ALMA Overview

Adele Plunkett
NRAO

Associated Universities, Inc.

Atacama Large Millimeter/submillimeter Array

Overview of this talk

- How does ALMA work (briefly)
- ALMA Cycle 6 capabilities
- Recent science results from ALMA (even more briefly)
- Some resources

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What is ALMA?

- **Atacama:** a high, dry site
- **Large:** sensitive to detect faint objects
- **Millimeter/sub-millimeter:** study the “cold” universe
- **Array:** (interferometer) can resolve (“distinguish”) two points of light with small separation

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ALMA by the Numbers:

Elevation = 5000 m

Number of Antennas = 66

Baselines = 150 m to >16 km

Antenna Locations = 192

Best Resolution = 0.015" (at 300 GHz)

Wavelengths = 0.32 – 3 mm

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What is ALMA?

The ALMA project in summary:

A global partnership between North America, Europe, and East Asia to deliver a revolutionary millimeter/submillimeter telescope array (in collaboration with Chile)

Provides unprecedented imaging and spectroscopic capabilities at millimeter wavelengths

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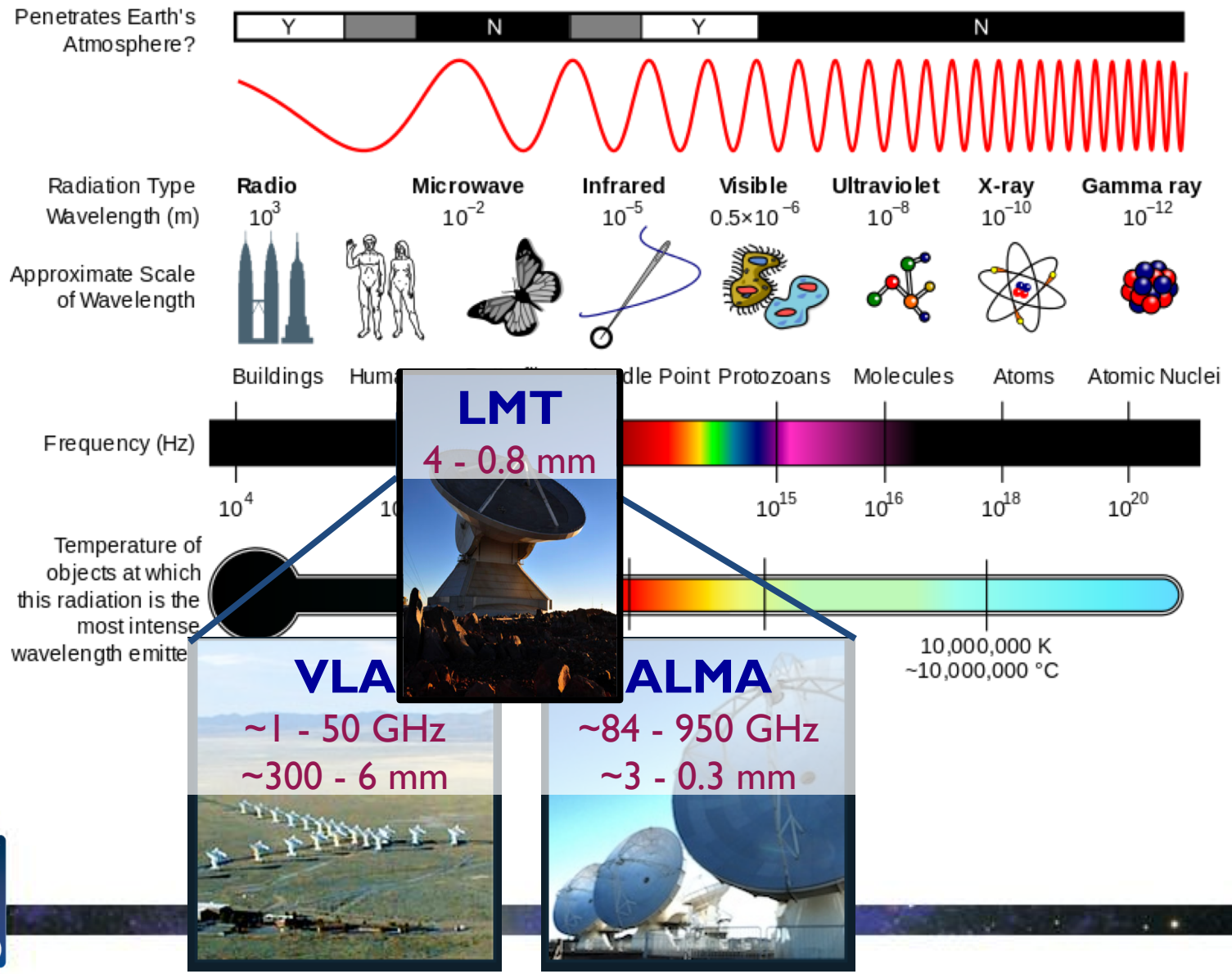
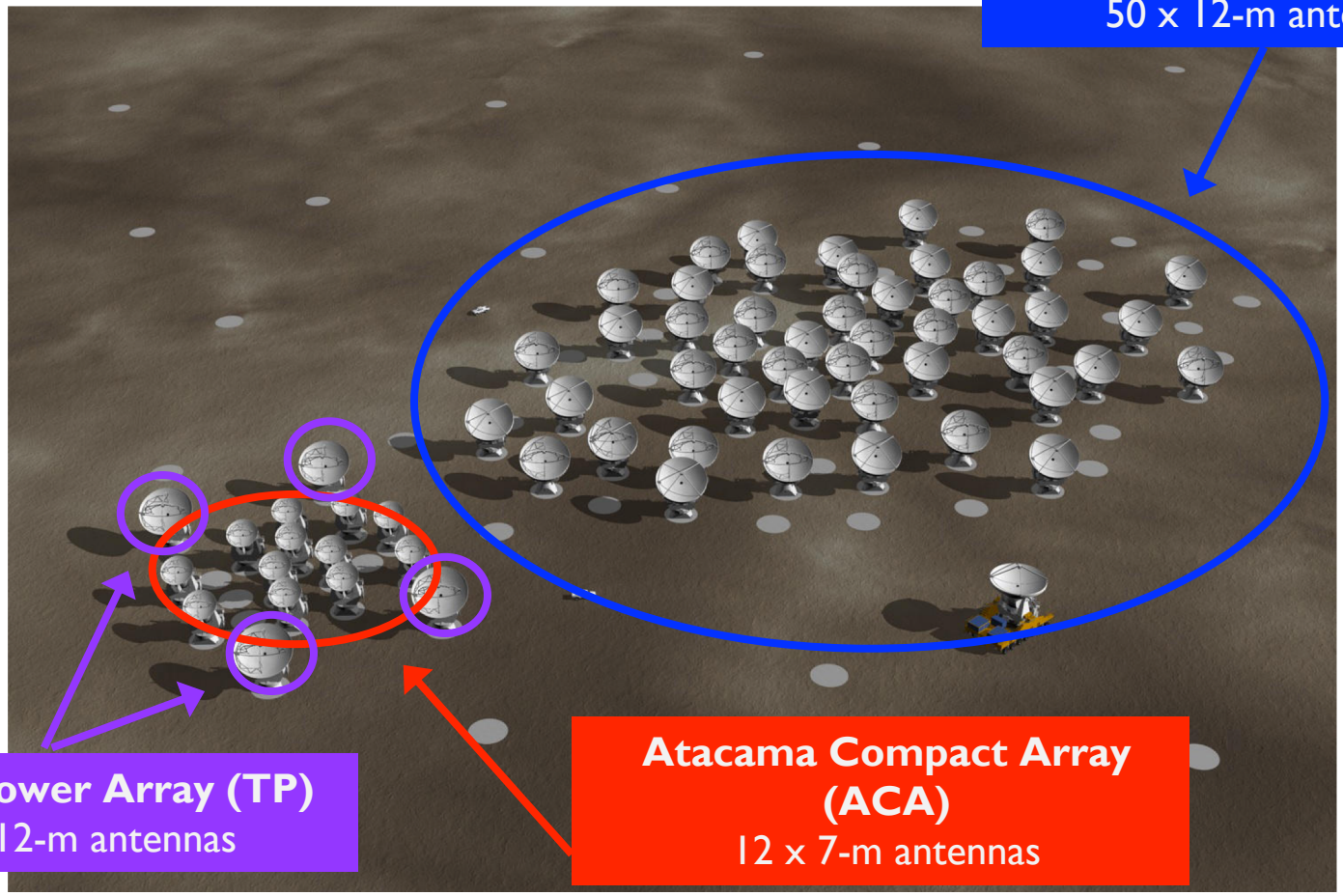
Radio waves, and their place in the EM spectrum



Array Configurations



*TP + ACA = Morita Array

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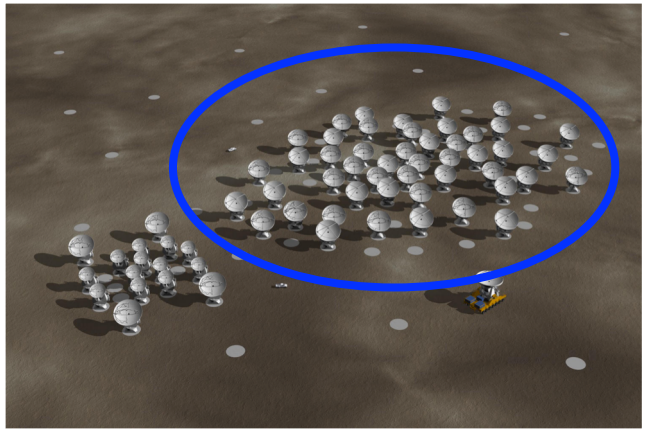
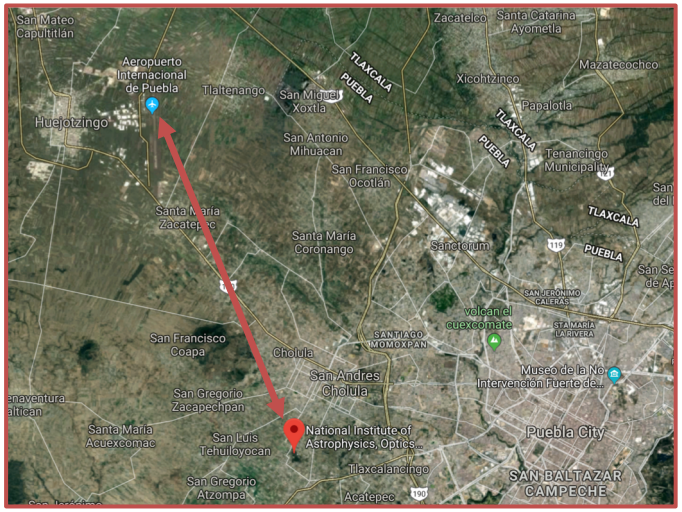
Array Configurations



A ‘Puebla-Centric’ View of ALMA Configurations…

Most extended = INAOE to Puebla International Airport



Most compact configuration = plaza/kiosko at centro de Cholula

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Array Configurations

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Cycle 6 Array Configuration Schedule

Array configuration schedule cycles every few years to accommodate range of LST

Cycle 6: Extended configurations during southern hemisphere winter for more high frequency observations

*NOTE: No PI observing in February!

Start date	Configuration	Longest Baseline	LST for best observing conditions
2018 October 1	C43-6	2.5 km	~ 22h – 10h
2018 October 15	C43-5	1.4 km	~ 0h – 12h
2018 November 25	C43-4	0.78 km	~ 2h – 14h
2018 December 15	C43-3	0.50 km	~ 4h – 15h
2019 January 5	C43-2	0.31 km	~ 5h – 16h
2019 January 20	C43-1	0.16 km	~ 6h – 17h
2019 February 1-28	No observations due to February shutdown		
2019 March 1	C43-1	0.16 km	~ 8h – 21h
2019 March 15	C43-2	0.31 km	~ 8h – 22h
2019 April 1	C43-3	0.50 km	~ 9h – 23h
2019 April 15	C43-4	0.78 km	~ 10h – 0h
2019 May 1-31	No observations due to major antenna relocation		
2019 June 1	C43-10	16.2 km	~ 13h – 3h
2019 June 20	C43-9	13.9 km	~ 14h – 5h
2019 July 10	C43-8	8.5 km	~ 16h – 6h
2019 August 1	C43-7	3.6 km	~ 18h – 8h
2019 September 5	C43-6	2.5 km	~ 20h – 9h

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We operate with **queue observing**, using a **dynamic scheduler tool,** and performing **quality assurance** at the telescope.

Array configuration schedule:

Table 3: Planned 12-m Array Configuration Schedule for Cycle 6

Start date	Configuration	Longest baseline	LST for best observing conditions
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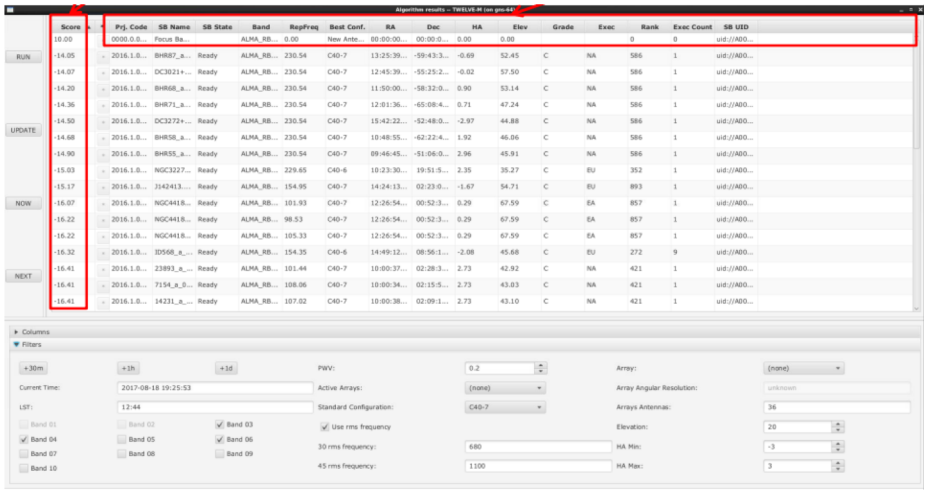
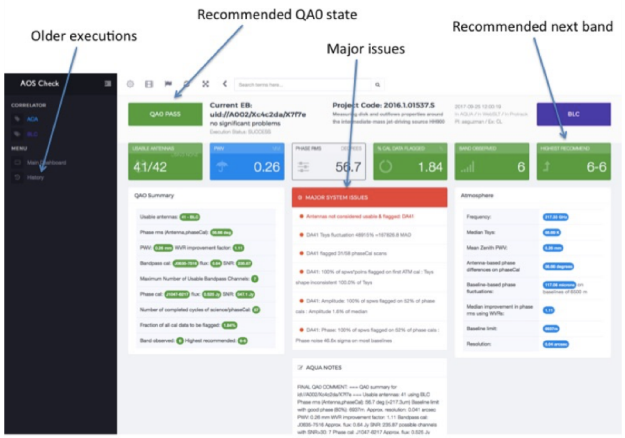
*See Cycle 6 Proposer's guide

Dynamical Scheduler tool:



Quality Assessment (at the telescope):



Overview of this talk

- How does ALMA work (briefly)
- **ALMA Cycle 6 capabilities** ** beginning October 2018
- Recent science results from ALMA (even more briefly)
- Some resources

Overview of ALMA Capabilities

Number of Antennas

12-m Array	7-m Array	12-m TP
43 (50)	10 (12)	3 (4)

Receiver Bands and 12-m Array Configurations

Band:	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Wavelength (mm):	3.1	2.1	1.6	1.3	0.87	0.74	0.44	0.35
Frequency (GHz):	100	150	183	230	345	460	650	870
Max Baseline (km):	16	16	16	16	8.5	3.6	3.6	3.6
Max Resolution (″):	0.042	0.028	0.021	0.018	0.028	0.046	0.033	0.024

For reference, see Appendix A of the ALMA Proposer's Guide available at: https://almascience.nrao.edu/documents-and-tools

Overview of ALMA Capabilities

Available Observing Time

	12-m Array	7-m Array	12-m TP
Time (hours):	4000*	3000	3000

* Includes DDT, Cycle 5 carryover and resubmissions

Spectral Line, Continuum, and Mosaic Observations

- **Spectral line and continuum:** 12-m Array and the 7-m Array, All Bands
- **Single pointing:** 12-m Array, 7-m Array, All Bands
- **Mosaics:** 12-m Array, 7-m Array, Band 3-9
- **TP spectral line (no continuum):** Bands 3-8

Polarization

- Single pointing, on axis, full (including circular) polarization for both continuum and full-spectral-resolution in Band 3, 4, 5, 6, and 7 offered for 12-m Array
- Minimum detectable degree of circular polarization = 1.8% of peak flux
- Only for on-axis sources with an angular size <10% of FWHM primary beam

New Cycle 6 Capabilities!

Band 6 Bandwidth Increase

Increased by 0.5 GHz for simultaneous observations of ^{12}CO, ^{13}CO, and $C^{18}O$

Circular Polarization

Only for Band 3, 4, 5, 6, and 7

Time Simultaneous Observations

Restrictions between 12-m and 7-m Arrays from Cycle 5 lifted

Band 8 as Standard Observing Mode

Allows for ACA-only observations in Band 8

Standard vs. Non-Standard Modes

What does 'non-standard' mean?

- No guarantee that observations can be reduced with the standard pipeline
- ~20% of time in Cycle 6 will go to non-standard modes

Non-standard observing modes include …

- Bands 9 and 10 observations
- Band 7 observations with maximum baselines >5 km
- All polarization observations
- Spectral scans
- Bandwidth switching projects (<1 GHz aggregate bandwidth all spectral windows)
- Solar observations
- VLBI observations
- Non-standard calibrations (user-defined calibrations selected in the OT)
- Astrometric Observations

Proposal (or project) types

- Regular Proposals
- Target of Opportunity.
- Large Programs.
- mm-VLBI Proposals
- Director Discretionary Time Proposals

Regular proposal

- Any project <50 hours with the main array, or standalone mode for ACA < 150 hours.
- Regular Proposals may include standard or non-standard modes, Multiple-epoch observations, Monitoring a target over a fixed time interval.

Large Projects (started in Cycle 4)

- 15% of available time
- Any project >50 hours, or standalone ACA > 150 hours
- Standard observing modes
- Automatic ‘A’ grade

- Proposal: +2 pages for Science Case
  - Data/Project Mgmt. Plans
  - Enhanced Data Products

- *https://almascience.nrao.edu/observing/highest-priority-projects*

ToO (Target of Opportunity)

- Transient events occurring at frequent and unpredictable intervals (e.g. gamma ray bursts).
- Regular proposal submission.
- Target list may be left unspecified, observing modes and sensitivity requests must be specified
- Triggers needed and maximum response time

VLBI

- 5% of available time
- VLBI observations cannot be included in Large Programmes and DDT Proposals.

DDT (Director's Discretionary Time)

- 5% of available time
- Submission at any time, for current cycle

1. Immediate observation of a sudden and *unexpected* astronomical event (ToO).
2. Observations of a highly competitive scientific topic, motivated by developments that have taken place after the regular proposal submission deadline.
3. Follow-up observations of a program recently conducted with ALMA or any other observing facility, quick implementation is expected to provide breakthrough results.

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ALMA Science in Cycle 6 by category

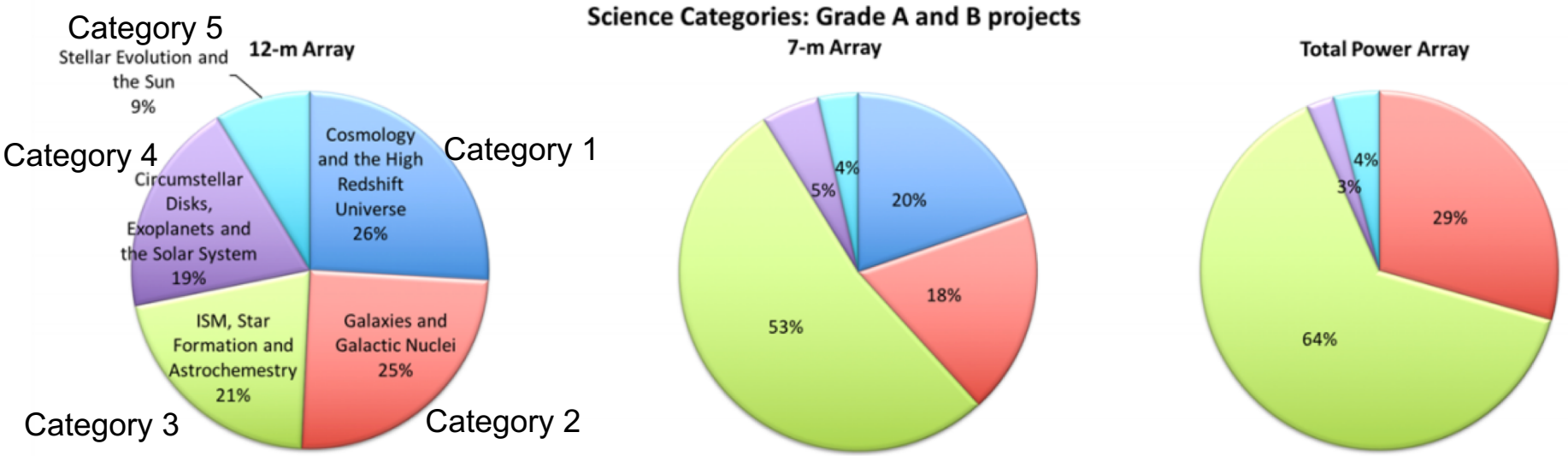
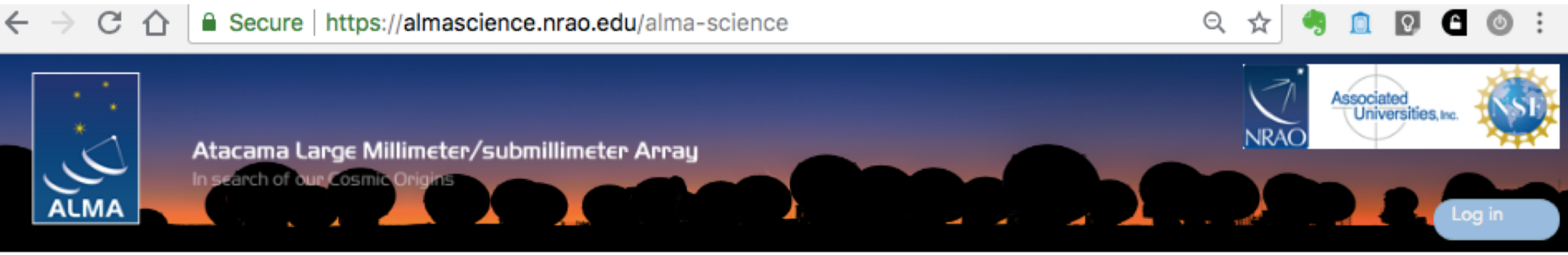


Figure 2. Distribution of the estimated execution time for Grade A and B projects by science category for the 12-m (left), 7-m (center), and Total Power (right) arrays. The results for the 7-m and Total Power arrays include both ACA standalone proposals and proposals requesting the 12-m Array + ACA.

Check out the “science” tab for overviews



Science

Here we present a science background for six science themes, including some recent results when applicable. The intention with this expose is not to be exhaustive regarding the science that can be done with ALMA, but rather serve as a general guideline and inspiration to what is possible to achieve with the ALMA observatory. The recent results will be updated on a regular basis, so please stay tuned.

1. Cosmology and the high redshift universe
2. Galaxies and galactic nuclei
3. ISM, star formation and astrochemistry
4. Planet-forming disks
5. Stellar evolution
6. Solar system

** Ignore category numbers

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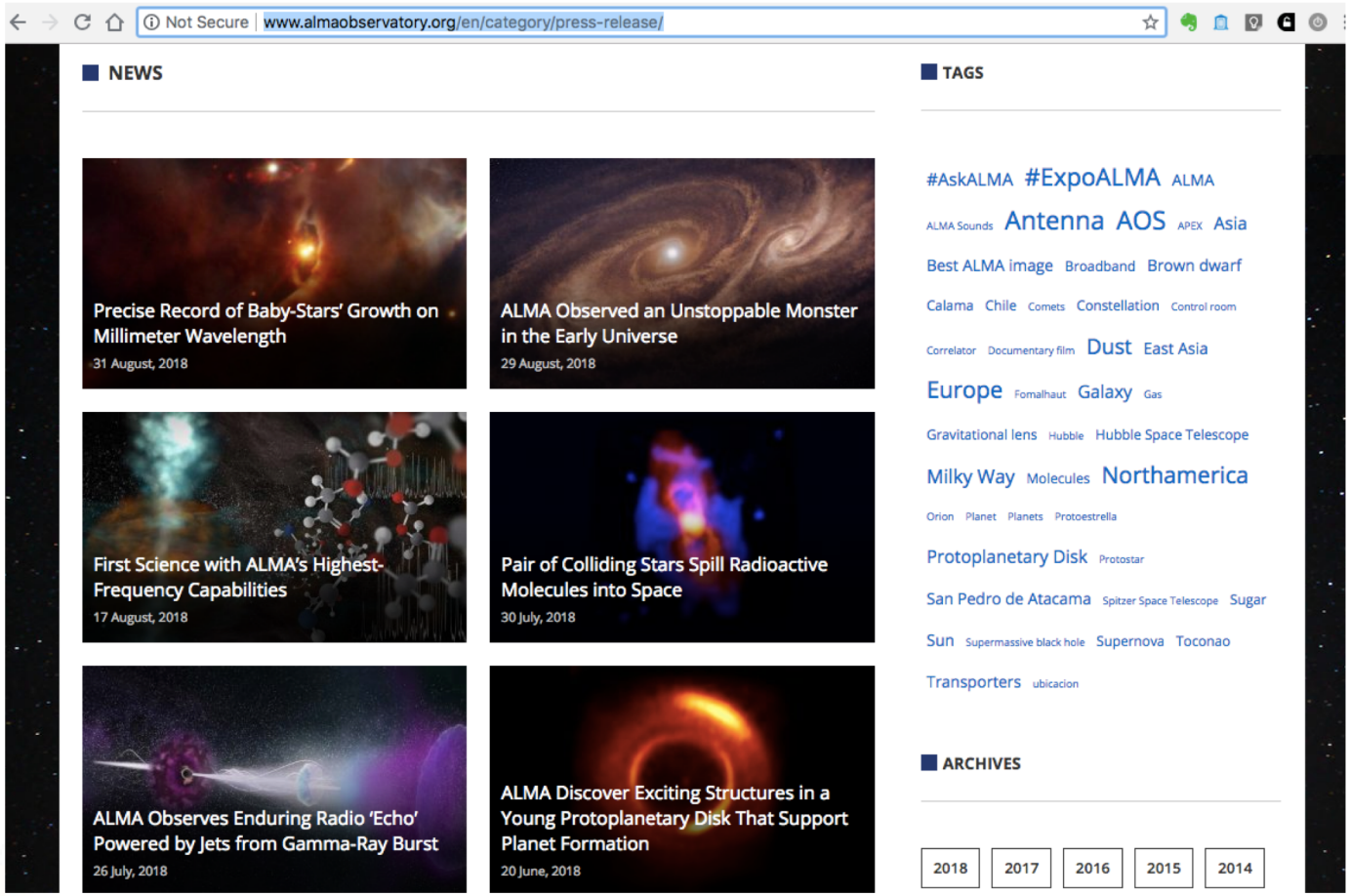
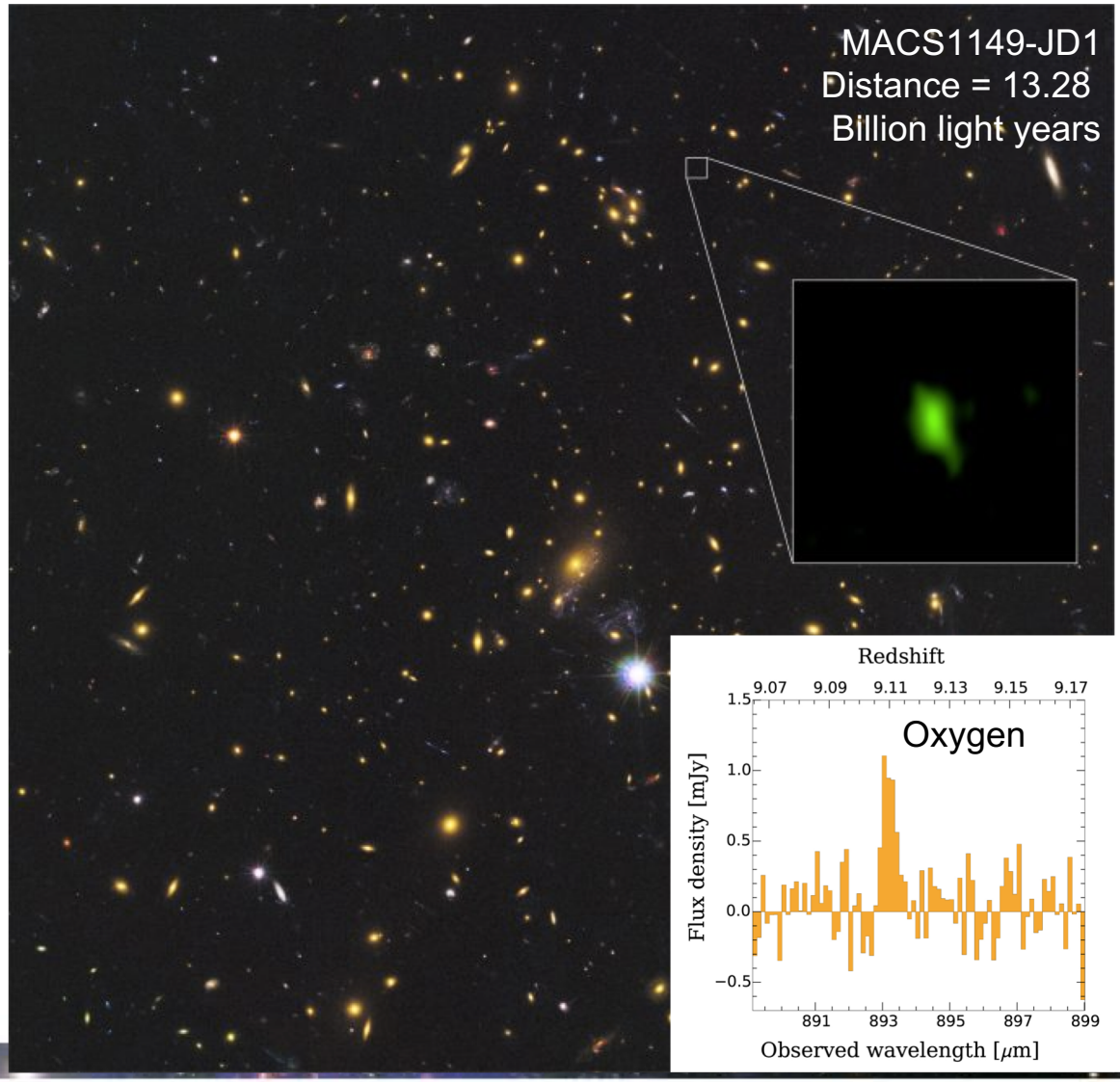
ALMA press page shows recent science results (in a comprehensible way)



Category 1. Cosmology, and high-z universe

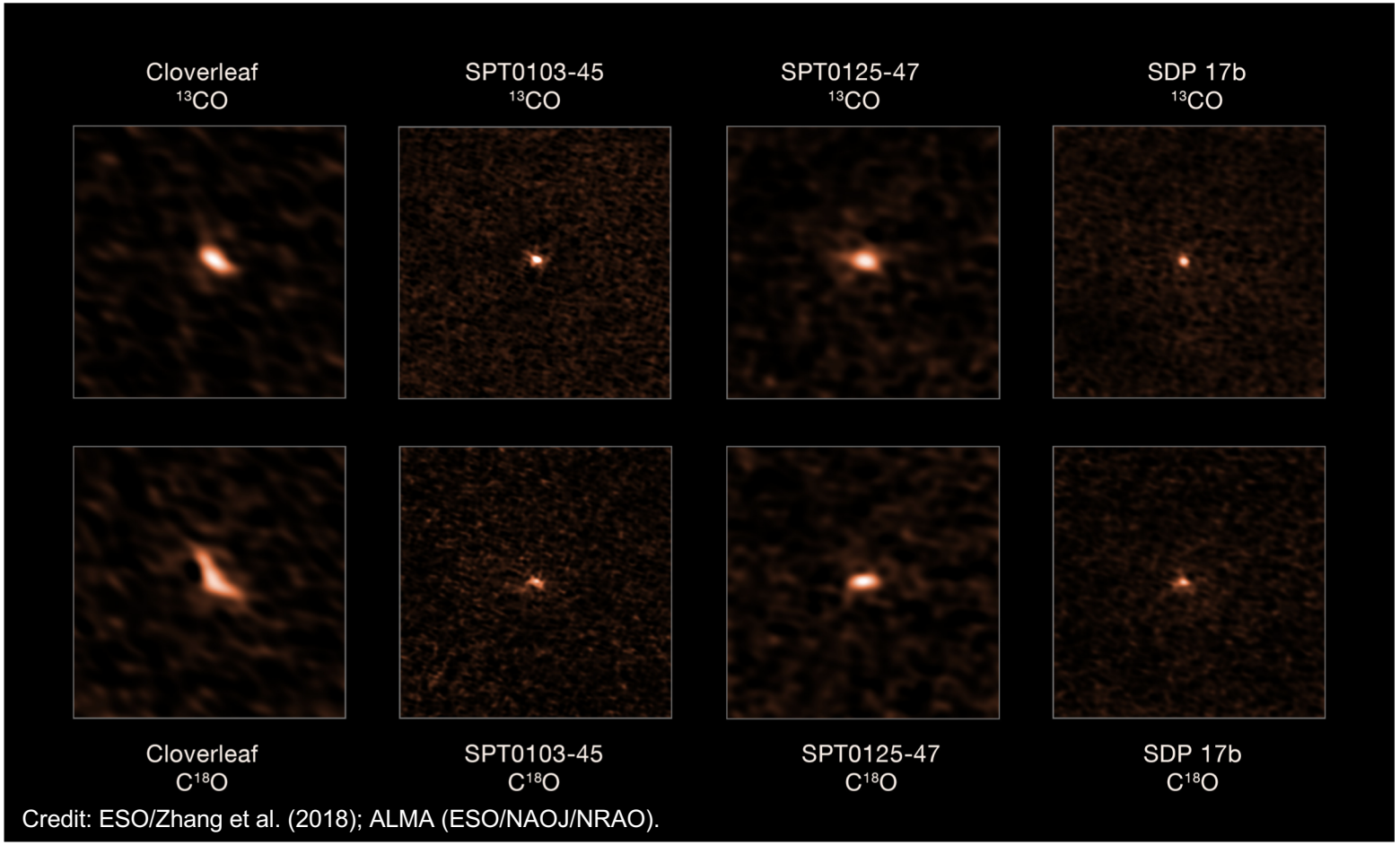
"ALMA Finds Most-Distant Oxygen in the Universe"
May 15, 2018



See the paper by Hashimoto et al. (2018): "The onset of star formation 250 million years after the Big Bang" in journal Nature.

2. Galaxies and Galactic Nuclei

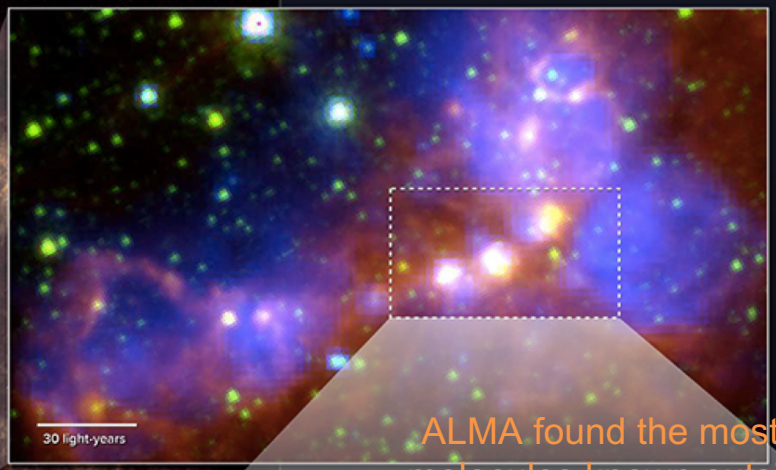
"ALMA and VLT Find Too Many Massive Stars in Starburst Galaxies, Near and Far"
June 1, 2018



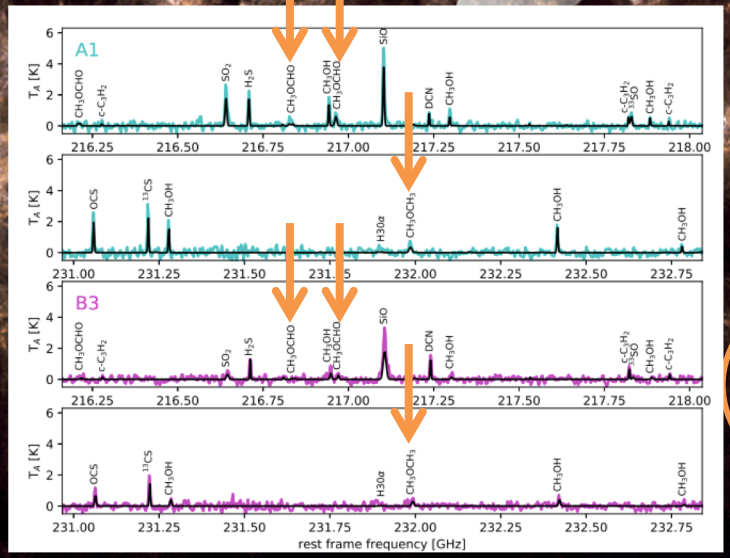
Credit: ESO/Zhang et al. (2018); ALMA (ESO/NAOJ/NRAO).

3. Inter-stellar medium, Star Formation and Astrochemistry

"Large Magellanic Cloud Contains Surprisingly Complex Organic Molecules"
January 30, 2018
See: Sewilo et al. (2018)



ALMA found the most complex molecules known outside of our Galaxy



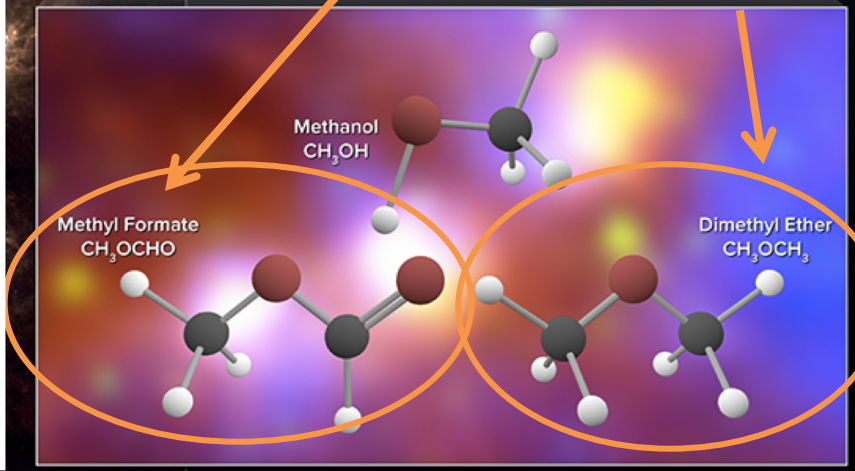


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Image credit: NRAO/AUI/NSF; ALMA (ESO/NAOJ/NRAO); Herschel/ESA; NASA/JPL-Caltech; NOAO

4. Circumstellar disks, exoplanets, solar system

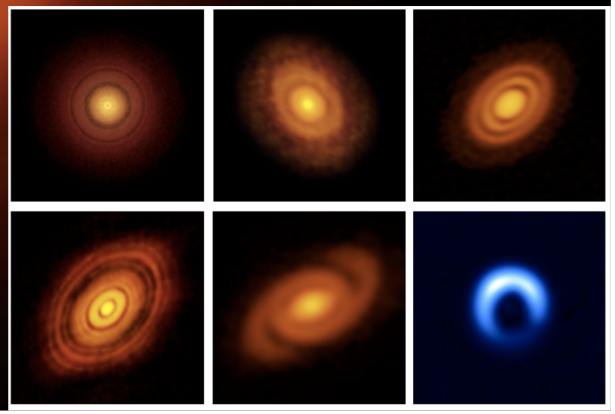
"ALMA Discovers Trio of Infant Planets around Newborn Star" June 18, 2018

See papers by: Pinte et al. (2018) and Teague et al. (2018)

See also: "Compelling evidence" of planets found by Isella et al. (2016)
And previous study by ESO's Itziar de Gregorio et al. (2013)

HD 163296

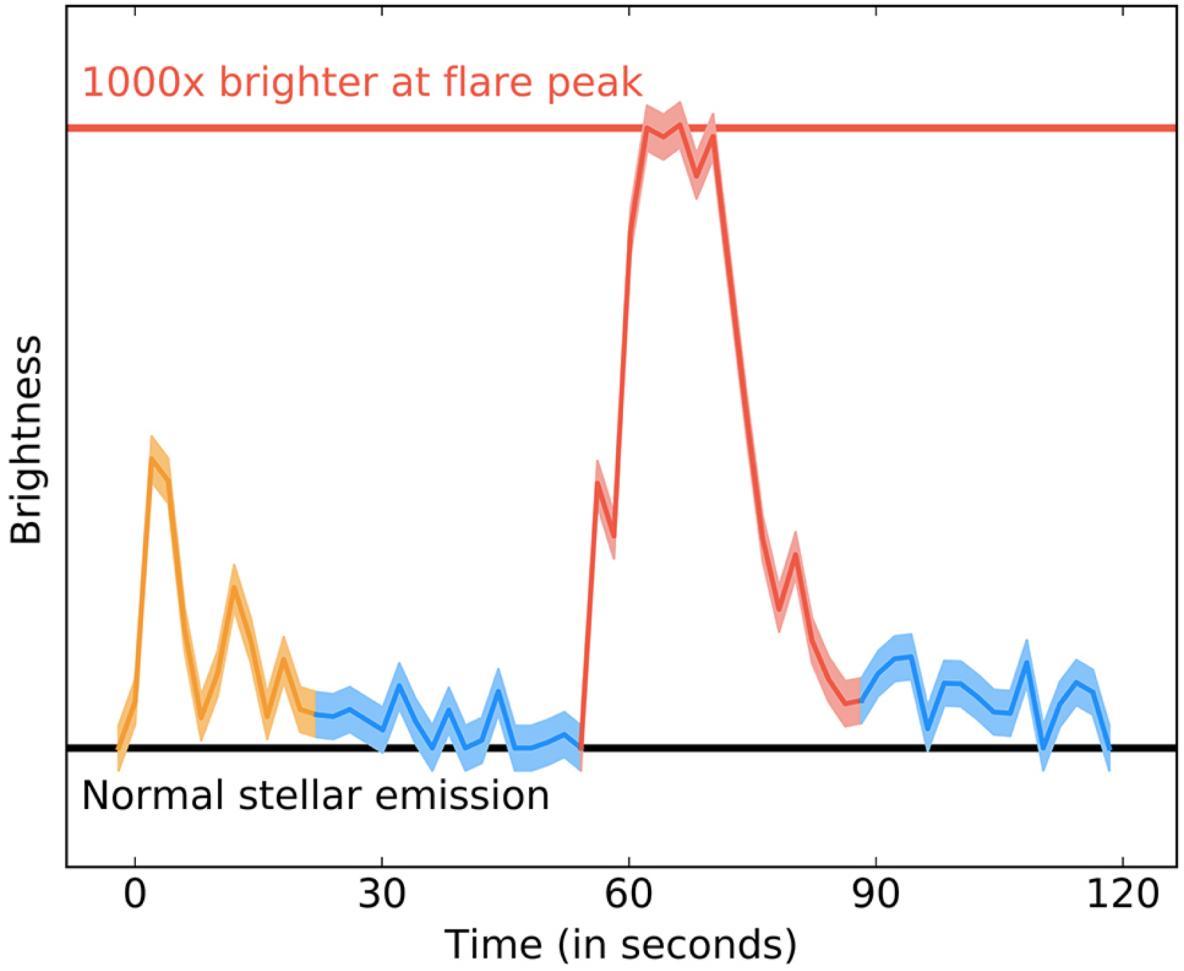
Image Credit: ESO, ALMA (ESO/NAOJ/NRAO); A. Isella; B. Saxton (NRAO/AUI/NSF).



See also:
https://almascience.nrao.edu/alma-science/planet-forming-disks

5. Stellar Evolution, the Sun

"Powerful Flare from Star Proxima Centauri Detected with ALMA"
February 26, 2018



See paper by:
MacGregor et al. (2018)

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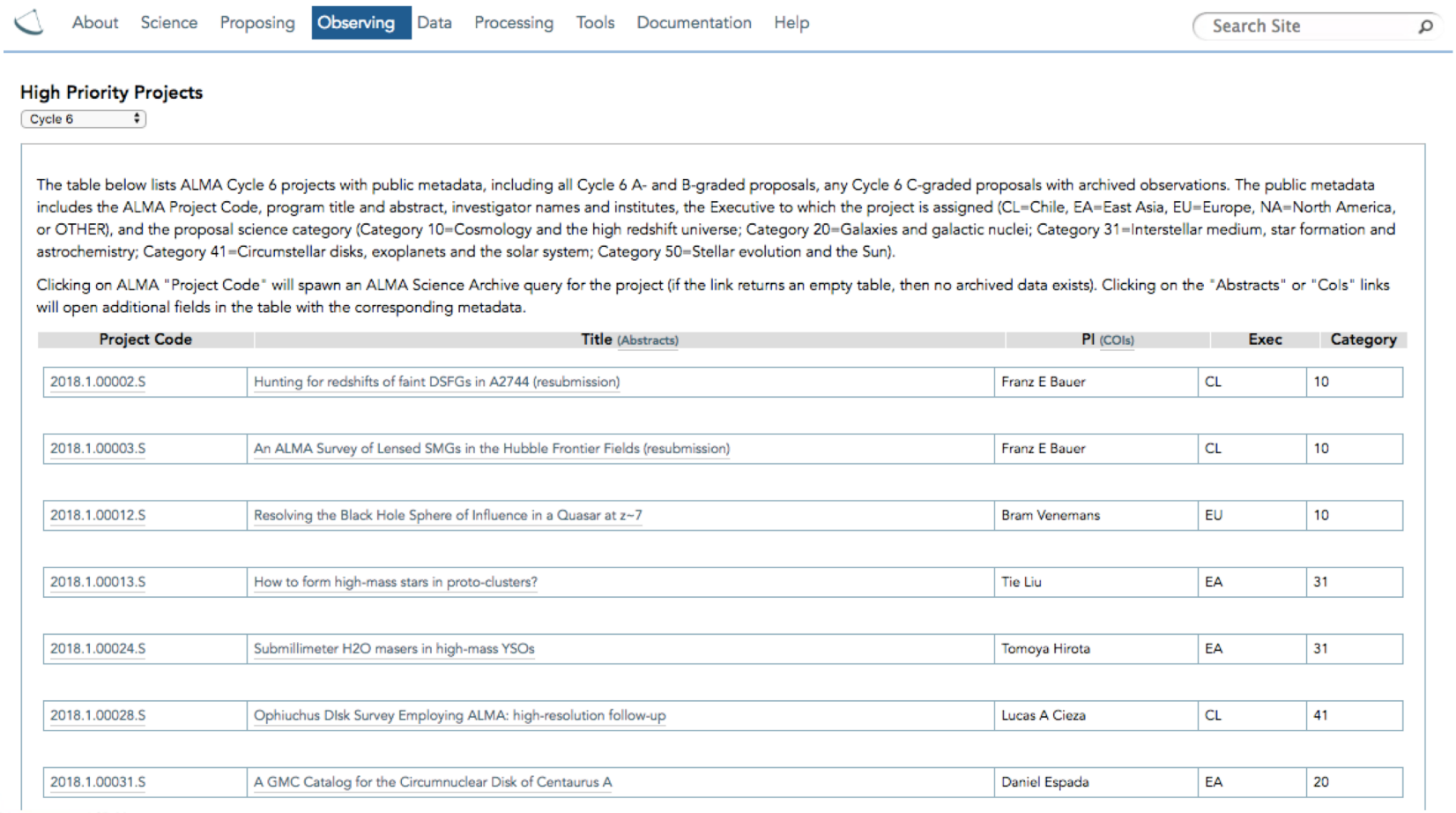
See what to expect in Cycle 6

https://almascience.nrao.edu/observing/highest-priority-projects



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High Priority Projects

Cycle 6

The table below lists ALMA Cycle 6 projects with public metadata, including all Cycle 6 A- and B-graded proposals, any Cycle 6 C-graded proposals with archived observations. The public metadata includes the ALMA Project Code, program title and abstract, investigator names and institutes, the Executive to which the project is assigned (CL=Chile, EA=East Asia, EU=Europe, NA=North America, or OTHER), and the proposal science category (Category 10=Cosmology and the high redshift universe; Category 20=Galaxies and galactic nuclei; Category 31=Interstellar medium, star formation and astrochemistry; Category 41=Circumstellar disks, exoplanets and the solar system; Category 50=Stellar evolution and the Sun).

Clicking on ALMA "Project Code" will spawn an ALMA Science Archive query for the project (if the link returns an empty table, then no archived data exists). Clicking on the "Abstracts" or "CoIs" links will open additional fields in the table with the corresponding metadata.

Project Code	Title (Abstracts)	PI (COIs)	Exec	Category
2018.1.00002.S	Hunting for redshifts of faint DSFGs in A2744 (resubmission)	Franz E Bauer	CL	10
2018.1.00003.S	An ALMA Survey of Lensed SMGs in the Hubble Frontier Fields (resubmission)	Franz E Bauer	CL	10
2018.1.00012.S	Resolving the Black Hole Sphere of Influence in a Quasar at z~7	Bram Venemans	EU	10
2018.1.00013.S	How to form high-mass stars in proto-clusters?	Tie Liu	EA	31
2018.1.00024.S	Submillimeter H2O masers in high-mass YSOs	Tomoya Hirota	EA	31
2018.1.00028.S	Ophiuchus DIsk Survey Employing ALMA: high-resolution follow-up	Lucas A Cieza	CL	41
2018.1.00031.S	A GMC Catalog for the Circumnuclear Disk of Centaurus A	Daniel Espada	EA	20

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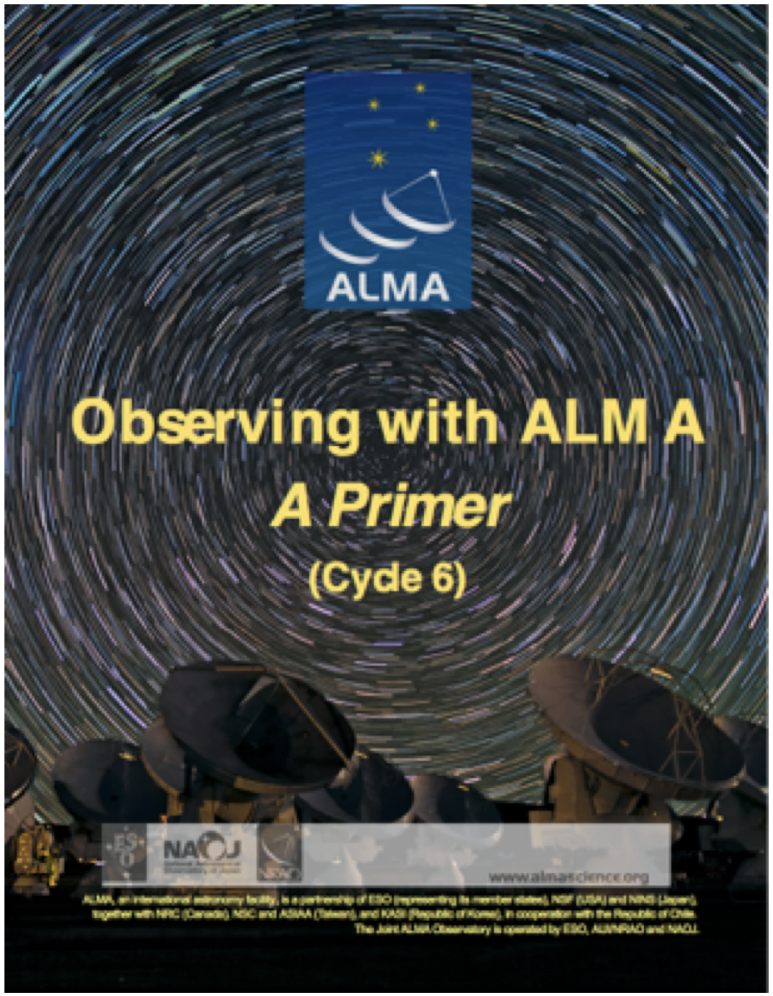
Cycle 6 Documentation & Timeline

- Call for Proposals
- Proposer's Guide
- ALMA Primer
- OT Guide
- ALMA Tech Handbook
- For reference, Cycle 6 timeline (similar each cycle):
  - Mar. 20 – Call for Proposals
  - Apr. 19 – Proposal Deadline
  - End July – Results to PIs
  - Aug. 2018 – PIs submit SBs
  - Oct. 2018 – Start of Cycle 6
  - Sept. 2019 – End of Cycle 6



https://almascience.nrao.edu/documents-and-tools/latest/documents-and-tools/cycle6/alma-science-primer

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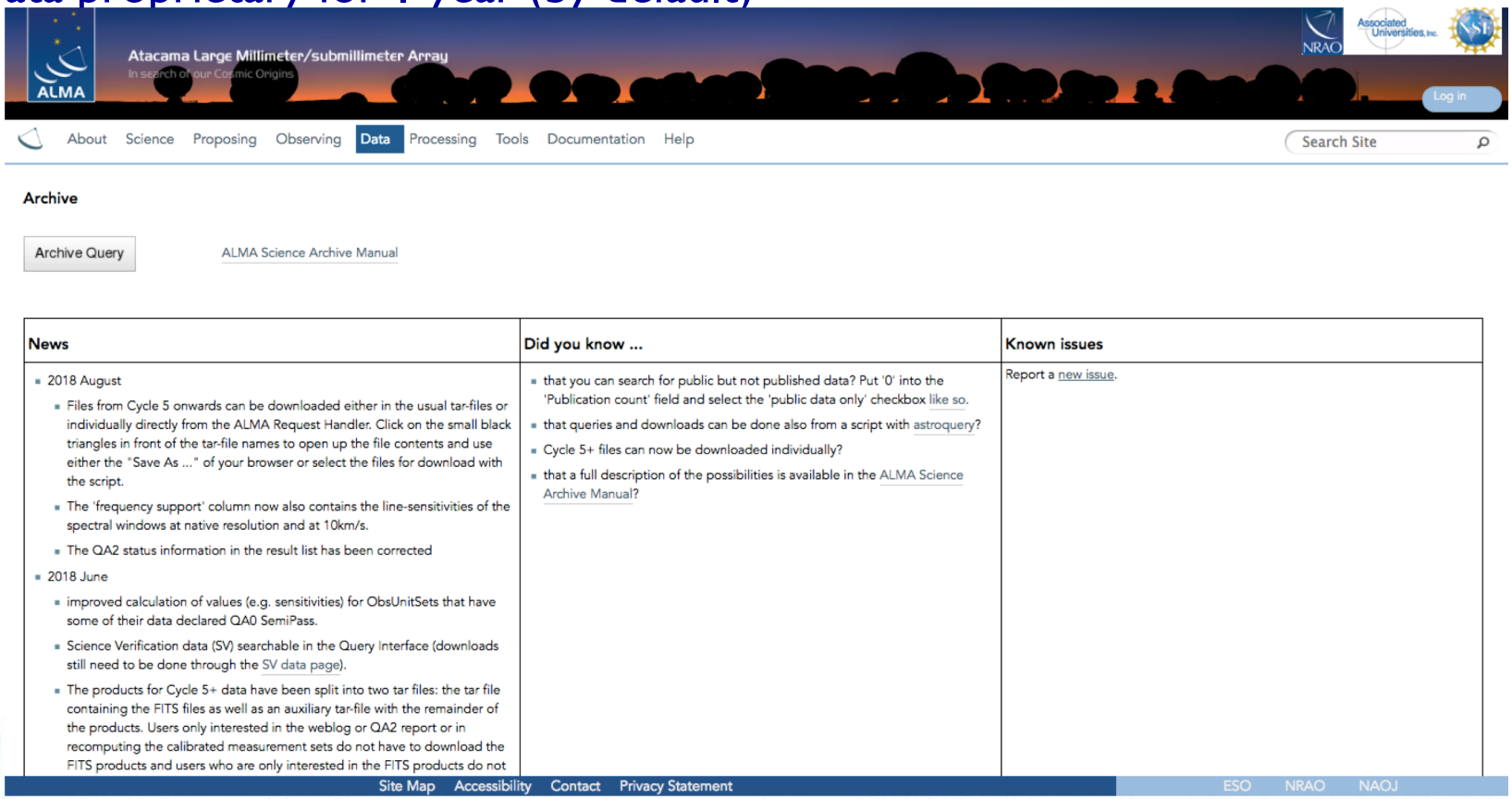
The data archive

Go to the science portal: https://almascience.nrao.edu

(Later, it will prompt you to log-in to download your proprietary data.)

- Click on "Data" and select "Archive"
- Data proprietary for 1 year (by default)



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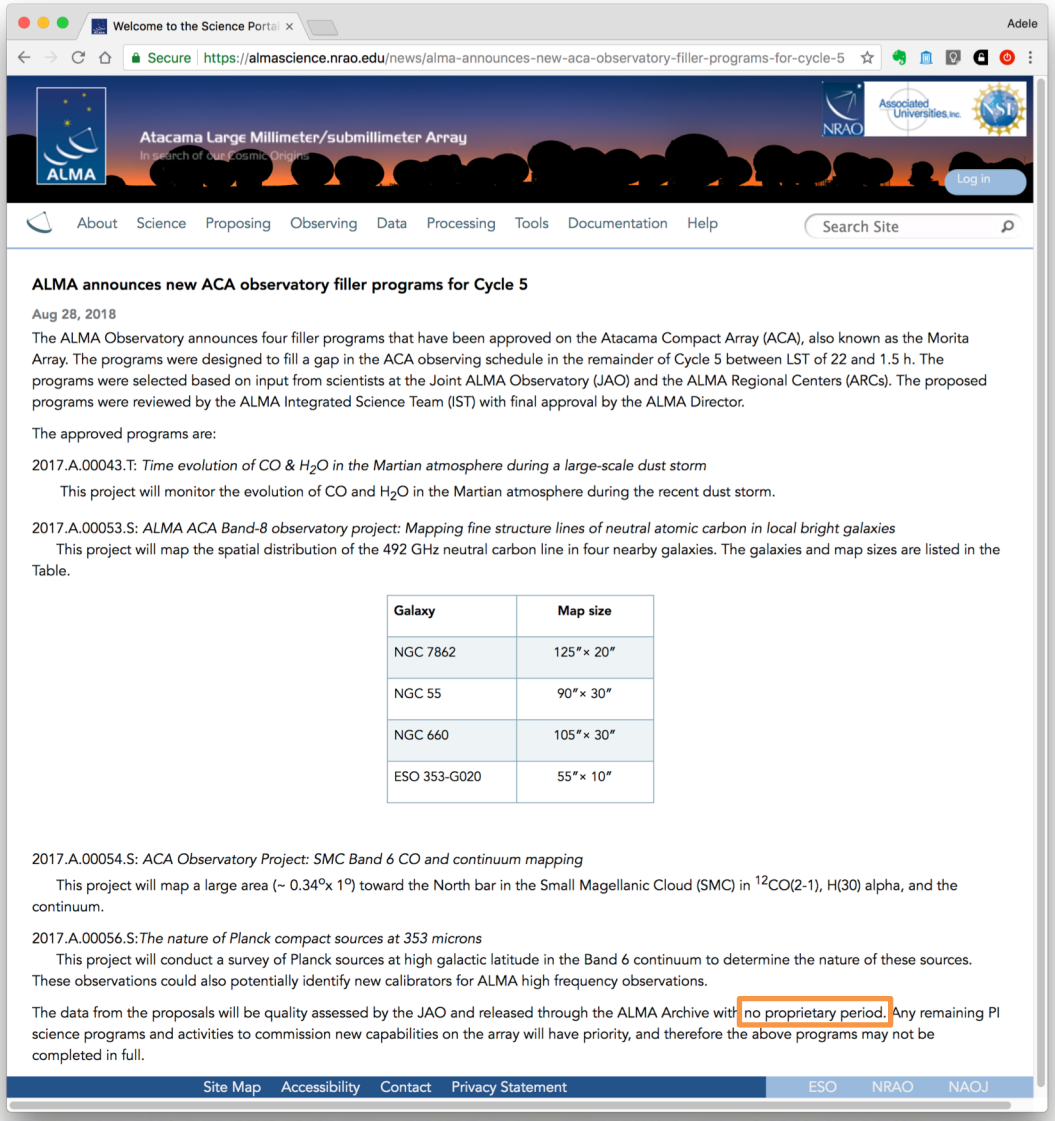
ACA Observatory projects



Welcome to the Science Portal

Adele

Secure | https://almascience.nrao.edu/news/alma-announces-new-aca-observatory-filler-programs-for-cycle-5

Atacama Large Millimeter/submillimeter Array

In Search of Our Cosmic Origins

ALMA

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ALMA announces new ACA observatory filler programs for Cycle 5

Aug 28, 2018

The ALMA Observatory announces four filler programs that have been approved on the Atacama Compact Array (ACA), also known as the Morita Array. The programs were designed to fill a gap in the ACA observing schedule in the remainder of Cycle 5 between LST of 22 and 1.5 h. The programs were selected based on input from scientists at the Joint ALMA Observatory (JAO) and the ALMA Regional Centers (ARCs). The proposed programs were reviewed by the ALMA Integrated Science Team (IST) with final approval by the ALMA Director.

The approved programs are:

2017.A.00043.T: *Time evolution of CO & H_2O in the Martian atmosphere during a large-scale dust storm*

This project will monitor the evolution of CO and H_2O in the Martian atmosphere during the recent dust storm.

2017.A.00053.S: *ALMA ACA Band-8 observatory project: Mapping fine structure lines of neutral atomic carbon in local bright galaxies*

This project will map the spatial distribution of the 492 GHz neutral carbon line in four nearby galaxies. The galaxies and map sizes are listed in the Table.

Galaxy	Map size
NGC 7862	125″× 20″
NGC 55	90″× 30″
NGC 660	105″× 30″
ESO 353-G020	55″× 10″

2017.A.00054.S: *ACA Observatory Project: SMC Band 6 CO and continuum mapping*

This project will map a large area (~ 0.34^ox 1^o) toward the North bar in the Small Magellanic Cloud (SMC) in ^{12}CO(2-1), H(30) alpha, and the continuum.

2017.A.00056.S:*The nature of Planck compact sources at 353 microns*

This project will conduct a survey of Planck sources at high galactic latitude in the Band 6 continuum to determine the nature of these sources. These observations could also potentially identify new calibrators for ALMA high frequency observations.

The data from the proposals will be quality assessed by the JAO and released through the ALMA Archive with no proprietary period. Any remaining PI science programs and activities to commission new capabilities on the array will have priority, and therefore the above programs may not be completed in full.

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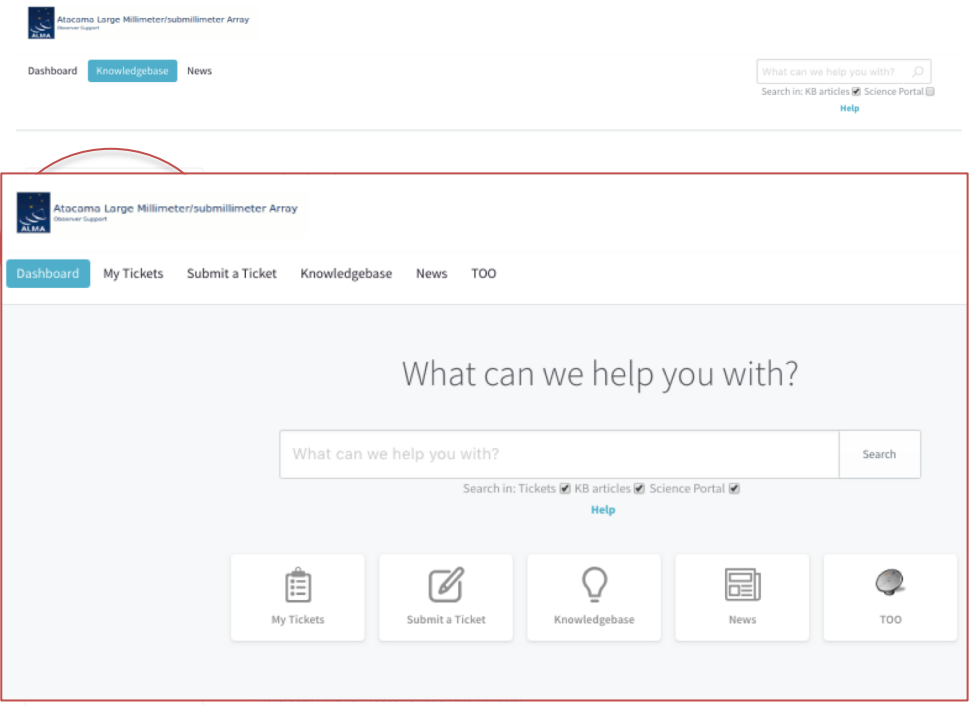
Support

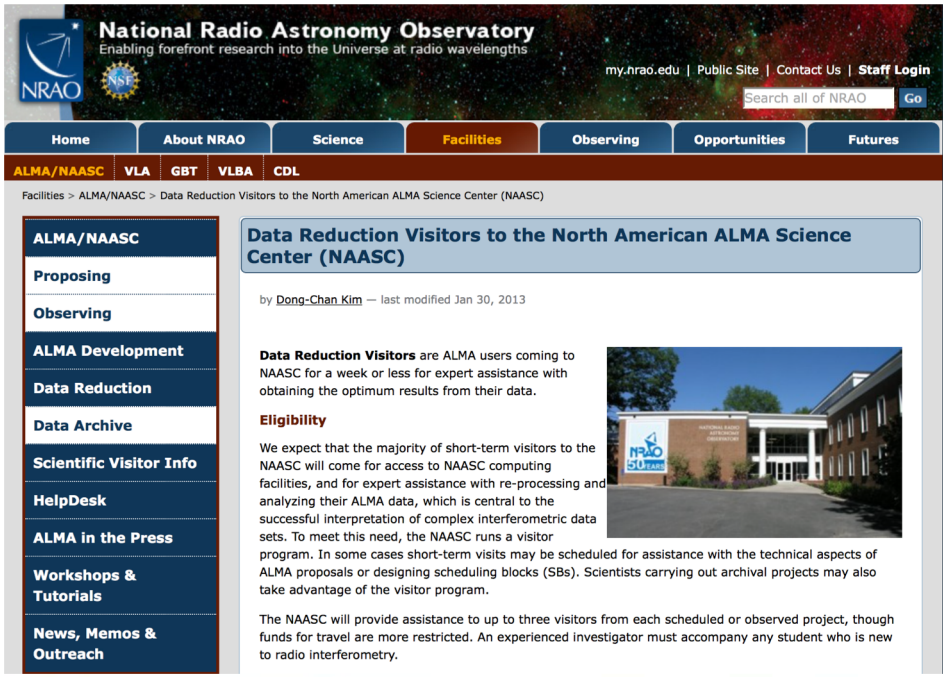
HelpDesk & Knowledgebase:

help.almascience.org



Face-to-Face visits in Charlottesville:

https://science.nrao.edu/facilities/alma/visitors-shortterm



ALMA is designed to be a telescope for *ALL* astronomers

Documentation

Call for Proposals

Documentation supporting the current ALMA Call for Proposals – **Cycle 6**. Documents from previous Cycles are provided here.

Document	Description
ALMA Proposer's Guide	Contains all pertinent information regarding the ALMA Call for Proposals
ALMA Technical Handbook	A comprehensive description of the ALMA observatory and its components
ALMA Users' Policies	The long-term core policies for use of the ALMA and ALMA data by the science community
Observing With ALMA - A Primer	Introduction to interferometry and how to use ALMA
ALMA Proposal Template	LaTeX format. Recommended but not mandatory
ALMA Proposal Review Process	The latest version of the ALMA Principles of the ALMA Proposal Review Process

Contents

1. Call for Proposals
2. Phase 1 & 2
3. Guides to the ALMA Regional Centers
4. ALMA Science Data Tracking, Data Processing and Pipeline, Archive and QA2 Data Products
5. ALMA Reports, Memos and Newsletters

https://almascience.nrao.edu/documents-and-tools

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