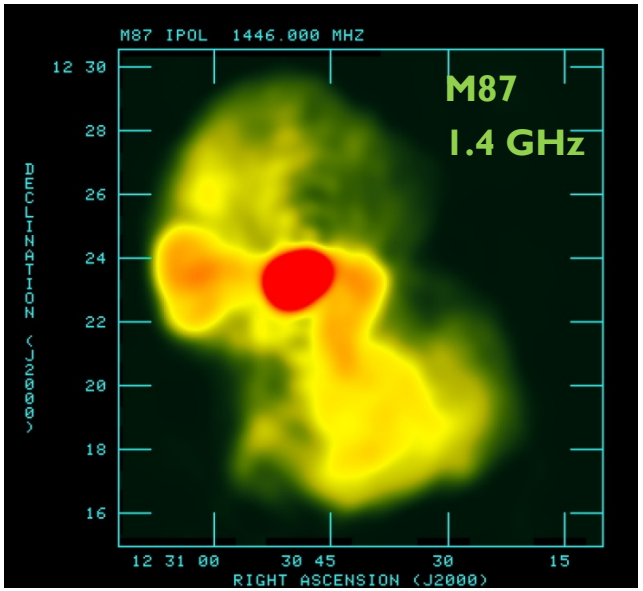
- Initial test for start of RSRO project AB1346
- 8 x 8 MHz subbands with 256 channels RR only; referenced pointing
- 10 minutes on source!

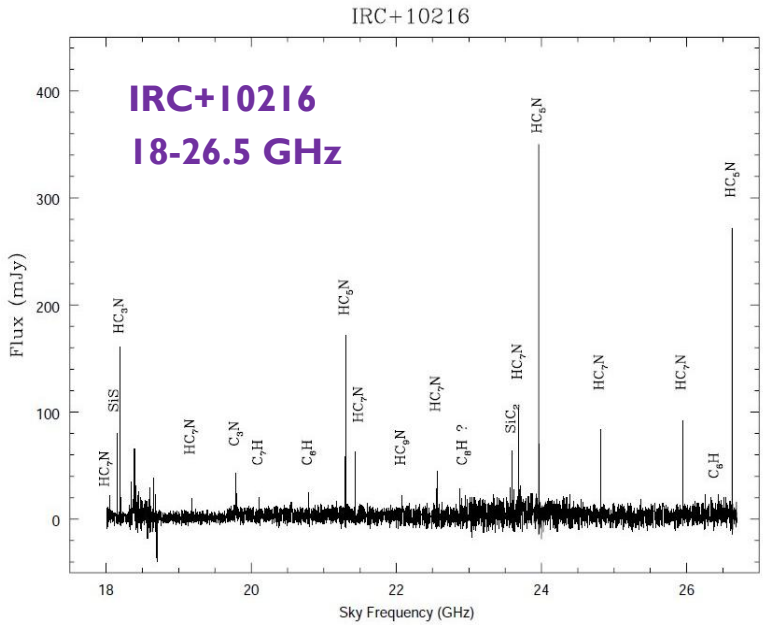


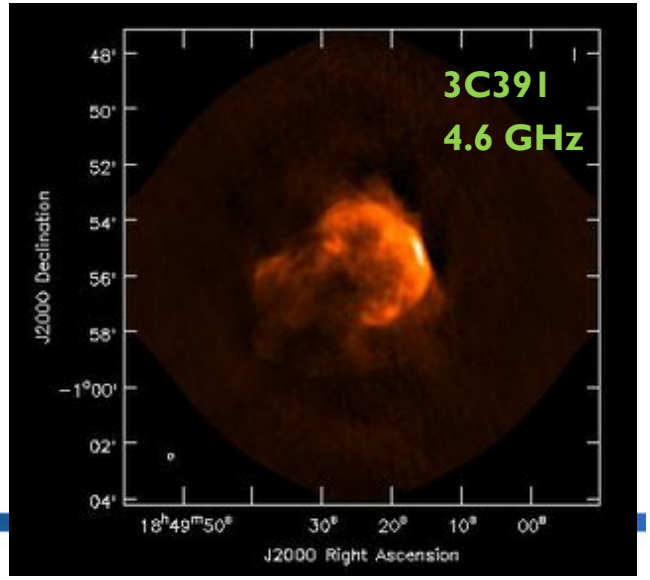
EVLA Demo Science



- Taken in low-resolution D and C configurations
- Higher resolution A and B configuration data forthcoming





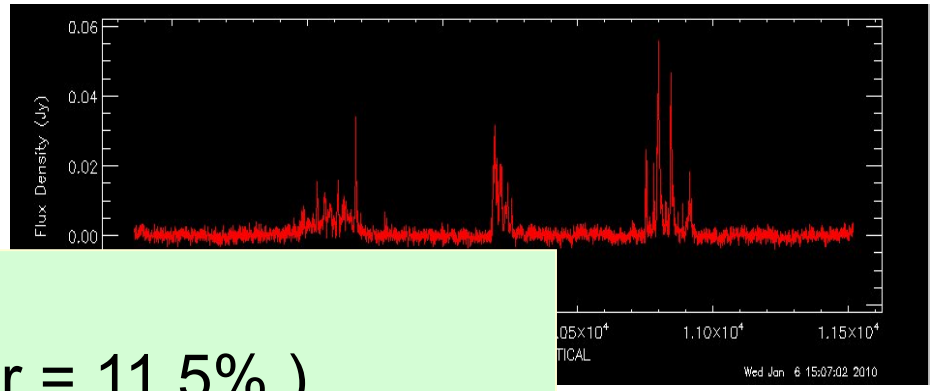


Very Long Baseline Array

- Ten 25m diameter radio telescopes
- Longest baseline: **8,600 km**
- **Highest resolution** imaging telescope: sub-milliarcsecond resolution
- **Highest precision** astrometric telescope: 10 μsec precision now!
- **Key Science Projects**
- **Sensitivity Enhancement**: >2 Gbps BW, upgrade C-Band receivers (international collaboration)

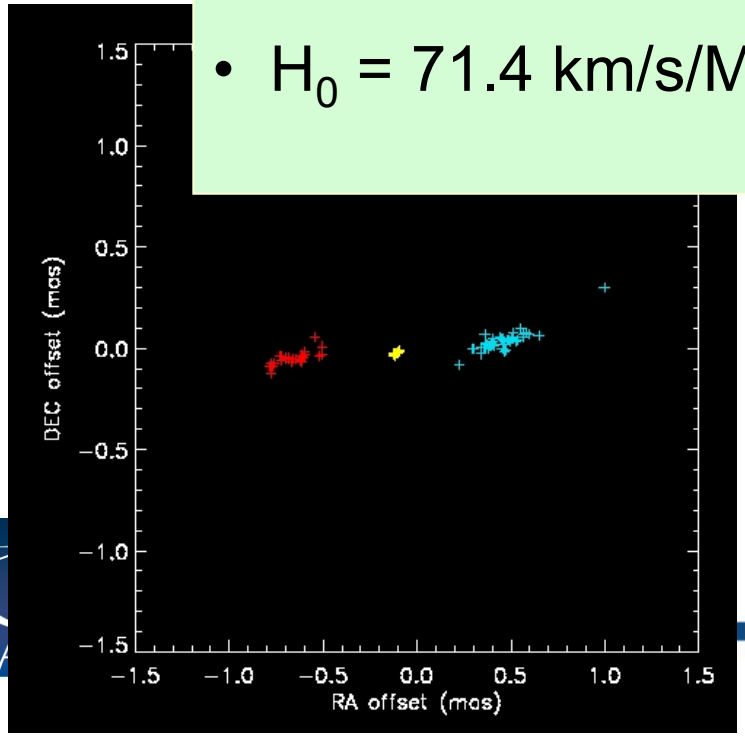
Mega-maser Cosmology Project

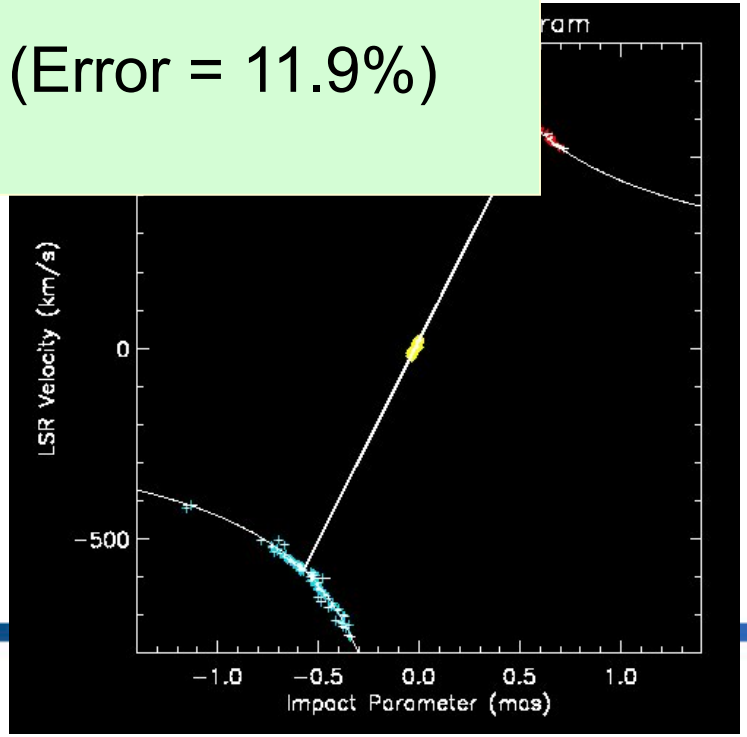
Angular Diameter Distance to NGC 6264 and the Hubble constant



46 hou

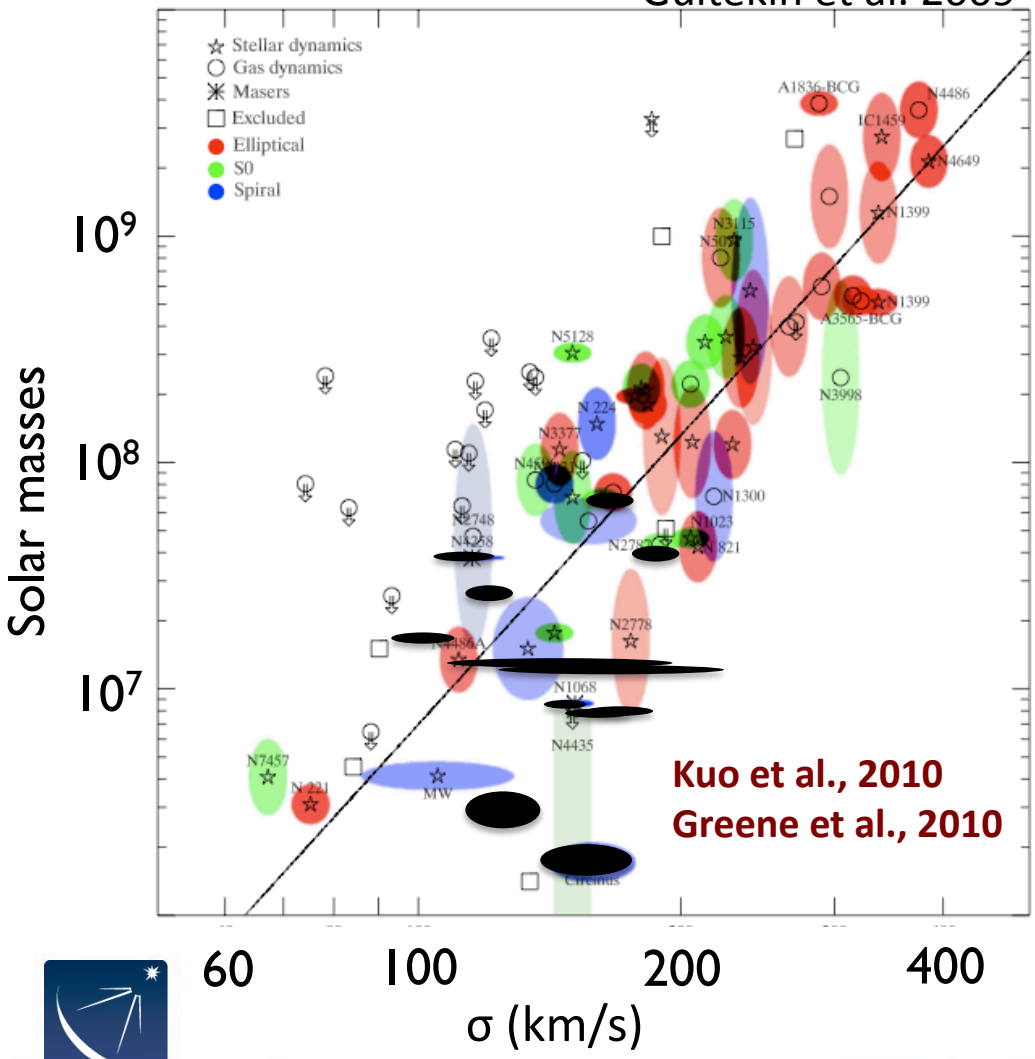
- D_A = 141 Mpc (Error = 11.5%)
- H_0 = 71.4 km/s/Mpc (Error = 11.9%)





M-σ Relation (?)

Gultekin et al. 2009



- Black ovals: Sy2 galaxies with black hole mass measured via H_2O megamasers
- **Accuracy of black hole masses limited by H_o accuracy only**
- Some megamaser galaxies fall below the M-σ relation defined by elliptical galaxies

Green Bank Telescope

- Largest **fully-steerable** radio telescope – offset parabola
- **Sensitivity** & **frequency coverage** (υ: 300 MHz-98 GHz; λ: 0.3-100 cm)
- **Detector suite** for spectroscopy, pulsar observations, continuum, VLBI
- **Focal Plane Array (FPA)**
  - KFPA (1cm), MUSTANG
  - developing W-Band (3mm) array and Lband (~20cm) cooled phased array