ALMA Science Examples

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ALMA Science Requirements

- High Fidelity Imaging
- Precise Imaging at 0.1” Resolution
- Routine Sub-mJy Continuum Sensitivity
- Routine mK Spectral Sensitivity
- Wideband Frequency Coverage
- Wide Field Imaging Mosaicking
- Submillimeter Receiver System
- Full Polarization Capability
- System Flexibility

ALMA Science Requirements

High Fidelity Imaging

- Imaging spatial structures within galactic disks;
- Imaging chemical structure within molecular clouds;
- Imaging protostars in star formation regions

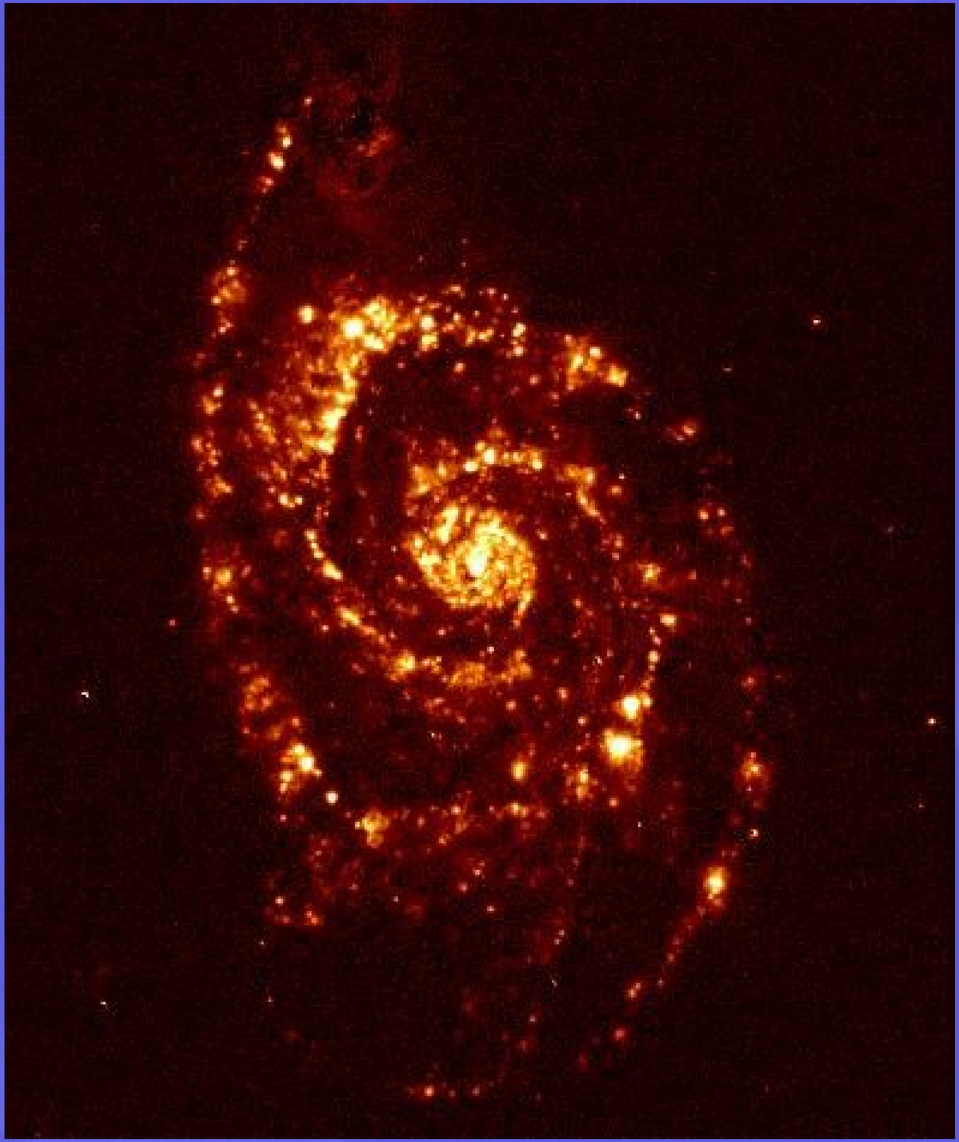
Precise Imaging at 0.1” Resolution

- Ability to discriminate galaxies in deep images
- Imaging tidal gaps created by protoplanets around protostars
- Imaging nuclear kinematics

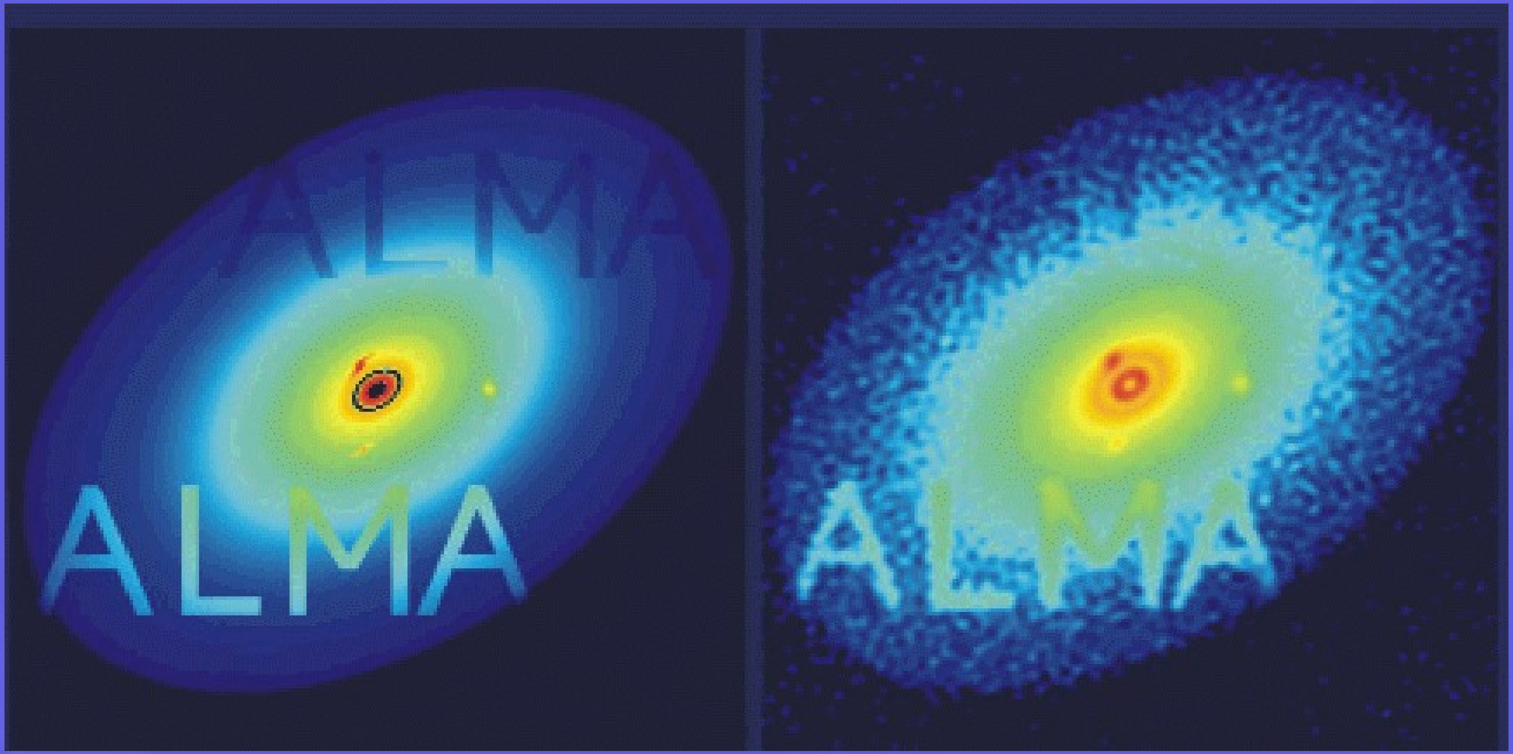
Routine Sub-mJy Continuum Sensitivity

- To enable imaging of the dust continuum emission from cosmologically-distant galaxies (SMGs, LBGs, EROs)
- To enable imaging of protostars throughout the Milky Way
- To enable astrometric observations of solar system minor planets and Kuiper-belt objects

M51 in Hα



Simulated Protoplanetary Disk



Credit: L. Mundy

ALMA Science Requirements

Routine mK Spectral Sensitivity

- Spectroscopic probes of protostellar kinematics
- chemical analysis of protostars, protoplanetary systems and galactic nuclei
- Spectroscopic studies of galactic disks and spiral structure kinematics
- Spectroscopic studies of Solar System objects

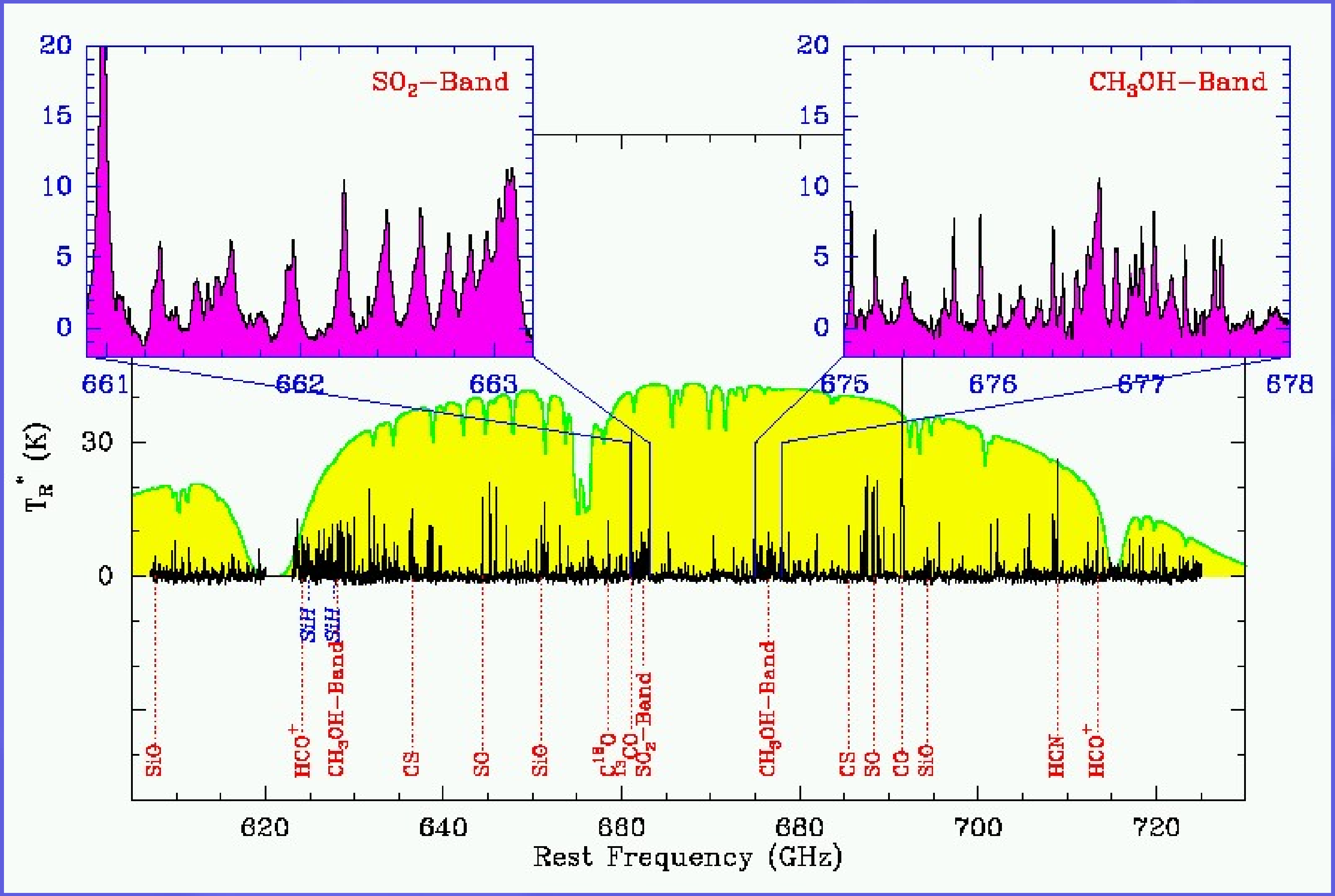
Wideband Frequency Coverage

- Spectroscopic imaging of redshifted lines from cosmologically distant galaxies
- comparative astrochemical studies of protostars, protoplanetary disks and molecular clouds
- quantitative astrophysics of gas temperature, density and excitation

Wide Field Imaging Mosaicking

- Imaging galactic disks
- Imaging the astrophysical context of star formation regions
- Imaging surveys of large angular regions
- Imaging planetary surfaces
- Solar astrophysics

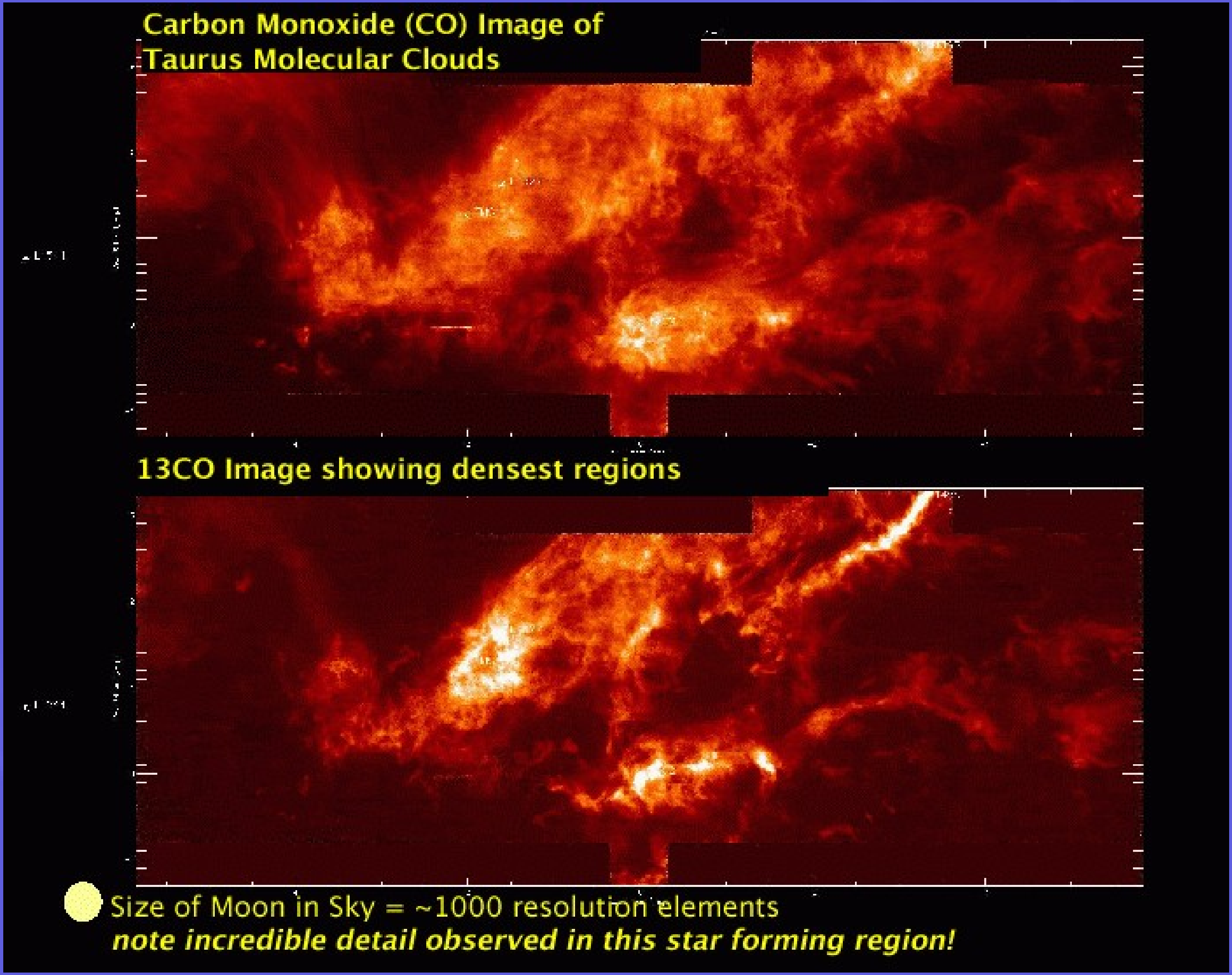
Forests of Spectral Lines



Schilke et al. (2000)

Physics of Interstellar Medium

Credit: M. Heyer



ALMA Science Requirements

Submillimeter Receiver System

- Spectral energy distribution of high redshift galaxies
- Chemical spectroscopy using C I and atomic hydrides
- C II and N II abundance as a function of cosmological epoch
- Chemistry of protoplanetary systems

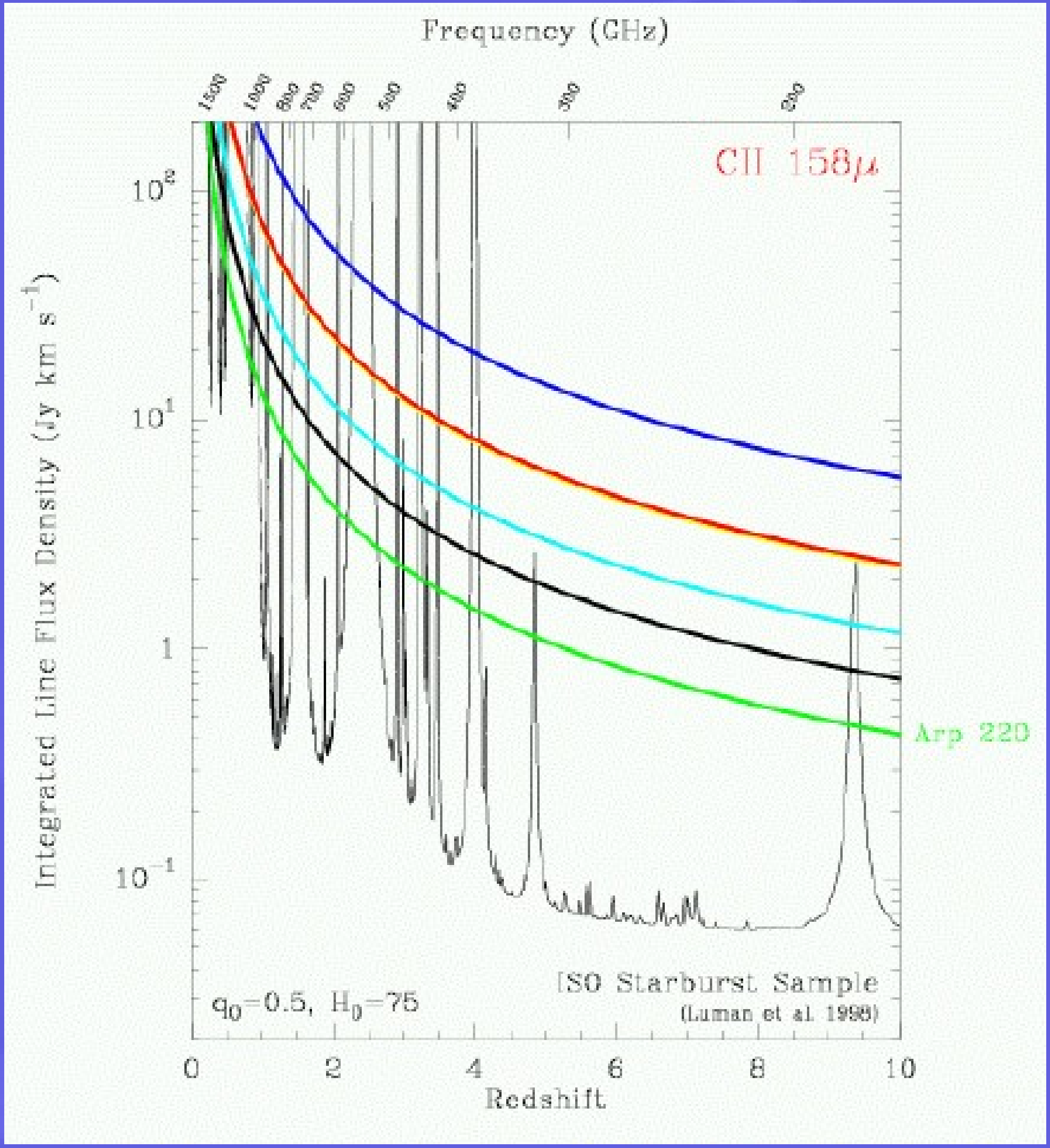
Full Polarization Capability

- Measurement of the magnetic field direction from polarized emission of dust
- Measurement of the magnetic field strength from molecular Zeeman effect observations
- Measurement of the magnetic field structure in solar active regions

System Flexibility

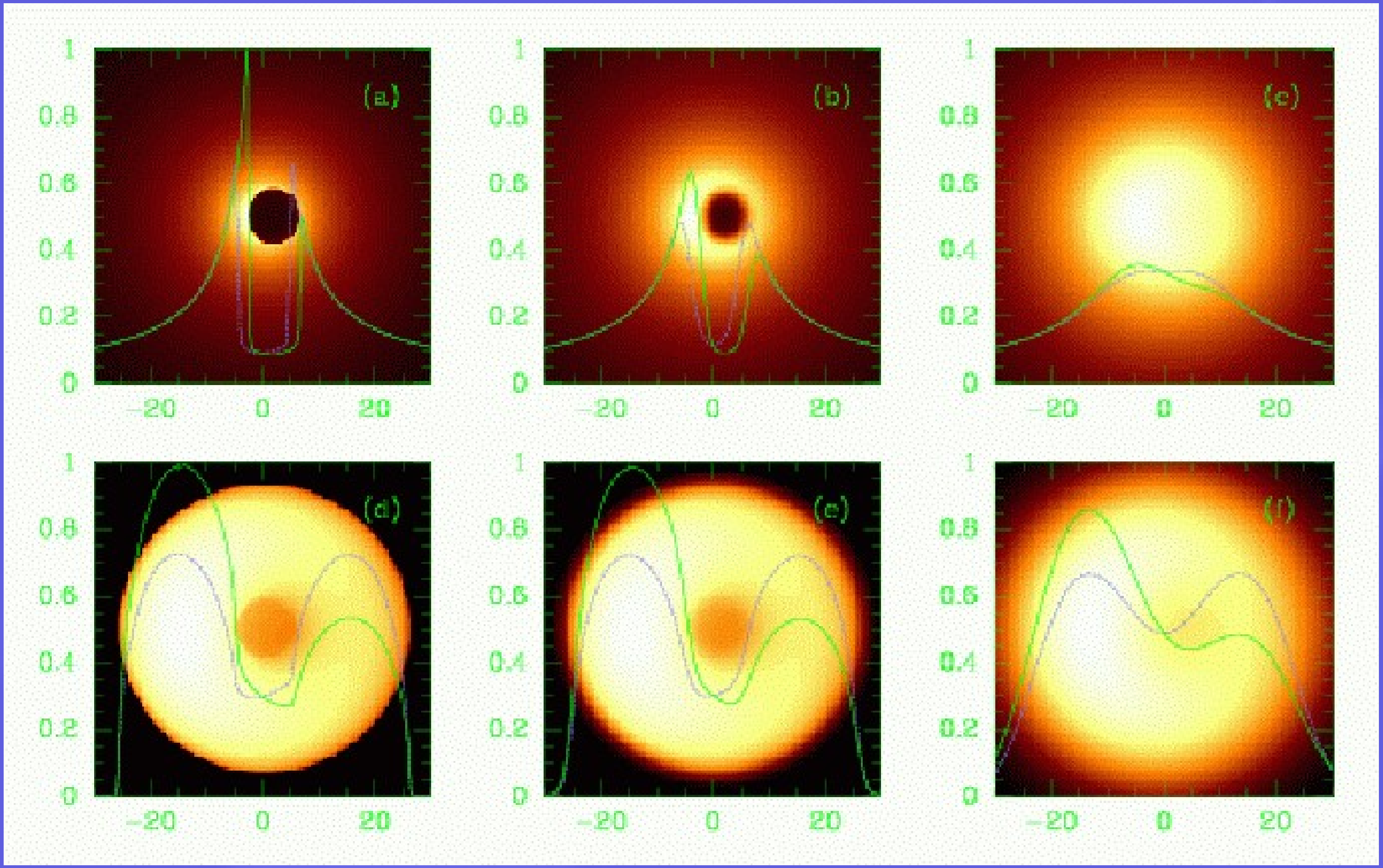
- To enable VLBI observations
- To enable pulsar observations
- For differential astrometry
- For solar astronomy

[C II] Emission from High-z Galaxies



Credit: K. Menten

VLBI Imaging of SgrA*



Falke et al. (2000)

Summary of detailed requirements

Frequency	30 to 950 GHz (initially only 84-720 GHz)
Bandwidth	8 GHz, fully tunable
Spectral resolution	31.5 kHz (0.01 km/s) at 100 GHz
Angular resolution	1.4 to 0.015" at 300 GHz
Dynamic range	10000:1 (spectral); 50000:1 (imaging)
Flux sensitivity	0.2 mJy in 1 min at 345 GHz (median conditions)
Antenna complement	64 antennas of 12m diameter
Polarization	All cross products simultaneously

ALMA Design Reference Science Plan (DRSP)

- Goal: To provide a prototype suite of high-priority ALMA projects that could be carried out in ~3 yr of full ALMA operations
- Started planning late April 2003; outline + teams complete early July; submitted December 2003
- 128 submissions received involving ~75 astronomers
- Review by ASAC members completed; comments included

Current version of DRSP on Website at:

http://www.strw.leidenuniv.nl/~joergens/alma

Example: ALMA Deep Field

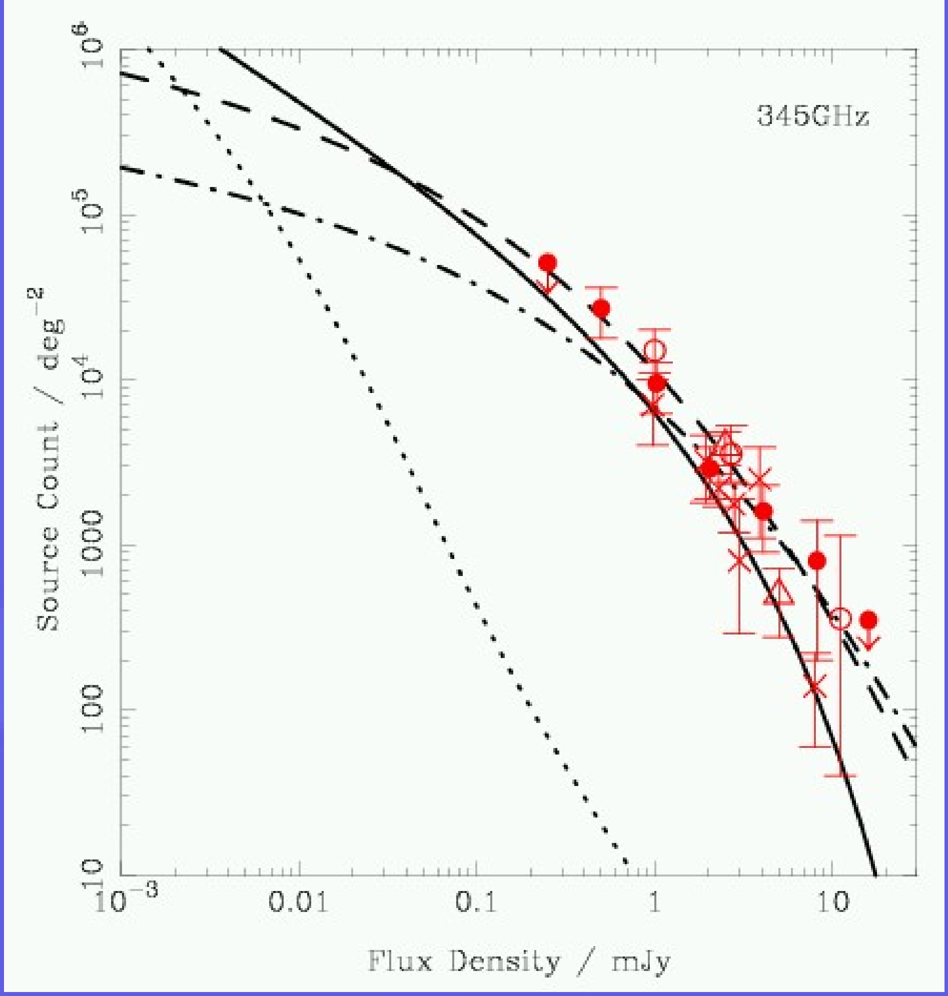
Step 1: 300 GHz Continuum Survey

4' x 4' Field
(3000x3000 pixels)

Sensitivity: 0.1 mJy (5σ)

- 30 minutes per field
- 140 pointings
- A total of 3 days

100-300 sources

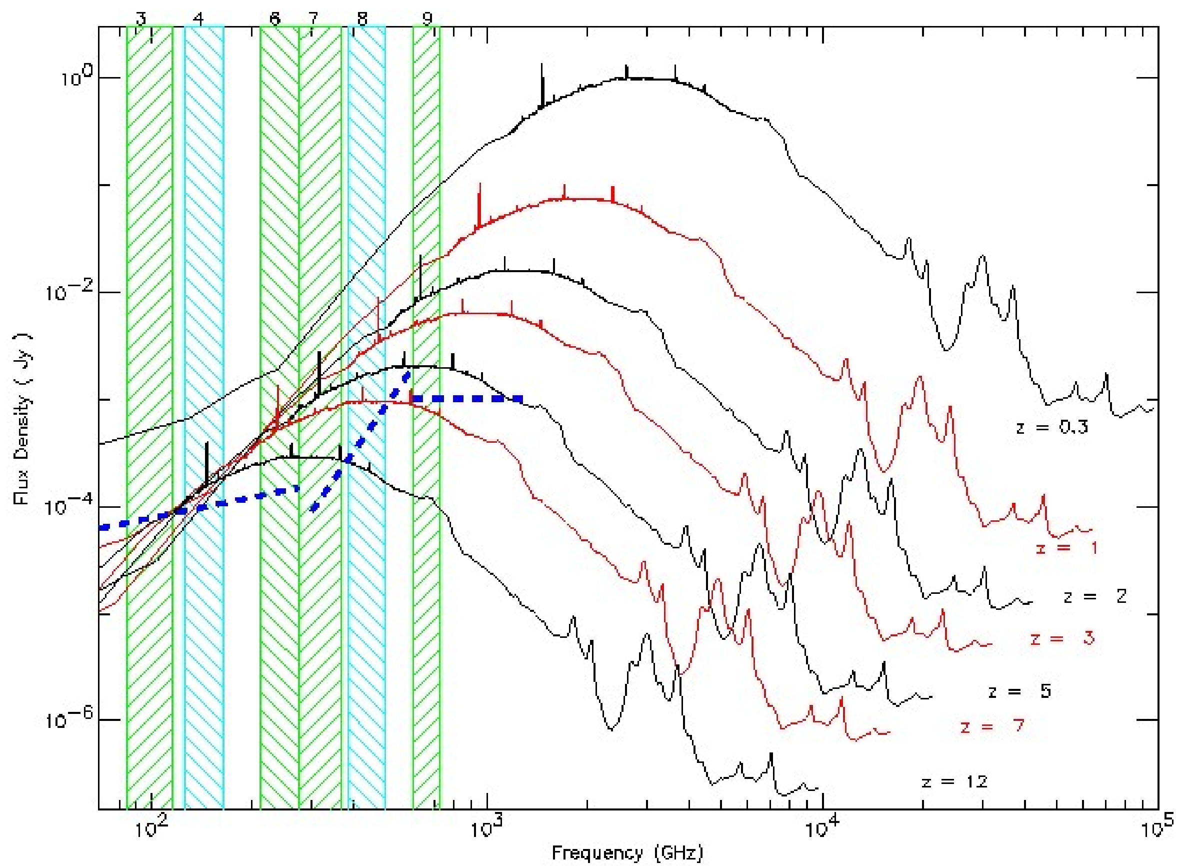


Determine the contribution of LBGs to the IR background

Infrared Luminous Galaxies

M82 from ISO, Beelen and Cox, in preparation

As galaxies get redshifted into the ALMA bands, dimming due to distance is offset by the brighter part of the spectrum being redshifted in. Hence, galaxies remain at relatively similar brightness out to high distances.



Hubble Deep Field

Rich in Nearby Galaxies, Poor in Distant Galaxies

Source: K. Lanzetta, SUNY-SB

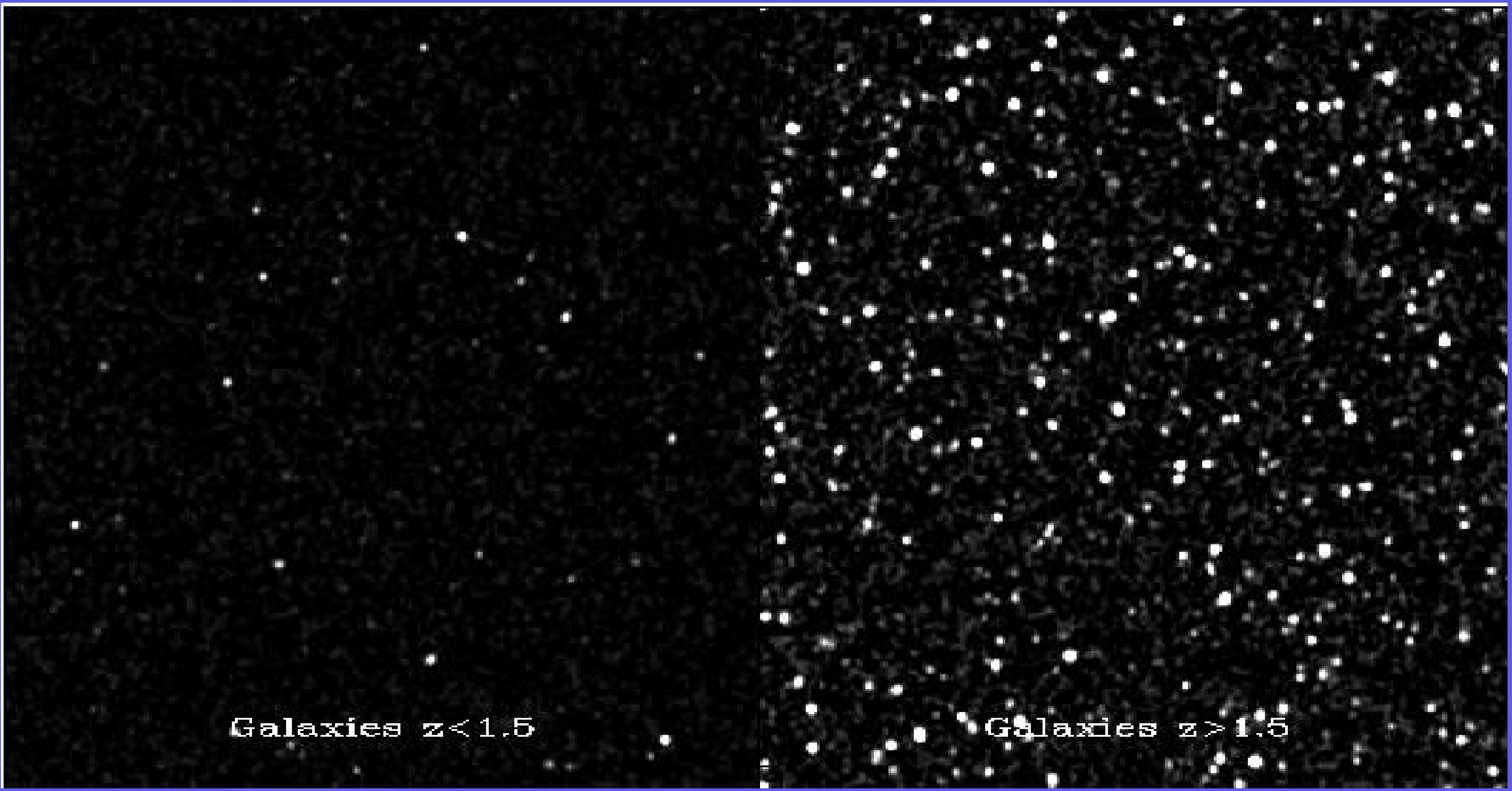
Nearby galaxies in HDF

Distant galaxies in HDF

ALMA Deep Field

Poor in Nearby Galaxies, Rich in Distant Galaxies

Source: Wootten and Gallimore, NRAO



Nearby galaxies in ALMA Deep Field

Distant galaxies in ALMA Deep Field

Example: ALMA Deep Field

Step 2: 100 GHz Spectroscopic Survey

4' x 4' Field (1000x1000 pixels)

Sensitivity: 7.5 μJy continuum and 0.02 Jy km/s for a 300 km/s line (5σ)

- 12 hrs per field
- 16 pointings (a total of 8 days)
- 4 tunings

One CO line for all sources at z>2 and two or more at z>6 → Obtain spectroscopic redshifts

Photometric redshifts

Example: ALMA Deep Field

Step 3: 200 GHz Spectroscopic Survey

4’ x 4’ Field (2000x2000 pixels)

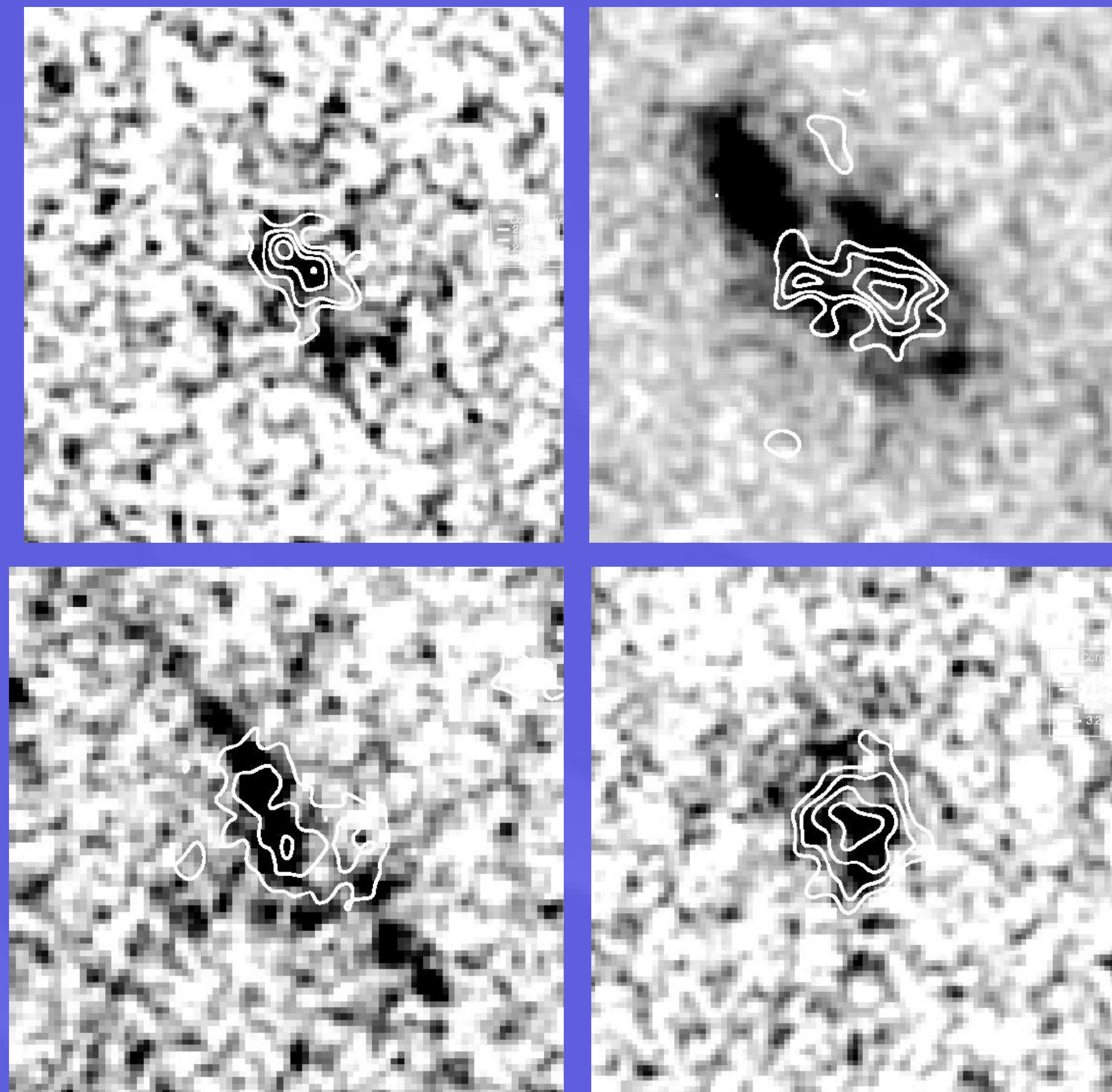
Sensitivity: 50 μJy continuum (5σ)

- 1.5 hrs per field
- 90 pointings (a total of 6 days)
- 8 tunings

Along with Step 2, at least one CO line for all redshifts, two CO lines at z>2

Photometric redshifts

Gas Distribution and Kinematics



Chapman et al. (2004)

Summary: ALMA Deep Field

Fully resolve the cosmic IR background into individual sources and determine FIR properties of LBGs and EROs as well as SMGs

Quantify the properties of high-z dusty galaxies (SFRs, gas content, dynamical mass, etc.)

Map the cosmic evolution of dusty galaxies and their contribution to the cosmic star formation history