ALMA Proposal Workshop

Welcome!

Patrick Sheehan

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array

Introductions

Who am I and what's an ALMA Ambassador?

- ALMA Ambassadors:
  - NRAO program to ease logistics/burden of running multiple serial Community Days
  - Train local postdocs to run events, create new centers of expertise, expand the user base, and foment collaborations
- Who am I?
  - A postdoc here at OU! (Find me in office 215)
  - I work on studying the masses and structures of embedded disks
  - psheehan@ou.edu

Agenda

- 9:00 – 9:15 Welcome
- 9:15 – 9:30 ALMA Overview
- 9:30 – 10:00 Basics of Interferometry
- 10:00 – 10:45 ALMA Cycle 6 Capabilities
- 10:45 – 11:00 Break
- 11:00 – 12:00 The ALMA Proposal Preparation Process
- 12:00 – 1:30 Lunch
- 1:30 – 2:45 The Cycle 6 ALMA Observing Tool (hands-on)
- 2:45 – 3:00 Break
- 3:00 – 5:00 Imaging and Simulating Observations in CASA (hands on)

Software to Download

If you haven't downloaded in advance, you will need both to participate in the afternoon hands-on time!

1) ALMA OT

https://almascience.nrao.edu/proposing/observing-tool

Download the webstart version (will automatically download the most recent version each time you open it)

2) CASA

https://casa.nrao.edu/casa_obtaining.shtml

Download most recent version 5.1.2

Where Can I Get Help After This Workshop?

ALMA Helpdesk	Questions answered within 48 hours (around the clock staffing in the week leading up to the proposal deadline) https://help.almascience.org
Student Observing Support	Up to $35k to support undergraduate or graduate student involvement in successful ALMA proposals https://science.nrao.edu/opportunities/student-programs/sos
Page Charges	Support available upon request for authors from US institutions reporting ALMA/VLA results https://library.nrao.edu/pubsup.shtml
Face-to-face Visits	NRAO covers travel expenses for up to 2 people from 2 teams per week to get support for data reduction, proposal preparation, etc. at the NAASC https://science.nrao.edu/facilities/alma/visitors-shortterm
ALMA Ambassadors	You too can become an ALMA Ambassador! https://science.nrao.edu/facilities/alma/ambassadors-program

National Radio Astronomy Observatory

Patrick Sheehan

Associated Universities, Inc.

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array

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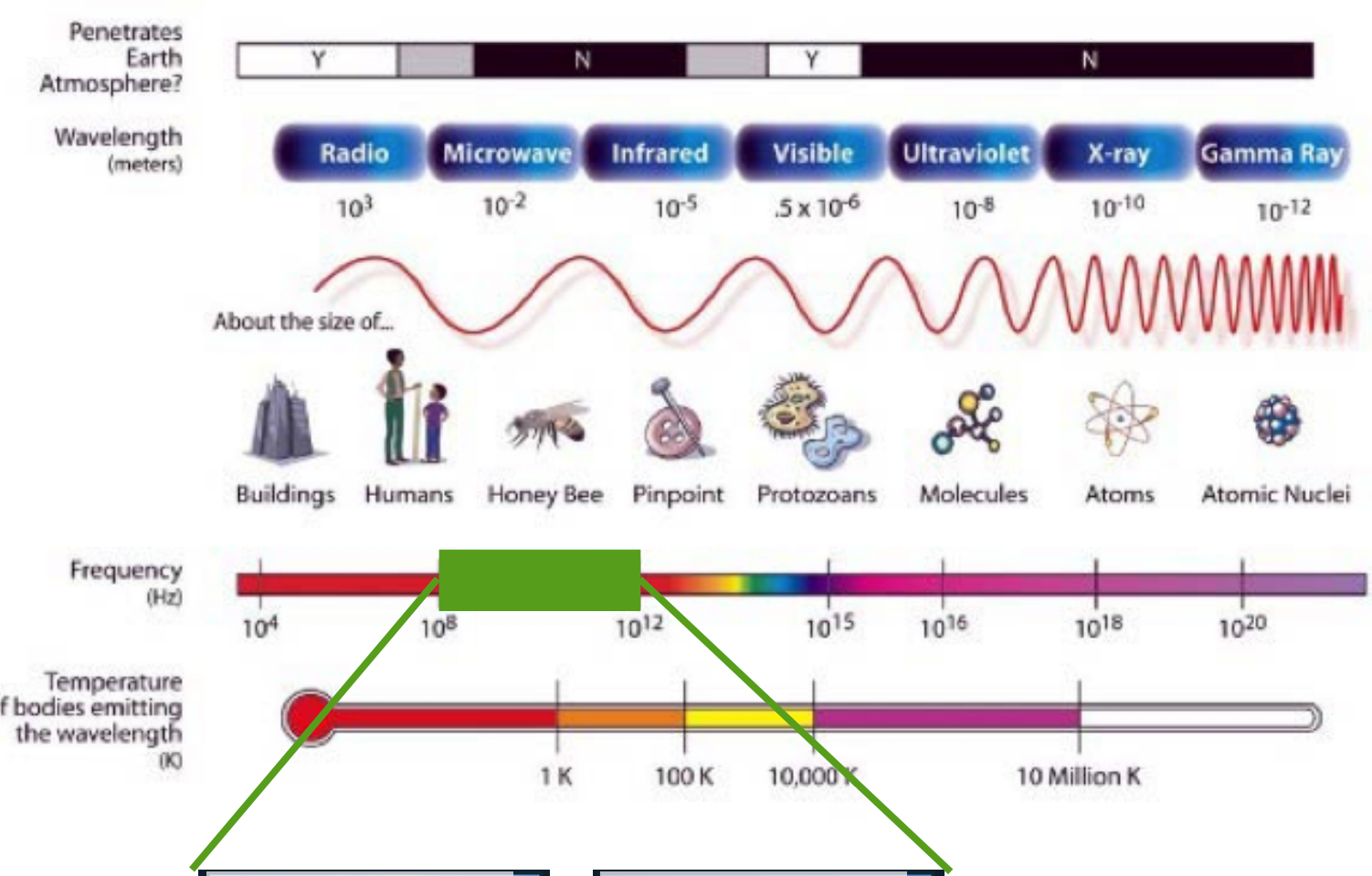
NRAO:
One Observatory, Two World Class Facilities

Other Affiliated Telescopes and Observatories include the Green Bank Observatory (http://greenbankobservatory.org/) and the Long Baseline Observatory (https://www.lbo.us/)

NRAO:
One Observatory, Two Facilities

Atacama Large Millimeter/submillimeter Array:
a 66-antenna array in Chile


Penetrates Earth Atmosphere?
Y
N
Y
N
Wavelength (meters)
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
10^3
10^-2
10^-5
.5 x 10^-6
10^-8
10^-10
10^-12
About the size of...
Buildings
Humans
Honey Bee
Pinpoint
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^4
10^8
10^12
10^15
10^16
10^18
10^20
Temperature of bodies emitting the wavelength (K)
1 K
100 K
10,000 K
10 Million K


VLA
~1 - 50 GHz
~300 - 6 mm


ALMA
~84 - 950 GHz
~3 - 0.3 mm

Broad Science Topics with NRAO Telescopes

- Sun – coronal mass ejections, magnetic field activity
- Solar system, KBOs – atmospheres, astrometry, composition
- Star-forming regions – dust and gas environment, kinematics (infall, outflows, jets), proto-planetary disks, cores, chemistry, feedback, and natal cloud / star interactions
- Exoplanets – direct imaging, gaps in disks, kinematics
- Pulsars – neutron star physics, pulse morphology, gravity, ISM probe
- Galactic structure – spiral arms, bars, global atomic and molecular gas properties
- Nearby galaxies – molecular / atomic gas content and kinematics, dynamics of galaxies at high resolution, star formation, obscured SF, gas flow
- Galaxy groups and clusters – atomic and molecular gas across systems, star formation efficiency, kinematics, dynamical mass measurements
- Black holes – mass measurements, kinematics
- High redshift galaxies – extragalactic background light, source counts, star formation history and efficiency, evolution of gas content (atomic and molecular)
- Cosmology – H_0 measurement, SZE

Atacama Large Millimeter/submillimeter Array
In search of our Cosmic Origins

NRAO Associated Universities, Inc.

Science Proposing Observing Data Processing Tools Documentation Help

Search Site

ation

oposals

on supporting the current ALMA Call for Proposals – **Cycle 5**. Documents from previous Cycles are provided here.

	Description
er's Guide	Contains all pertinent information regarding the ALMA Call for Proposals
al Handbook	A comprehensive description of the ALMA observatory and its components
Policies	The long-term core policies for use of the ALMA and ALMA data by the science community
h ALMA - A Primer	Introduction to interferometry and how to use ALMA
al Template	LaTeX format. Recommended but not mandatory
al Review Process	An updated 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 QA2 Data Products
5. ALMA Reports, Memos and Newsletters

ALMA is a telescope for *all* astronomers

What is ALMA?

A global partnership to deliver a revolutionary millimeter/submillimeter telescope array (in collaboration with Chile)

- North America
- Europe
- East Asia

66 reconfigurable, high precision antennas

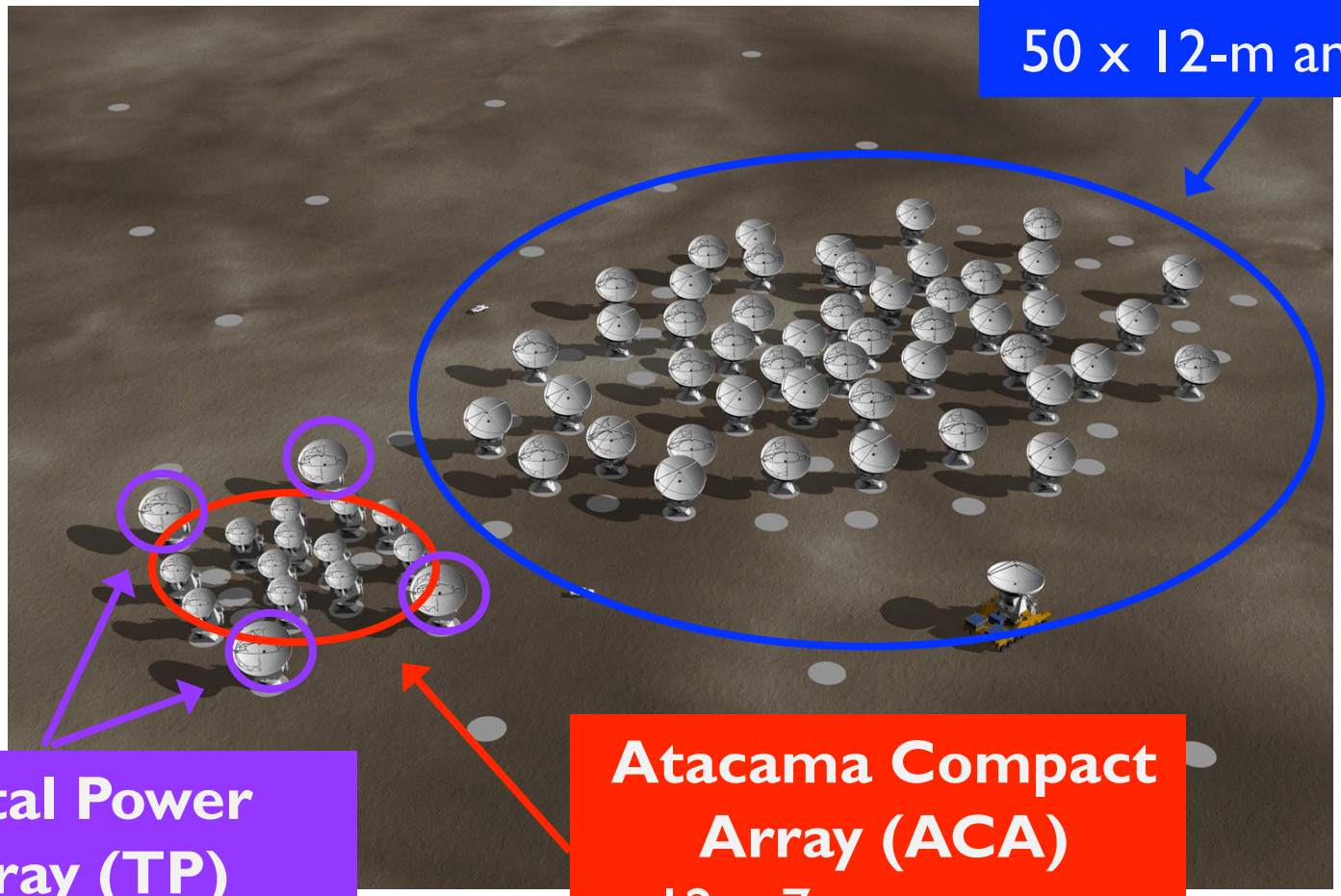
λ ~ 0.32 – 8.5mm. Array configurations between 150 meters and >16 kilometers: 192 possible antenna locations:

- Main Array: 50 x 12m antennas
- Total Power Array: 4 x 12m antennas
- Atacama Compact Array (ACA): 12 x 7m antennas
- TP + ACA (Morita Array)

Array Operations Site is located at 5000m elevation in the Chilean Andes

Provides unprecedented imaging* & spectroscopic capabilities at mm/submm λ

Array Configurations



Main Array
50 x 12-m antennas

Total Power Array (TP)
4 x 12-m antennas

Atacama Compact Array (ACA)
12 x 7-m antennas

**TP + ACA = Morita Array*

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What is ALMA?

Array configurations between 150 meters and >16 kilometers: 192 possible antenna locations:

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ALMA in a Nutshell...

- Angular resolution down to 0.015" (at 300 GHz)
- Sensitive, precision imaging 84 to 950 GHz (3 mm to 320 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 including circular.
- Estimated 1 TB/day data rate
- All science data archived
- Pipeline processing

ALMA is10-100 times more sensitive and has 10-100 times better angular resolution than current mm interferometers*

*With 90 Degree Walsh Switching in Bands 9 and 10, this gives 16 GHz of instantaneous bandwidth.

In either case, this is using the Time Division Mode (TDM) modes.

What is ALMA?

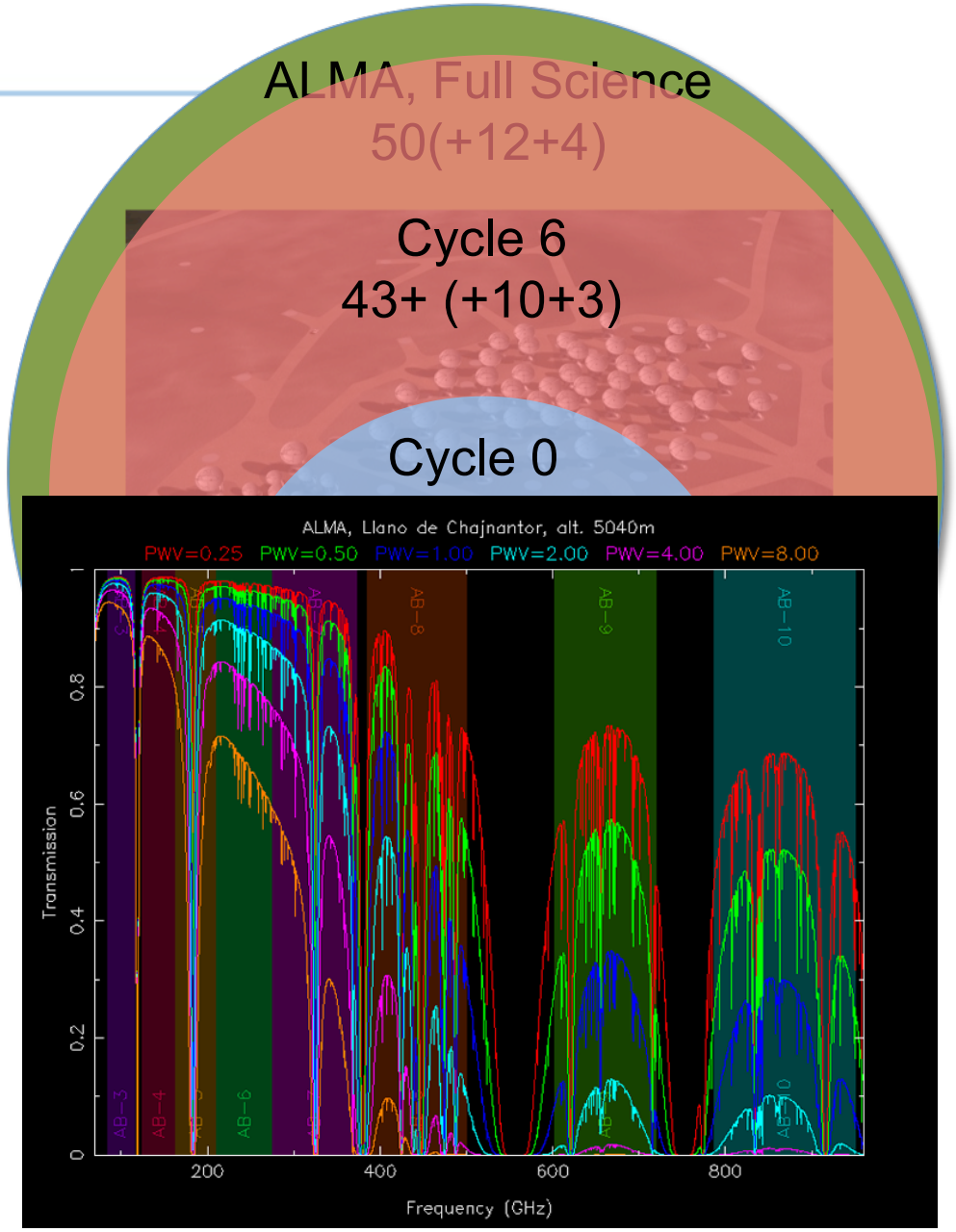
Collecting Area

Not only sensitivity but the collecting area (1.6 acres or 6600+ m2) + huge number of baselines provides excellent image fidelity

Spectral Coverage - Covers

ten atmospheric windows with 50% or more transmission above 35 GHz

https://almascience.nrao.edu/proposing/about-alma/atmosphere-model



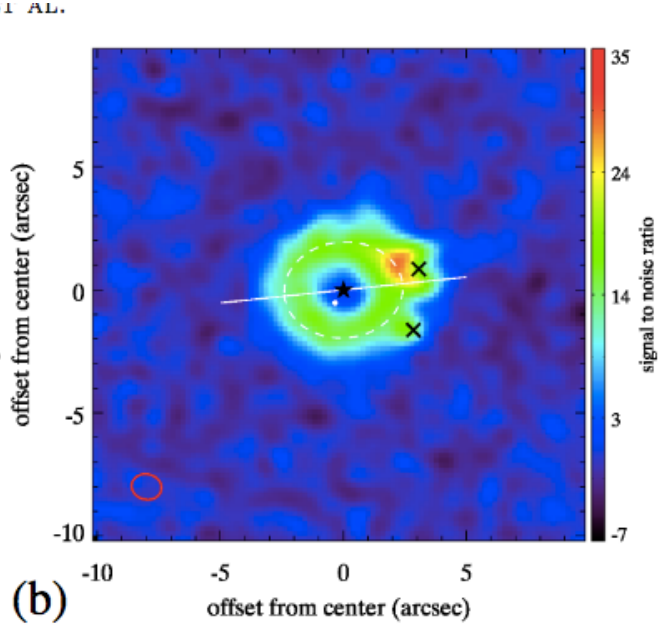
ALMA Current Status

- Construction Project ended in September 2014
- Routine science observing has been out to **greater than 12 km baselines (C40-9)** thanks to the highly successful Long Baseline Campaigns in 2014 and 2015
- **All 66 antennas accepted**
  - Currently all 66 antennas are at the high site (AOS), of which ~47 on average (up to max ~54) are being used for Cycle 5 observations
  - Some construction and verification items remain to be finished (e.g., wide-field polarization; various observing modes)
- The ACA (Atacama Compact Array) or Morita Array – up to 12x7m antennas and 4x12m antennas for TP observations – is currently being used for Cycle 5 observations
- More on Capabilities later… however, first on to science!

Science Highlight (1)

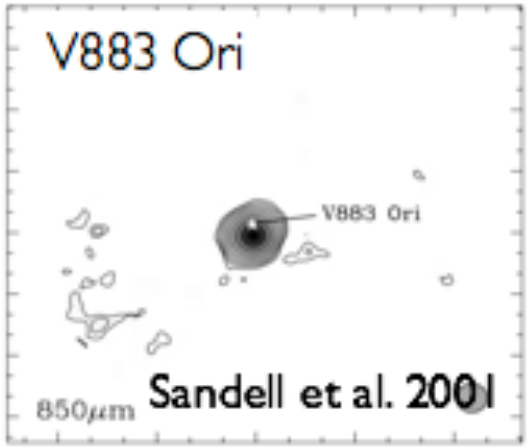
ALMA Images First Kuiper Belt Analogue Around Sun-like Star

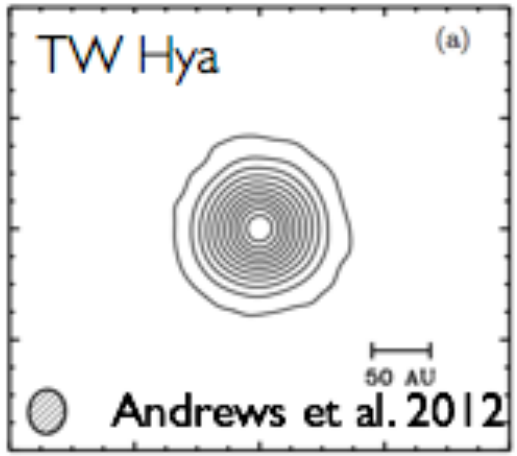
- HD 95086 is a 1.6 M_{sun} A star about 17 Myr years old, 83.8 pc from the Sun
- HD 95086 hosts a directly-imaged ~4M_{Jup} planet about 57 AU from the star
- ALMA has imaged a debris disk outside the planetary orbit
  - The disk is inclined 30°
  - The disk extends from an inner radius ~100 AU to an outer radius ~320 AU.
  - A bright source near the edge of the ring is almost certainly a background galaxy.
  - A second planet may shepherd the inner edge of the cold disk, could be 0.2-1.5 M_{jup}

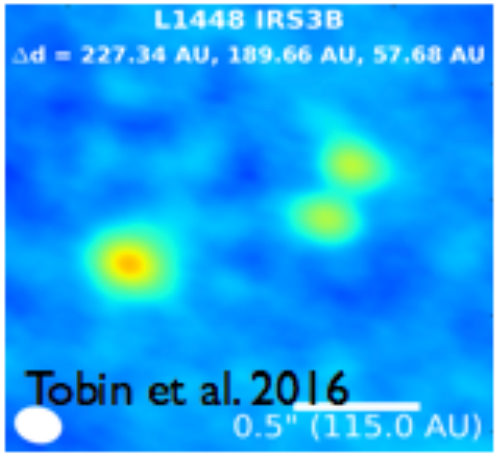


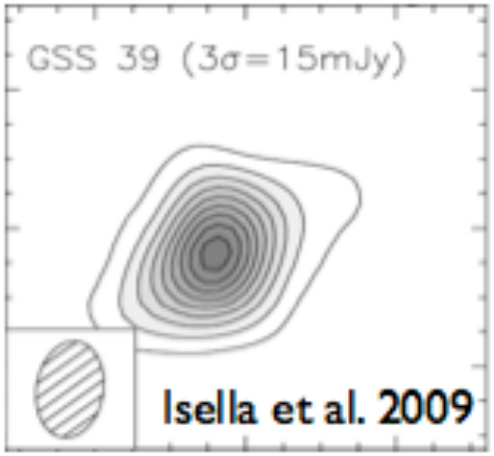
ALMA Science Highlights: Protoplanetary Disks

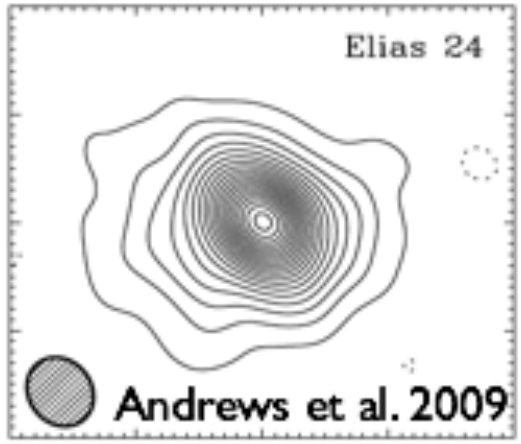
Protoplanetary Disks: Pre- ALMA











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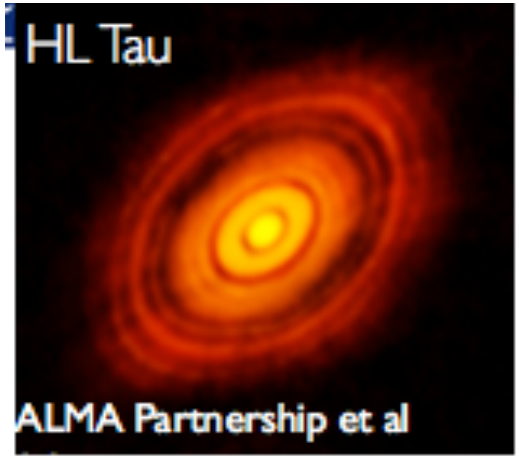
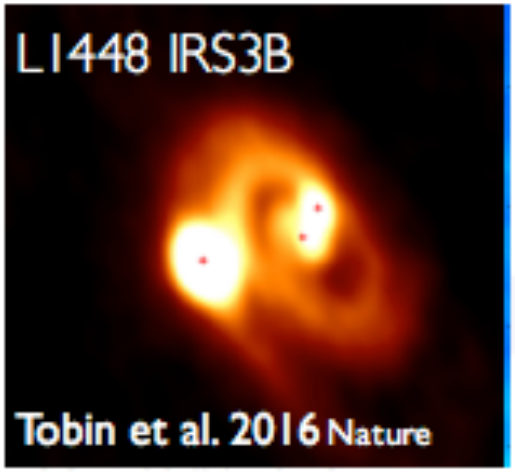
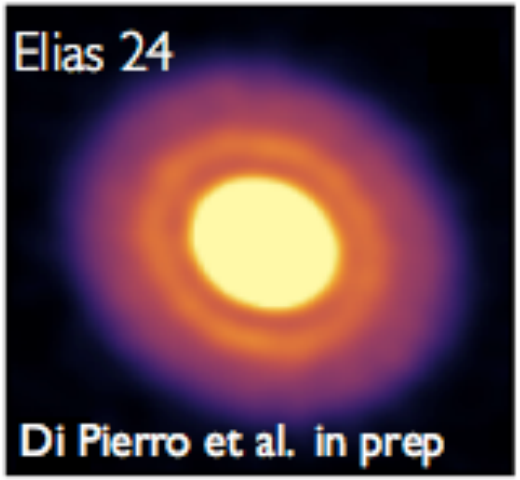
ALMA Science Highlights: Protoplanetary Disks

Protoplanetary Disks: With ALMA







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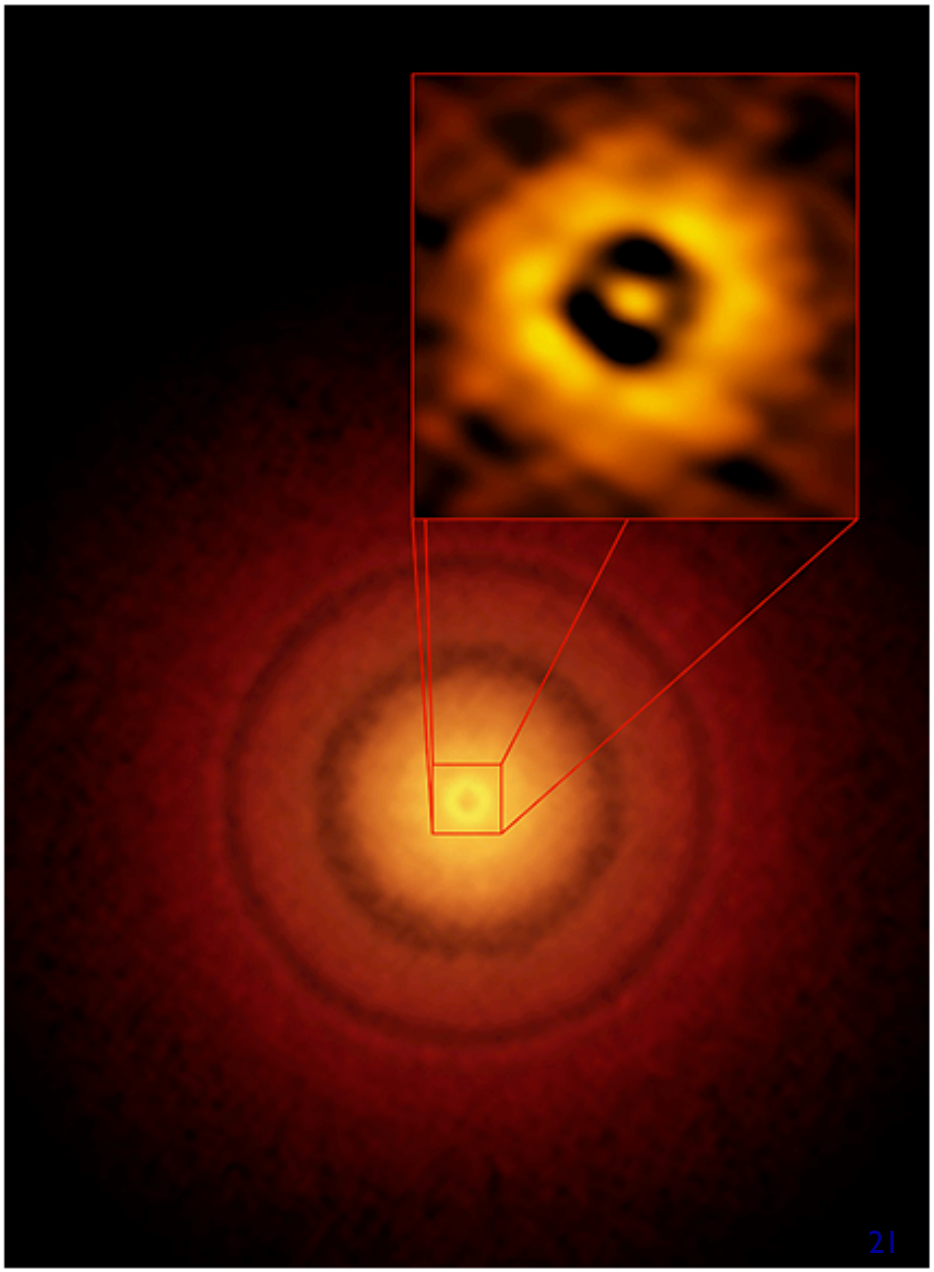
ALMA Science Highlights: Protoplanetary Disks

TW Hydrae

ALMA's better-than Hubble resolution details as small as the Earth's distance from the Sun may be discerned in this young (10Myr) nearby (175 light years) planet forming Sun-like star



Andrews et al. 2016

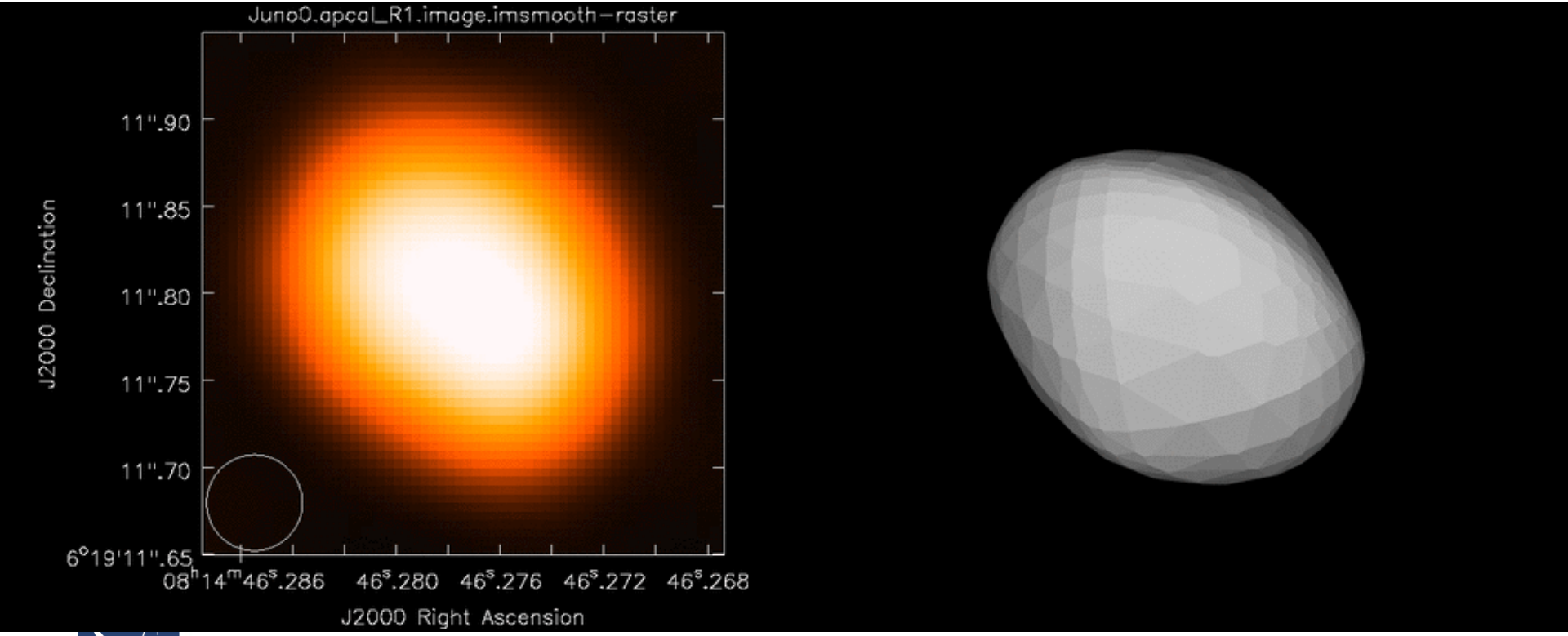
ALMA Science Highlights: Solar System

Band 6 Observations of Juno: Frequency = 233 GHz (Science Verification)

Five consecutive executions over 4.4 hours

Beamsize ~ 0.04”x0.03” (~60x45 km)

Model: Durech et al. 2010: **Database of Asteroid Models from Inversion Techniques**

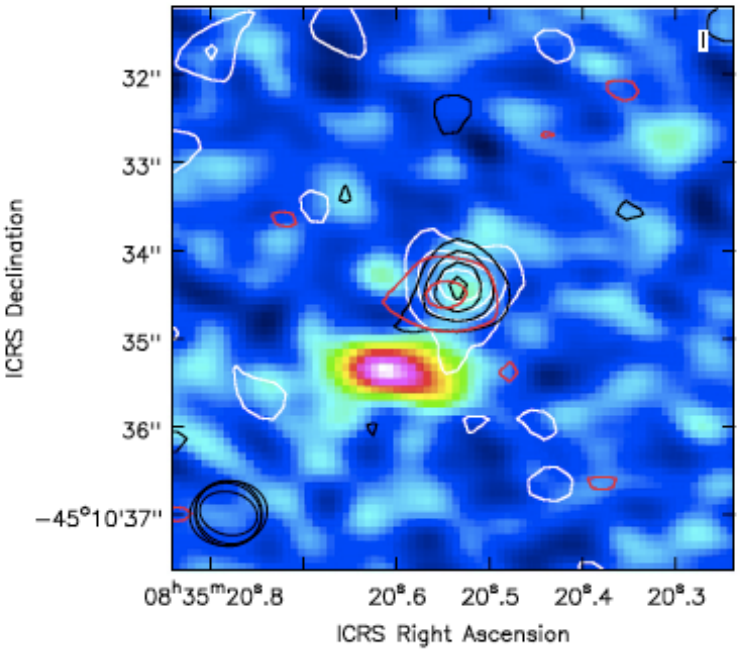


ALMA Image of Juno (ALMA Partnership, Hunter et al. 2015)

Science Highlight (2)

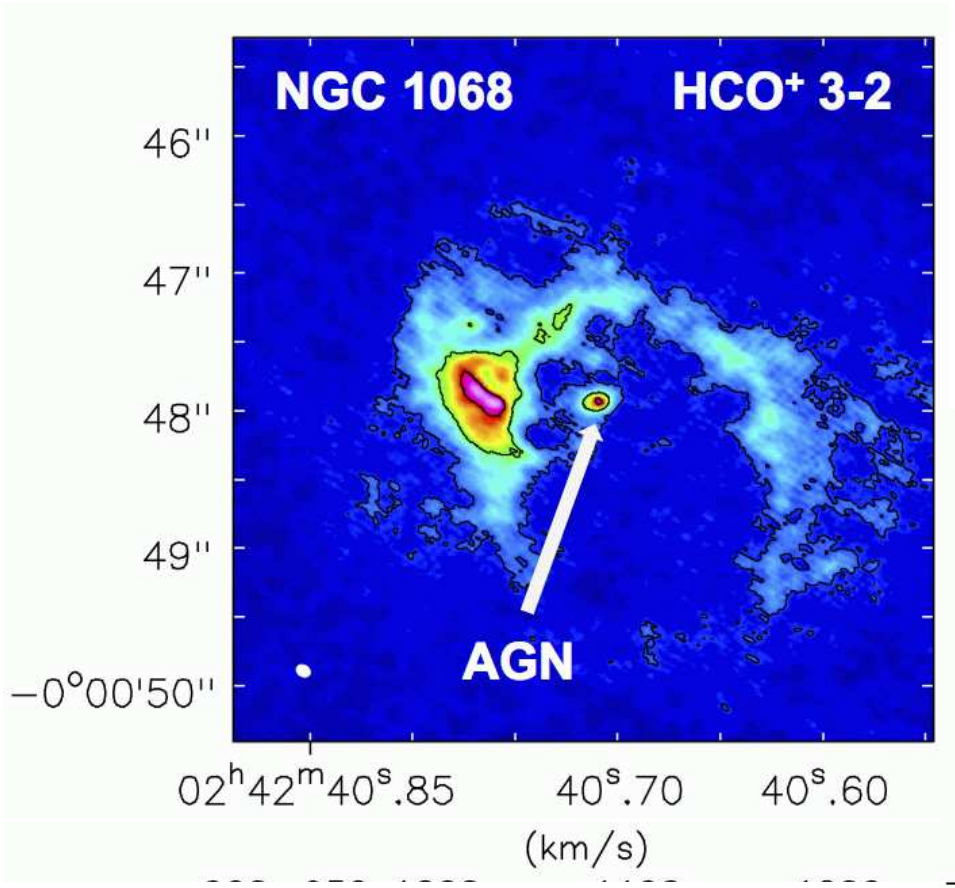
ALMA Images Vela Pulsar

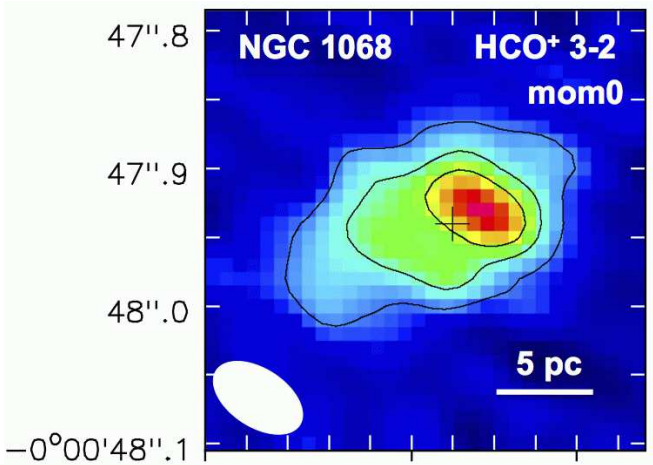
- ALMA Development Study results on pulsar observations will appear soon.
  - Successful measurement of pulsar profiles were achieved on Vela
- Detections in non-time resolved mode were made on Vela, SgrA* magnetar, and Crab pulsar.
  - Vela pulsar was detected in ALMA Bands 3, 4, 6 and 7 (see B7 image)
  - Extended structure seen in B7 may be a counter-jet protruding from the pulsar

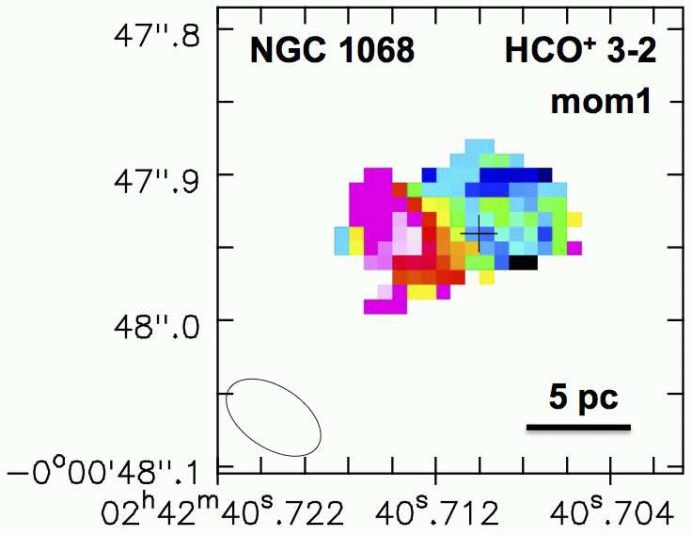


Science Highlight

Rotating gas and dust donut around a supermassive black hole







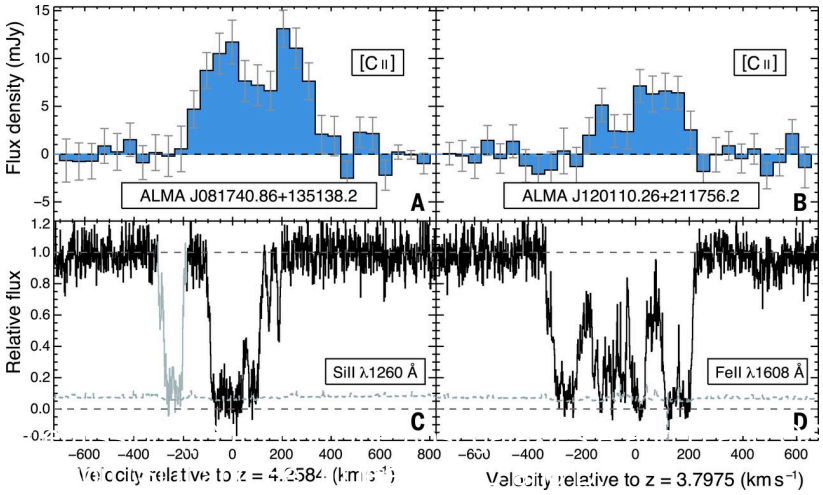
Science Highlight (VI)

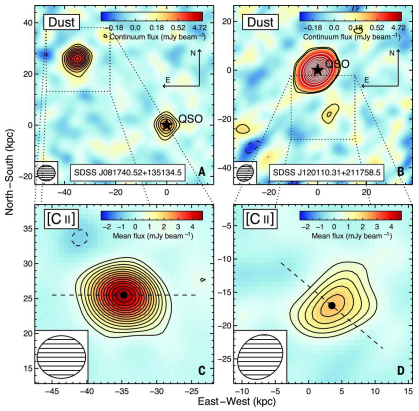
ALMA: SuperHaloes Surround Early Milky-Way-like Galaxies

With ALMA, US astronomers observed young Milky-Way like galaxies at z~4 and probed their haloes by measuring even more distant QSOs through them.

QSO-galaxy offsets probe the galaxy halo far beyond the ~5kpc extent of [C II] emission

- The host galaxy has enriched its inner gaseous halo
- The halo is bound to the host, will eventually be accreted and enrich star-forming gas.

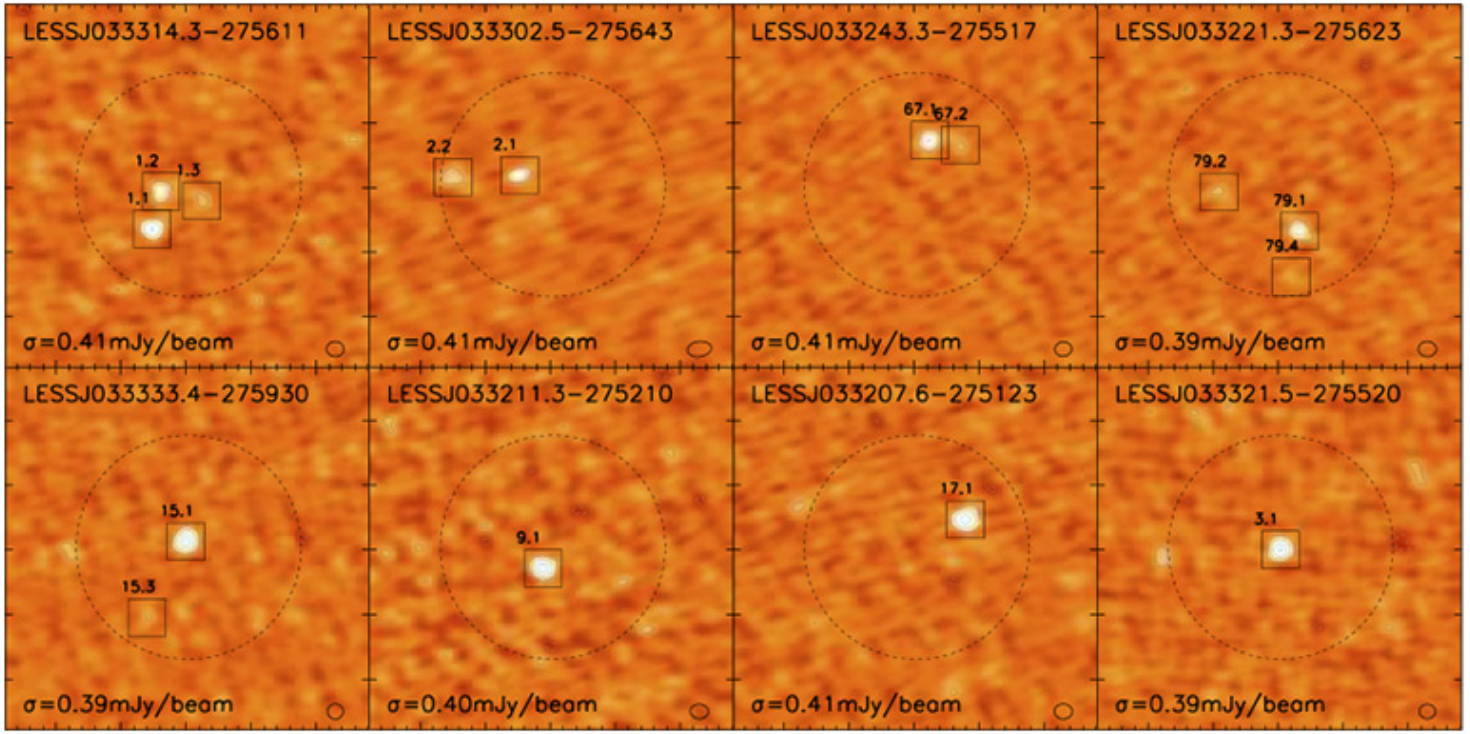




Above: The ≈400-GHz continuum emission near two QSOs (black stars). xes give the relative physical (proper) distance at the DLA. Below: Mean flux density over the full [C] 158-μm line profile displayed above. The dashed line is the measured major axis of the galaxy.

ALMA Science Highlights: the Distant Universe

Resolving High-z Submm Galaxies



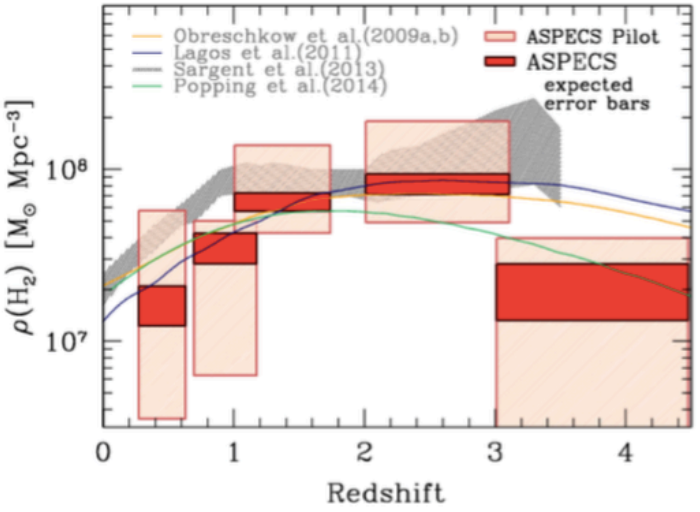
Hodge et al. 2013

- 126 submm sources observed with ALMA at 870 μm
- 2x deeper, 10x higher angular resolution than previous surveys
- **99 sources detected in 88 fields, integration time ~120 sec (!!)**
- Significant multiplicity (35-50%) found at 0.2" resolution

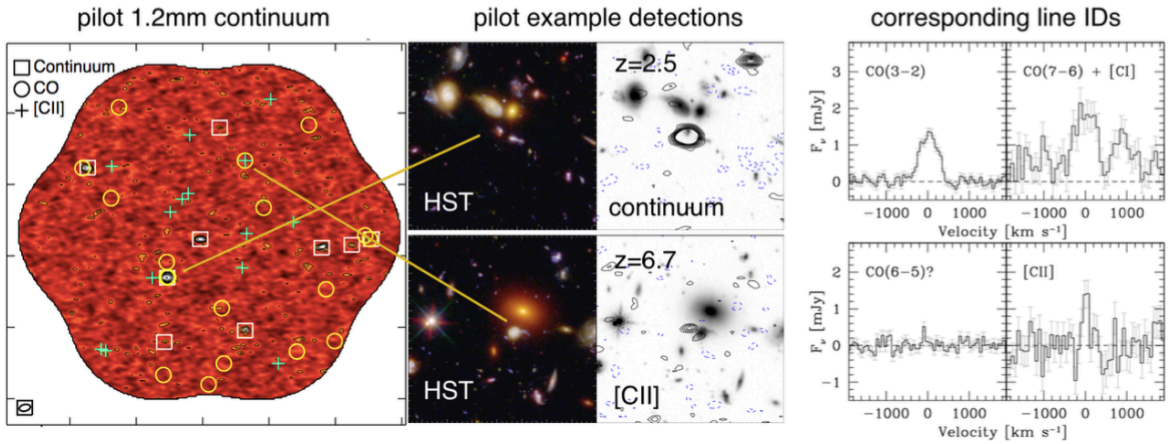
ALMA Science Highlights: the Distant Universe

ALMA Deep Fields: a new era of cosmological surveys

- ALMA has opened a new window on the cosmos: large volume surveys for cold gas throughout the Universe = the fuel for star formation. ASPECS is the first line deep field, involving full frequency scans of Band 3 and 6 in the Hubble UDF.
- 21 candidate line galaxies were detected, including CO emission from galaxies at z=1 to 5, and [CII] at z > 6, plus 9 dust continuum sources at 1.2mm
- These data determine the dense gas history of the Universe, the necessary complement to the star formation history of the Universe.



Examples of line and continuum sources from the ASPECS program, plus constraints on the dense gas history of the Universe (see papers by Walter, Decarli, Aravena)



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