EUROPEAN ARC
ALMA Regional Centre

Calibrating ALMA

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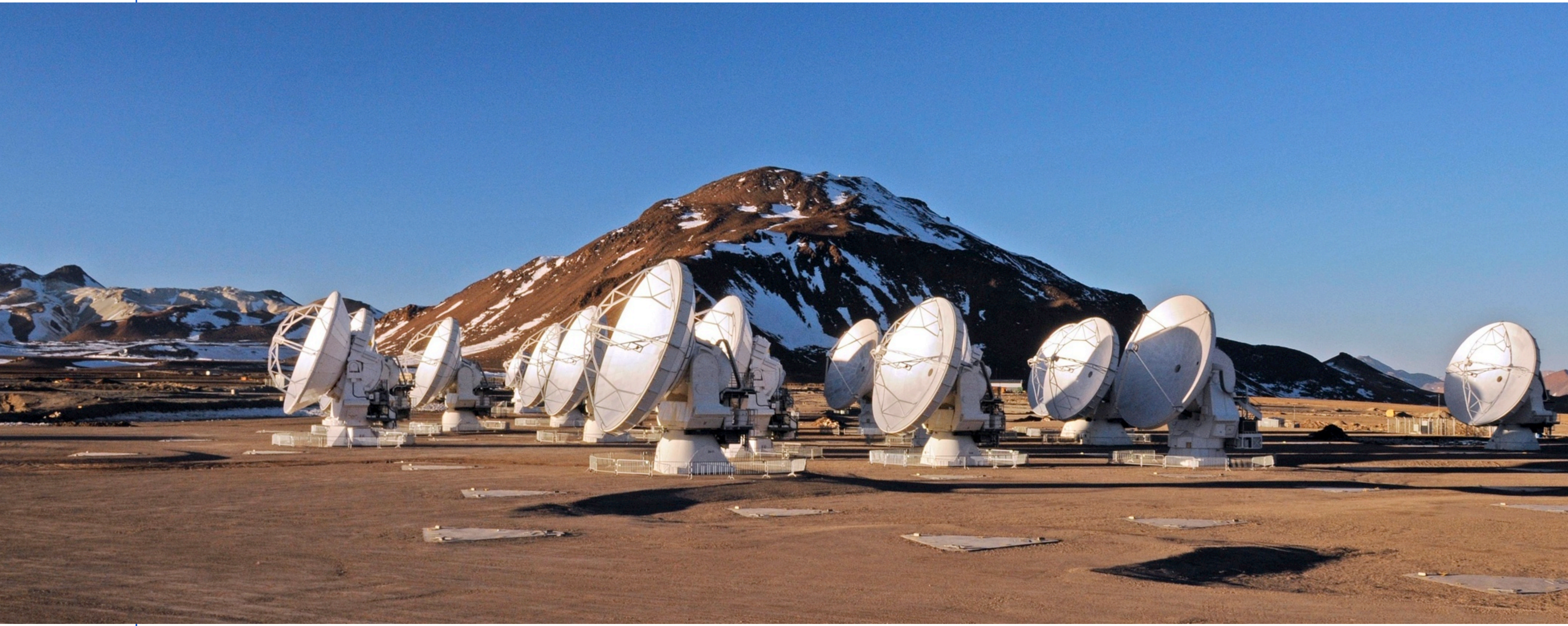


Long- and short-term calibration

Two basic types of calibration:

- *long-term effects*: no need to calibrate before a given science observation – done periodically by ALMA staff

- *short-term effects*: need to be measured before/during the science observations – involvement of many people

Long-term effects

- All-sky pointing (correcting overall antenna and pad imperfections)
- Focus models
- Baseline vectors (actual relative telescope positions: they move !)
- Cable delay (errors in the signal delay from receiver to correlator)
- Antenna characteristics (surface errors, beam patterns)

ALMA staff will carry out periodic measurements of these long-term effects and apply the required corrections to the ALMA system so that they are shared by all observational projects.

Short-term effects

- Offset pointing (residual pointing errors with respect to the all-sky pointing model)
- System and receiver temperature fluctuations
- Sideband ratio leakage
- Absolute flux calibration (weather, elevation, etc.)
- Bandpass (calibrating spectral response of the combined atmosphere and receiving system)
- Gain (amplitude & phase) fluctuations, due to atmospheric fluctuations in the troposphere at various timescales

Some of these calibrations are done at the beginning of a 'Scheduling Block' (basic unit of observation), some during the SB.

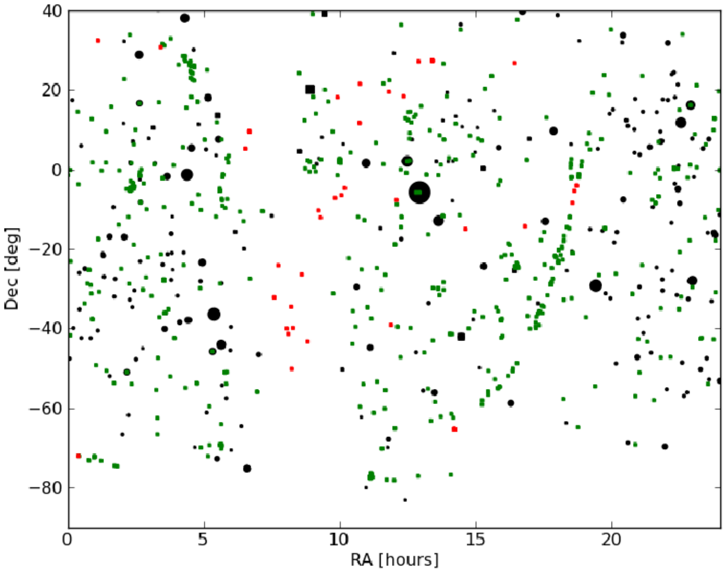
Two topics …

- WVR corrections

Recent paper:
Nikolic et al. (2013), A&A, in press
(arXiv:1302.6056)

- Dynamic calibrators

New in Cycle 1



ALMA's sky is dry … but not perfect

Atmospheric phase fluctuations

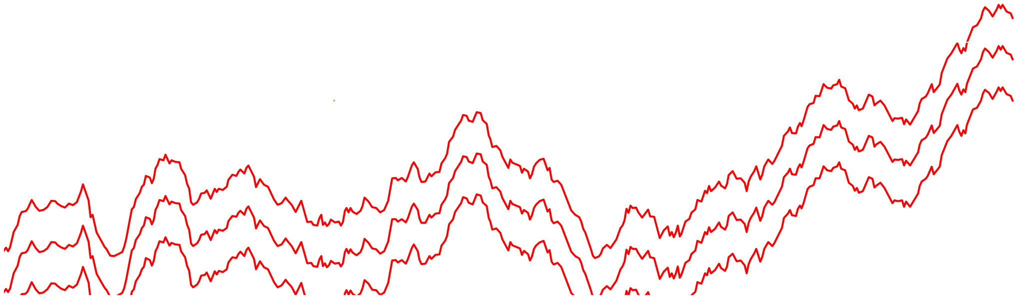
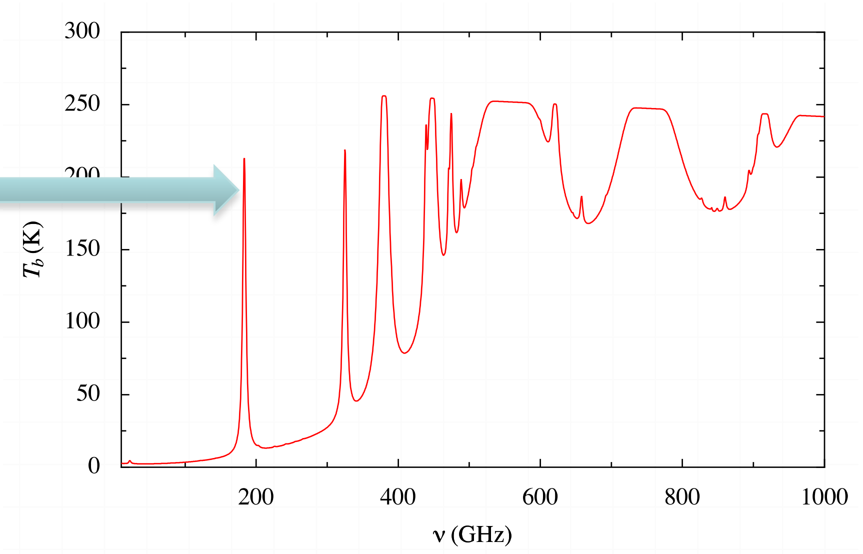


Figure: Bojan Nikolic

ALMA WVR system

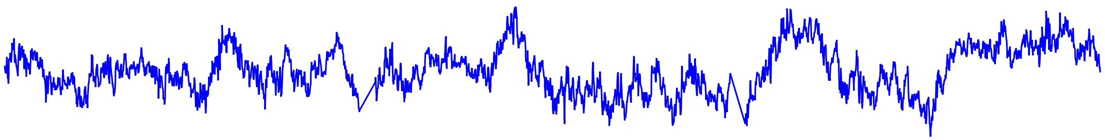
The Water Vapour Radiometry system on ALMA uses the 183 GHz water line



Each antenna has its own WVR receiver

WVR correction for a long (600m) baseline

Red: uncorrected phase; Blue: corrected phase



Running ALMA observations

- Observations are prepared using the ‘Observing Tool’
  (see the talk by Suzanna Randall tomorrow)
- This tool saves all the observing parameters in a structured ‘project file’, which is read by the telescope control software
- The basic unit of observation in a project is a Scheduling Block (SB), which is usually executed multiple times

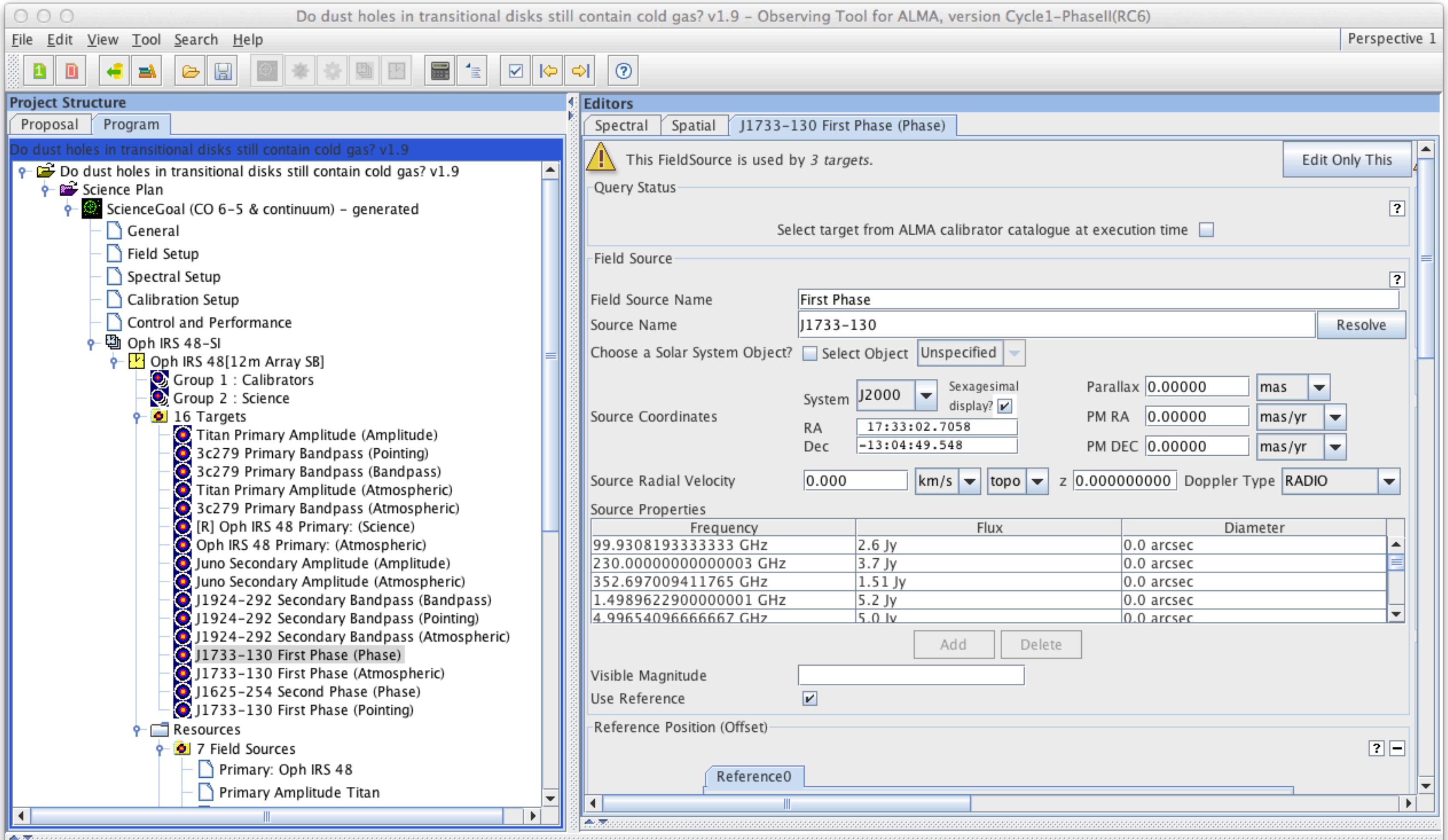
Special for ALMA Cycle 1: dynamic calibrator selection

SBs are full of calibrators …

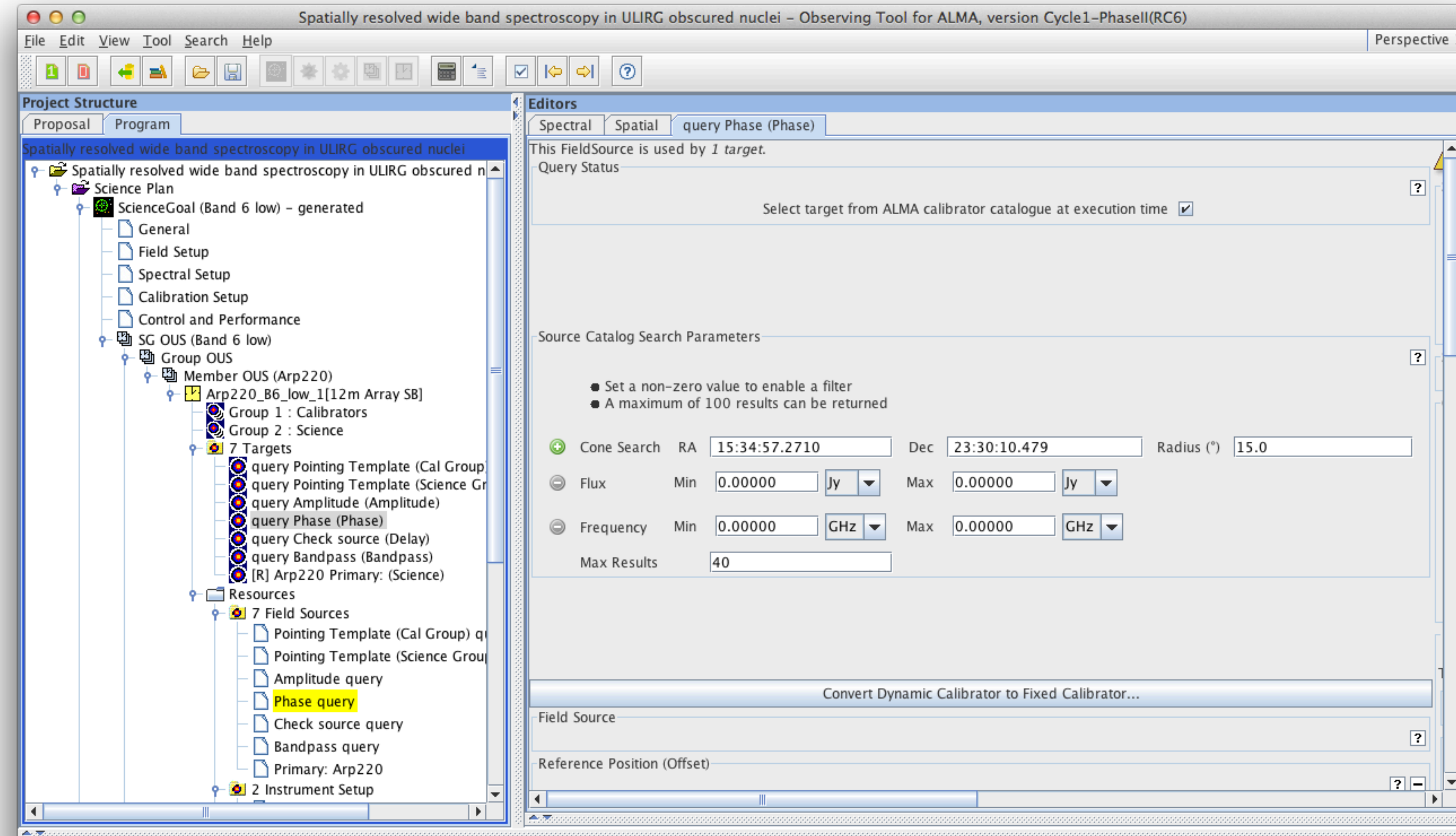
- Group 1: Calibration Group (with non-cyclic calibrators)
  - Pointing (e.g. near amplitude/bandpass calibrator) in B3/B6
  - Bandpass calibrator
  - Amplitude calibrator

- Group 2: Science Group (with cyclic calibrators)
  - Pointing (e.g. on phase calibrator) in B3/B6 (every hour)
  - Phase calibrator (every five minutes or so)
  - Science Target (rest of the time …)

Calibrator selection in Cycle 0



Calibrator selection in Cycle 1



Calibrator query

Main selection criteria:

- distance to science target
- signal to noise ratio and maximum integration time
- minimum elevation (to prevent shadowing)
- range in frequency

All calibrators are selected before actually taking data.

The query script searches the ‘live’ calibrator database, and rates each possible calibrator with a weighting scheme for the search parameters. The top choice is then selected for observation for the whole SB. This does not have to be the same choice for a repeat execution of the SB.

Data will not be taken if suitable calibrators can not be selected.

Dynamic calibrator selection

Phase calibrator selection example

Top five sources from selection script:

sname	sep (deg)	rating	flux (mJy)	fl_err (mJy)	last (yr)	number obs	FR
J2253+1608	9.8	0.22	2761	936	1.1	9	1.04
J2225+2118	11.3	0.07	125	12	0.5	1	1.06
J2217+2421	12.5	0.06	396	39	0.5	1	1.06
J2212+2355	13.7	0.05	239	23	0.5	1	1.06
J2219+1806	14.1	0.05	93	9	0.5	1	1.06

Dynamic calibrator selection

Bandpass calibrator selection example

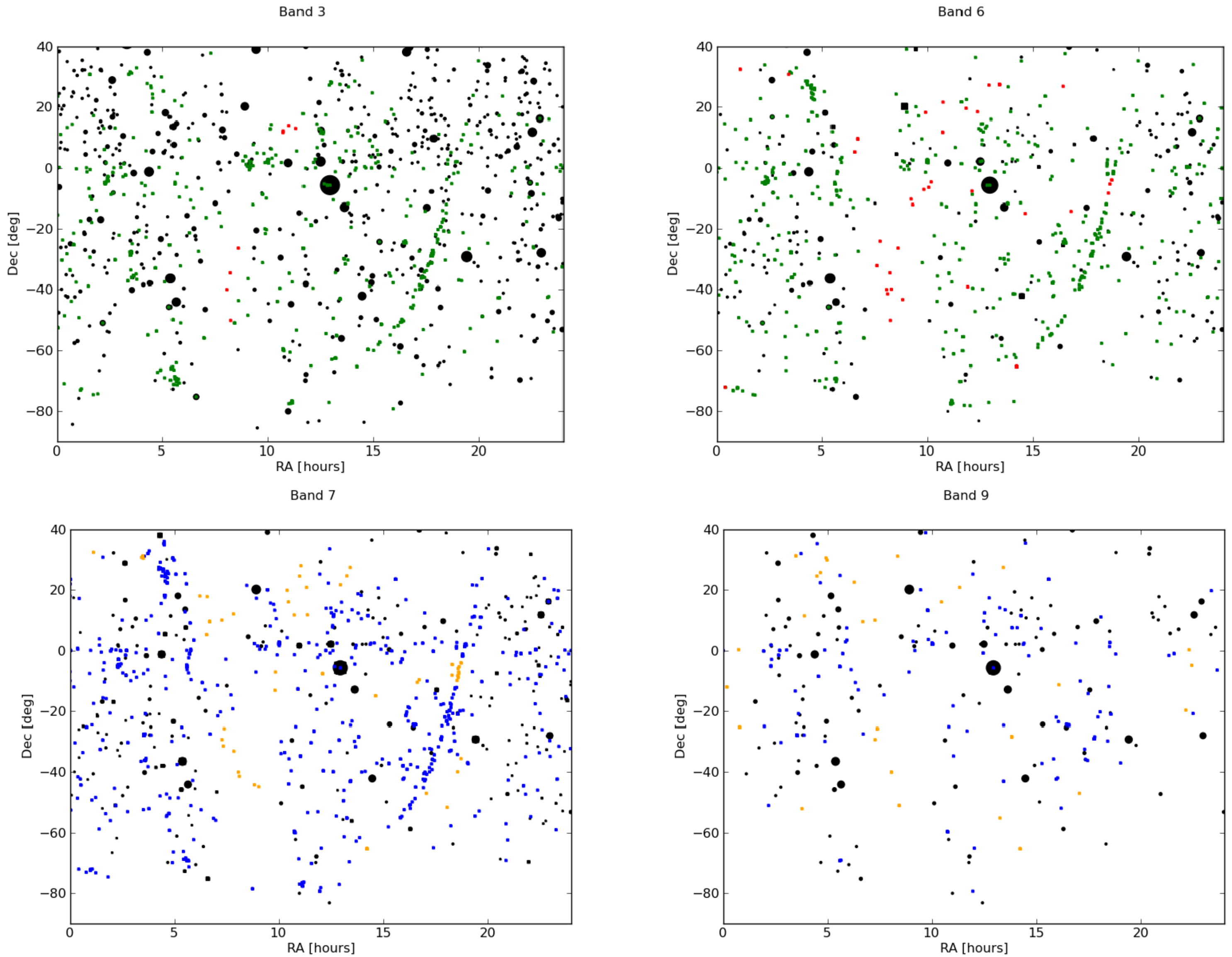
Top five sources from selection script:

sname	sep (deg)	rating	flux (mJy)	fl_err (mJy)	last (yr)	number obs	FR
J2232+1143	16.2	1.12	3827	1181	0.2	14	1.04
J2253+1608	9.8	0.98	2761	936	1.1	9	1.04
J2323-0317	28.4	0.22	829	88	1.1	6	1.04
J2334+0736	18.2	0.15	526	86	0.3	2	1.06
J2217+2421	12.5	0.14	396	39	0.5	1	1.06

Example of a simulated SB execution

$t_{\rm run}$	Scan	Source	$t_{\rm int}$	$N_{\rm sub}$	*BP*	*AMP*	*PHASE*	*SCI*	$\odot$	$\Updownarrow$	*atm*	*wvr*	*Setup*
0:00	1	J1427-4206	0:50	5					•			•	A
0:50	2	J1427-4206	1:00	2						•		•	B
1:50	3	J1427-4206	0:12	3							•	•	B
2:02	4	J1427-4206	1:00	2	•							•	C
3:02	5	J1427-4206	1:01	2						•		•	D
4:03	6	J1427-4206	0:11	3							•	•	D
4:14	7	J1427-4206	5:03	10	•							•	E
9:17	8	J1445-1629	0:50	5					•			•	A
10:07	9	Titan	0:12	3							•	•	B
10:19	10	Titan	2:31	5		•						•	C
12:50	11	J1625-2527	0:11	3							•	•	B
13:01	12	J1625-2527	0:31	1			•					•	C
13:32	13	IRAS_16293-2422	0:11	3							•	•	D
13:43	14	IRAS_16293-2422	6:33	13				•					E
20:16	15	J1625-2527	0:31	1			•					•	C
20:47	16	IRAS_16293-2422	6:33	13				•					E
27:20	17	J1625-2527	0:30	1			•					•	C
27:50	18	IRAS_16293-2422	0:11	3							•	•	D
28:01	19	IRAS_16293-2422	6:34	13				•					E
34:35	20	J1625-2527	0:11	3							•	•	B
34:46	21	J1625-2527	0:30	1			•					•	C
35:16	22	IRAS_16293-2422	6:33	13				•					E
41:49	23	J1625-2527	0:31	1			•					•	C
42:20	24	IRAS_16293-2422	0:11	3							•	•	D
42:31	25	IRAS_16293-2422	1:31	3				•					E
44:02	26	J1625-2527	0:30	1			•					•	C

ALMA Cycle 1 Calibrator database
(black points)



Further reading

ALMA Cycle 1 Technical Handbook, chaper 10

Available on the ALMA Science Portal: http://almascience.org/

Phase Correction for ALMA with 183 GHz Water Vapour Radiometers

Nikolic et al. (2013), A&A, in press (arXiv:1302.6056)

Phase Correction for ALMA: Adaptive Optics in the Submillimetre

Nikolic et al. (2008), ESO Messenger vol. 131

How ALMA is calibrated: I Antenna-based pointing, focus and amplitude calibration

van Kempen et al. (2012), ALMA Newsletter vol. 9 (arXiv:1210.1899)

Dynamic calibrator selection

On the ALMA Science Portal, in the near future …