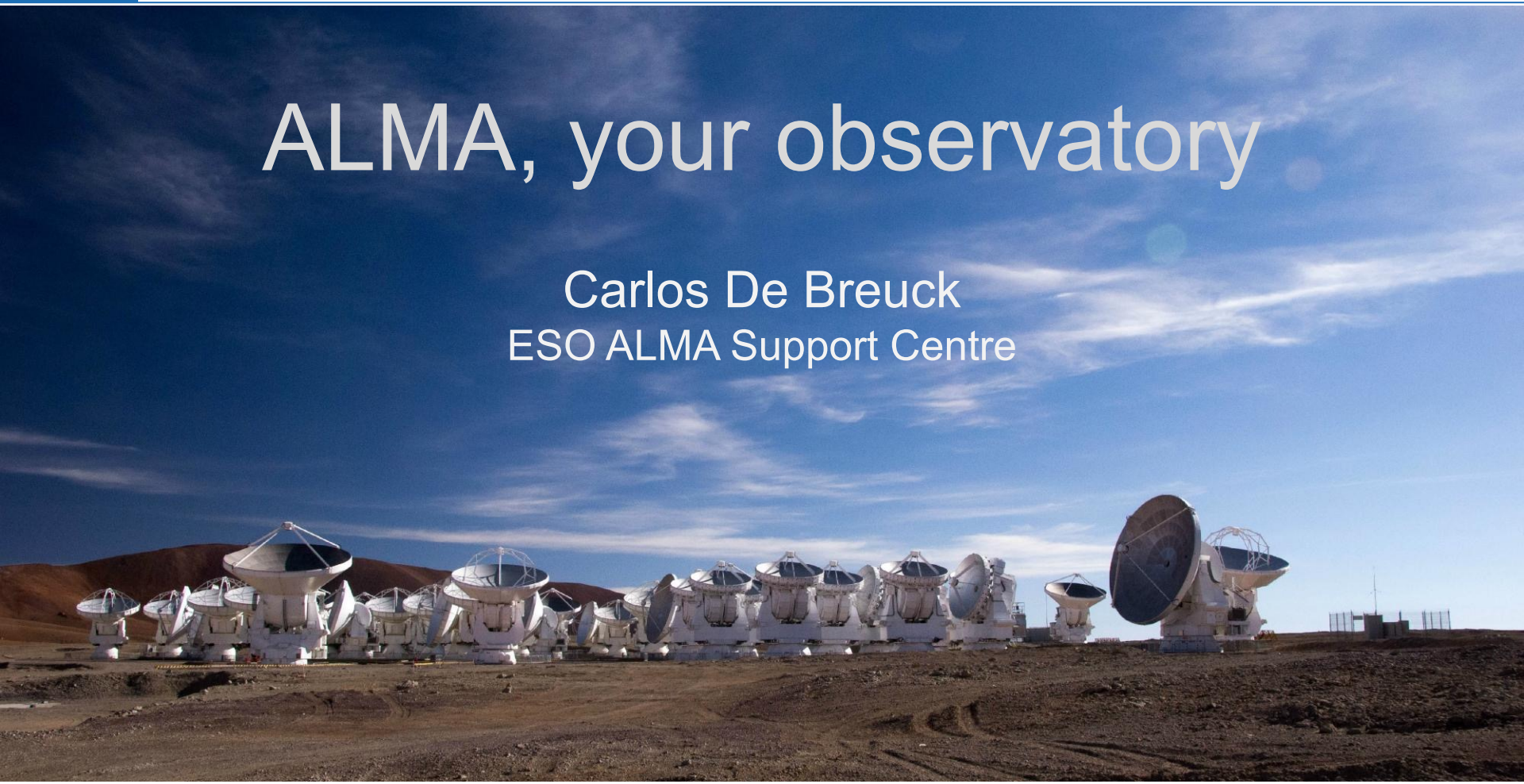
ALMA, your observatory

Carlos De Breuck
ESO ALMA Support Centre

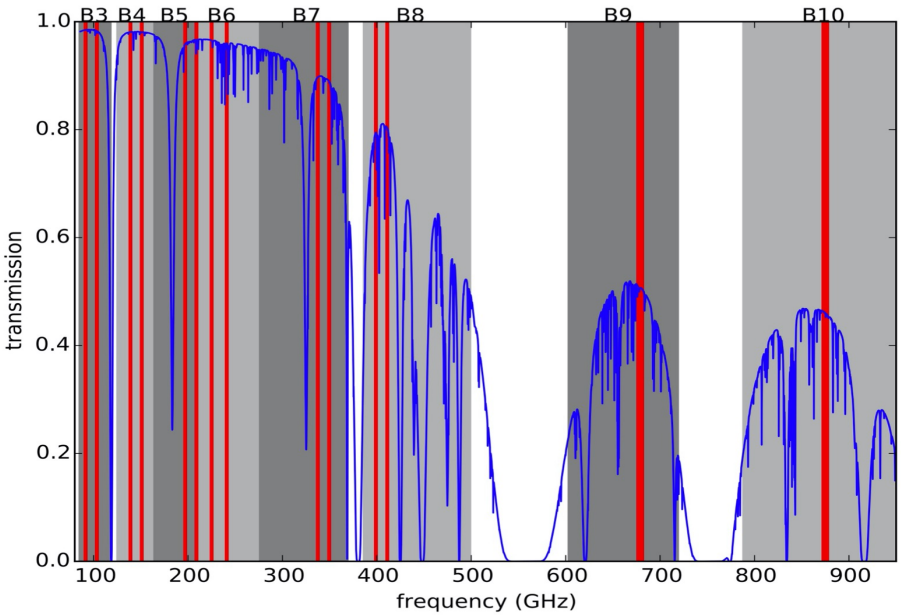


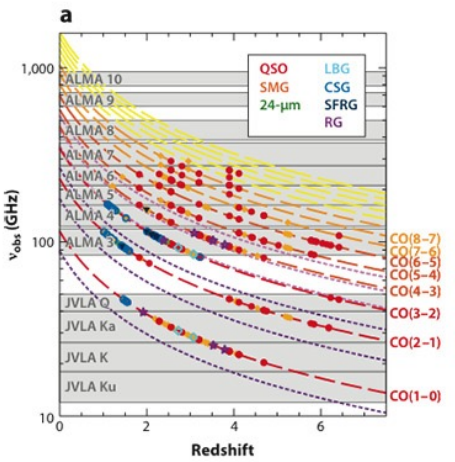
Who am I?

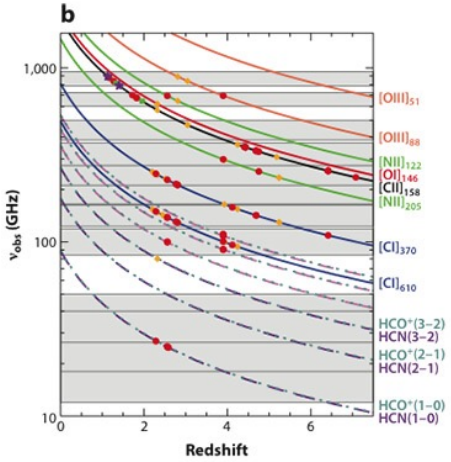
- Born and raised in Belsele (Sint-Niklaas)
- Thesis and postdocs in Leiden (NL), Livermore (USA) and Paris (FR)
- Started at ESO as fellow in 2003
- Became ESO staff in 2006
- Project scientist for APEX
- Coordinator of ALMA development studies
- Extragalactic astronomy
- Unofficial ambassador for Belgian fries in Chile and Germany

Promoting Belgian culture at ESO

ALMA capabilities: frequency coverage





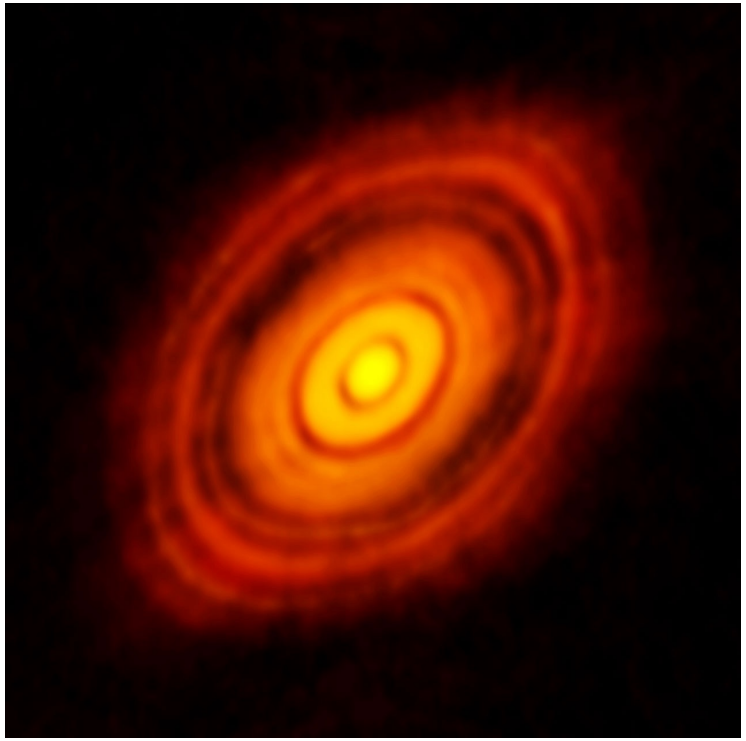


Carilli & Walter 2013

Spectral resolution: 30.5 kHz (equivalent to 0.079 km/s in Band 3 and 0.011 km/s in Band 10)

ALMA capabilities: superb imaging

ALMA partnership, 2015



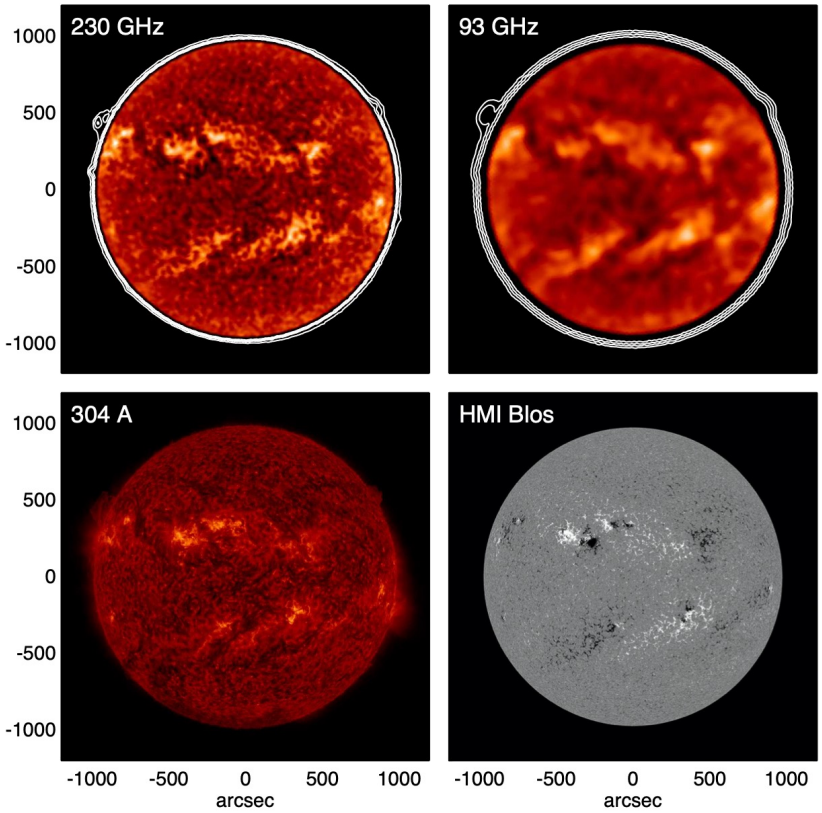
Angular resolution of 0.025-0.075” (3.5-10 AU)

- Baselines from 150 m up to 16.2 km
- Resolutions from 3.38” in Band 3 (C-1) to 0.009” in Bands 8 (C-10) and 9 (C-9)

ALMA capabilities

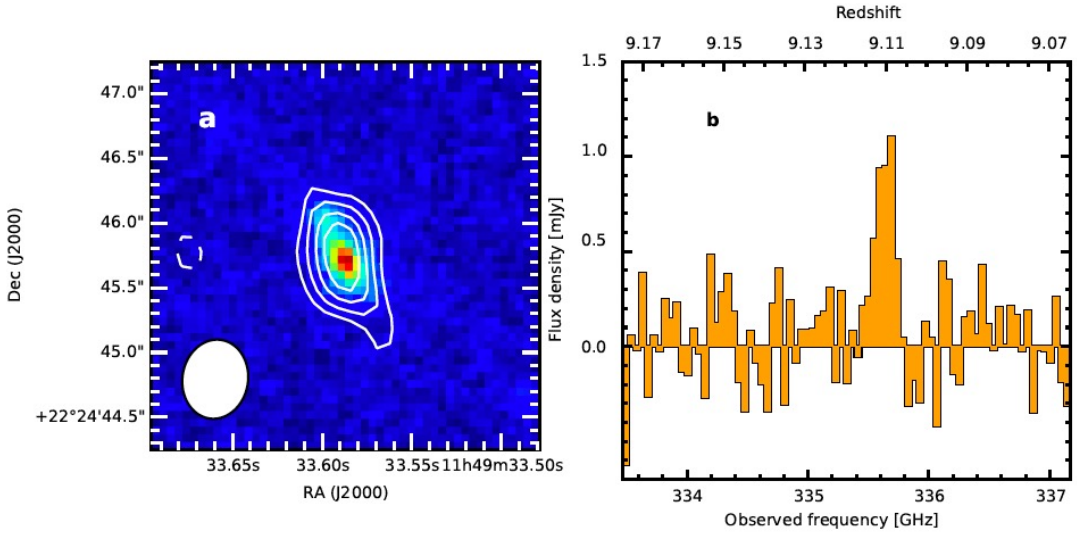
… and:

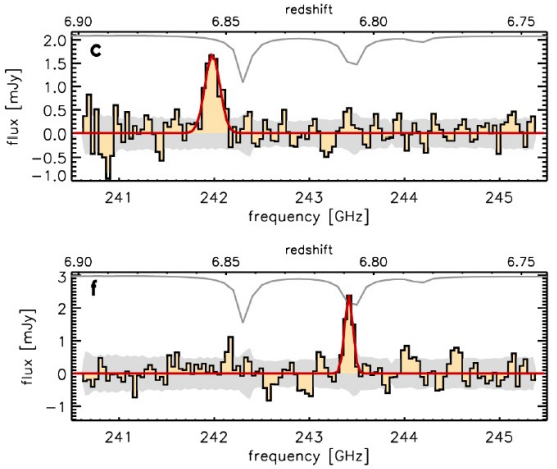
- Full polarization up to Band 7
- Solar observations
- VLBI (GMV, EHT)
- Phased array observations
- Time critical observations



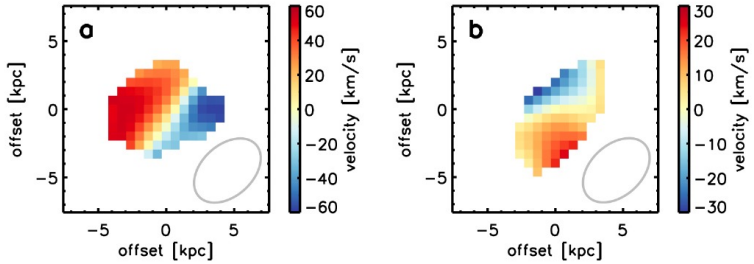
White et al. 2017

High redshift



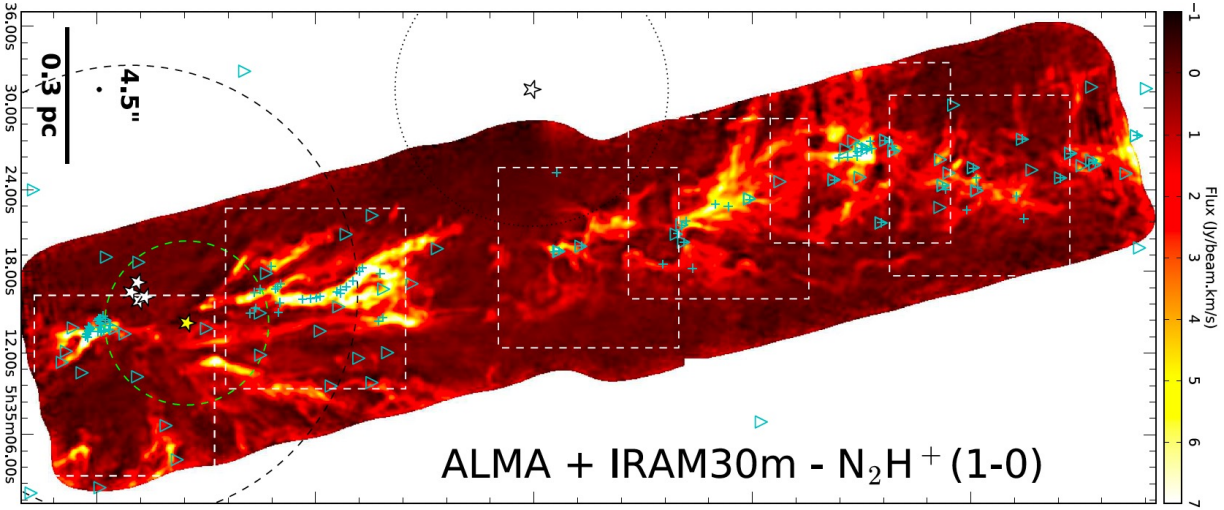


MACS 1149-JD1 @ z = 9.1096 ± 0.0006
(Hashimoto et al. 2018)
(See also Tokuoka et al. 2022 for velocity structure)



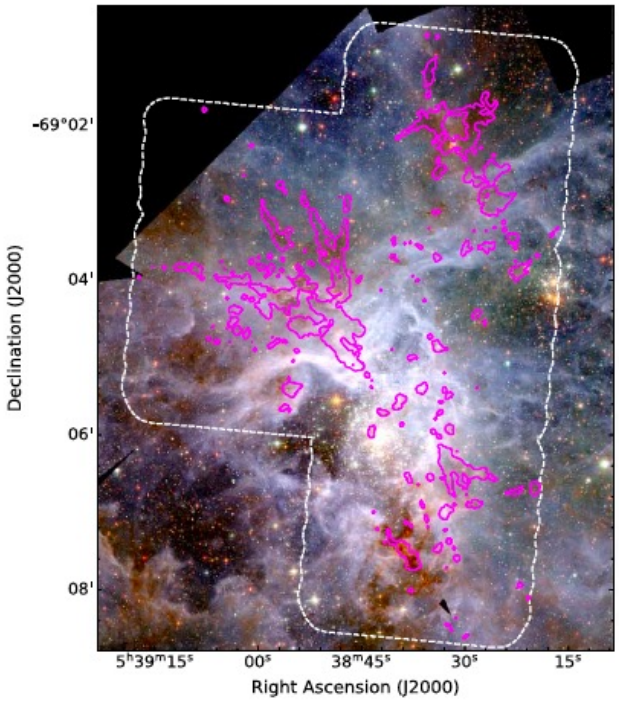
Velocity structure in two galaxies @ z = 6.8 (Smit et al. 2018)

ISM / Star formation



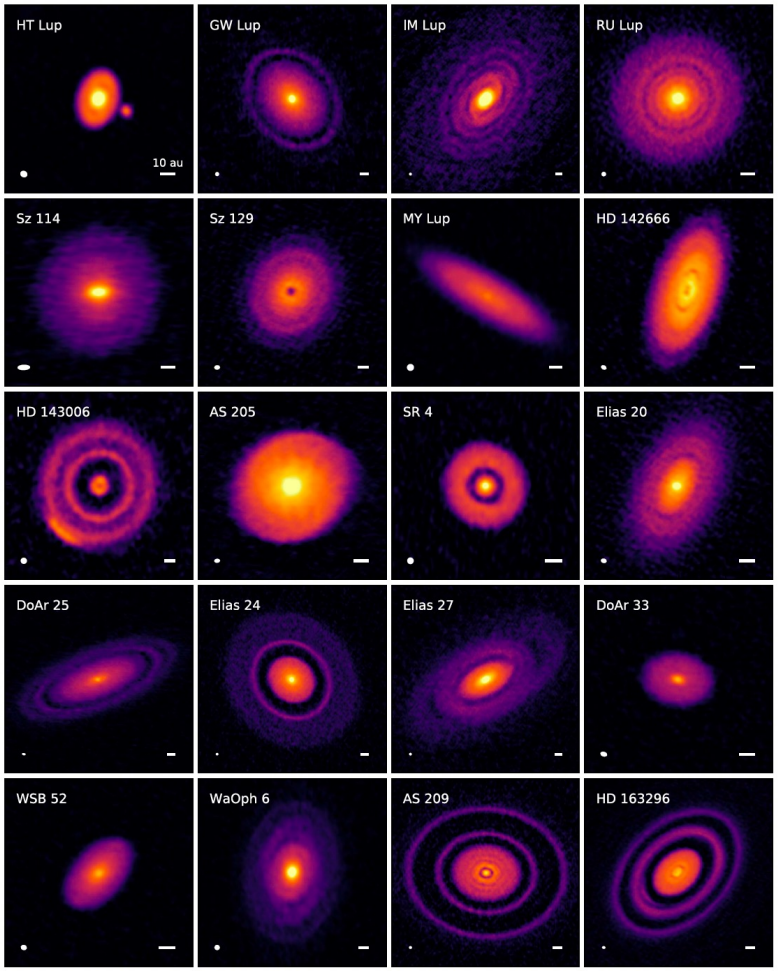
Hacar et al. 2018

Filaments are hierarchical structures with no characteristic scale

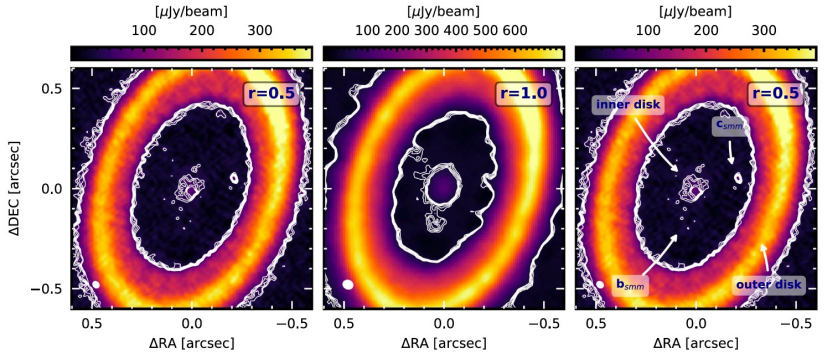


LMC: Wong et al 2022

Planet formation

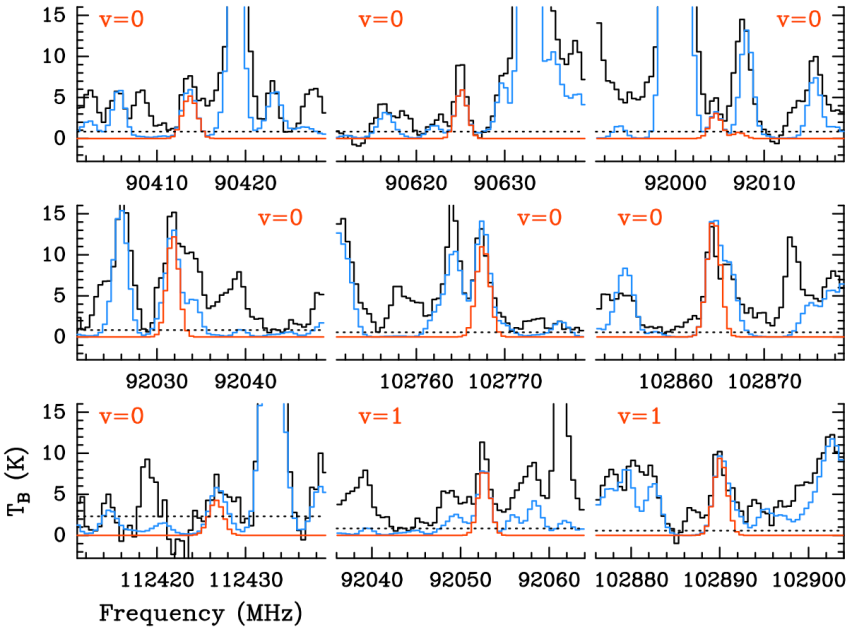


Andrews et al. 2018

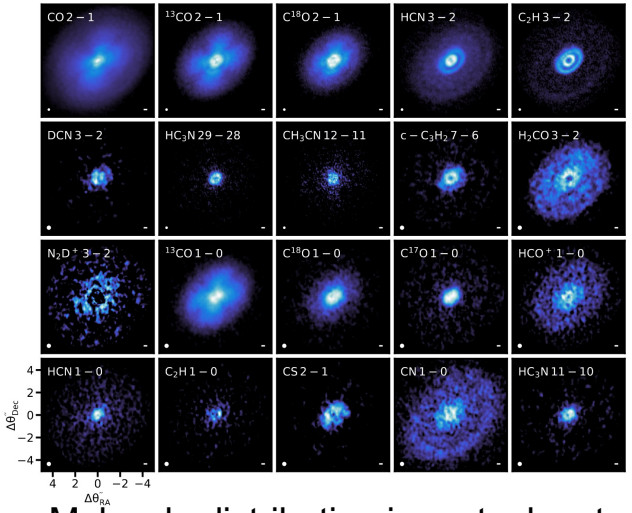


Benisty et al. 2021

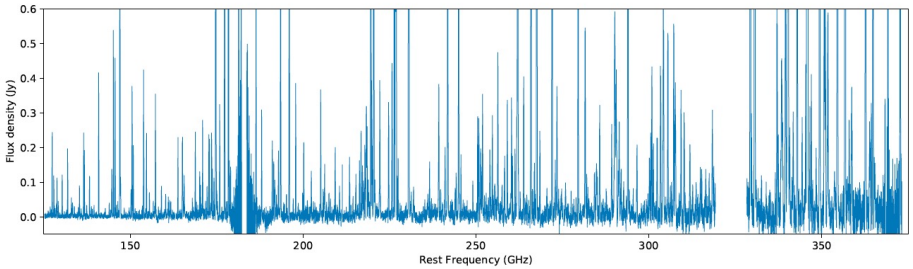
Chemical complexity



Detection of urea towards Sgr B2(N1S)
(Belloche et al. 2019)
(also in the ISM, Jimenez-Serra et al. 2020)



Molecule distribution in protoplanetary disk HD 163296 (Oberg et al. 2021)

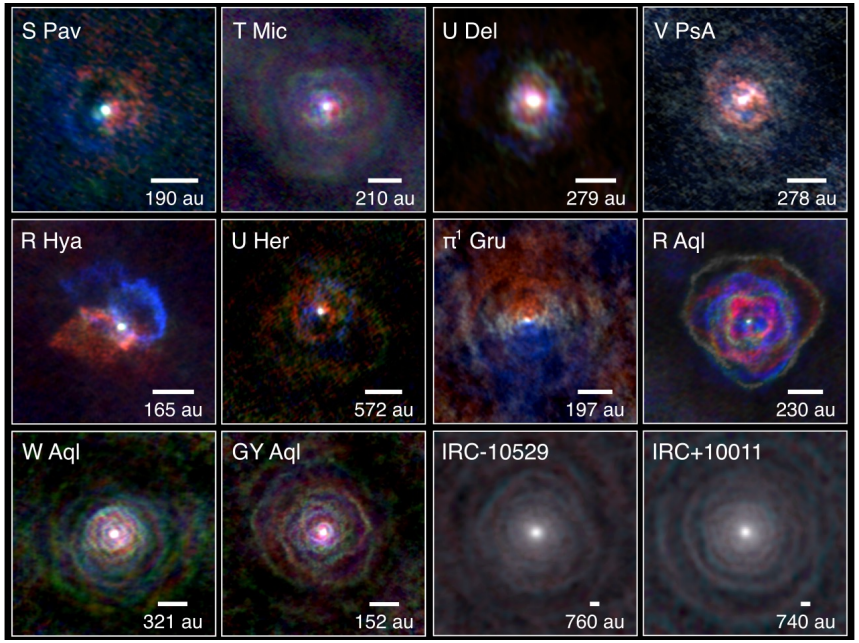


ACA spectral scan towards the starburst galaxy NGC253 (Martin et al. 2021)

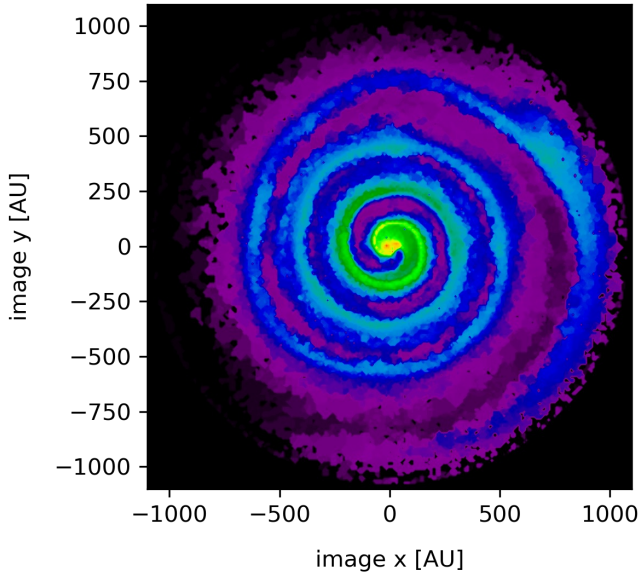
ATOMIUM large programme

Observations ⟷ *Simulations*

- hydrodynamics
- chemistry
- radiation

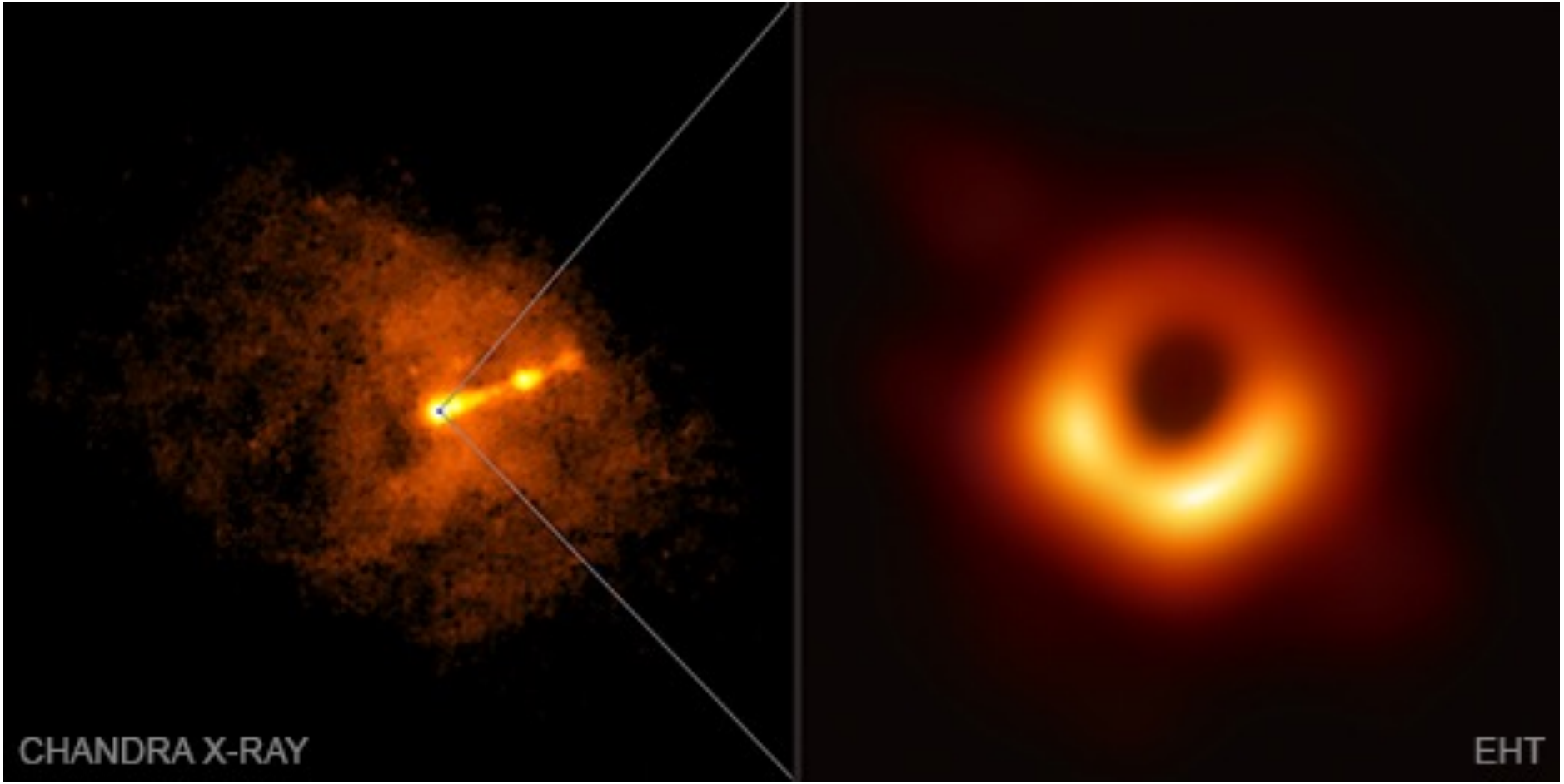


e.g. Decin+(2020), Homan+(2020,2021), Danilovich+(2020, 2021), Montargès+(2021), Gottlieb+(2022)



e.g. Maes+(2021), Malfait+(2021), De Ceuster+(2020), Van de Sande+(2022)

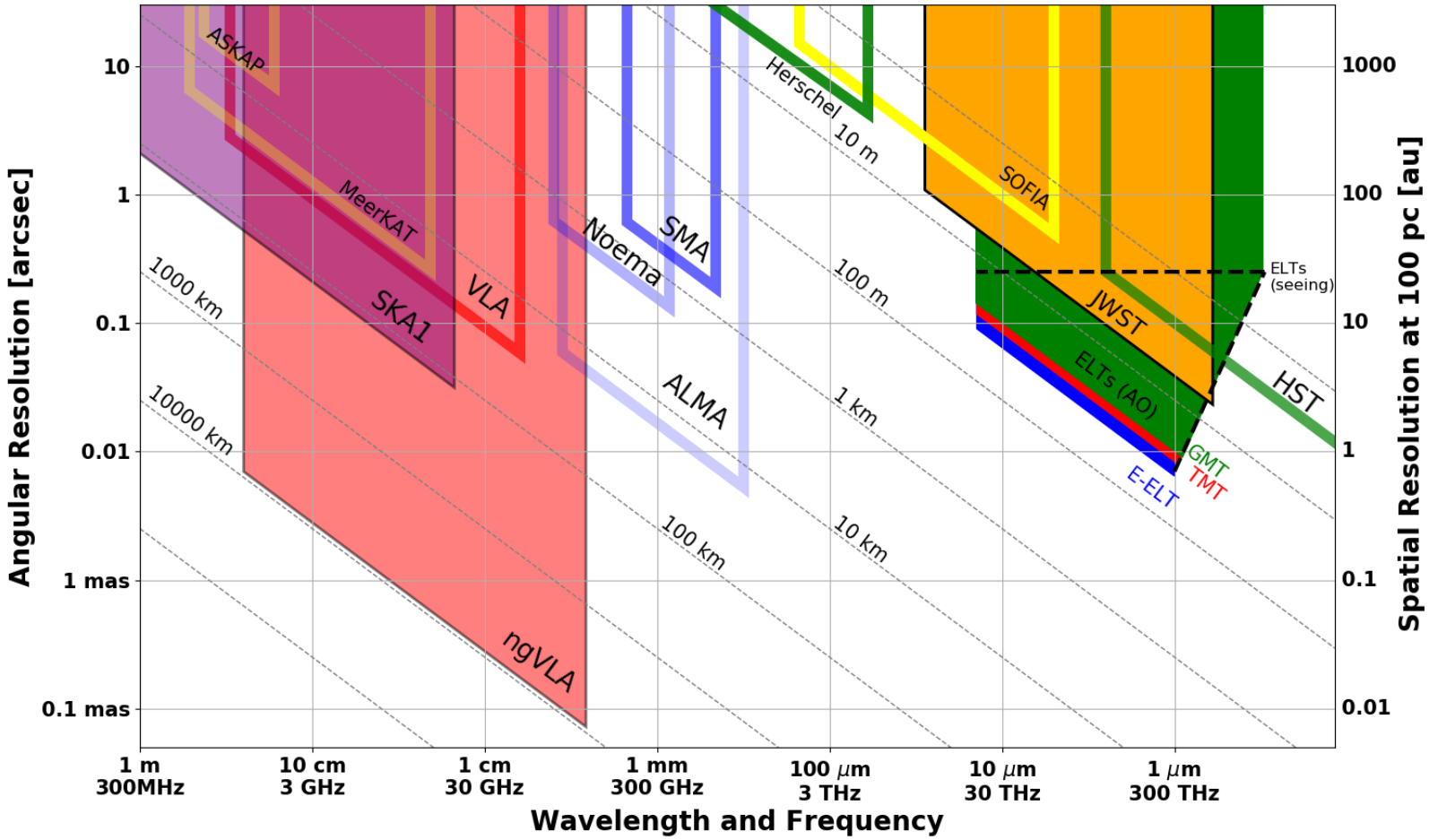
ALMA and the Event Horizon Telescope



Credit: X-ray: NASA/CXC/Villanova University/J. Neilsen; Radio: Event Horizon Telescope Collaboration

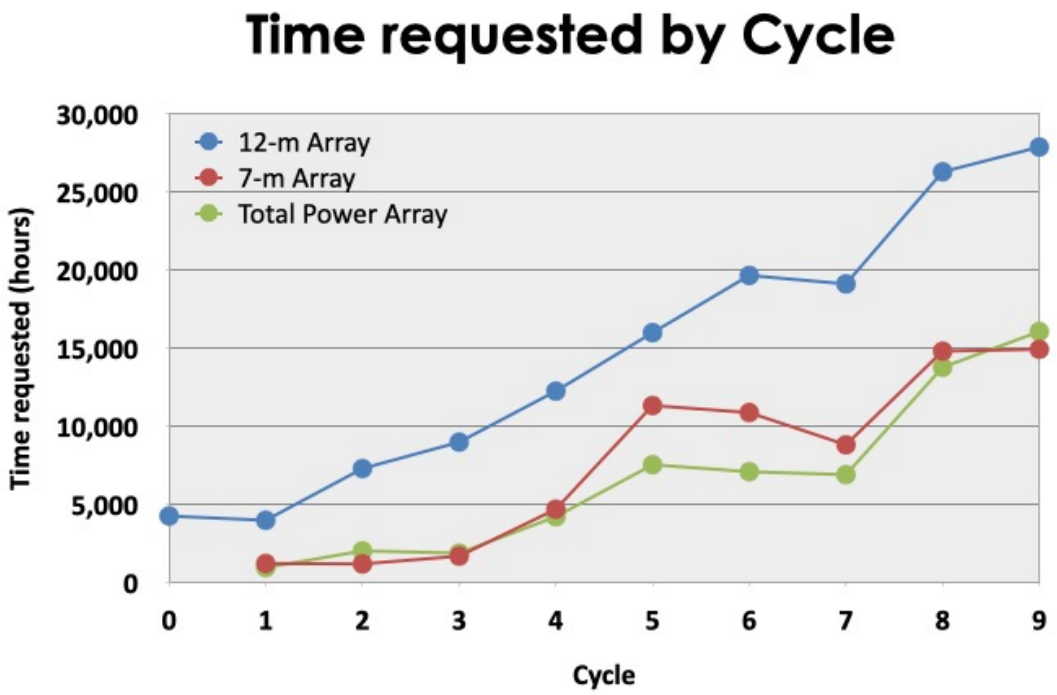
ALMA synergies

ALMA already reaches the spatial resolution of the ELT!

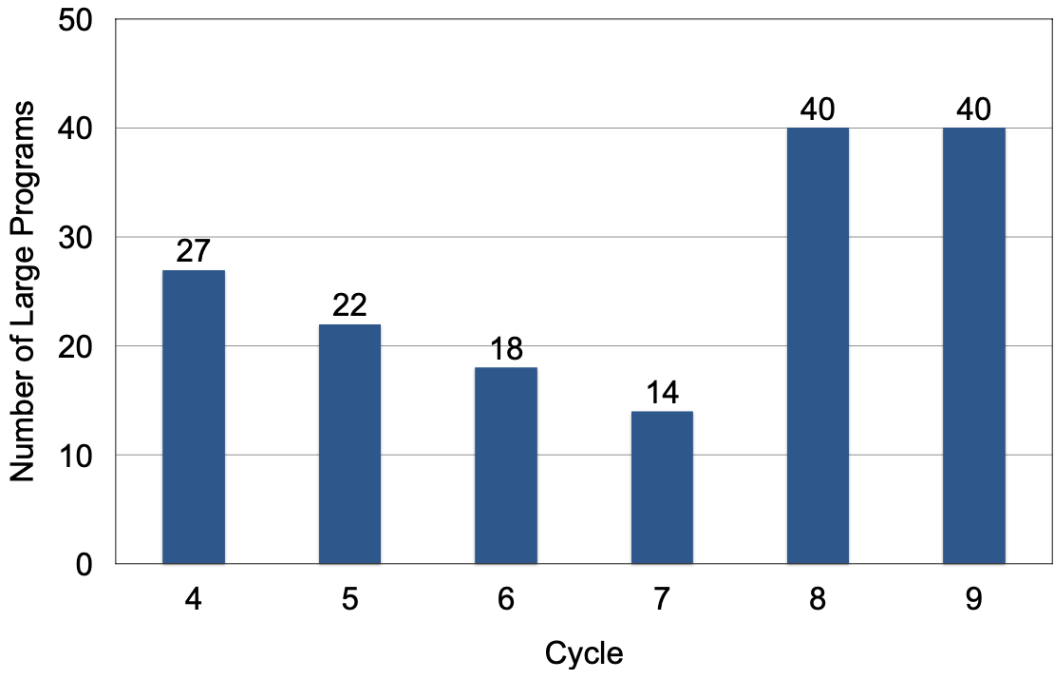


ALMA is a highly oversubscribed facility

- Total time request exceeds time available with factor 6.5
- Incredible enthusiasm by the communities in all regions to use ALMA

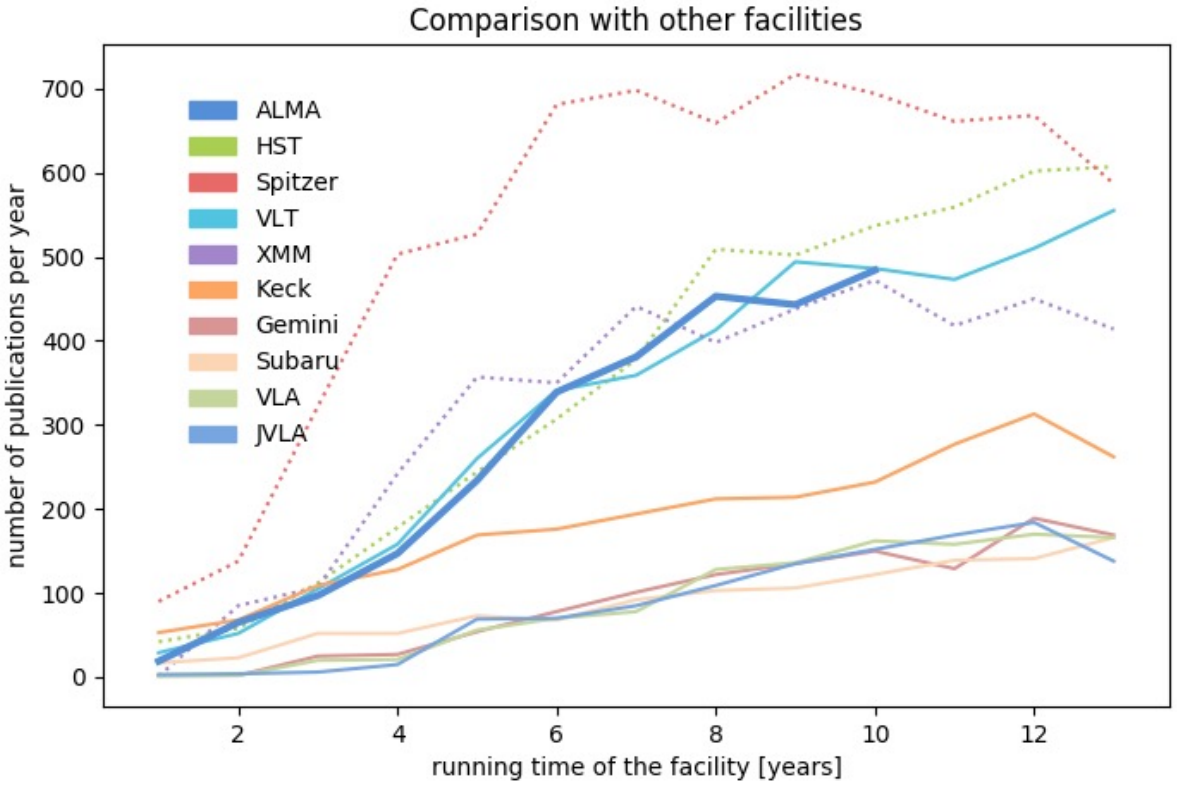


ALMA Large Programs



- Demand for Large Programs is high (40 requested in last 2 cycles)!
- One of these large programmes is Belgian: ATOMIUM

ALMA science output



- ALMA peer-reviewed publication rate on par with HST, VLT, XMM
- Largest fraction (40%) are European-led publications

Future of ALMA

Upcoming new ALMA capabilities

- **Joint proposals** with JWST, VLA, and ESO
  - Planned for ALMA Cycle 10, JWST Cycle 2, ESO Period 111
- New **Guaranteed Time Observations** (GTO) policy
  - In exchange for contributions to the ALMA development programme, institutes can apply for access the European share of ALMA time
- New initiative for **Advanced Data Products**
  - Soliciting input from ALMA user community on priorities
- ALMA Band 1 installation half-way
  - Adding a new frequency coverage from 35 to 50 GHz
- ALMA Band 2 entering pre-production
  - Covering 67 to 116 GHz, reaching below coverage of current Band 3

ALMA 2030 Roadmap

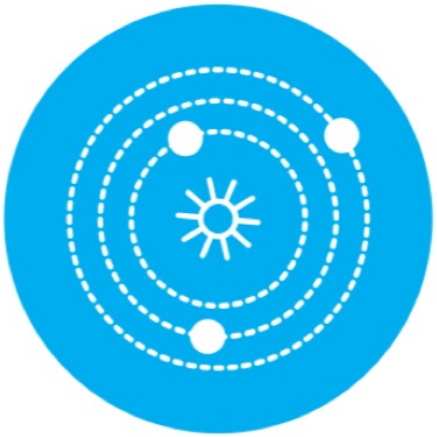
- New fundamental science drivers

ORIGINS OF GALAXIES

Trace the cosmic evolution of key elements from the first galaxies (z>10) through the peak of star formation (z=2–4) by detecting their cooling lines, both atomic ([CII], [OIII]) and molecular (CO), and dust continuum, at a rate of 1-2 galaxies per hour.

ORIGINS OF CHEMICAL COMPLEXITY

Trace the evolution from simple to complex organic molecules through the process of star and planet formation down to solar system scales (~10-100 au) by performing full-band frequency scans at a rate of 2-4 protostars per day.



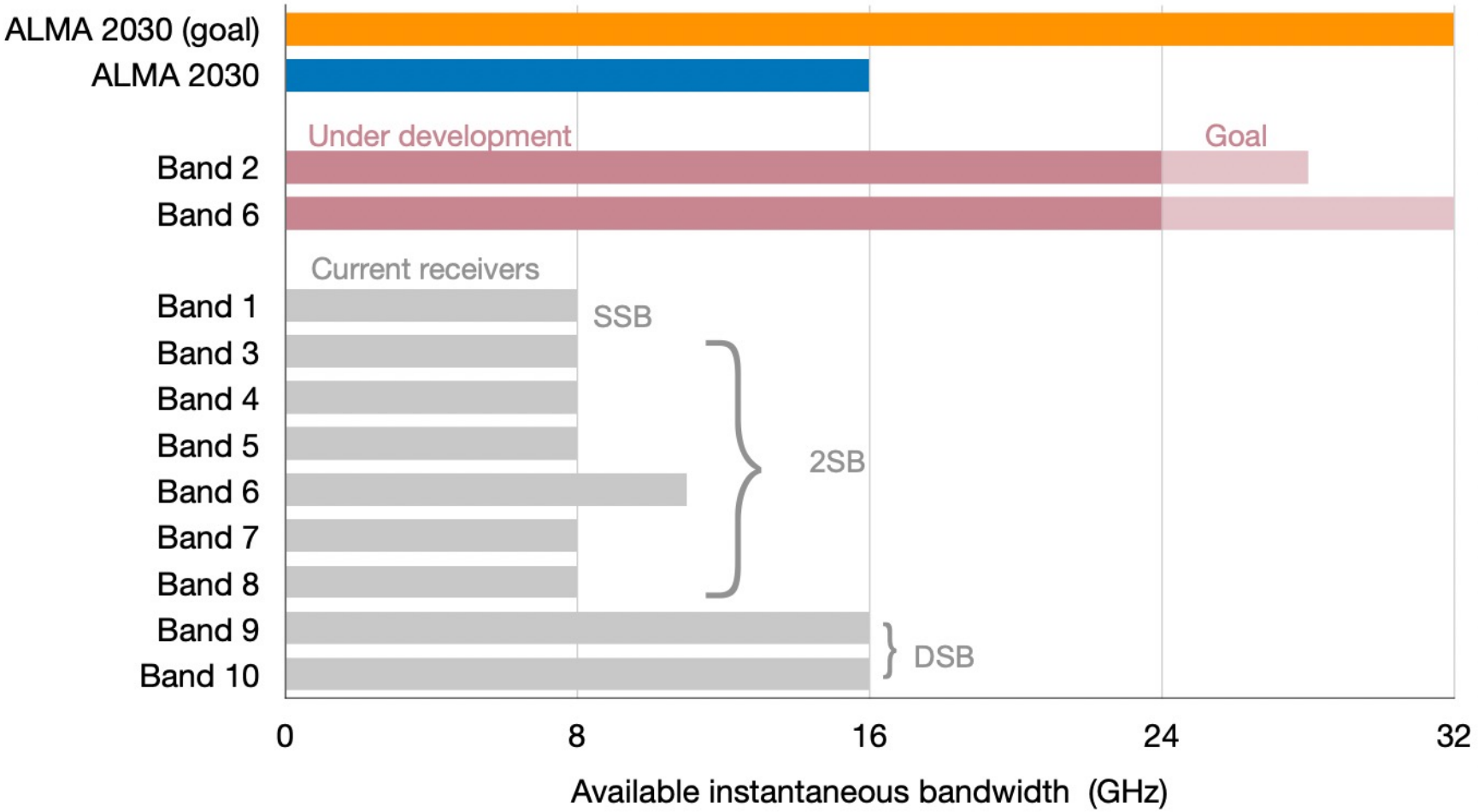
ORIGINS OF PLANETS

Image protoplanetary disks in nearby (150 pc) star formation regions to resolve the Earth forming zone (~ 1 au) in the dust continuum at wavelengths shorter than 1mm, enabling detection of the tidal gaps and inner holes created by planets undergoing formation.

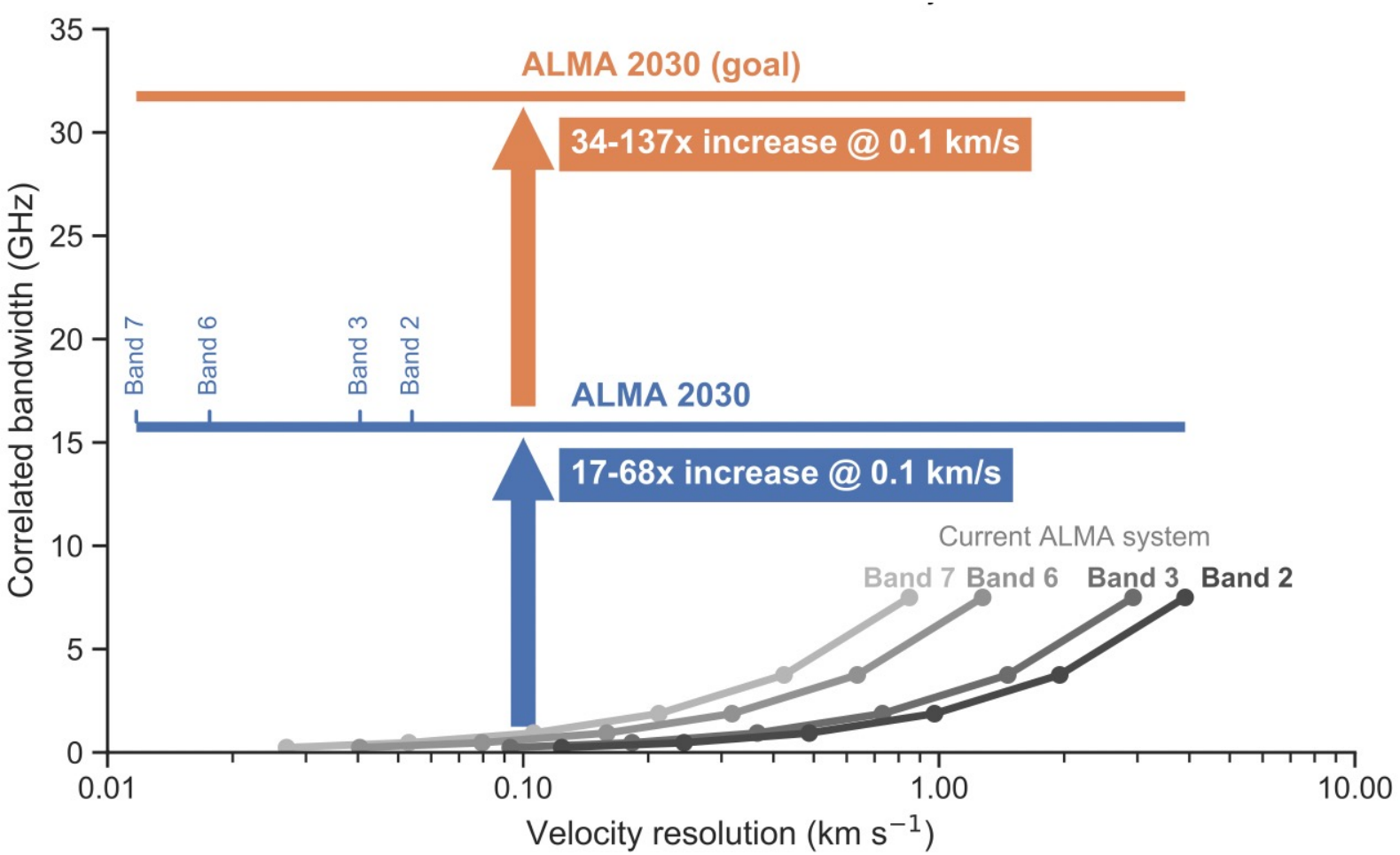
Wideband Sensitivity Upgrade

- Keep ALMA at the forefront!
- Upgrade of the **bandwidth** and **throughput** of the ALMA system with improved sensitivity
  - receivers with increased bandwidth and improved receiver temperatures
  - new digitizers and data transmission system
  - correlator with improved efficiency
  - improved data processing and archive
- Major upgrade of virtually the entire ALMA system!

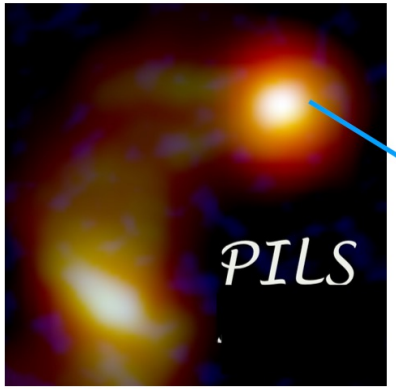
Wideband Sensitivity Upgrade

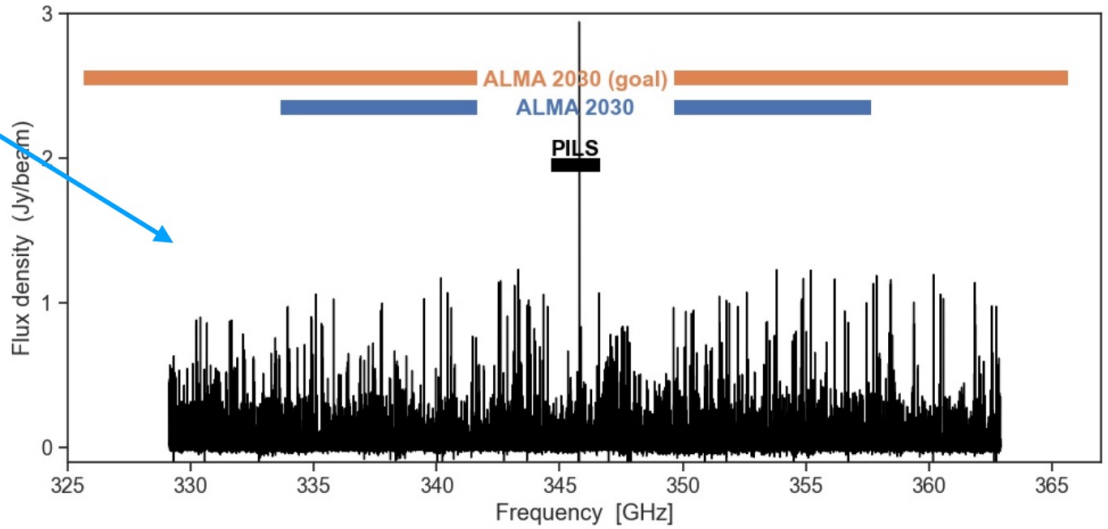


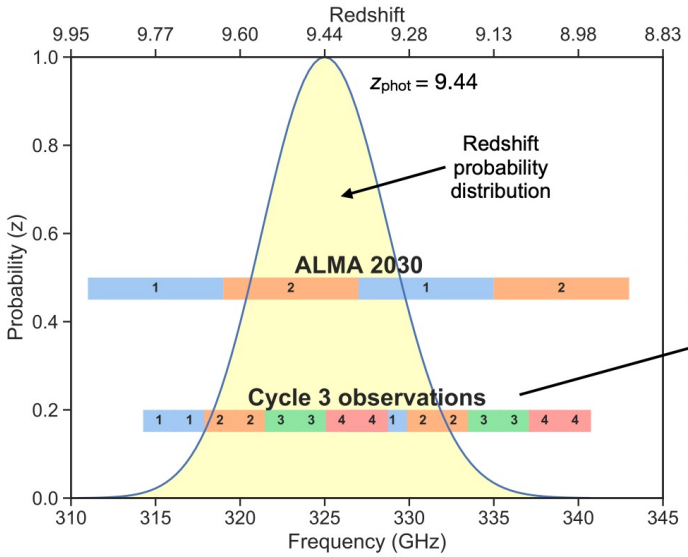
Wideband Sensitivity Upgrade

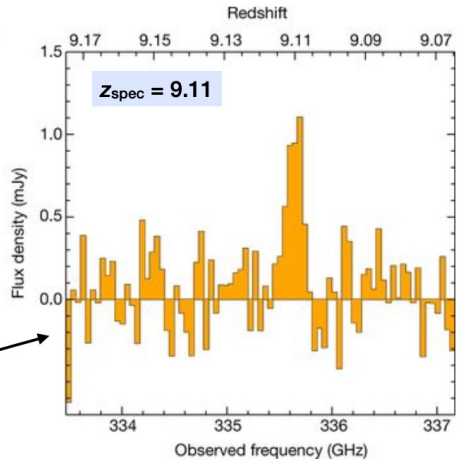


Wideband Sensitivity Upgrade









- ALMA 2030 upgrade will be at least 3 times faster plus any improvements from lower receiver noise

Wideband Sensitivity Upgrade

- Technical upgrades
  - Available bandwidth : **factor of 2-4 increase**
  - Correlated bandwidth : **more than an order of magnitude increase with ~ 0.1 km / s resolution**
  - Observing speed : **2.2-4.7x faster for spectral lines, 4.8x faster for continuum** (Band 6 upgrade)
- Scientific impact
  - Planet formation: comprehensive studies of physical, kinematic, and chemical structure of disks
  - Star formation: efficient surveys of all stages in the star formation process
  - Galaxy formation: probe the formation and evolution of galaxies across cosmic time

Wideband Sensitivity Upgrade

- Europe is preparing for Band 2, Digitizers, Fibre Optics, Band 7 and 9
  - All contingent on approval and funding
- Other executives responsible for correlator, other bands, etc
- Challenges
  - Deploy the new system with minimal impact on operations
  - Complete the full overhaul and mitigate overall obsolescence

ALMA's future is bright!