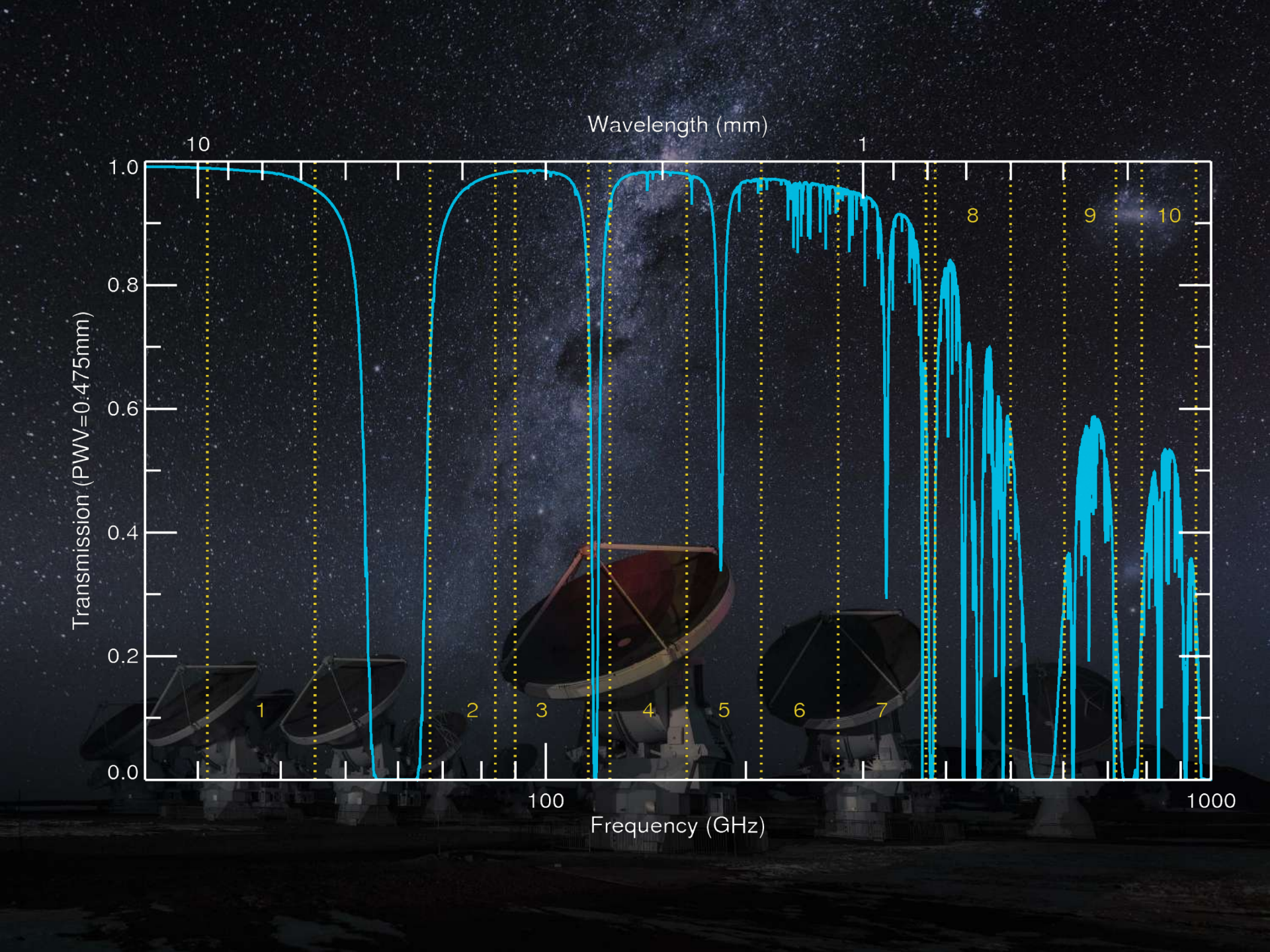
ALMA-SPICA Synergies

George J. Bendo
UK ALMA Regional Centre Node
Jodrell Bank Centre for Astrophysics
The University of Manchester

ALMA is the world's premier submillimetre/millimetre telescope. The observatory, located in Chile, is operated by a partnership of North American, European, and East Asian organizations.

Credit: Ariel Marinkovic / X-Cam


Wavelength (mm)
10
1
1.0
0.8
0.6
0.4
0.2
0.0
Transmission (PWV=0.475mm)
1
2
3
4
5
6
7
8
9
10
100
1000
Frequency (GHz)

Band	Frequency (GHz)	Wavelength (mm)	Primary Beam (arcsec)	Angular Resolution (arcsec)	
				Compact Configuration	Extended Configuration
3	84-116	2.6-3.6	63	3.4	0.042
4	125-163	1.8-2.4	43	2.3	0.028
5	163-211	1.4-1.9	30	1.8	0.023
6	211-275	1.1-1.4	25	1.5	0.018
7	275-373	0.80-1.09	19	1.0	0.028
8	385-500	0.60-0.78	14	0.74	0.046
9	602-720	0.42-0.50	9.2	0.52	0.033
10	787-950	0.32-0.38	7.1	0.39	0.024

SPICA is focused on these three areas of research:

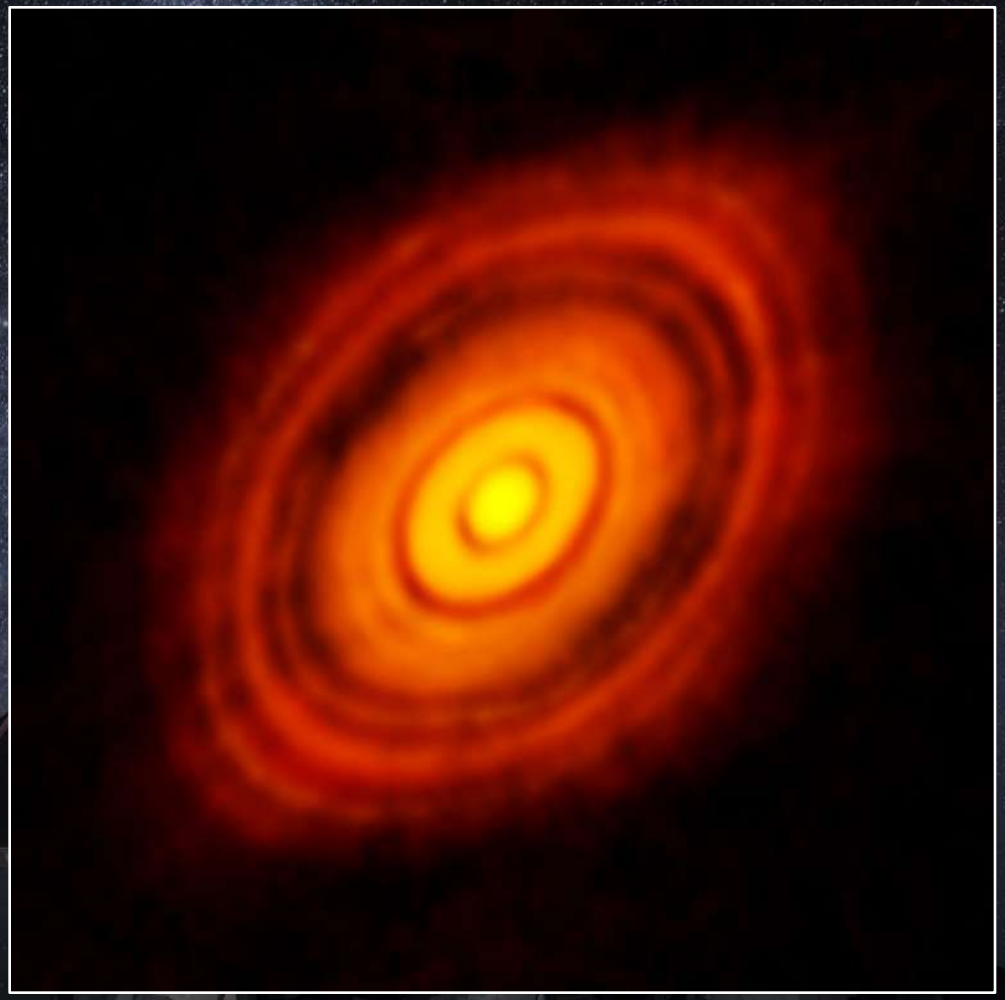
- Protoplanetary disc evolution
- Galaxy evolution
- Polarisation in filaments

ALMA has performed observations that are connected to these topics.

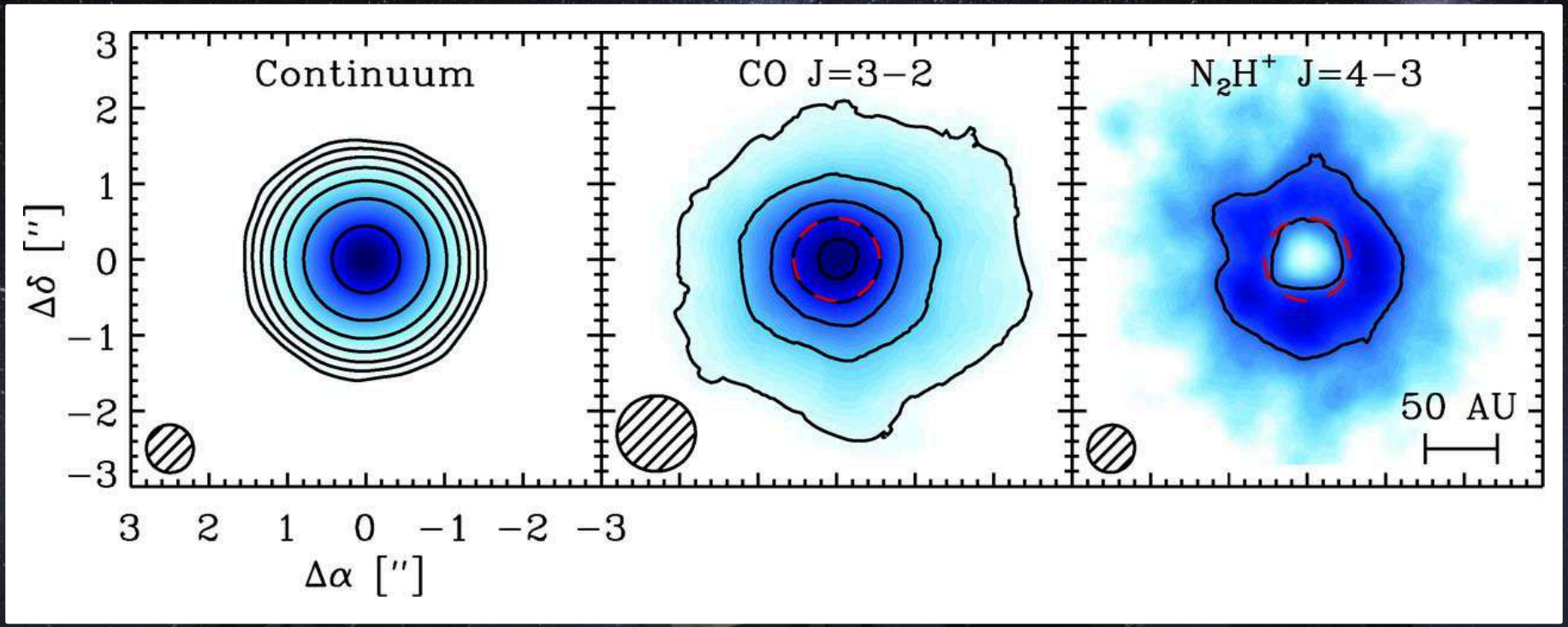
Protoplanetary Disk Evolution

ALMA is already able to image dust continuum and lower frequency molecular line emission from protoplanetary discs.

SPICA can measure the warmer dust emission and the higher frequency /higher energy lines.



Credit: ALMA (NRAO/ESO/NAOJ)



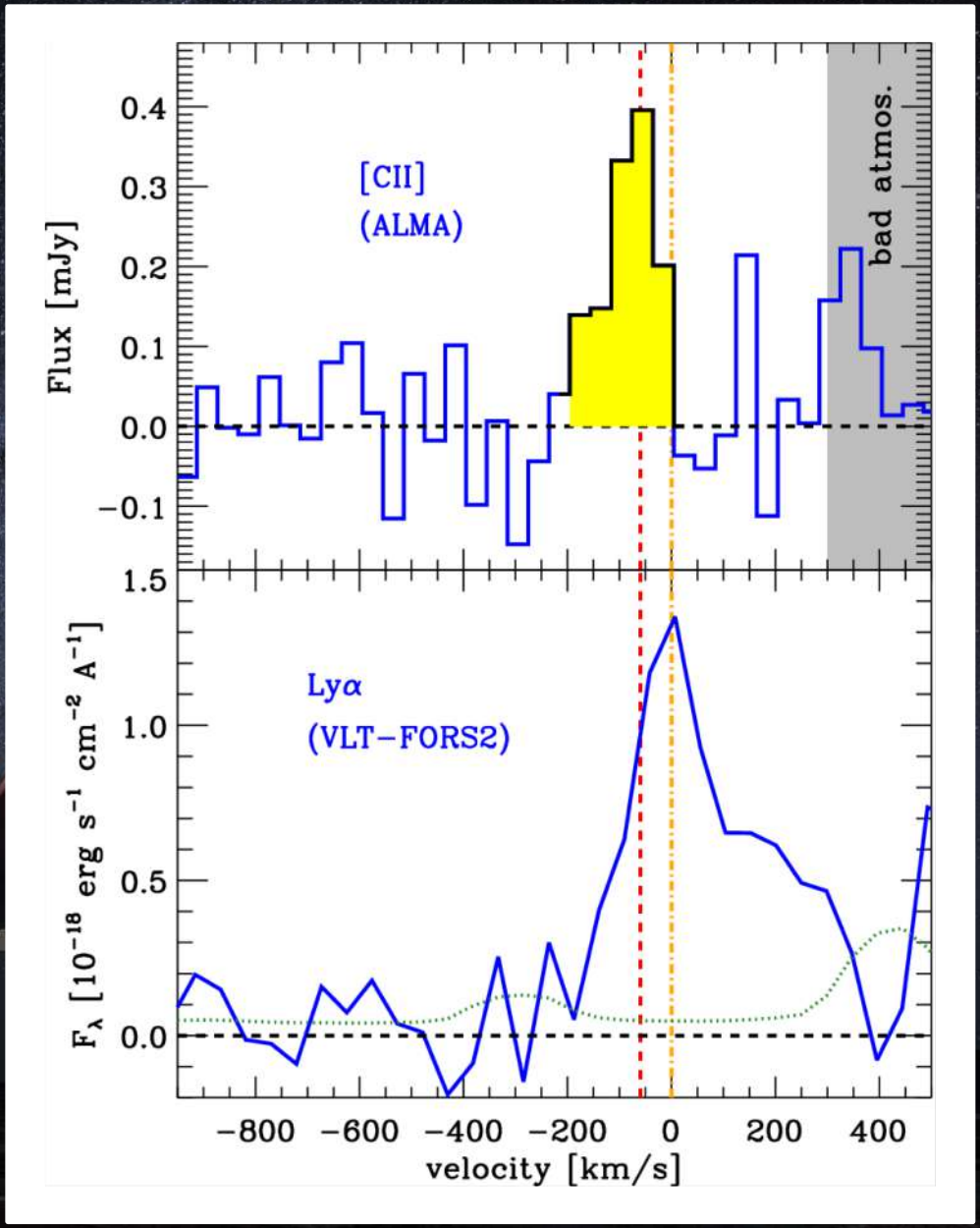
Qi et al., 2013, Science, 341, 630

Galaxy Evolution

SPICA will focus on observing redshifted mid- and far-infrared lines to measure SFR and AGN activity.

ALMA can provide molecular gas measurement as well as measurements of line shifted out of SPICA bands.

Additionally, ALMA can be used for high-resolution follow-up observations of sources.



Maiolino et al., 2015, MNRAS, 452, 54

Galaxy Evolution

SPICA will focus on observing redshifted mid- and far-infrared lines to measure SFR and AGN activity.

ALMA can provide molecular gas measurement as well as measurements of line shifted out of SPICA bands.

Additionally, ALMA can be used for high-resolution follow-up observations of sources.

Credit: H-ATLAS

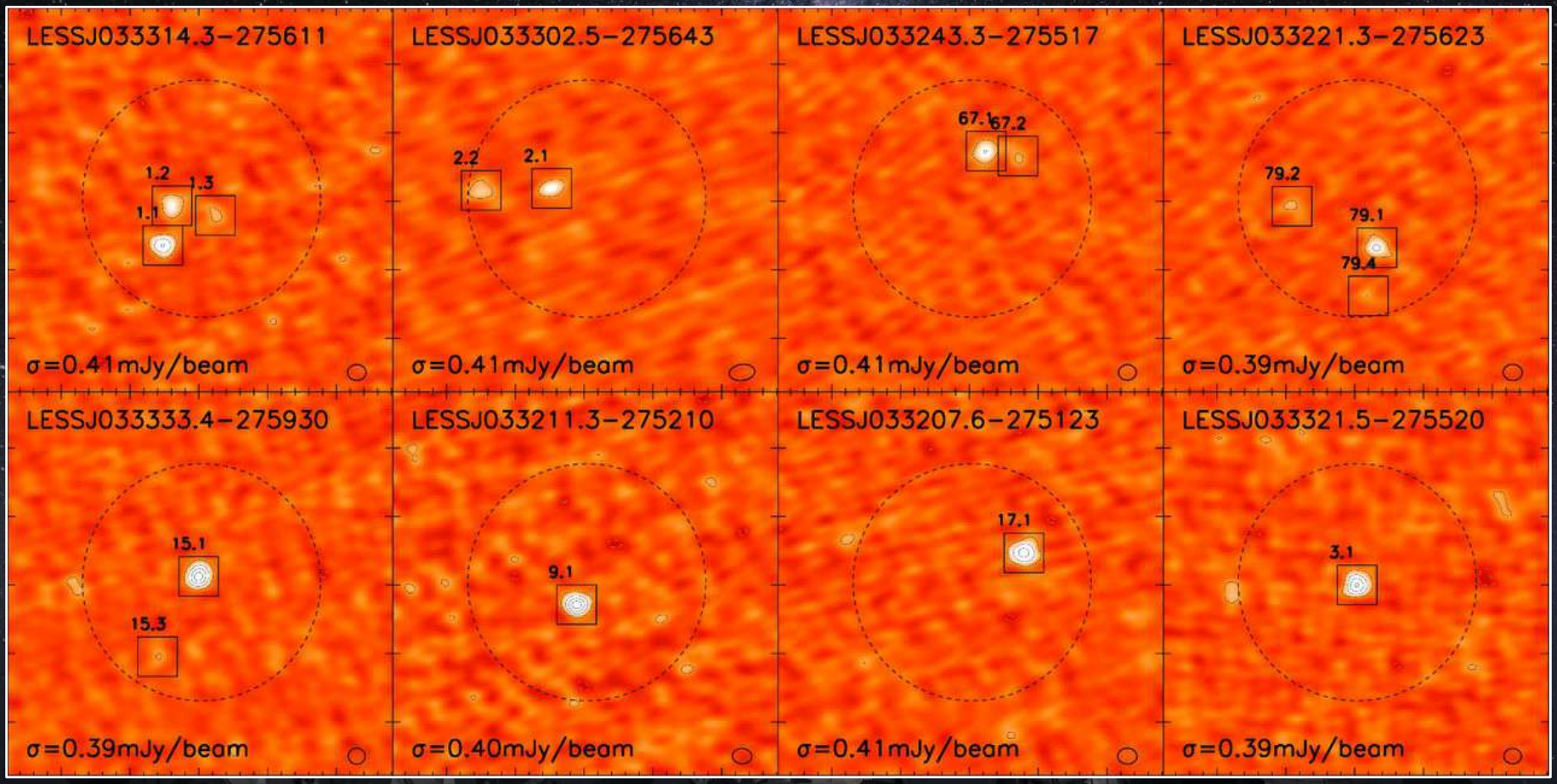
Galaxy Evolution

SPICA will focus on observing redshifted mid- and far-infrared lines to measure SFR and AGN activity.

ALMA can provide molecular gas measurement as well as measurements of line shifted out of SPICA bands.

Additionally, ALMA can be used for high-resolution follow-up observations of sources.

Credit: ALMA (NRAO/ESO/NAOJ); B. Saxton NRAO/AUI/NSF

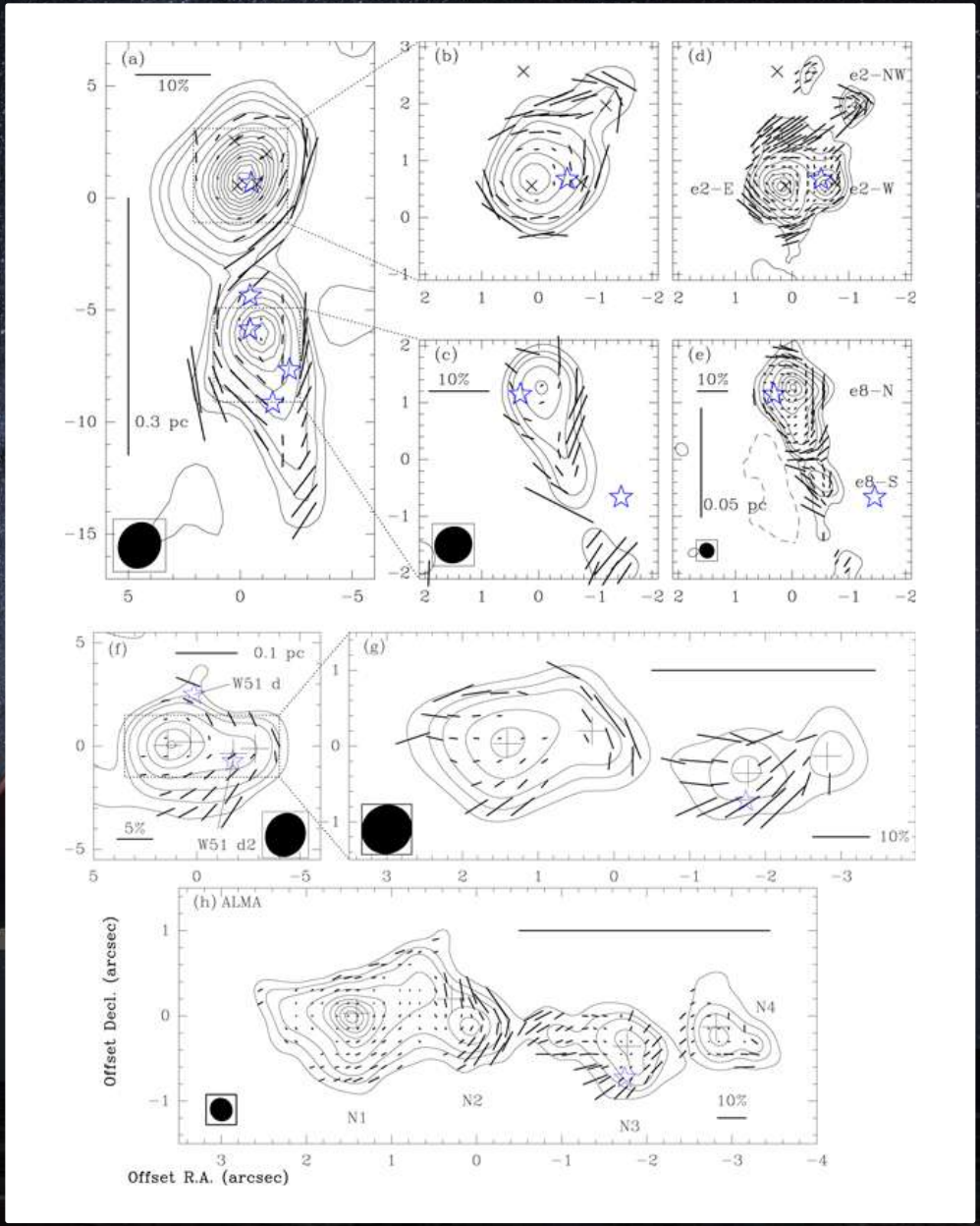


Karim et a., 2013, MNRAS, 432, 2

Polarisation in filaments

ALMA has produced polarisation obsevations of compact Galactic sources.

SPICA will map polarisation on larger spatial scales.



Koch et al., 2018, ApJ, 855, 39

Cycle 6 capabilities

- 43 main array, 10 ACA, 3 total power antennas operational during observing
- 84-950 GHz covered
- Angular resolutions up to 0.025” possible
- Spectral resolutions up to ~0.01 km/s possible
- Linear and circular polarization capabilities in bands 3-7

High-Priority Improvements for 2030

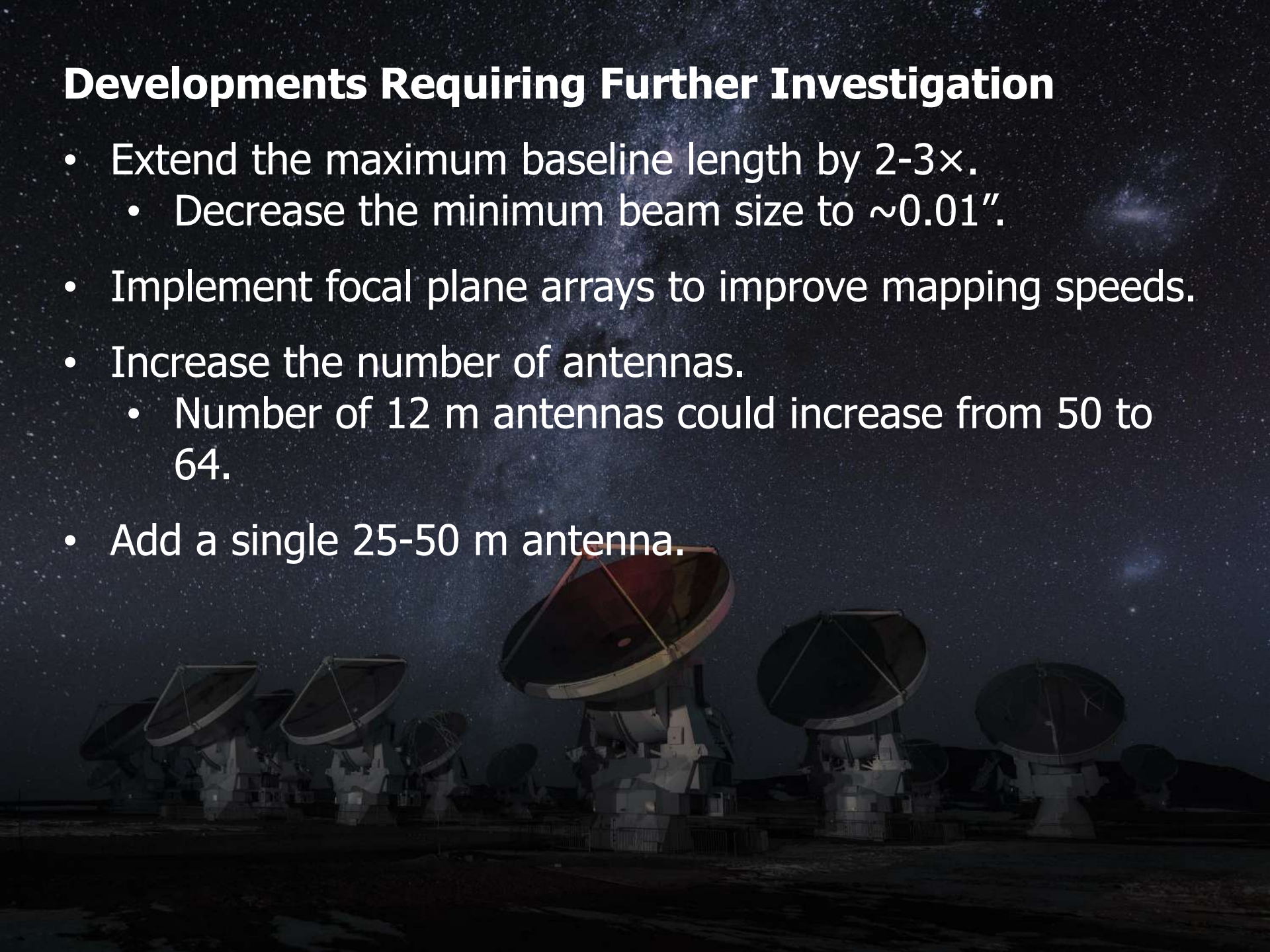
- Broaden the receiver bandwidth by ≥2×, with priority given to 200-450 GHz bands.
  - Improve spectral coverage.
  - Perform spectral scans faster.
  - Improve continuum sensitivity.
- Improve the ALMA archive.

Intermediate frequencies (200-450 GHz) will be given priority for bandwidth upgrades.

- Ideal for observing infrared spectral lines like [CII] 158 μm from high-redshift galaxies.
- Best for astrochemistry studies.
- Best combination of sensitivity and angular resolution for stellar disc studies.

Developments Requiring Further Investigation

- Extend the maximum baseline length by 2-3×.
  - Decrease the minimum beam size to ~0.01”.
- Implement focal plane arrays to improve mapping speeds.
- Increase the number of antennas.
  - Number of 12 m antennas could increase from 50 to 64.
- Add a single 25-50 m antenna.



List of current studies on receiver upgrades

- Concept Study of a Millimeter Camera for ALMA
- Supra-THz interferometry with ALMA
- Towards a Second Generation SIS Receiver for ALMA Band 6
- Towards a Second Generation SIS Receiver for ALMA Band 10
- Overview of current ALMA Band 9 2SB mixer results
- Advanced Materials and On-wafer Chip Evaluation: 2nd Generation
- Performance and Characterization of a Wide IF SIS-Mixer-Preamplifier Module Employing High-Jc SIS Junctions
- Prototype of a Complete Dual-Linear 2SB Block and a Single-Polarization Balanced 2SB Block
- Development of 2nd Generation SIS Receivers for ALMA
- The Case for a Combined Band 2+3 Receiver

List of current studies on other upgrades

- ALMA Extended Array
- Digitizer upgrade
- Enhancing the Spectral Performance of the 64-antenna ALMA Correlator
- Doubling the Bandwidth of the 64-Antenna ALMA Correlator
- Spectral Resolution and Bandwidth Upgrade of the ALMA Correlator
- Digital Correlation and Phased Array Architectures for Upgrading ALMA

Summary

ALMA and SPICA complement each other well in covering different spatial scales.

- SPICA can survey broad areas.
- ALMA can perform high-resolution imaging of interesting objects.

ALMA and SPICA are needed for complete coverage of the infrared-to-millimetre spectrum.

- SPICA can detect infrared lines (including high frequency molecular lines) and hot/warm dust emission.
- ALMA can image cooler dust emission and lower frequency lines.