Summary of ALMA Cycle 1 and 2

December 2016

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Contributors

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1 Executive Summary

This document summarises the final statistics related to ALMA Cycle 1 and 2 of Early Science observations, including the data reduction and delivery statistics. It includes publications statistics which show the overarching interest of the astronomy community in ALMA and the high quality of the delivered data.

For an overview of ALMA's science results, see the ALMA Science Portal at http://almascience.org/folder-for-science and browse the proceedings of the science conference 'Revolution in Astronomy with ALMA – the 3rd Year' (ASP Conference Series Volume 499) and the website of the conference `Half a Decade of ALMA Astronomy' (http://www.cvent.com/events/half-a-decade-of-alma-cosmic-dawns-transformed/custom-20-12c52aba230240578621efced142116e.aspx).

2 ALMA Cycle 1 and 2

Cycles 1 and 2 are the second and third Early Science (ES) periods that were made available to the international ALMA community for Principal Investigator (PI) science on a "best efforts" basis, meaning that priority was given to the completion of the full 66 element array and the commissioning and delivery of the full ALMA capabilities. Cycle 1 and 2 PIs shared risk with ALMA, and project completion was not guaranteed. Major new capabilities for cycle 1 included: ACA, and maximum baselines out to 1 km, while for cycle 2: Band 4 and Band 8 receivers (~150 GHz and ~460 GHz respectively), polarization (on-axis, continuum only, Bands 3, 6 and 7) and maximum baselines out to 1.5 km.

Cycle 1 PI observing officially began on January 1, 2013 with a total of 800 h allocated to PI science observations. Cycle 1 finished at the end of May 2014, with uncompleted A and B-graded programmes transferred to Cycle 2.

Cycle 2 PI observing began on June 3, 2014. In addition to ~1700 h allocated to Cycle 2 A- and B-graded proposals, there were 428 h of Cycle 1 Highest Priority projects that transferred into Cycle 2 (see November 2014 Status Update in the SP at http://almascience.org/documents-and-tools/cycle-2/alma-status-update-november-2014).

Cycle 2 extended through the end of September 2015. Only incomplete Cycle 2 A-graded proposals were transferred into Cycle 3, regardless of the overall completion percentage.

From March 2014 Early Science (ES) observing "blocks" were scheduled from Tuesdays to Mondays over a three-week cycle for two consecutive ES weeks, followed by one week dedicated to improving and extending array capabilities (EOC week). During ES observing blocks, science observations were scheduled 16h per day on weekdays, with 24h observing on the weekends.

3 Observing Statistics

Table 1 gives the statistics of all the ES observing blocks allocated to Cycle 1 observations from end of October 2013 until the completion at the end of May 2014 for the 12-m Array observations (see also Cycle 1 status updates in the SP news items). The table presents the following information: (1) the ES observing block number; (2) the dates of the observing block; (3) the time allocated for ES observing; (4) the time associated with successful executions of PI science observations; (5) the Science execution efficiency (the fraction of the scheduled time used for successful PI observations divided by the allocated time); (6) the overall observing efficiency (time spent on successful PI observations divided by the allocated time and excluding any weather downtime); (7) the average number of antennas available during the executions; and (8) the approximate configuration[1] of the available 12-m antennas, using the naming convention given in the Cycle 1 Proposers Guide (where the most compact configuration is called C32-1, and the most extended is called C32-6). Table 1 indicates that fewer 12-m Array antennas was on the average available compared to what was advertised in Cycle 1 (~27 compared to 32), although the situation improved towards the end of Cycle 1. This means that more time was needed to obtain the PI requested sensitivity.

Table 1: Cycle 1 Observing Session summary for the 12-m Array from October 2013 to May 2014

(1) Block	(2) Dates	(3) Allocated time (h)	(4) Successful Executions (h)	(5) Science Execution Efficiency (%)	(6) Overall Observing Efficiency (%)	(7) Average number of antennas	(8) Approx. 12-m Array config.
19	Oct 30-Nov 5	105.8	54.6	52%	52%	27.8	C32-3
20	Nov 13-20	122.7	53.0	43%	43%	27.8	C32-3
21	Nov 27-Dec 3	103.5	58.3	56%	56%	25.3	C32-3
22	Dec 11-17	107.0	40.2	38%	38%	27.7	C32-2
23	Dec 25-31	107.3	31.2	29%	30%	26.8	C32-2
24	Jan 8-14	108.7	16.6	15%	16%	24.1	C32-1
25	Jan 22-28	100.0	20.3	20%	34%	24.9	C32-1
26	Feb 20-25	80.0	40.4	51%	51%	27.0	C32-2
27	Mar 5 - 11	105.2	45.6	43%	43%	27.1	C32-3
28	Mar 19 - 25	112.6	54.4	48%	49%	30.5	C32-3
29	Apr 2 - 8	131.6	21.5	16%	23%	33.8	C32-4
30	Apr 9 - 15	98.9	18.0	18%	18%	32.5	C32-4
31	Apr 23 - 29	98.6	47.9	48%	49%	34.9	C32-5
32	Apr 30-May 6	80.6	25.9	32%	40%	33.0	C32-5
33	May 14 - 20	37.1	12.0	32%	32%	30.5	C32-6
34	May 21 - 27	10.0	3.5	35%	35%	34.0	C32-6
	TOTAL	1509.3	543.4	36%	38%	27.8	

Table 2 gives the statistics of all the ES observing blocks since the start of Cycle 2 until the completion at the end of September 2015 for the 12-m Array observations. The table

[1] The configurations are considered "representative", since the array is seldom exactly in one of the advertised Cycle 1 configurations (due to antenna or receiver maintenance or other issues).

presents the same information as in Table 1: (1) the ES observing block number; (2) the dates of the observing block; (3) the time allocated for ES observing; (4) the time associated with successful executions of PI science observations; (5) the Science execution efficiency (the fraction of the scheduled time used for successful PI observations divided by the allocated time); (6) the overall observing efficiency (time spent on successful PI observations divided by the allocated time and excluding any weather downtime); (7) the average number of antennas available over the session; and (8) the approximate configuration[2] of the available 12-m antennas, using the naming convention given in the Cycle 2 Proposers Guide (where the most compact configuration is called C34-1, and the most extended is called C34-7. Configurations listed with a slash indicate that the configuration contained sufficient baselines to approximate either configuration). The numbers in first nine ES observing blocks differ slightly from the numbers presented in the November 2014 ALMA Status Update due to updates and improvements in the reporting procedures and the system used to produce the observing statistics.

Overall, 2084 h of successful 12-m Array executions have been obtained. An additional 1532 h of successful executions have been completed on the ACA (578h with the 7-m Array and 954h with the TP Array). These values include some Cycle 2 C-graded proposals that were observed when no higher priority projects suited to the prevailing conditions were available. The overall science execution efficiency matches the number adopted for Cycle 2 planning (50%). The trend was encouraging, with most observing blocks achieving efficiencies well above this value. Since December, the average number of antennas used for 12-m Array observations consistently exceeded the planned number for Cycle 2 (34).

Table 2: Cycle 2 Observing Session summary for the 12-m Array through September, 2015

(1) Block	(2) Dates	(3) Allocated time (h)	(4) Successful Executions (h)	(5) Science Execution Efficiency (%)	(6) Overall Observing Efficiency (%)	(7) Average number of antennas	(8) Approx. 12-m Array config.
1	Jun 3-10	109.6	38.4	35%	47%	34.2	C34-4
2	Jun 10-17	125.7	57.4	46%	54%	34.5	C34-4
3	Jun 24-July 1	112.3	39.4	35%	57%	31.2	C34-4
4	Jul 1-8	124.7	35.3	28%	48%	31.6	C34-4
5	Jul 15-22	122.4	50.4	41%	52%	32.4	C34-4/5
6	Jul 22-29	116.4	49.4	43%	60%	31.3	C34-5
7	Aug 5-12	124.0	7.8	6%	26%	31.4	C34-5
8	Aug 12-19	122.2	32.6	27%	42%	33.6	C34-5/6
9	Aug 26-Sep 1	118.4	65.8	56%	80%	34.7	C34-6
10	Dec 2-9	114.4	65.6	57%	68%	32.5	C34-1/2
11	Dec 9-16	84.5	55.7	66%	75%	38.2	C34-1/2
12	Dec 23-30	130.0	83.7	64%	80%	39.0	C34-1/2
13	Dec 30-Jan 6	130.3	88.3	68%	77%	37.1	C34-1/2
14	Jan 13-20	123.4	83.3	68%	73%	35.3	C34-1/2
15	Jan 20-27	124.0	42.8	35%	81%	37.3	C34-1/2
16	Jan 27-Feb 2	119.2	18.2	15%	62%	37.2	C34-1/2
17	Mar 31-Apr 7	121.7	56.9	47%	68%	37.3	C34-1/2

18	Apr 7-14	125.2	59.2	47%	92%	37.2	C34-1/2
19	Apr 21-28	118.5	51.3	43%	62%	38.2	C34-1/2
20	Apr 28-May 5	119.7	63.7	53%	64%	36.9	C34-1/2
21	May 12-19	119.2	96.3	81%	87%	37.3	C34-3/4
22	May 19-26	124.2	84.0	68%	83%	35.5	C34-3/4
23	Jun 2-9	119.7	86.9	73%	83%	37.5	C34-4/5
24	Jun 9-16	126.0	97.9	78%	85%	36.4	C34-4/5
25	Jun 23-30	120.0	79.3	66%	68%	41.1	C34-6/7
26	Jun 30-Jul 6	117.3	59.7	51%	70%	41.0	C34-6/7
27	Jul 15-20	118.0	79.4	67%	75%	41.5	C34-6/7
28	Jul 21-27	124.3	74.0	60%	60%	41.9	C34-6/7
29	Aug 4 - 10	114.0	50.6	44%	59%	40.9	C34-4/5
30	Aug 11 - 17	110.0	61.0	56%	60%	39.5	C34-6/7
31	Aug 25 -31	119.3	79.2	66%	66%	37.4	C34-6/7
32	Sep 1 - 7	131.1	62.0	47%	68%	34.1	C34-6/7
33	Sep 15 - 22	113.5	55.6	49%	52%	35.0	C34-6/7
34	Sep 22 -28	107.4	72.3	67%	67%	34.0	C34-6/7
	TOTAL	4050.6	2083.6	51%	58%	36.4	

[2] The configurations are considered "representative", since the array is seldom exactly in one of the advertised Cycle 2 configurations (due to antenna or receiver maintenance or other issues). At any given time the array should be in a configuration with similar imaging properties – resolution and Maximum Recoverable Scale – as one of the representative configurations.

4 Completion Statistics

The progress towards project completion is given in Tables 3 & 4, separately for Cycle 1 and Cycle 2 and separately for High Priority Projects and Fillers (C-graded Projects). Partially completed projects contain part of the individual components (OUSs) that make up projects. Each OUS consists of scientifically meaningful data.

Table 3: Cycle 1 Project Summary

Final State	Number of High Priority & DDT Projects	Number of Filler Projects
Accepted	198	93
Completed	138 (70%)	14 (15%)
Partially completed	51 (25%)	20 (22%)
Not started	9 (5%)	59 (63%)

Table 4: Cycle 2 Project Summary

Final State	Number of High Priority (grade=A,B) &	Number of Filler Projects

	DDT Projects	(grade=C)
Accepted	357	159
Completed	206 (58%)	24 (15%)
Partially completed	111 (31%)	47 (30%)
Not started	40 (11%)	88 (55%)

Overall, these tables show that the majority of projects have useful data, but the fraction of completed projects remains fairly low. At the end of the observing season, all incomplete Cycle 2 A-graded SBs were transferred to Cycle 3, while the incomplete Cycle 1 and Cycle 2 B-graded components were set to "ObservingTimedOut" and delivered once they achieved a status of QA2_PASS or QA2_SEMIPASS (see: http://almascience.org/documents-and-tools/cycle-2/alma-qa2-products-v2.2/view).
All projects which have passed QA0 are visible in the archive and PIs may request the delivery of these data.

5 Data reduction and delivery

Data delivery is performed once the second level of Quality Assurance (QA2) of data reduction using the calibration pipeline and/or performed manually by the ALMA Data Reducers Team is performed. This process implies a detailed analysis to confirm that the observations have achieved the science goals requested by the PI (frequency setup, spatial setup, and continuum and/or line detection sensitivity). If the requirements are met, the data are declared "QA2 pass", packaged in a standardized way, and delivered to the PI.

In Cycles 1 and 2, the MemberOUS (or MOUS: the smallest scheduling entity which is processed and delivered individually) contains in all cases only one Scheduling Block (SB), even in the case of Total Power Array observations.
Hence, in Cycles 1 and 2, QA2 is carried out together on all the Execution Blocks (EBs) of a single SB corresponding to one MOUS. The products for each MOUS are delivered separately, and the delivery of the products for each MOUS is labeled with the MOUS UID.

Details about the Quality Assurance stage 2 and the data delivery products can be found in the document in the Science Portal under http://almascience.org/documents-and-tools/cycle-2/alma-qa2-products-v2.2/.

A number of projects (roughly 60%) did not run through the calibration pipeline, including observing modes that were not implemented in the pipeline (e.g. Total Power, polarization, high frequency, bandwidth switching) or projects that fail pipeline processing (e.g. low signal-to-noise calibrators, poor phase stability). These data have been manually processed by experts at the JAO and ARCs.

As a result, PIs received data that were calibrated either manually or by the pipeline. All the imaging has been made manually.

We remind all researchers that there are opportunities to visit their regional ARCs or ARC nodes to work on proprietary or archival ALMA data. Visit requests should be submitted using the ALMA helpdesk (http://help.almascience.org). Researchers receiving assistance from an ARC or ARC node should add this to the standard ALMA acknowledgement (see http://almascience.org/alma-data/publication-acknowledgement) to be included in all publications making use of ALMA data.

6 Publication Statistics

We show in Figures 5-10 the number of publications which make use of ALMA Cycle 1 and 2 data. The reader should be aware that the final delivery of cycle 2 data occurred in March 2016 and many of the Cycle 2 projects are still in proprietary time and publications may be under way.

The figures highlight the scientific outcome made possible with the ALMA data. They hint at the extraordinary quality of the ALMA data and the interest of our community in the science with ALMA.

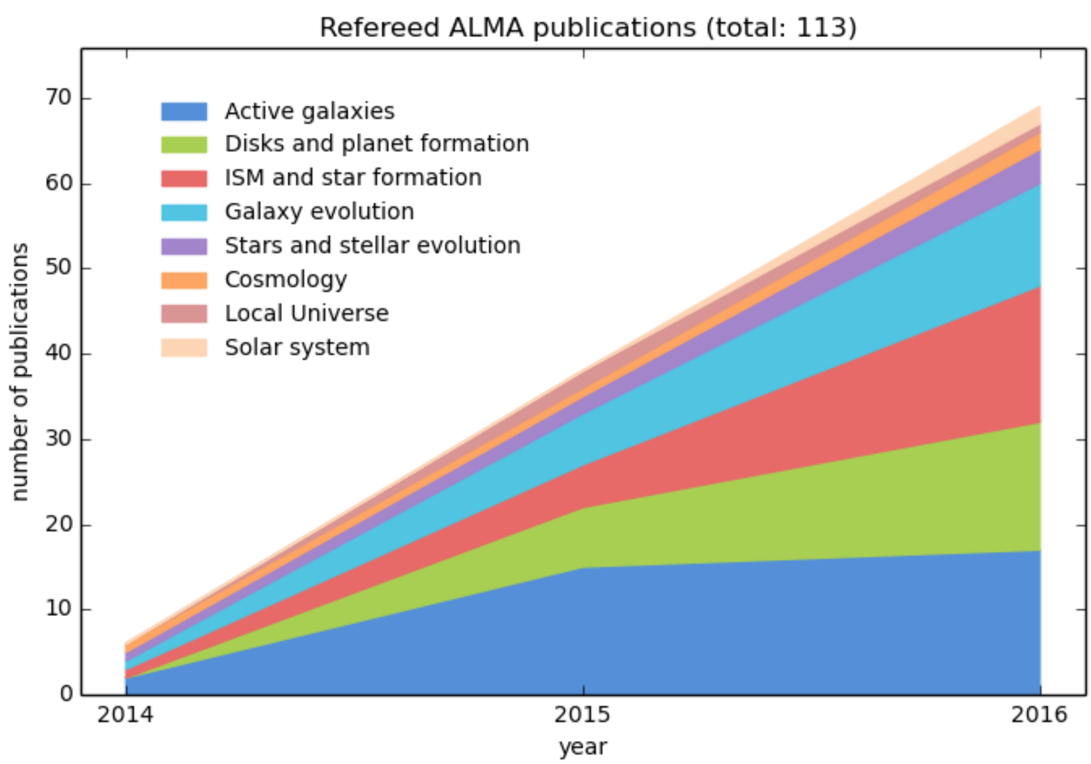

Figure 5: Number of publications based on Cycle 1 data divided by scientific categories extracted from the keywords defined by the authors, as of Dec 12, 2016

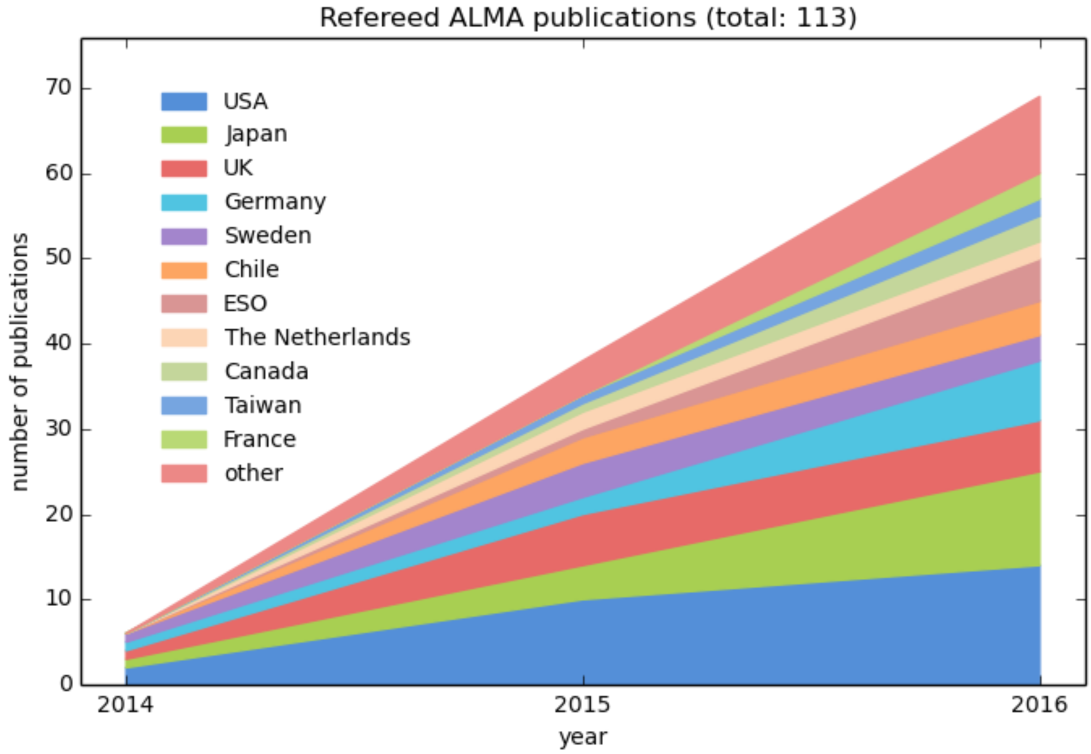

Figure 6: Number of publications making us of Cycle 1 only data divided by countries defined by the PI affiliation of the associated project, as of Dec 12, 2016.

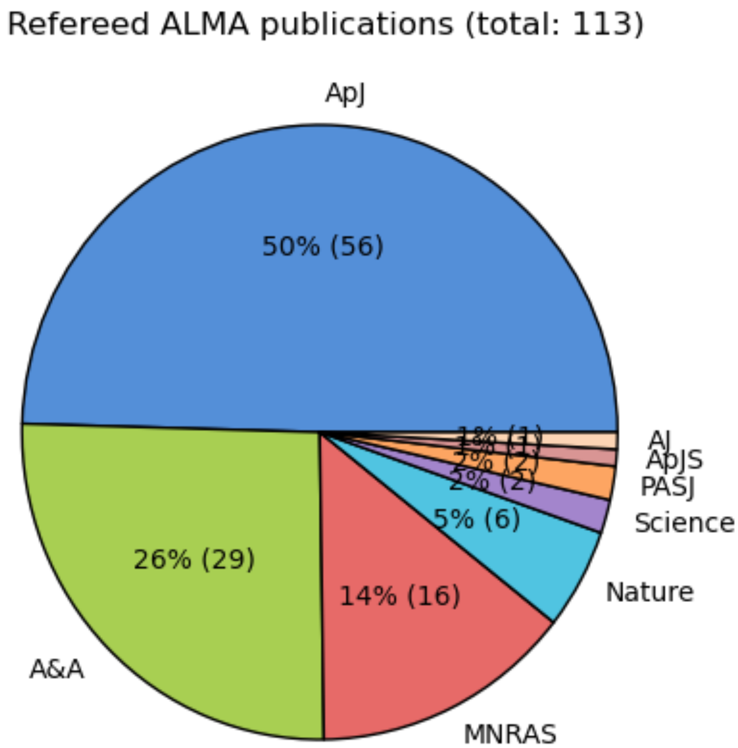

Figure 7: Pie chart containing the percentage of publications based on Cycle 1 data in main astronomical journals, as of Dec 12, 2016.

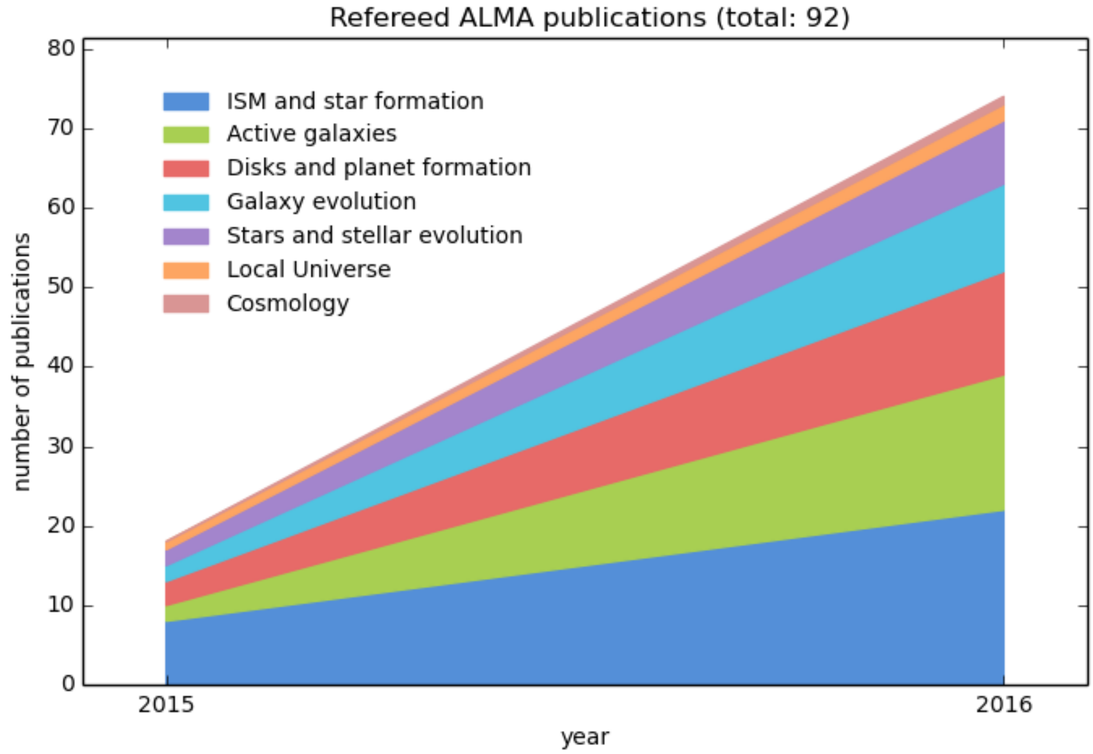

Figure 8: Number of publications based on Cycle 2 data only divided by scientific categories extracted from the keywords defined by the authors, as of Dec 12, 2016.

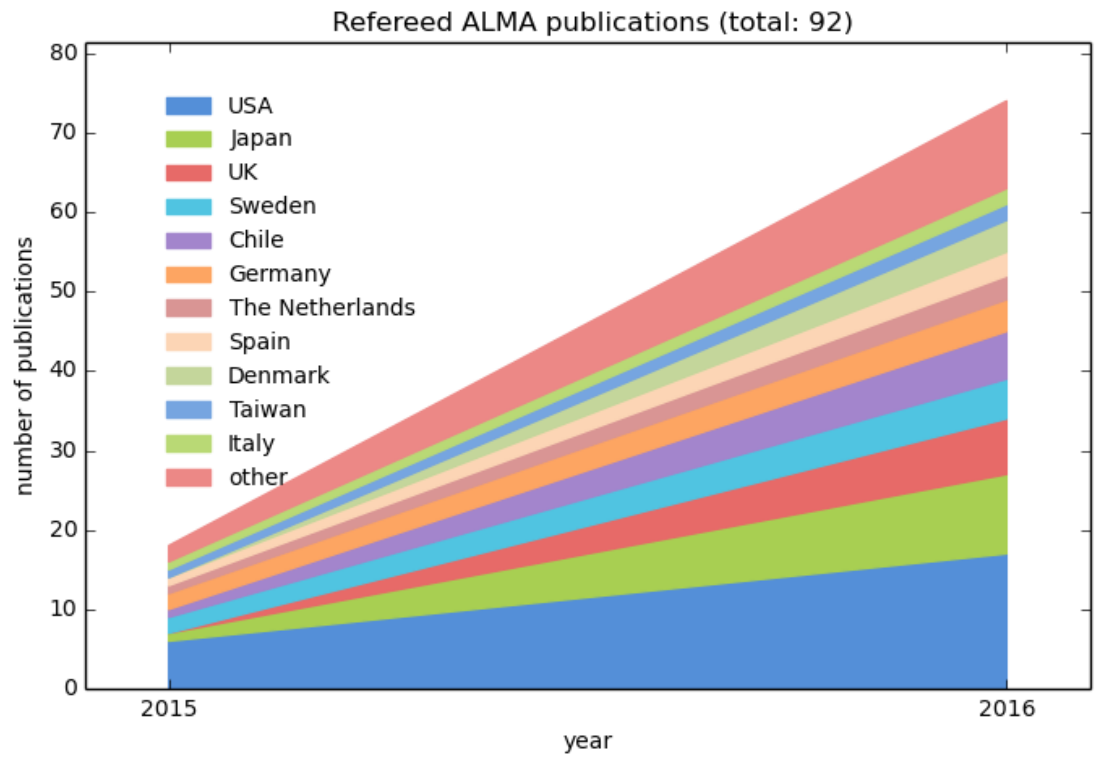

Figure 9: Number of publications making us of Cycle 2 only data divided by countries defined by the PI affiliation of the associated project, as of Dec 12, 2016.

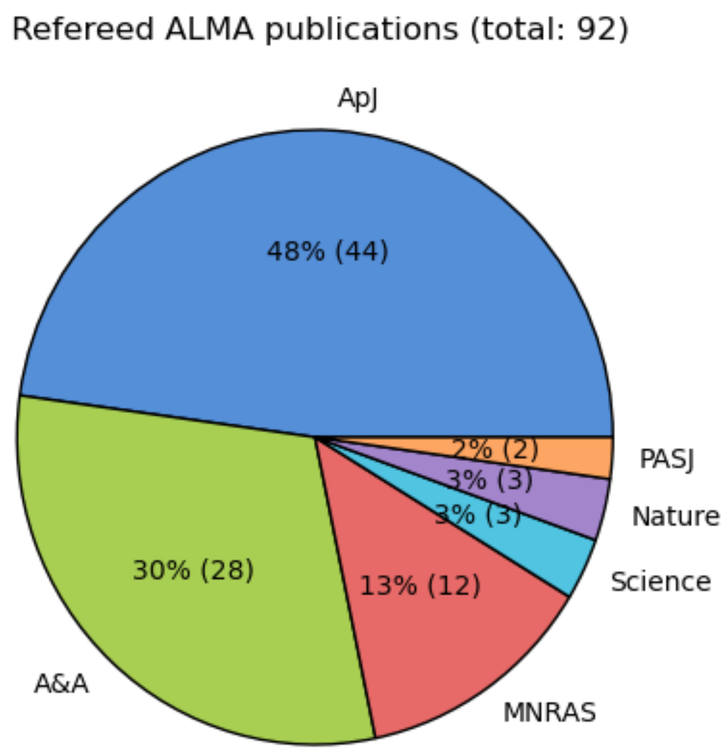

Figure 10: Pie chart containing the percentage of publications based on Cycle 2 data only in main astronomical journals, as of Dec 12, 2016.

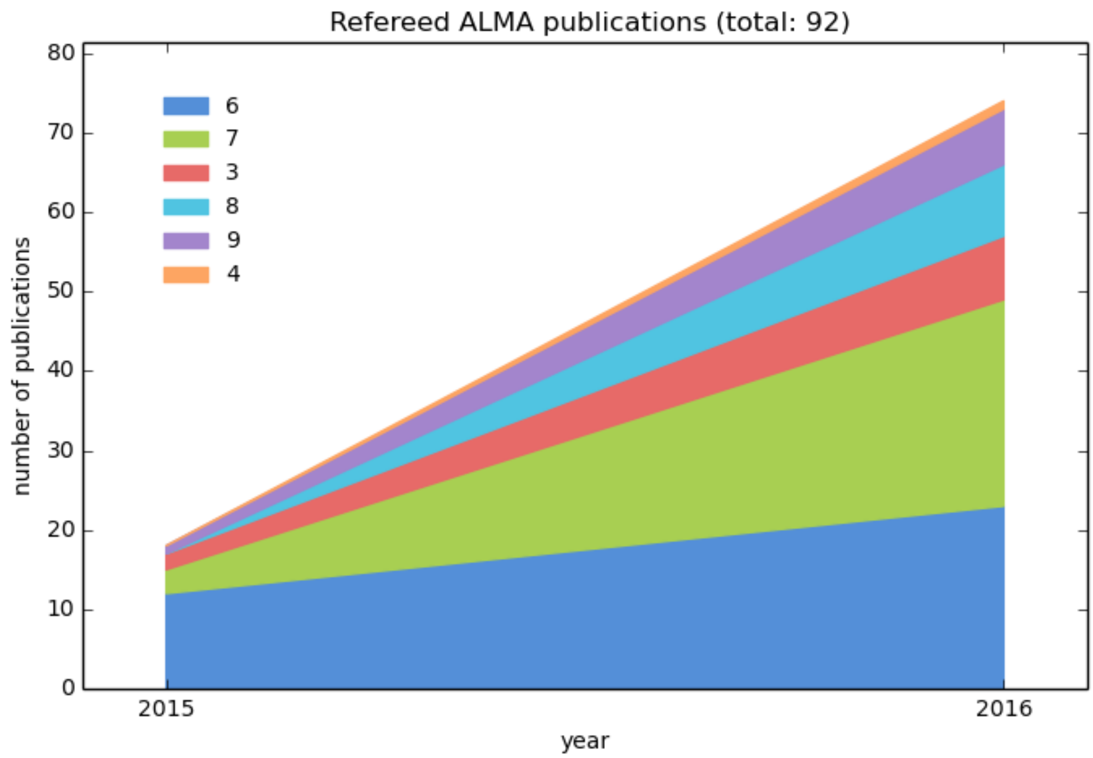

Figure 11: Number of Publications in Cycle 2 split by frequency bands, as of Dec 12, 2016.

As of 2016 November, the total number of citations for all cycles currently is 8181, of which the cumulative number of citations of publications making use of cycle 1 or cycle 2 data including DDT is 1419. That from Cycle 0 data is 7144.

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of the European Organization for Astronomical Research in the Southern Hemisphere (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA is funded by ESO on behalf of its Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI).

ALMA construction and operations are led by ESO on behalf of its Member States; by the National Radio Astronomy Observatory (NRAO), managed by Associated Universities, Inc. (AUI), on behalf of North America; and by the National Astronomical Observatory of Japan (NAOJ) on behalf of East Asia. The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.