

ALMA: Atacama Large MM/Submm Array

Status and Overview



Crystal Brogan
(NRAO/North American ALMA Science Center)

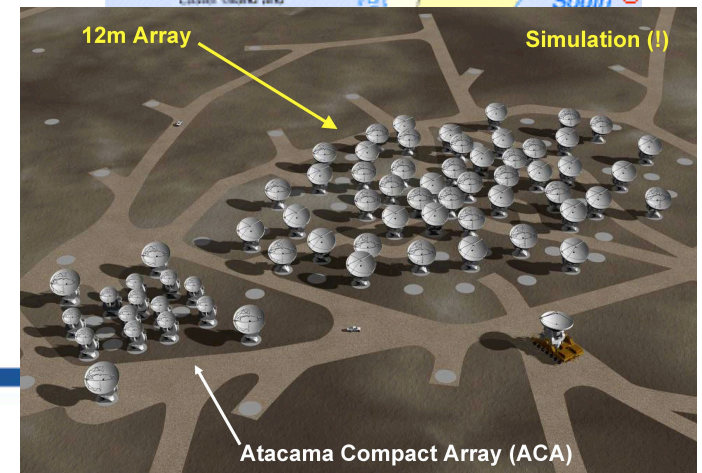


Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array



The Atacama Large MM/Submm Array :ALMA

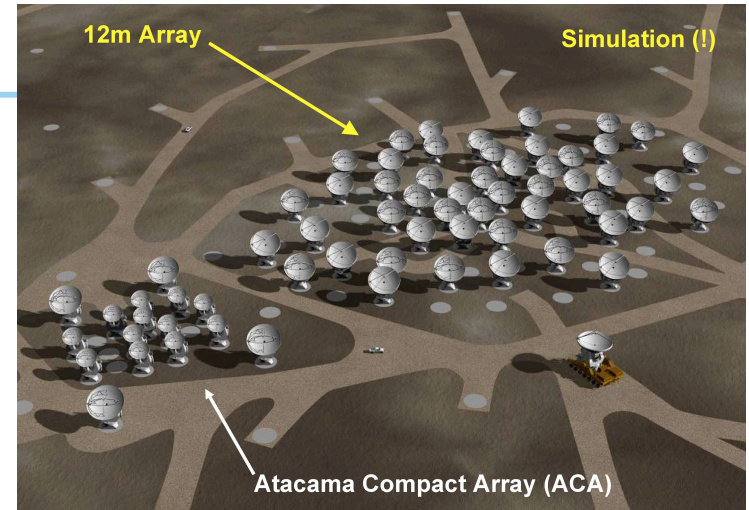
- A global partnership to deliver a transformational millimeter/submillimeter interferometer
 - North America (US, Canada, Taiwan)
 - Europe (ESO)
 - East Asia (Japan, Taiwan)
 - In collaboration with Chile
- 5000m (16,500 Ft) site in Chilean Atacama desert
- Main Array: 50 x 12m antennas
 - + Total 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 μ m)
- 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

- A resource for ALL astronomers

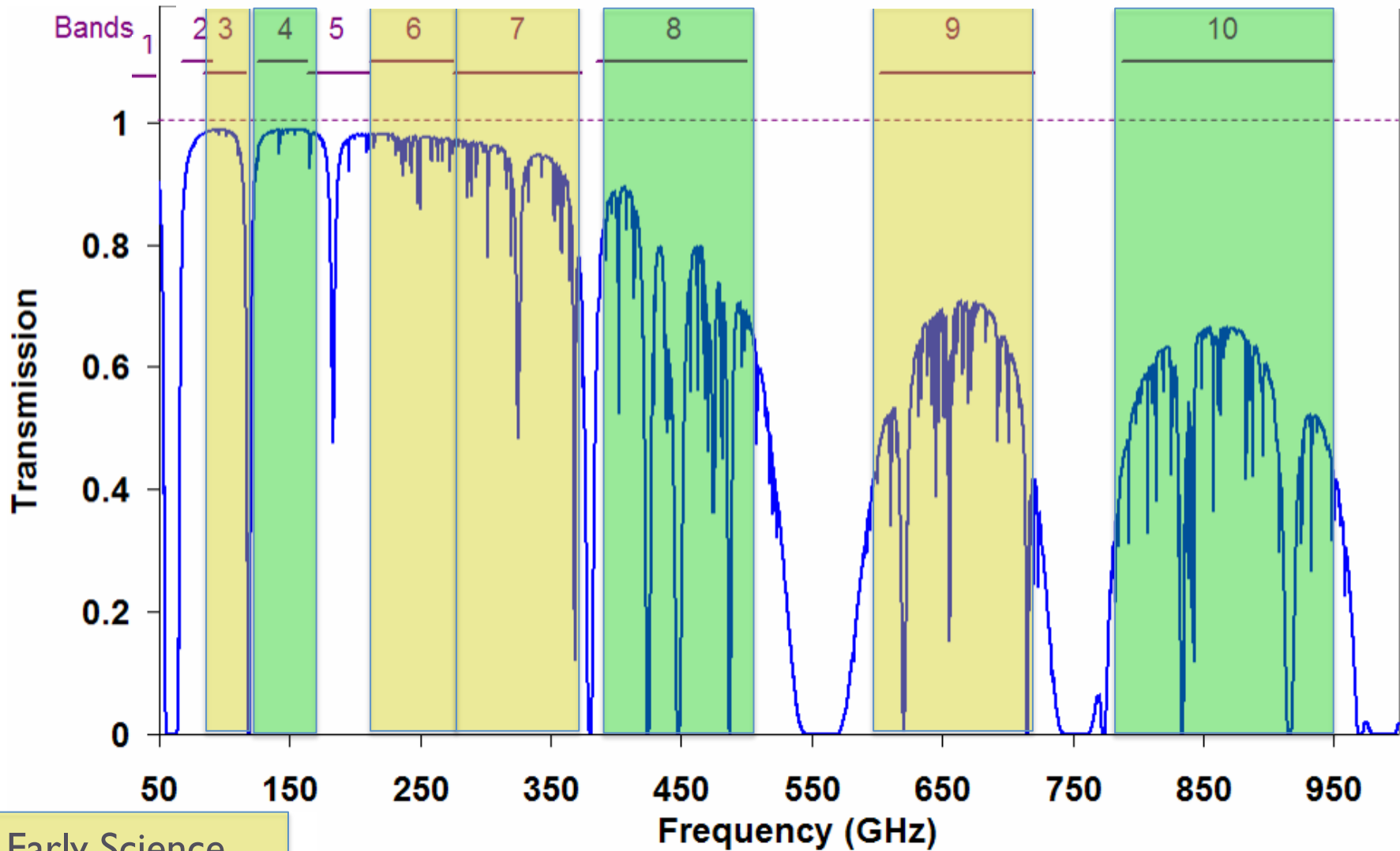


ALMA will be 10-100 times more sensitive and have 10-100 times better angular resolution compared to current millimeter interferometers

Receiver Bands



Chajnantor - 5000m, 0.25mm pwv

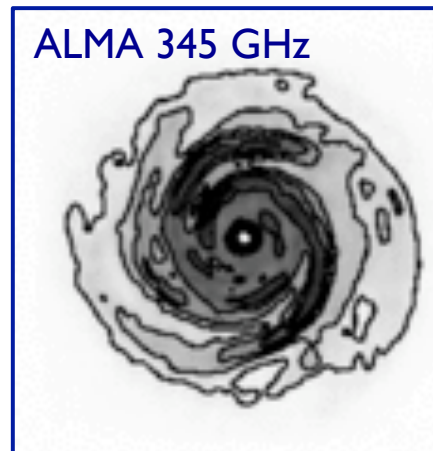
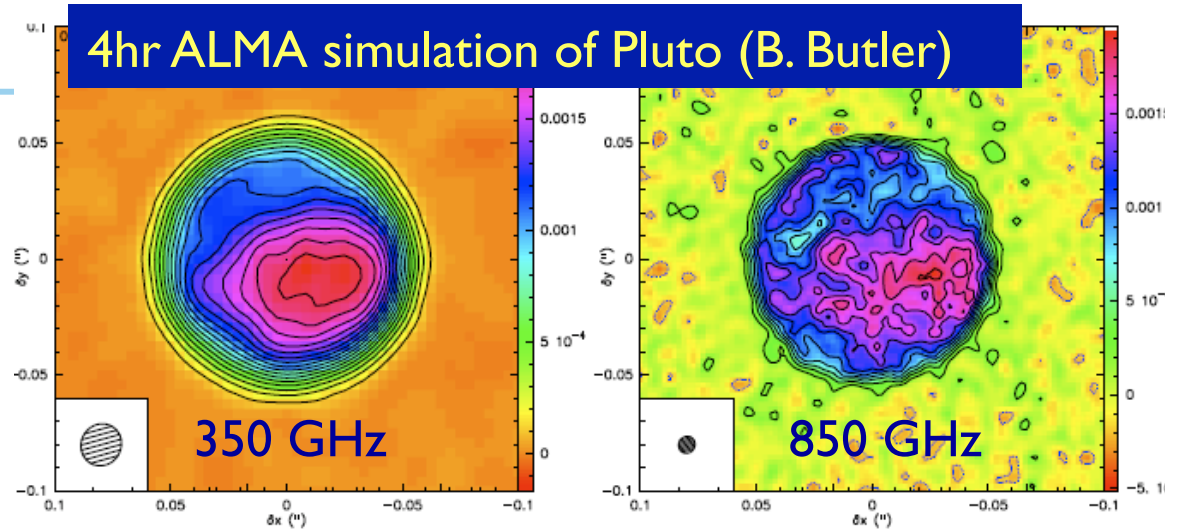


Early Science

Full Operations

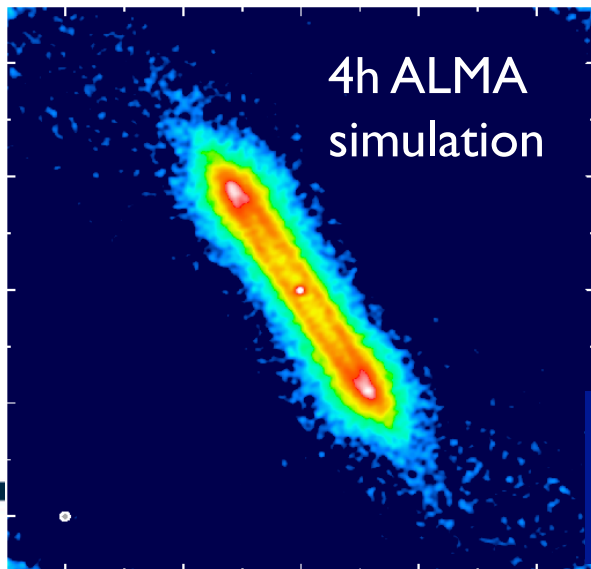
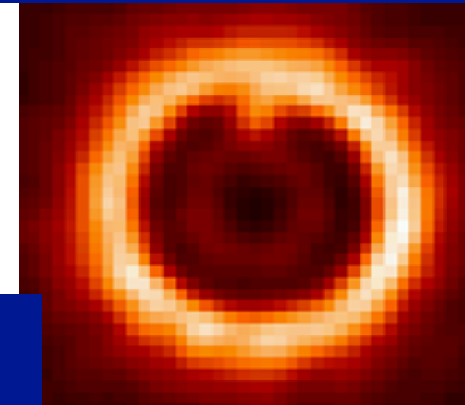
Breadth of Full Science: Galactic

- Exploring the Solar System from the sun to minor planets and moons
- Revealing disks and forming protoplanets around nearby stars



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)

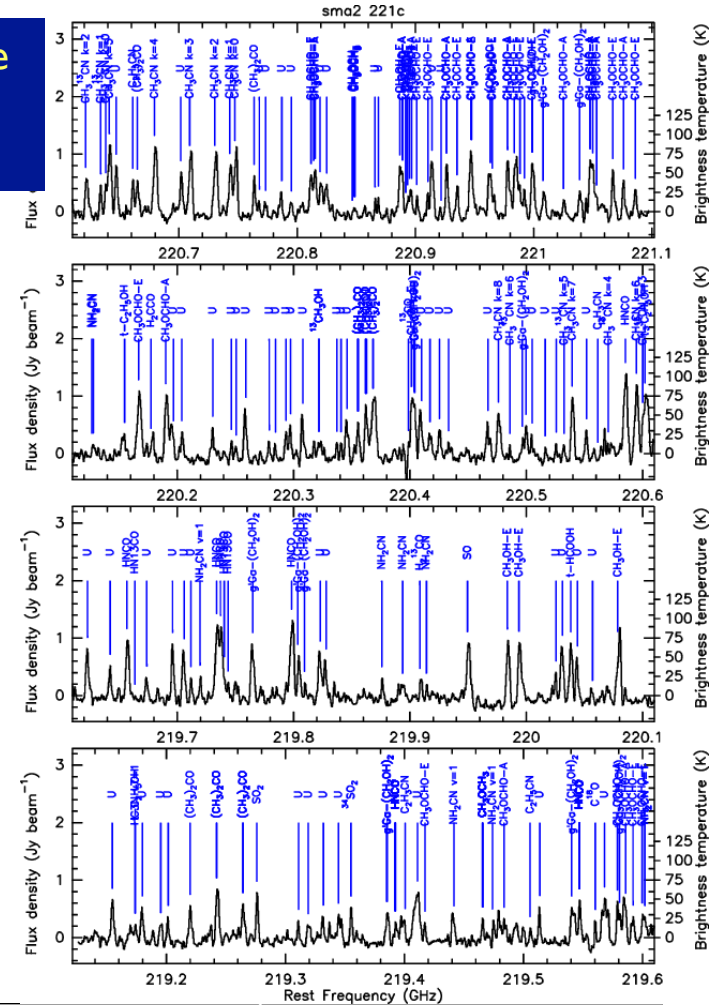
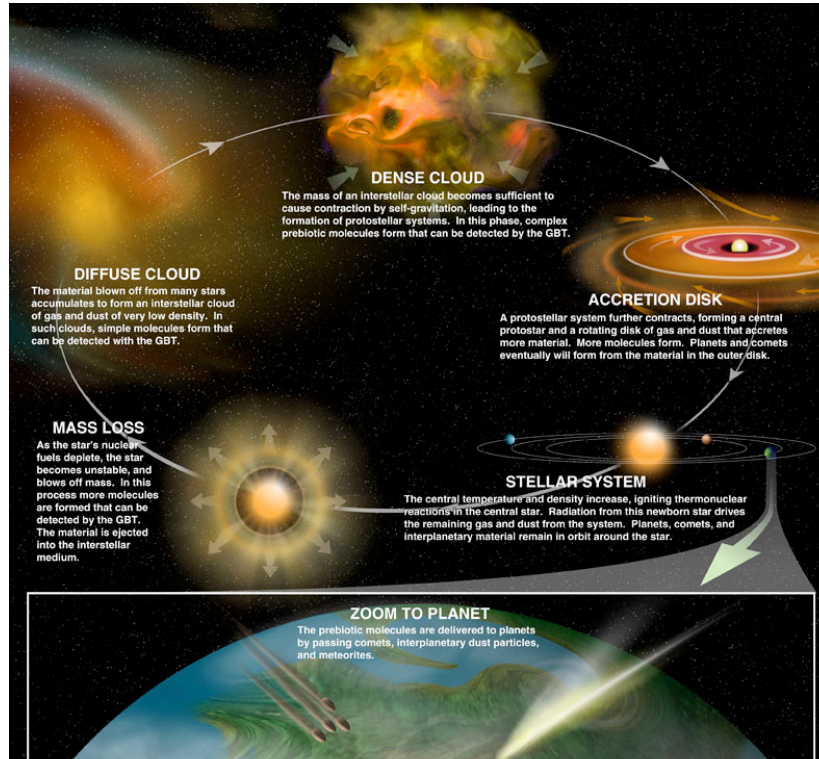


Simulation of dust in Beta Pictoris debris disk using model by Chris Stark (D. Wilner)

Breadth of Full Science: Galactic

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

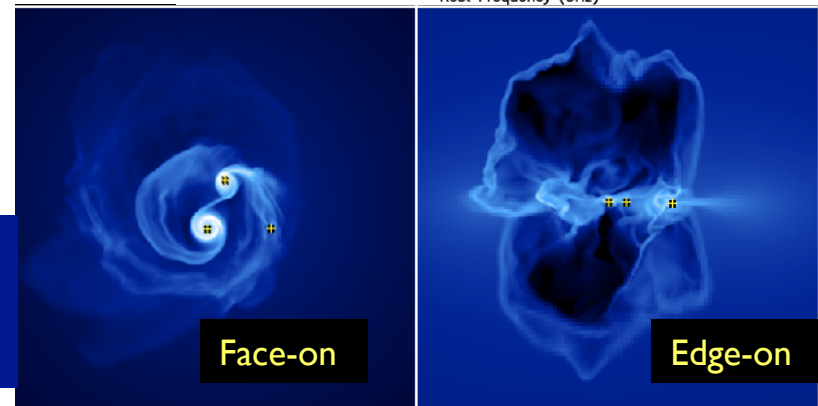
- The life cycle of molecular gas and chemistry



- 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)

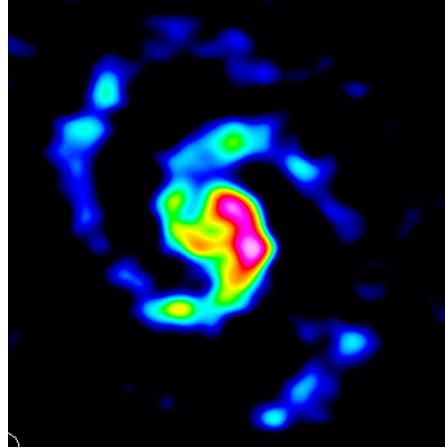


Breadth of Full Science: Extragalactic

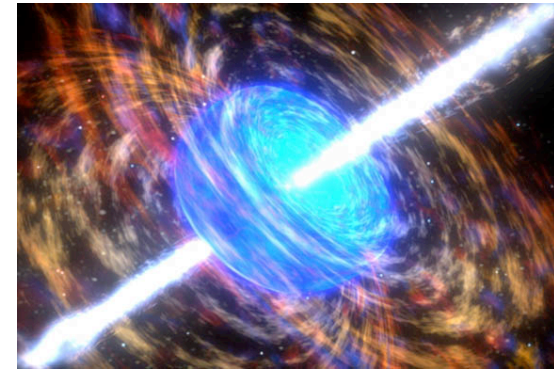


- Detailed imaging of dust and gas in nearby galaxies

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

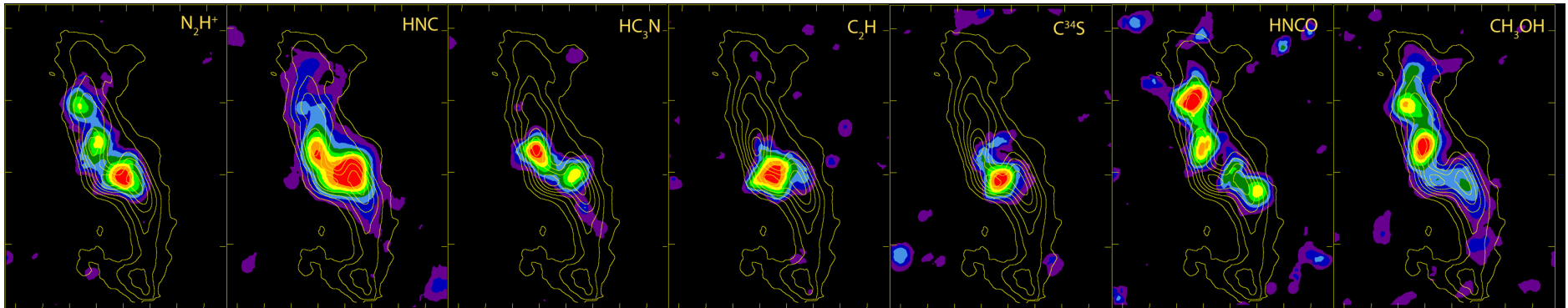
HC_3N

C_2H

$C^{34}S$

HNCO

CH_3OH

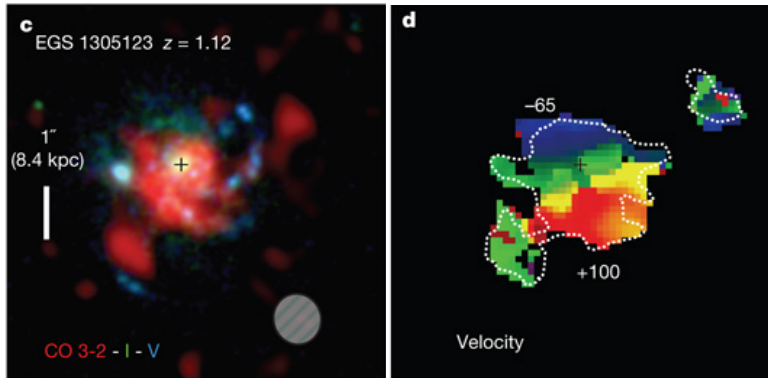


IC 342 with OVRO at 3 mm (Meier & Turner 2005); with ALMA chemical census of all nearby galaxies possible

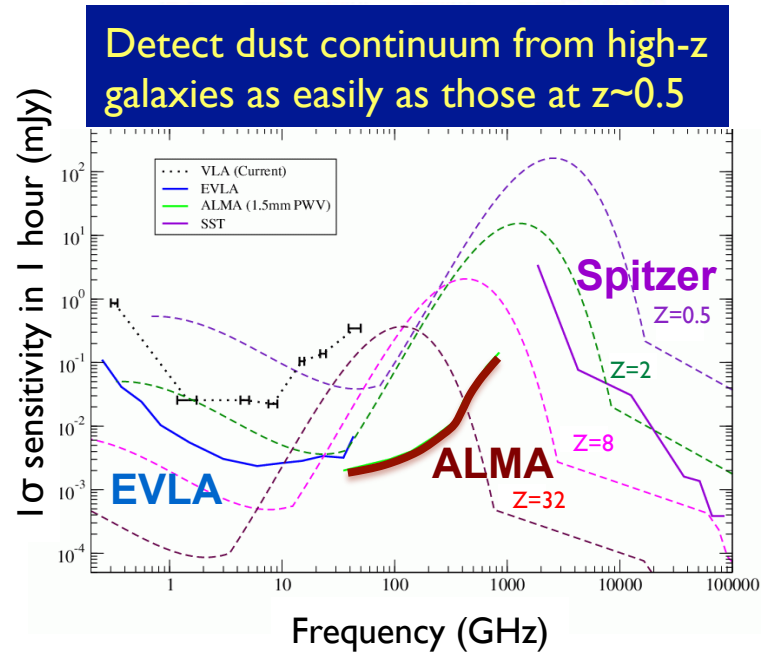
Breadth of Full Science: Extragalactic



- Imaging dust and gas from high redshift galaxies

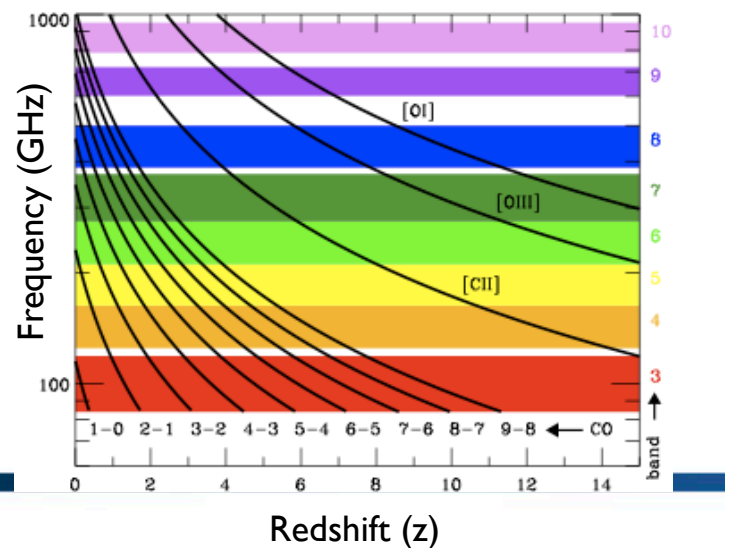


CO(3-2) with PdBI in 20 hours at $Z=1.1$ (Tacconi et al. 2010); full ALMA in a few hours

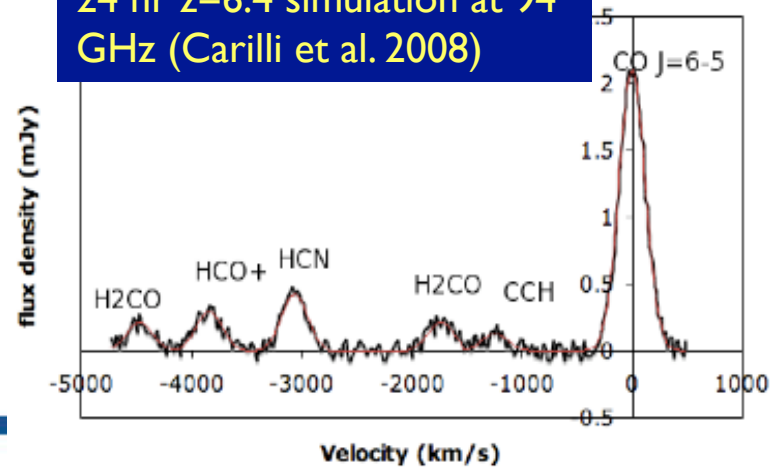


Detect dust continuum from high-z galaxies as easily as those at $z\sim 0.5$

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



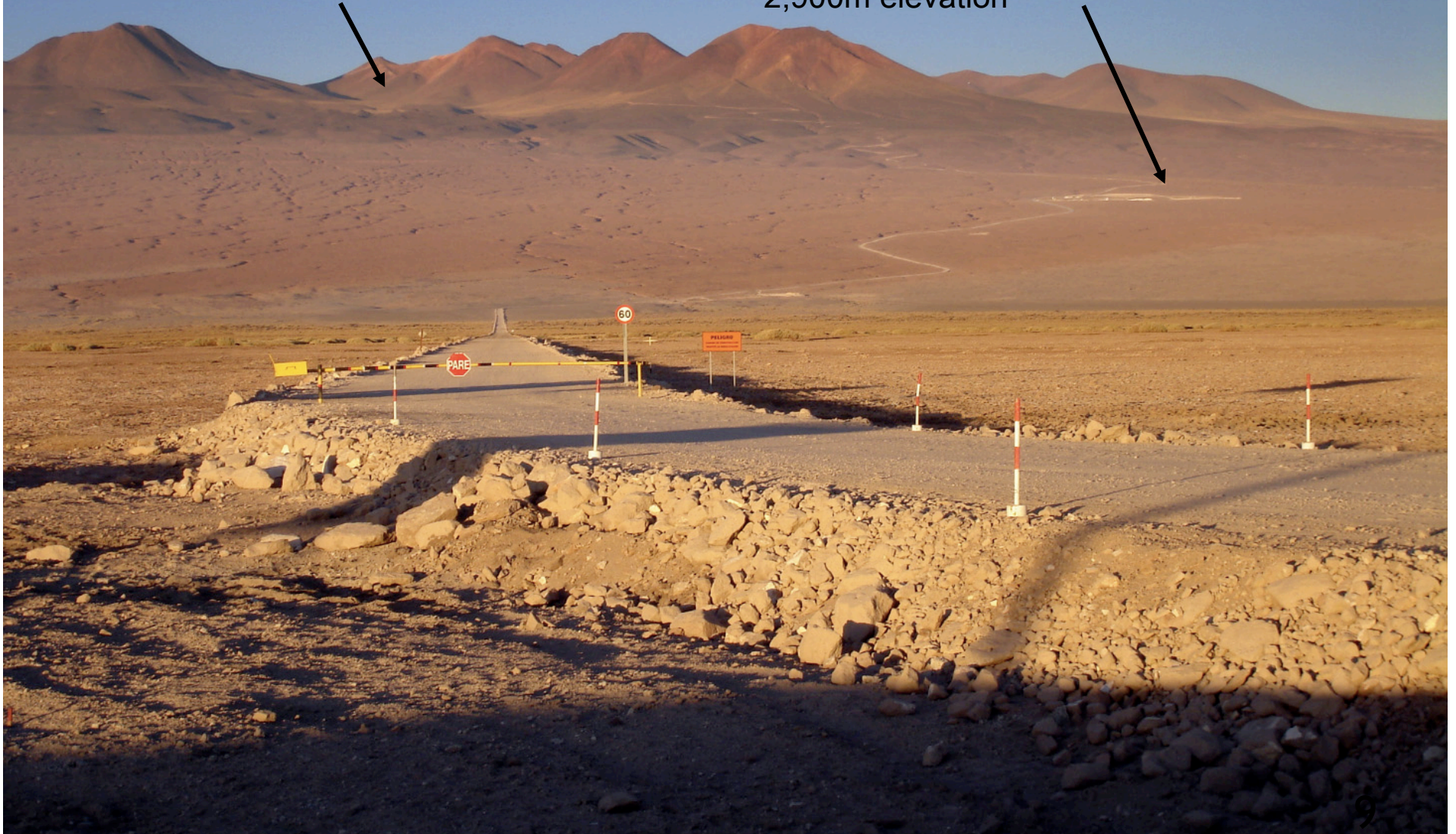
24 hr $z=6.4$ simulation at 94 GHz (Carilli et al. 2008)



The Road to ALMA

43 km to Array Operations Site (AOS)
5,000m elevation

15 km to Operations Support Facility (OSF)
2,900m elevation



Operations Support Facility (2900m level)



Melco, Vertex, and AEM,
(EA), (NA), (EU) antenna assembly
Contractors camp



There are now >27 antennas in various stages of completion

Progress at the Array Operations Site at 5000m → the “high site”

ALMA 

11



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

Current antenna count = 10



ALMA Timeline

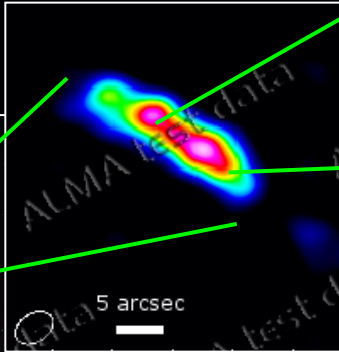
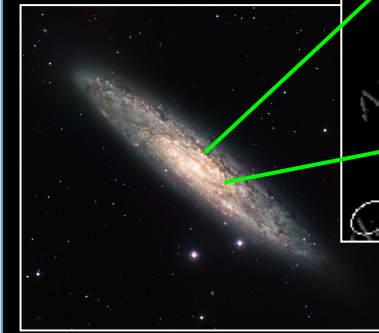
All Last Year (2010)	Commissioning (began Late 2009)
March 31 2011	1st call for Early Science Proposals
3 rd Quarter 2011	Early Science observing begins
Late 2012	Pipeline images for standard modes
Late 2013	Baseline ALMA construction complete



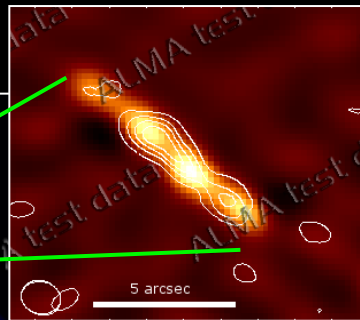
Commissioning: Stunning Test Images



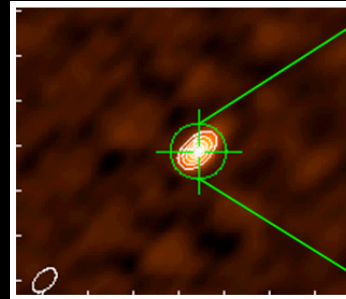
The heart of a star forming galaxy: NGC253



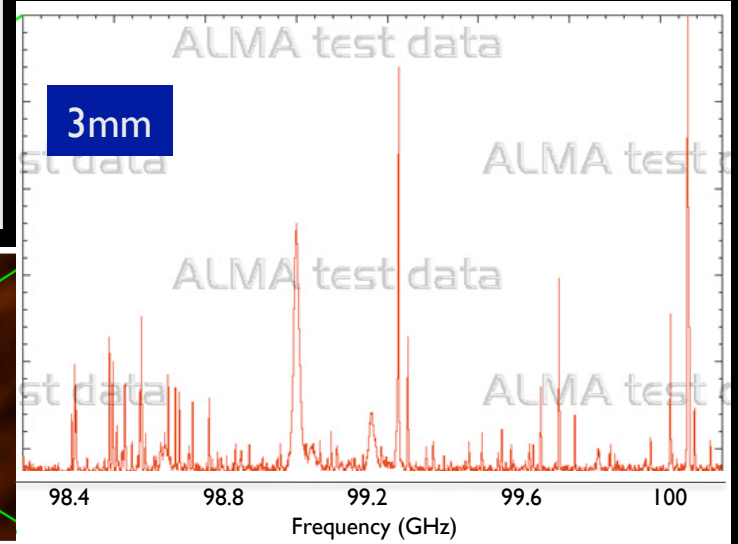
CO(2-1): 220 GHz;
1.3mm



Continuum: 670 GHz;
450 μ m

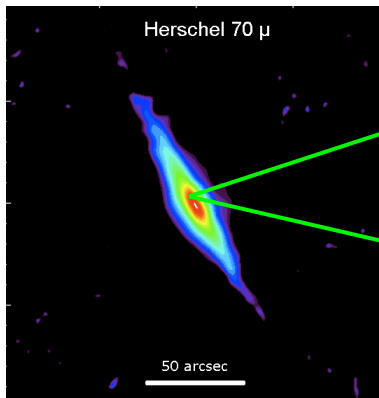


Spectral line forest from a Galactic massive protostar

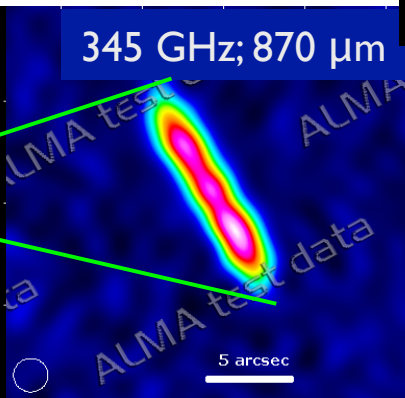


Herschel 70 μ

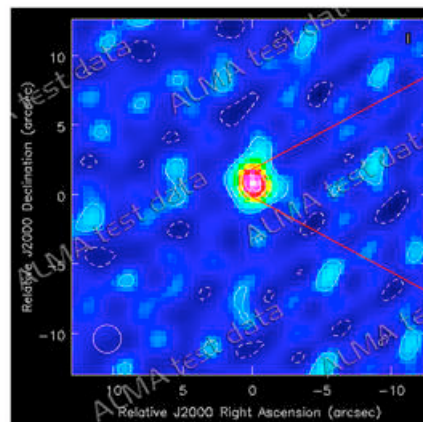
345 GHz; 870 μ m



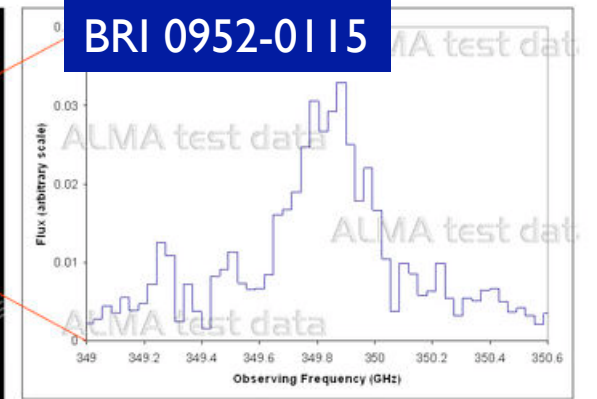
50 arcsec



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

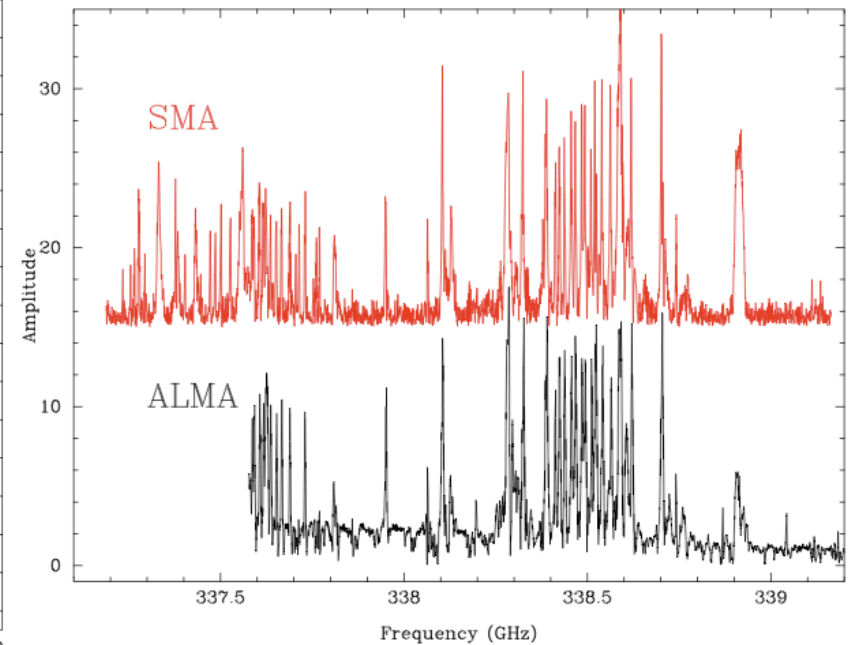
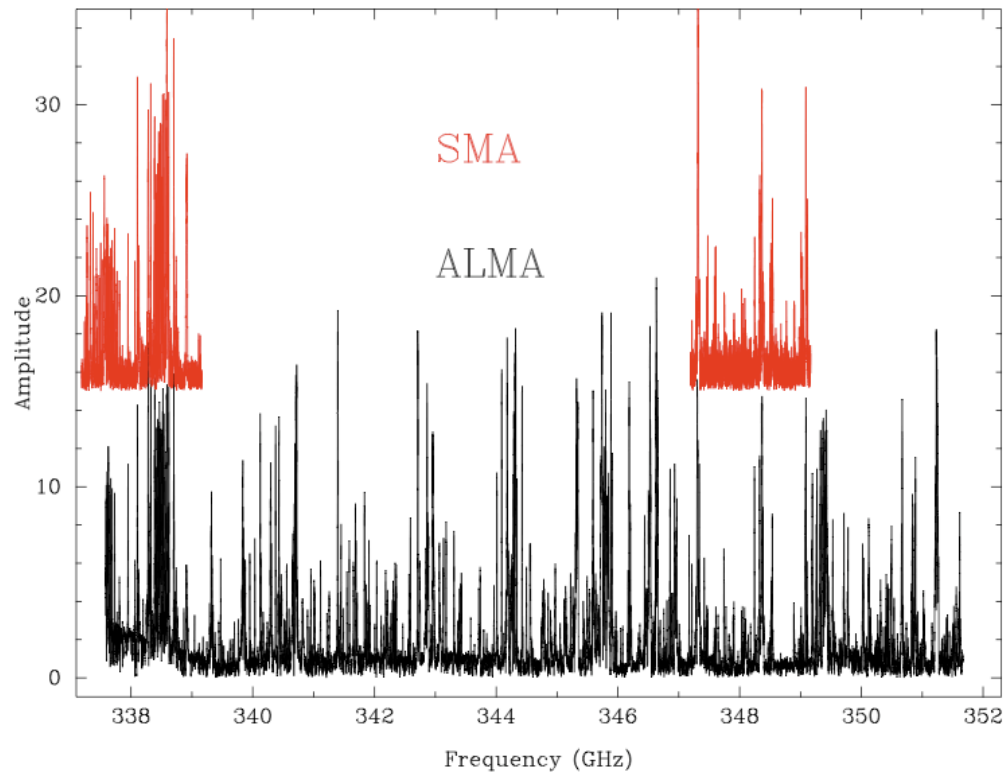


BRI 0952-0115



Ionized Carbon (CII @ 158 μ m) at z=4.43

Towards Science Verification: Orion Band 7 test data



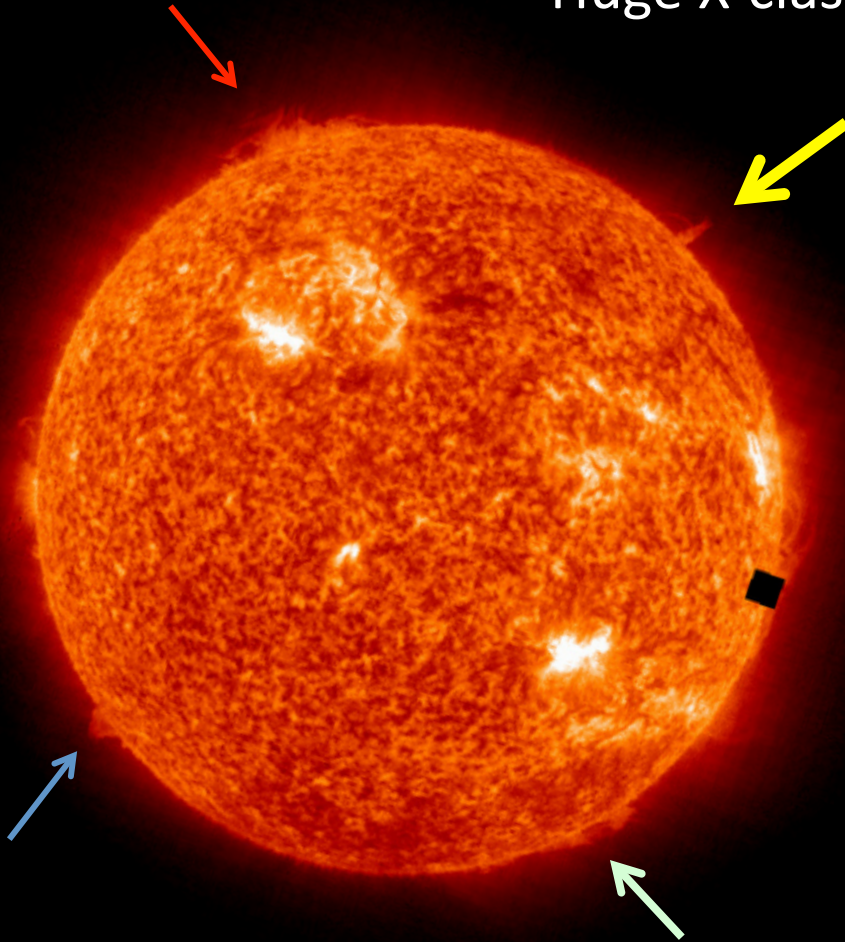
- See ALMA solicitation for Science Verification (SV) ideas
<http://www.almaobservatory.org/en/announcements-events/251-alma-scientif>
- First SV data will be released near the call
- SV will continue throughout commissioning process



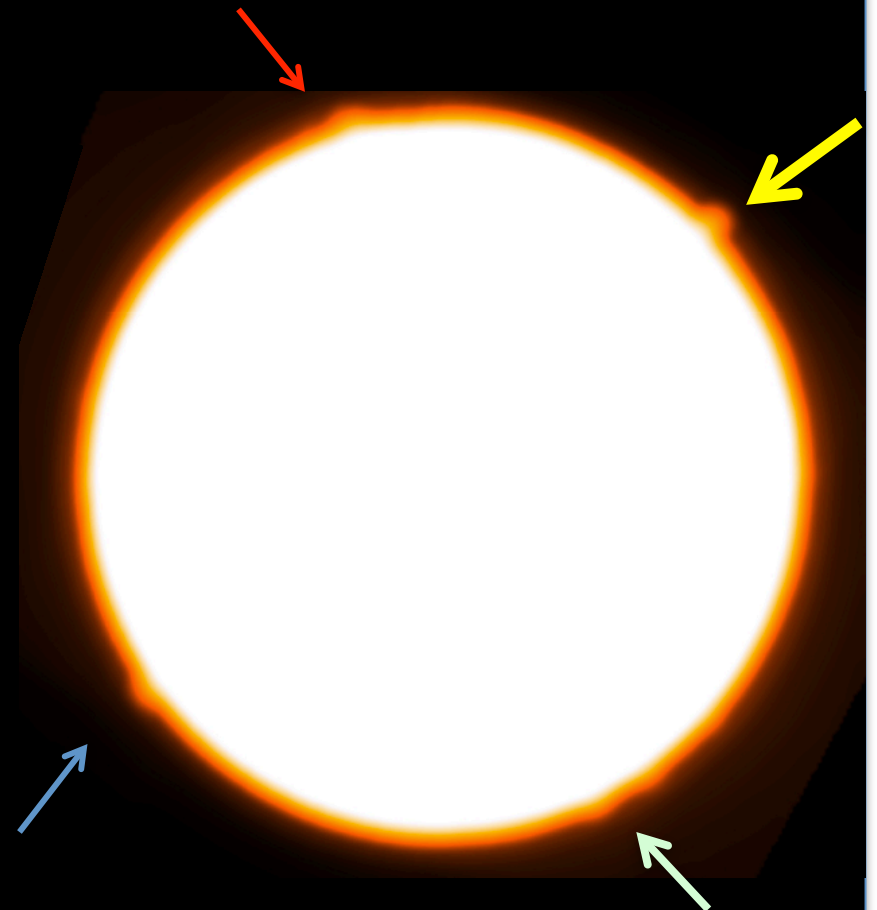
Single Dish Progress: The Sun



ALMA Band 3 on 2011-02-16
Huge X-class flare on 15 Feb.



SOHO EIT 304 Image



DV10 Band 3 Nyquist-sampled

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 μ m (670 GHz) resolutions of ~0.7" or ~0.2"
- Range of correlator modes: up to 4 spectral windows and 8 GHz bandwidth
 - @ 870 μ m (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?

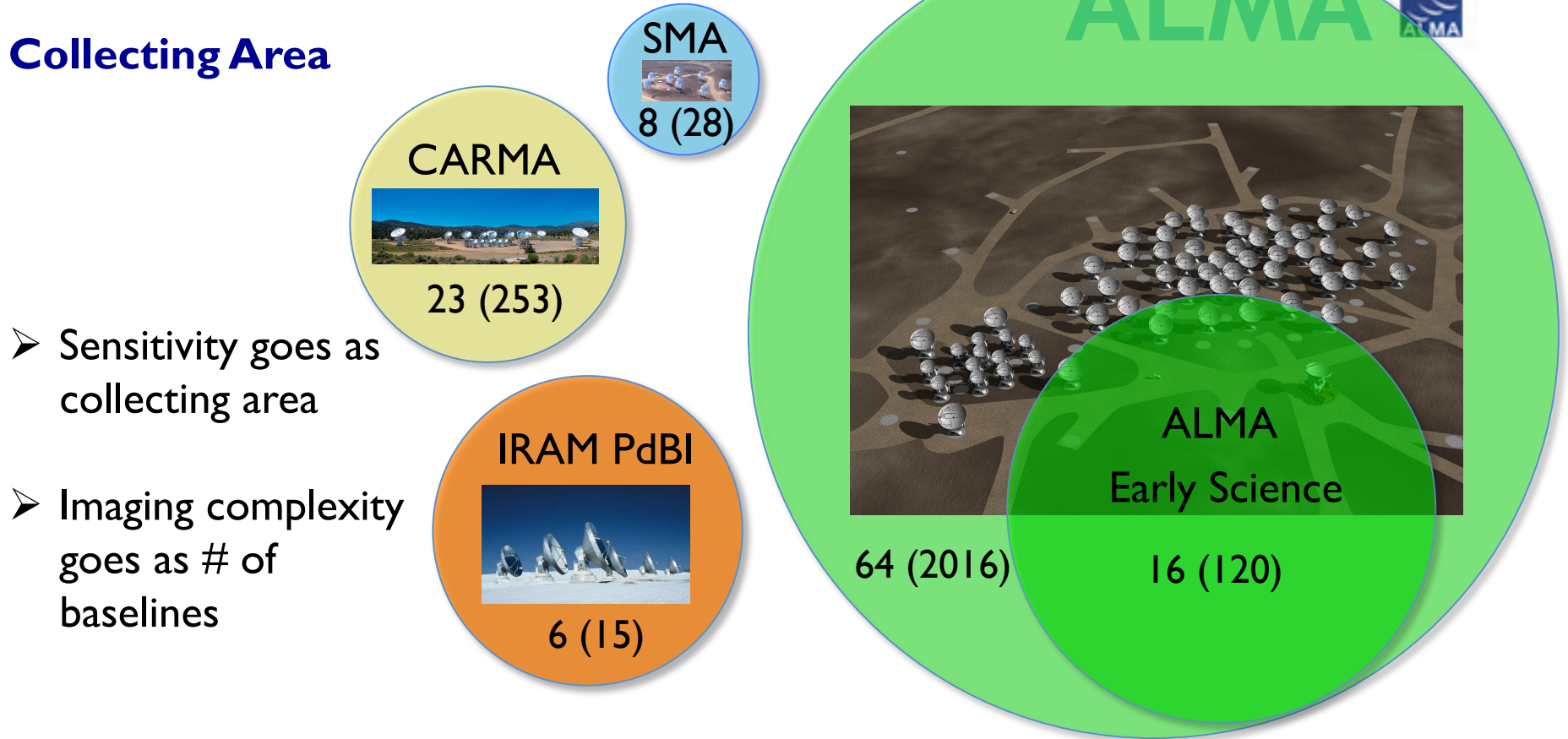


- Single international proposal review: Science panels rank science, Uber panel adjusts for partner shares. Process Spitzer/HST – like
 - Chair of committee will be Neal Evans
 - Four Science Areas
 - A (best efforts), B (if time allows), C (filler), and will not be observed
- Proposals submitted using “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

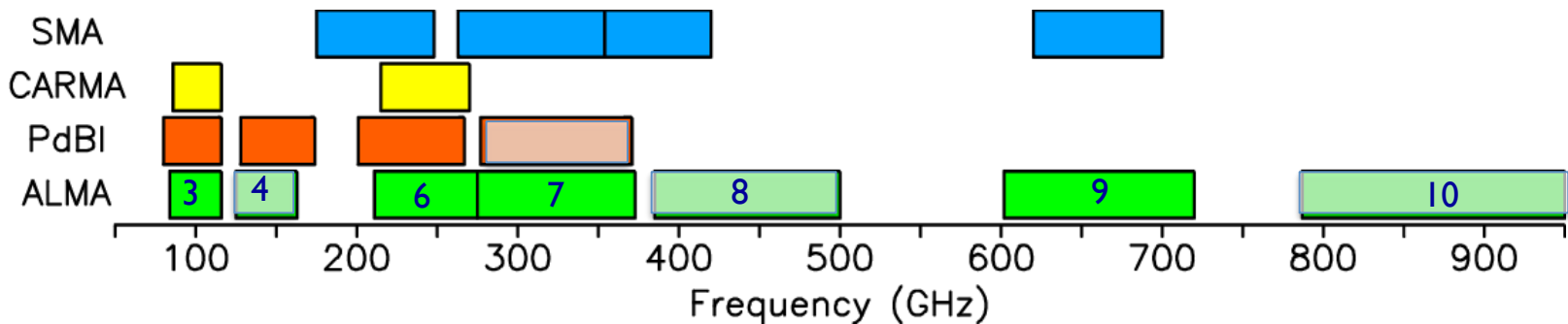


Comparison

Collecting Area



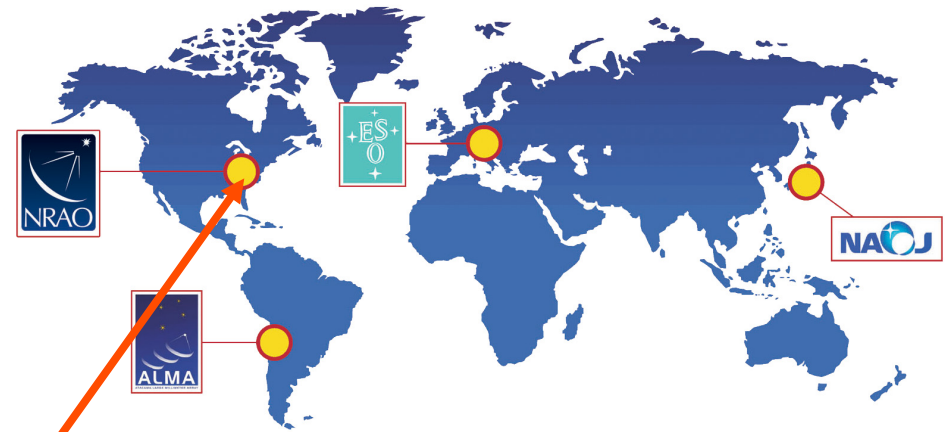
Spectral Coverage



Science Support

ALMA 

- 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:

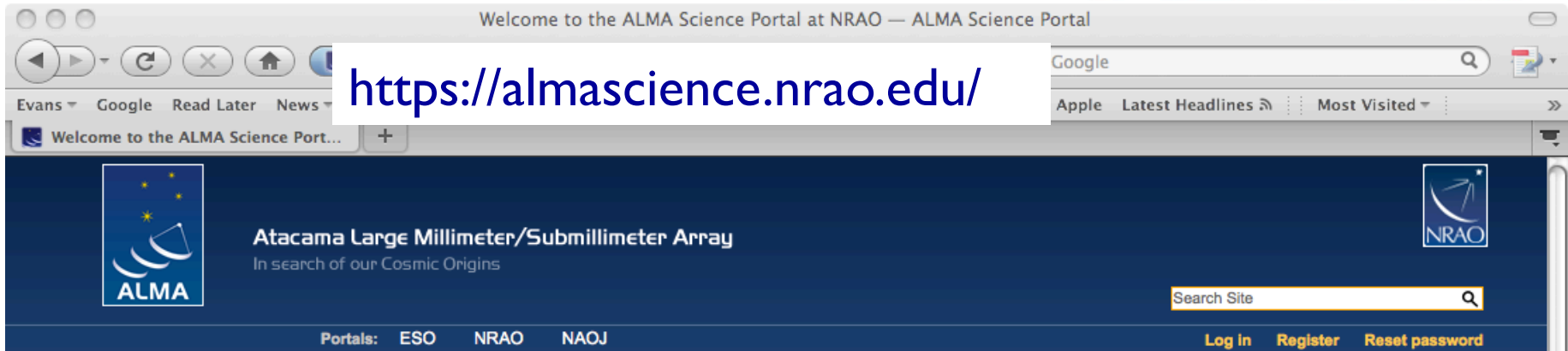
- Proposal Help and Submission
- Observation preparation
- Data archive
- Data processing
- Community outreach





NAASC in Charlottesville, VA

What do you need to know?



- Modern Helpdesk with self-help capability (also used by NRAO, Spitzer, and Herschel)
- Comprehensive User Tools
 - OT (Observing Tool) for proposal and observation preparation
 - Project Tracker for tracking the status of your project
 - ALMA Science Archive for public and proprietary data retrieval
 - CASA for simulations, data reduction and eventually pipeline products

NRAO User Support

Helpdesk

Call for Proposal

Login



NAASC User Support



http://science.nrao.edu/alma

National Radio Astronomy Observatory
Enabling forefront research into the Universe at radio wavelengths

Home About NRAO Science Research Facilities Observing Opportunities

ALMA/NAASC EVLA GB VLBA NTC

Research Facilities > ALMA/NAASC > About ALMA/NAASC

ALMA / NAASC Home

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- Scientific Visitor Info
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- Workshops & Tutorials
- News & Outreach

ALMA Early Science and NAASC Community Training Events




Image courtesy ALMA (ESO/NAOJ/NRAO).

The ALMA Board, at its meeting on November 16-18, 2010 enthusiastically endorsed the progress of the ALMA project and announced that the first Call for Proposals is expected by the end of the first quarter of 2011. They noted that "ALMA is on track to begin Early Science observations late in 2011, as planned. While many challenges remain, it is already clear that ALMA 'works'". It is anticipated that the ALMA Director will issue a Call for Proposals for Early Science in the first quarter of 2011. That announcement will provide more details of the expected timeline and capabilities to be offered." The full November 2010 ALMA Board meeting minutes including recent ALMA test data images are available at www.almaobservatory.org.

To prepare the North American community for the first ALMA Early Science (ES) call, the North American ALMA Association (NAASC) will organize community outreach activities throughout the month leading up to the proposal deadline.

More News

- First Quarter of the Antennas**
Dec. 7, 2010
- Postdoctoral Positions Available**
Nov. 5, 2010
- Two more antennas wait to be joined**
Nov. 5, 2010
- Halfway to the Early Science Antenna Array**
Oct 6, 2010


[ALMA News Archive](#)

Events

- Observing with ALMA: AAS Special Session**
Jan 12, 2011 | 2:00 PM
Seattle, WA

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


The Atacama Large Millimeter Array (ALMA) Quick Reference




	3	4	5	6	7	8	9	10
Bands:	3	4	5	6	7	8	9	10
Frequency (GHz)	84-116	125-163	163-211	211-275	275-373	385-500	602-720	787-950
Wavelength (mm)	3.57-2.59	2.40-1.84	1.84-1.42	1.42-1.09	1.09-0.80	0.78-0.60	0.50-0.42	0.38-0.32

	Early Science	Array Completion
Antennas	≥ 16 x 12m	At least 54 x 12m & 12 x 7m
Bands	Bands 3, 6, 7, 9	Bands 3, 4, 6, 7, 8, 9 & 10
Maximum Bandwidth	16 GHz (2 polarizations x 8 GHz)	
Correlator Configurations	21 (0.02 - 40 km/s)	71 (0.01 - 40 km/s)
Maximum Angular Resolution	0.02" ($\frac{\lambda}{1 \text{ mm}}$)	10 km (Max Baseling)
Max Baseline	250m (may achieve 500m)	15 km
Continuum Sensitivity (60 sec, Bands 3-9)	~0.2 - 4.2 mJy/beam	~0.05 - 1 mJy/beam
Spectral Line Sensitivity (60 sec, 1 km/sec, Bands 3-9)	~30 - 250 mJy/beam	~7 - 62 mJy/beam

Sensitivity Calculator: <http://science.nrao.edu/alma/tools.html>



Observing with ALMA
A Primer for Early Science



NRAO ESO NAOJ

Version: 2010.12.21



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



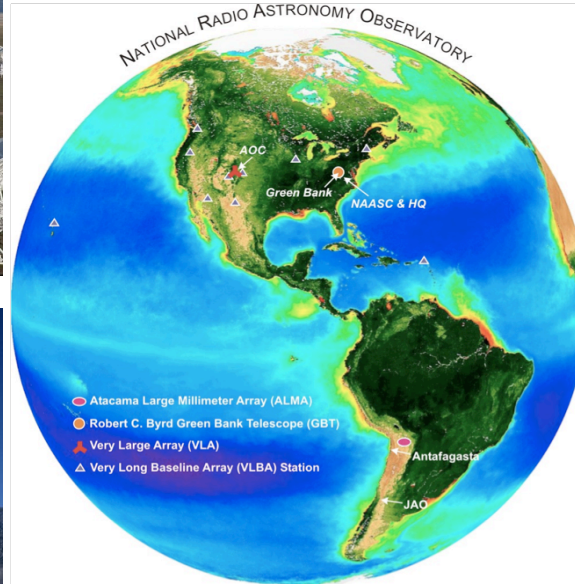
EVLA



GBT



VLBA

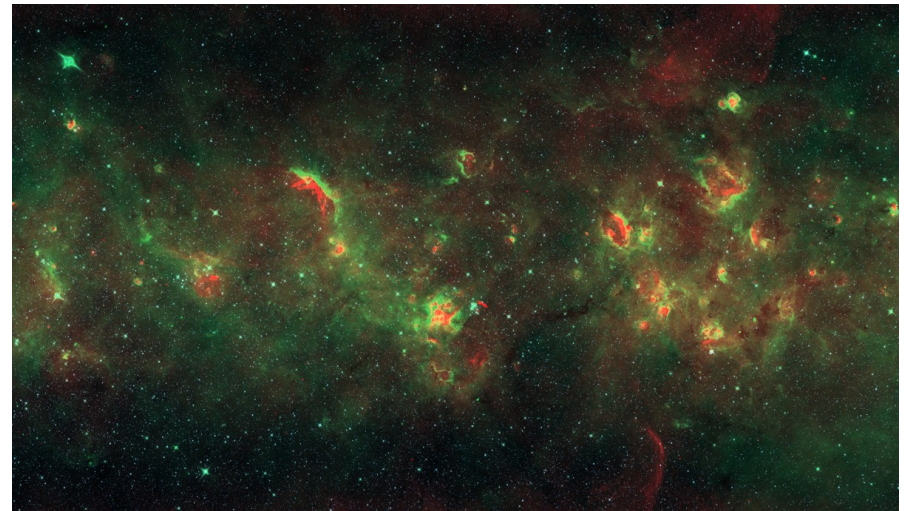


ALMA



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 μ Jy	3 μ Jy	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

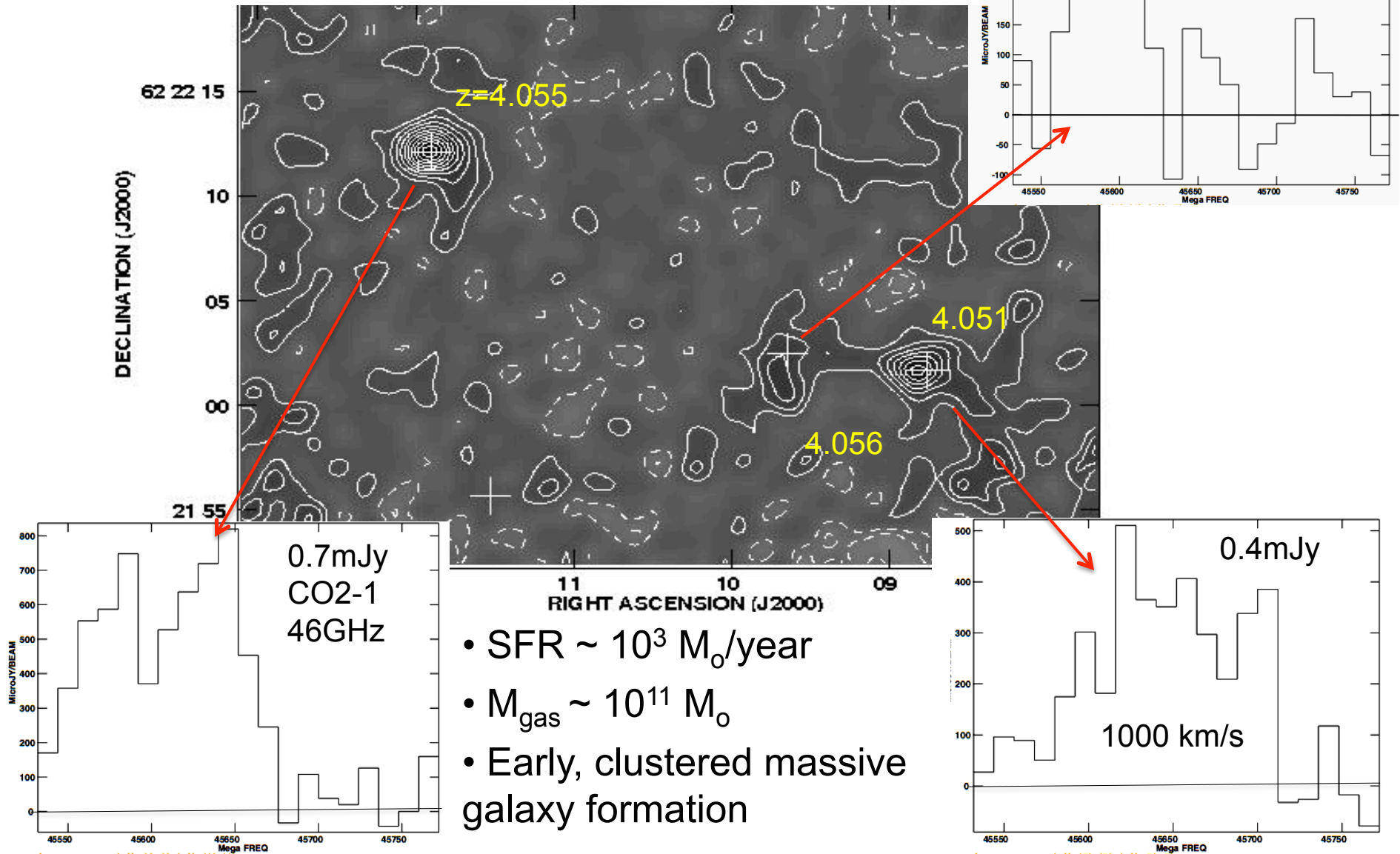
EVLA Milestones

- 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.



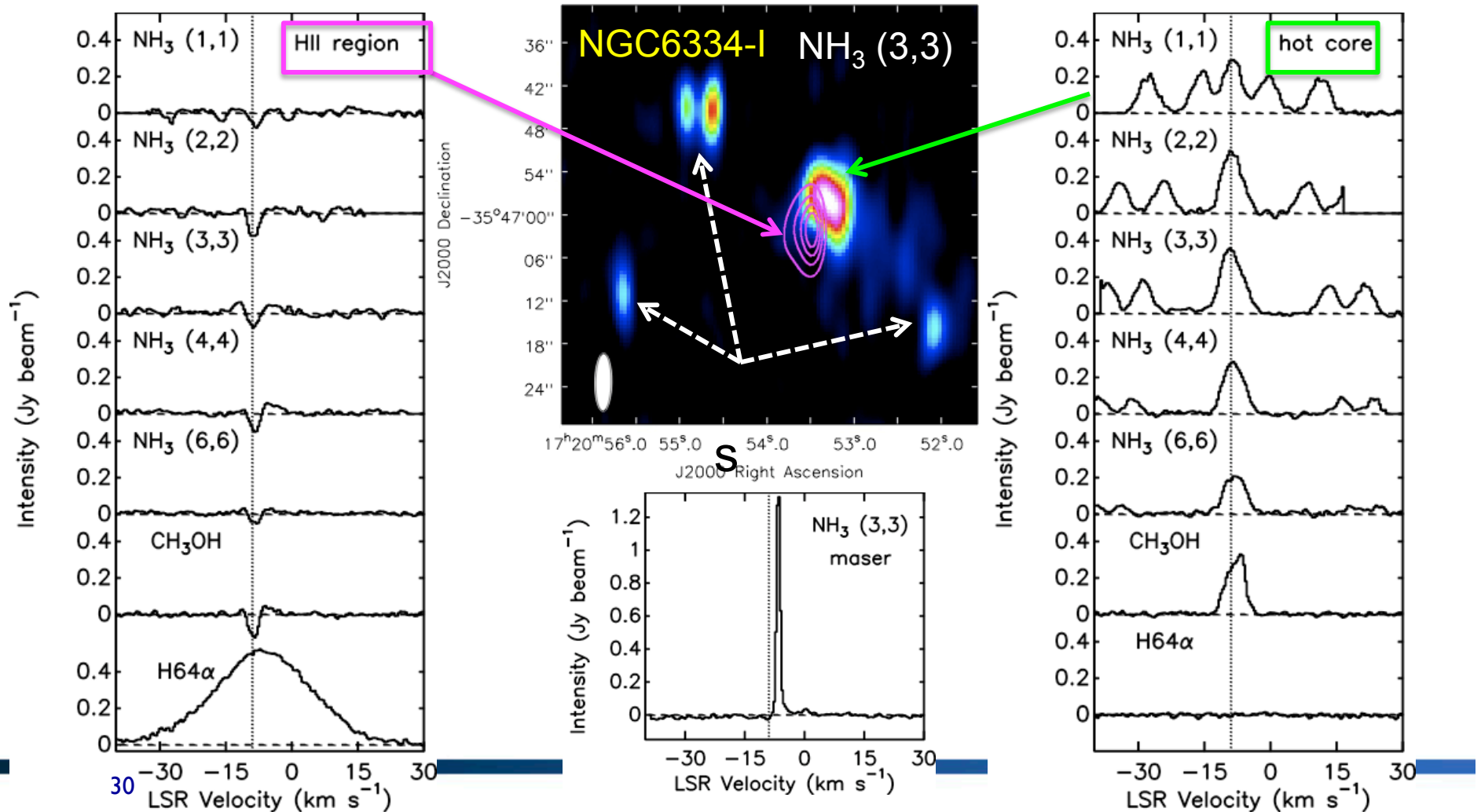
GN20 molecule-rich proto-cluster at $z=4$ (Daddi)
CO 2-1 in 3 submm galaxies, all in 256 MHz BW



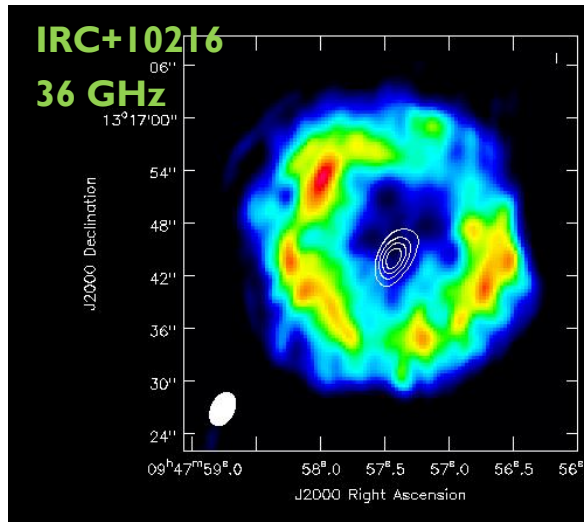
EVLA K-band: massive young stellar objects in NGC6334-I



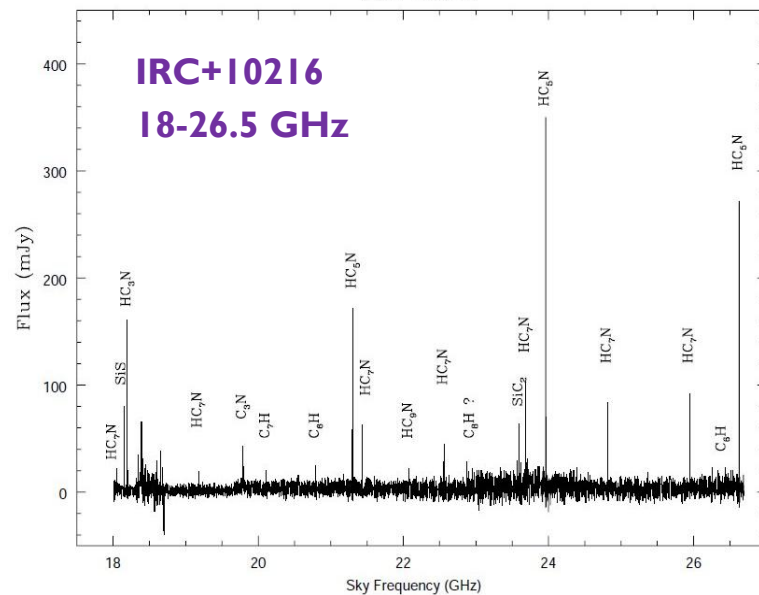
- Initial test for start of RSRO project AB1346
- 8 x 8 MHz subbands with 256 channels RR only; referenced pointing
- 10 minutes on source!



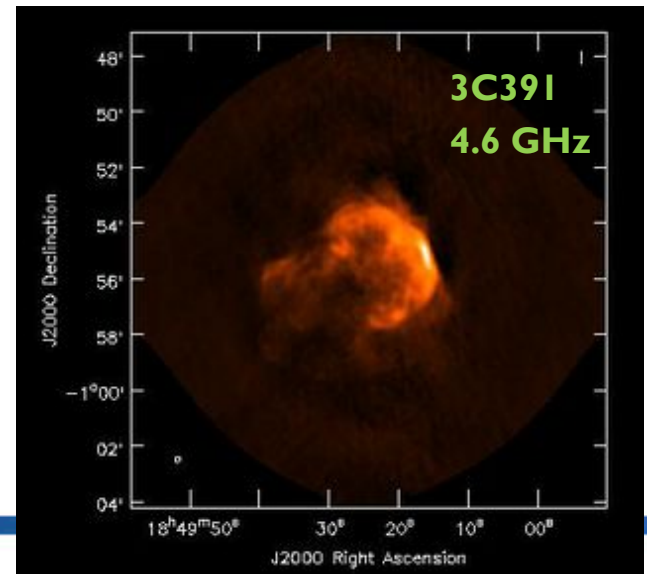
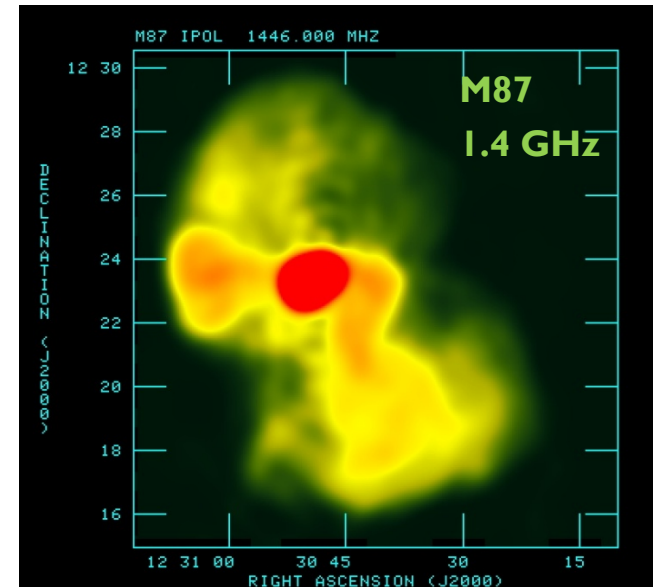
EVLA Demo Science



IRC+10216



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

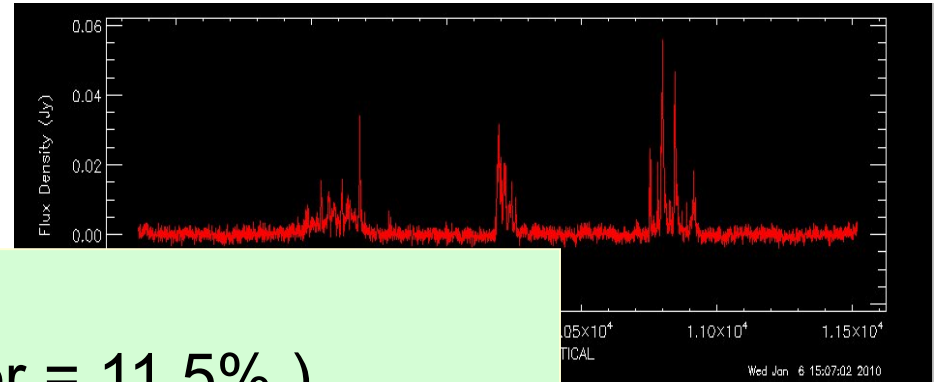


Very Long Baseline Array

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

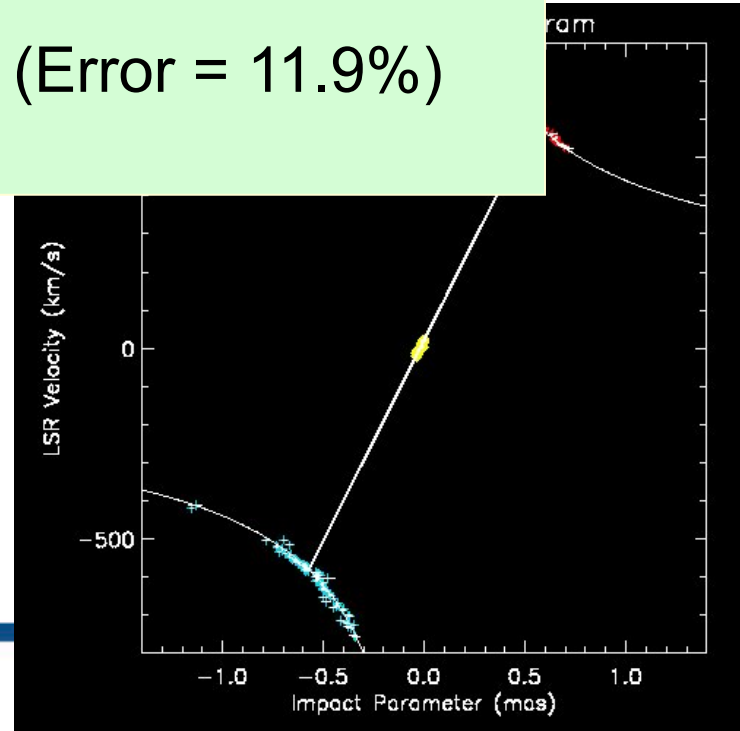
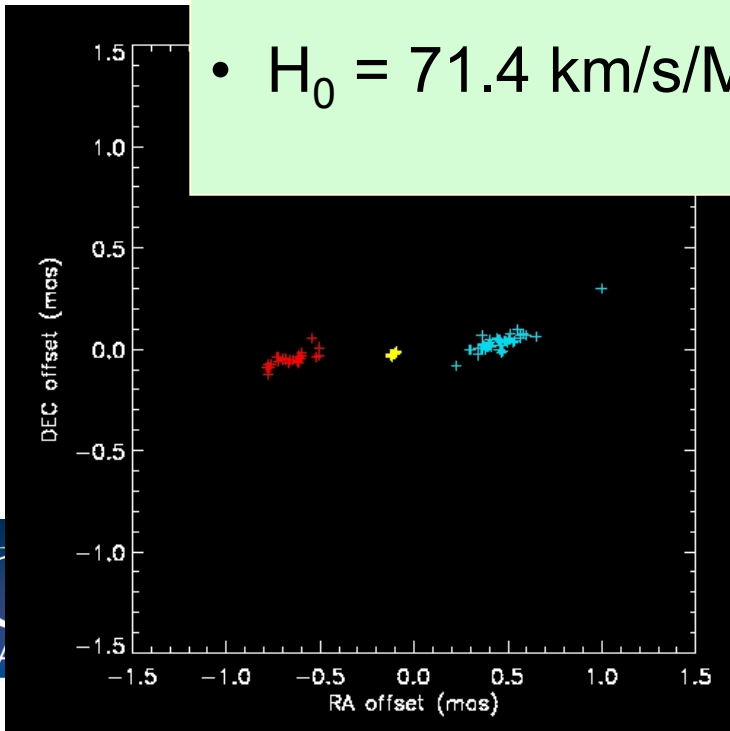


Angular Diameter Distance to NGC 6264 and the Hubble constant



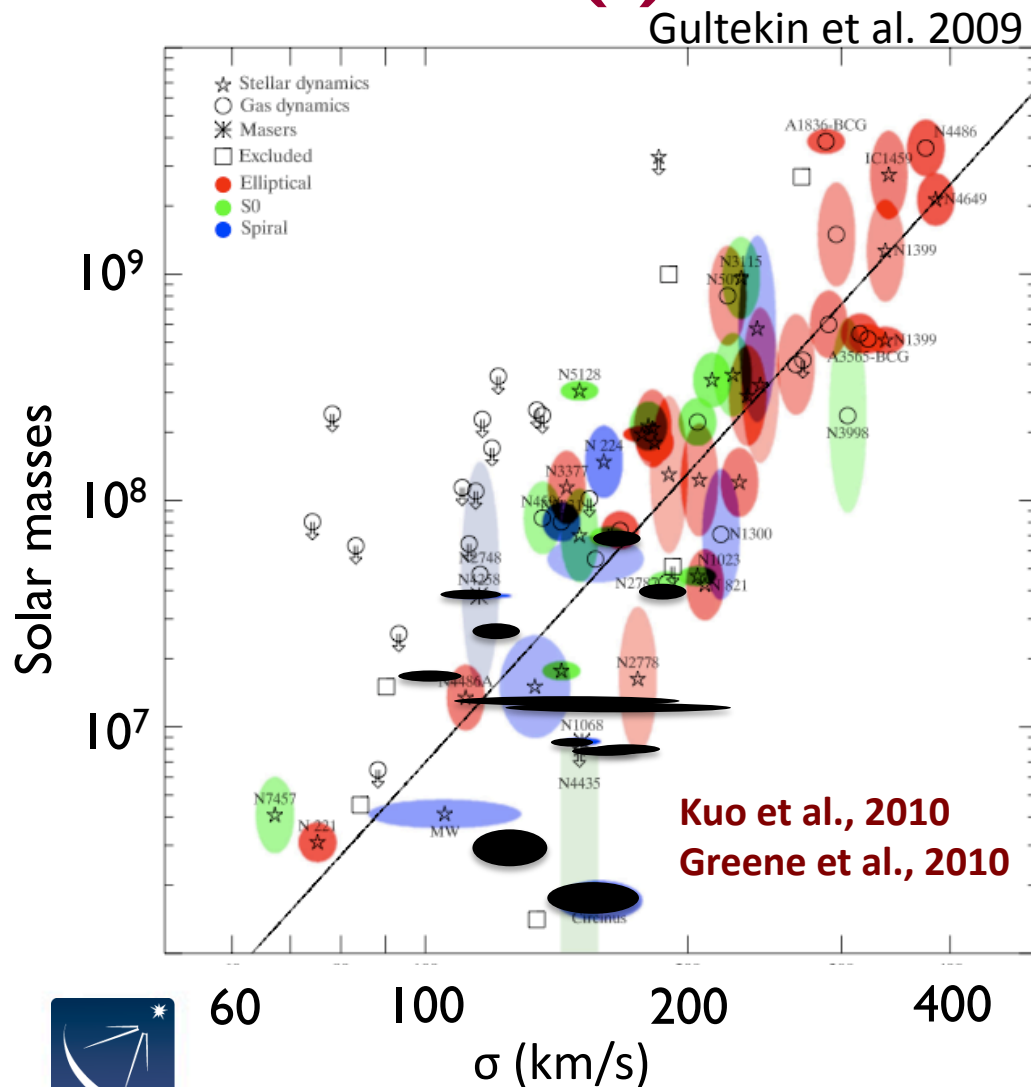
- $D_A = 141 \text{ Mpc}$ (Error = 11.5%)
- $H_0 = 71.4 \text{ km/s/Mpc}$ (Error = 11.9%)

46 h



Mega-maser Cosmology Project

M- σ Relation (?)



- Black ovals: Sy2 galaxies with black hole mass measured via H₂O megamasers
- **Accuracy of black hole masses limited by H₀ 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** (ν: 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

