Current Large Programs

Rosita Paladino

Italian ALMA Regional Center
INAF-Istituto di Radioastronomia (Bologna)

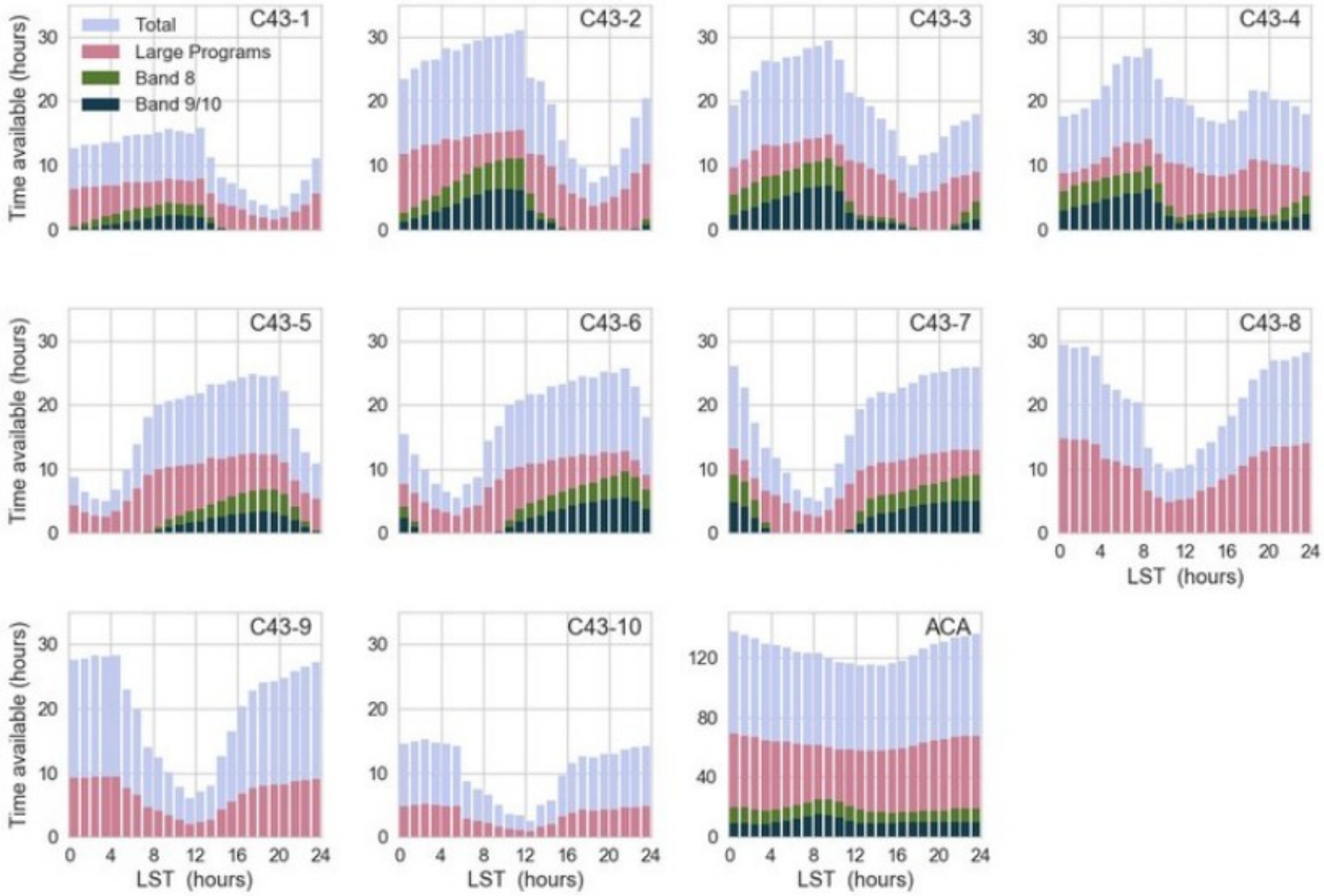
Bologna, 27.02.2019

Large Programs

Up to 15% of the time may be allocated to Large Programs:
645 hrs for the 12-m Array and **450 for stand-alone ACA**

Proposals including **only standard modes** with an estimated execution time of
> 50 hours on the 12-m Array (with or without accompanying ACA time) or
> 150 hours on the ACA in stand-alone mode

Strategic scientific issues, that will lead to a major advance in the field, **not reproducible by a combination of regular proposals**.
The programme teams are expected **to deliver their data products and documentation within one year of the final delivery of calibrated data**.



To optimize the success in completing the observations,scheduling constraints are imposed when selecting Large Programs:
<50% and <33% of available time for a given LST range in compact or extended configurations

Current ALMA Large programs

https://almascience.eso.org/alma-data/lp

Cycle 4	2016.1.00324.L	**Fabian Walter**	**ASPECS**: the ALMA SPECtral line Survey in the Hubble Ultra Deep Field
	2016.1.00484.L	**Sean Andrews**	**DSHARP**: Small-Scale Substructures in Protoplanetary Disks
Cycle 5	2017.1.00428.L	**Olivier Le Fevre**	**ALPINE**: The ALMA Large Program to Investigate CII at Early Times
	2017.1.00161.L	**Sergio Martin**	**ALCHEMI**: the ALMA Comprehensive High-resolution Extragalactic Molecular Inventory
	2017.1.00886.L	**Eva Schinnerer**	**PHANGS**: 100,000 Molecular Clouds Across the Main Sequence: GMCs as the Drivers of Galaxy evolution
	2017.1.01355.L	**Frederic Motte**	**ALMA-IMF**: ALMA transforms our view of the origin of stellar masses
Cycle 6	2018.1.00035.L	**Kotaro Kohno**	ALMA lensing Cluster Survey
	2018.1.00659.L	**Leen Decin**	**ATOMIUM**: ALMA tracing the Origins of Molecular In dUst-forming oxygen-rich M-type stars
	2018.1.01055.L	**Karin Oberg**	The chemistry of Planet Formation
	2018.1.01205.L	**Satoshi Yamamoto**	**FAUST**: Fifty AU Study of the chemistry in the disk/envelope of Solar-like protostars

Cosmology and high z universe

Galaxies and AGN

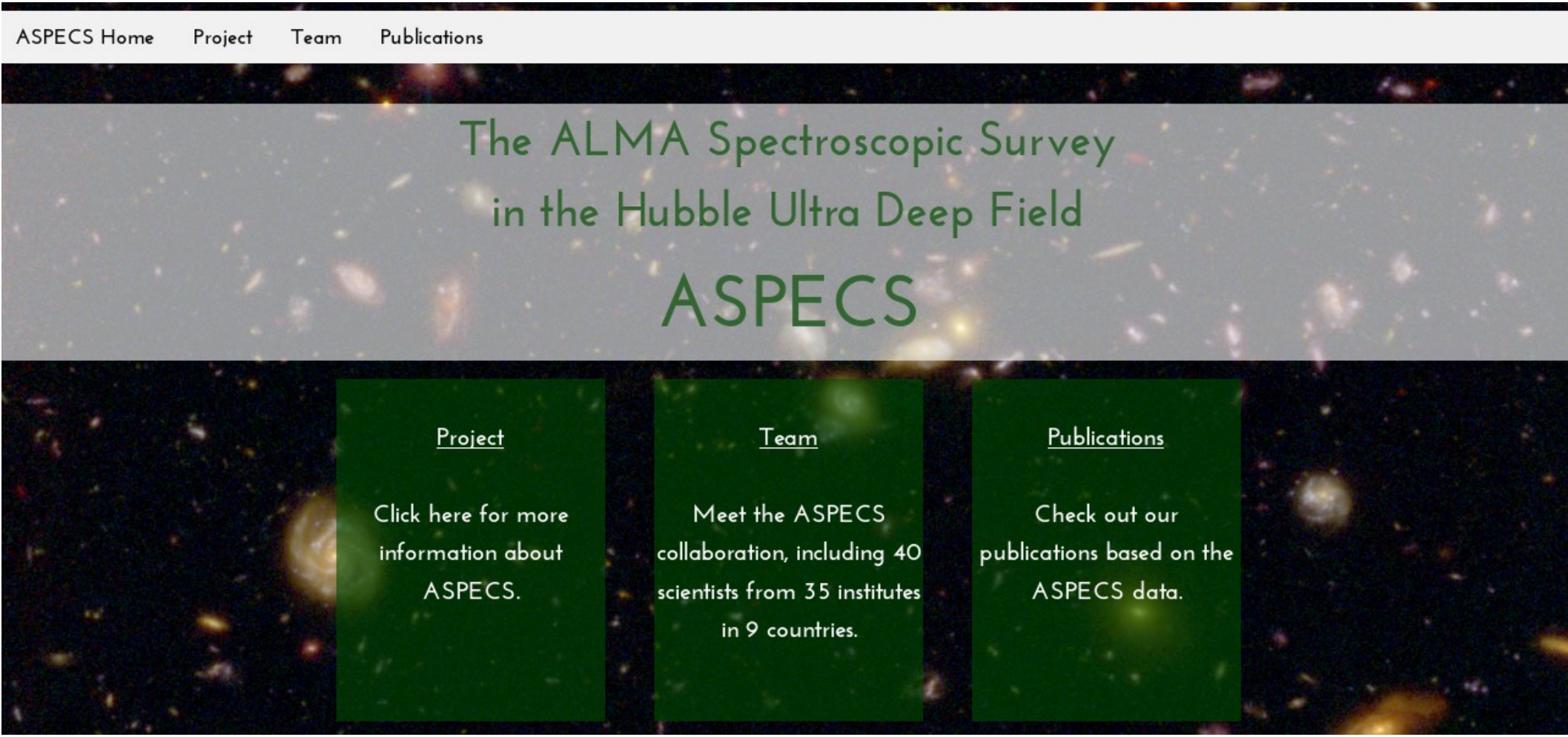
ISM Star formation astrochemistry

Circumstellar disk, Exoplanets and SS

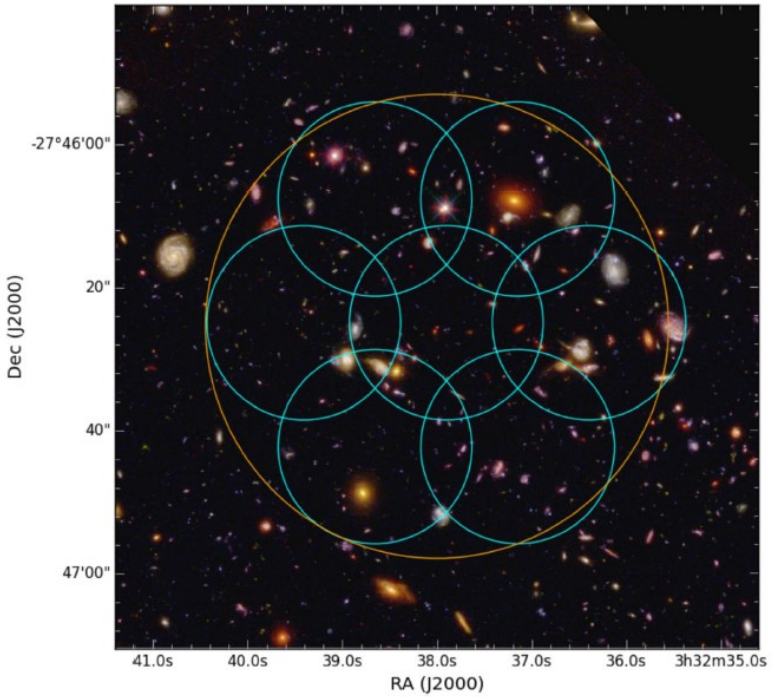
Stellar evolution And the Sun

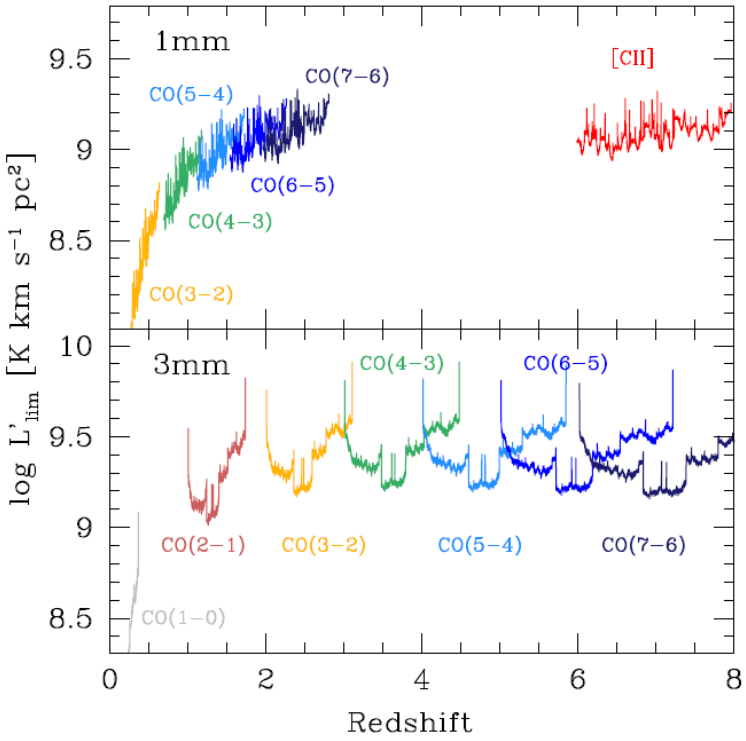
ASPECS: the ALMA SPECtral line Survey in the Hubble Ultra Deep Field

http://www.mpia.de/~ASPECS/index.php



ASPECS: the ALMA SPECtral line Survey in the Hubble Ultra Deep Field



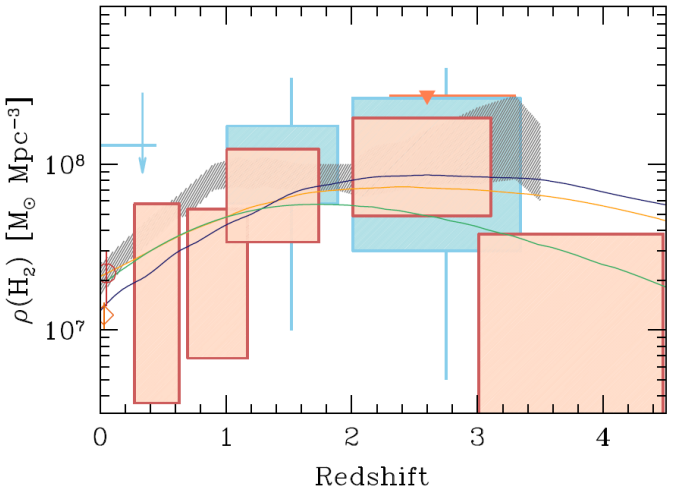


- It is built on the results of the pilot project observed in Cycle 2 (Walter 2016, Aravena 2016, DeCarli 2016….)
- **4 squared arcmin** region within the UDF observed from Hubble
- Spectral scans in Band 3 and 6
- **Natural and essential contribution of ALMA to the existing and planned multi-frequency campaigns of the UDF.**

ASPECS: the ALMA SPECtral line Survey in the Hubble Ultra Deep Field

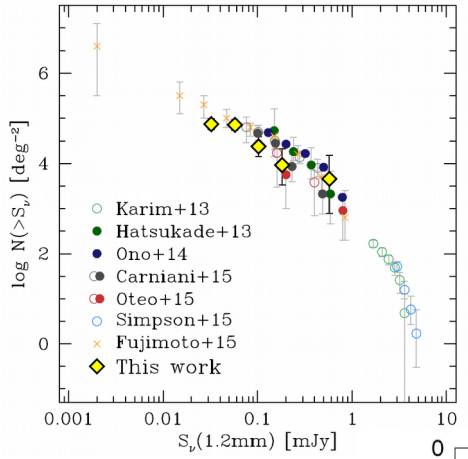
Main questions:

- **The H2 luminosity functions and cosmic H2 density.** The results from the pilot study can be improved observing a larger area.



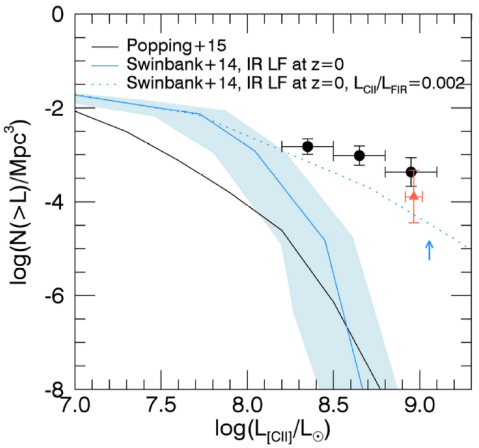
DeCarli et al, 2016

- **Deepest dust continuum images**



Aravena et al, 2016 a, b

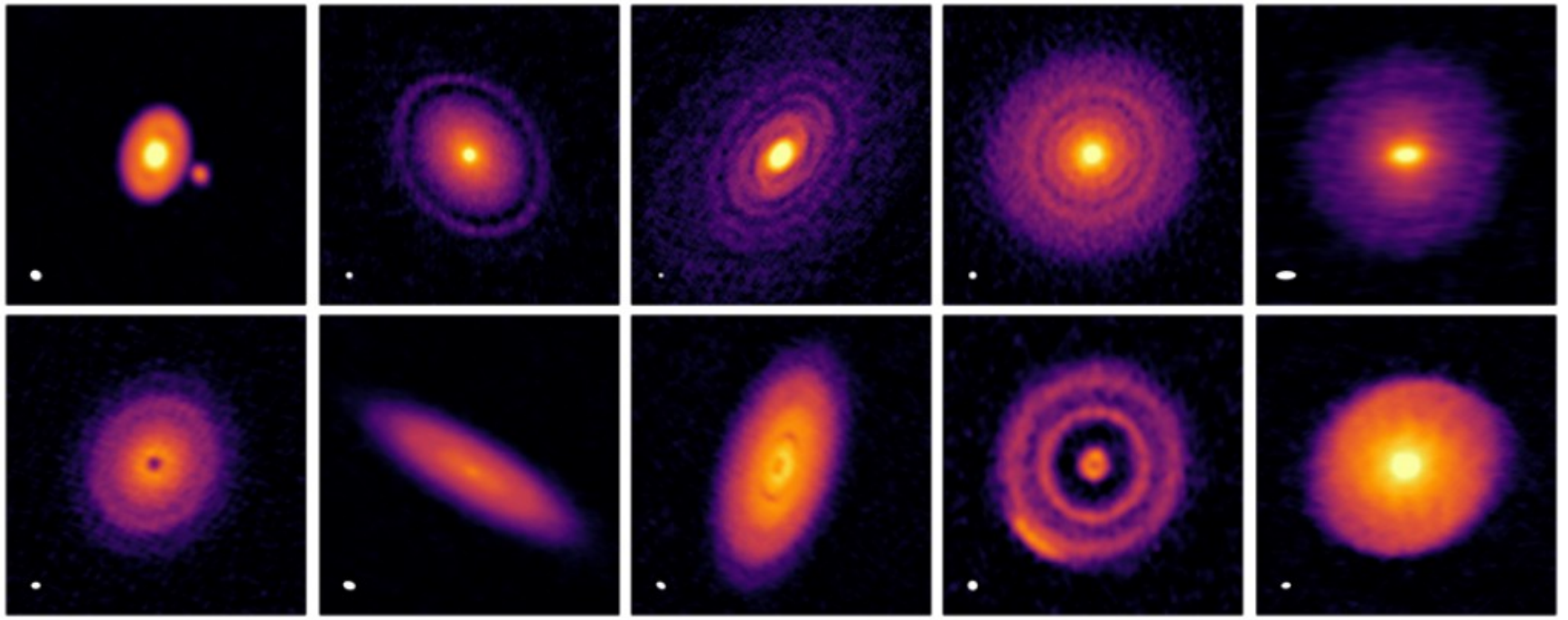
- **CII emission from the first galaxies (at z>6)** Few CII line candidates detected in the pilot at low significance. Even if only one confirmed it already puts constraints on the models



DSHARP: Small-Scale Substructures in Protoplanetary Disks

https://almascience.eso.org/almadata/lp/DSHARP/

Disk Substructures at High Angular Resolution Project (DSHARP)



Target	Scripts (.py)	Final Calibrated MS (.tar.gz)	Fiducial Images (.fits)	profiles (ascii); README	SEDs (ascii)
HT Lup	continuum; CO	continuum (0.8 GB); CO (0.6 GB); CO+cont (0.6 GB)	continuum (62 MB); CO (1.9 GB)	continuum profile	SED
GW Lup	continuum; CO	continuum (0.8 GB); CO (0.5 GB); CO+cont (0.5 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
IM Lup	continuum; CO	continuum (1.8 GB); CO (0.8 GB); CO+cont (0.8 GB)	continuum (62 MB); CO (920 MB)	continuum profile	SED
RU Lup	continuum; CO	continuum (0.9 GB); CO (0.7 GB); CO+cont (0.7 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
Sz 114	continuum; CO	continuum (0.5 GB); CO (0.4 GB); CO+cont (0.4 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
Sz 129	continuum; CO	continuum (0.9 GB); CO (0.6 GB); CO+cont (0.6 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED

DSHARP: Small-Scale Substructures in Protoplanetary Disks

https://iopscience.iop.org/journal/2041-8205/page/Focus_on_DSHARP_Results

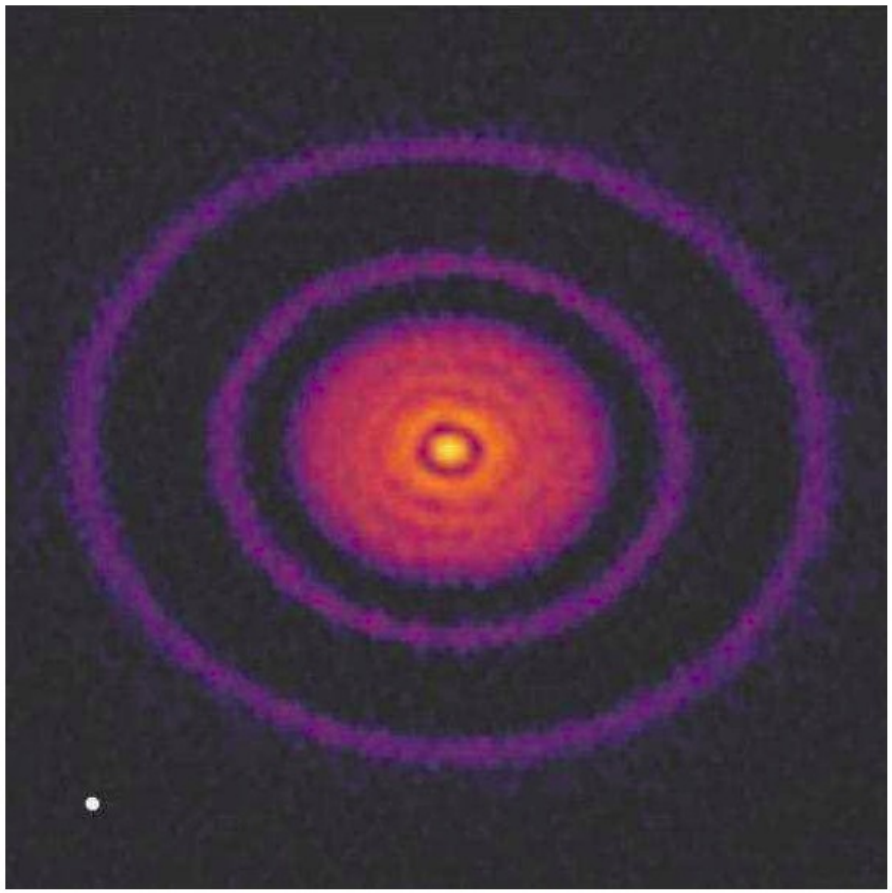
THE ASTROPHYSICAL JOURNAL LETTERS

A A S IOP
A publishing partnership

Focus on DSHARP Results

Sean Andrews (Harvard Smithsonian Center for Astrophysics)

December 2018



The disks of gas and dust that orbit young stars are the birthplaces of planetary systems. Decades of theoretical work has focused on the complex physical mechanisms at play in these disks, which both facilitate and frustrate the planet formation process. The ongoing census of exoplanets has made clear that there is remarkable diversity in the planet population in terms of orbital architectures, masses, sizes, and atmospheres. The theoretical work has argued that much of this variety is imprinted at the formation epoch, controlled by where a planet forms in the disk, how much mass it accretes, and to where it migrates. To put it simply, the properties of planetary systems are expected to depend intimately on the interactions between planets and their disk birth environments.

Until recently, models of that mutual evolution and

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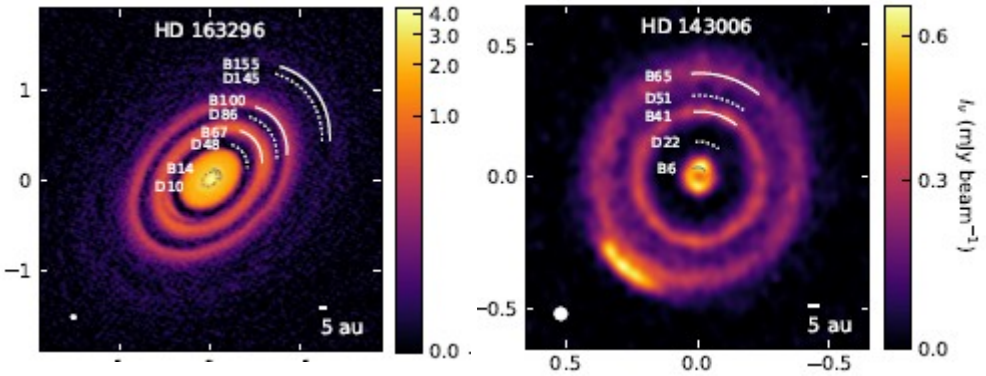
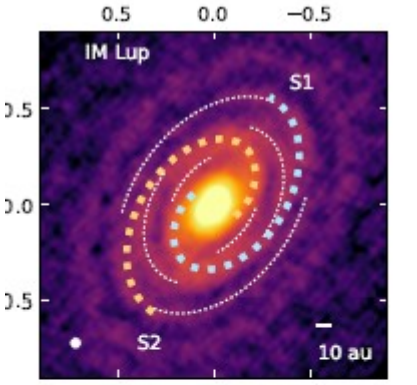
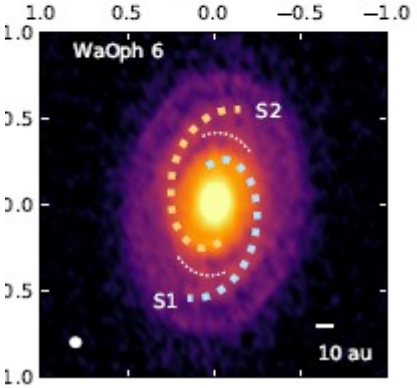
DSHARP: Small-Scale Substructures in Protoplanetary Disks

- **A homogeneous survey both in resolution and sensitivity**
  20 Targets: close enough to reach 5 AU resolution, and bright enough to ensure a 10% contrast out to 40 AU, and satisfying LST constraints

- **Ubiquitous continuum substructures @ any disk radius (from 5 to 150 au)**
  The most common observed substructures are rings and dark gaps.
  Less common: striking spiral structures are detected for 3 targets, possibly due to gravitational instabilities (Huang et al. 2018 a,b)







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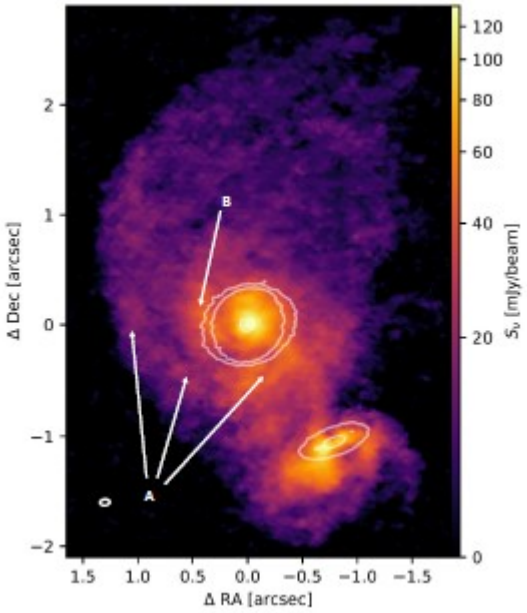
- For the two **multiple systems** in the sample, the disk around the primary stars show a clear two-armed spirals and complicated CO distribution, indicative of strong dynamical interactions (Kurtovic et al 2018)



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- The ring sizes and amplitudes suggest that these features can be understood as **dust trapped in axisymmetric gas pressure bumps** (Dullemond et al. 2018, Birnstiel et al 2018)

- **New hydrodynamics simulations** (Zhang et al. 2018)

ALPINE: the ALMA large program to investigate CII at early times

https://cesam.lam.fr/a2c2s/project.php

The Project The Team

The Project

The A2C2S will measure the C+ and far-infrared (FIR) continuum emission for a representative sample of 122 main sequence star-forming galaxies spectroscopically confirmed at 4~10 M_Sun/yr and stellar mass ~9 < log(Mstar) < ~11. The proposed A2C2S data are crucial to understanding the gas and dust properties at a time of rapid galaxy maturation.

At the key epoch 4 < z < 6, the A2C2S will provide :

- The first comprehensive and precise (<20%) measurement of the star formation rate density (SFRD) at these epochs from UV+FIR continuum and C+ emission, allowing to constrain mechanisms which fuel the initial growth of typical galaxies in the early universe.
- A first detailed characterization of the ISM properties using LFIR/LUV and C+/FIR diagnostics.
- A first measurement of dynamical masses from spectrally resolved C+, combined with stellar masses and statistical estimates of dark matter halo masses to measure dust content, gas fraction, and their evolution.

Beyond these immediate results, the A2C2S will provide a lasting legacy in data-rich ECDFS and COSMOS areas. These data will pave the way for detailed follow-up observations, e.g., with ALMA at higher spatial resolution, and provide a reference sample for studies with future facilities like JWST.

ALPINE: the ALMA large program to investigate CII at early times

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A2C2S | ALMA ALPINE [CII] Survey

The Project The Team

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ALPINE Survey is feeling fantastic.
February 8 at 12:42 PM

We just got the Email announcing the release of the last ALPINE observation

Champagne!!!

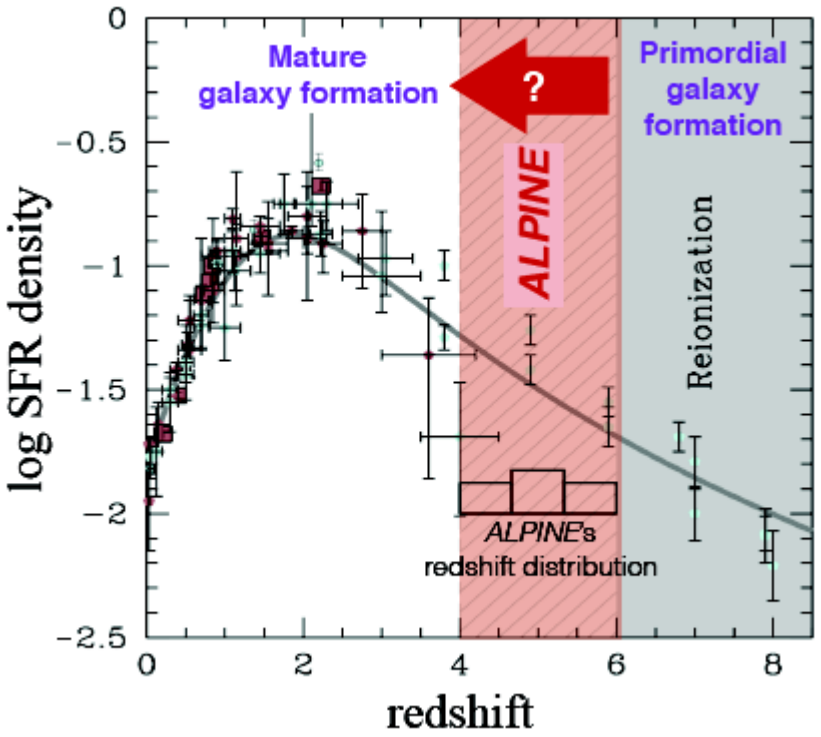
ALPINE: the ALMA large program to investigate CII at early times

- **70 hrs Band 7 observations to detect CII and FIR continuum of 122 main sequence galaxies**

- Pre-selected samples in the COSMOS (Scoville 2007) and E-CDFS (Giacconi 2002) fields, well studied at UV and near-IR

  Main questions:

- How does the total star-formation evolve at 4<z>6?
- Is CII a reliable SFR indicator at high-z?
- How dusty are galaxies in the early universe?
- How does the gas fraction evolve at z>4?



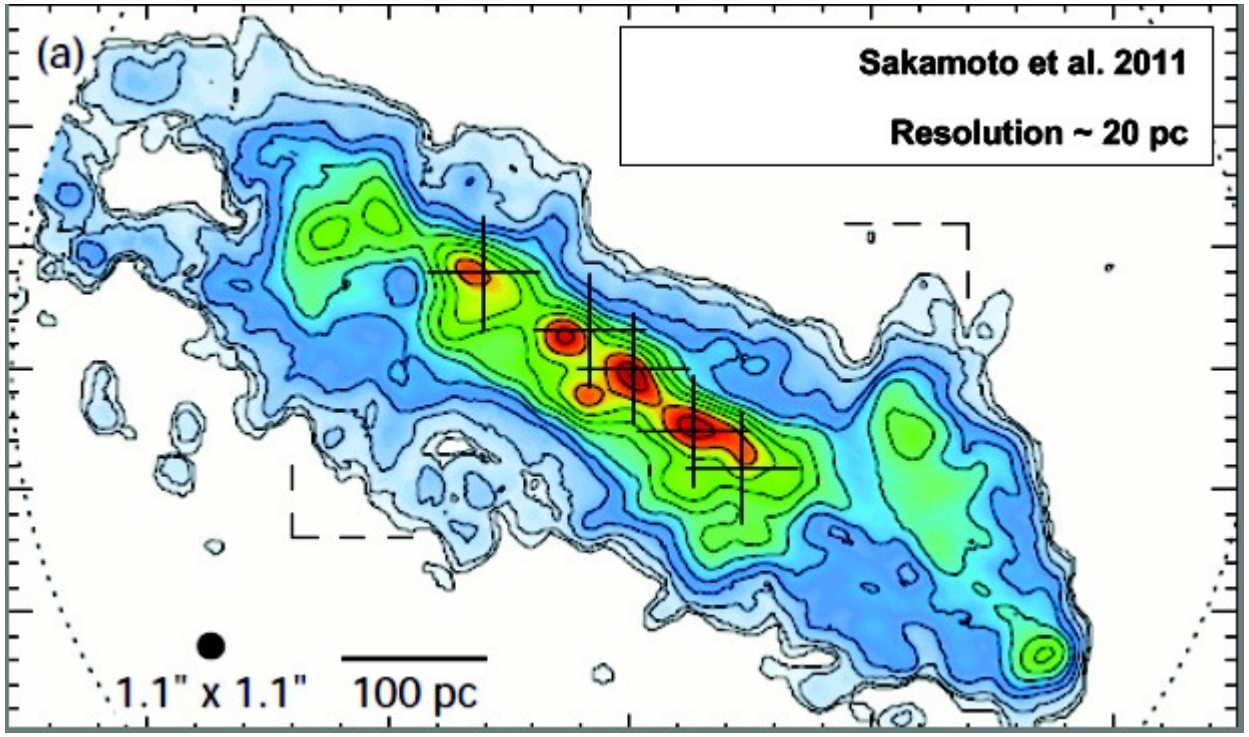
Faisst et al, 2019

ALCHEMI: the ALMA Comprehensive High-resolution Extragalactic Molecular Inventory

- **Bands 3, 4, 6, and 7 spectral observations**
- **Angular matched resolution 1” (17pc): giant molecular cloud scale**
- **Images of the central molecular zone of the starburst galaxy NGC253**
- **Sensitivity: 30 mK (Band 6 and 7), 50 mK (Band 3 and 4)**
- **77.5 hrs for 12-m Array and 210 hrs for ACA**

ALCHEMI: the ALMA Comprehensive High-resolution Extragalactic Molecular Inventory

- **Why NGC253?**
  Very nearby (3 Mpc)
  pure starburst galaxy prototype (SFR~2M/yr)
  driving a molecular outflow



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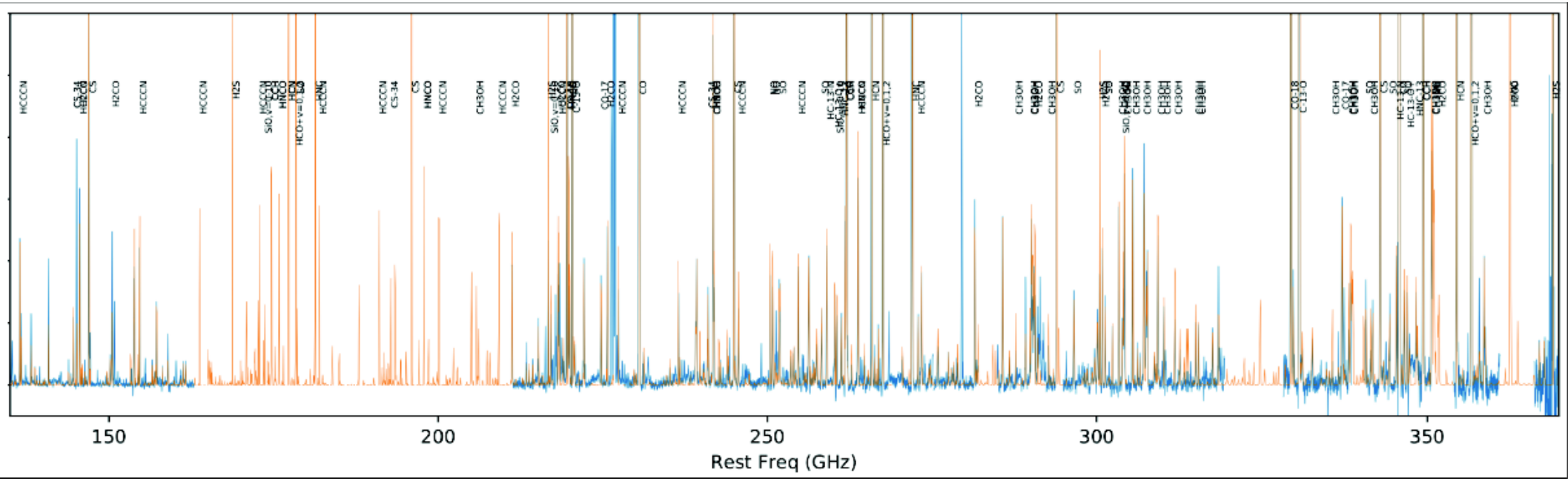
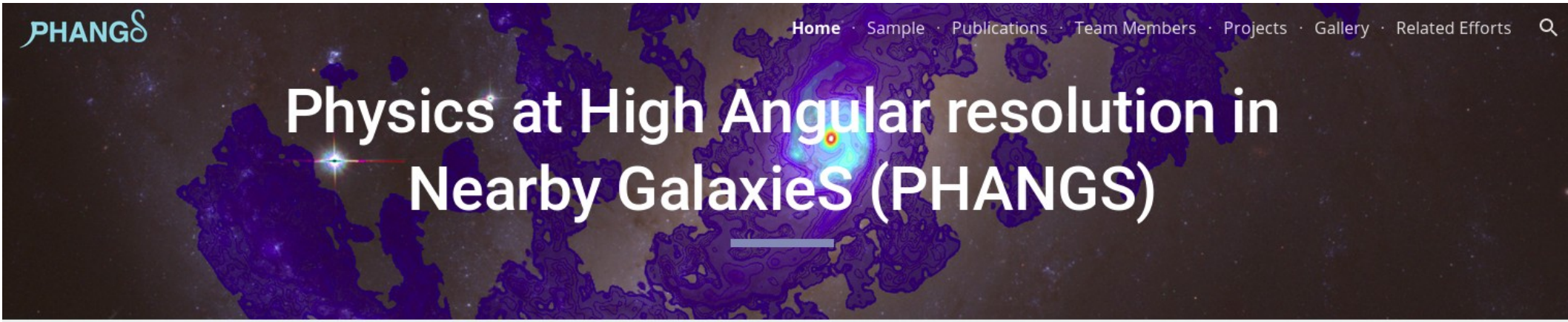


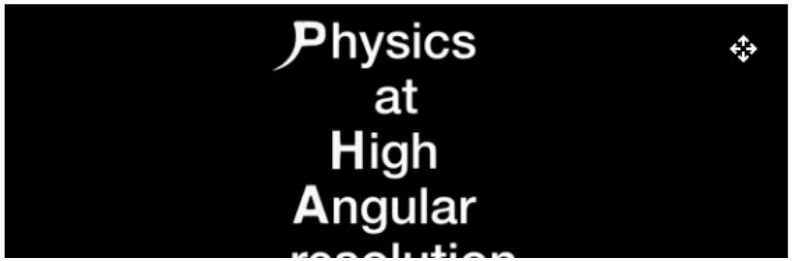
Martin, Harada, Mangum+ in prep

PHANGS: 100,000 Molecular Clouds Across the Main Sequence: GMCs as the Drivers of Galaxy evolution

https://sites.google.com/view/phangs/home



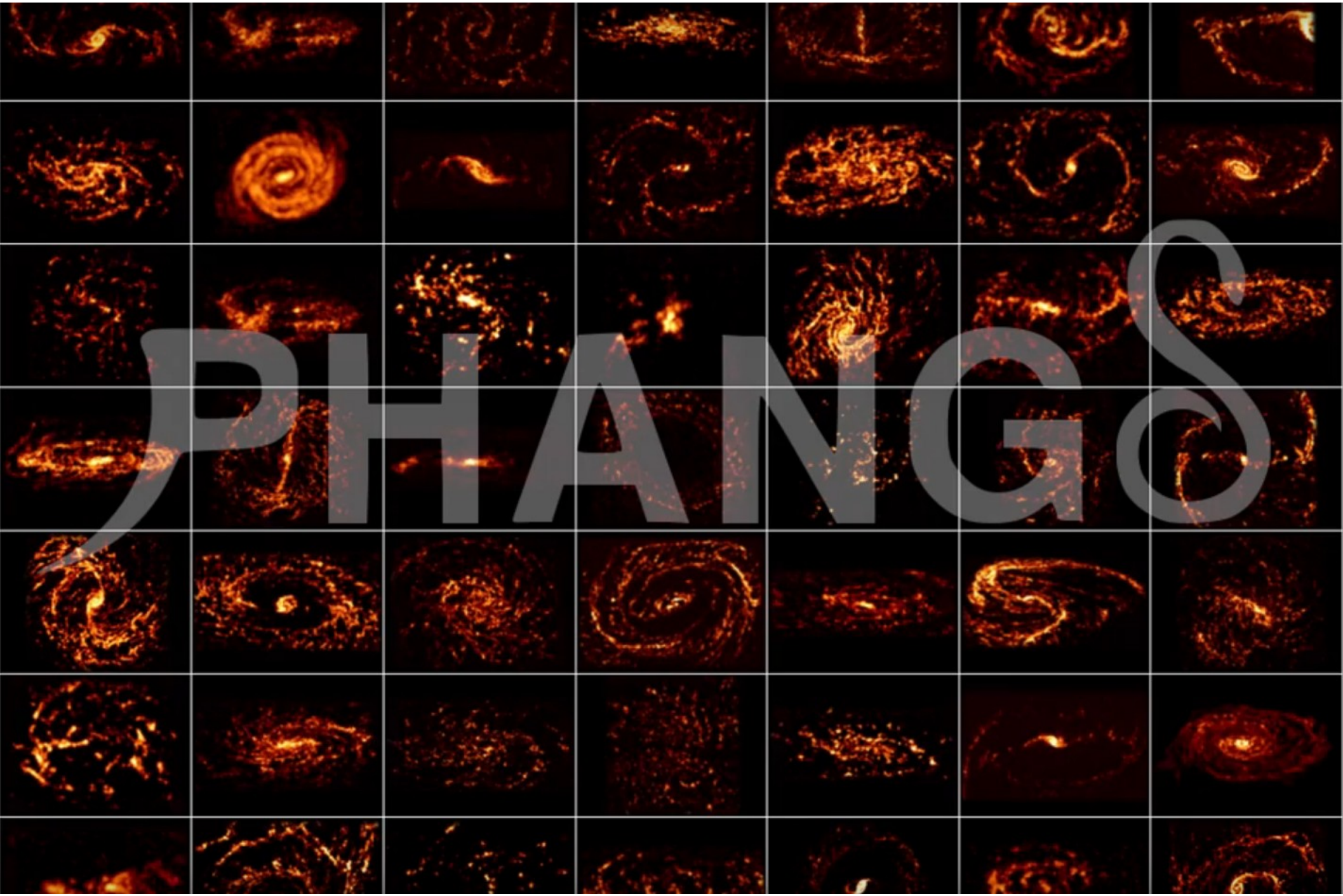
We aim to understand the interplay of the small-scale physics of gas and star formation with galactic structure and galaxy evolution. Observations of nearby galaxies will be utilized to understand how physics at or near the "cloud" scale are affected by galaxy-scale conditions, how they affect still smaller scale processes, and how these influence the evolution of whole galaxies.



Coming soon

MUSE movie

Credit: F. Santoro & T. Müller (HdA)/PHANGS/MUSE


PHANGS

PHANGS: 100,000 Molecular Clouds Across the Main Sequence: GMCs as the Drivers of Galaxy evolution

- 75 hrs of 12-m Array to observe CO(2-1) emission

- 74 galaxies nearby galaxies (d < 17 Mpc)

- Resolution 1”

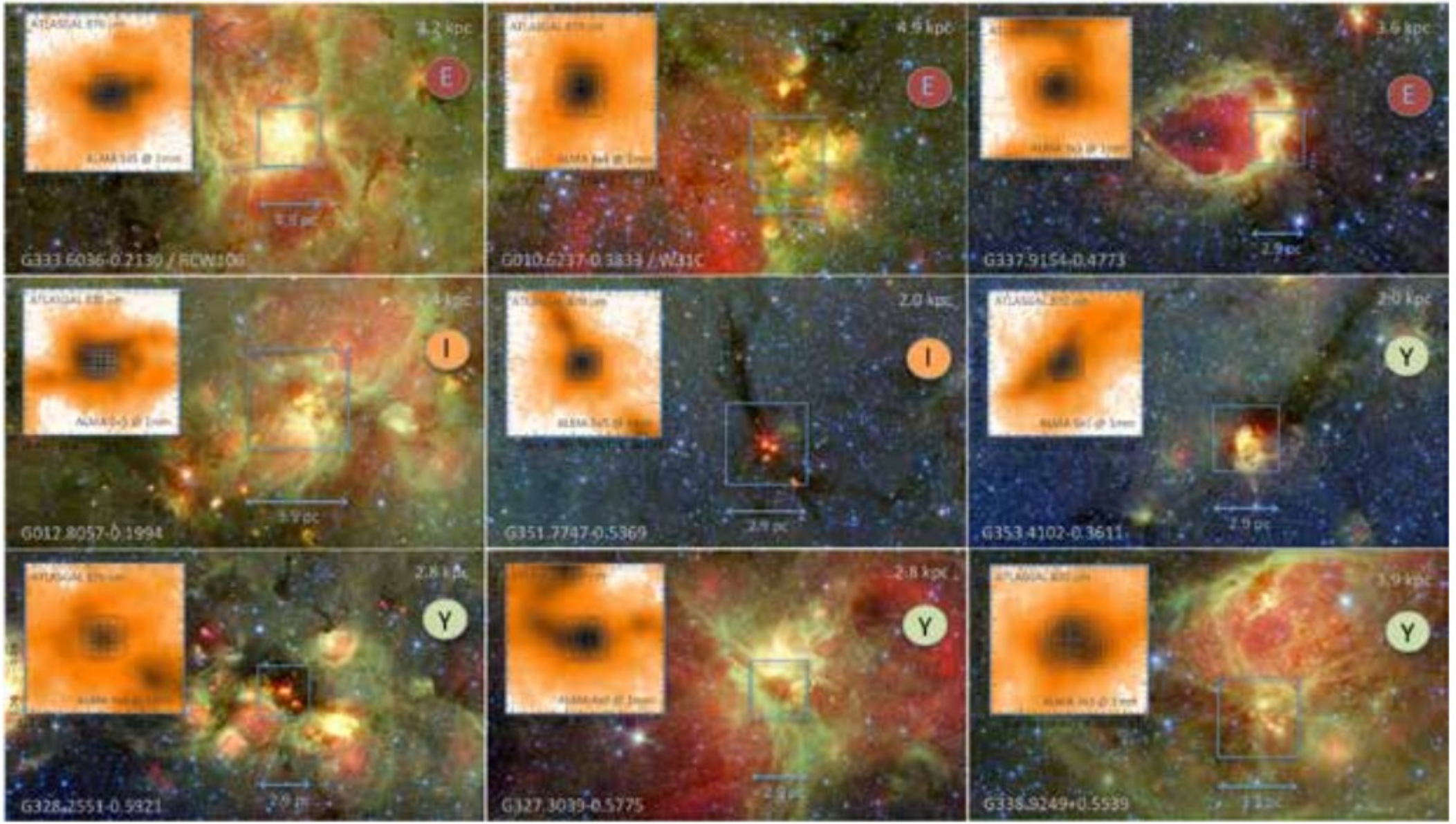
- 100,000 GMCs spread across a sample of galaxies and environments truly representative

- To measure as a function of local environment:

the molecular cloud population
the efficiency per free fall time
the cloud lifetime and destruction time
the scale and mechanism for star formation self-regulation

ALMA-IMF: ALMA transforms our view of the origin of stellar masses

http://ipag.osug.fr/~mottef/doc/ALMA-IMF_cycle5LP.pdf



ALMA-IMF: ALMA transforms our view of the origin of stellar masses

- Observations of a nearby complete sample of nearby protoclusters (2-6 kpc)

  To investigate:

- the origin of the Initial mass function in the typical, yet extreme environments where massive stars are born

- The Core Mass Function evolution

Cycle 6 ALMA Large programs

https://almascience.eso.org/observing/highest-priority

ALMA lensing cluster survey
PI: Kotaro Khono

ATOMIUM: ALMA Tracing the Origins of Molecular In dUst-forming oxygen-rich M-type stars
PI: Leen Decin

The chemistry of Planet Formation
PI: Karin Oberg

FAUST: Fifty AU Study of the chemistry in the disk/envelope of Solar-like protostars
PI: Satoshi Yamamoto

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They provide a homogeneous
(in resolution or spectral coverage or sensitivity)
database to address specific scientific issues
of interest for the community at large.

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of interest for the community at large.

Special emphasis on the results from the first round will be given at the ALMA conference

Cycle 6: ALMA lensing cluster survey
PI: Kotaro Khono

- Extensive survey of 33 clusters to a depth of 0.08 mJy @ 1.2 mm

- Spectral scan 14 GHz wide, to enlarge the survey volume on line emitting galaxies

- Sample selected from the best-studied clusters observed with HST, such as CLASH, HFF and RELICS

- The high-magnification regions will be mapped with a total coverage of 88 squared arcmin

- To determine the nature of Submillimeter galaxies and line emitters
- Probe the origin of the extragalactic background light
- Measure the CII luminosity functions near the Epoch of Reionization
- Constrain the evolution of the molecular gas mass density up to the peak epoch of cosmic star formation
- Discover rare highly lensed objects for future follow-up

ATOMIUM: ALMA Tracing the Origins of Molecular In dUst-forming oxygen-rich M-type stars

- Observations of winds of oxygen-rich evolved stars over a range of stellar masses, pulsation behaviours, mass-loss rates, and evolutionary phases.

- The goal is to unravel the phase transition from simple molecules to larger gas-phase clusters and eventually dust grains.
- Pinpoint the chemical pathways
- Map the morphological structure, and study the interplay between dynamical and chemical phenomena

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ATOMIUM KICK-OFF MEETING

ATOMIUM

ATOMIUM KICK-OFF MEETING

The ATOMIUM kick-off meeting brings together all co-Is of the ALMA Large program. The meeting is dedicated to properly preparing ourselves for the upcoming products, discussing their reduction and analysis, and forming the first scientific working groups.

The meeting took place on **Tuesday 30 October 2018** at the Atomium in Brussels from 10:00-18:00.

A downloadable logo can be found here.

Cycle 6 LP: The chemistry of Planet Formation
PI: Karin Oberg

- **Investigate the disk chemical structure.**

- The chemistry is sensitive to the distribution of dust and pebbles in disks, and as planet open up disk gaps they may change the chemical environment within which they form.

- Molecular emission is the only tool to explore disk ionization level, kinematics and mass distribution, all key ingredients of planet formation models.

- Proposed sample: **5 disks** where dust sub-structure is detected and planet formation appears ongoing

FAUST: Fifty AU Study of the chemistry in the disk/envelope of Solar-like protostars

- Focus on the early history of Solar-like protostars and their chemical diversity at scales of ~ 50 au, where planets are expected to form

- To reveal and quantify the variety of chemical composition of the envelope/disk system at scales of 50 au in a sample of Class 0 and I protostars representative of the chemical diversity observed at larger scales.

- A set of molecules able to:
  disentangle the components of the 50-2000 au envelope/disk system
  characterize the organic complexity in each source
  probe the ionization structure
  measure the molecular deuteration

- It will provide a homogeneous database of thousands of images from different lines and species