A review of (sub)mm band science and instruments in the ALMA era

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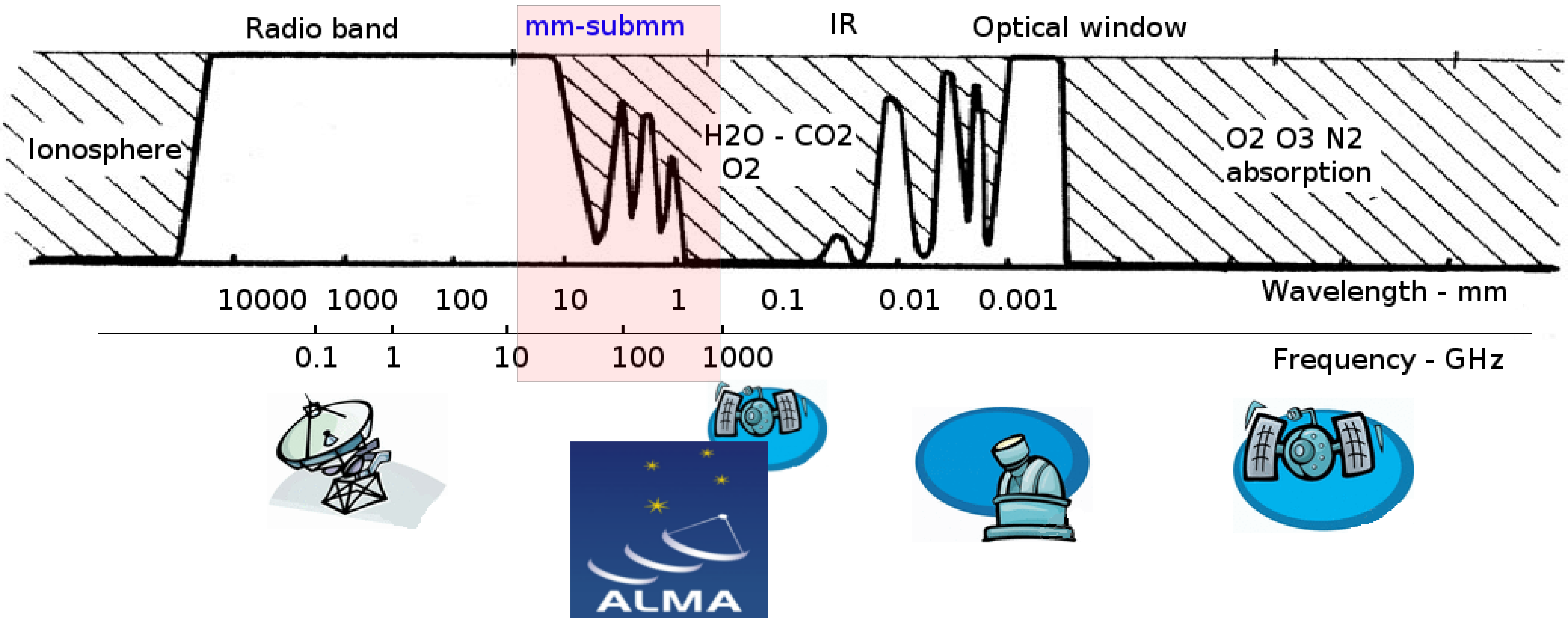
ALMA
EUROPEAN ARC
ALMA Regional Centre || Italian

SISSA – May 2019

Outline



Observing instruments: **Interferometers (ALMA)**

Signals in the (sub)mm bands

Science cases parade

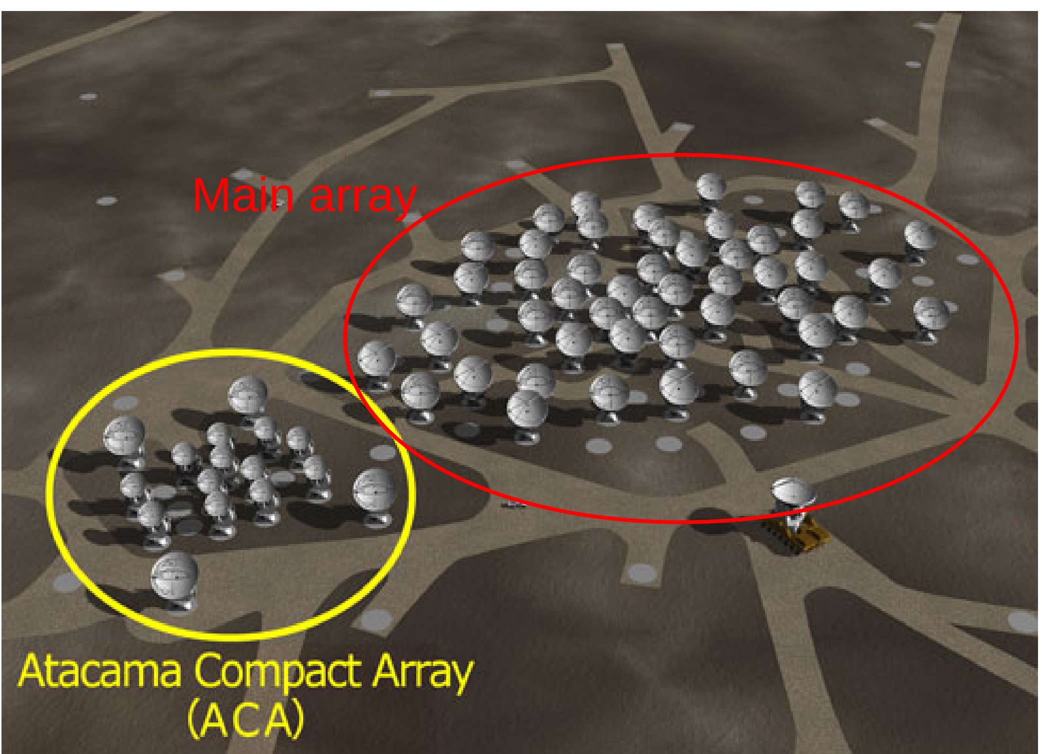
Observing processes: **Proposals, archives & images**

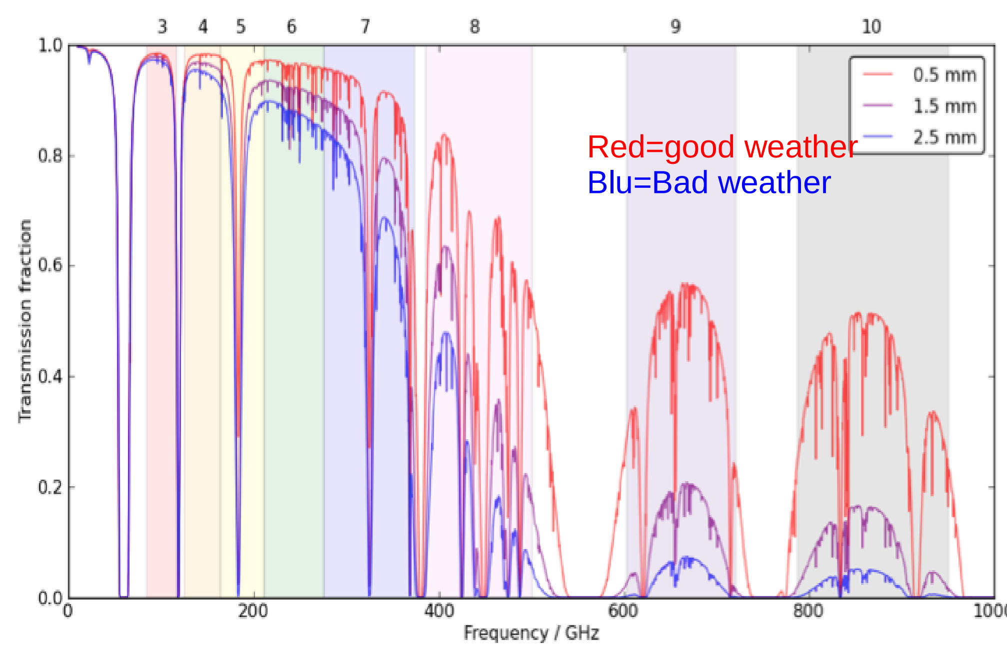
How to extract science from images: hands-on tutorial

ALMA full array

The Atacama Large Millimeter Array is a **mm-submm reconfigurable interferometer**

- Antennas: **50x12m** main array + **12x7m** ACA **+ 4x12m** Total Power
- Baselines length: **15m ->150m-16km** + **9m->50m**
- Frequency range: **10 bands between 30-900 GHz** (0.3-10 mm)
- Bandwidth: **2 GHz x 4 basebands**
- Polarimetry: Full Stokes capability
- Velocity resolution: **As narrow as 0.008 × (300GHz/Freq) km/s**
  ~0.003 km/s @ 100 GHz, ~0.03 km/s @ 950 GHz





ALMA full array

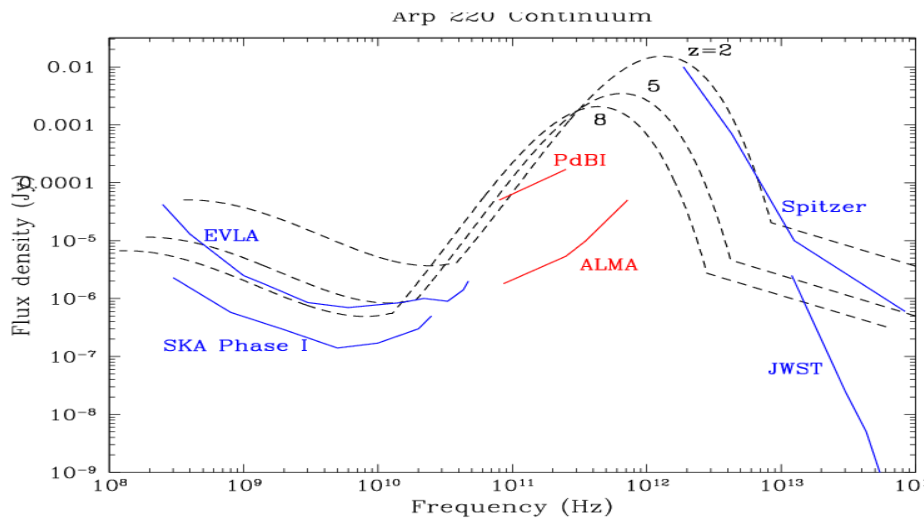
An interferometer reconstructs an image of the sky at fixed spatial scales
(i.e. measures single points in the Fourier domain)
corresponding to the projection of the baselines (i.e. distances among the antennas) on the sky.

Sensitivity

$$\Delta S_\nu = 2\,k\,\frac{T_{\rm sys}}{A_{\rm e}\sqrt{2t\,\Delta\nu}}$$

- 6500sqm of effective area and 1225 baselines
 for the 12m array + Short spacings with ACA
- Excellent instantaneous uv coverage

<0.05mJy @100 GHz in 1 hr



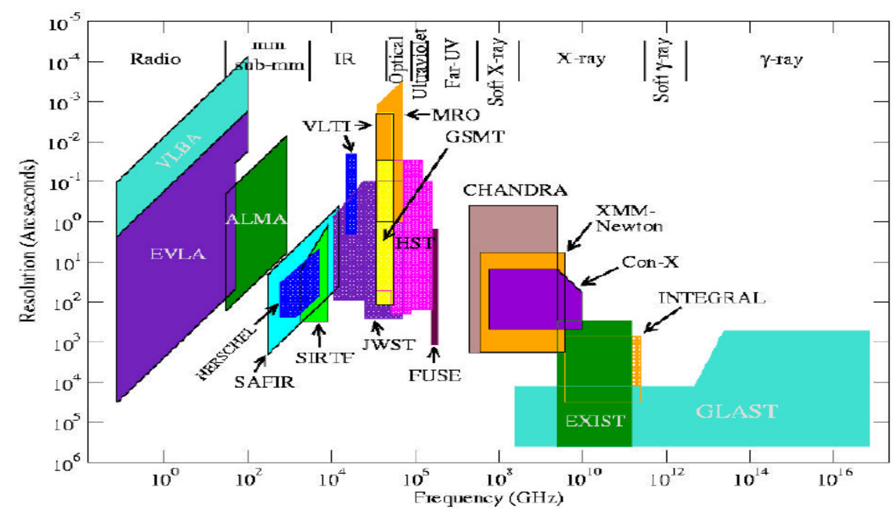
Spatial scales

$$\theta = k\,\lambda / D$$

- **Resolution:**
 0.2” x (300GHz / freq) x (1km / max_baseline)

- **Largest angular scale:**
 1.4” x (300GHz / freq) x (150m / min_baseline)

- **FOV 12m array: 21” / (300GHz / freq)**
- **FOV 7m array: 35” / (300GHz / freq)**



General words: ALMA pros for science

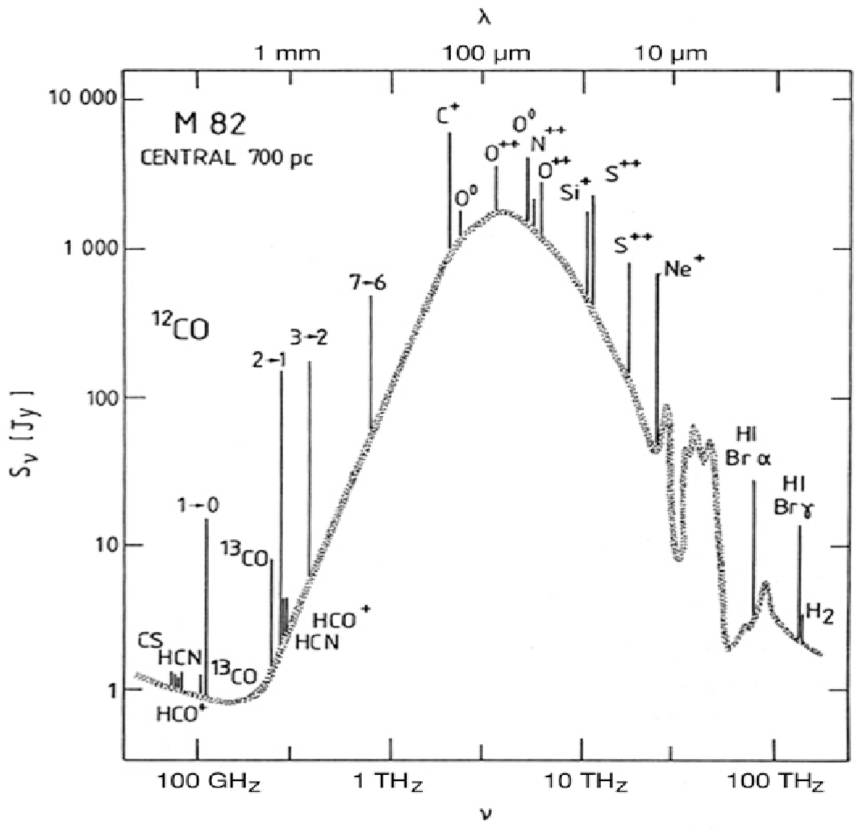
Sub(mm) is characterized by dust and rich chemistry.

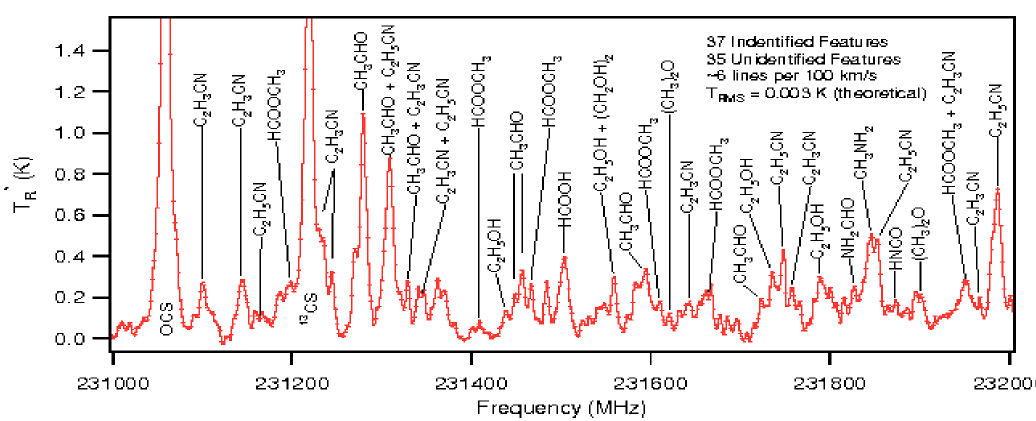
Dust and molecules are mostly (but not only) associated with forming structures.

Hence **sub(mm) helps studying structure formation.**

Higher resolution and sensitivity allows to go farther so to investigate a deeper sky region, getting more sources and more statistics on populations.

Higher spectral resolution allows to detect more narrow lines and more details from broad lines, and hence investigate chemical compositions, source dynamics and pressure and temperature structures.





ALMA science fields

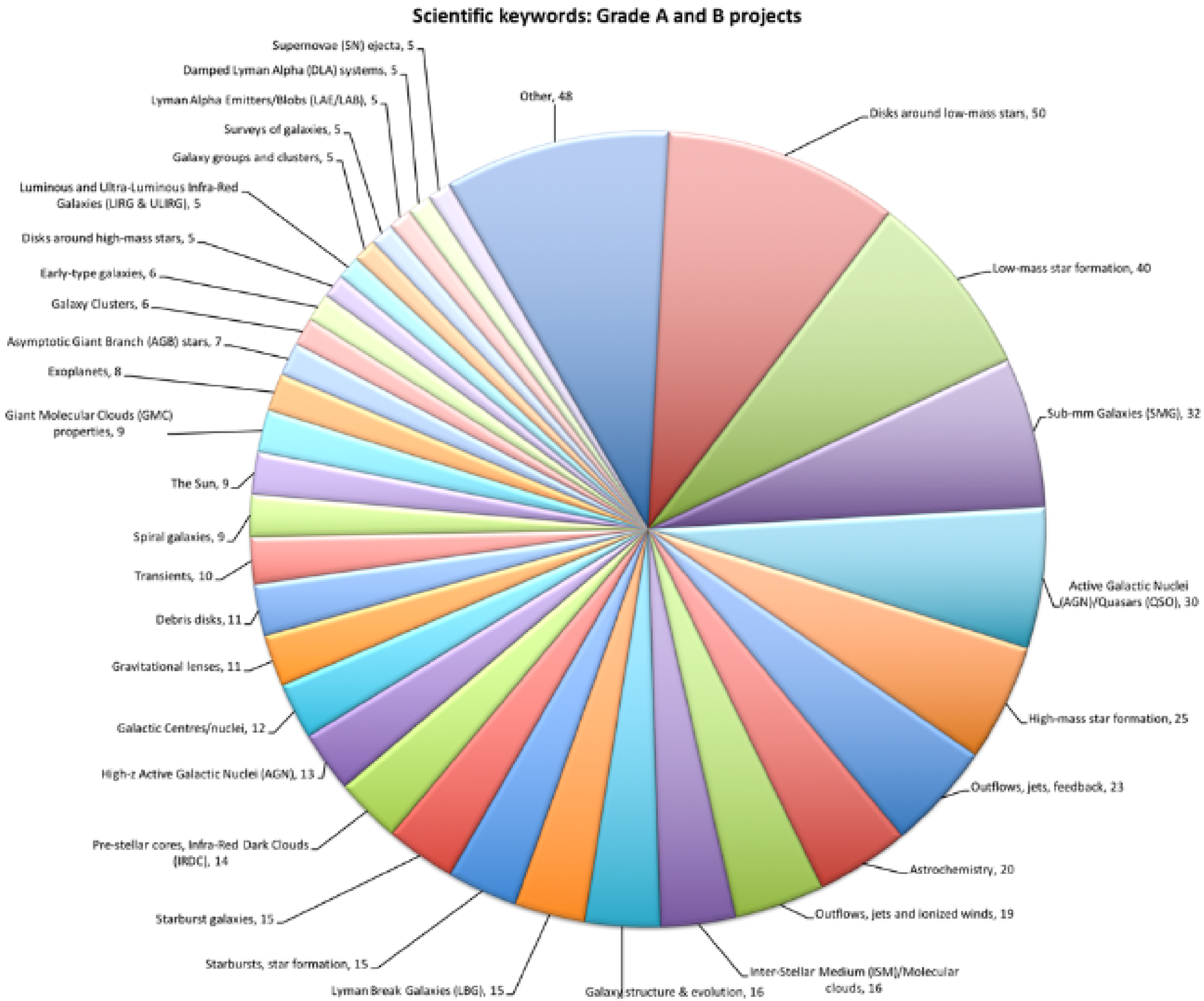
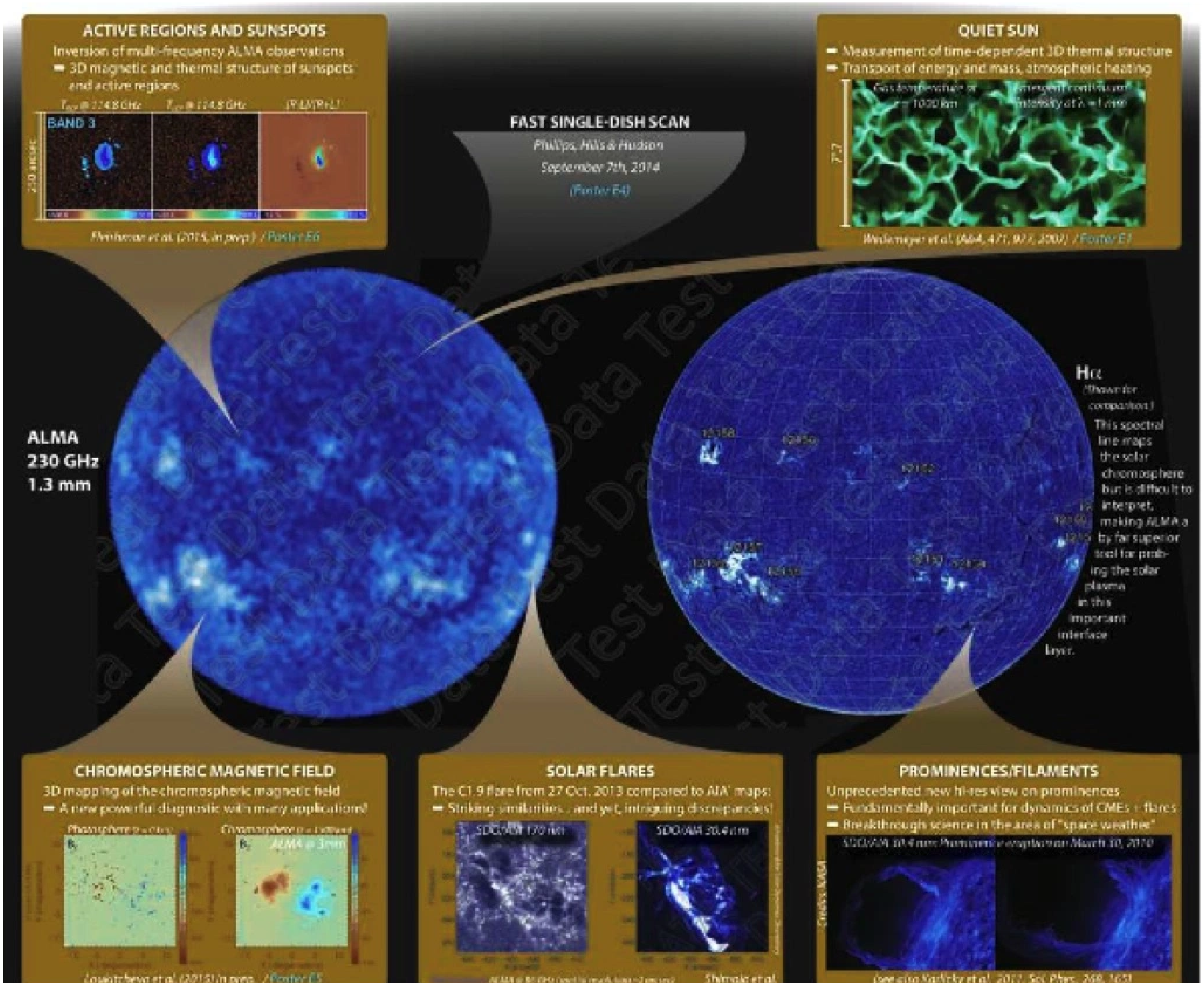


Figure 6. Breakdown of the Grade A and B projects by scientific keyword, across all ALMA scientific categories. For each science keyword, the number of proposals in which it is selected is indicated.

The Sun

Sunspots are transient features occurring where the Sun's magnetic field is concentrated and powerful. They are lower in temperature than their surrounding regions, which is why they appear relatively dark.
The ALMA image is essentially a **map of temperature differences in the chromosphere**.
Observations at shorter wavelengths probe deeper into the solar chromosphere than longer wavelengths.



(Wedemeyer et al. 2015)

The Sun

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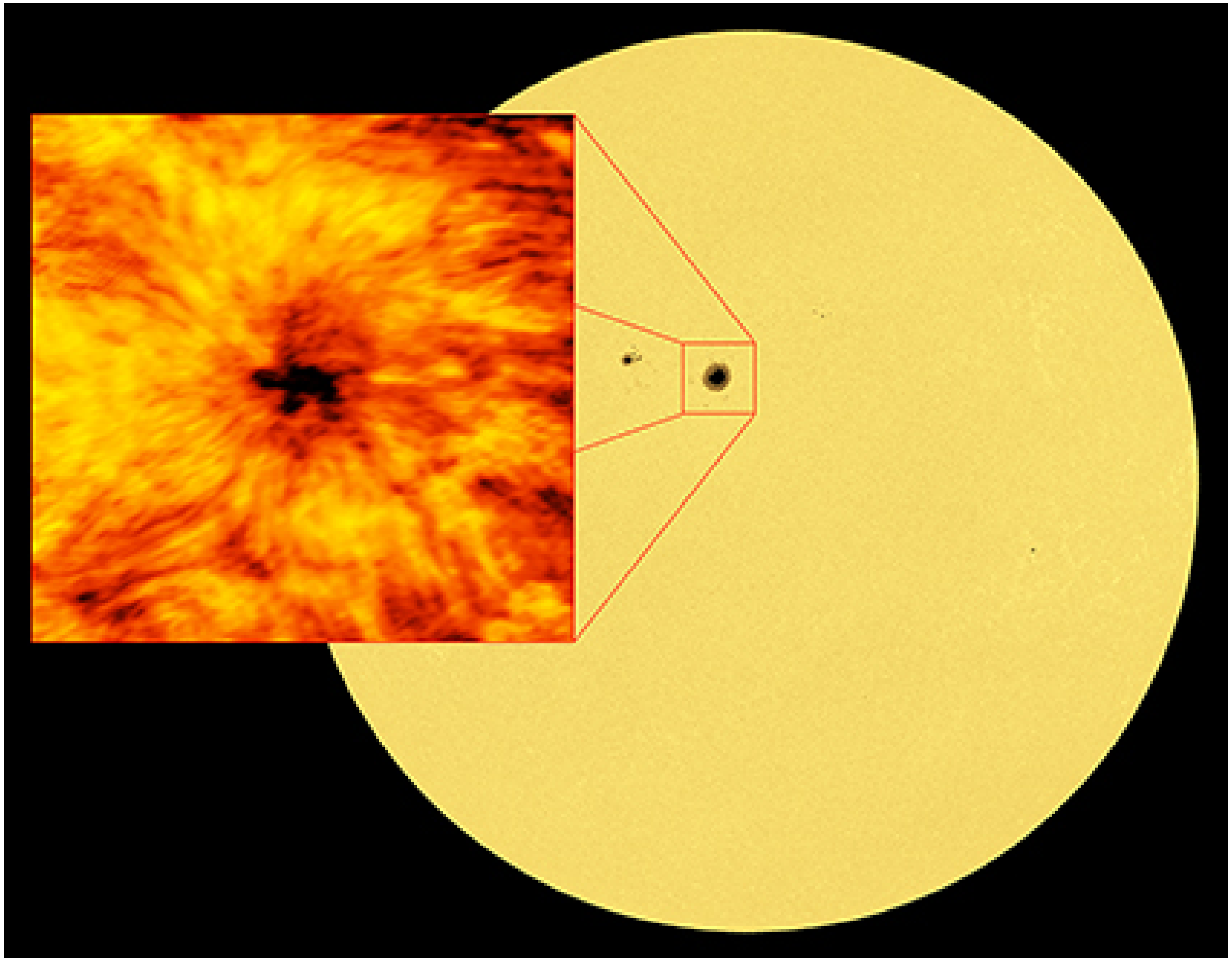


(Shimojo et al. 2017)

Planets & small bodies

Surface studies

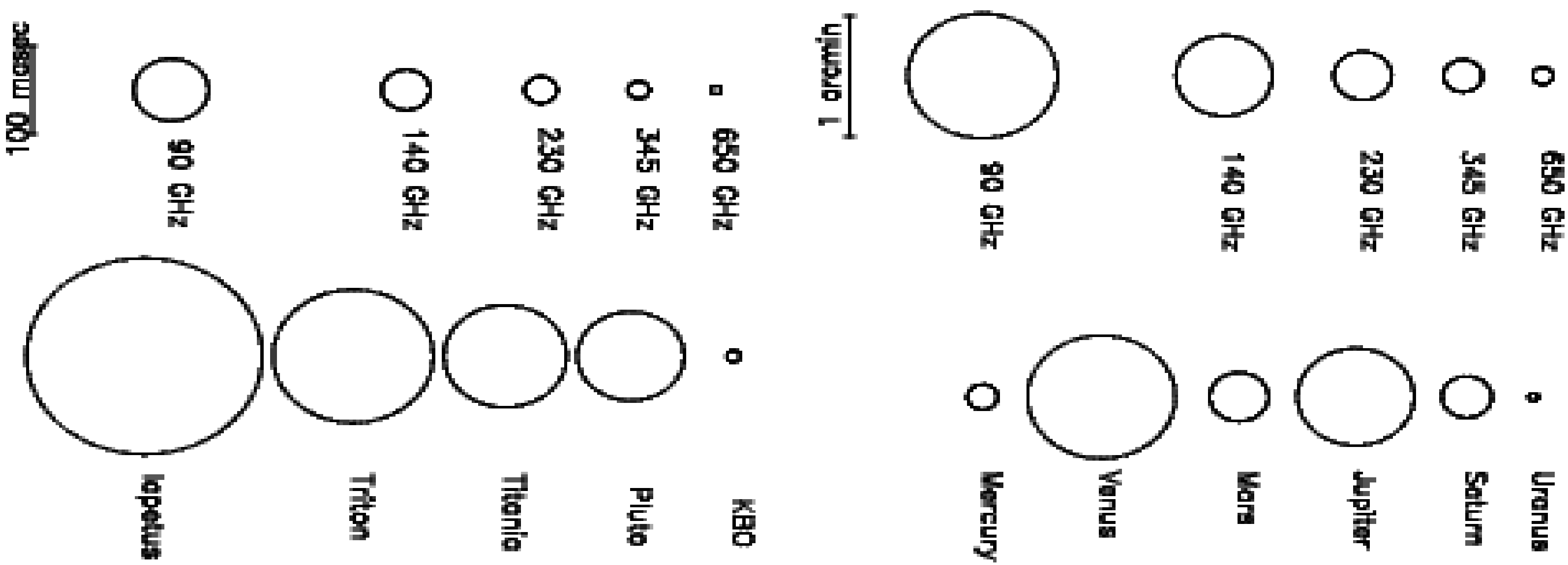
- Mapping regions that may contain ice to determine the surface temperatures and **if the ice is stable** (e.g. Mars polar caps).

- Mapping the surface temperature vs wavelength to constrains the planet heat from the interior and **the planetary magnetic fields.** (e.g. to determine if Mercury has a molten core)

Calibrations

- Planets & satellites are “relatively” stables, so are used as **flux calibrators at sub(mm).**
Proper models of flux density distribution (they are typically extended wrt to telescope beams) and time variability (e.g. seasonal variations) are crucial also for other science observations.

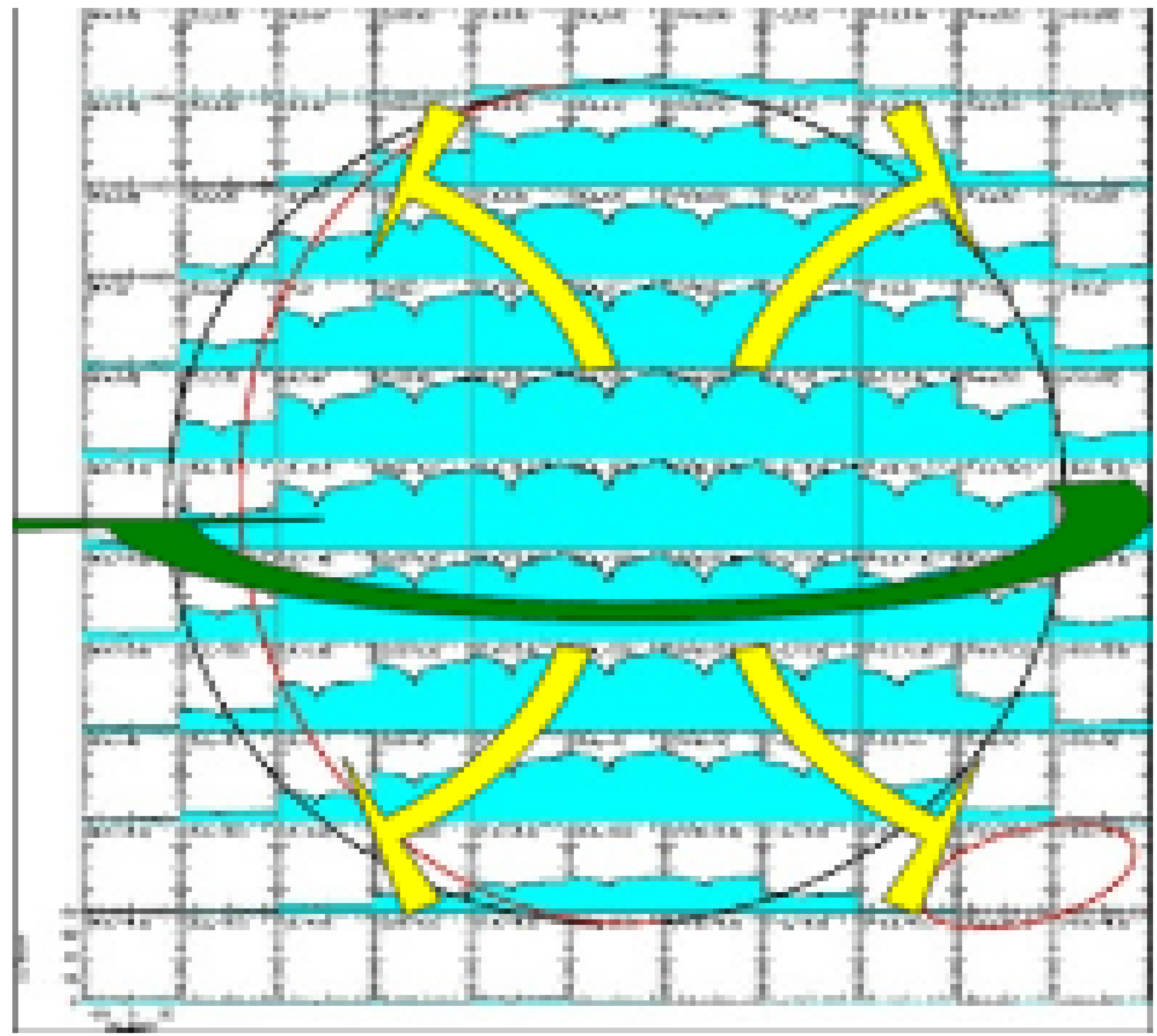
ALMA beam sizes



Solar System bodies sizes

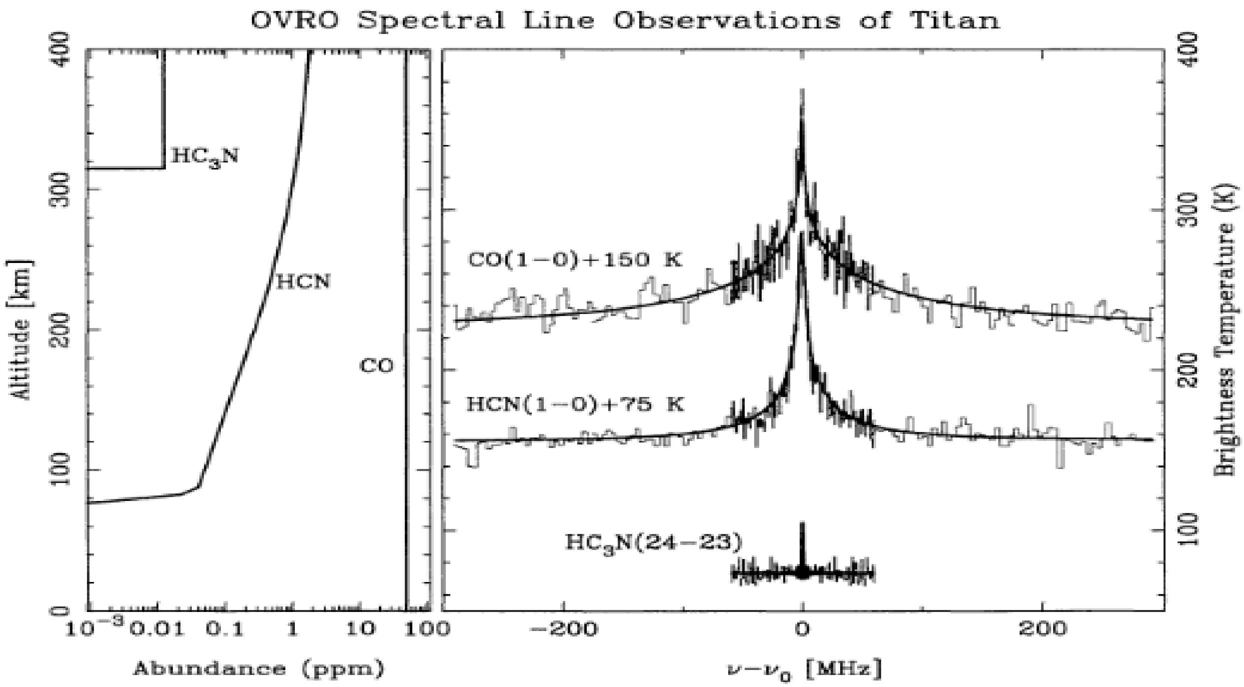
Planets & small bodies

Atmospheric studies - dynamics
From spetral profiles it is possible to reconstruct
dynamics of planetary atmospheres, (wind maps, seasonal variations and climate models)



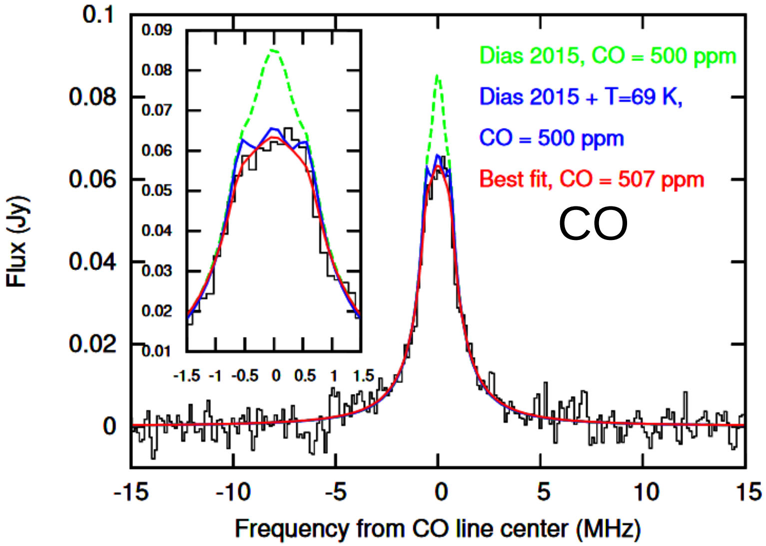
Moullet et al. 2013 - Cycle0
Venus wind field near the upper boundary of the mesosphere, through the CO(3-2) line's Doppler-shifts maps

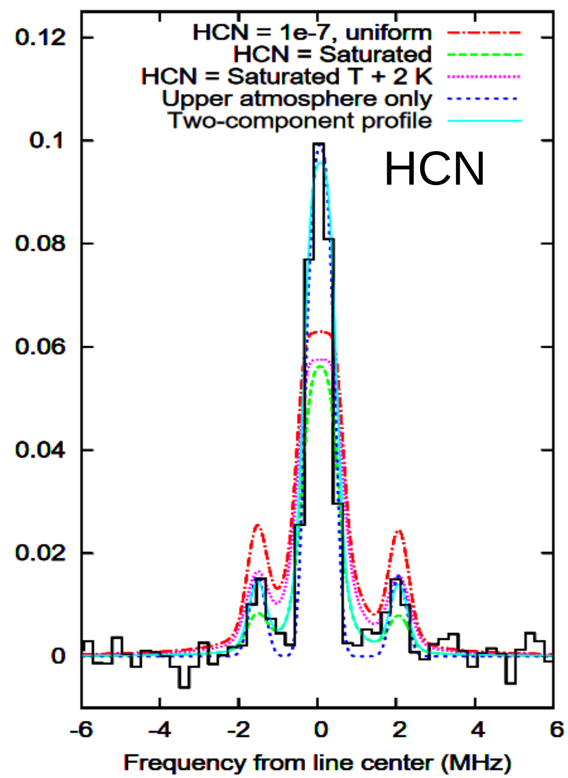
Planets & small bodies

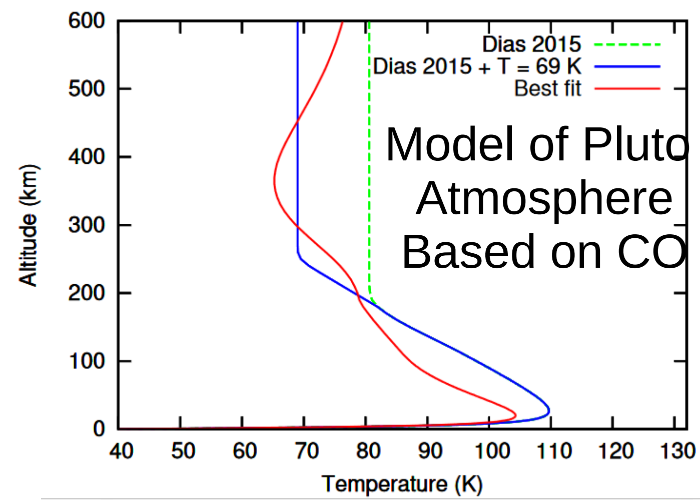


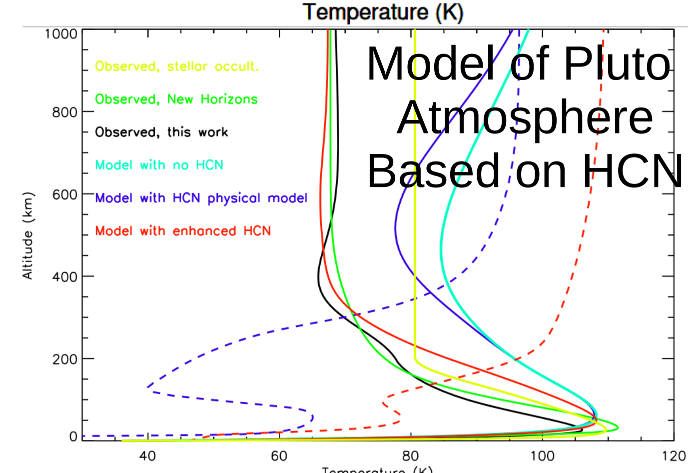
Atmospheric studies - structure

- Since spectral line shape (i.e. Doppler and pressure broaden lines) depends on molecular abundances and temperature profiles they can be used to reconstruct **vertical structures of planetary atmospheres, (chemical composition, pressure and temperature)**









Lellouch et al. 2017 - Cycle2

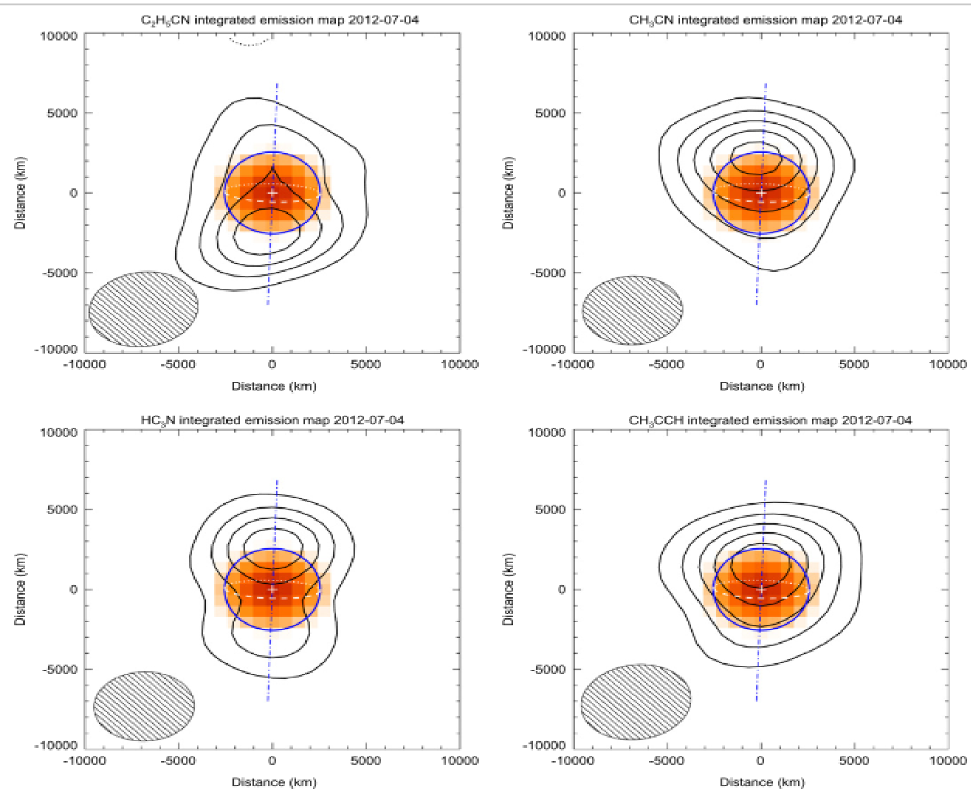
Pluto's lower atmosphere from CO and HCN line shapes

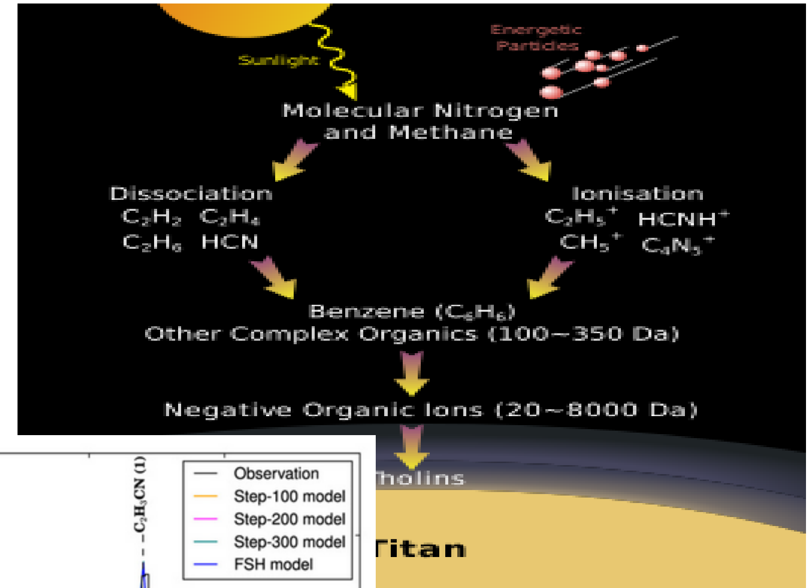
- Cycle 0 -20 antennas
- 8min on-source
- Band 6 (1.7 mm)
- **Spectral res 1.3km/s**
- Angular Res 0.7" (~5000km~Titan diameter)

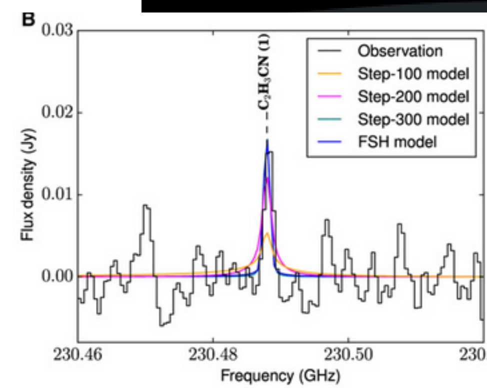
Ethyl Cyanide & HCN on Titan

Cordiner et al. 2015
Molter et al. 2016
Palmer et al. 2017

Titan has a thick atmosphere composed primarily of molecular nitrogen (98%) and methane (2%). Organic molecules form at various altitude from ionization and photodissociation processes.

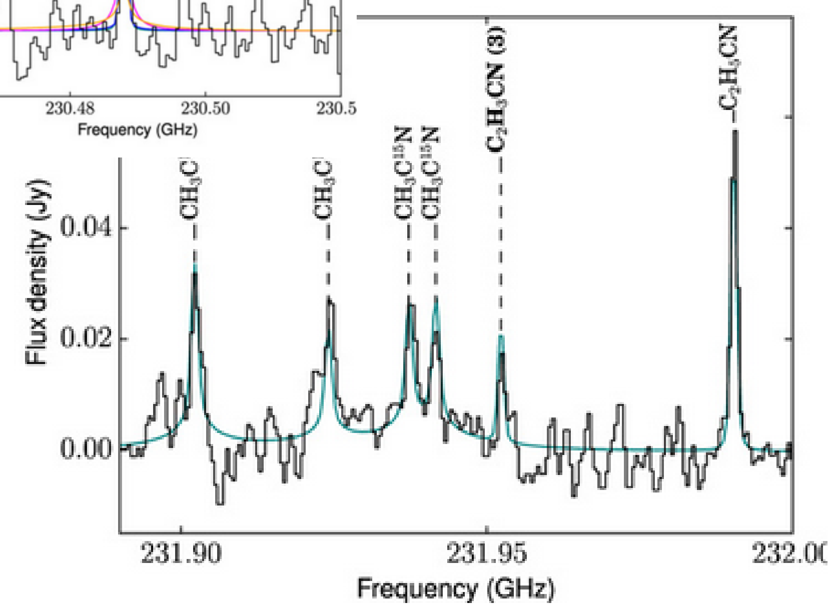




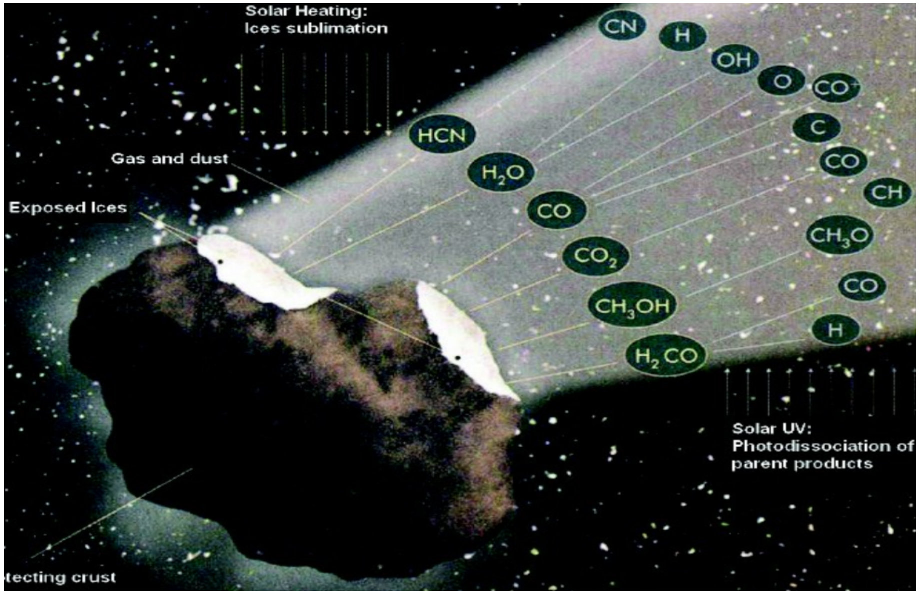


Ethyl Cyanide (C2H5CN) is detected on Southern hemisphere indicating a shorter lifetime (during northern winter-spring transition) than HC3N, CH3CN and CH3CCN which are found to the north. Comparison with models show that C2H5CN is produced in the moon's stratosphere and above 200km.

Vinyl Cyanide (C2H3CN) originates >200km. Abundances confirm the possibility of presence of cell membranes in Titan lakes.



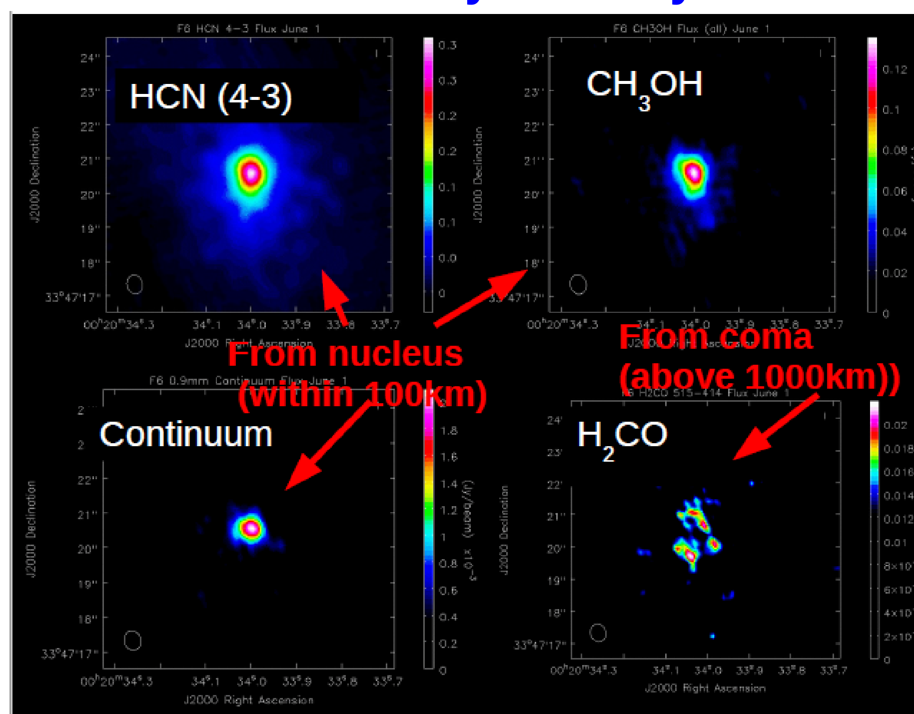
Comets & small bodies



Observing **small bodies** will allow to **image their surfaces**, determine their sizes and orbits.
At 3AU a 10km asteroid has flux $1/\lambda^2$ mJy

Comets come back as remnants of the Planet formation era. Comets preserve the material left from the protoplanetary Solar nebula.
Cometary ices aggregated at the time the Solar System formed (c. 4.5 Gyr ago), and have remained in a frozen, relatively quiescent state ever since
Their composition and structure may provide information about the physical and chemical conditions in the Early Solar System.

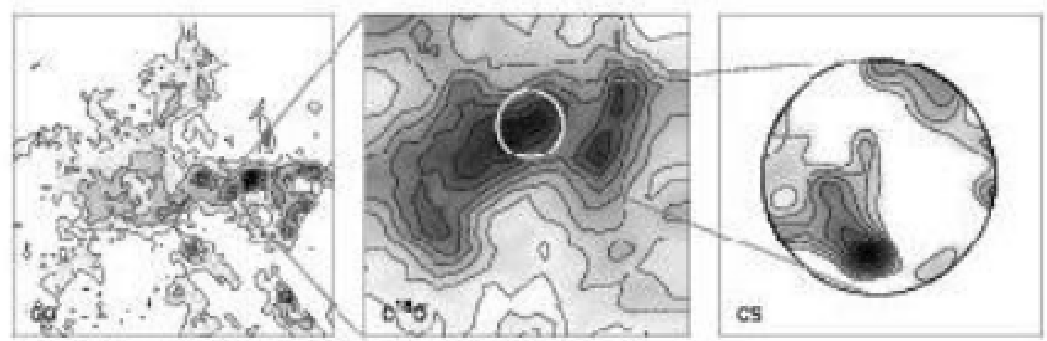
Getting closer to the Sun, dust and ice grains are released. mm observations can unveil the nuclear mechanisms, composition and evolution as function of distance from Sun. Spectroscopy reveals the composition of comae, and the dynamics of the emission. Typical lines are molecules of H, C, N, O, including prebiotic moleculae



Cordiner et al. 2014 -Cy1
Comet Lemmon

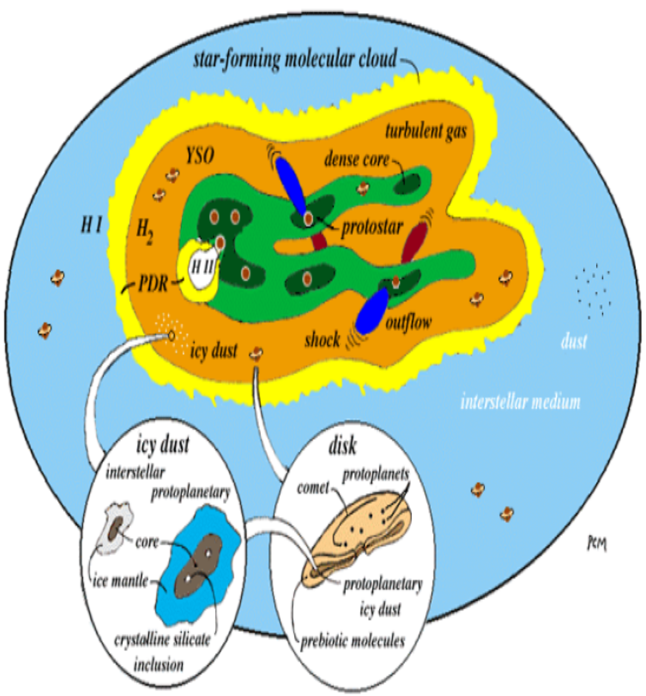
ISM structure and chemical enrichment

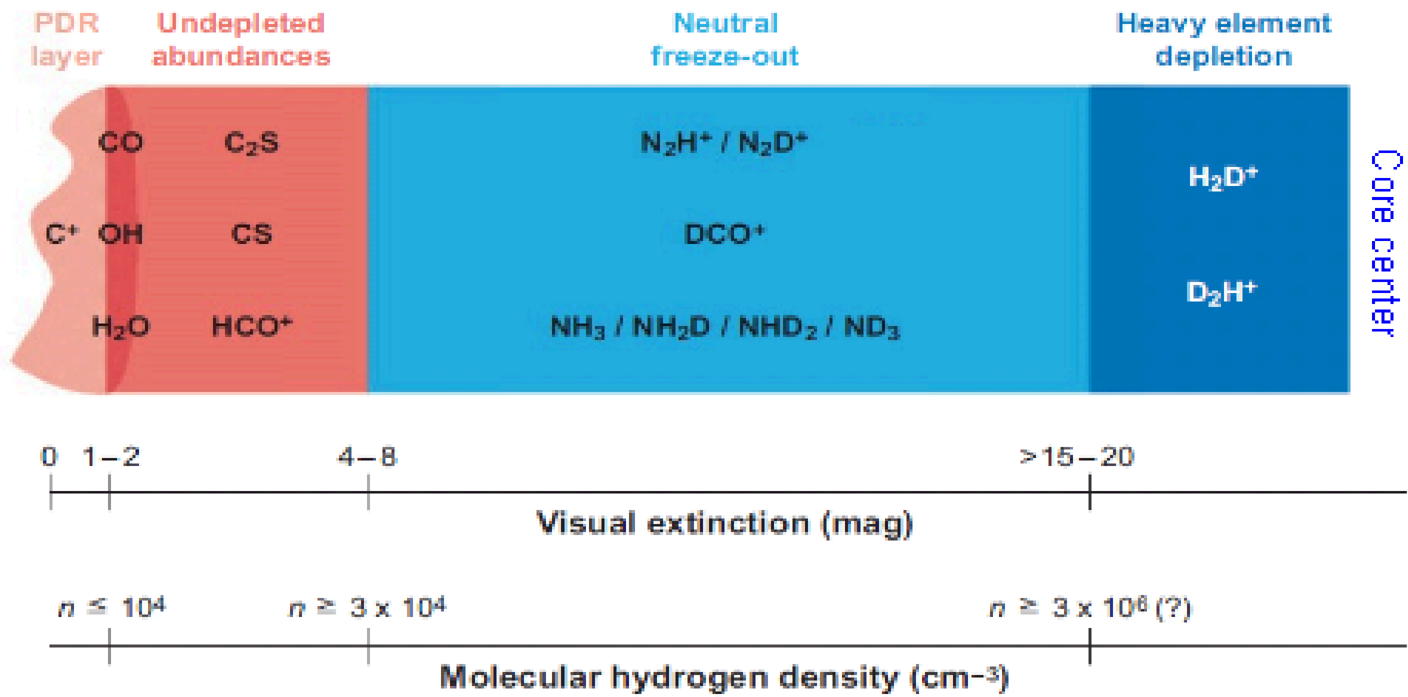
The ISM is constituted by 90% of H,
9% of He, and traces of other components
80% of H2 is in molecular clouds,
peaking in the Galactic center.



Molecular clouds are highly structured complexes made of clumps (where clusters can form) and cores (where a single or binary star form).

	Clouds[a]	Clumps[b]	Cores[c]
Mass ($M_\odot$)	$10^3 - 10^4$	50–500	0.5–5
Size (pc)	2–15	0.3–3	0.03–0.2
Mean density (cm^{-3})	50–500	10^3–10^4	10^4–10^5





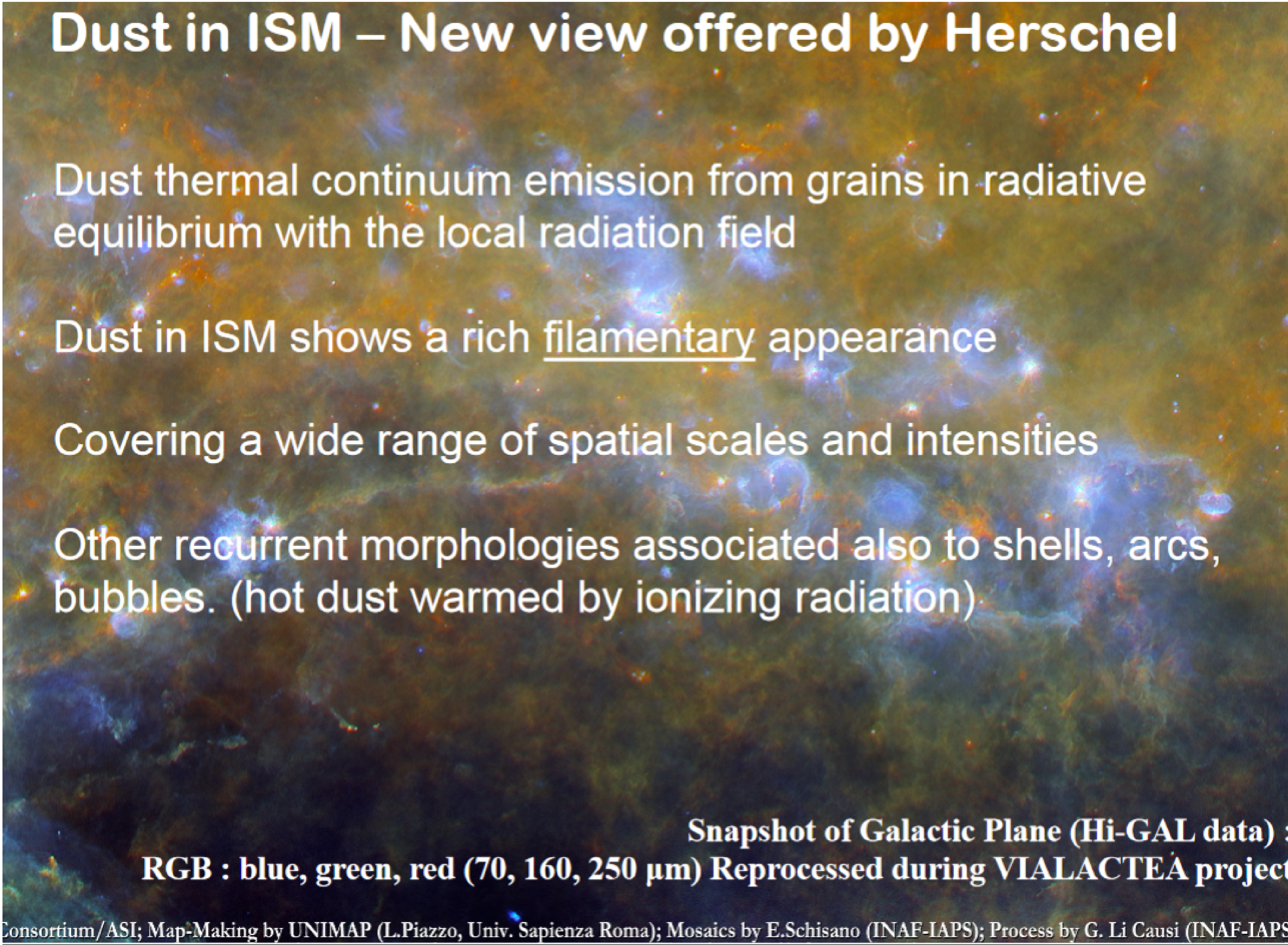
Dust in ISM – New view offered by Herschel

Dust thermal continuum emission from grains in radiative equilibrium with the local radiation field

Dust in ISM shows a rich filamentary appearance

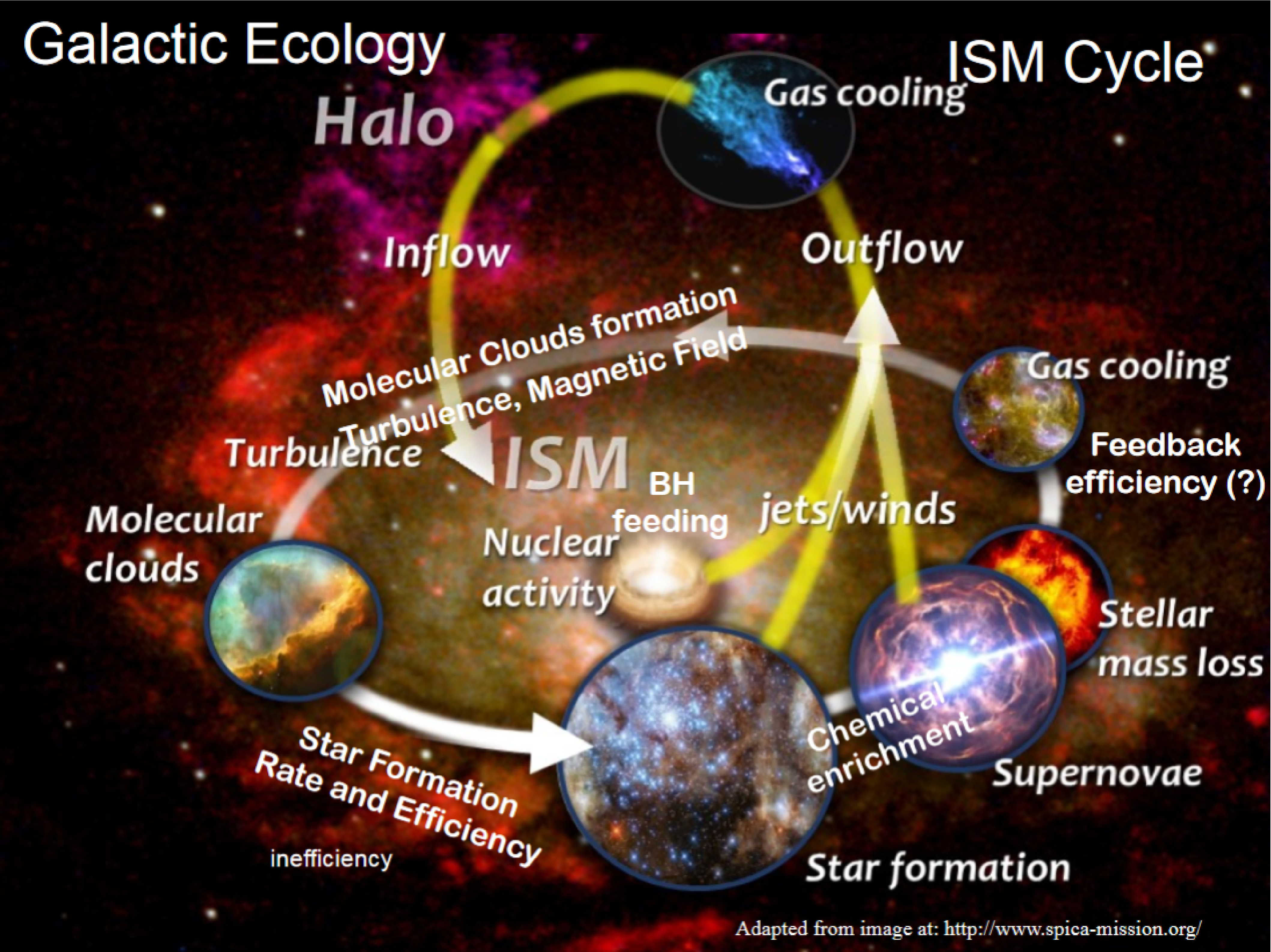
Covering a wide range of spatial scales and intensities

Other recurrent morphologies associated also to shells, arcs, bubbles. (hot dust warmed by ionizing radiation)



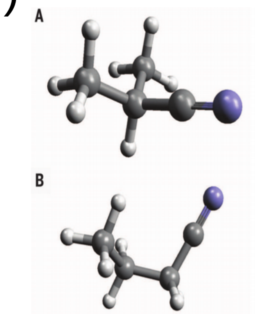
Snapshot of Galactic Plane (Hi-GAL data) :
RGB : blue, green, red (70, 160, 250 μm) Reprocessed during VIALACTEA project

Consortium/ASI; Map-Making by UNIMAP (L.Piazzo, Univ. Sapienza Roma); Mosaics by E.Schisano (INAF-IAPS); Process by G. Li Causi (INAF-IAPS)

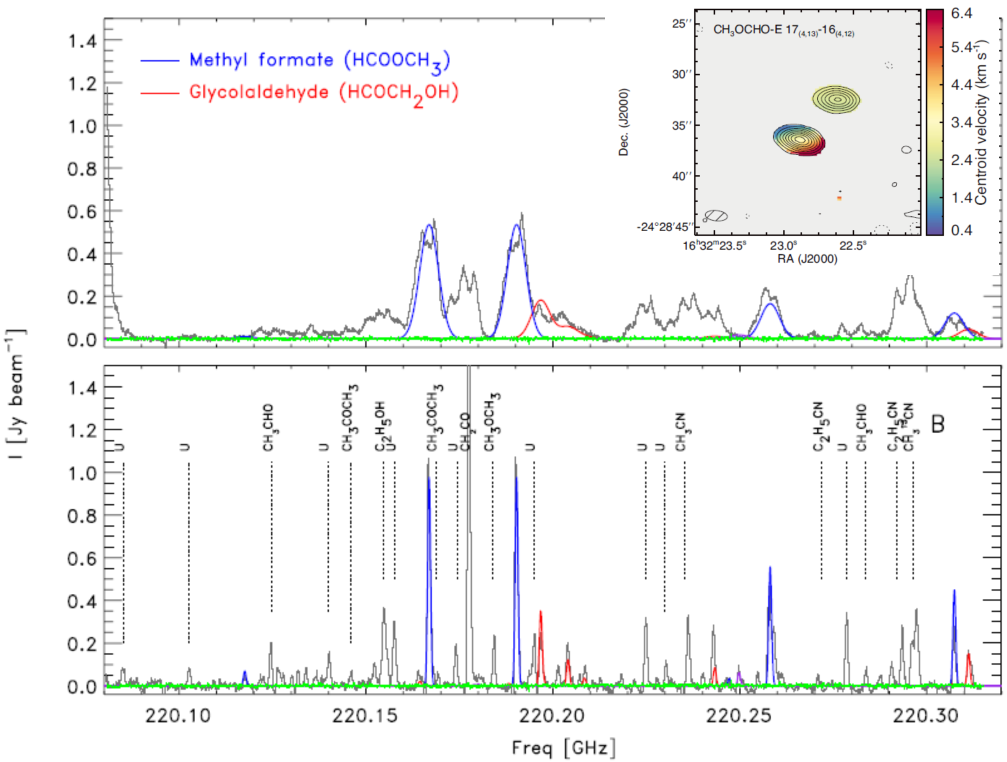

Galactic Ecology
ISM Cycle
Halo
Gas cooling
Inflow
Outflow
Molecular Clouds formation
Turbulence, Magnetic Field
Gas cooling
Feedback
efficiency (?)
Turbulence
ISM
BH
feeding
jets/winds
Molecular
clouds
Nuclear
activity
Stellar
mass loss
Chemical
enrichment
Supernovae
Star Formation
Rate and Efficiency
inefficiency
Star formation
Adapted from image at: http://www.spica-mission.org/

ISM structure and chemical enrichment

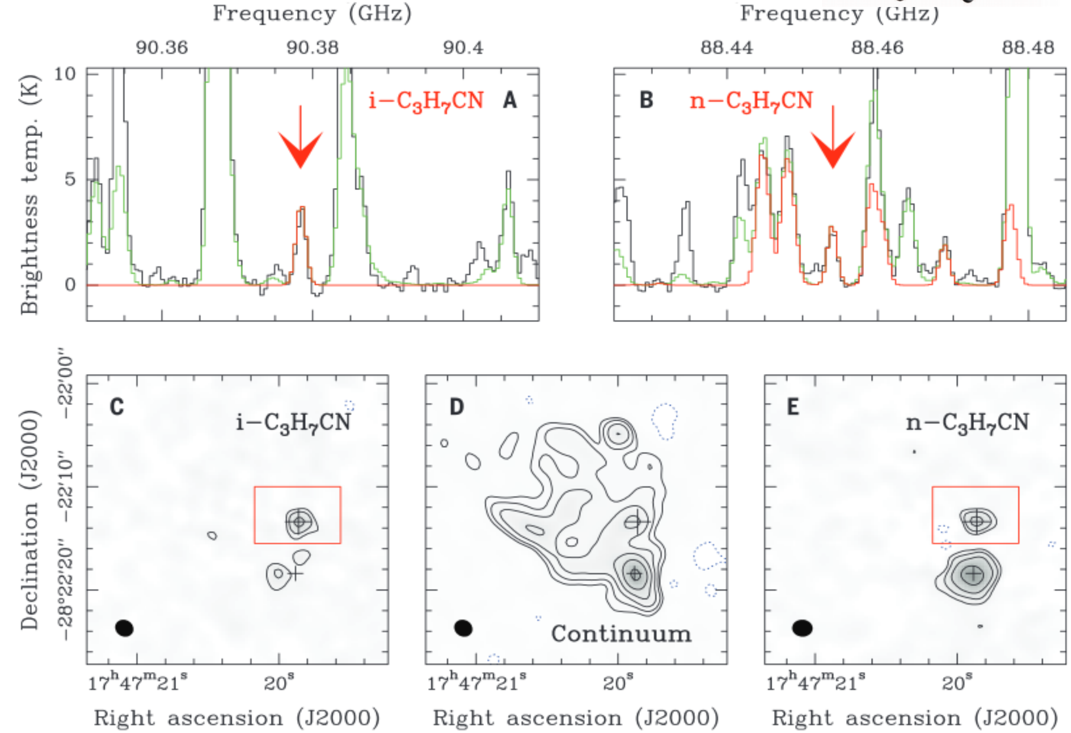
More than 80 amino acids have been identified in meteorites found on Earth.
They are the building blocks of proteins.
This suggests that they or their direct precursors have an inter-stellar origin.
ISM chemistry might be capable of producing organic molecules more complex than those detected so far and thus of great importance to astrobiology.
The chemical complexity of ISM is still an open question (e.g. aminoacids in ISM)



Glicolaldehyde in IRAS16293-2422 proto-binary (Pineda et al. 2012)



Iso-methyl cyanide in a hot core (Belloche et al. 2014)

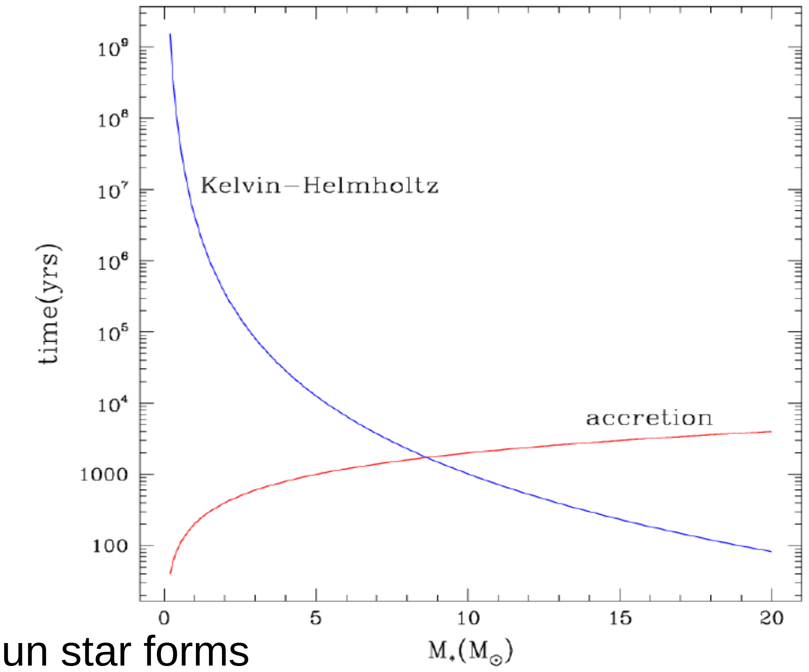


Massive star formation

Accretion on the protostar
Contraction of the protostar

$t_{acc} = M_* / (dM_{acc}/dt)$

$t_{KH} = GM^2/R_* L_*$



For $M_* < 8M_{sun}$ $t_{acc} < t_{KH}$
For $M_* > 8M_{sun}$ $t_{acc} > t_{KH}$
Hence massive stars enter MS while still accreting.

However they are crucial for ISM enrichment
(via winds and supernovae explosions)
and UV radiation.

High-mass stars are **rare**
- For each 1000 stars of 1 Msun, only a single 10 Msun star forms
- The nearest star with M > 10 Msun is at d ~ 400 pc

High-mass stars **evolve fast**
- The most massive stars go supernova in 3 Myr
- Fast evolution means there are only very few objects in each phase!

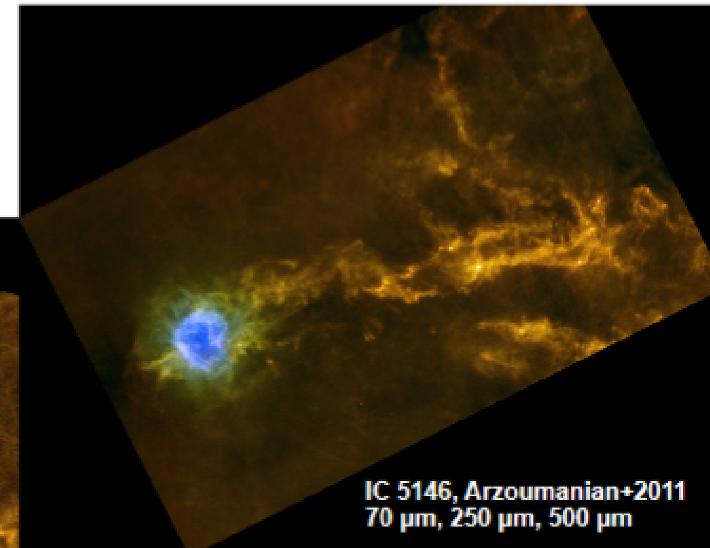
=> Observing each stage of evolution is difficult (resolution, distance, time...)

High-mass stars are frequently **obscured** or in dense clusters
- Need high-resolution observations to disentangle dense cluster cores
- Need deep infrared observations to penetrate the dust

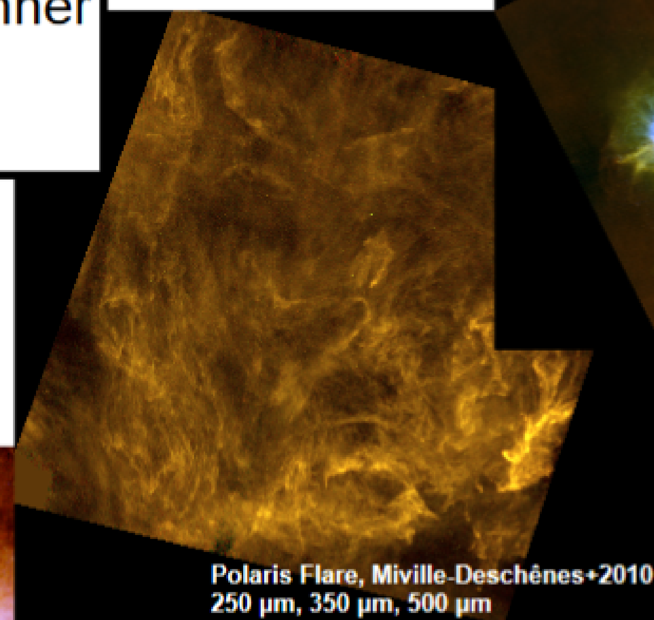
Herschel view of galaxy formation

e.g. Ward-Thompson+2010, Konyves+2015, Schisano+2014/2019, Arzoumanian+2019

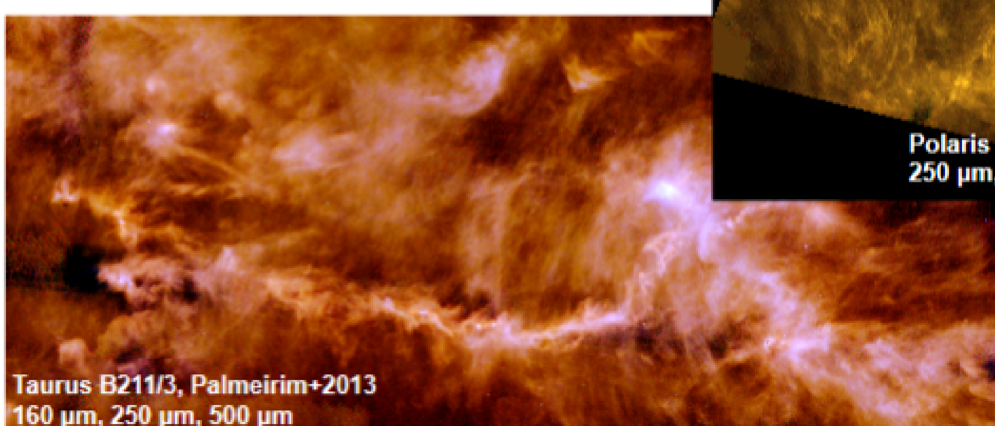
- *Herschel* revealed a “universal” filamentary structure in the cold ISM
- filaments are ubiquitous (~60 object per square degree in the inner Galaxy)
- filaments exist prior to SF



IC 5146, Arzoumanian+2011
70 μm, 250 μm, 500 μm



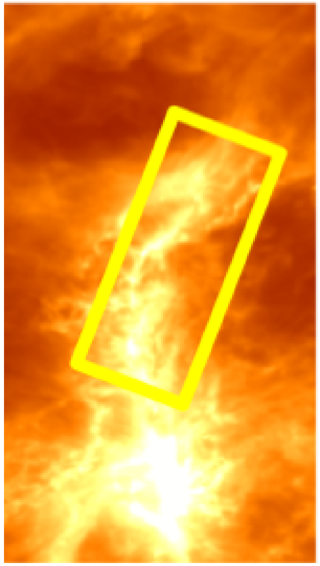
Polaris Flare, Miville-Deschênes+2010
250 μm, 350 μm, 500 μm

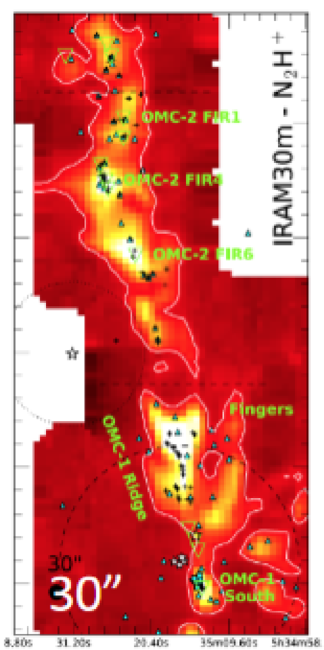


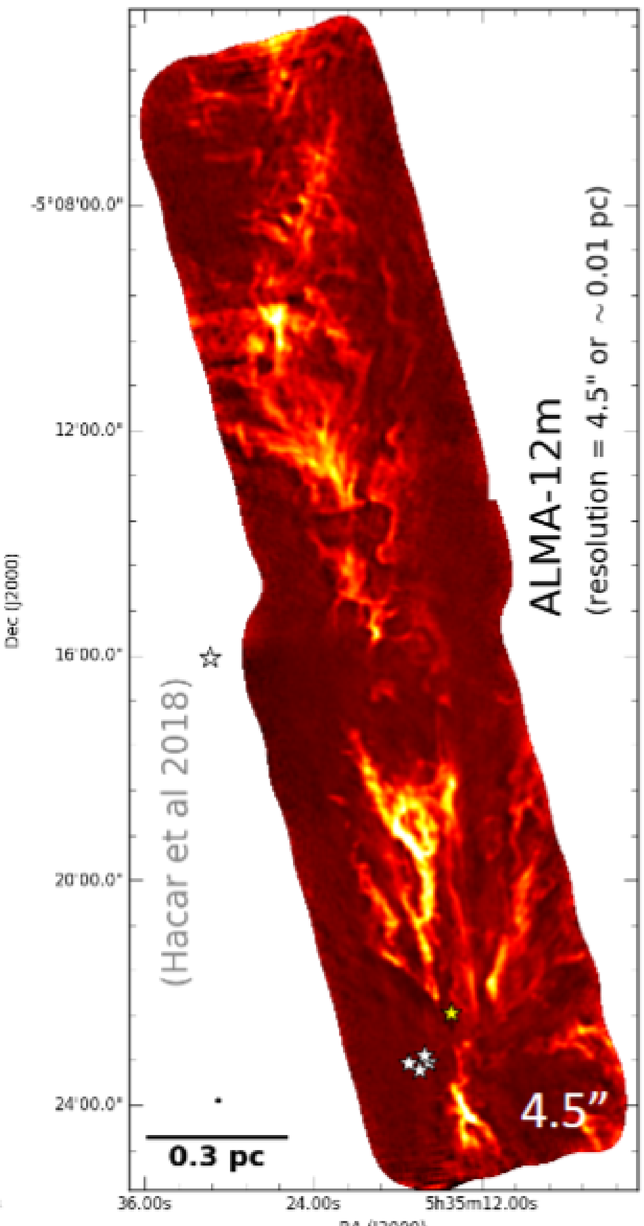
Taurus B211/3, Palmeirim+2013
160 μm, 250 μm, 500 μm

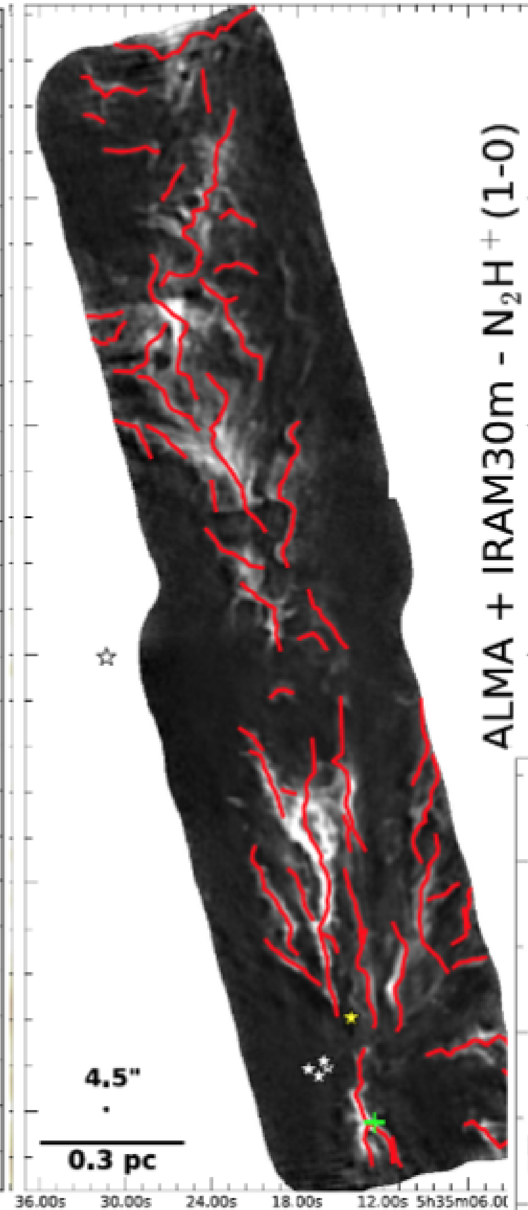
Filament Substructures

Northern region of Integral Shape Filament









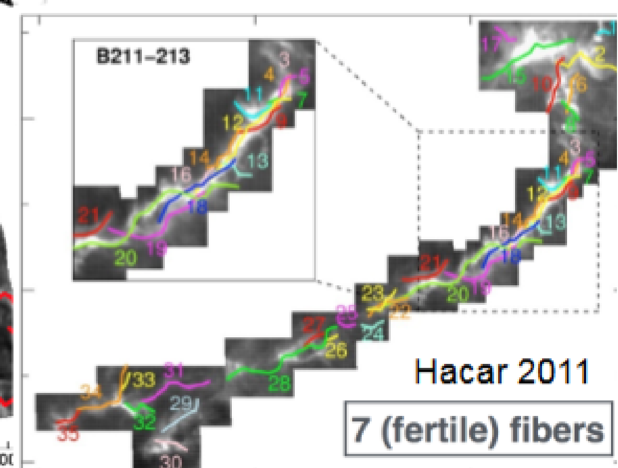
Hacar et al 2018

Monolithic structure in dust continuum reveal a very complex substructure

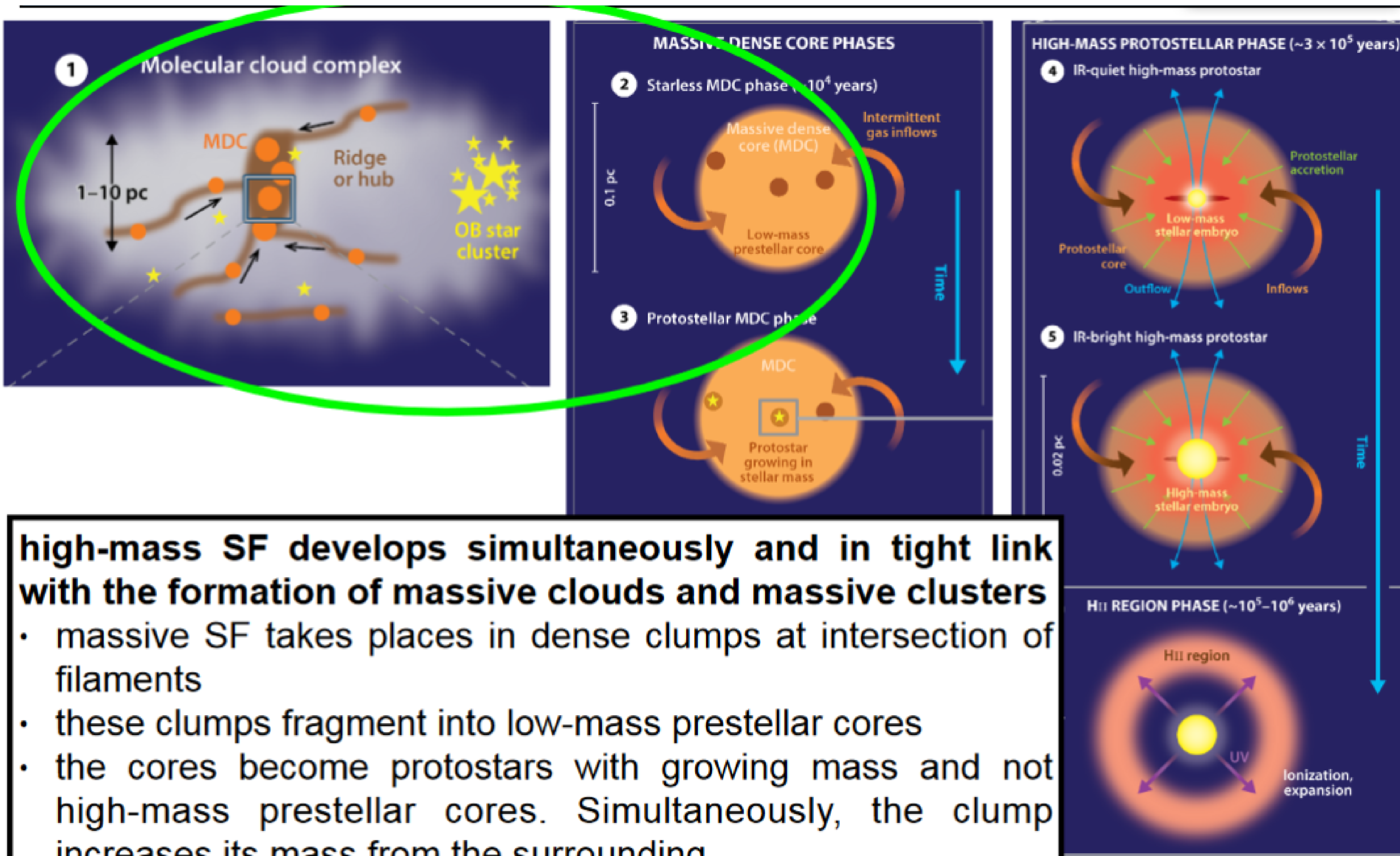
Large number of subfilaments - Fibers

~55 fibers hosting most of the detected cores

#Orion >> #Taurs



Massive star formation



high-mass SF develops simultaneously and in tight link with the formation of massive clouds and massive clusters

- massive SF takes places in dense clumps at intersection of filaments
- these clumps fragment into low-mass prestellar cores
- the cores become protostars with growing mass and not high-mass prestellar cores. Simultaneously, the clump increases its mass from the surrounding

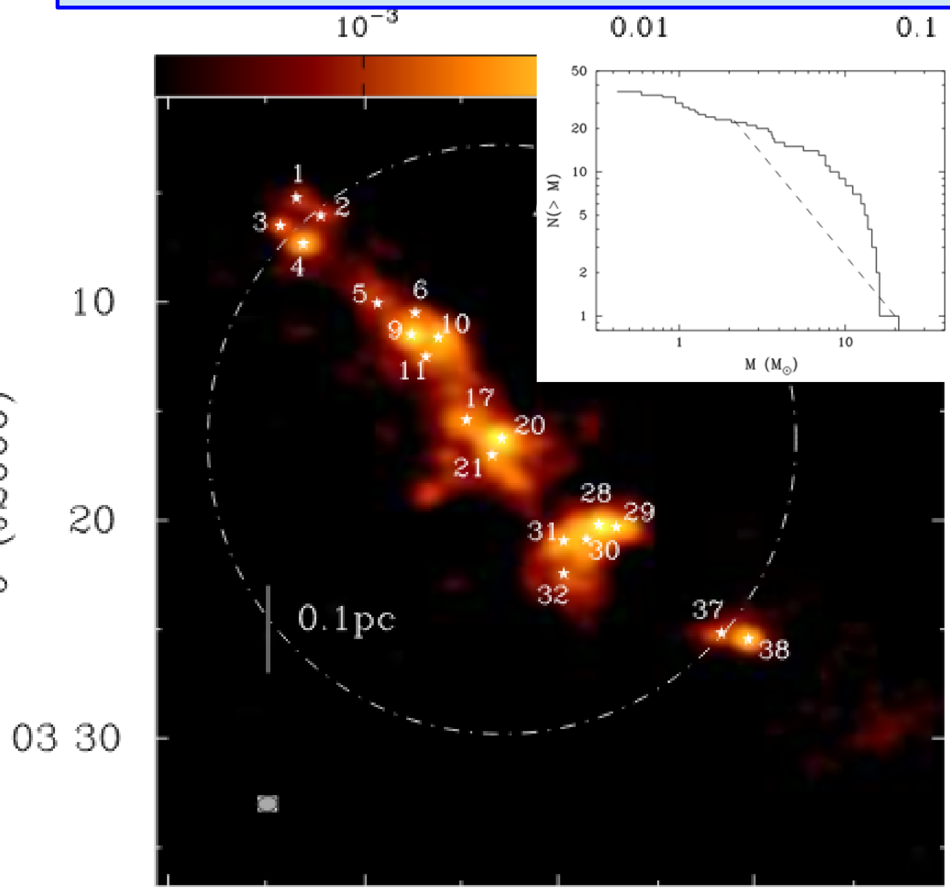
Motte+2018

Massive star formation

The earliest stages of star formation should be bound prestellar cores of which the mass can be measured via thermal dust emission.
High angular resolution can measure the dust fragments down to subsolar masses.

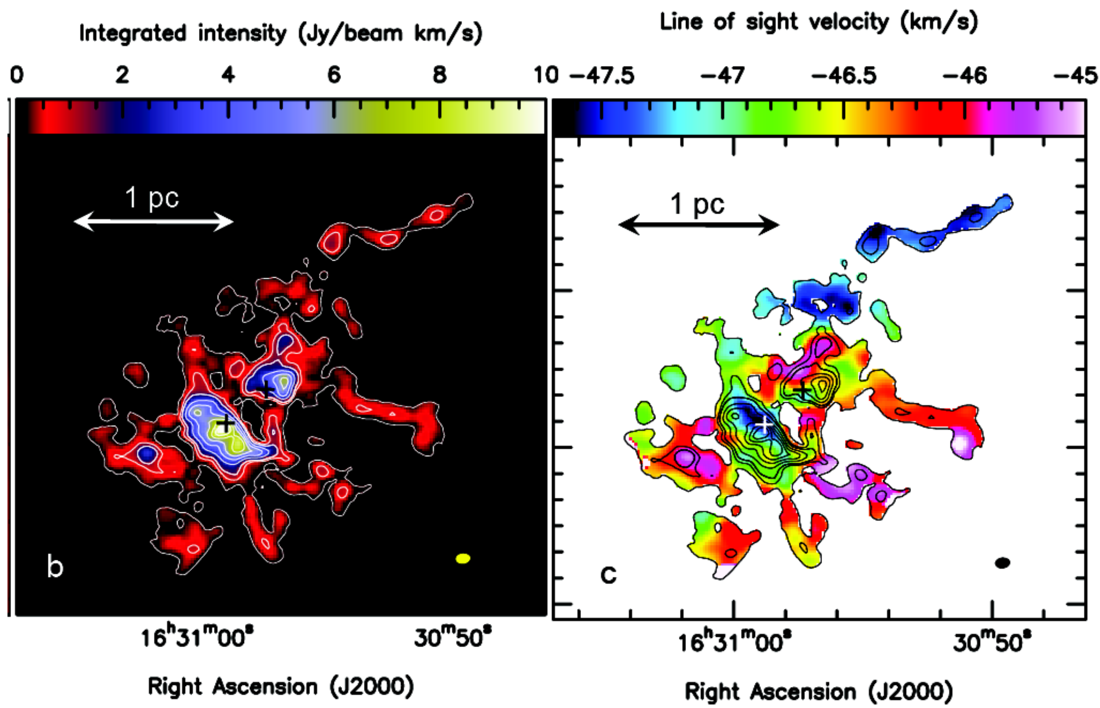
Fragmentation in G28.34 IR dark cloud
Arbouring massive star formation
(Zhang et al. 2015)

- Cycle 0 – 29 antennas
- Band 6
- **Angular resolution ~ 0.8''**



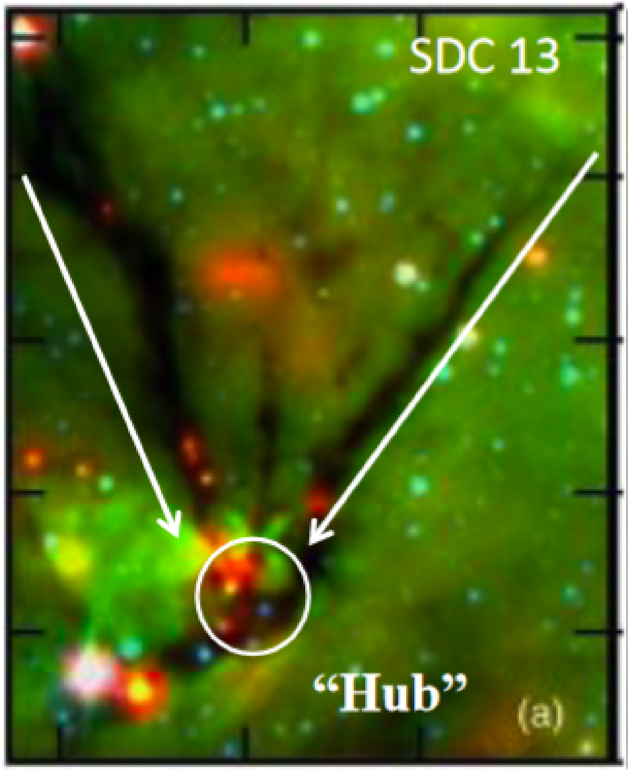
Network of cold, dense, pc-long filaments in SDC335: a global collapse along filaments (Peretto et al. 2013)

- 3mm continuum, CH_3OH(13-12), N_2H^+(1-0)
- 16 antennas, 11 mosaic points
- Beam = 5.6'' x 4.0''
- Vel. Resolution = 0.1 km/s
- Continuum rms 0.40 mJy/beam
- Line rms 14 mJy/beam

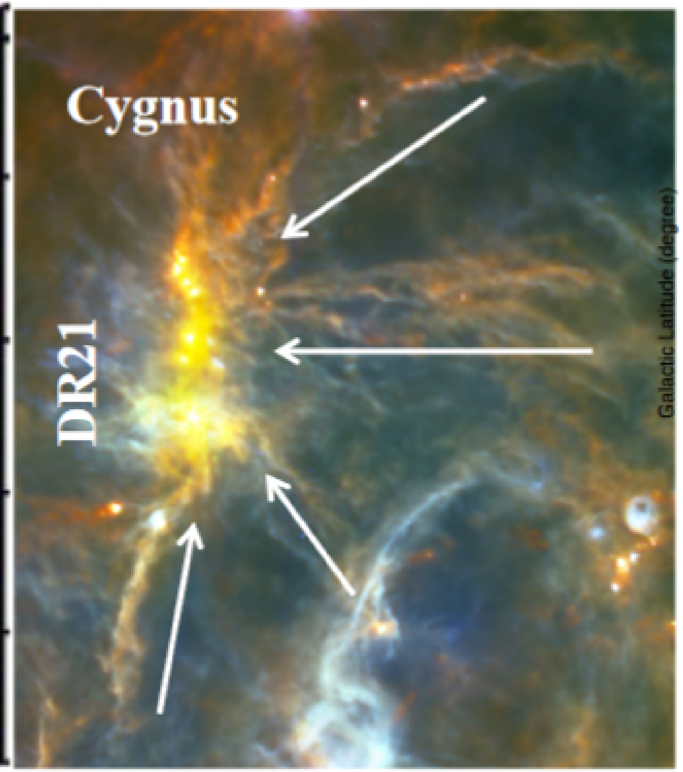


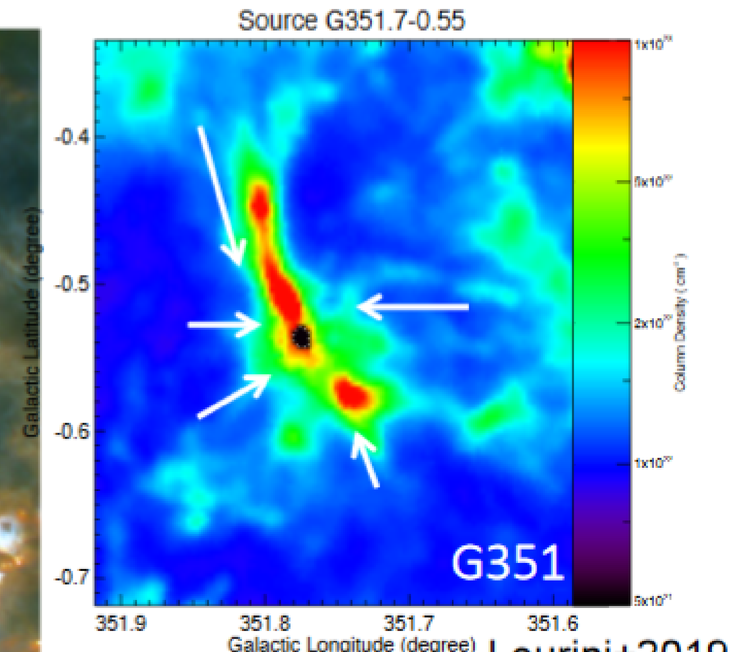
Hub-filaments systems / subfilament network

Peretto+ 2013, Williams, 2017



Schneider+ 2010





Leurini+2019

Observed with ALMA
PI Leurini 2015.1.00601

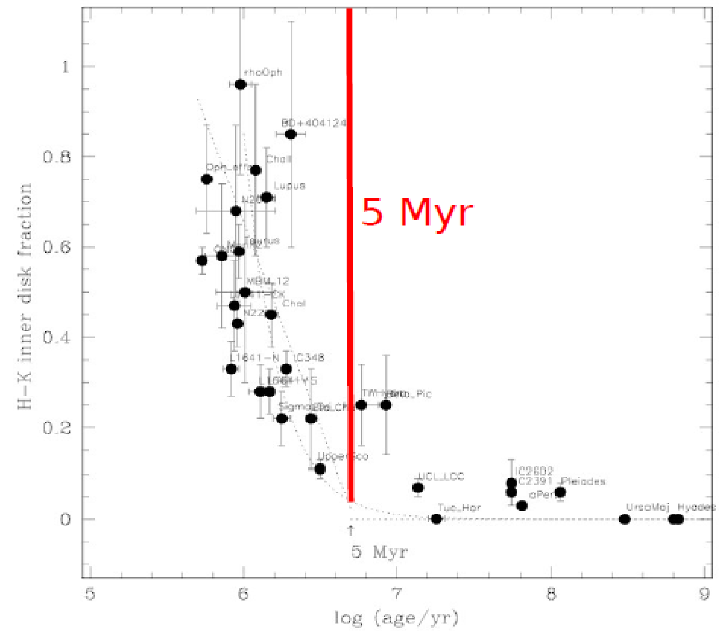
Intersecting filaments are the preferential enviroment for massive star and cluster formation

Likely to collapse on pc scales gathering matter at their centre.

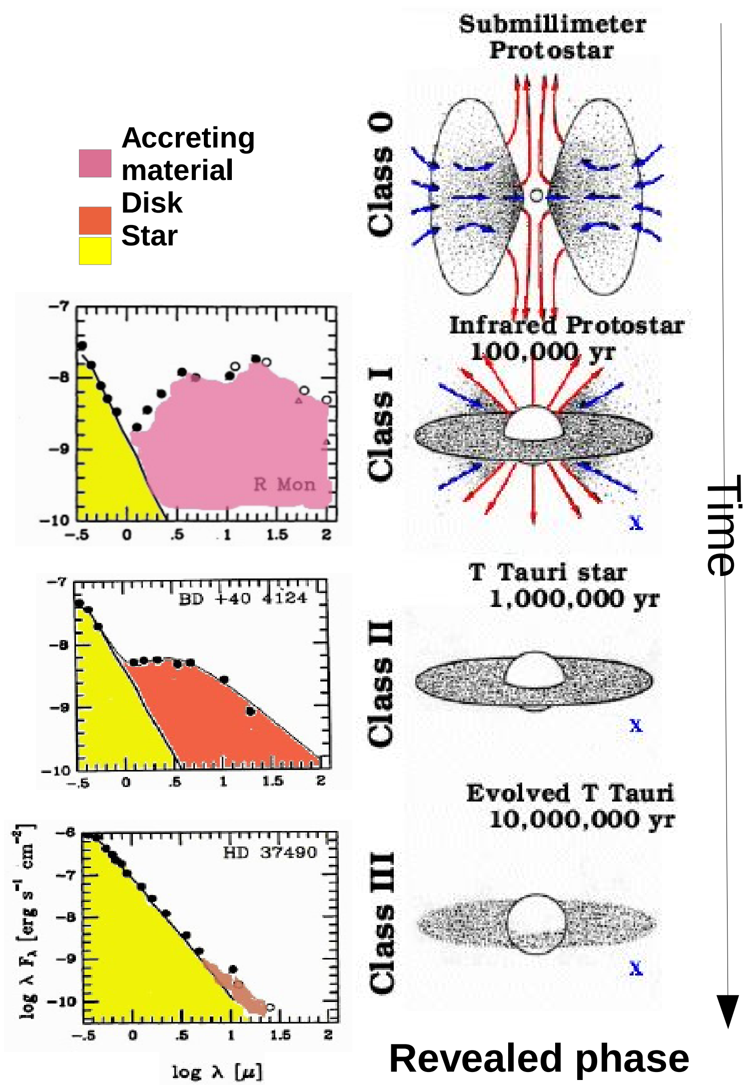
Disks everywhere!

Massive star loose disk more rapidly than low-mass star of same age.
For star masses 0.04<M<10Msun the disk is typically 1% of the star mass.

(Hillebrand et al. 2005)



For O-type star no disk were detected (before ALMA) in submm indicating very short disk life or a different formation scenario.



Observables

Dusty environment
Infall
Outflows

Disk
Outflows
Infall

Disk without accretion

Protoplanetary disk

NOTES on SCALES

Jeans scale 10000 AU
Planet formation 1-10 AU
Outflows < 10AU
Protostellar disk = 100 AU
PDR (HII regions) 1000 AU
Nearest Ttauri star 50 pc
Lowmass SF sites 150 pc
High mass SF sites 500 pc

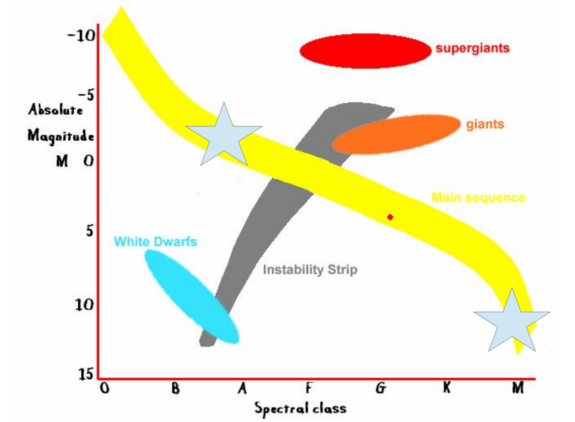
10 AU @ 100 pc -> 0.1arcsec

ALMA reaches 20-100 mas @ 200kpc (LMC) -> Jeans scale

Disks everywhere!

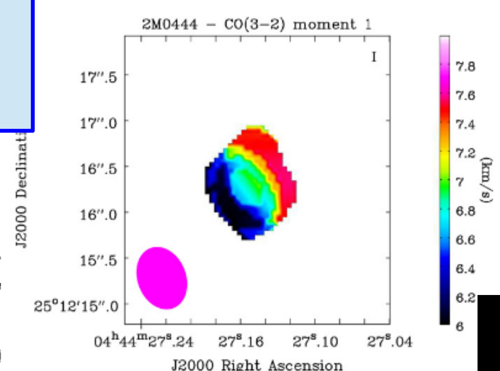
Massive star loose disc more rapidly than low-mass star of same age. For star masses 0.04<M<10Msun the disk is typically 1% of the star mass.

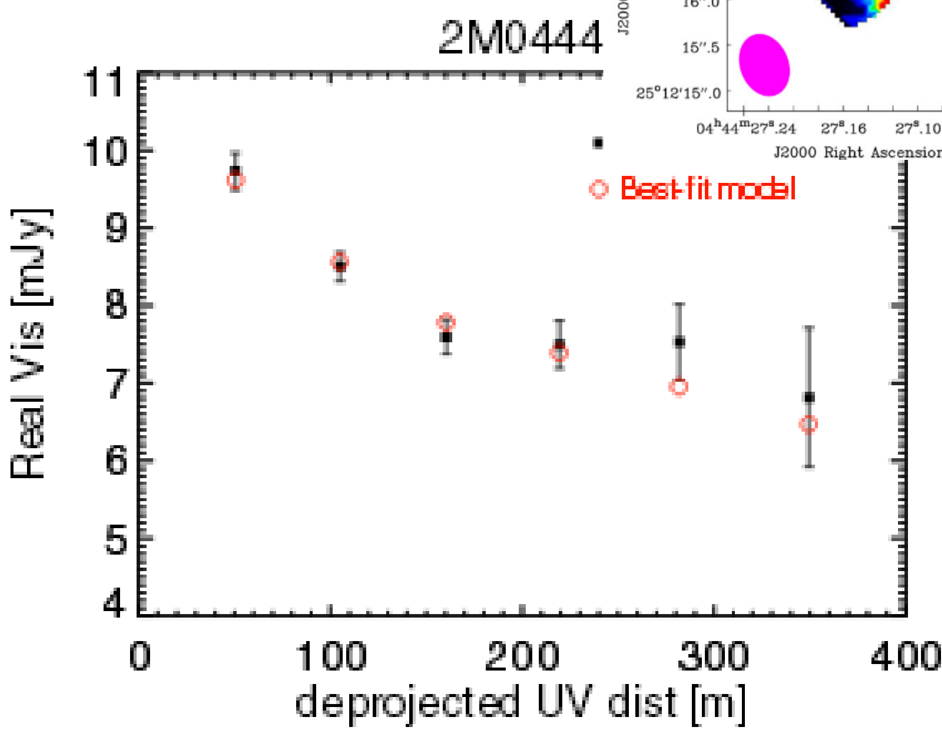
For O-type star no disk were detected (before ALMA) in submm indicating very short disk life or a different formation scenario.



Disk around 3 brown dwarfs (Ricci et al. 2014)

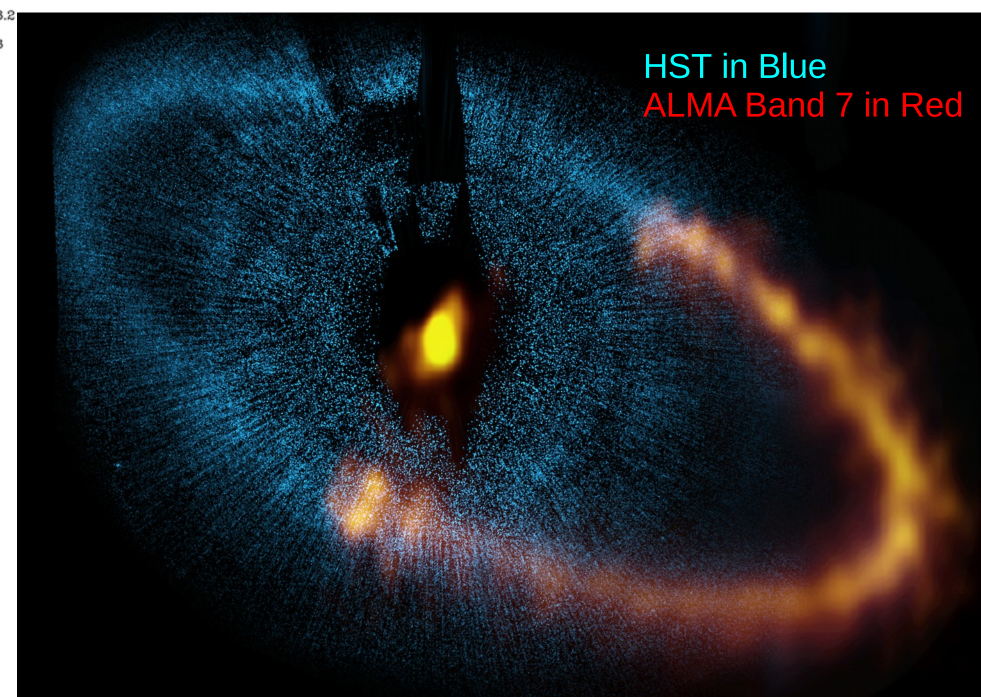
- Cycle 0 – 29 antennas
- Band 6
- **Angular resolution ~ 0.8'**



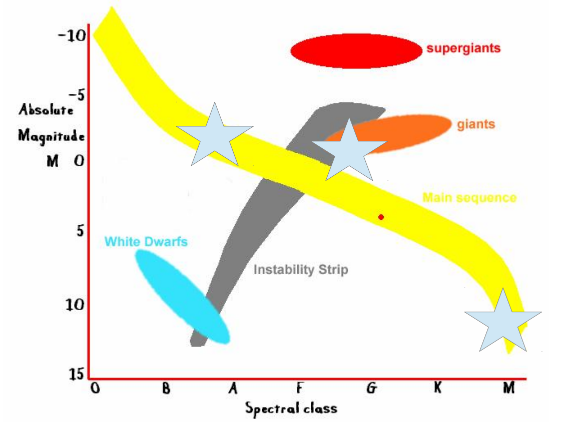


Disk around Fomalhaut A3V (Boley et al. 2012, MacGregor et al. 2017)

- Band 7 – continuum
- 140 min on source
- rms~0.06 mJy/beam
- **Angular resolution ~1.5''**



Disks everywhere!

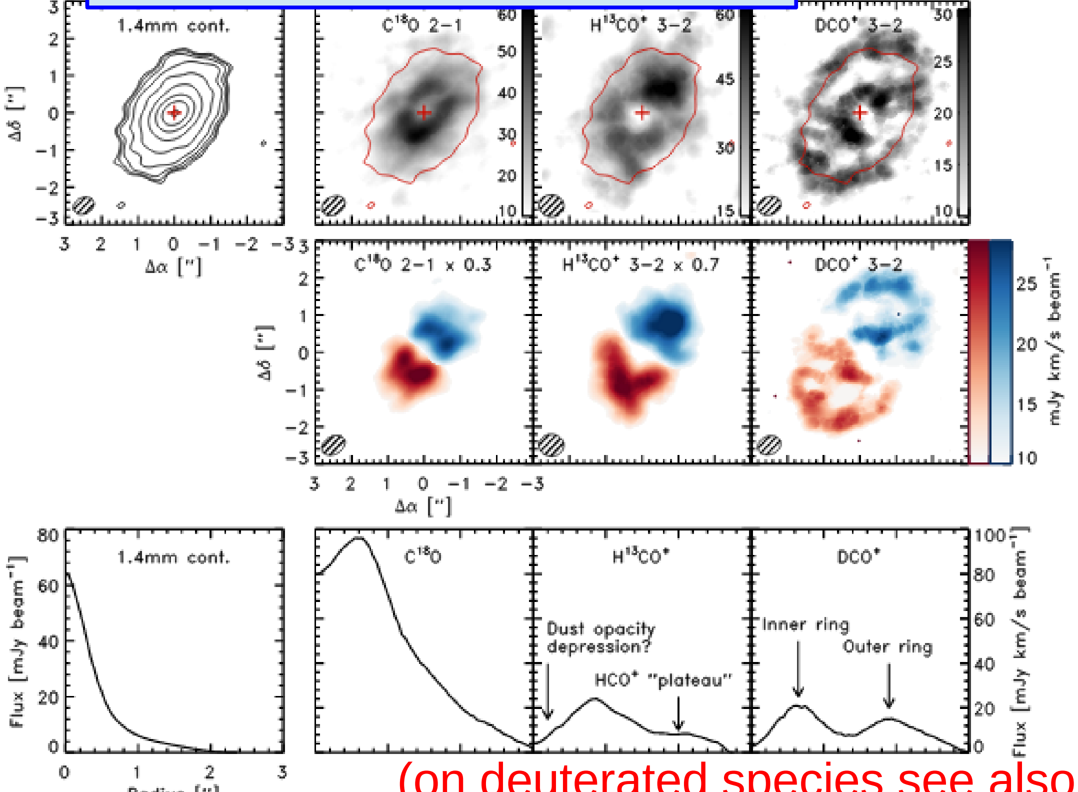


Massive star loose disk more rapidly than low-mass star of same age.
For star masses 0.04<M<10Msun the disk is typically 1% of the star mass.

For O-type star no disk were detected (before ALMA) in submm indicating very short disk life or a different formation scenario.

IM-Lup:T-Tauri disk (Oeberg et al. 2015)

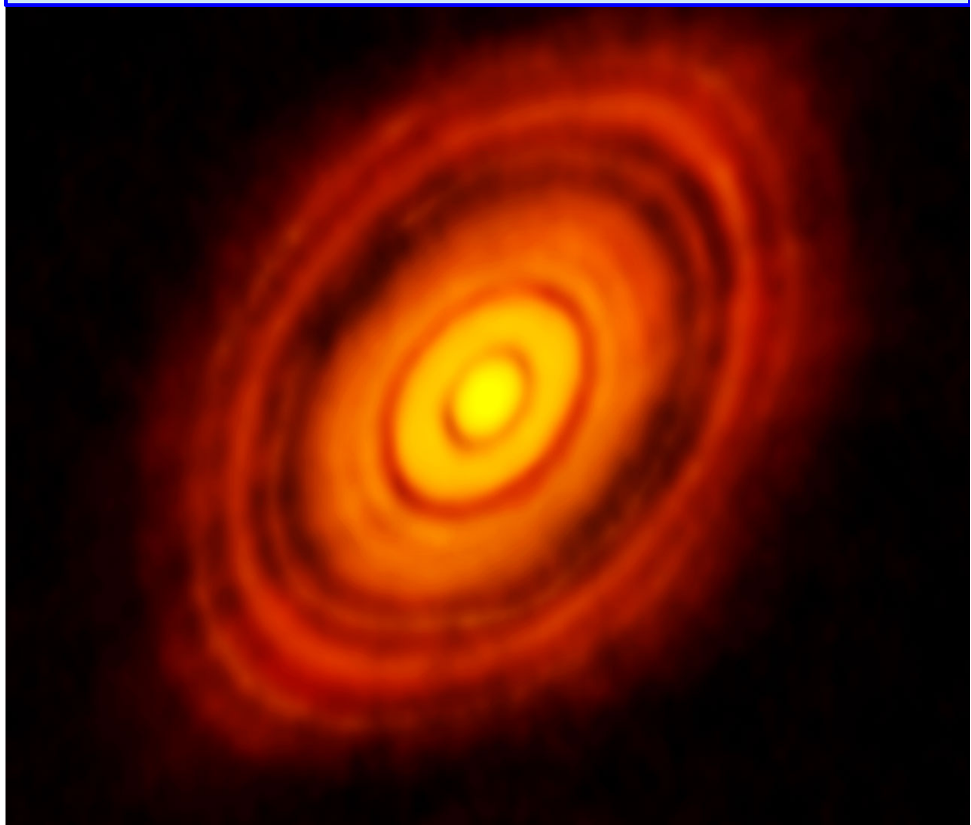
- Cycle 1 – 32 antennas
- Band 6
- **Angular resolution ~ 0.6''**



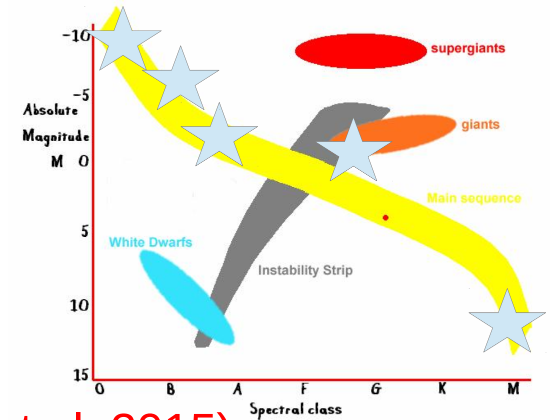
(on deuterated species see also Huang et al. 2017, Salinas et al. 2017)

HL-Tau: young T-Tau star (ALMA Partnership 2015)

- Long Baseline Campaign SV
- Band 3, 6,7 – continuum
- **Angular resolution ~ 85 x 61 mas, 35 x 22 mas, and 30 x 19 mas**



Disks everywhere!



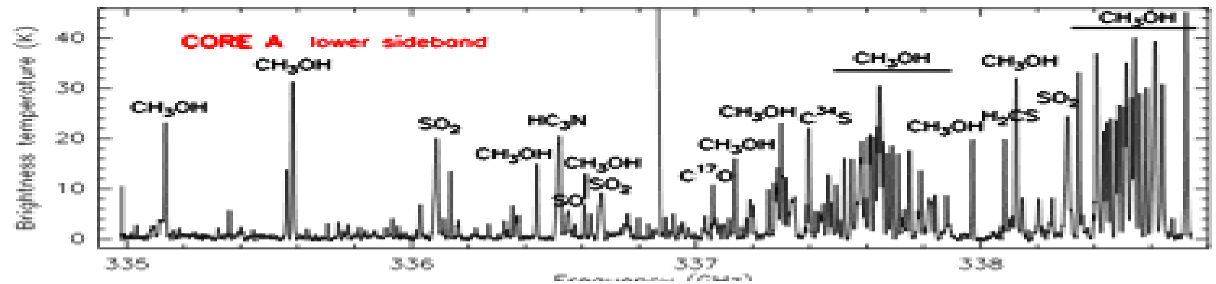
Massive star loose disk more rapidly than low-mass star of same age.
For star masses 0.04<M<10Msun the disk is typically 1% of the star mass.

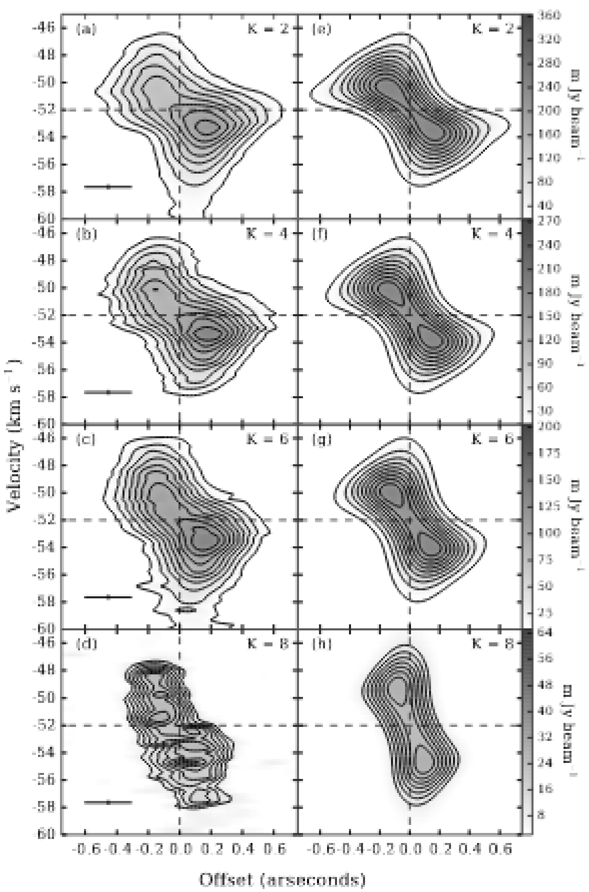
For O-type star no disk were detected (before ALMA) in submm indicating very short disk life or a different formation scenario.

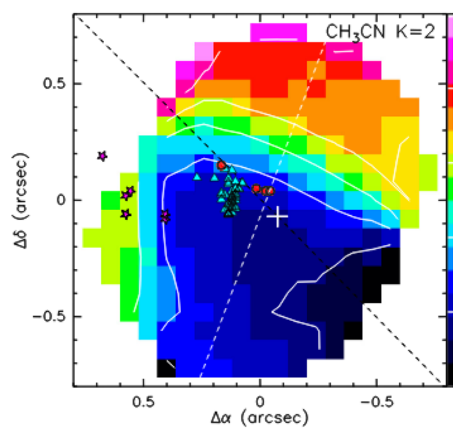
Disk around O star (Johnston et al. 2015
Cesaroni et al. 2017`

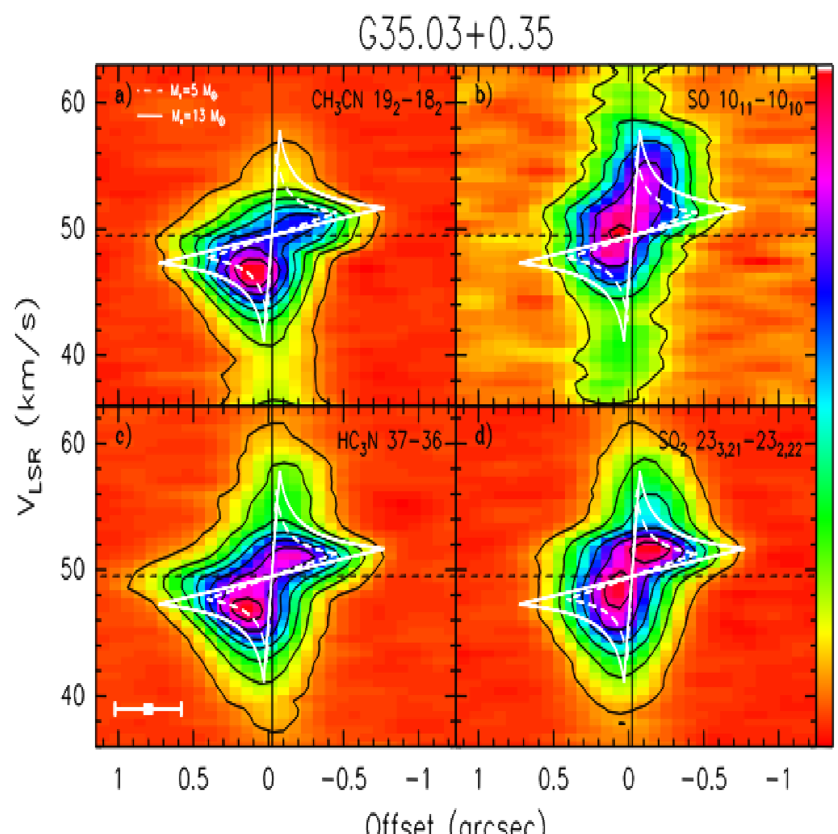
Disk around B star (Beltran et al. 2015)

- Cycle 1 – 29 antennas
- Band 6
- **Angular resolution ~ 0.3"**



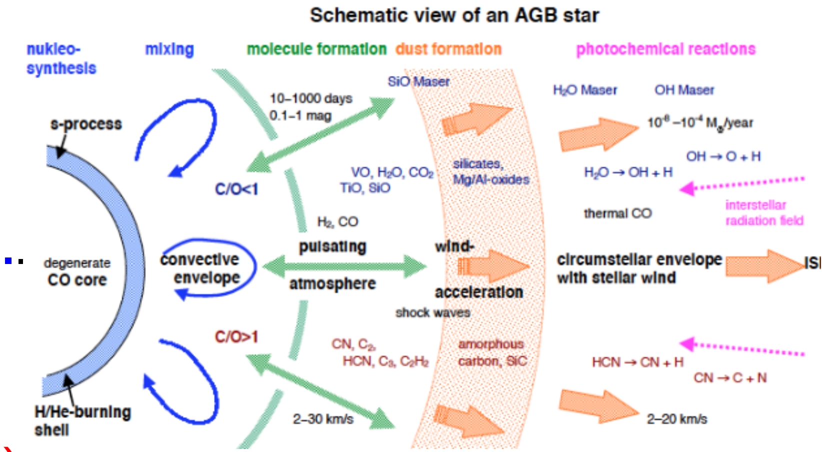




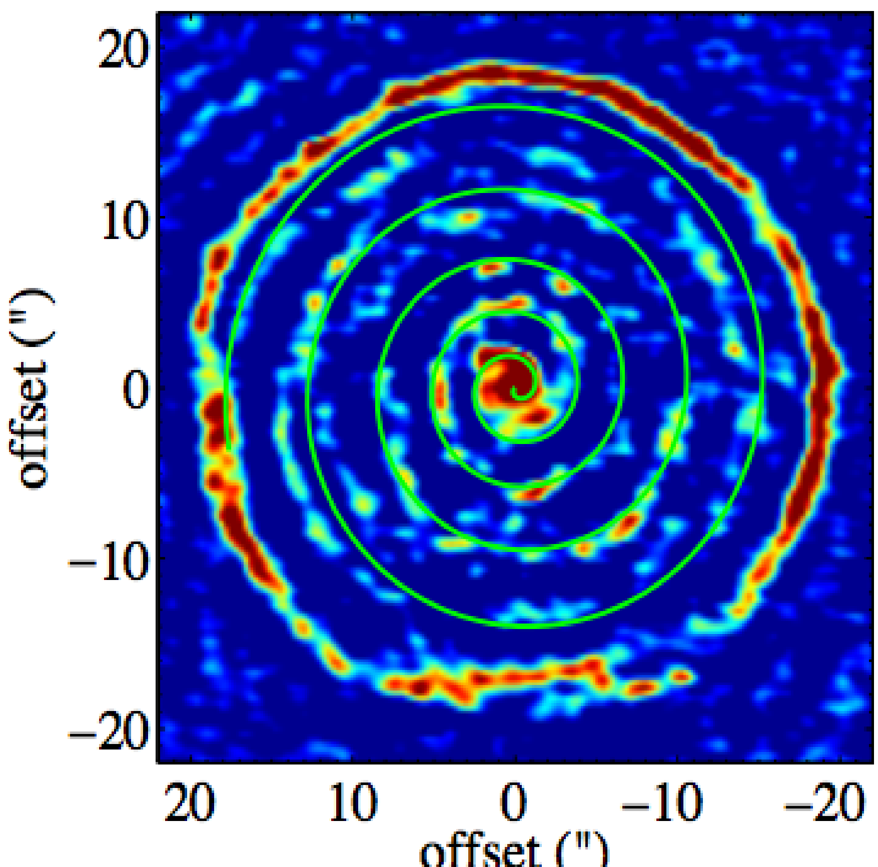


AGB stars

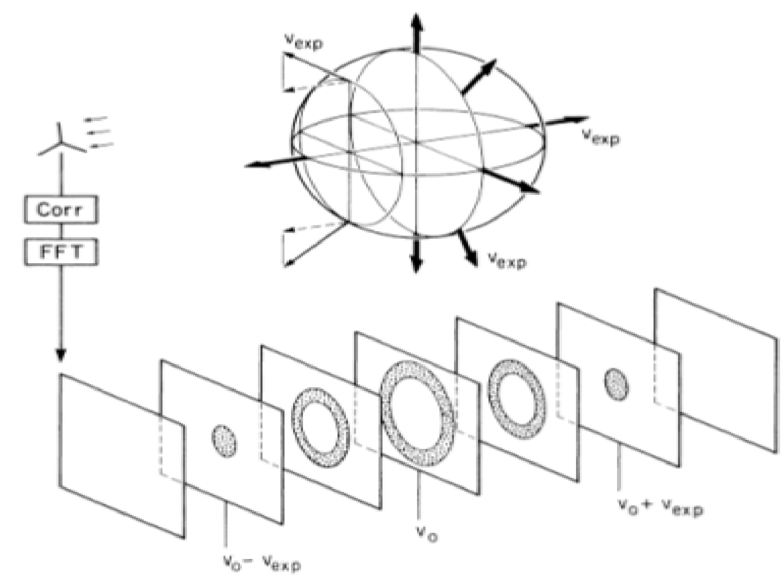
AGB stars (last stages of 0.6-10 Msun stars) are typically long-period variables, and suffer mass loss in the form of a stellar wind.
Thermal pulses produce periods of even higher mass loss and may result in detached shells of circumstellar material..
For an envelope expanding with constant velocity the iso-velocity curves are circles



R-Sculptoris (Maercker et al. 2012, Vlemmings et al. 2013)



video



- ~15 antennas, ~4 hrs
- Band 7: CO(3-2),
- **resolution = 1.3"**
- 45 pointed mosaics (50" x 50" field)

General words & ALMA pros

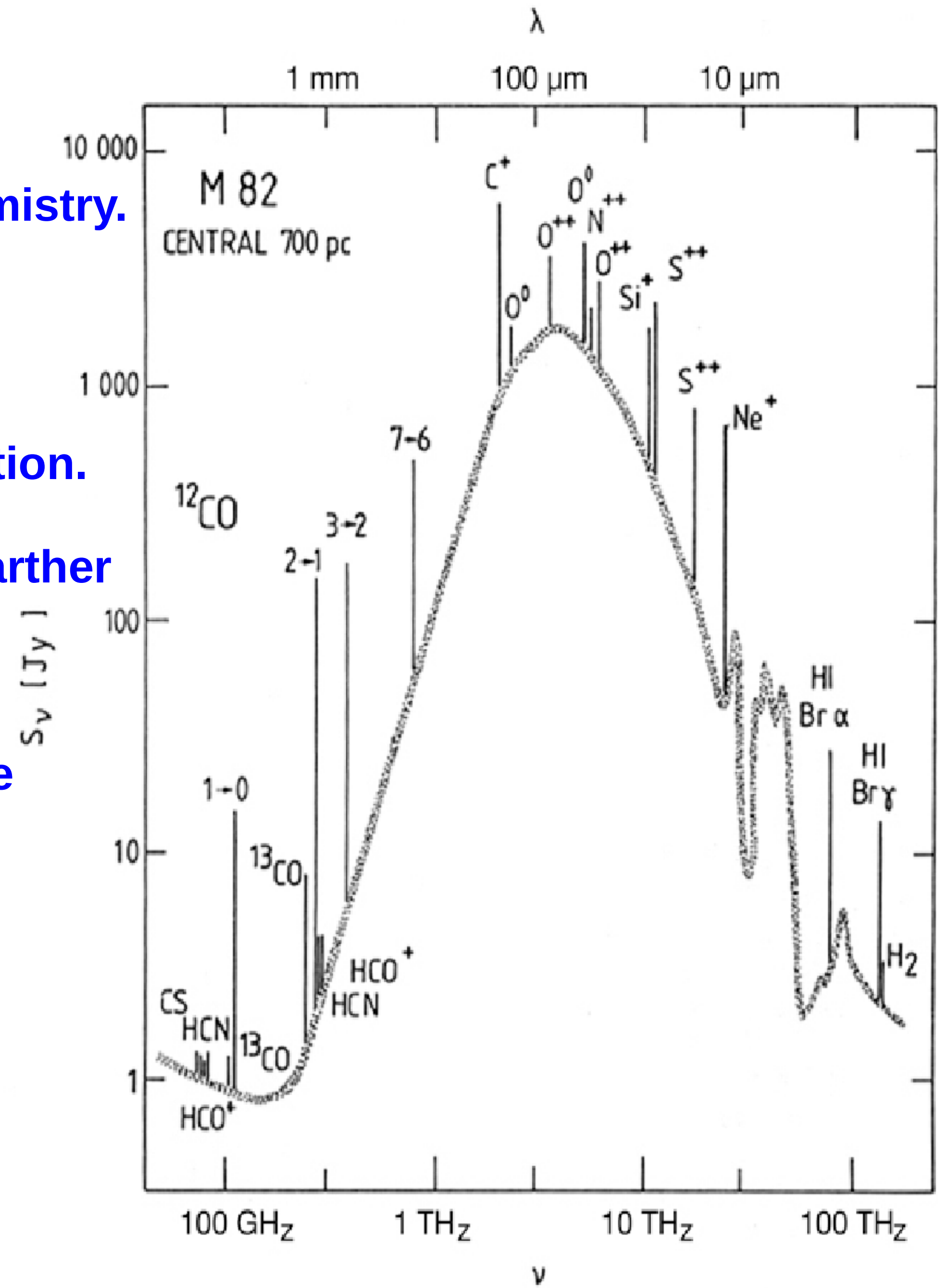
Sub(mm) is characterized by dust and rich chemistry.

Dust and moleculae are mostly (but not only) associated with forming structures.

Hence **sub(mm) helps studying structure formation.**

Higher resolution and sensitivity allows to go farther so to investigate a deeper sky region, getting more sources and more statistics on populations.

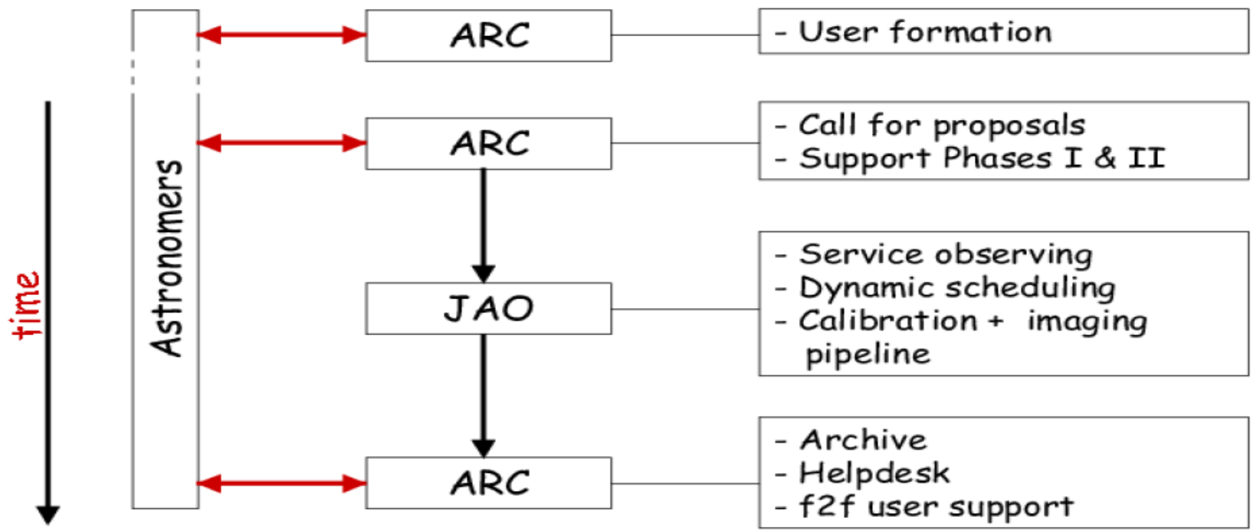
Higher spectral resolution allows to detect more narrow lines and more details from broad lines, and hence investigate chemical compositions, source dynamics and pressure and temperature structures.



Tips to write a proposal

A project lifetime: phase 1 Proposal submission

PI has a good idea!	
PI estimates feasibility	Simulations are not compulsory (Sensitivity Calculator, OST, CASA)
PI splits project in Science Goals	**Minimum proposed observational unit including targets in the same sky region that roughly share the same calibration and spectral setup**
PI writes the science case in pdf and register to the Science Portal	Max 4 page, font no smaller than 12, all included (<20MB) www.almascience.org
PHASE I – Proposal submission	With the ALMA Observing Tool (OT) A copy of the project with the project ID must be saved and should be used for any resubmission within the deadline
TAC evaluation	**A**=high ranked pass to Cycle 4 if not finished **B**=high ranked but not passed over **C**=maybe filler (depends on time shares and ranking)



The proposal review process

Proposals will be reviewed by an international peer review committee.
The peer review by committee is a group of hopefully well informed peers examines your proposal, ranks it against other proposals, and then allocates resources to the highest ranked proposals.

There will at least one Review Panel for each of the **main themes**:

- Cosmology and the High Redshift Universe
- Galaxies and Galactic Nuclei
- ISM, Star Formation/protoplanetary Disks and their Astrochemistry, Exoplanets
- Stellar Evolution, the Sun and the Solar System

The ranked proposals from the different panels and sub-panels will be merged into a single ranked list in the ALMA Proposal Review Committee (APRC) and assigned a letter grade A through D:

- A the proposal will be carried over to the following cycle if it is not finished
- B the proposal should be finished during the current cycle but will not be carried over to the next cycle.
- C are 'filler' programs observed when no A or B can be scheduled
- D proposals will not be observed.

Now, this process is NOT perfect,
BUT it is NOT a lottery, or fundamentally flawed and/or fixed…..
DO NOT let that idea impact on how you write ..

Everything you can do to give your proposal a broader context, make it easier to read, more enjoyable, more clear, … all will help your chances

What should a proposal look like?

- Should have a good, readable **"Executive Summary"** that sets the research in context, sets out the big issues in a field, says what you will do, and how the results from that will address the big issues.

- Should have a **well set out background** that expands on the context and big questions in the field.

- Should clearly **explain why the observations you propose are critical** for answering those questions

- Should clearly **demonstrate the observations / research is technically feasible**, that the time / resources requested are appropriate

- Should clearly **demonstrate that your team will be able to do the work**, and/or has a track-record for having dome similar work in the past.

- Should include **"only" useful figures**

- **Must be readable and should be pleasurable to read**.

The technical justification

The Technical Justification should fully justify the technical aspects of the requested observations and should address the following aspects:

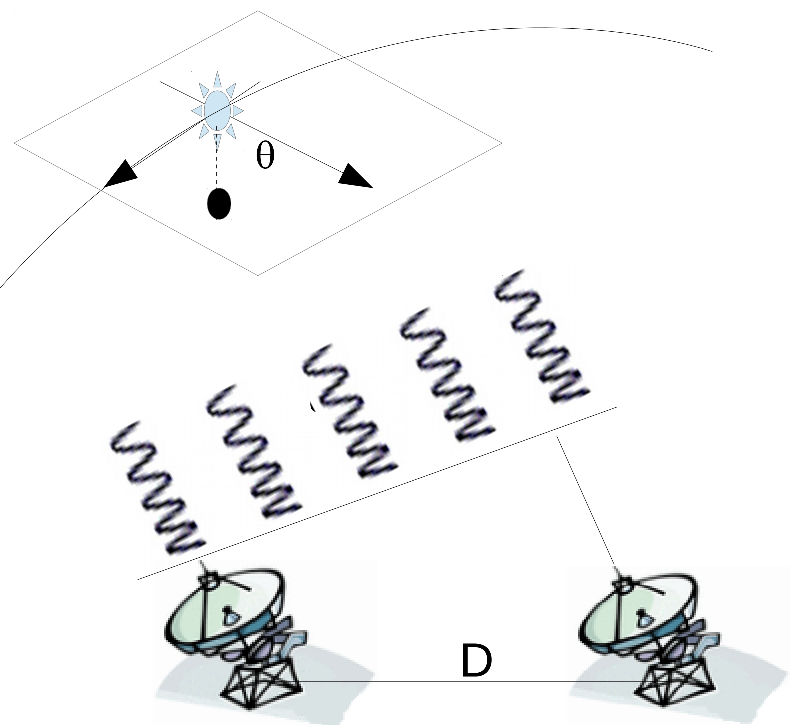
- **sensitivity**
- **angular resolution**
- **largest angular scale**
- **array configuration**
- **correlator setup (spectral windows, frequency, spectral resolution, averaging)**
- **calibration**
- **scheduling/time constraints**
- **special constraints**
- **any non-standard choices**

The technical justification must be very, very clear – say what your assumptions, required S/N, number of pointings etc are, so your reasoning can be reproduced by the technical assesors.

Try to know/understand the telescope or ask to someone who knows it

Angular scales

An interferometer reconstructs an image of the sky at fixed spatial scales corresponding to the projection of the distances among each couple of antennas (=baselines) on a plane centered in the target position.



$$\theta \propto \lambda / D$$

Angular scale ∝ Wavelength/ Physical scale

Field of View	↔	**Antenna Diameter**
Angular Resolution	↔	**Longest Baseline**
Largest Angular Scale	↔	**Shortest Baseline**

Angular scales not sampled by the available couples of antennas are filtered out:
Signal on smaller scales is smoothed,
Signal on larger scale is not collected.

Source Peak Flux Density

In the OT you should indicate the Peak Flux densities and sensitivity at the requested frequency and resolutions.

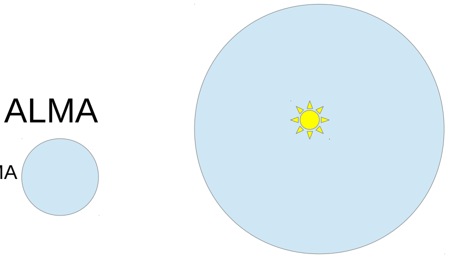
What to do if the literature data you have come from an observation with different resolutions?

1) The source is smaller than the ALMA beam

Flux density in Jy/beam is independent from the beam area

Beam other tel = Ω_{tel}

Beam ALMA = Ω_{ALMA}



$$F_{tel} = 2\,k\,T_{tel}\Omega_{tel} / \lambda^2$$

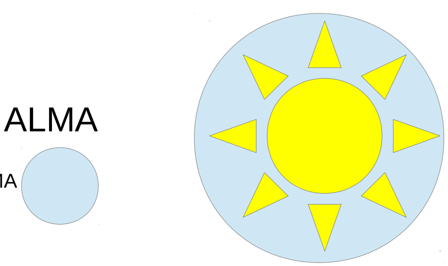
$$F_{ALMA} = F_{tel}$$

2) The source is larger than the ALMA beam

Flux density in Jy/beam depends on the beam area (i.e. on the beam FWHM θ)

Beam other tel = Ω_{tel}

Beam ALMA = Ω_{ALMA}



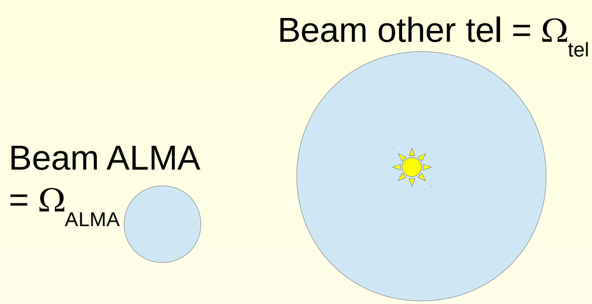
$$F_{tel} = 2\,k\,T_{tel}\Omega_{tel} / \lambda^2$$

$$F_{ALMA} = F_{tel}(\Omega_{ALMA}/\Omega_{tel}) = F_{tel}(\theta_{ALMA}/\theta_{tel})^2$$

Source Peak Flux Density in time

A source is observed with a single dish with θ_{tel}=10” and has T_{tel}= 1 K at 300 GHz
Which is the sensitivity required for ALMA observations at θ_{ALMA}=1” resolution ?

1) The source is smaller than the ALMA beam

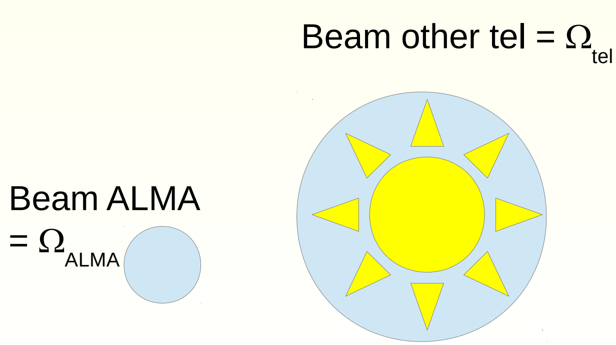


$$F_{tel} = 2\,k\,T_{tel}\Omega_{tel} / \lambda^2$$

$$F_{ALMA} = F_{tel} = 7.36 \text{ Jy/beam}$$

A factor 100 in flux
Corresponds to
A factor 10000 in time

2) The source is larger than the ALMA beam



$$F_{tel} = 2\,k\,T_{tel}\Omega_{tel} / \lambda^2$$

$$F_{ALMA} = F_{tel}(\theta_{ALMA}/\theta_{tel})^2 = 0.0736 \text{ Jy/beam}$$

Choose carefully your resolution!!!

Sensitivity

The rms noise in the signal for a radiometer is given by:

$$\Delta S_\nu = 2\,k\,\frac{T_{\rm sys}}{A_{\rm e}\sqrt{2t\,\Delta\nu\,N(N-1)}}$$

Boltzmann k

Brightness temperature corresponding to all the signals collected including source, atmosphere and instrument

Effective collecting Area per antenna

Bandwidth

Number of baselines

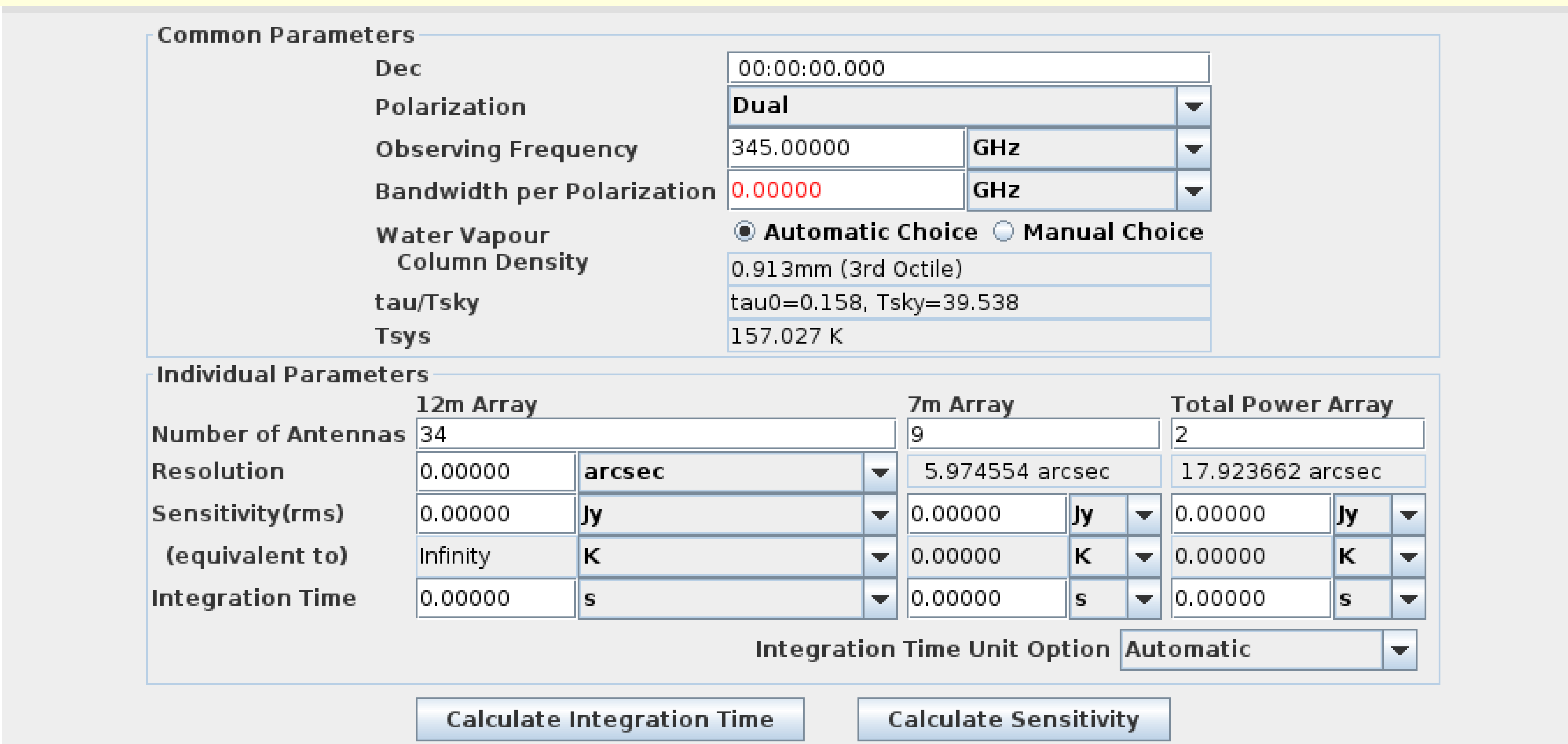
Time on source

# of polarizations

Sensitivity can be increased by increasing the bandwidth and/or the integration time

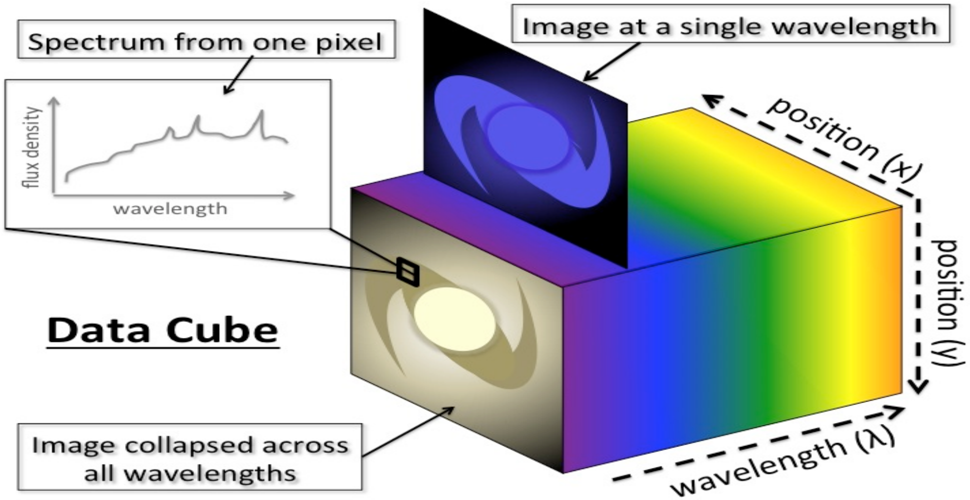
Sensitivity Calculator

https://almascience.eso.org/proposing/sensitivity-calculator



Spectral Resolution

The Spectral resolution **is the minimum separation in frequency whereby adjacent features can be distinguished.**
It depends on how the correlator is set.

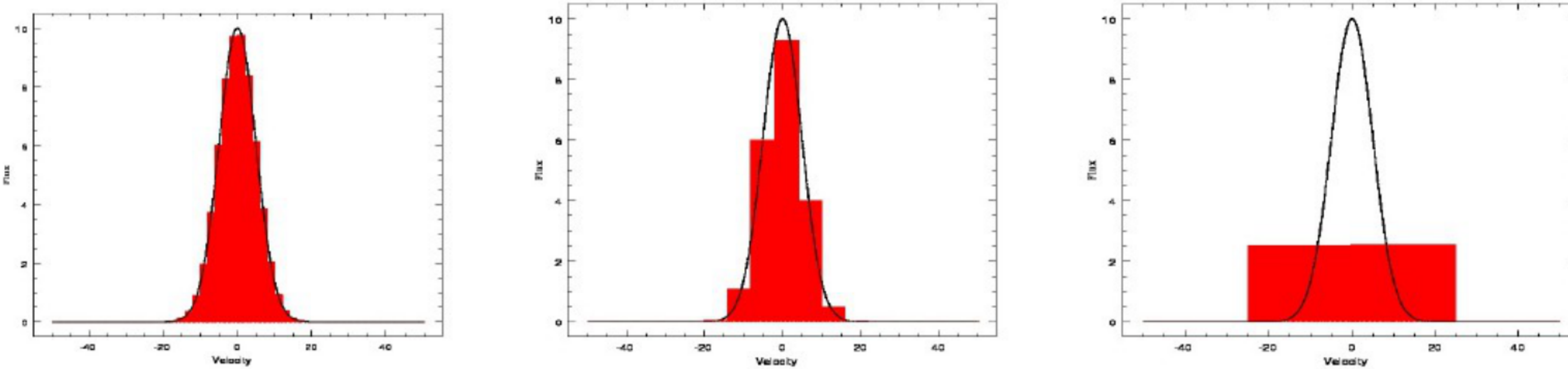


Polarization products

Continuum bandwidth is as large as 7.5GHz/pol
The finest spectral detail you want to observe determines your resolution in the ranges
from 0.1-111 km/s at 84 GHz to 0.01 - 10 km/s at 950 GHz.

ALMA data are always Hanning smoothed (i.e. resolution is almost half the requested).
Smoothing at data reduction stage is possible (e.g. to increase sensitivity for broad lines)
Channel averaging smooths data at acquisition stage
(i.e. finest resolution cannot be recovered later) but it is sometimes needed to reduce data rate.

Spectral resolution: lines



- If channel width < FWHM the peak flux is independent of channel width
- If the channel width is too large you lose in line details and eventually in sensitivity

- Choose at least 3 resolution elements per FWHM
    But In OT spectral resolution > channel spacing !!
    Channel spacing < 2 x resolution element because of Hanning smoothing
    → Hence leave the default averaging=2 and choose 3 ch/line width

- Remember that sensitivity depends on spectral resolution as rms(Jy) $\propto$ $1/\Delta\upsilon^{1/2}$
- $\Delta\upsilon$ [Hz] $=\upsilon$ [Hz] Δv [m/s] / c [m/s]

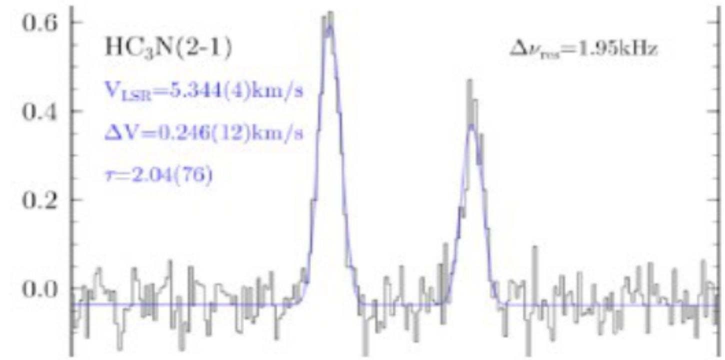
Sensitivity: spectral line

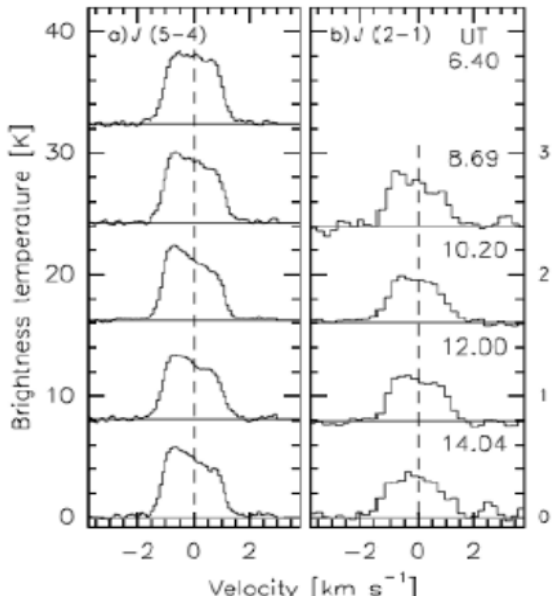
- Gaussian profile
  - SN on the peak

$$rms(Jy) = \frac{Area(Jy \cdot kms^{-1})}{FWHM(kms^{-1}) \cdot SN}$$

- Undefined profile
  - SN on the area

$$rms(Jy) = \frac{Area(Jy \cdot kms^{-1})}{N_{chan}^{1/2} \cdot \Delta v(kms^{-1}) \cdot SN}$$





What to never do

- Do not ignore the grading or funding criteria.
- Don't submit proposals that are badly written – if English is not your first language, get a collaborator to proof read or rewrite it for you.
- Don't ask for the wrong instrument, the wrong amount of time, or the wrong semester.
- Don't rage at the panels - its not their fault they didn't have enough money or telescope time last time
- Don't waffle - less is more
- **Don't use jargon & acronyms**
- **Don't assume everyone knows this scientific area is the most compelling thing ever done.**

Few tips

- **Tell a story**. Make your proposal and enjoyable narrative that leads the reader from point to point.
- **"Close the Loop"**
- Frame your project as an experiment ("Hypothesis and Testing") rather than data gathering.
- Think seriously about the risks of a "new class of object" discovery project.
- Avoid the evil "Constrain"
- **The more you "quantify" the better you get the point** (i.e. avoid generic "more, much, less, few" but give numbers to give the idea that you have already dirty hands on the matter)

RS
RV
VLM
SMBH
AGN
FIR

FRII
ULIRG
ERO
SMG

CDFS
PCCS
EMU
WALLABY
POSSUM
DINGO
APEX
SCUBA
WTHDIM

Ask yourself...

- **Would you want to read this proposal? Late at night? On a plane? Along with 80 others just like it?**

- **Would you be able to read and understand this proposal in under 5m per page?**

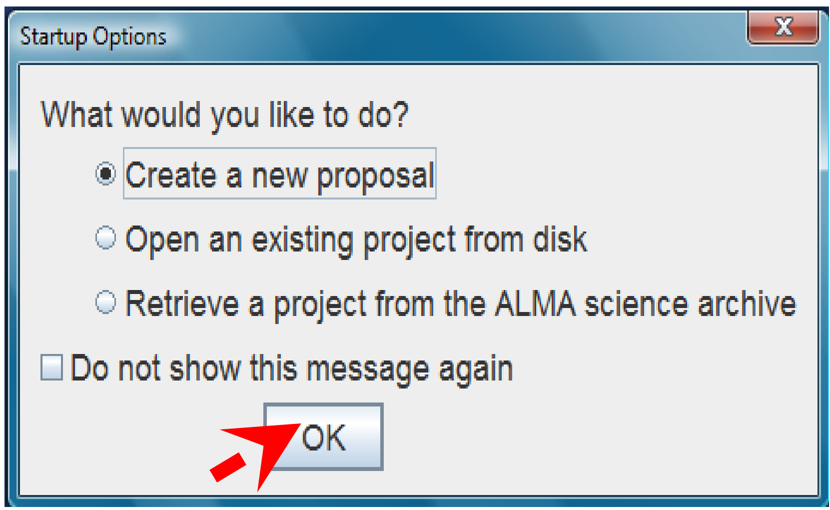
- **Can you FIND the main points in the proposal without reading the whole thing in all its gory detail?**

- **Imagine its your hard earned money, would you pay for this project?**

It’s not the reader’s job to understand your proposal
... its your job to make them understand it.

Readers are looking for enjoyable,
understandable proposals to read that
present innovative ideas for new research

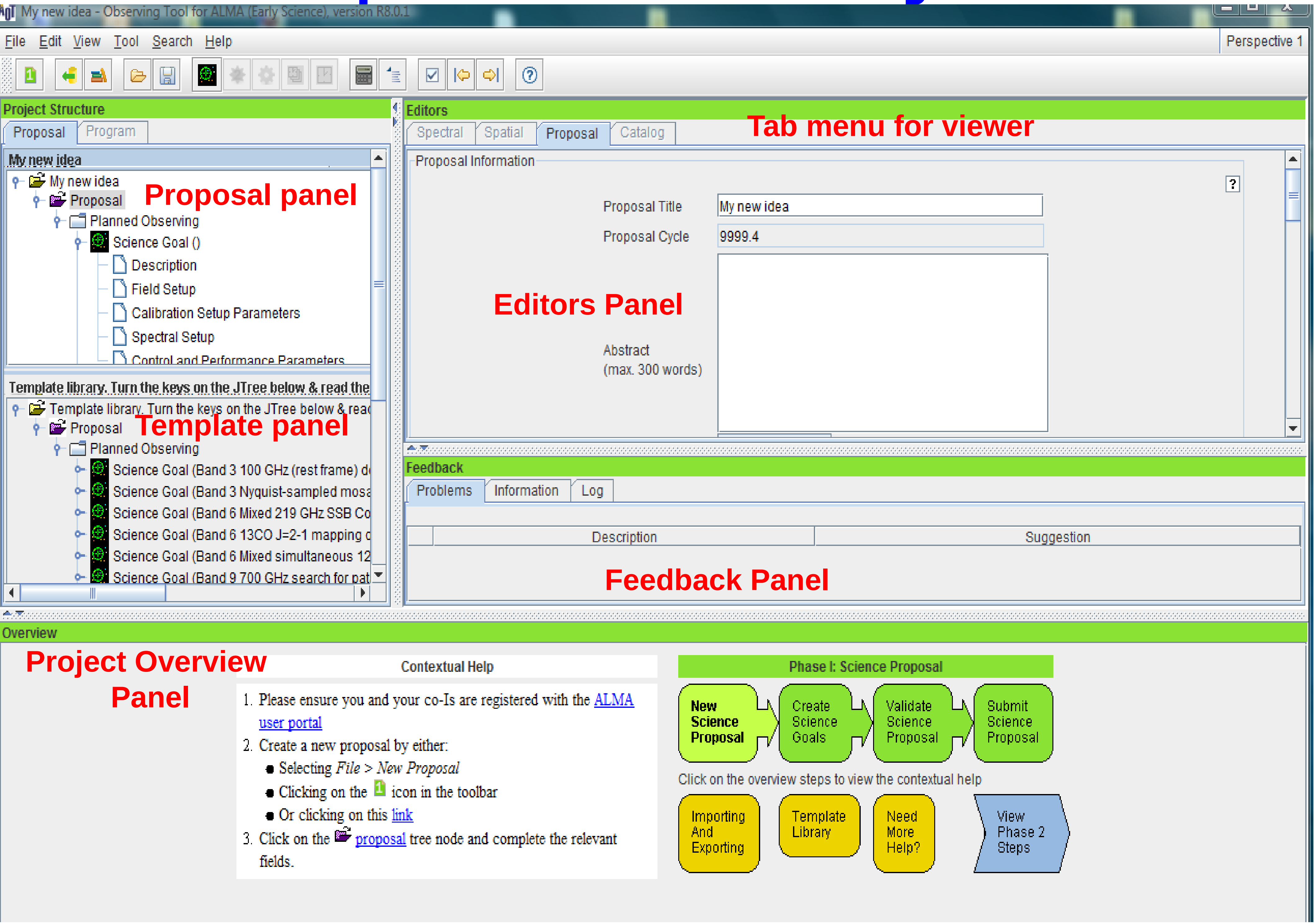
The ALMA Observing Tool



OT is a java-based client program,
runs on Linux (various distr.),
MacOS (10.5-10.6), Windows (>XP).

The graphic interface allows one to get help/feedback and hints even with small knowledge of the system.

Proposals with the ALMA Observing Tool



A project lifetime: phase 2 Observing process

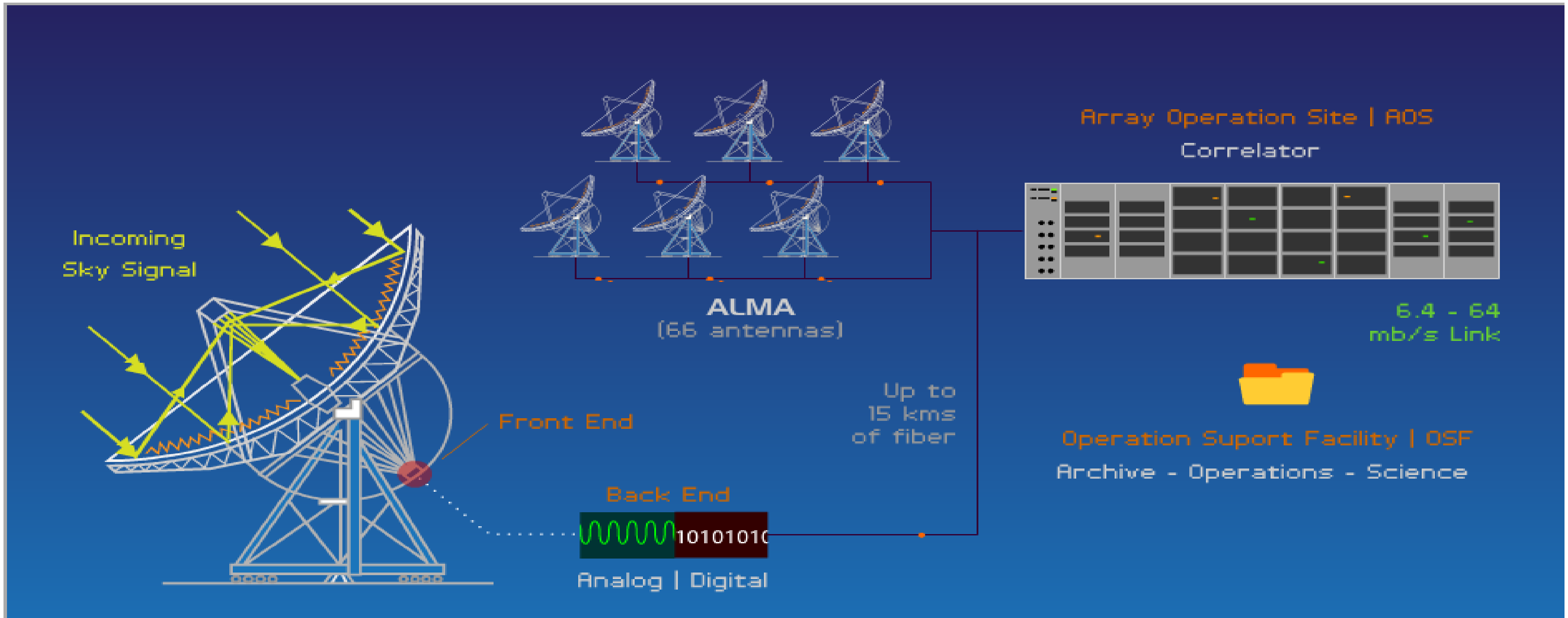
PHASE II – Observing process

Scheduling Block — Each SG is converted into a **Scheduling Block, an observational unit including targets in the same sky region and their Calibrators to be observed with the same instrumental setup.** They are the minimum set of instructions to perform an observation.

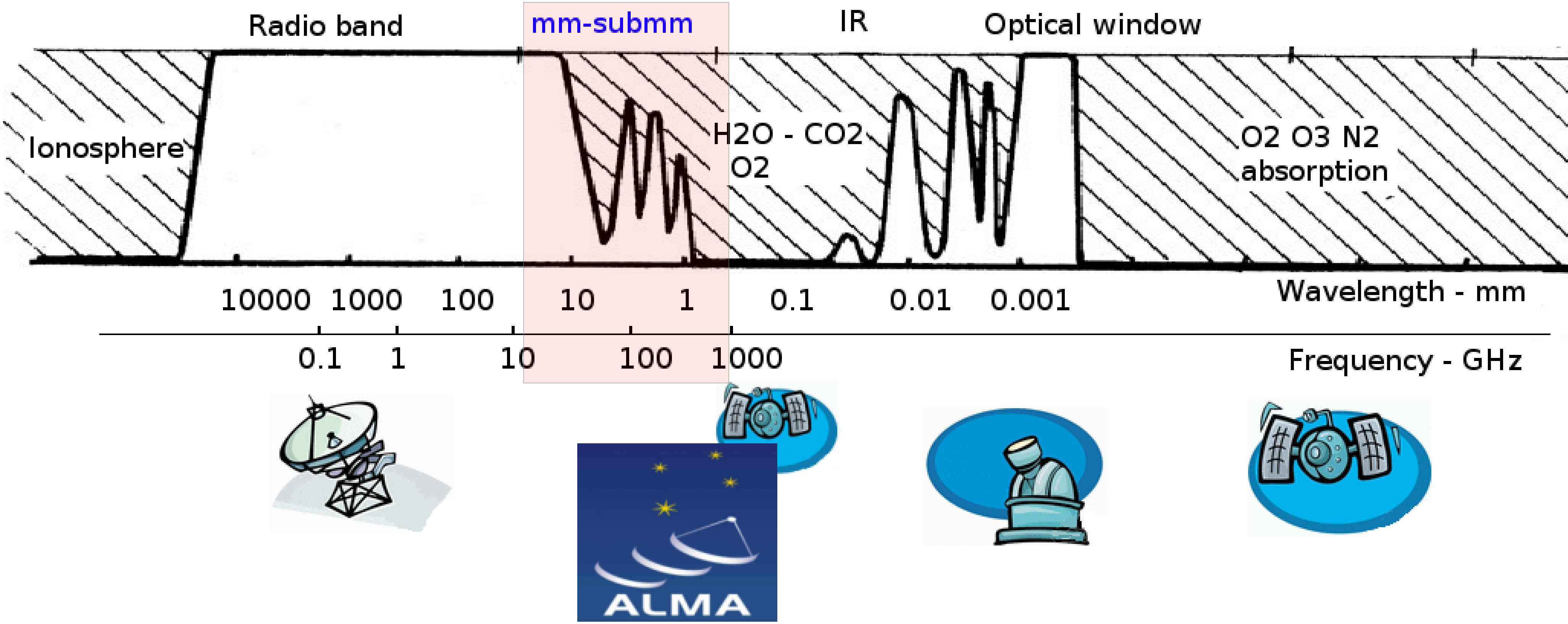
Observations — **Projects are dynamically scheduled according to telescope configuration, weather, ranking, project status...**

Quality assessment — **QA0 and 1 = telescope conditions**
QA2 = Check for PI sensitivity requests performed by ARC staff

Data archival and delivery — **1 yr of proprietary period before data are public through the archive**



Outline



Signals in the (sub)mm bands

Observing instruments: **Interferometers (ALMA)**

Science cases parade and proposals

Observing processes: **archives & images (with hands-on tutorial)**