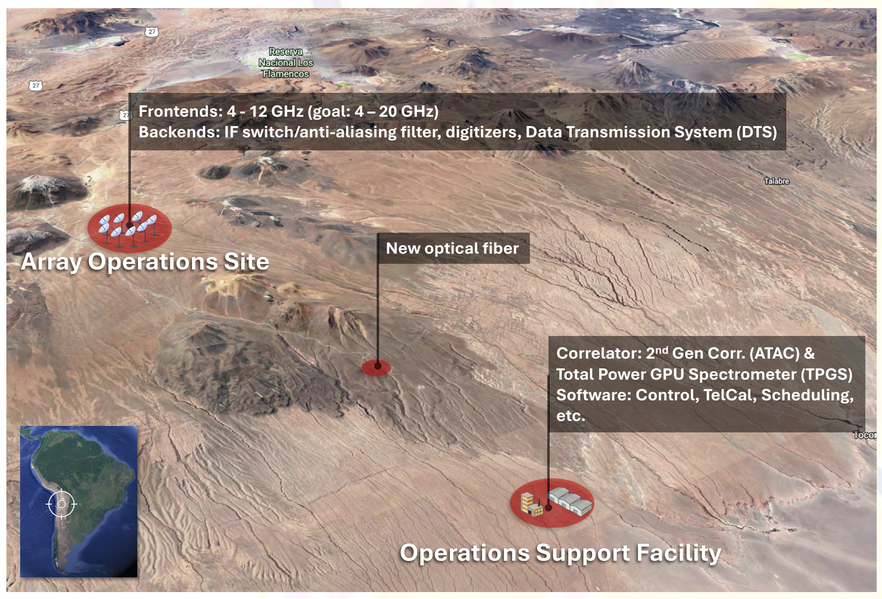
# Science enabled by the ALMA Wideband Sensitivity Upgrade (WSU)

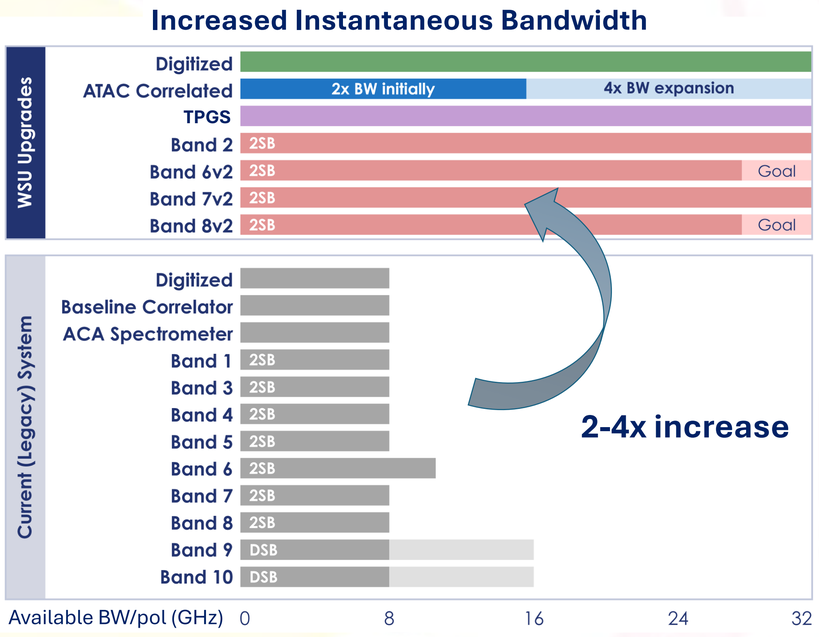
**Bunyo Hatsukade**, Misato Fukagawa, Satoru Iguchi, Shun Ishii, Takuma Izumi, Kenichi Kikuchi, George Kosugi, Kana Sugimoto, & ALMA Project team (National Astronomical Observatory of Japan)

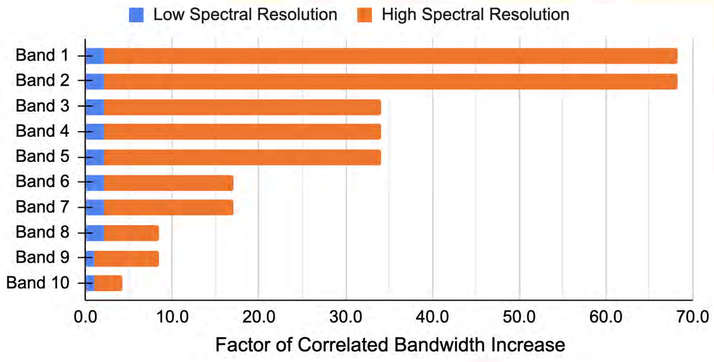
The Wideband Sensitivity Upgrade (WSU) aims to significantly enhance ALMA's observational capabilities towards the 2030s. WSU will initially double, eventually quadruple ALMA's system bandwidth, while significantly enhancing its sensitivity through comprehensive upgrades to the receivers, digital electronics, correlator, and spectrometer. Once completed, WSU will provide at least 6x faster continuum imaging speed, 2x faster spectral line imaging speed, and 10-100x enhancement in correlated bandwidth at high spectral resolution (~0.1 km/s). WSU will enable a wide range of scientific goals, including advancing our understanding of planet formation, chemical evolution, and galaxy assembly.

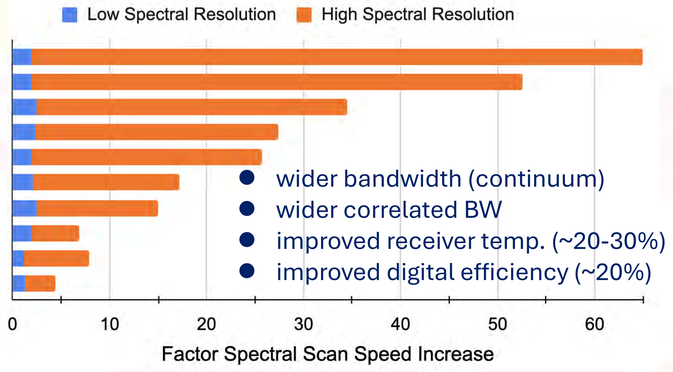
## Wideband Sensitivity Upgrade (WSU)

- Broaden the receiver IF bandwidth by at least 2x and upgrade associated electronics and correlator
- Highest priority development motivated by new science goals quantified for the next two decades



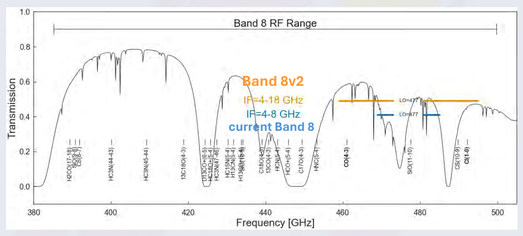




## Development Projects led by East Asia

### Band 8 version 2 receivers

A wider IF and improved receiver temperature






### Data Transmission System

Supporting high-speed data transmission (1.2 Tbps/antenna at least) from antennas in AOS to the correlator at OSF (over distances up to 80 km)

### Total Power GPU Spectrometer

New spectrometer for Total Power observations, supporting 4x IF bandwidth with much finer spectral resolutions

| Capabilities | Improvement |
|---|---|
| Instantaneous Bandwidth | **2–4x** (16–32 GHz per polarization) |
| Correlated bandwidth | **4–68x** (for high spectral resolution) |
| Spectral scan speed | **4–64x (**for high spectral resolution) |
| Spectral line imaging speed | **Net gain ~2–3x** |
| Continuum imaging speed | **At least 3x** (for 2x BW), **6x (**for 4x BW) |
| Ultrahigh spectral resolution | **<0.01 km/s** (in exchange of bandwidth) |

## WSU Science

### Origins of Planets

ALMA has revolutionized the field of planet formation by revealing stunning images of protoplanetary disks, where planets form. The expanded bandwidth will enable simultaneous observations of multiple molecular transitions, offering a comprehensive view of how gases and dust interact to form planets.

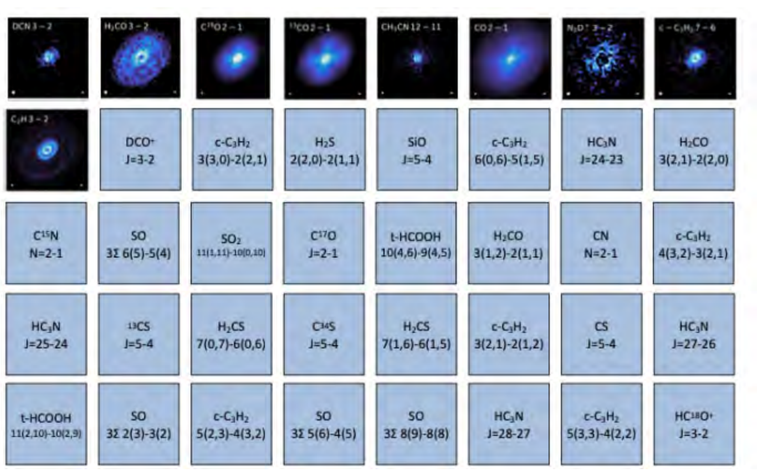
### Origins of Chemical Complexity

WSU will allow researchers to build large samples of interstellar clouds and protostars and study their chemical compositions in unprecedented detail, leading to a better understanding of how chemical complexity evolves from simple molecules to more complex structures that eventually contribute to the development of life-supporting environments.

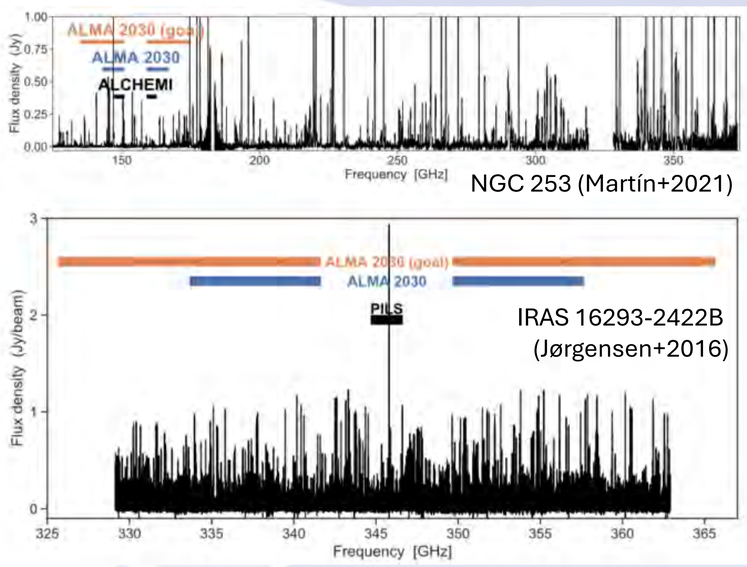
### Origins of Galaxies

The increased spectral grasp and sensitivity will enable more efficient surveys of galaxy properties across cosmic time. WSU will enable comprehensive studies of galaxy dynamics, star formation, and interactions with their environments, offering fresh insights into the universe's history and the mechanisms driving galaxy formation.

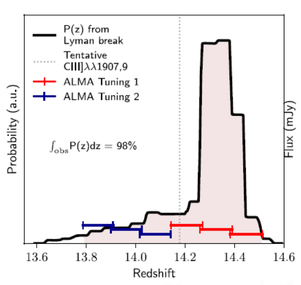
Illustration of the throughput power of WSU that can be obtained with a receiver and correlator that can process 16 GHz of bandwidth per polarization. 9 images of HD 163296 obtained with the MAPS Large Program (Öberg+2021) are shown. The remaining squares show additional lines that can be observed simultaneously.




Spectral scans across multiple bands. WSU will improve instantaneous coverage by 2–4x for coarse spectral resolution. For surveys such as PILS, which required 18 tunings at high spectral resolution, similar spectral coverage can be achieved in **only 2** tunings.




ALMA observations of the z=14 galaxy JADES-GS-z14-0 (Schouws+2025). The top panel shows the redshift probability distribution. ALMA observations used 2 tunings to cover the range, resulting in the detection of oxygen at z=14.19 (bottom panel). Given the wider bandwidth and improved sensitivity, WSU will be more efficient for such surveys.




Schouws+2025

