

ACA Spectrometer

Shun Ishii, Jihyun Kang, Yusuke Aso, Hiroshi Nagai
on behalf of the ACA Spectrometer team

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ACA Spectrometer (ACASPEC)

- New backend for the Total Power array from an EA Development Program
- Development is led by KASI in collaboration with NAOJ

Engineering Team



Jongsoo Kim (PI)



Manabu Watanabe



Makoto Shizugami



Jongsuk Hong



Scott Zang



Susumu Nakayama

CSV Team



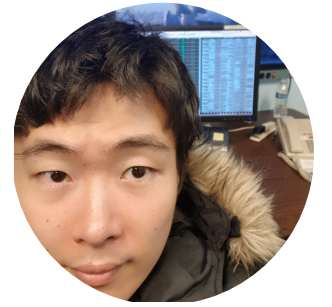
Shun Ishii



Jihyun Kang



Hiroshi Nagai



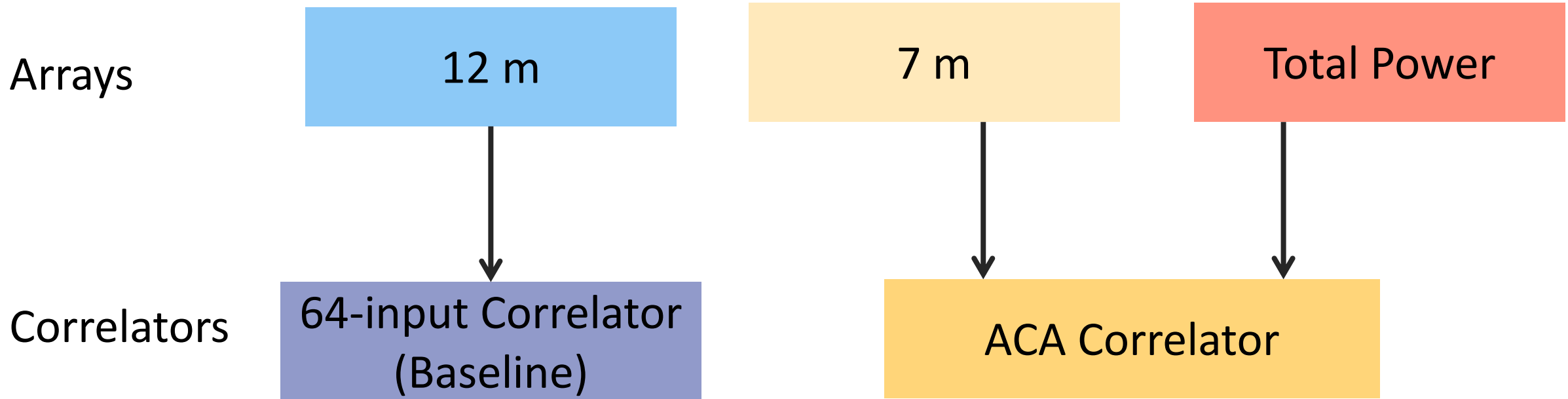
Yusuke Aso



ACA Spectrometer (ACASPEC)

- Replace the functionality of the ACA Correlator for the TP array
- Target to offer from Cycle 10

Current Configuration

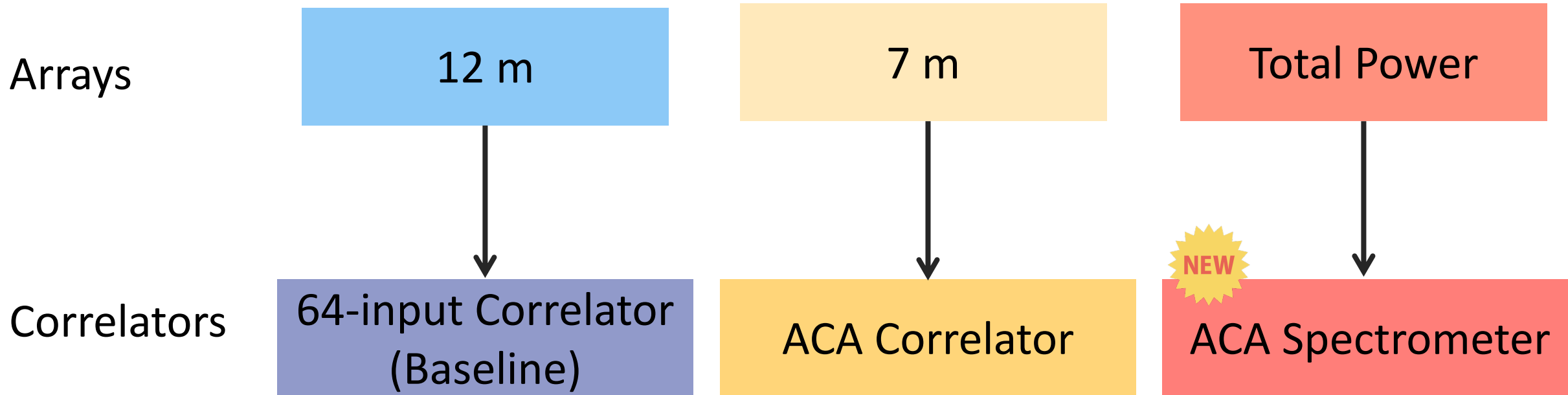




ACA Spectrometer (ACASPEC)

- Replace the functionality of the ACA Correlator for the TP array
- Target to offer from Cycle 10
 - All arrays will be independent!

New Configuration





Expected Benefit

- **Operational Advantage:**

- The TP array will be operated independently from the 7m array/the ACA correlator, which increases the observing efficiency of the TP array.

- **Better spectral dynamic range:**

- The spectral dynamic range can be improved up to 10000:1 by increasing the number of bits to 32-bits for FFT/multiplication. (the ACACORR uses 16-bits for FFT and 4-bits for multiplication).

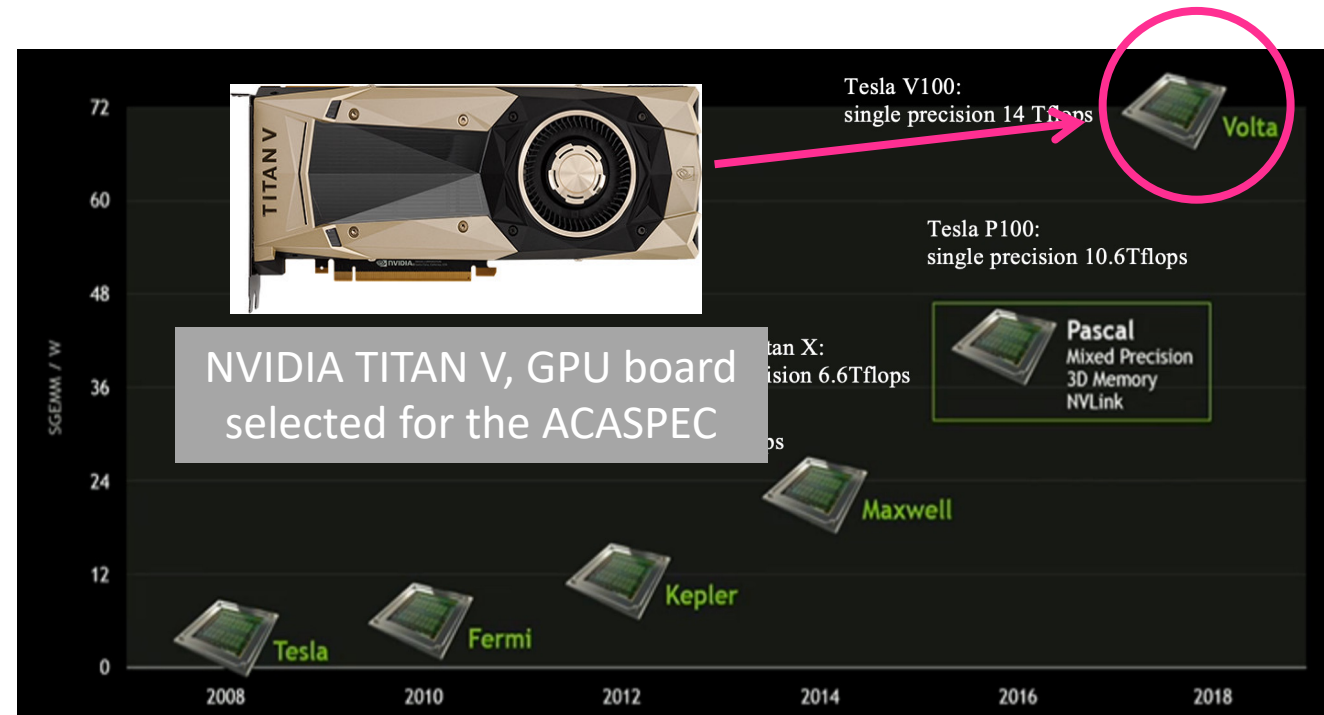
- **Expandability:**

- The ACASPEC is a GUP Spectrometer. Thanks to the software-based development and native parallel processing of GPU, the ACASPEC has excellent scalability to basebands, wider bandwidths, or complex processing in the WSU and further upgrades near future.



Functionality and Architecture

- The ACASPEC will
 - Provide auto-correlation data streams from the four TP antennas
 - Calculate cross-antenna correlation for calibration observations (ACASPEC is also a small correlator)
- Digital Spectrometer based on the Graphical Processing Unit (GPU) technology
 - Computing capacity is rapidly growing
 - All the processing is done in the software
- GPU has advantages on
 - Parallel processing
 - Pipeline processing
 - Expandability
- Currently being widely used for many backends of radio telescopes :
 - VEGAS at GBT
 - PolariS at NRO45m (Kameno et al. 2014)
 - LOFAR etc.

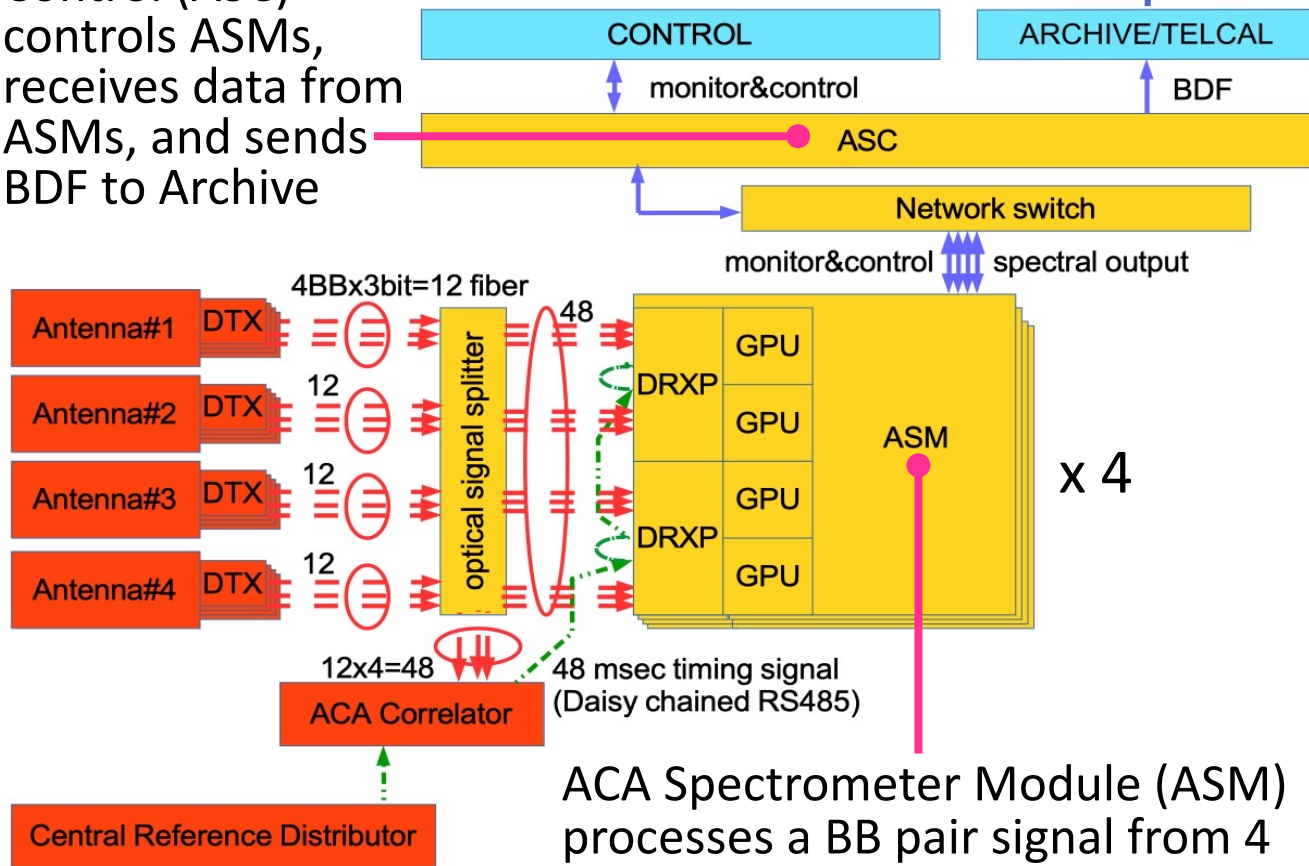




System of the ACASPEC: ASMs and ASC

ACA Spectrometer Control (ASC) controls ASMs, receives data from ASMs, and sends BDF to Archive

Science Data (ASDM)



ACA Spectrometer Module (ASM) processes a BB pair signal from 4 TP antennas, corresponding to a quadrant in the correlator

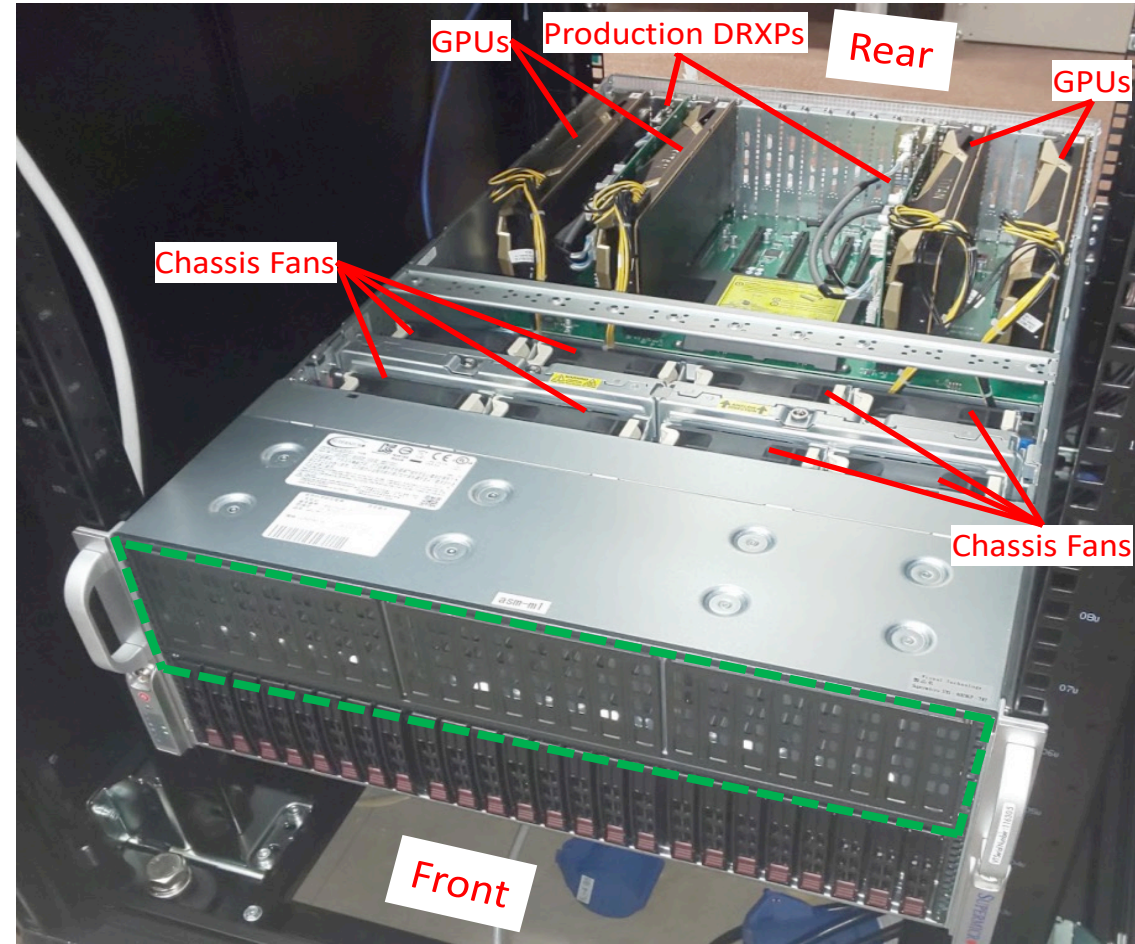
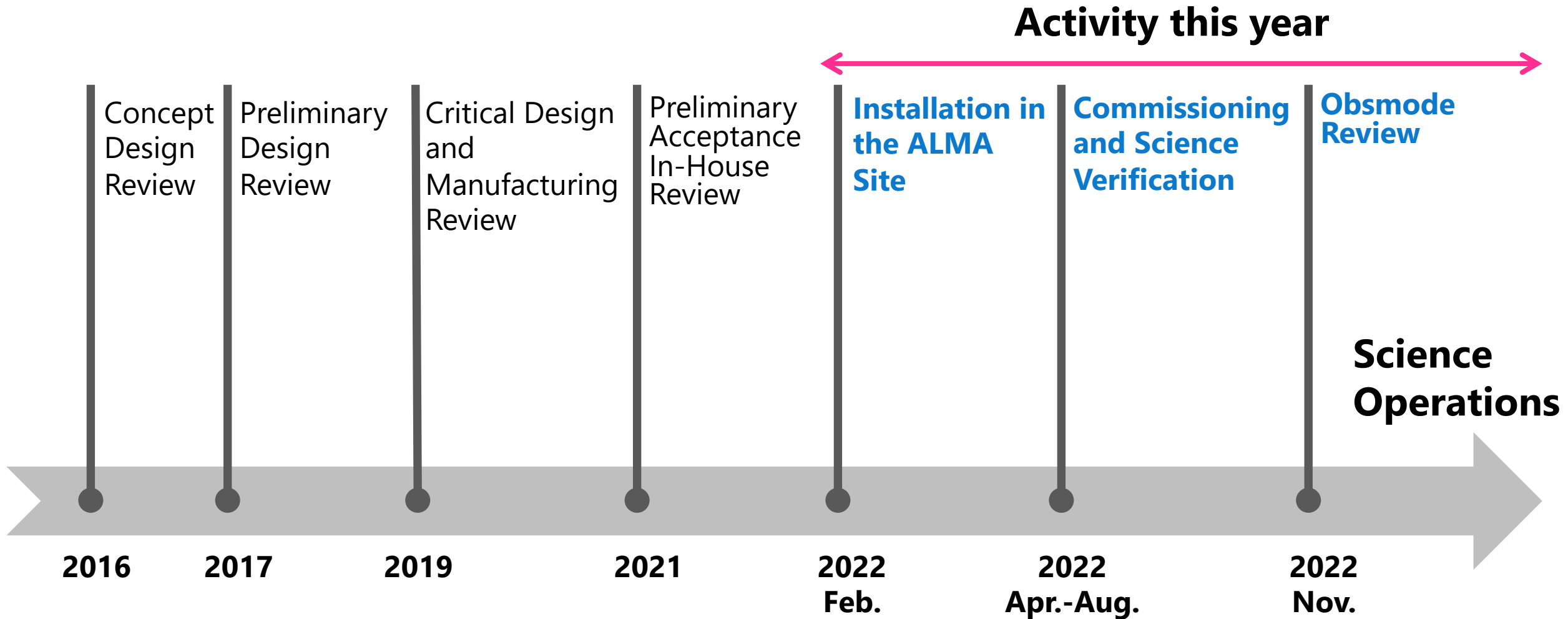


Photo of a module of the ACASPEC





Past and Future Milestones





Commissioning and Science Verification (CSV)

Parameter	Req. No.	Value	CSV ticket
IF bandwidth	CORL-64.00.00.00-00220-00/R	4 baseband pairs of 2 (polarizations) x 2 GHz (=16 GHz) bandwidth per antenna.	CSV-3771
Spectral resolution	CORL-64.00.00.00-00230-00/R	all the spectral resolutions offered in the observation modes in Table 1-7 of [AD01].	CSV-3771
Spectral windows	CORL-64.00.00.00	The ACA Spectrometer (as the ACA Correlator) should support the capability	CSV-3771

Parameter	Req. No.	Value	CSV ticket
Delay correction	CORL-64.00.00.00-00308-00/A	The sensitivity loss of the ACA Spectrometer due to imperfect delay correction should be smaller than 1% ¹ .	CSV-3756
Output data format	CORL-64.00.00.00-00310-00/R T	BDF	all

20 specifications/requirements have been identified and validated:

- **Basic capability as the backend of the TP array:**
 - Number of antenna, Bandwidth, Spectral setups, polarization, Frequency Profile Synthesis
- **Performance:**
 - Linearity, dynamic range, stability
- **End-to-End testing**
 - Generation and execution of SB, Data archiving with correct format, Manual and pipeline processing

Quantization levels of input data		3-bits	All input data should be 3-bits
Maximum output data rates		The maximum output data rate shall not exceed 17 MB/sec.	CSV-3778
Sensitivity Loss	CORL-64.00.00.00-00305-00/A	<2.1%. The sensitivity loss of FFT with 5% overlapped data is less than 2.1%, which is shown in Sect. 5.4 of [AD01].	Discussion can be found at CSV-3482.

Stability	#261 [RD01]	of	ASD < 1.0* 10 ⁻³ on time scales of 0.05 to 100 seconds ²	CSV-3757
Spurious signals	#295.2 [RD01]	of	to be suppressed down to 1/3 with respect to the standard deviation (SD) of a 16-hour integrated spectrum with 1-sec on-off cycles and 1-MHz of the spectral resolution.	CSV-3727
End-to-end test				CSV-3776

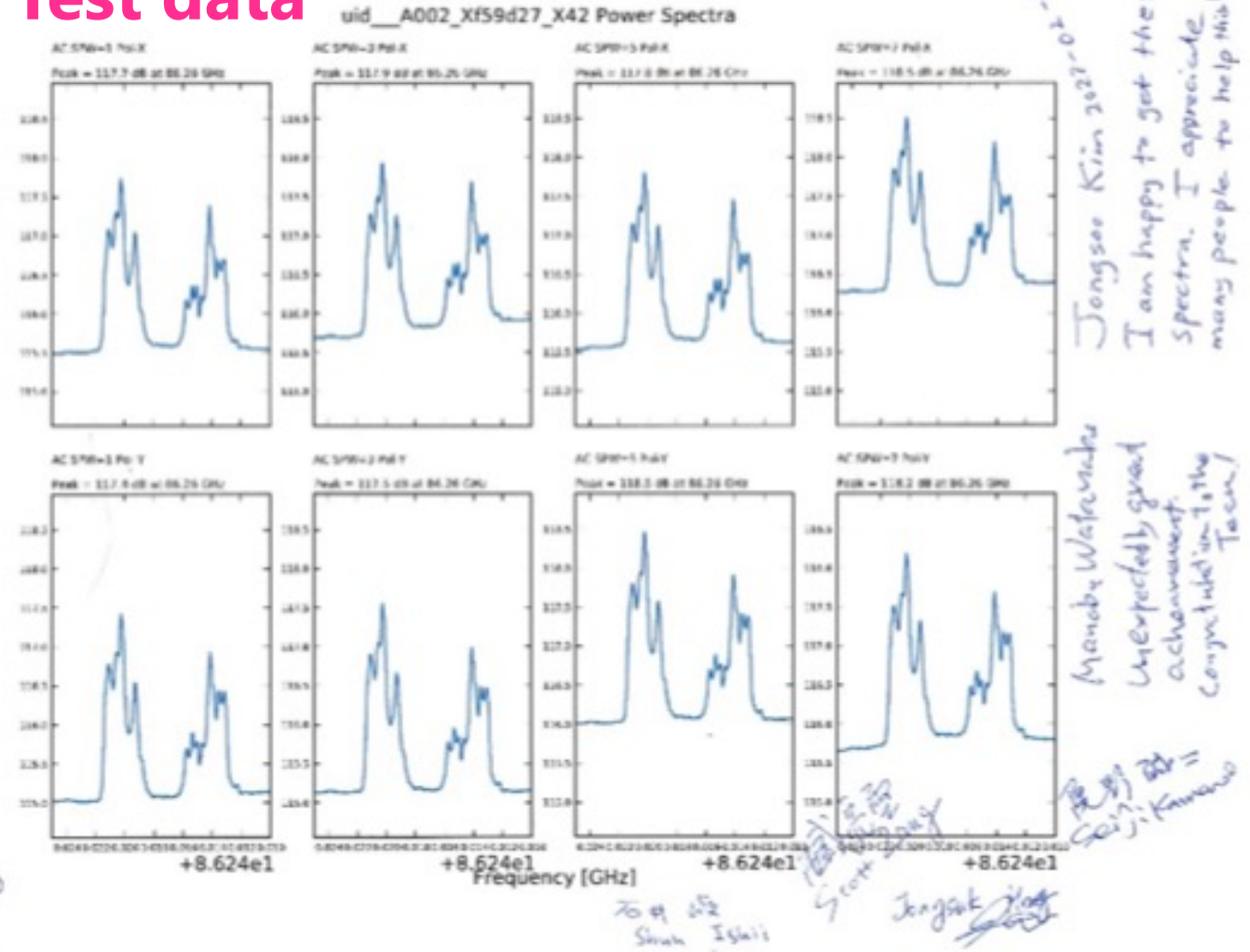




CSV Result: First light of auto-correlation

- The first light was archived on 2022-02-22 using the SiO(J=2-1) maser line at 86.243 GHz toward Orion KL.
- This confirmed that all the signal paths from the antenna to the archive are well connected and processed.

Test data





CSV Result: Consistency with the ACA Correlator

- Spectral setups and their consistency within the ACASPEC and with the ACACORR were verified for the combinations of the polarization, the resolution, and the averaging factor
- The consistency of the Jy/K factor was also confirmed.
 - ACASPEC: 42.0 ± 1.1
 - ACACORR: 42.0 ± 1.3
- The result indicates that the ACASPEC has enough linearity performance
- The linearity was also validated using Trx and Tsys spectra.

ACA Spectrometer			Target	BB	Freq (GHz)	Elevation (degree)	Temperature (C°)
Antenna	spw	Jy/K					
PM02	17	41.2414333	3c454.3	1	85.11	43.08	-5.57
PM02	19	41.4717804	3c454.3	2	87.00	43.08	-5.57
PM02	21	43.0697768	3c454.3	3	97.11	43.08	-5.57
PM02	23	43.7972127	3c454.3	4	99.00	43.08	-5.57
PM03	17	41.5022978	3c454.3	1	85.10	39.05	-5.57
PM03	19	42.8255566	3c454.3	2	87.00	39.05	-5.57
PM03	21	41.36979	3c454.3	3	97.10	39.05	-5.57
PM03	23	40.3893752	3c454.3	4	99.00	39.05	-5.57
PM04	17	43.3080328	3c454.3	1	85.11	43.08	-5.57
PM04	19	43.1285082	3c454.3	2	87.01	43.08	-5.57
PM04	21	40.6611562	3c454.3	3	97.11	43.08	-5.57
PM04	23	40.944874	3c454.3	4	99.00	43.08	-5.57

Test data

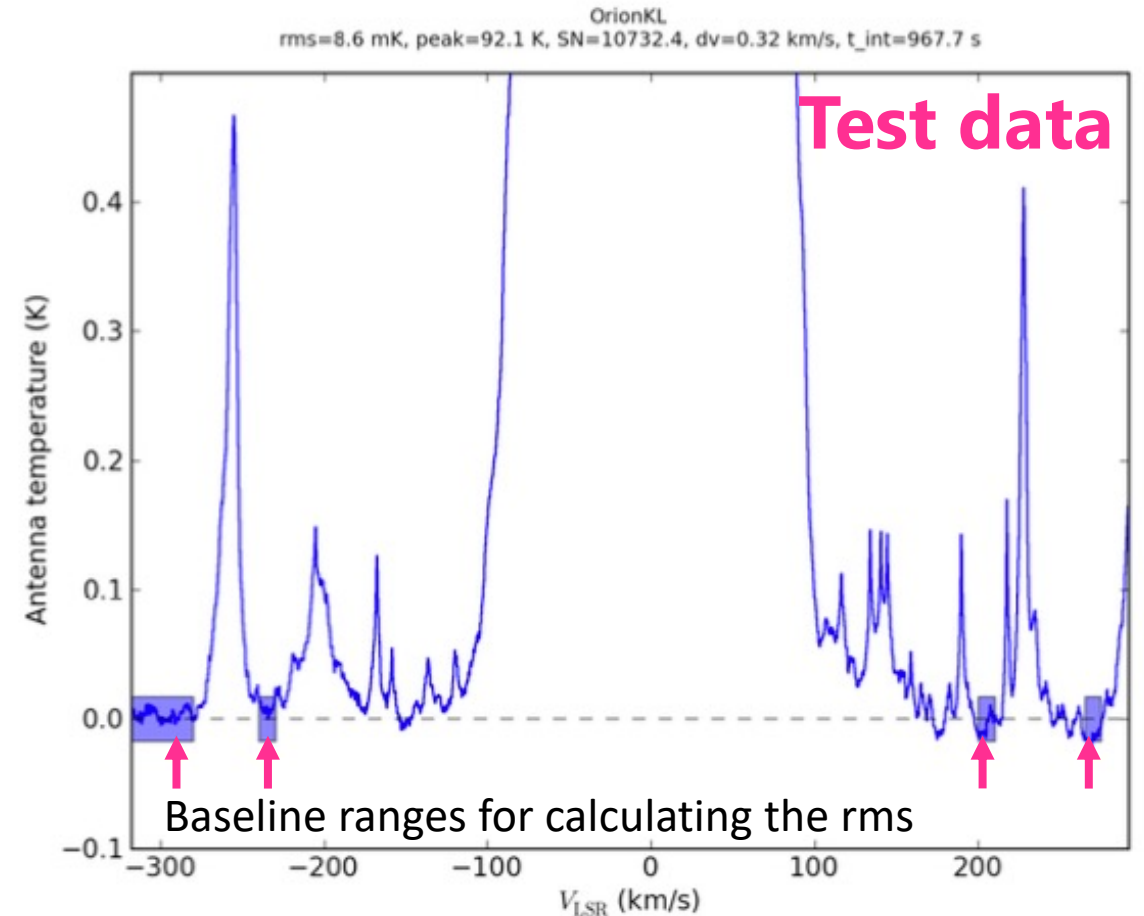
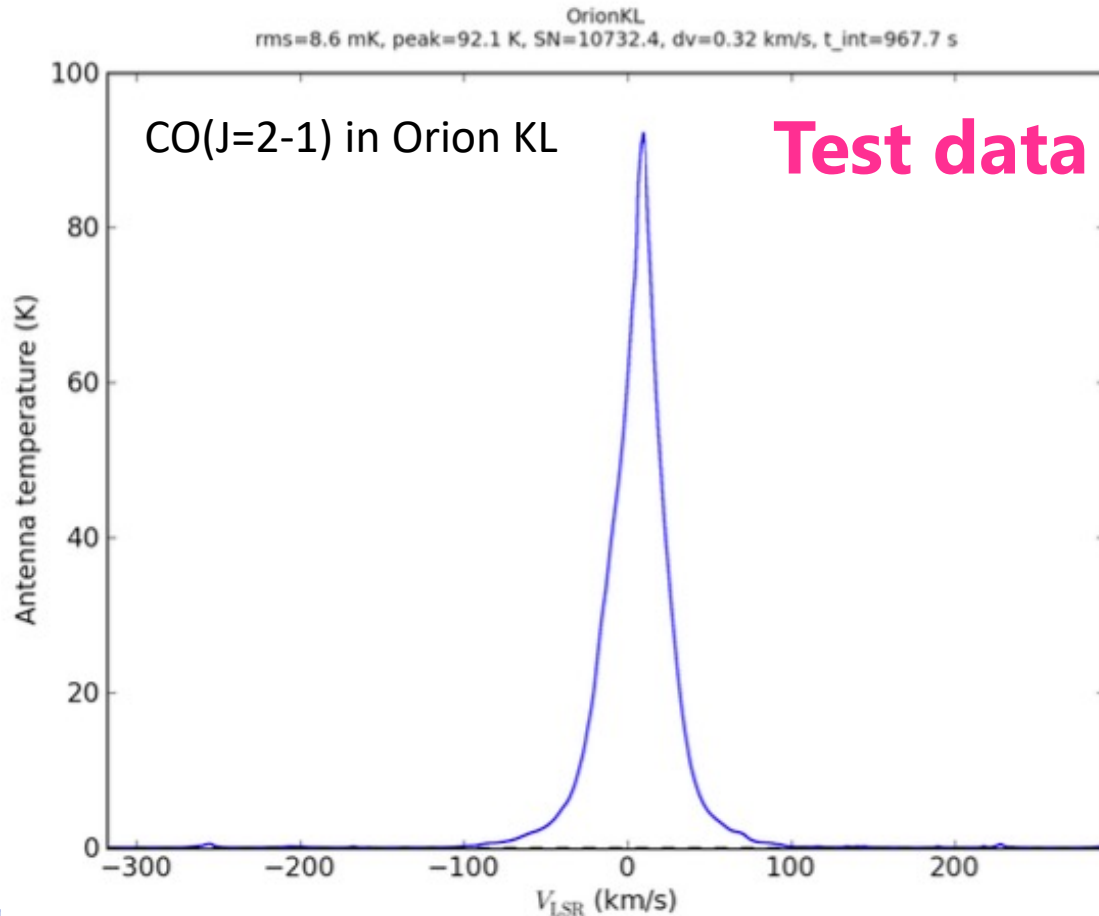
ACA Correlator			Target	BB	Freq (GHz)	Elevation (degree)	Temperature (C°)
Antenna	spw	Jy/K					
PM02	17	41.5338278	3c454.3	1	85.10	39.06	-5.58
PM02	19	42.3203145	3c454.3	2	87.00	39.05	-5.58
PM02	21	40.0194355	3c454.3	3	97.1	39.05	-5.58
PM02	23	40.906971	3c454.3	4	99.00	39.05	-5.58
PM03	17	41.2985662	3c454.3	1	85.10	39.05	-5.58
PM03	19	42.562381	3c454.3	2	87.00	39.05	-5.58
PM03	21	41.450369	3c454.3	3	97.10	39.05	-5.58
PM03	23	41.2984881	3c454.3	4	99.00	39.05	-5.58
PM04	17	44.9436385	3c454.3	1	85.10	39.05	-5.58
PM04	19	43.9136012	3c454.3	2	87.00	39.05	-5.58
PM04	21	42.2014481	3c454.3	3	97.10	39.05	-5.58
PM04	23	41.9915051	3c454.3	4	99.00	39.05	-5.58





CSV result: Spectral dynamic range

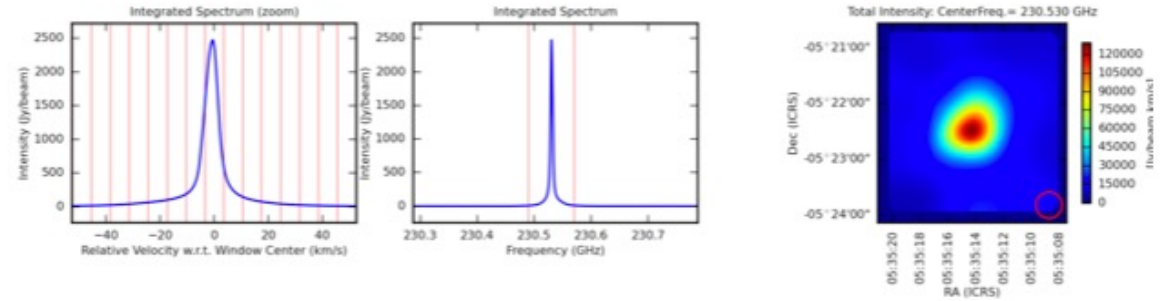
- The spectral dynamic range has been verified. The achieved noise rms is 8.6 mK for the peak intensity of 92.1 K, and thus the resultant S/N is ~ 11000 , achieving the goal.





CSV Result: CASA SD Pipeline processing

- CASA Single-Dish pipeline can process the data taken by the ACASPEC for SBs of the standard OTF mapping mode and the TP spectral scan mode
- The intensity in the ACASPEC data agrees well with that of the ACACORR data.



Overview of 'uid__A002_Xfc69ac_X2249.ms'

Test data

Observation Execution Time

Start Time	2022-08-04 09:22:16
End Time	2022-08-04 09:49:32
Total Time on Source	0:25:16
Total Time on Science Target	0:12:38

Spatial Setup

Science Targets	'Orion_KL'
Calibrators	'J0501-0159' and 'Orion_KL_OFF_0'

Antenna Setup

Min Baseline	59.8 m
Max Baseline	91.0 m
Number of Baselines	3
Number of Antennas	3
Antenna Diameters	3 of 12 m

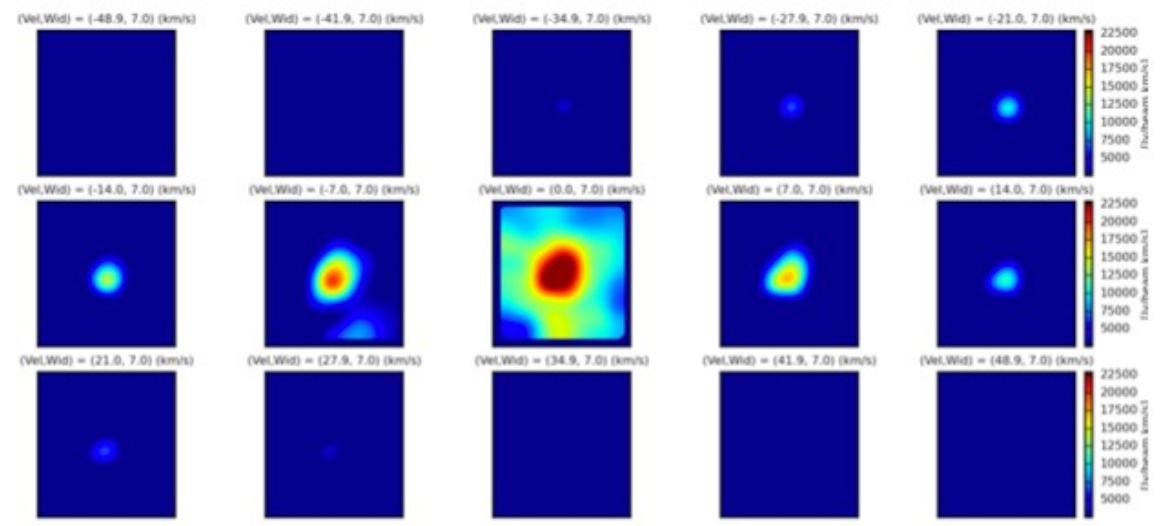
Spectral Setup

All Bands	'ALMA Band 6' and 'WVR'
Science Bands	'ALMA Band 6'

Sky Setup

Min Elevation	31.81 degrees
Max Elevation	38.34 degrees

Intert vs Time and Field vs Time plots are also shown.





Summary

- The ACA Spectrometer is the new backend for the TP array
- It is expected the ACASPEC will increase the observing efficiency of the TP array
- ACASPEC was installed on the ALMA site in February
- Commissioning and Science Verification has been carried out using the on-site environment.
- We successfully verified almost all test items, including end-to-end testing and ALMA single-dish pipeline processing, without blockers.
- Final implementation in the ALMA subsystems is ongoing toward offering science operations.

