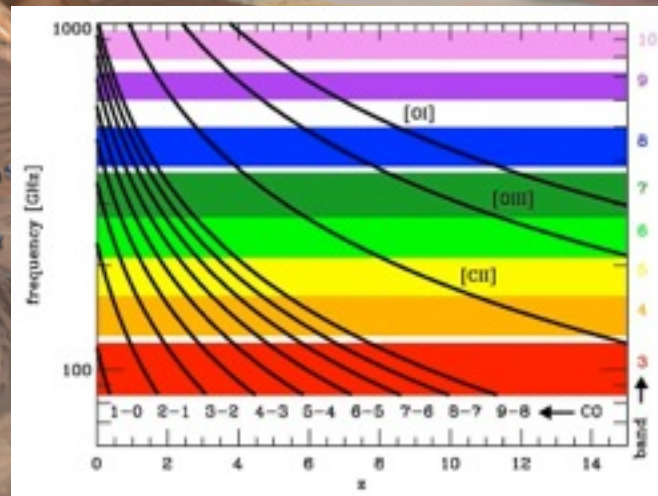
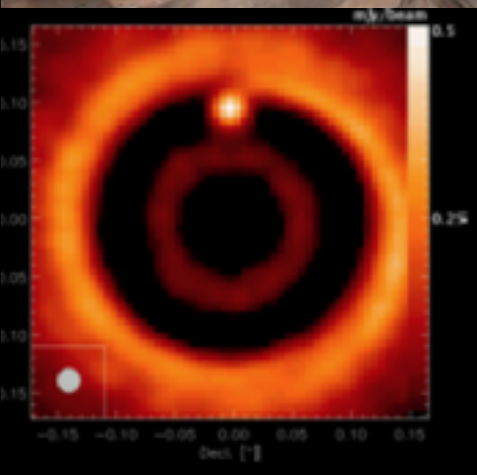
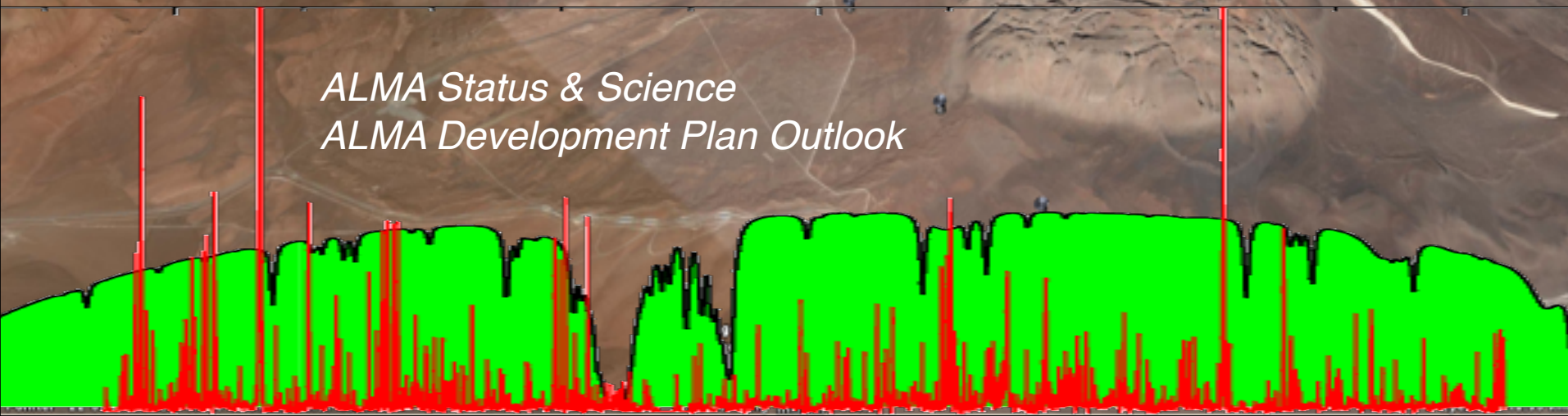


ALMA: Status, Science, Development

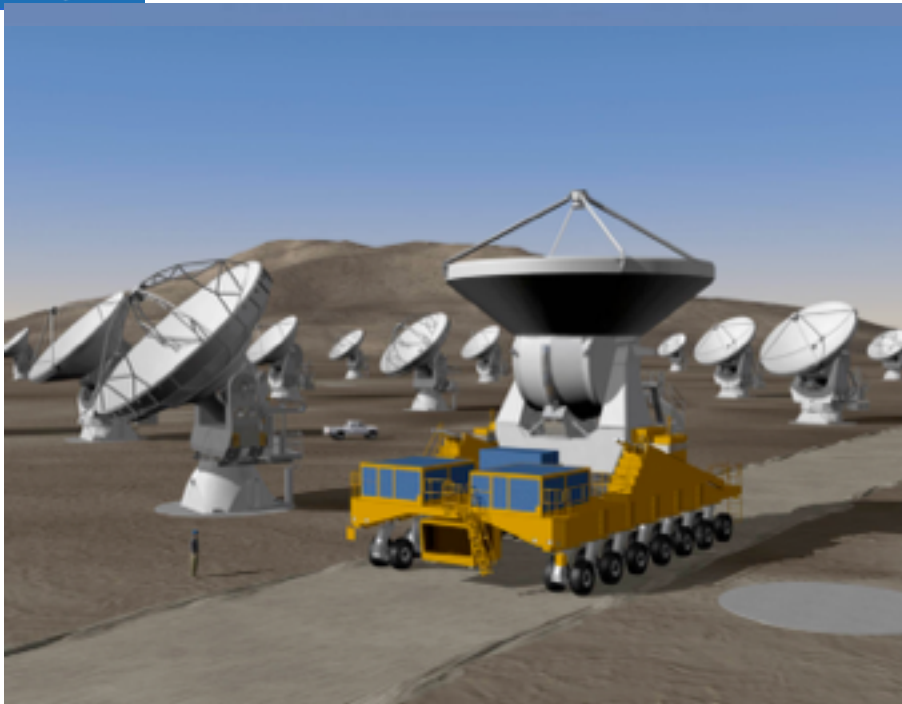
Leonardo Testi
ESO



ALMA Status & Science
ALMA Development Plan Outlook



Atacama Large Millimeter Array



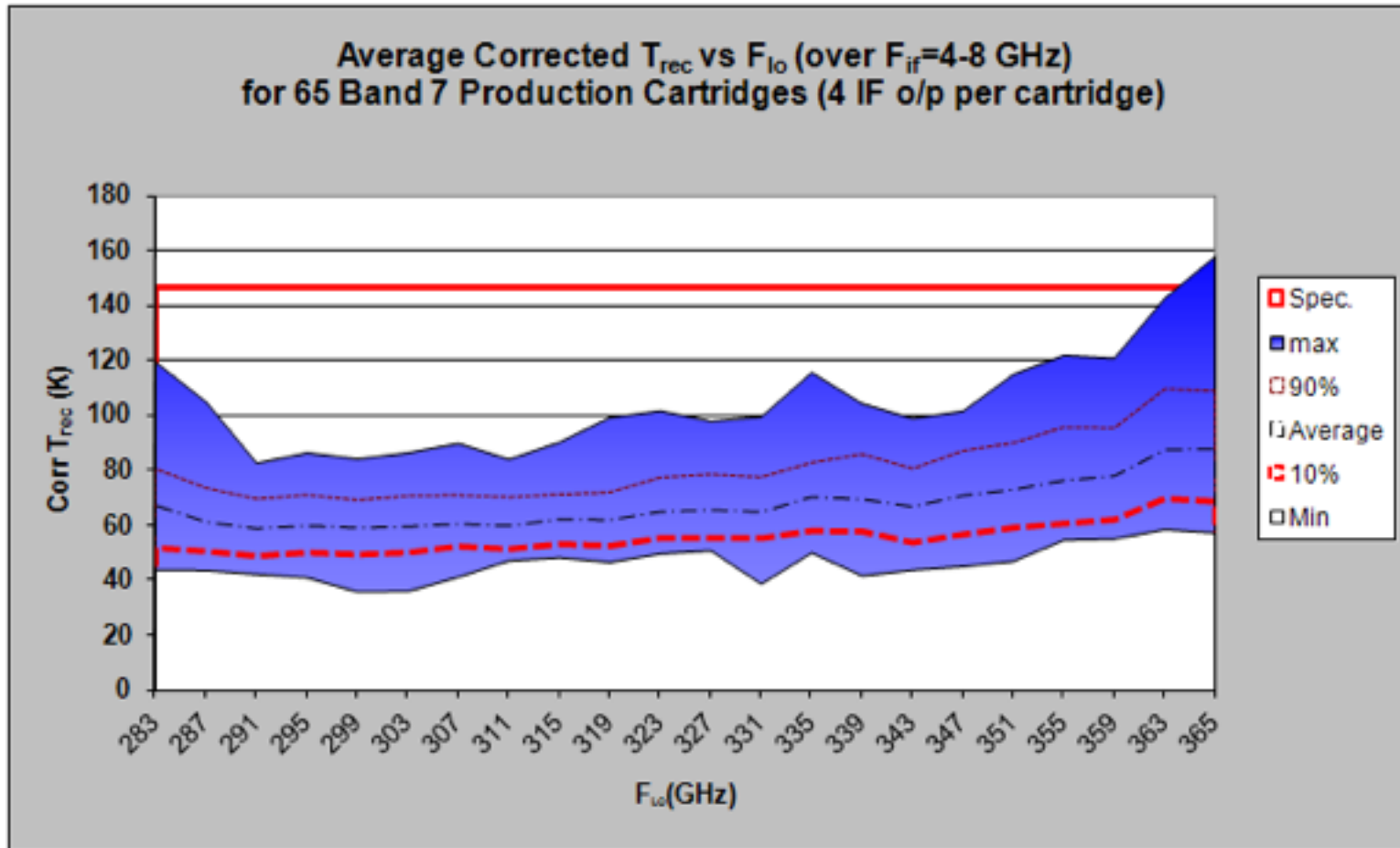
1. At least 50x12m Antennas
2. Frequency range 30-1000 GHz (0.3-10mm)
3. 16km max baseline (<10mas)
4. ALMA Compact Array (4x12m and 12x7m)

- 1. Detect and map CO and [C II] in a Milky Way galaxy at $z=3$ in less than 24 hours of observation**
- 2. Map dust emission and gas kinematics in protoplanetary disks**
- 3. Provide high fidelity imaging in the (sub)millimeter at 0.1 arcsec resolution**



Band 7 Performance

Sensitivity ~2 times better than specification



ALMA Early Science

ALMA Early Science C0 & C1

- 30-70% of the total number of antennas
- Maximum separation 1km (6% of final ALMA)
- Already the most powerful submm observatory

Enormous pressure to use ALMA worldwide

- Requests for 9 times the available time
- Top 8% science projects selected (ESO)



ALMA Science Results



eso1325 — Science Release
eso1334 — Science Release

SPACE SCOOP

eso1331 — Science Release
eso1336 — Science Release

eso1304 — Choose your language

eso1344 — Science Release

Choose your language:



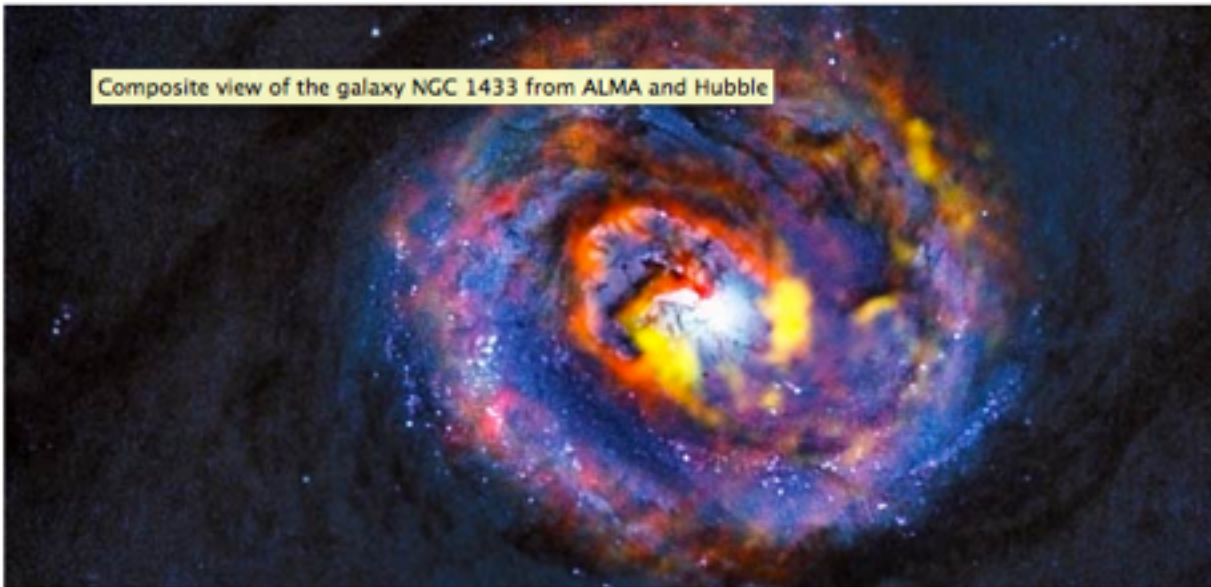
SPACE SCOOP

SPACE SCOOP

ALMA 10 July 2013

ALMA Probes Mysteries of Jets from Giant Black Holes

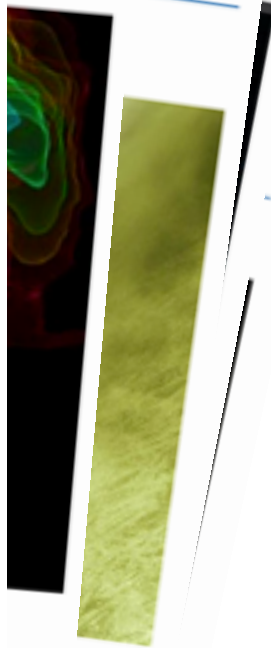
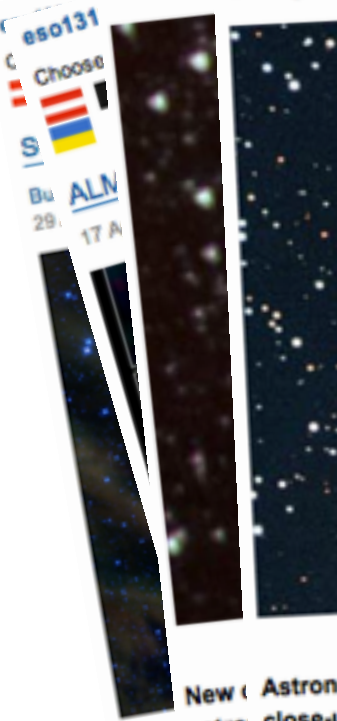
16 October 2013



Composite view of the galaxy NGC 1433 from ALMA and Hubble

Click to Enlarge

Two international teams of astronomers have used the power of the Atacama Large Millimeter/submillimeter Array (ALMA) to focus on jets from the huge black holes at the centres of galaxies and observe how they affect their surroundings. They have respectively obtained the best view yet of the molecular gas around a nearby, quiet black hole and caught an unexpected glimpse of the base of a powerful jet close to a distant black hole.



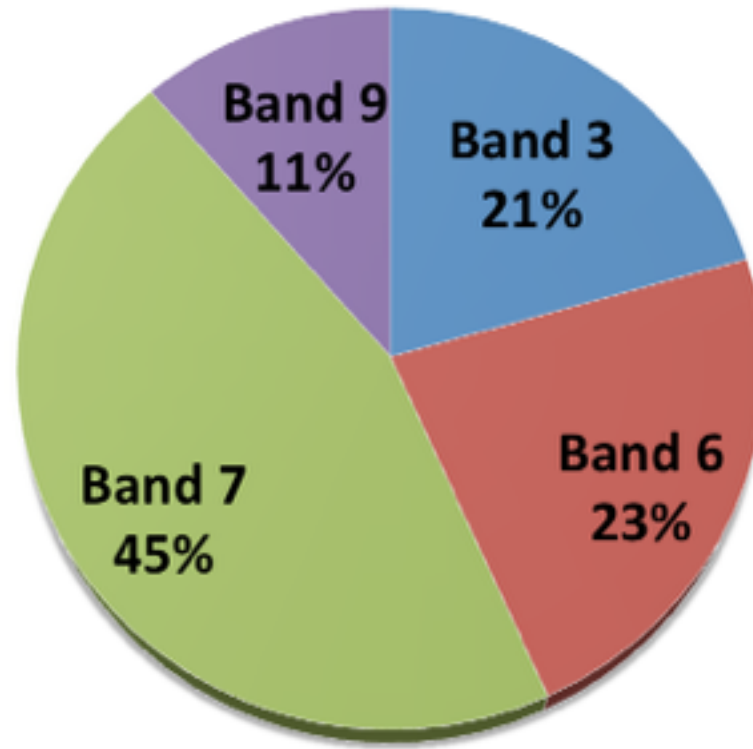
New (Astron
astro close-
woml carbor
— an even n
inwa previously unknown jet p...

...are the first direct observations of such stream... 2013.



ALMA Bands Usage

ALMA Cycle 0 Band Usage





Many results in published papers:

- High-z, Disks, ISM, Star Formation, Local Universe, Solar System, Stellar Evolution, Supernovae, Cosmology, Fundamental Physics
- For a sample, the First Year of ALMA Science Conference:
 - <http://www.almasc.org/2012/>



ESO MS are very much engaged with ALMA Science

- First authors of ~40% of papers so far
- Involved in ~80% of papers



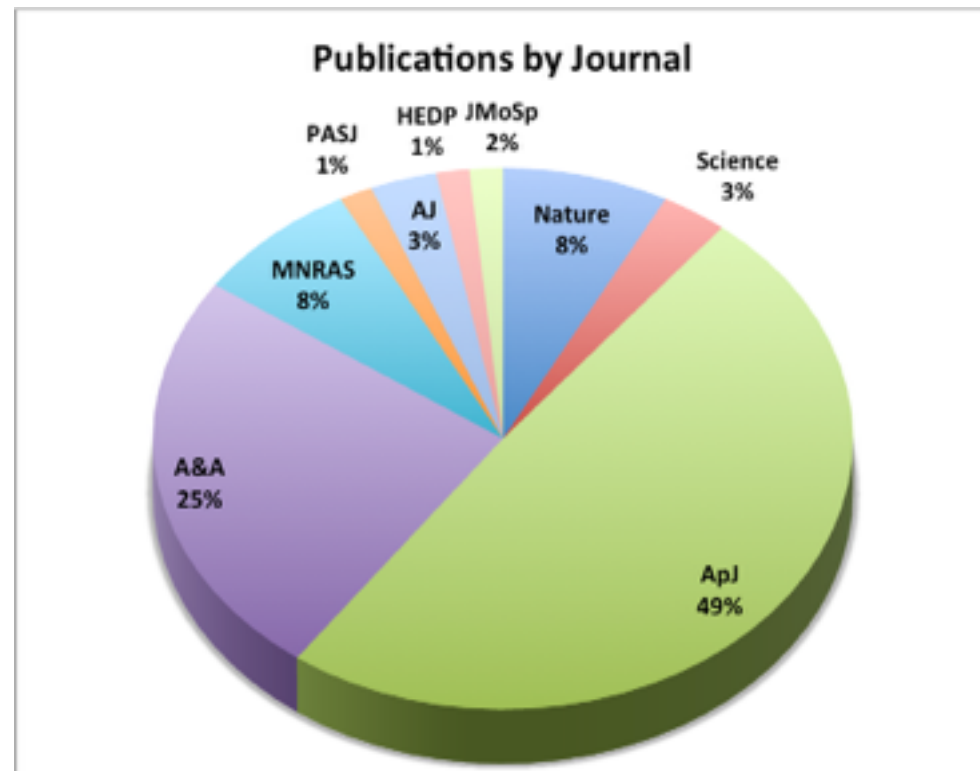
Very high oversubscription rate in ESO MS

Only refereed papers

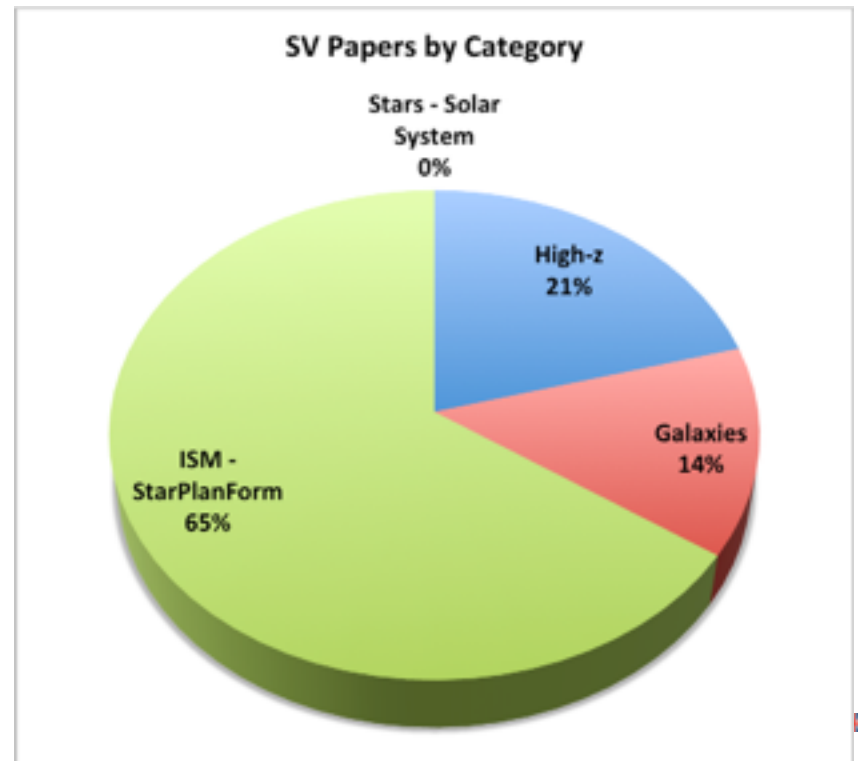
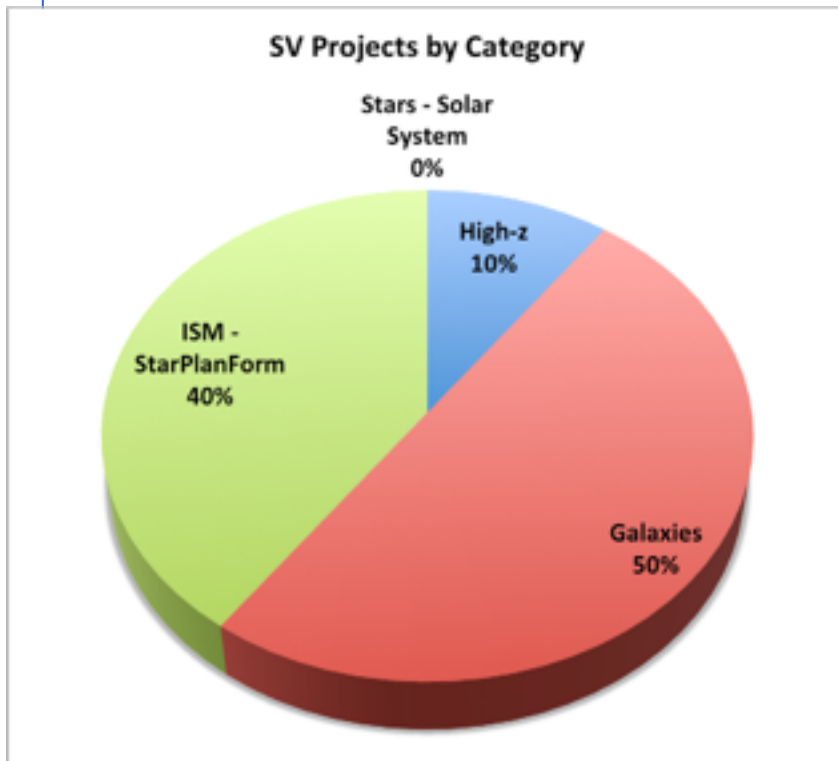
- Collected data as of **October 3, 2013** from telbib.eso.org (ESO, NAOJ and NRAO librarians cross check and coordinate the database)
- Only printed papers on refereed journals appear on the list
- We know of more submitted/accepted papers, but we cannot be complete on those

Database

- 65 refereed publications
- 29 based only on SV data
- 36 used Cycle 0 data
- **~10%** Nature/Science

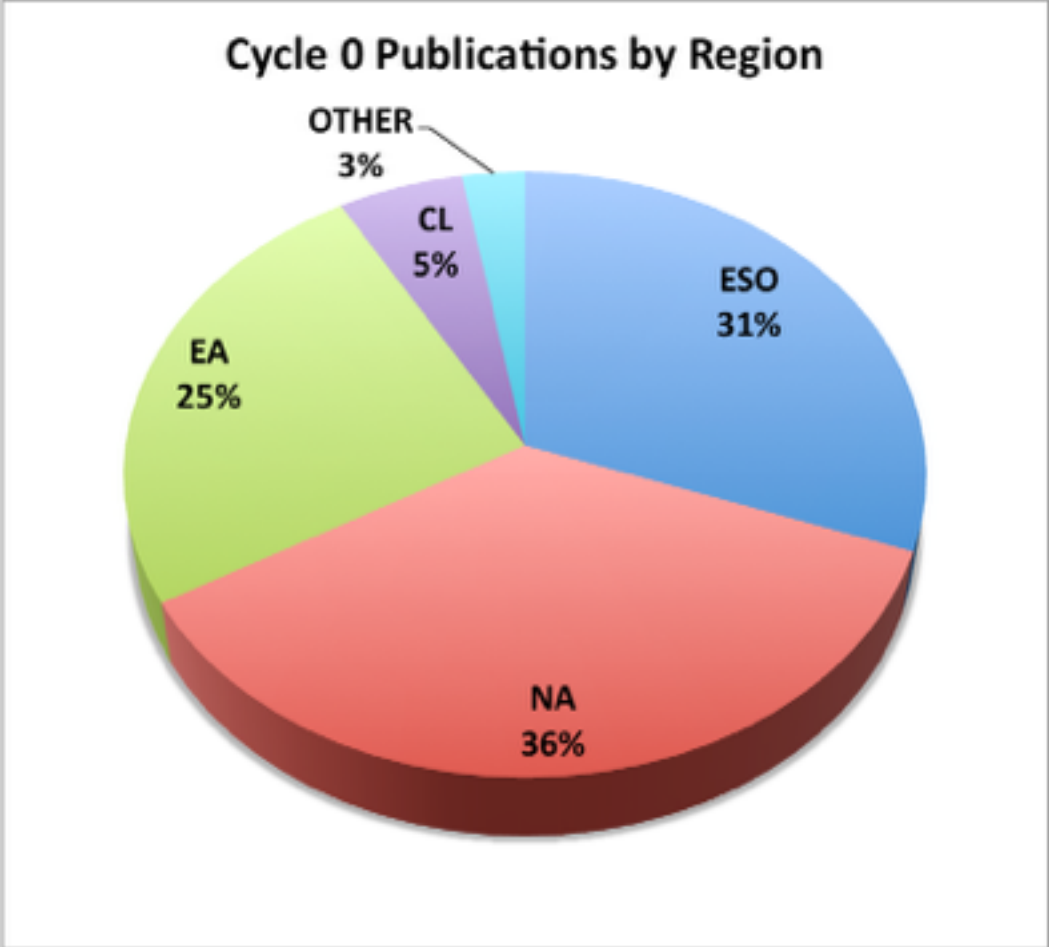
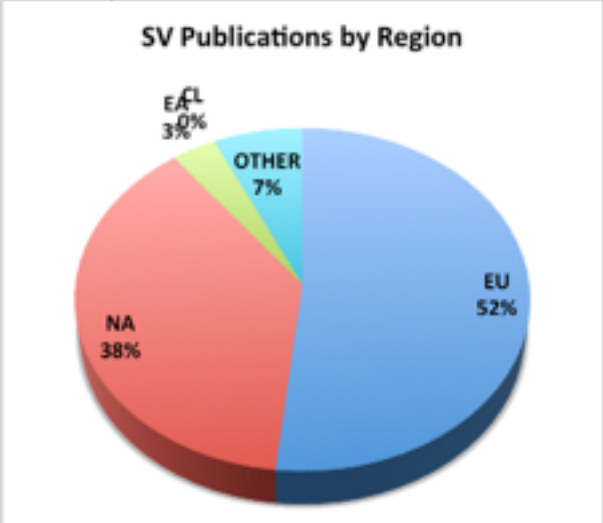


- ❗ Data was released for 10 SV projects
 - No Star/Solar System project so far
- ❗ Publications were produced for 7 projects (29 papers)
 - All high-z (1) and ISM-StarPlanForm (4) produced papers
- ❗ NB. Papers are not a goal of SV projects!!



Distribution by Region

- Very different use of SV data in the various regions
- Cycle 0 publications are well balanced



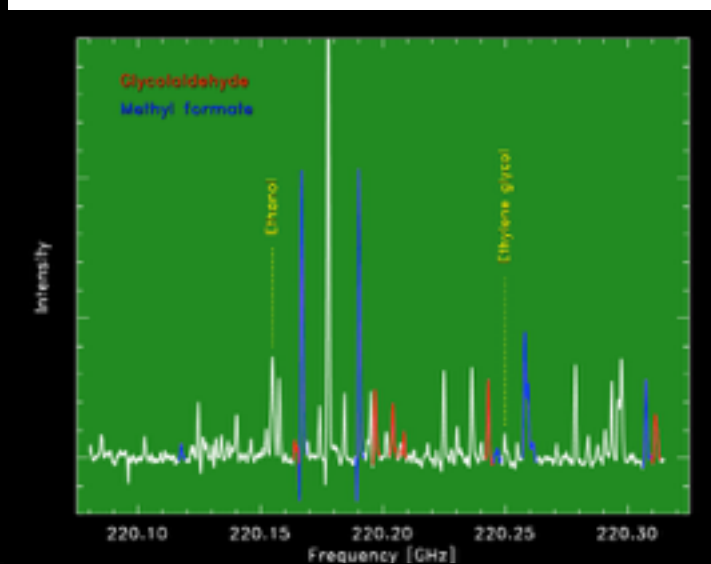
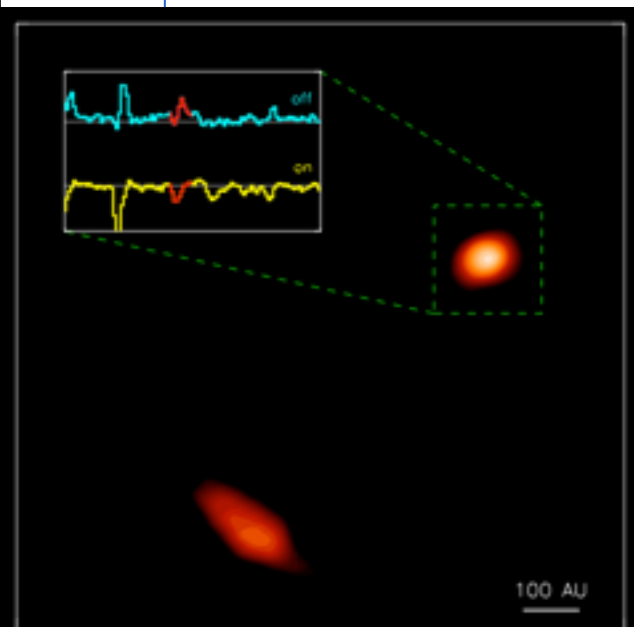
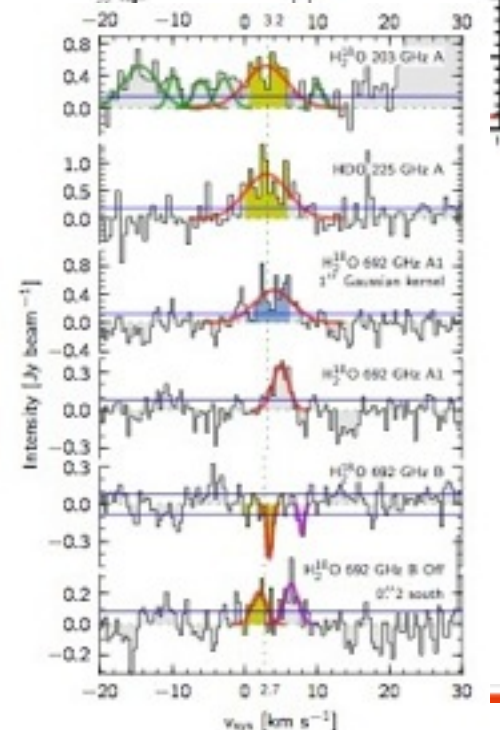
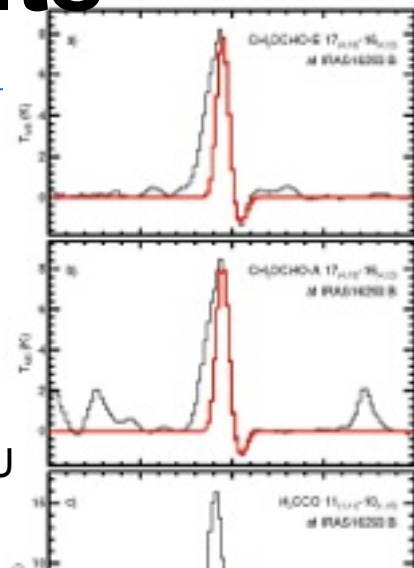
ALMA SV Science Results

☒ Infall and pre-biotic molecules in IRAS16293

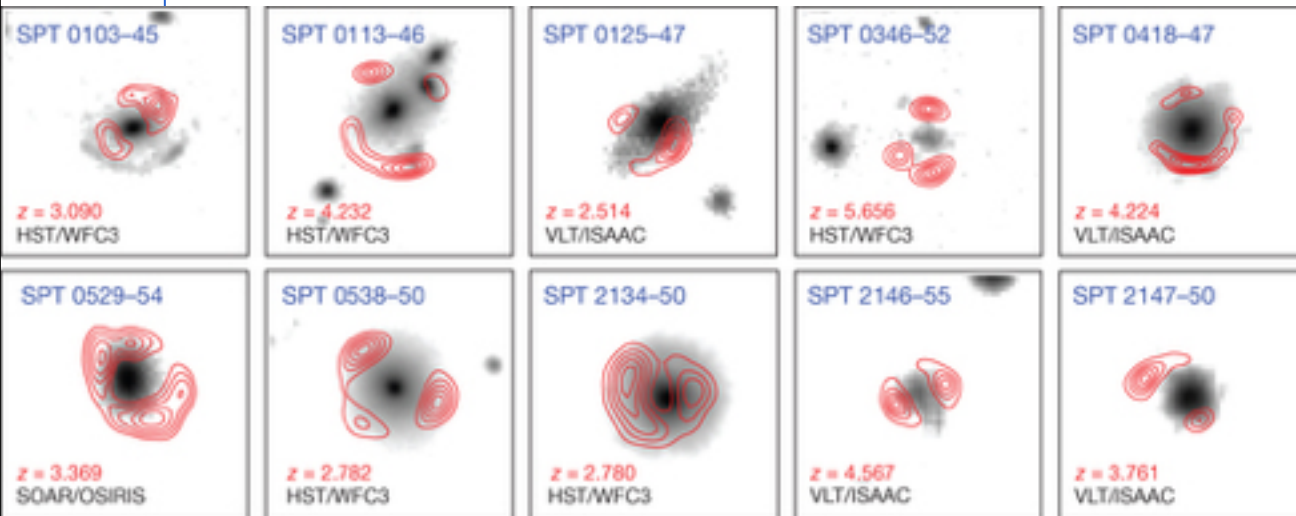
- Jorgensen et al. 2012, ApJ 757, L4; Pineda et al. 2012, A&A 544, L7
- Persson et al. 2013; Zapata et al. 2013

☒ First glycoaldeheyde detection in solar mass protostar

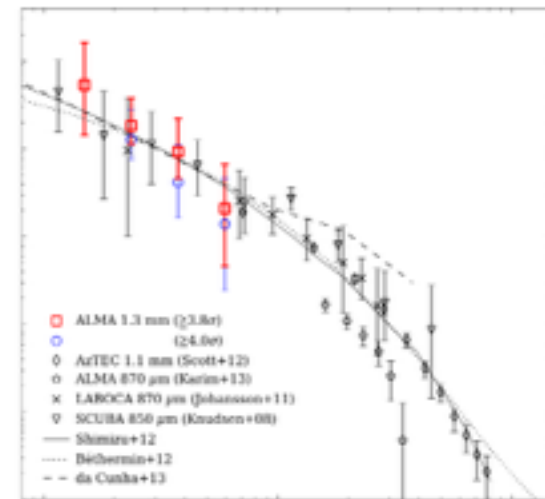
- From B9 first released dataset. This simple sugar is found within ~25~AU from the central protostar and infalling into the inner regions of the disk.
- Water isotopomers in Band 9



- W 1 Nature paper on the STP lensed SMGs
 - New redshift distribution
- W Other results in many areas
 - Deep galaxy counts, GRBs, metals in QSOs and first galaxies



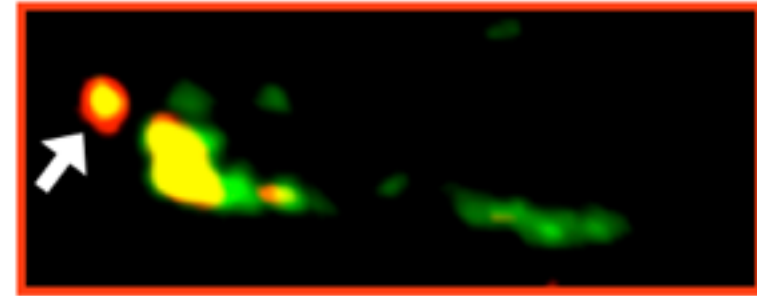
(Vieira et al. 2013; Weiss et al. 2013)



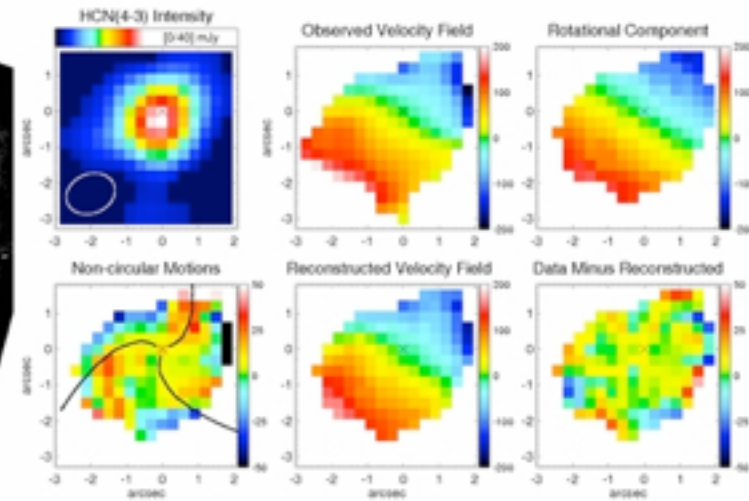
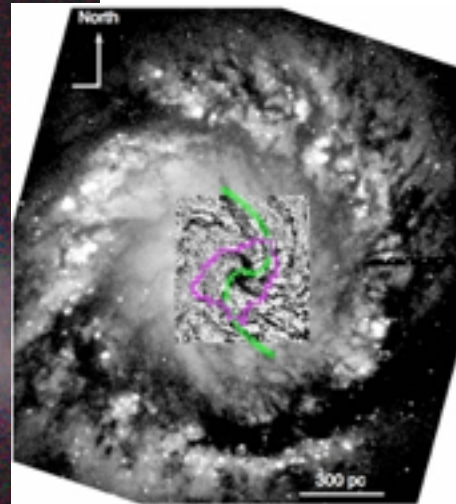
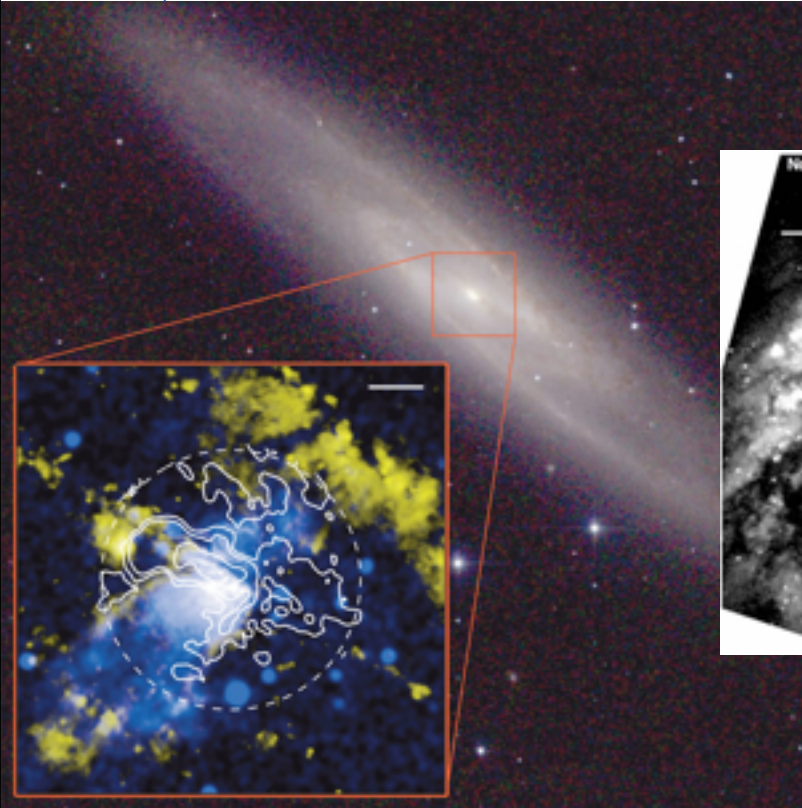
(Hatsukade et al. 2013)

Galaxies/AGN

- W 1 Nature paper on NGC 253
 - Molecular wind driven by starburst
- W Other results
 - Dense gas feeding AGN nuclei



(Iono et al. 2013)



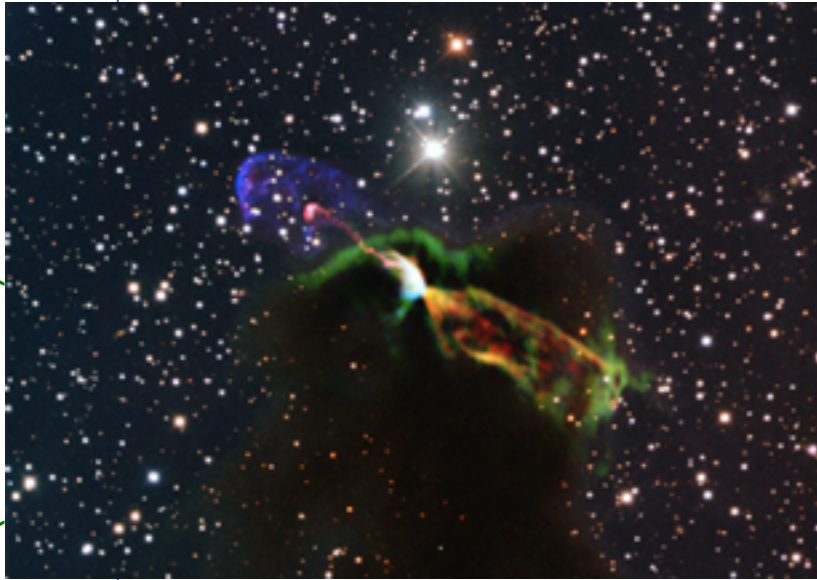
(Kambiz et al. 2013)

(Bolatto et al. 2013)

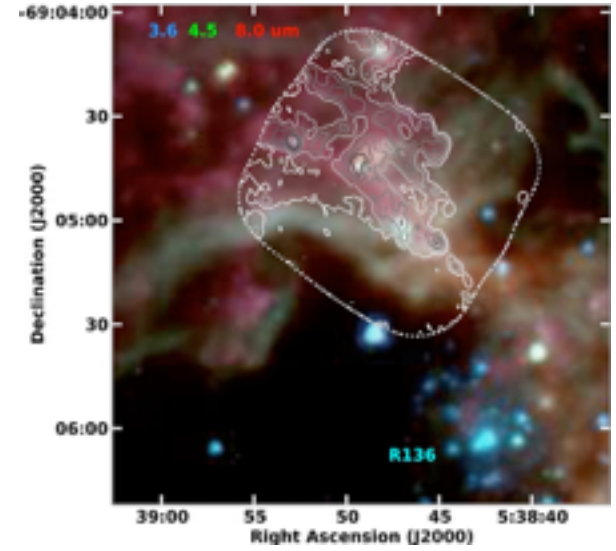
ISM Star Formation

Several important results

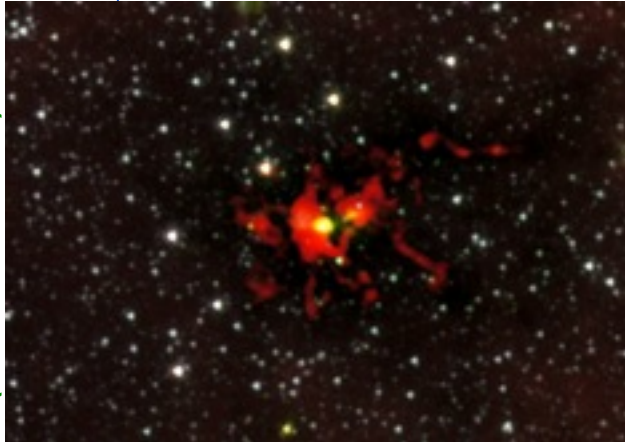
- Molecular outflows, disks around high mass protostars, IRDCs



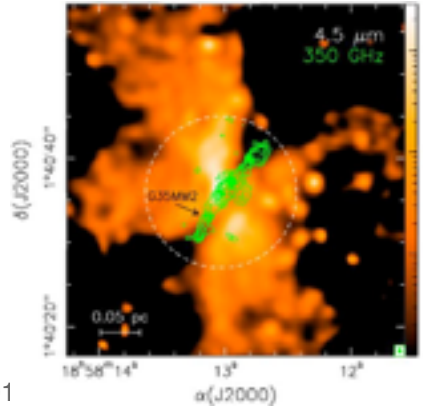
(Arce et al. 2013)



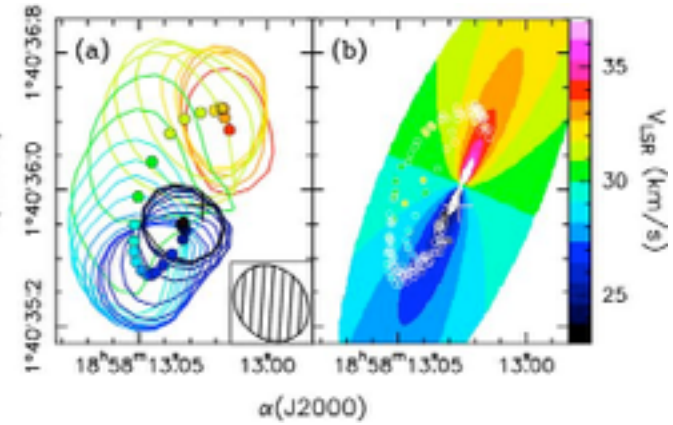
(Indebetouw et al. 2013)



(Peretto et al. 2013)



ov 201



(Sanchez-Monge et al. 2013)

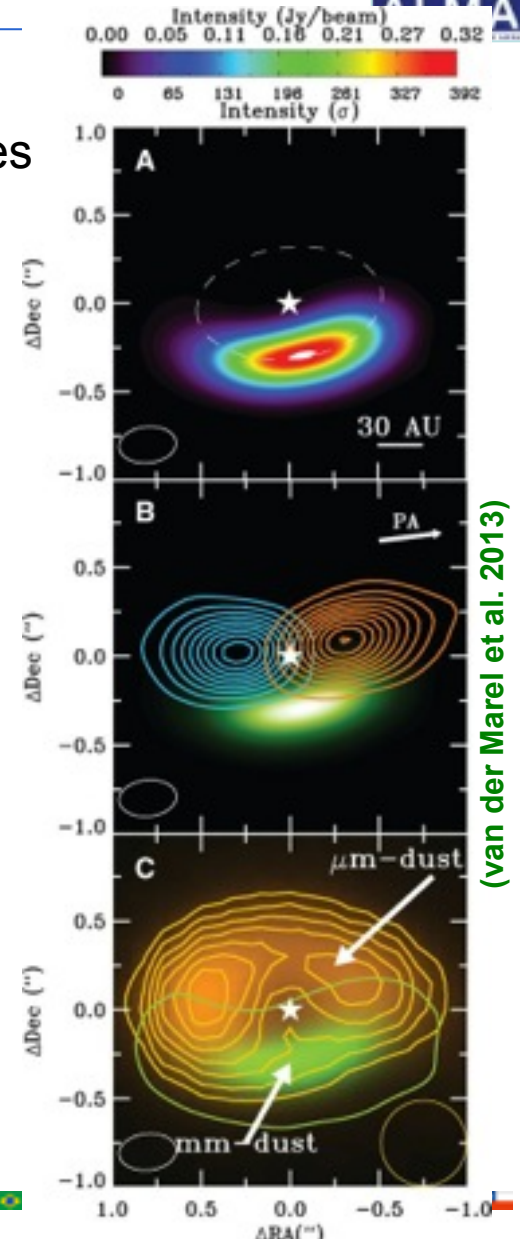
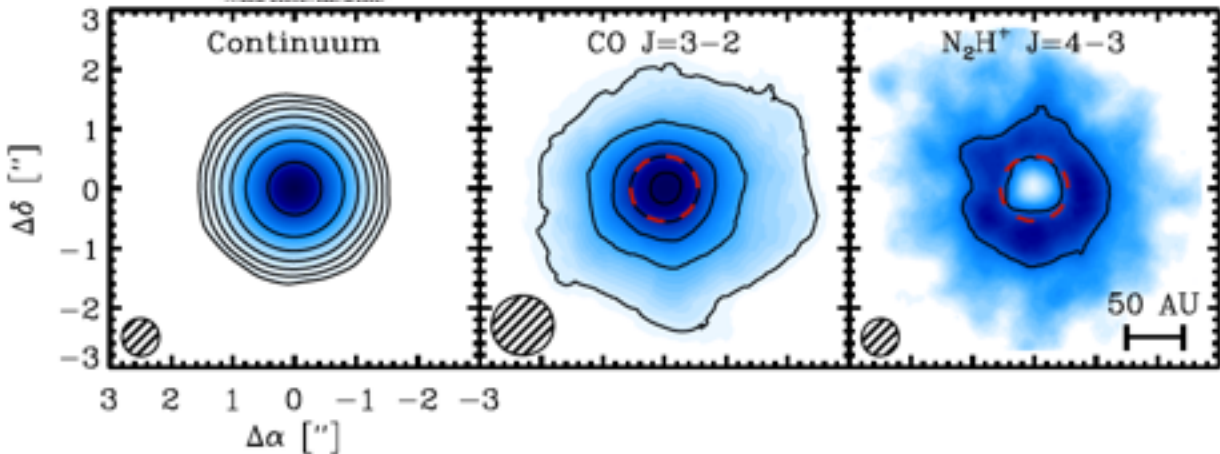
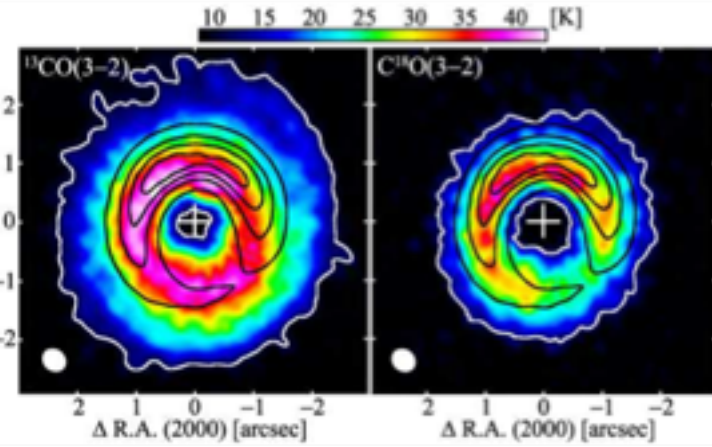
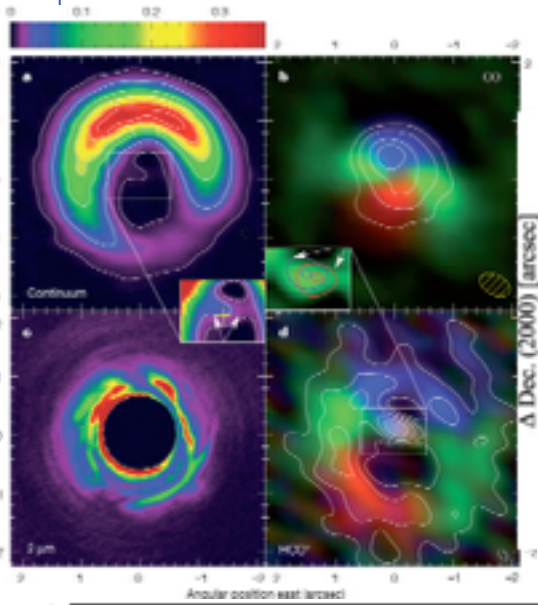
Protoplanetary disks

2 Nature, 2 Science papers

➤ Dust evolution, gaps, gas chemistry and snowlines

(Casassus et al. 2013; Fukagawa et al. 2013)

(Qi et al. 2013)



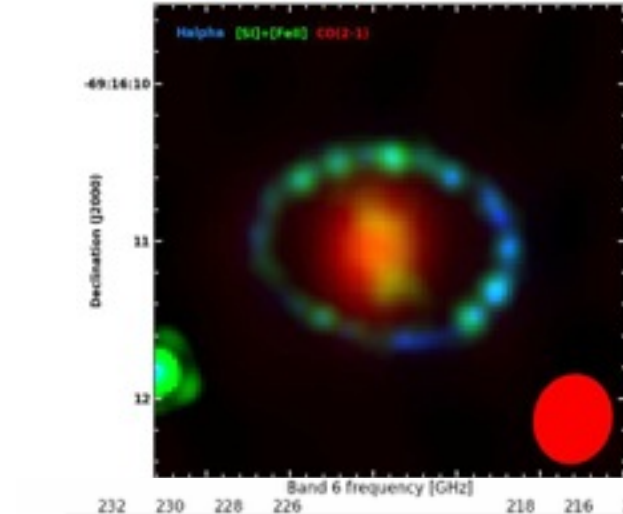
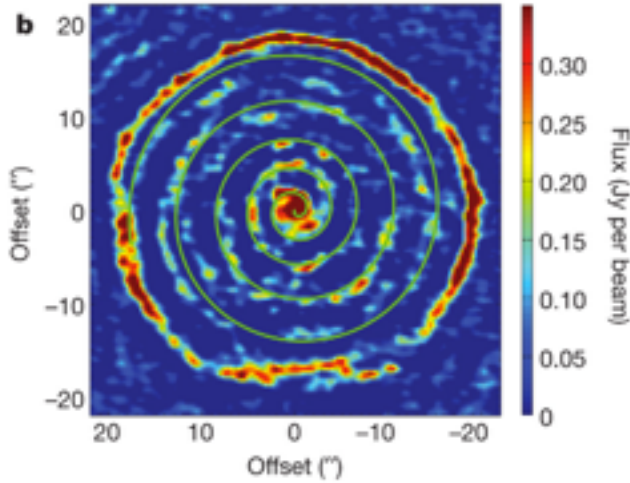
(van der Marel et al. 2013)

Stellar evolution

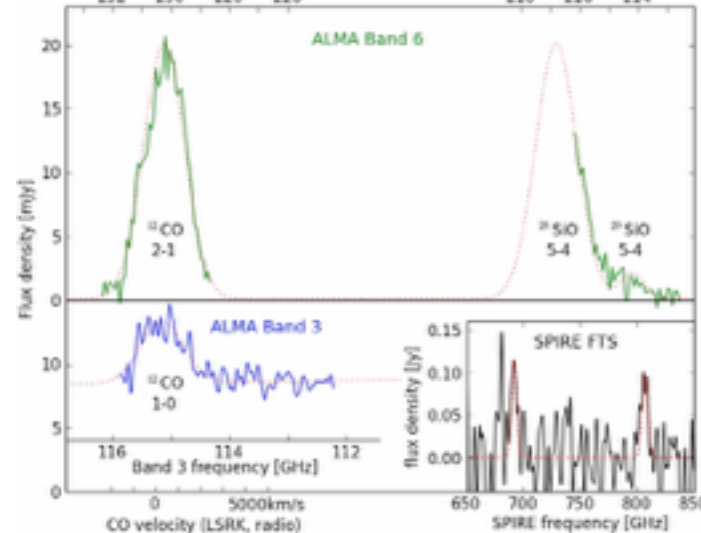
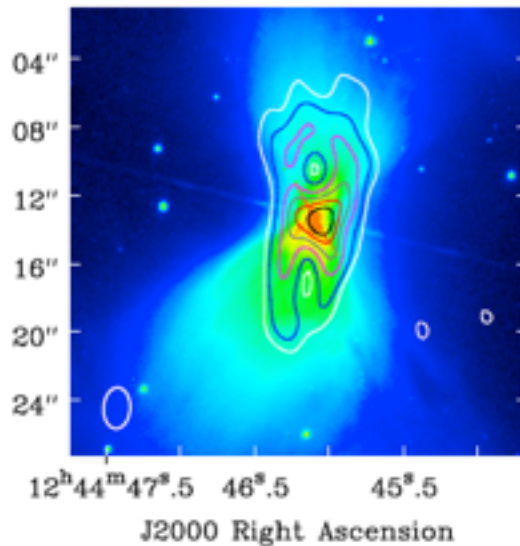
1 Nature paper

➤ Post AGB stars, pre-planetary nebula, SN 1987

(Maercker et al. 2012)

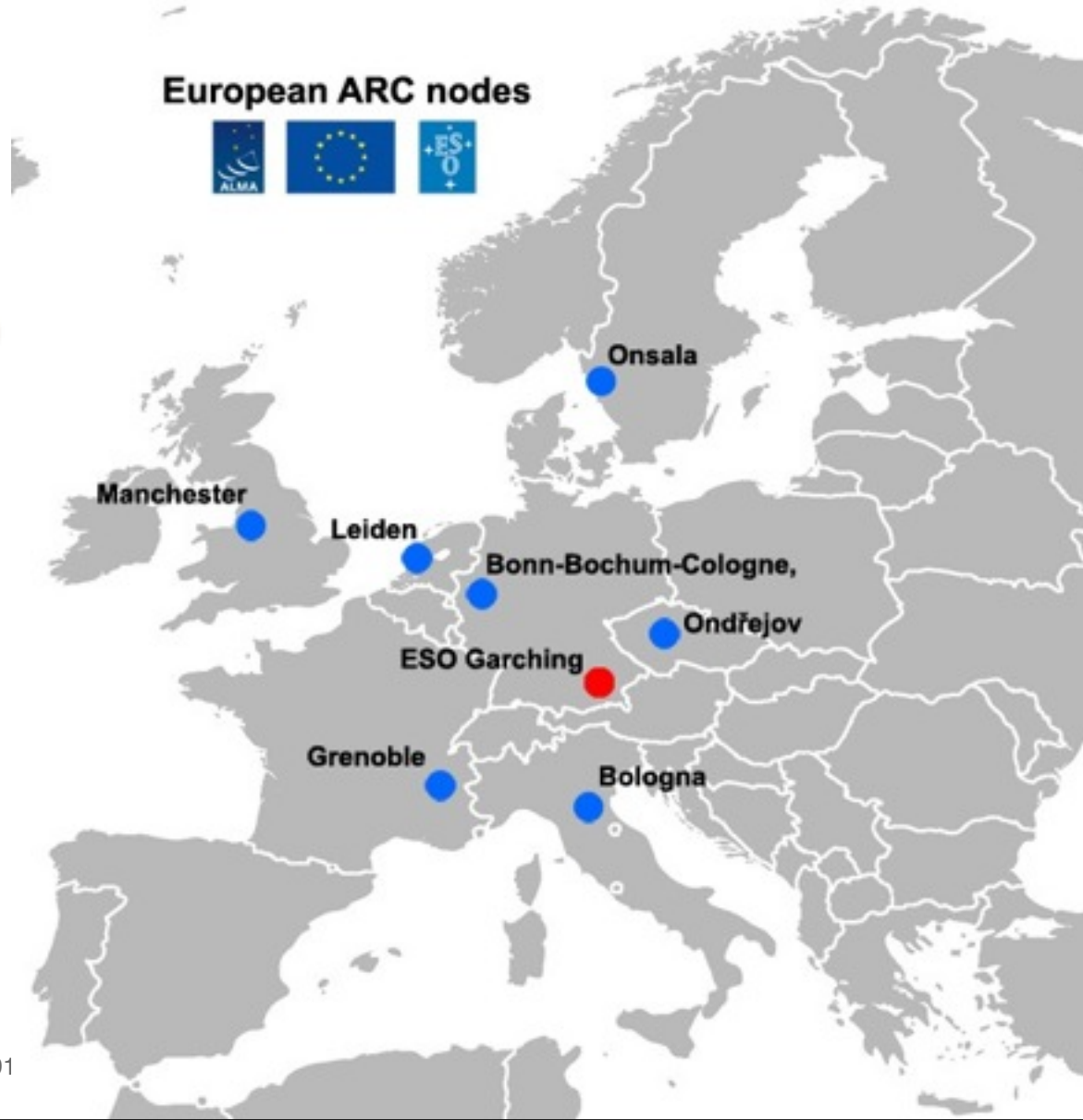
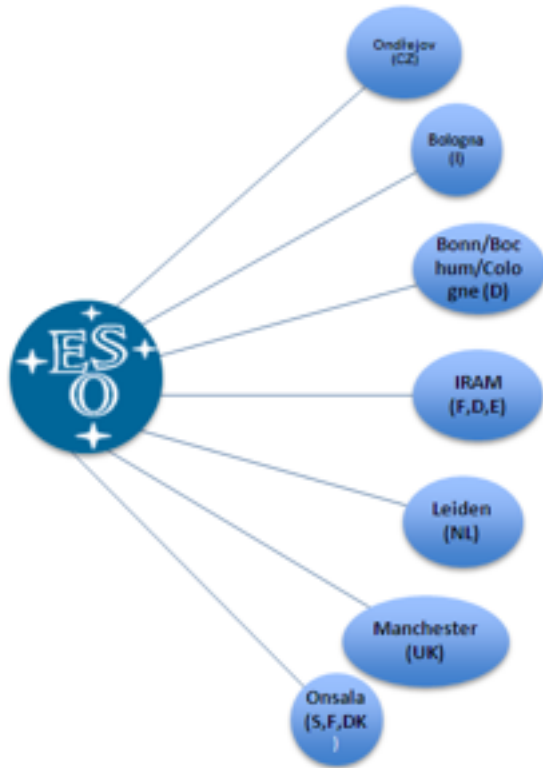


(Sahai et al. 2013)



(Kamenetzky et al. 2013)

ALMA Regional Centre Nodes



Cycle 2 capabilities

- Antennas/Configurations
 - 34 Antennas
 - Baselines up to ~1.5km (up to B7), in seven configurations
- Frequency Bands
 - 3,6,7 and 9 as for Cycle 0/1, plus 4 and 8
- Correlator
 - As in Cycle 1
- Mosaicing/Pointings
 - Max 150 pointings per science goal
- Polarization: continuum, on-axis, bands 3, 6 and 7
- Spectral scans (max 5 tunings, no mosaic, no ACA)
- ACA
 - 9x7m; 2x12m Single dish line (no band 9)

Outlook on future

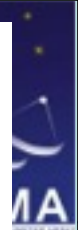
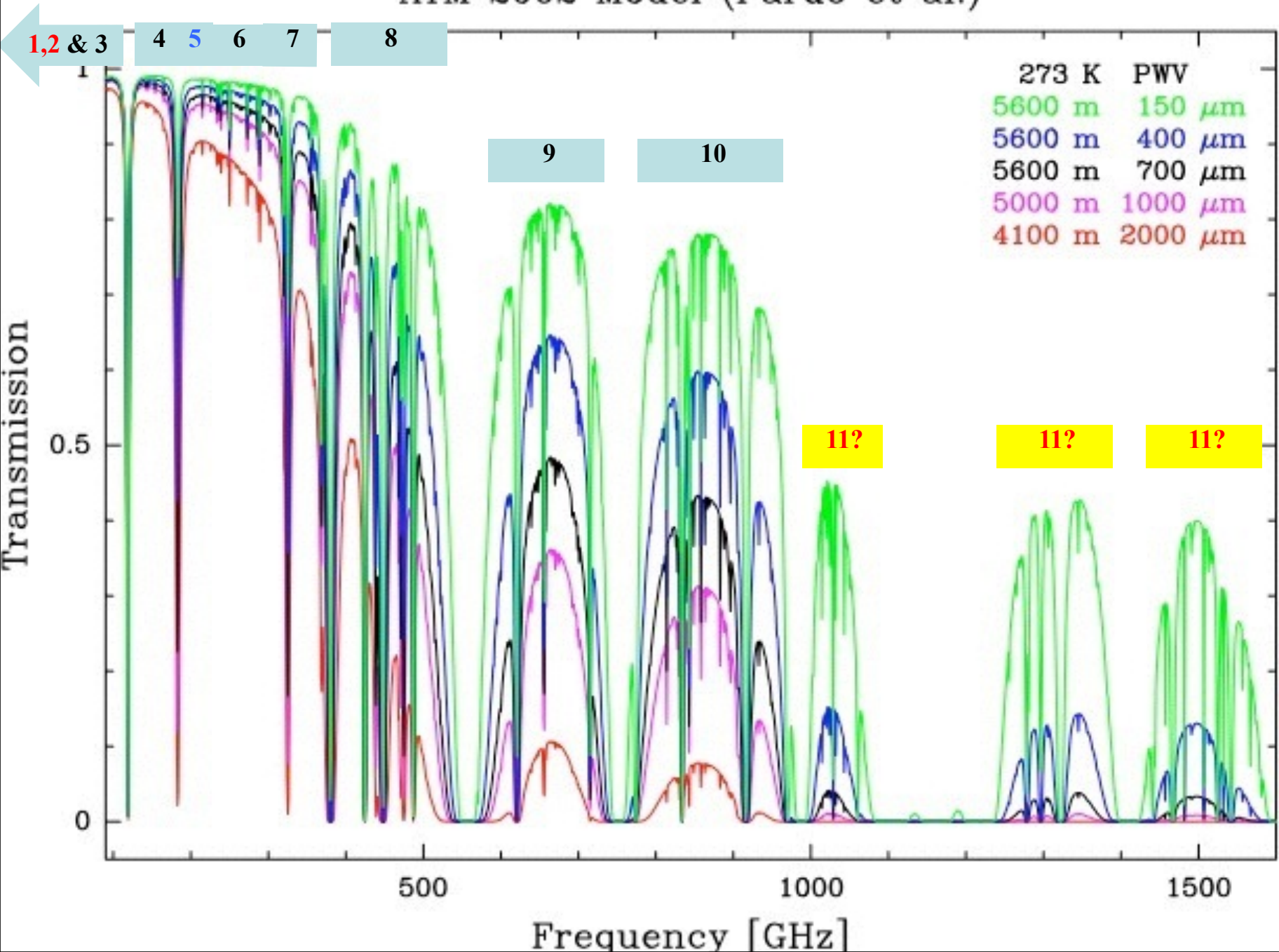
- ALMA is now in a consolidation phase, focusing at completing construction
- Additional capabilities will be added in the coming years in Cycle 3 and towards Full Science
 - Line pol, Solar, Long baselines, band 10 and 5
- APEX Extension/ARO
 - Submm Survey Telescopes
- Full Science & Development
 - Expected from 2014/2015



ALMA beyond ALMA

- ❑ ALMA will allow transformational science thanks to the sensitivity, angular resolution, spectral coverage and image fidelity, but...
- ❑ The baseline ALMA project will only achieve a fraction of the full potential of the site and instrument
- ❑ Incomplete Receiver Complement
- ❑ Limited Wide Field Capabilities
- ❑ Limited Correlator and Data Rate Capabilities
- ❑ Extended baselines (30-50km), VLBI (200-10000km)
- ❑ Advanced Calibration, Software, Science Tools....

ATM 2002 Model (Pardo et al.)

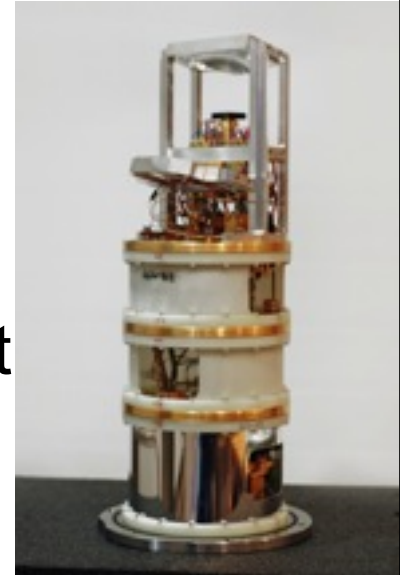


Band 5 Full Production Study

- ❑ Optimization of B5 design for production
- ❑ Completed Feb 2012

- ❑ Full production proposal prepared as part of the study - Approved Apr 2012

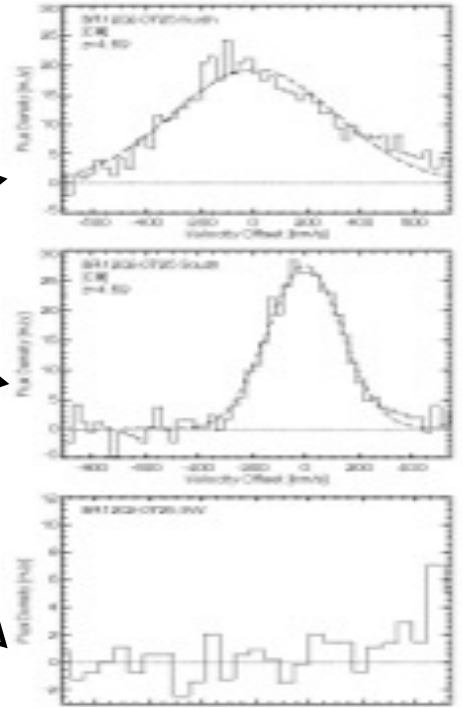
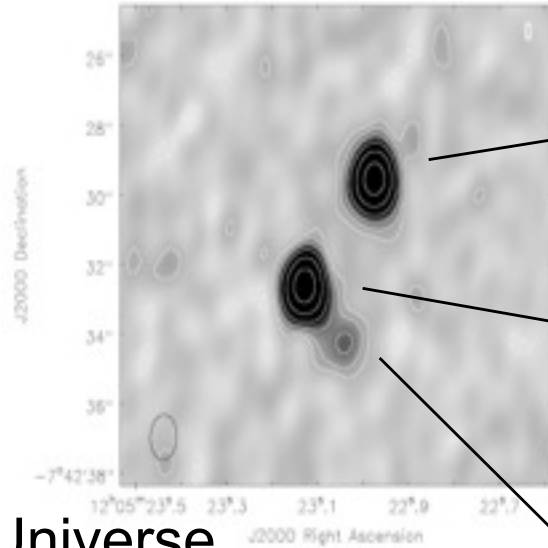
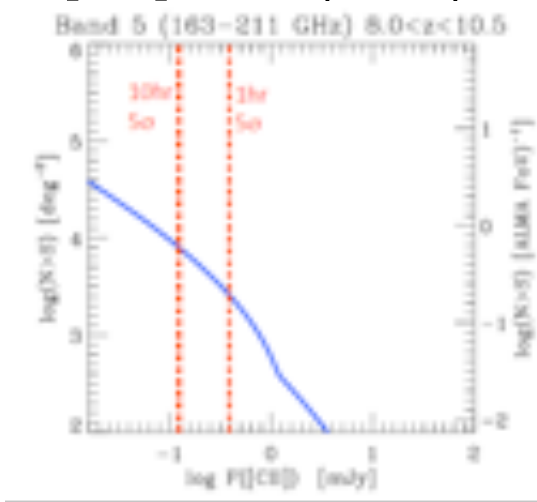
- ❑ Full production started on Feb 2013
 - Consortium led by NOVA (NL), includes GARD (S), with important contributions from NRAO
 - 67 cartridges to be delivered by 2017



Band 5 Science

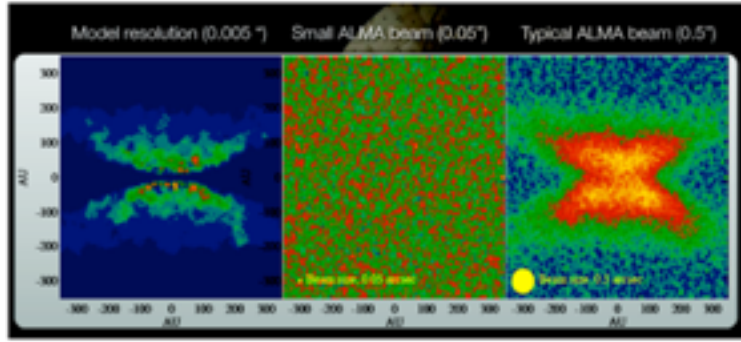
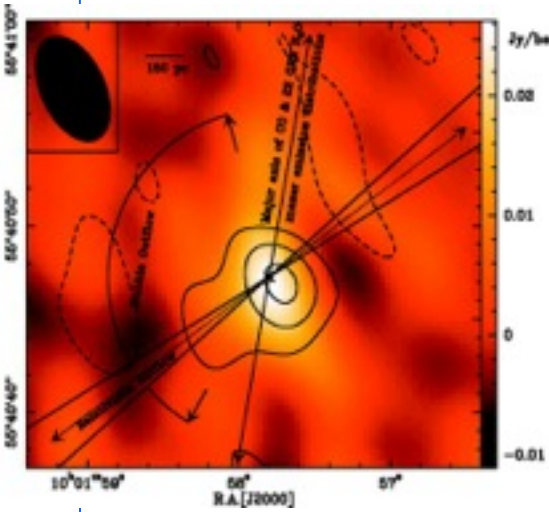


[CII] in $z \sim (8-10)$ and high-ex CO at high- z



Water in the local Universe

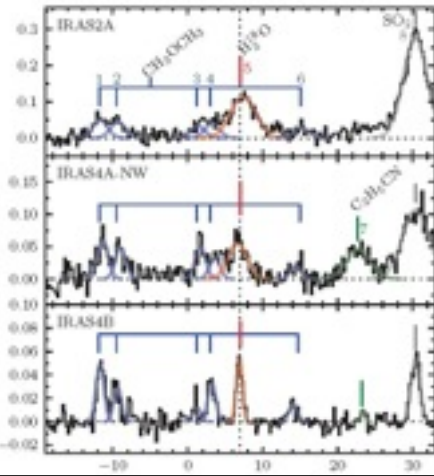
(Humphreys et al. 2005)



(Brinch 2010)

Nov 2013

Perrsson et al. 2012



. 2012)

Underlying concepts

- Work with institutes in ESO MS (expertise and funding opportunities)
- Develop a strategy based on science priorities from the user community

Procedures and policies

- Follow standard ESO practices, adapted for the ALMA context
- Competitive open Calls for Studies to develop science cases, designs, limited R&D in synergy with European/national/institute funding
- Mature study results are brought to ALMA for implementation as projects

Overarching goal

- Future key science requires: expanded frequency range, improved sensitivity, efficiency in spectral scans
- Strategy: fill in missing bands, develop next generation wideband-wideIF receivers, develop backend/correlator/software to handle these
- Develop a strategic approach to full system upgrade

The ALMA Context

Four ALMA Development Projects running

- Fiber link to Calama
- Full production of Band 5 (2013-2017)
- Prototype and Production of ALMA Band 1 (2013-2018)
- ALMA Phasing Project (2013-2015) and mmVLBI (2015-2016?)

Studies in the other regions

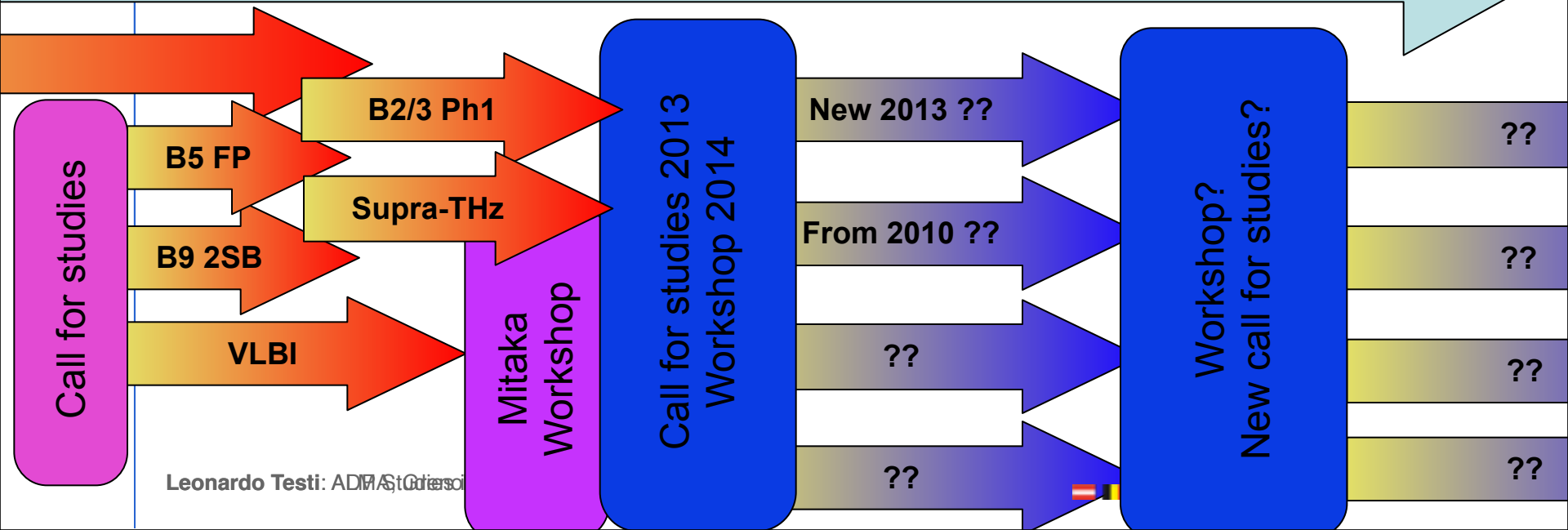
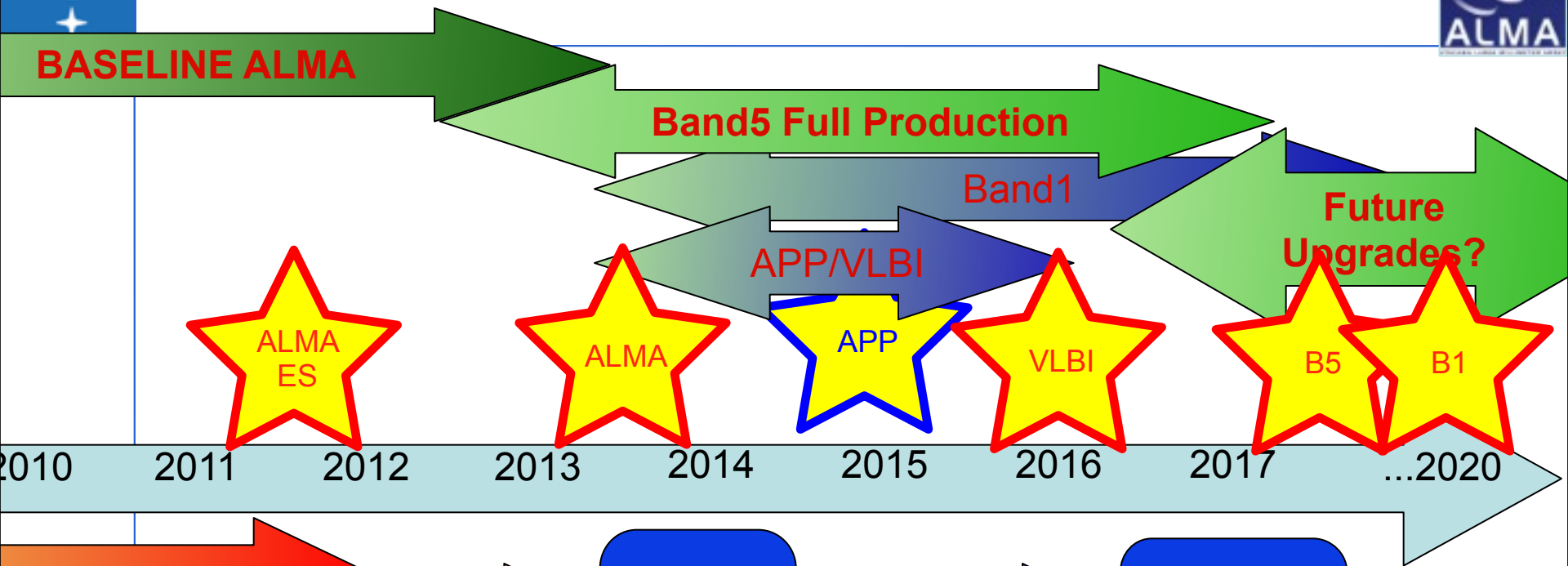
- Yearly study cycles in NA since 2012 (note also call for projects in 2013)
- Different selection process in EA

Coordination

- Process started independently in the three regions
- Executives-ASAC workshop in Feb 2013
- Working on planning a community workshop in 2014



Timeline summary



Upgrade paths





- ❑ Develop new generation receivers
 - Wider frequency coverage
 - Wider instantaneous bandwidth (≥ 16 GHz/pol)
 - Possibly start thinking about focal plane receivers
 - Upgrade of receivers, new bands, new concepts

- ❑ Develop upgrade path for digital electronics

- ❑ Develop upgrade paths for software system

- ❑ New calibration methods/algorithms and obs modes

Call 2013

-  Call and deadline over the 2013 Summer
-  Review completed in the Fall, discussion at ESAC/
STC Oct meetings
-  Studies kick-off 2014, lifecycle 2014-2016
-  Broader perspective:
 - Coordinate call timing with other executives
 - Common discussion with ASAC/ADSC

Summary



ALMA is producing transformational science!

- Key role of the ARC Network in Europe (thanks!!)



ALMA ES is just the beginning!

- Cycle 2 – 5 Dec 2013 – additional capabilities and time (bands, pol, spectral scans)
- Full Science Operations in 1-2yrs



ALMA is a long lifetime observatory with a healthy Development Plan

- Participation in the ALMA Upgrade Studies is important
- New cycle of studies will start in early 2014