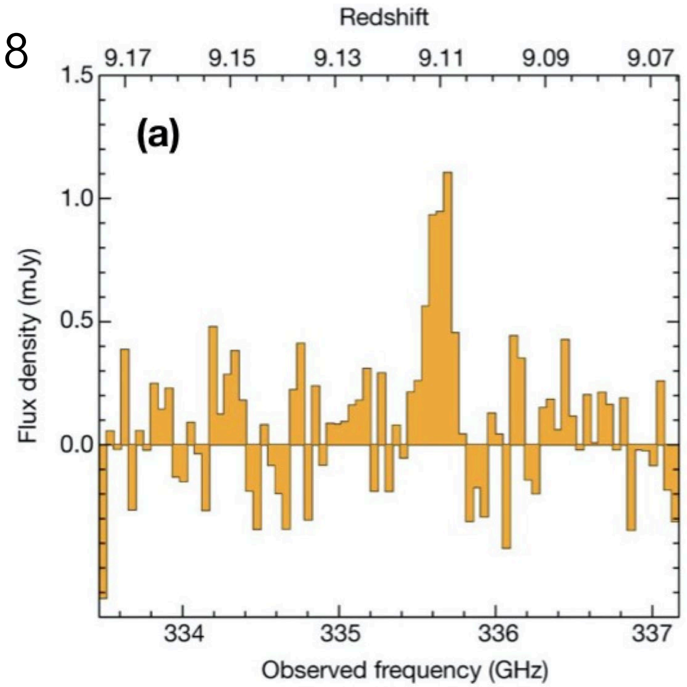
Updates on the science and instrumentation of the ALMA

Jongsoo Kim
Korea Astronomy and Space Science Institute
Presentation in January 17, 2023
at Survey Science Group Workshop

Atacama
Large
Millimeter/
Submimllimter
Array

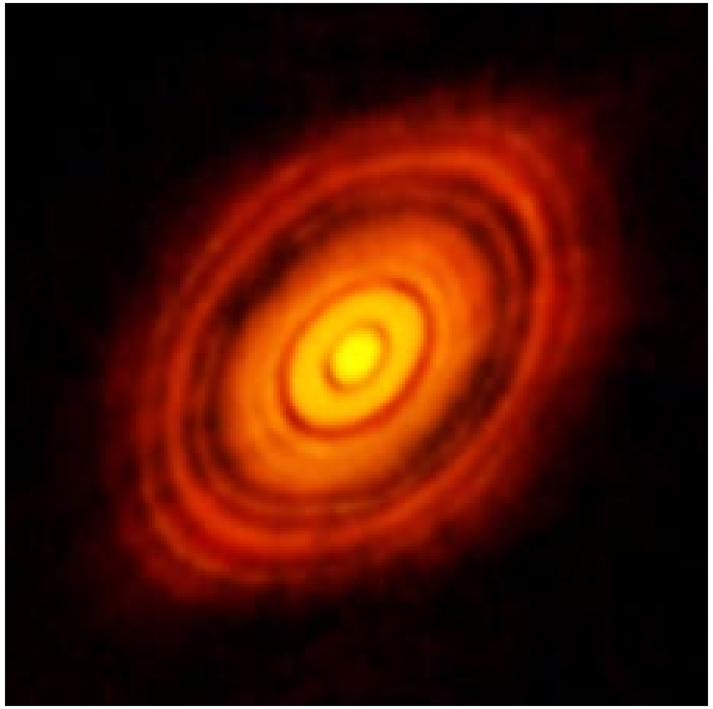
- 12m array: 50 x 12m antennas
- ACA array: 12 x 7m antennas + 4 x 12m antenna
- Longest distance between two antennas: 16 km

Hashimoto+ 2018
OIII at z=9.11



Level zero science goals

- The ability to detect spectral line emission from CO or C+ in a normal galaxy like the Milky Way at a redshift of $z = 3$, in less than 24 hours of observation.
- The ability to image the gas kinematics in a solar-mass protostellar/ protoplanetary disk at a distance of 150 pc.
- The ability to provide precise images at an angular resolution of 0.1″.

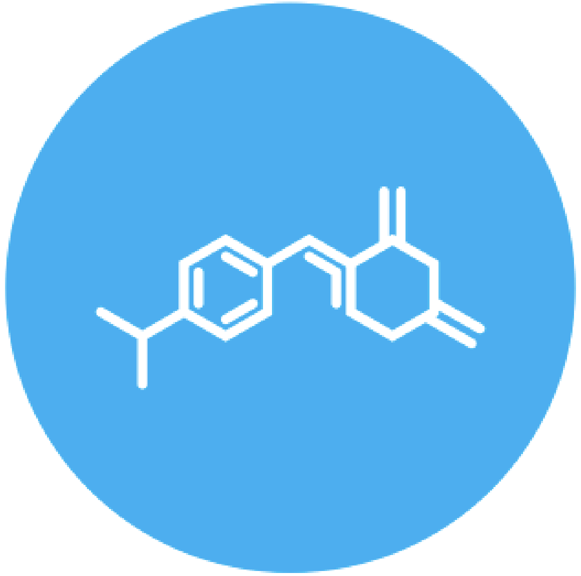


HL tau at d=140 pc
ALMA partnership+ 2005

Development Roadmap 2030

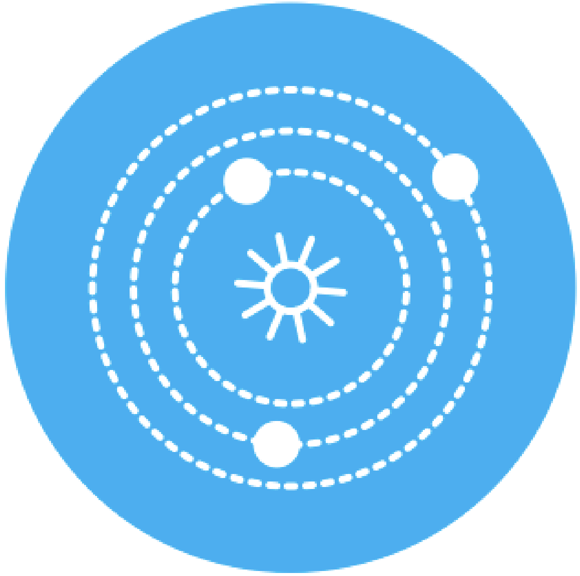
ORIGINS OF GALAXIES

Trace the cosmic evolution of key elements from the first galaxies (z>10) through the peak of star formation (z=2–4) by detecting their cooling lines, both atomic ([CII], [OIII]) and molecular (CO), and dust continuum, at a rate of 1-2 galaxies per hour.



ORIGINS OF CHEMICAL COMPLEXITY

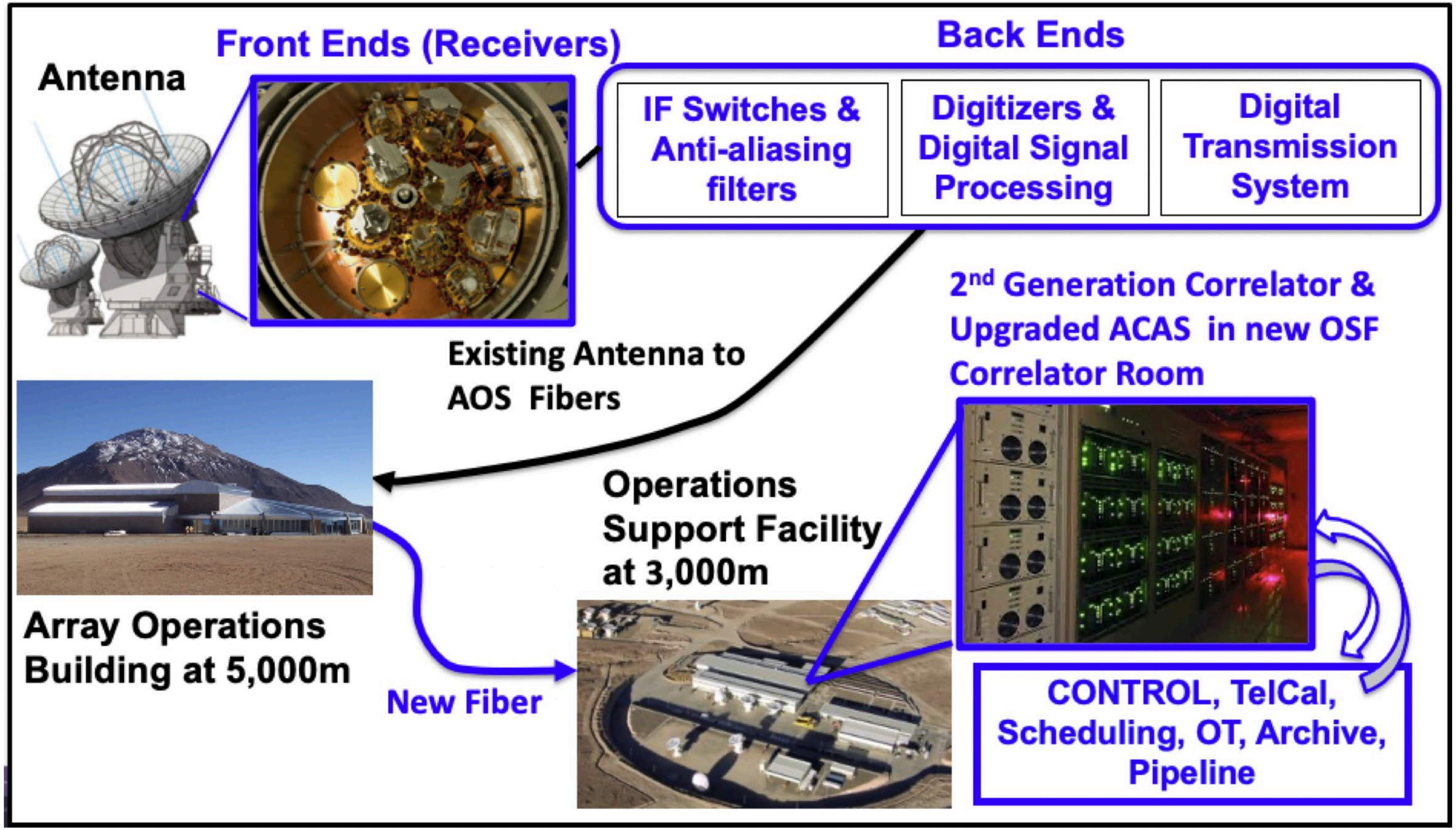
Trace the evolution from simple to complex organic molecules through the process of star and planet formation down to solar system scales (~10-100 au) by performing full-band frequency scans at a rate of 2-4 protostars per day.



ORIGINS OF PLANETS

Image protoplanetary disks in nearby (150 pc) star formation regions to resolve the Earth forming zone (~ 1 au) in the dust continuum at wavelengths shorter than 1mm, enabling detection of the tidal gaps and inner holes created by planets undergoing formation.

ALMA2030 Wideband Sensitivity Upgrade



Improvements by WSU

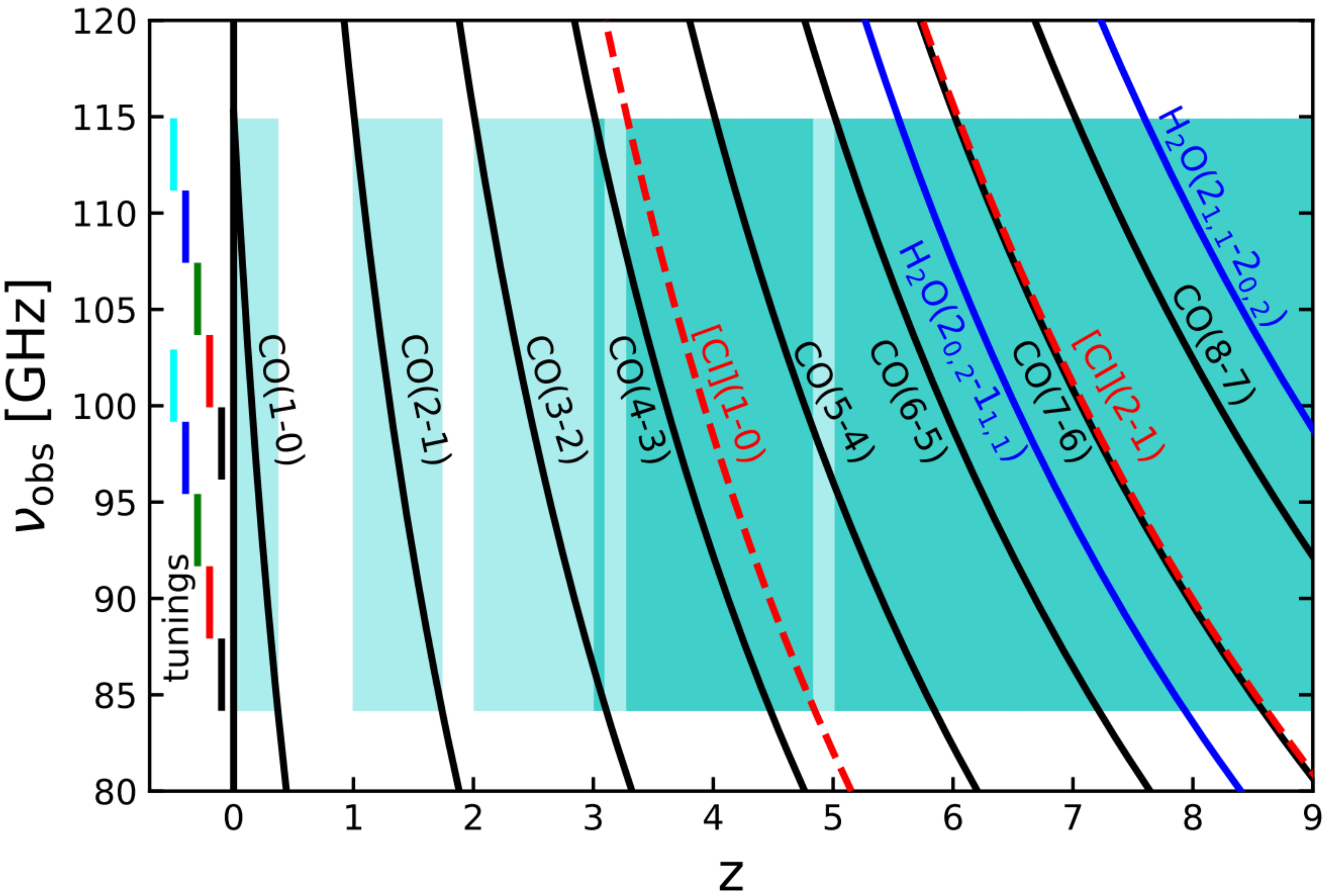
ALMA memo 621

Capability	Improvement
Instantaneous Bandwidth	• Factor of 2 to 4 increase in the *available* instantaneous bandwidth (16 to 32 GHz per polarization) compared to existing receivers.
Correlated bandwidth	• Factor of 4 to 68 increase in the *correlated* bandwidth at high spectral resolution (0.1–0.2 km s^{-1}), with larger gains in the lower frequency bands. • Observers will no longer need to trade off high spectral resolution for bandwidth.
Spectral scan speed	• Increase of at least a factor of 2, and up to a factor of 4 (Band 10) to 64 (Band 1) for a spectral resolution of 0.1–0.2 km s^{-1}.
Spectral line imaging speed	• Increased spectral line speed from lower receiver noise temperatures ($\sim$ 20%; up to $\sim$ 50% at edge of RF band in some receivers), improved digital efficiency ($\sim$ 20%), and upgrade to 2SB mixers (Bands 9 and 10 only). • Net gain in spectral line imaging speed of $\sim$ 2–3.
Continuum imaging speed	• Increase by at least a factor of 3 with 2× bandwidth increase and at least 6 for 4× bandwidth, including digital efficiency improvements. • Additional gains from improved receiver temperatures.
Ultra-high spectral resolution	• Provide for the first time unique access to ultra-high spectral resolution observations — better than 0.01 km s^{-1} at all ALMA frequencies.

Reuter+ '20

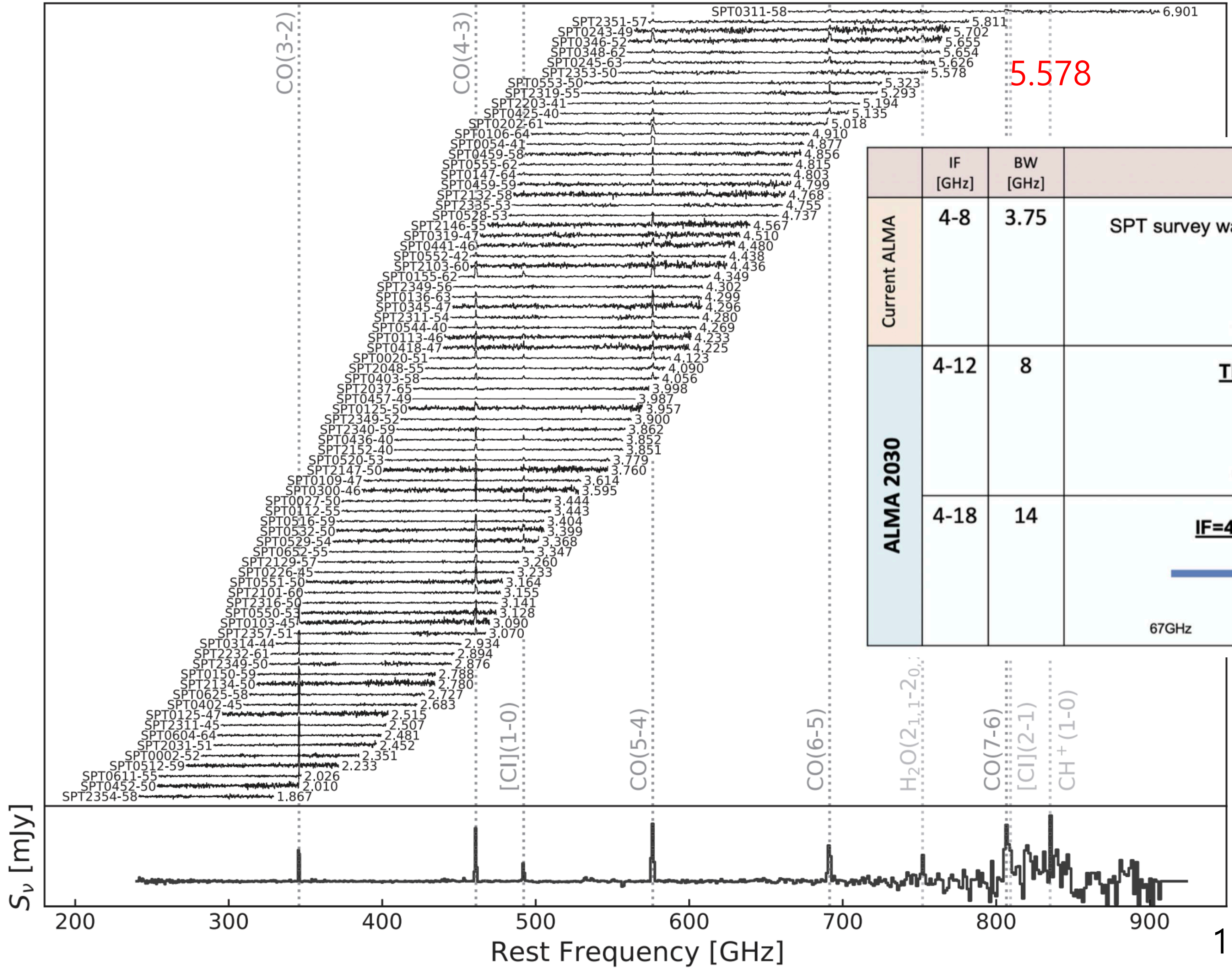
CO, [CI], H2O lines as a function of z

ALMA
Band 3
Five tunnings



Blain+Longair '93
Negative K-correction
$L_\nu \sim \nu^4$

ALMA memo 621



5.578

	IF [GHz]	BW [GHz]	Tuning setup
Current ALMA	4-8	3.75	SPT survey was carried out in 5 tunings with overlap in 96-103GHz LSB USB 84.17GHz 114.92GHz
ALMA 2030	4-12	8	**The SPT tuning can be covered with two tunings** LSB USB 84.17GHz 100.17GHz 114.92GHz
	4-18	14	**IF=4-18GHz scans the entire Band2/3 in two tunings** LSB 95GHz USB 67GHz 89GHz 117GHz

12~15 min on-source observing time

ACA Spectrometer (ACASPEC)

- New backend for the TP array from an EA Development Program
- ACASPEC has been developed by KASI and NAOJ

Engineering Team

CSV Tea
m

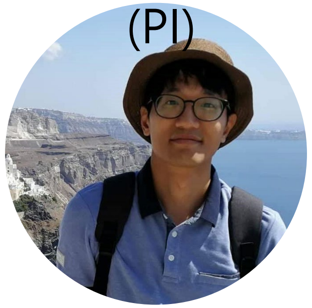
Jongsoo Kim
(PI)

Manabu Watanabe

Makoto Shizugam
i

Shun Ishii

Jihyun Kang

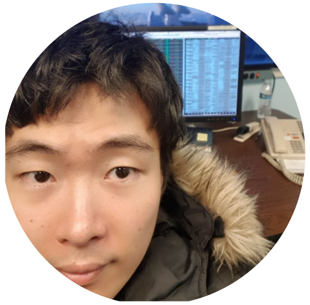


Jongsuk Hong

Scott Zang

Susumu Nakayama

Hiroshi Naga
i

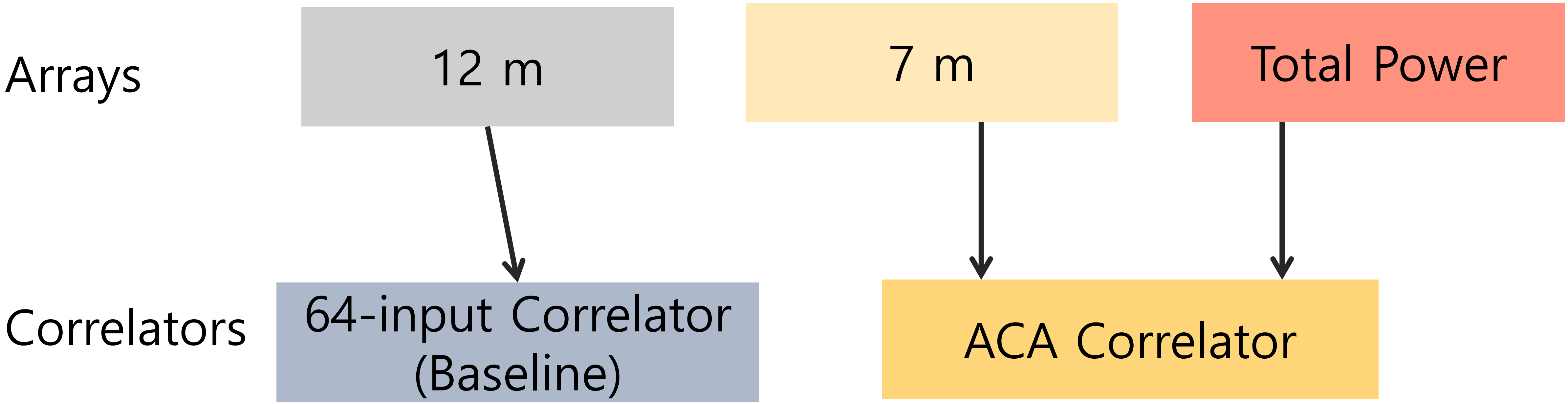


Yusuke Aso

ACA Spectrometer (ACASPEC)

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

Current Configuration

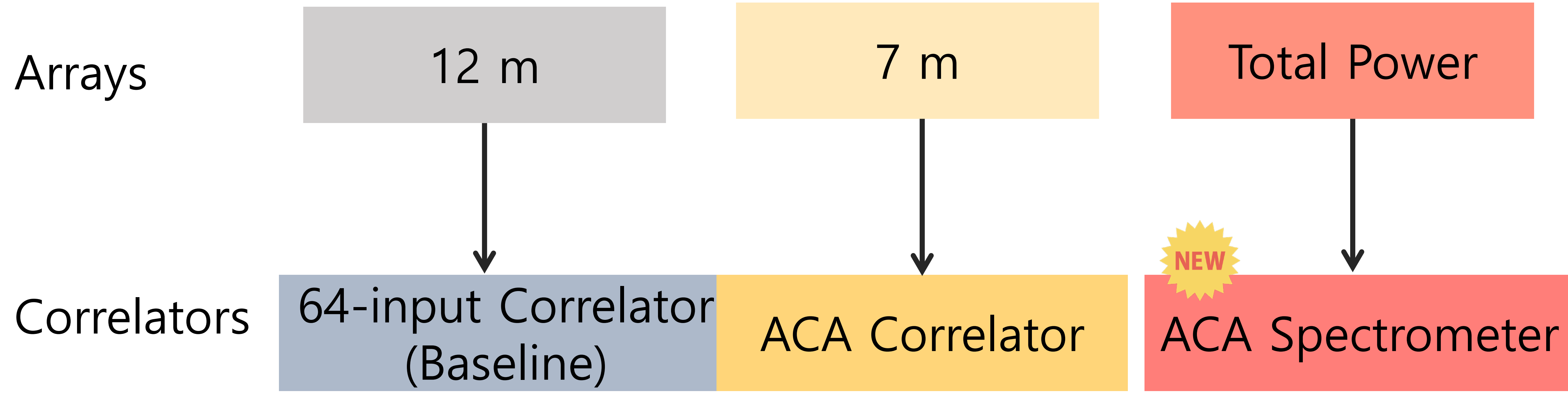


ACA Spectrometer (ACASPEC)

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

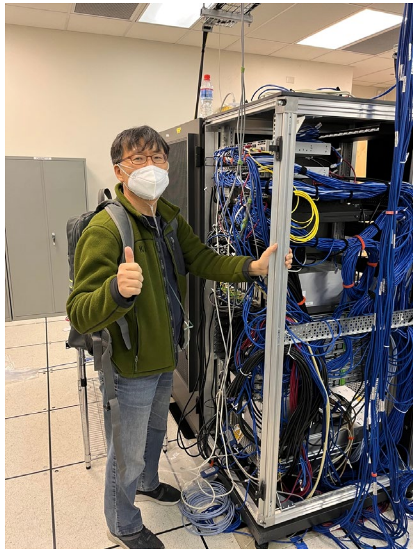
  → All arrays will be fully independent!

<u>New Configuration</u>



Milestones of ACA Spectrometer Development

- Concept Design Review at Indian Wells,
  - September 24, 2016
- Preliminary Design Review at KASI
  - February 20~21, 2017
- Critical Design and Manufacturing Review at KASI
  - December 4~5, 2019
- Preliminary Acceptance In-House Review
  - November 29~30, 2021
- Installation of ACA Spectrometer
- Acceptance on-Site Review
  - July, 2022
- Commission and Science Verification
  - April and May 2022
- ACA Spectrometer will be used from Cycle 10, Oct 2023



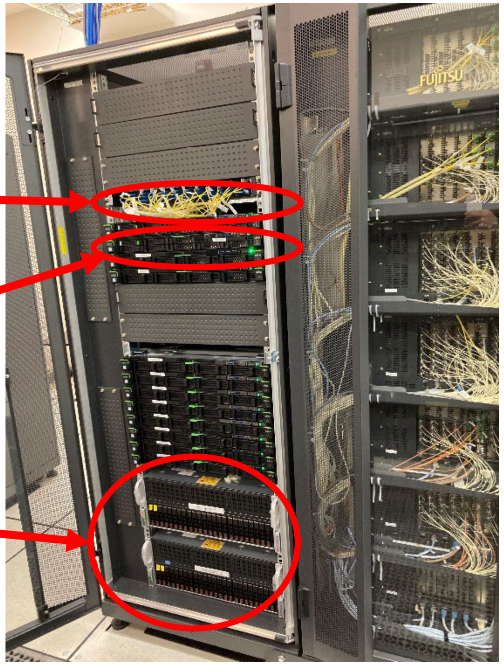
Installation

The ACA Spectrometer has been installed at AOS in Feb 2022.

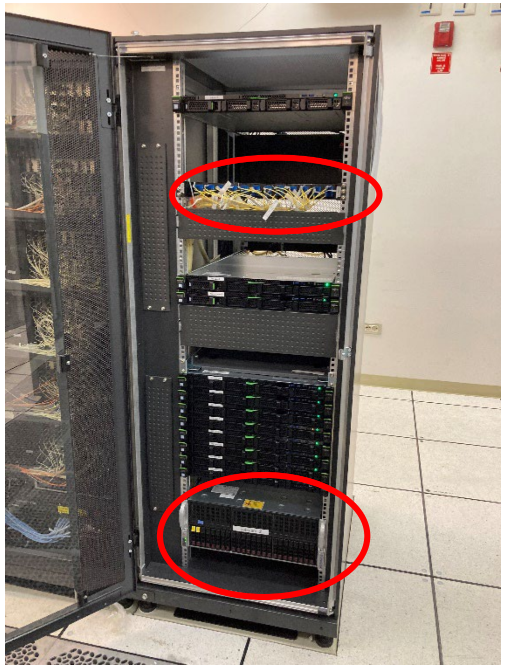
Optical Splitters

ASC

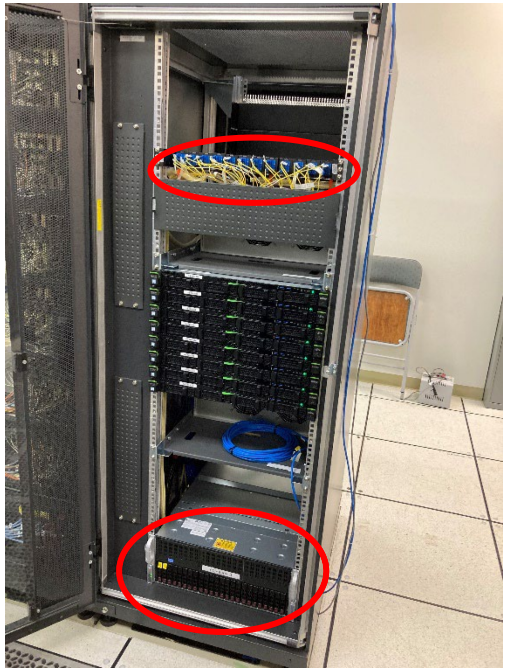
ASM



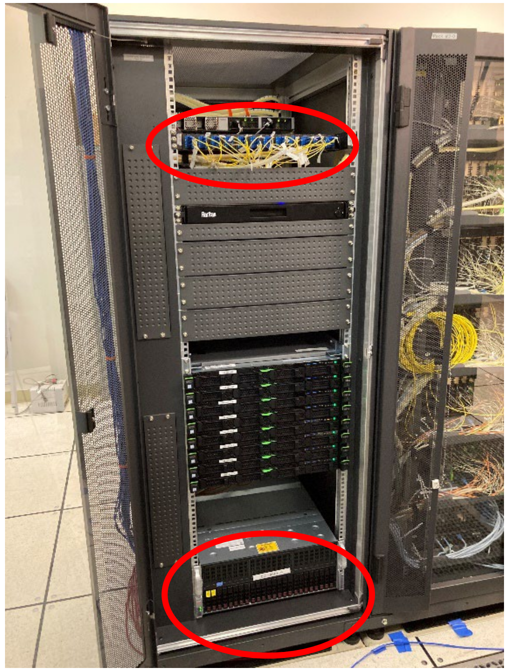
Q0 comp rack



Q1 comp rack

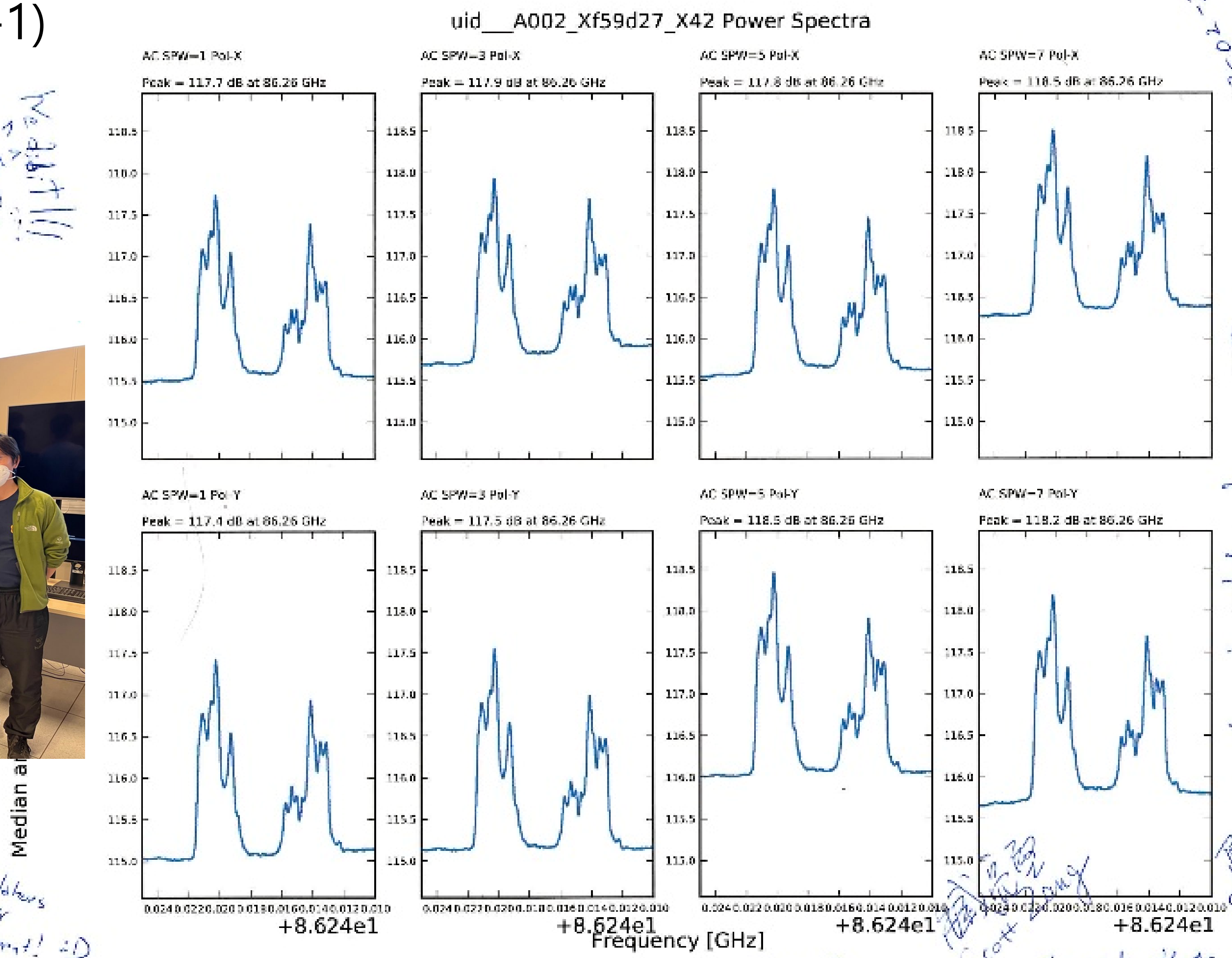


Q2 comp rack



Q3 comp rack

86 GHz SiO (v=1,J=2-1)
Orion
2022-02-22



Jongsoo Kim 2022-02-22
I am happy to get these spectra. I appreciate many people to help this pj

Manabu Watanabe
Unexpectedly great achievement.
Congratulation to the Team!

Congratulations on your achievement! :D
Camila Salazar

石井 峻
Shun Ishii

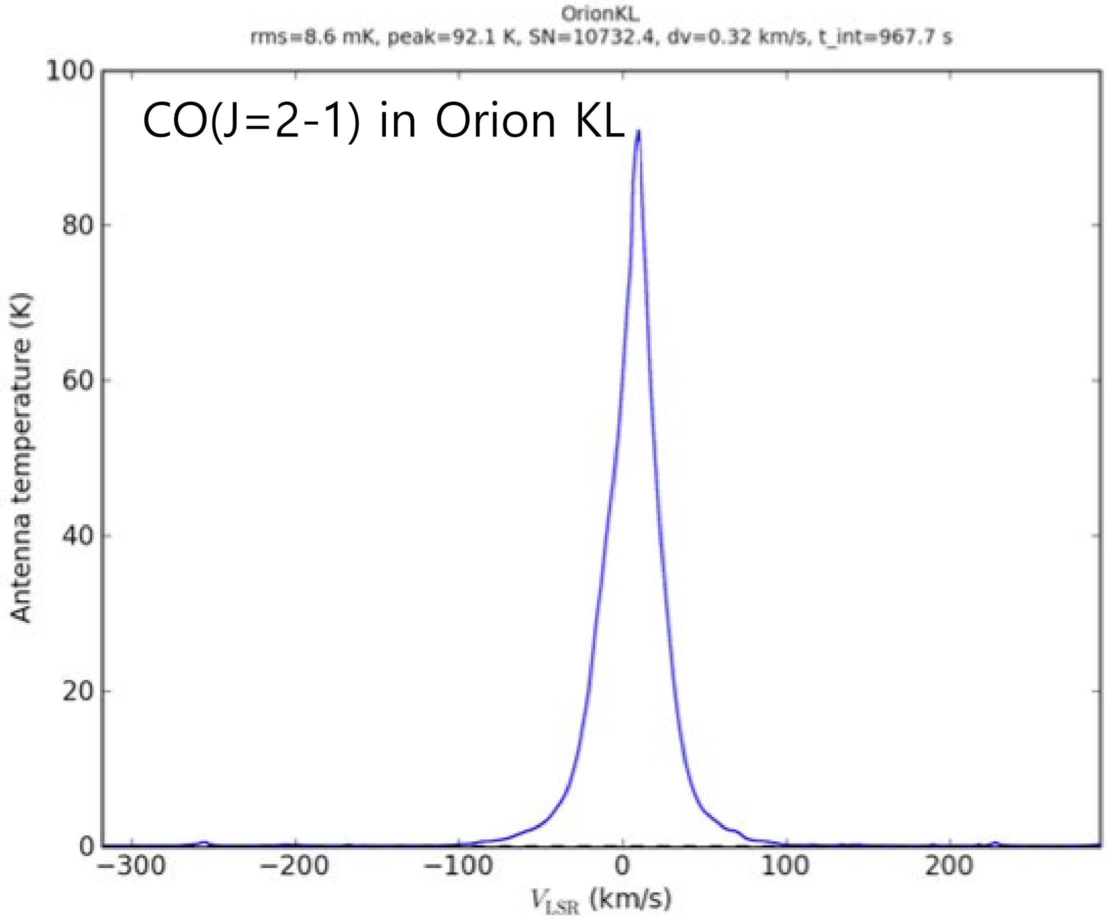
Scott

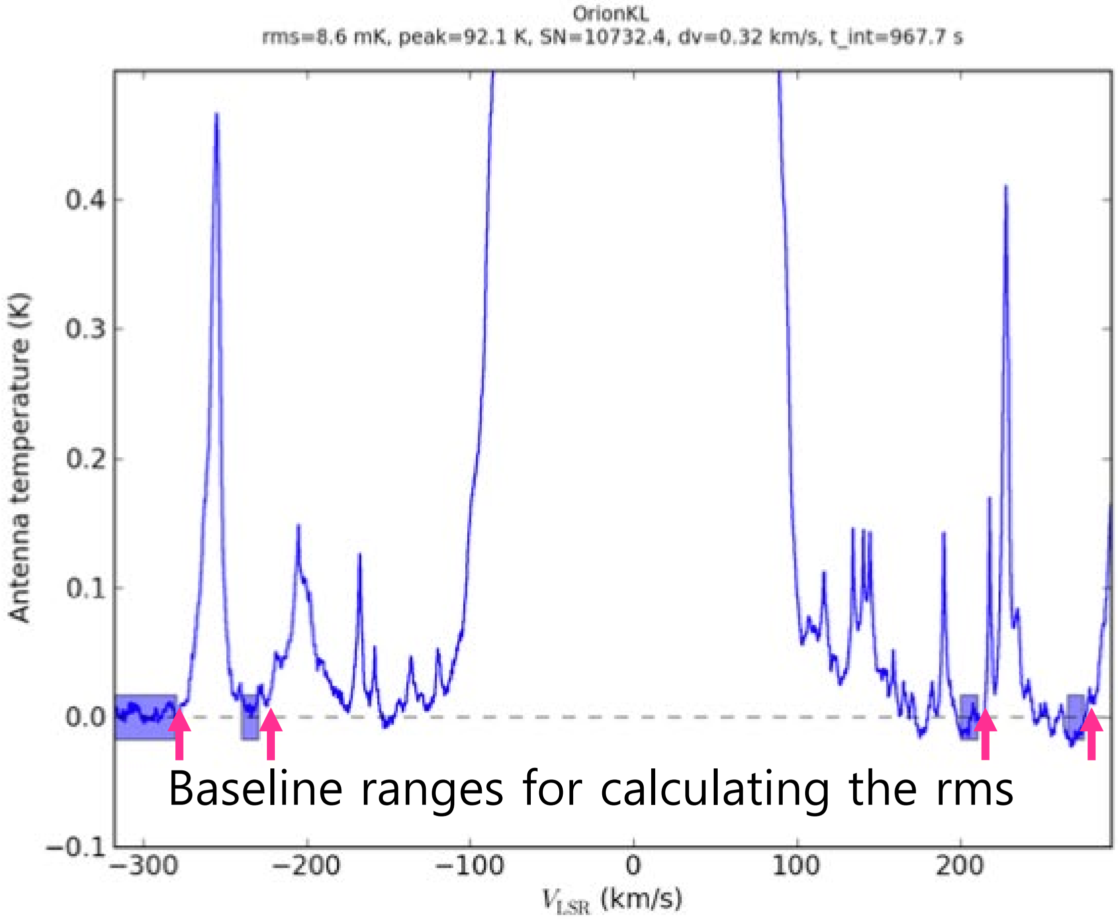
Jongsuk Hong

亀野 誠二
Seiji Kameno

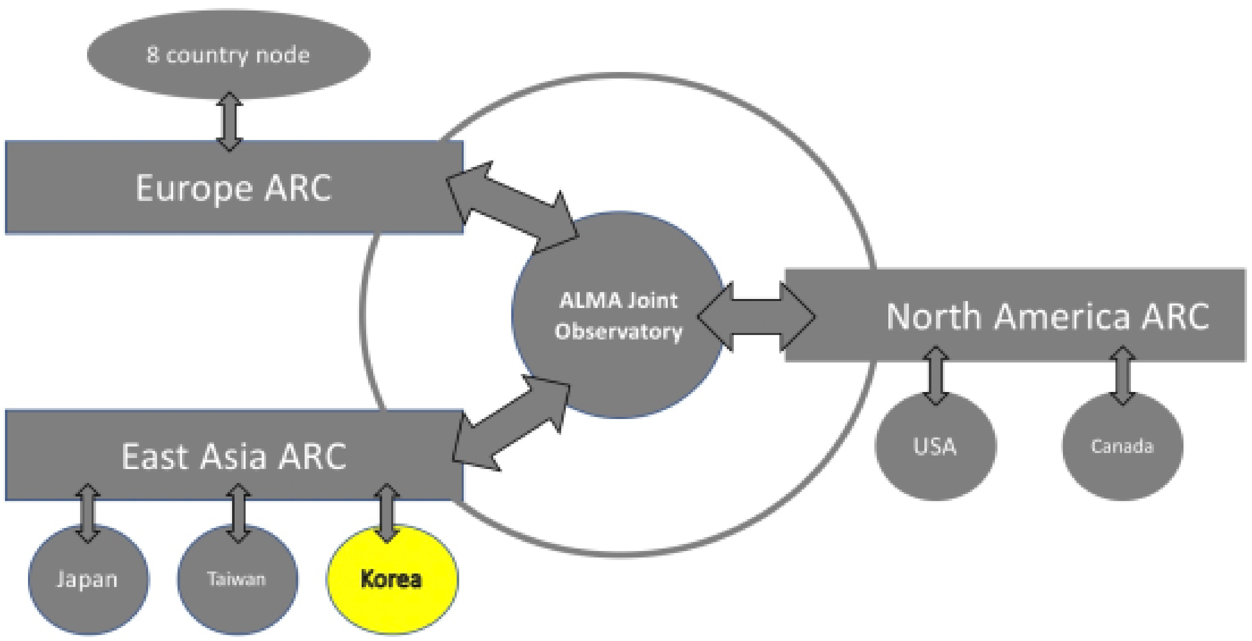
CSV Result 4: Spectral dynamic range

- 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.

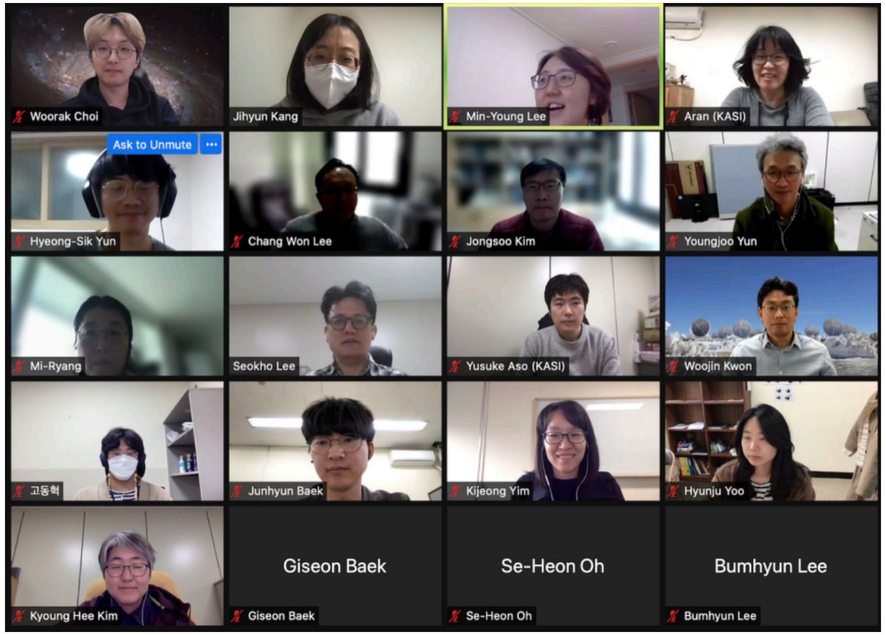




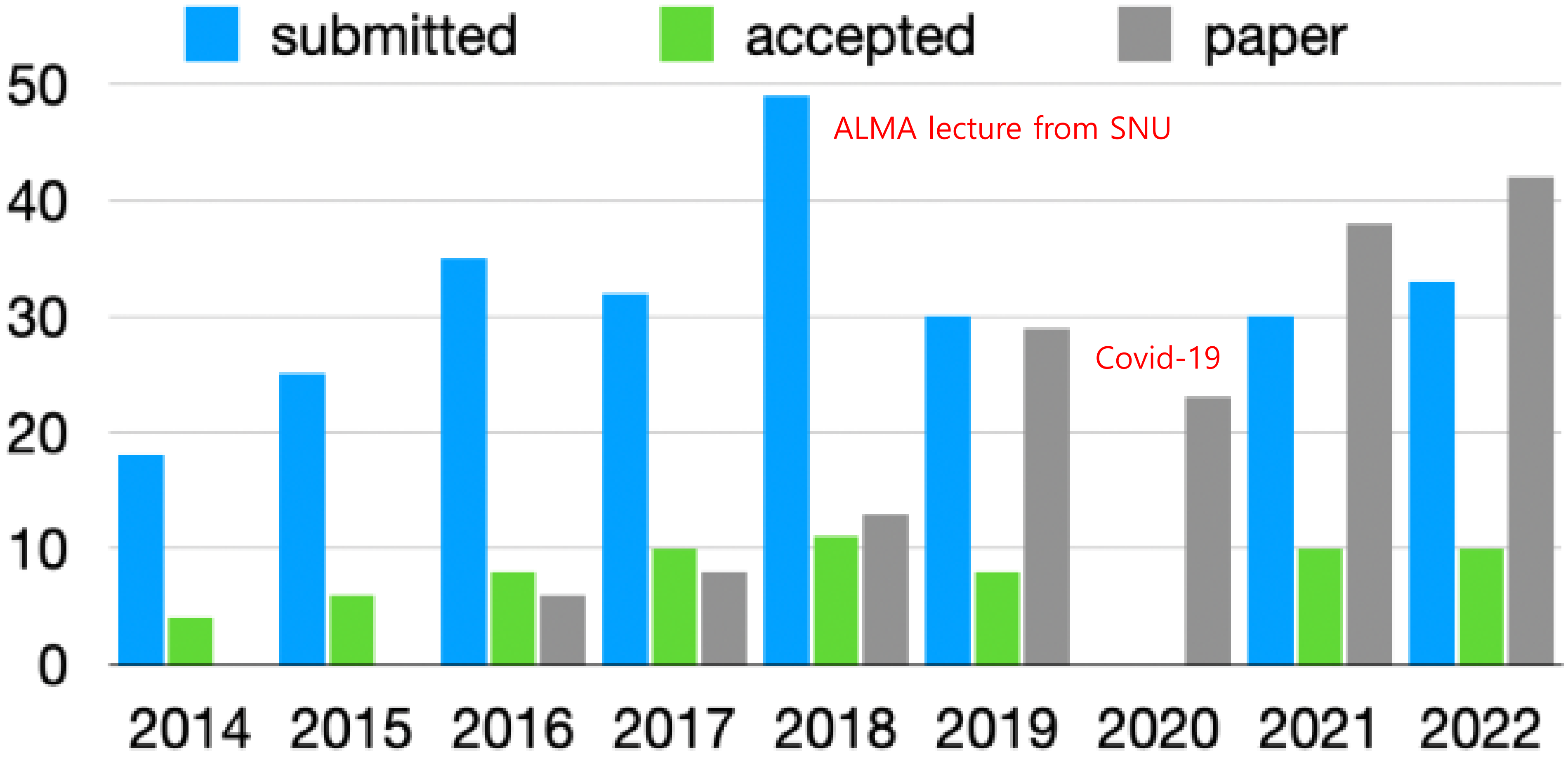
Structure of the ALMA Regional Center (ARC)



- Hold proposal workshop
- Hold data reduction summer school
- Hold EA ALMA science workshop
- Prepare observing scripts for acceptaced proposals
- Astronomers on Duty



Statistics of Korean ALMA proposals and papers



Press release in almaobservatory.org

Announcements

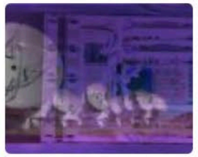
First light with the new spectrometer for the Atacama Compact Array

23 March, 2022 / Read time: **5 minutes**

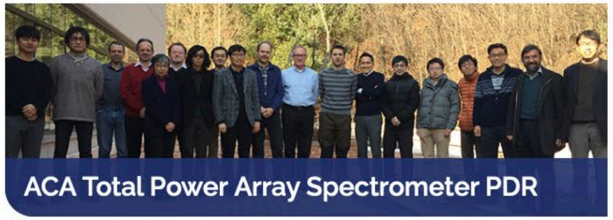
On February 22, 2022, the newly developed spectrometer for the Total Power Array of the Atacama Compact Array (ACA), also known as Morita Array, has successfully acquired its first radio spectra towards Orion KL. This is an important milestone for the East Asian ALMA Development Program, materialized through a strong collaboration between the Korea Astronomy and Space Science Institute (KASI) and the National Astronomical Observatory of Japan (NAOJ) within the East Asian ALMA partnership.

In collaboration with NAOJ, KASI has developed a new spectrometer for the Total Power array of the Morita Array based on Graphics Processing Unit (GPU) technology used widely in graphics processing and video games. The collaboration started more than five years ago. It reached an important milestone on February 22, 2022, when the development team successfully installed the spectrometer onsite and acquired its first radio spectra towards Orion KL, despite the challenges posed by the COVID-19 pandemic.

Gallery



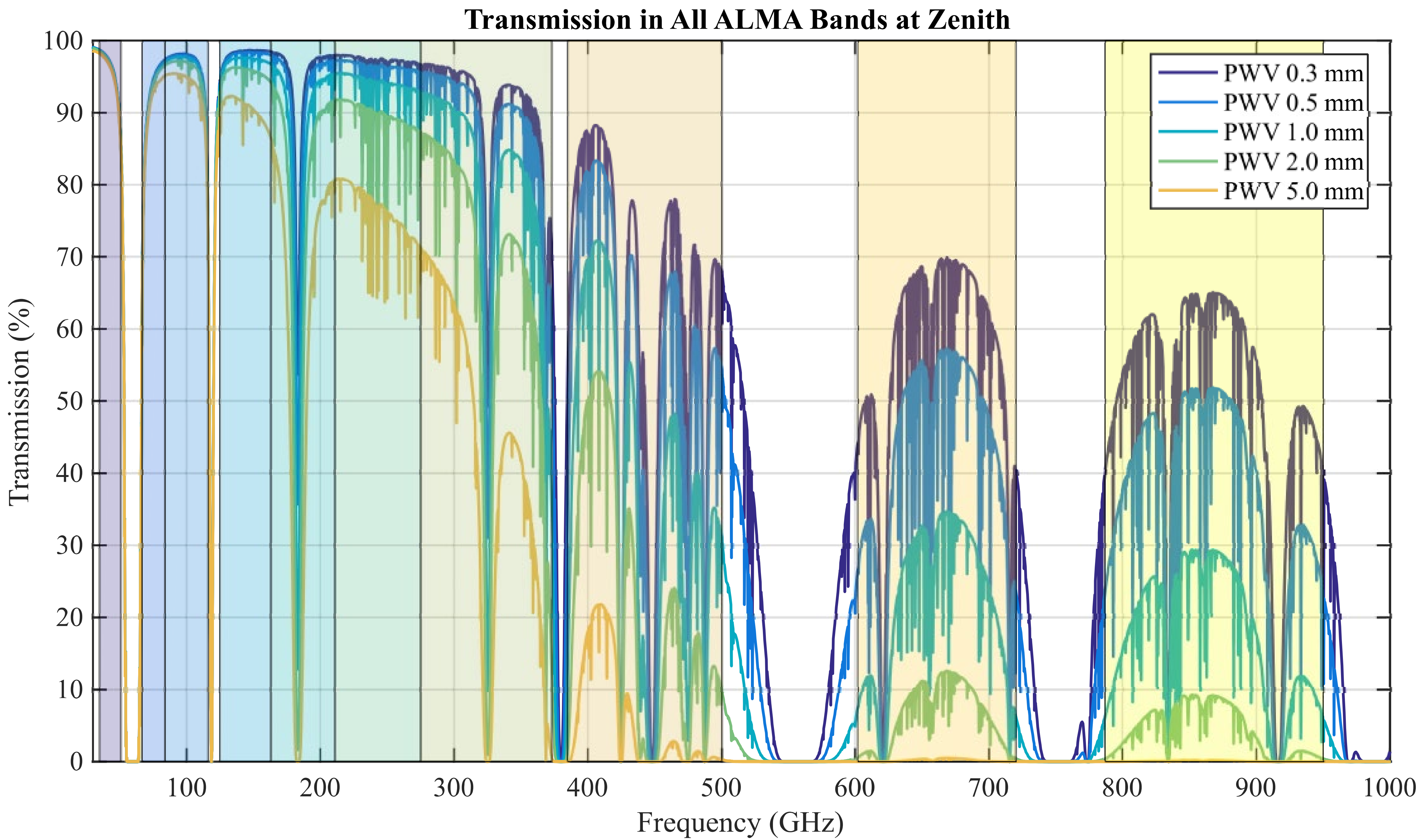
Related Posts



'21 증액된 천문연 ALMA 사업

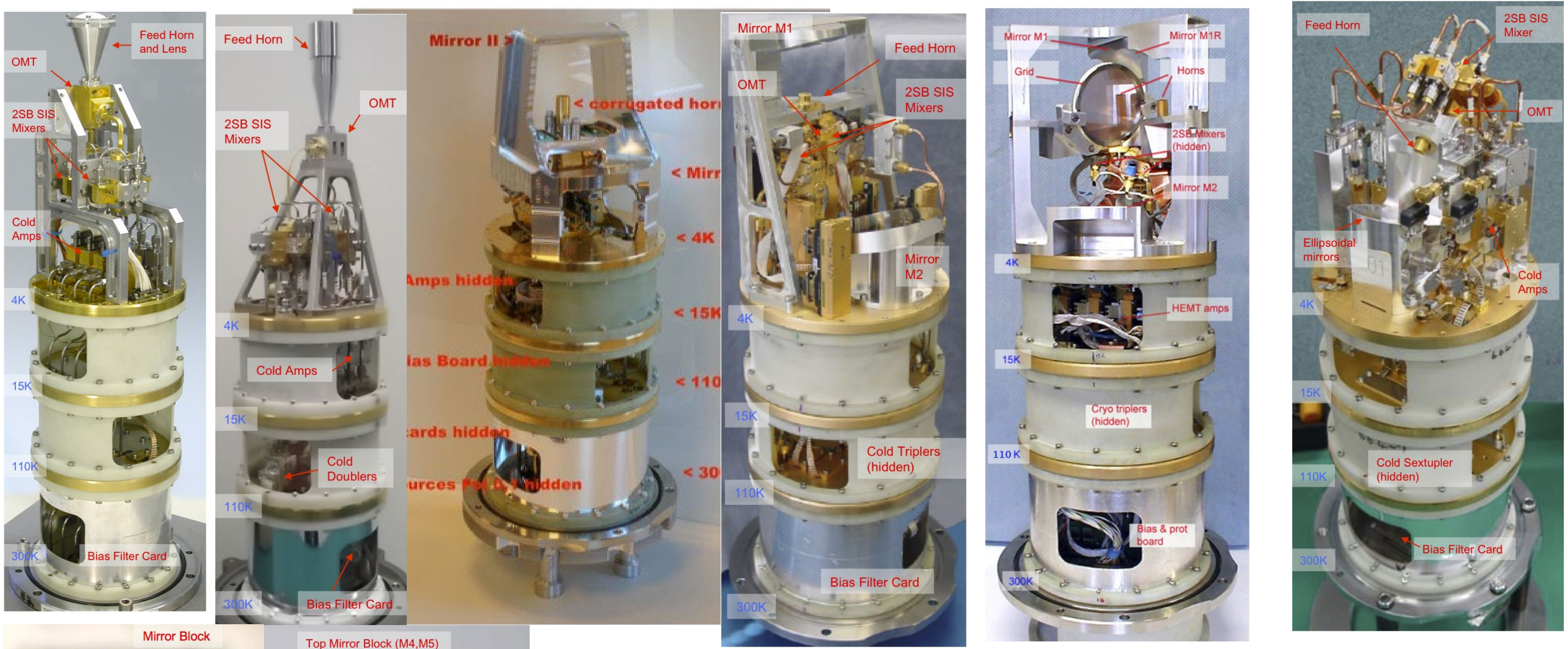
차세대 ALMA 기기 개발과 과학연구

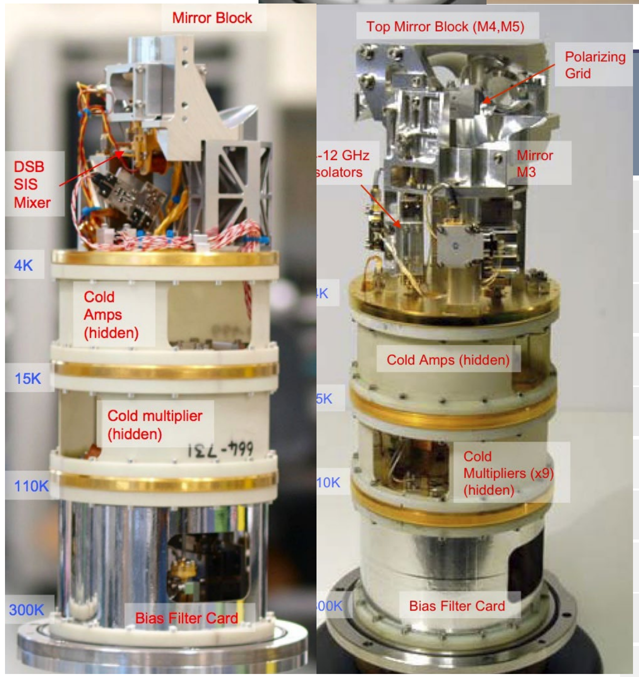
	2021	2022	2023	2024	2025	2026	2027	2028	2029
개발	ALMA 전전력 배열용 분광기 개발 및 납품		차세대 ALMA bandwidth upgrade 전전력 배열용 분광기 개발 및 납품						
개발	ASTE 용 광대역 수신기 개발		GPU 기술을 이용한 차세대 ALMA 분광기/상관기 개발 참여						
ARC 과학연구	ALMA 동아시아 지역센터 한국 노드 운영 + 은하, 별과 행성 생성 기원 연구								
신규인력	0 명	0 명	1 명	1 명	1 명	1 명	1 명	1명	1명
예 산	9.2억	14.5억	11.8억	21.5억	20억	26억	24.5억	40억	38억



Transmission in All ALMA Bands at Zenith
Transmission (%)
Frequency (GHz)
0
10
20
30
40
50
60
70
80
90
100
100
200
300
400
500
600
700
800
900
1000
PWV 0.3 mm
PWV 0.5 mm
PWV 1.0 mm
PWV 2.0 mm
PWV 5.0 mm

ALMA Receivers

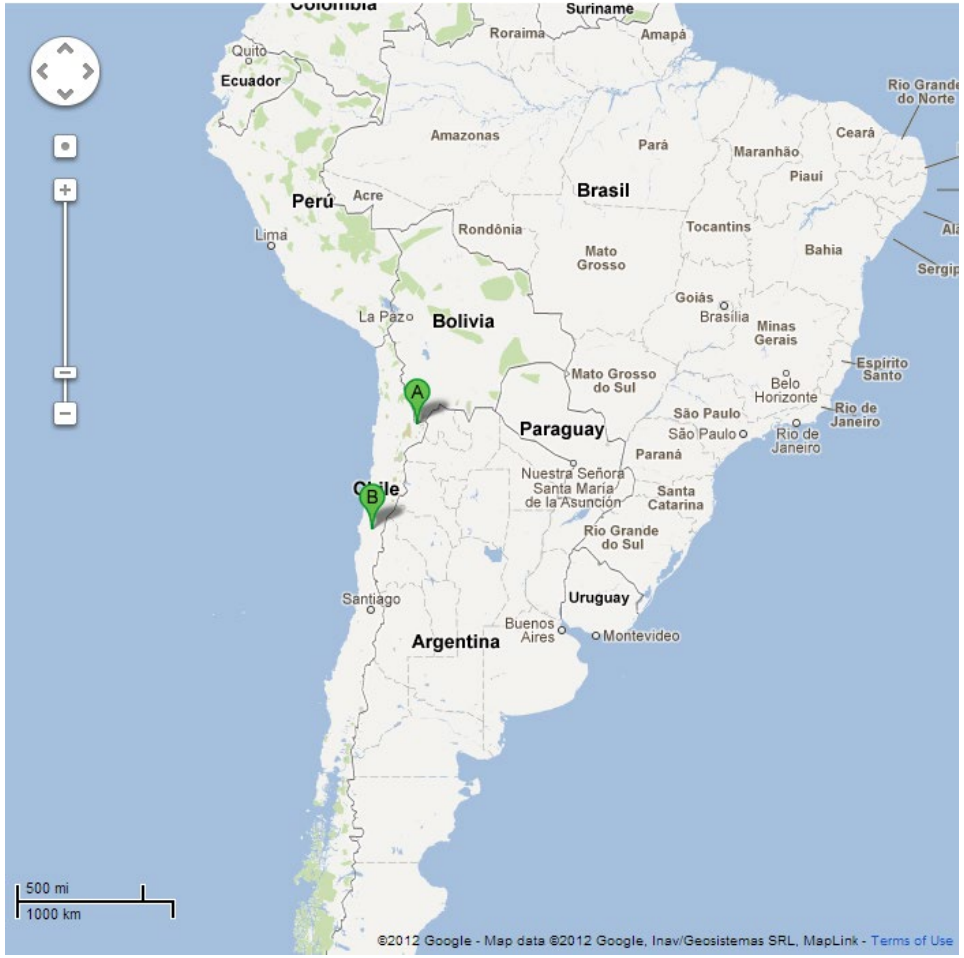




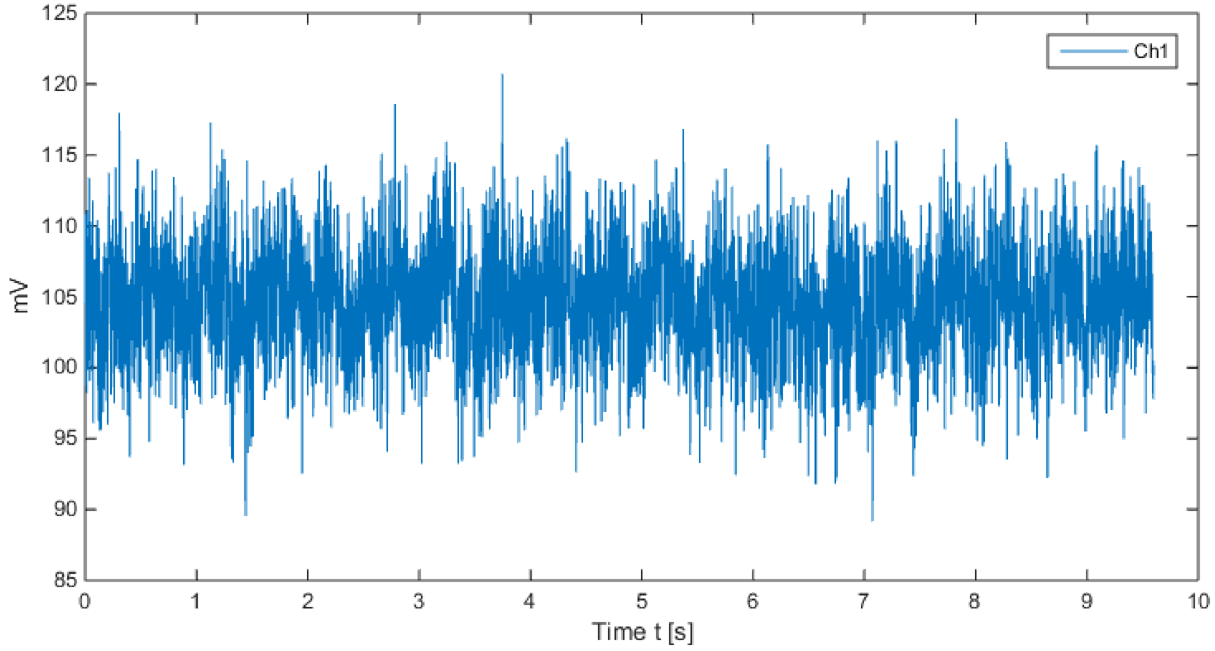
ALMA Band	Frequency Range (GHz)	Receiver Noise (K) over 80% of the RF band	Temperature (K) at any RF Frequency	To be produced by	Receiver Technology
1	31 - 45	17	26	tbd	HEMT
2	67 - 90	30	47	tbd	HEMT
3	84 - 116	37	60	HIA	SIS
4	125 - 163	51	82	NAOJ	SIS
5*	162 - 211	65	105	OSO	SIS
6	211 - 275	83	136	NRAO	SIS
7	275 - 373	147	219	IRAM	SIS
8	385 - 500	196	292	NAOJ	SIS
9	602 - 720	175	261	NOVA	SIS
10	787 - 950	230	344	NAOJ	SIS

ALMA correlators

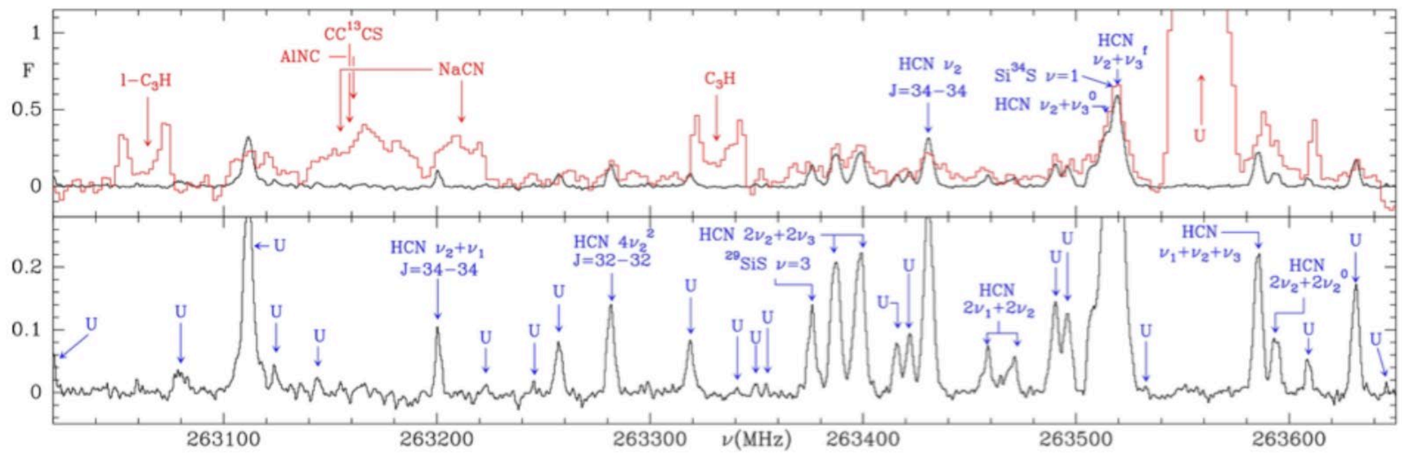
The ALMA Site

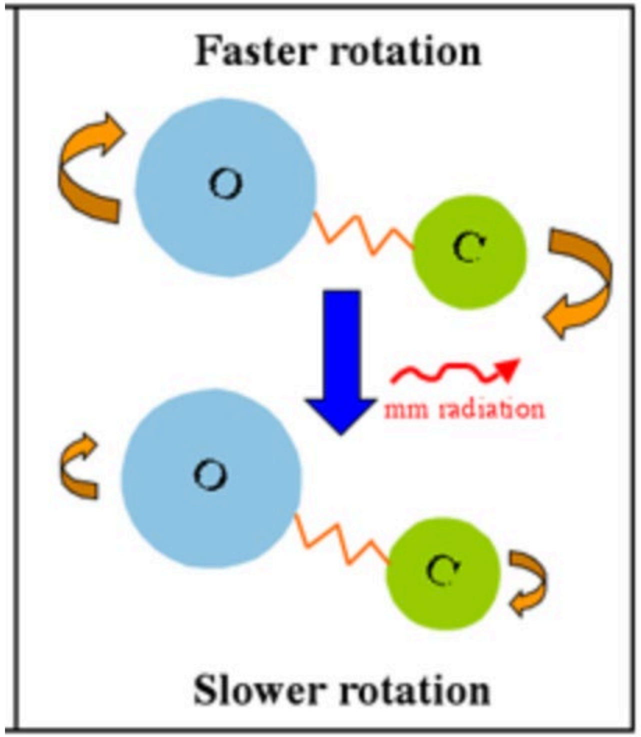


How to get a radio spectrum



Fourier Transform

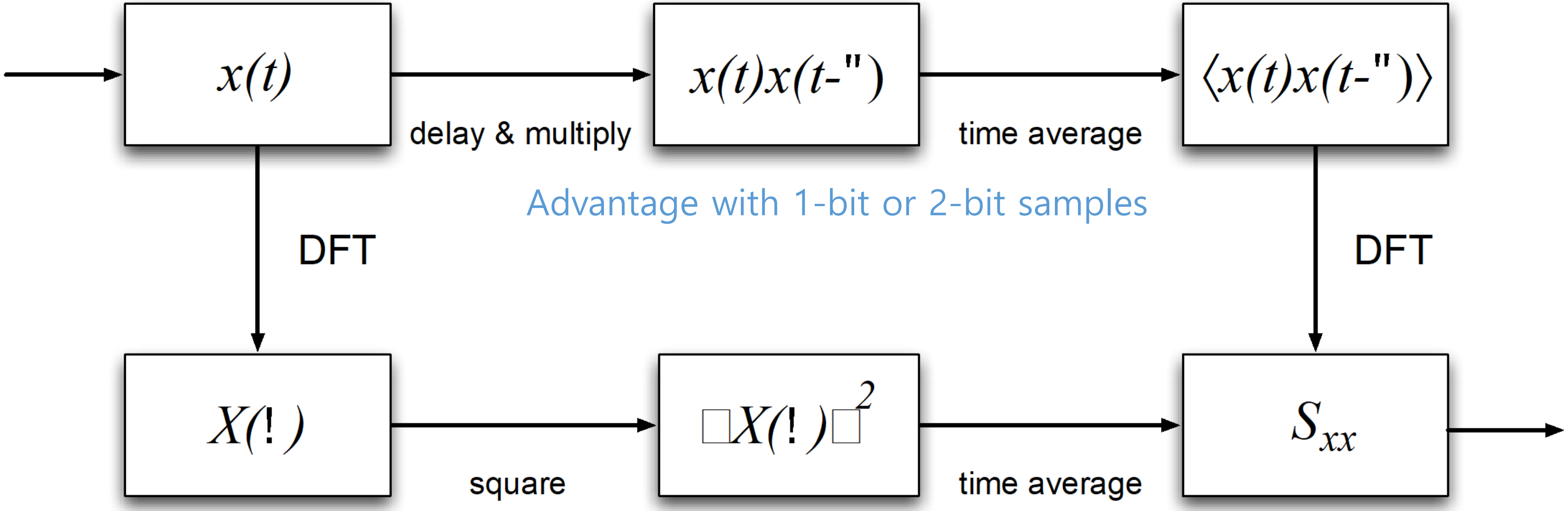




Wiener-Khinchin Theorem

$$\mathcal{R} = \frac{N}{\frac{2\log_2 N}{n_a - 1} + 2}$$ ~ 400,000 for na=66, $N=2^{20}$

XF



FX

Technologies for Spectrometers/Correlators

- ASIC (Application-Specific Integrated Circuit)
  - e.g, ALMA 64-antenna Correlator
- FPGA (Field-Programmable Gate Arrays)
  - e.g, ALMA 16-antenna ACA Correlator
- Software (high level-languages, e.g., C/C++, MPI, CUDA/OpenCL)
  - e.g, Spectrometer for the ALMA Total Power array

Advantages/Disadvantage of Software Spectrometer

- Advantages
  - rapid and easy development
  - flexibility (e.g., PFB, RFI) and expandability
  - 32bit floating point operations (high-precision)
  - Commodity Off-The-Shelf Technology (COTS)
  - high speed writing to storage
- Disadvantages
  - low performance/Watt

Comparison of Sensitivity loss

Correlator or Spectrometer	sampling loss	Loss due to internal calculation	Net loss
ALMA Baseline Correl ator	0.881 (2-bit sampling)	0.881 (2-bit calculation)	0.776
ACA Correlator	0.963 (3-bit sampling)	0.988 (4-bit re-quantization)	0.951
ACA Spectrometer	0.963 (3-bit sampling)	1.0 (32-bit floating point calcu lations)	0.963

Data rate and needed FFT performance from an ALMA antenna?

- Total sampling rate of a single ALMA antenna
  - Each baseband: 4 Gs/sec x 2 (polarization) = 8 Gs/s [Giga samples/second]
  - Total sampleing rate: 4 (baseband) x 8 Gs/s = 32 Gs/s
- Needed performance in units of FLOPS
  - 1M (2^{20}) point FFT
  - Number of floating point operations of 1M point FFT: $5\ N \log_2(N) = 5 * 10^6 * 20 = 0.1$ G floating point operations
  - Each baseband: $8 * 10^3 * 1$ M-point FFT /sec = 8k * 0.1 GFLOPS = 0.8 TFLOPS
  - Four basebands: 3.2 TFLOPS

NVIDIA GPU Roadmap

Tesla H100:
single precision 60 Tflops

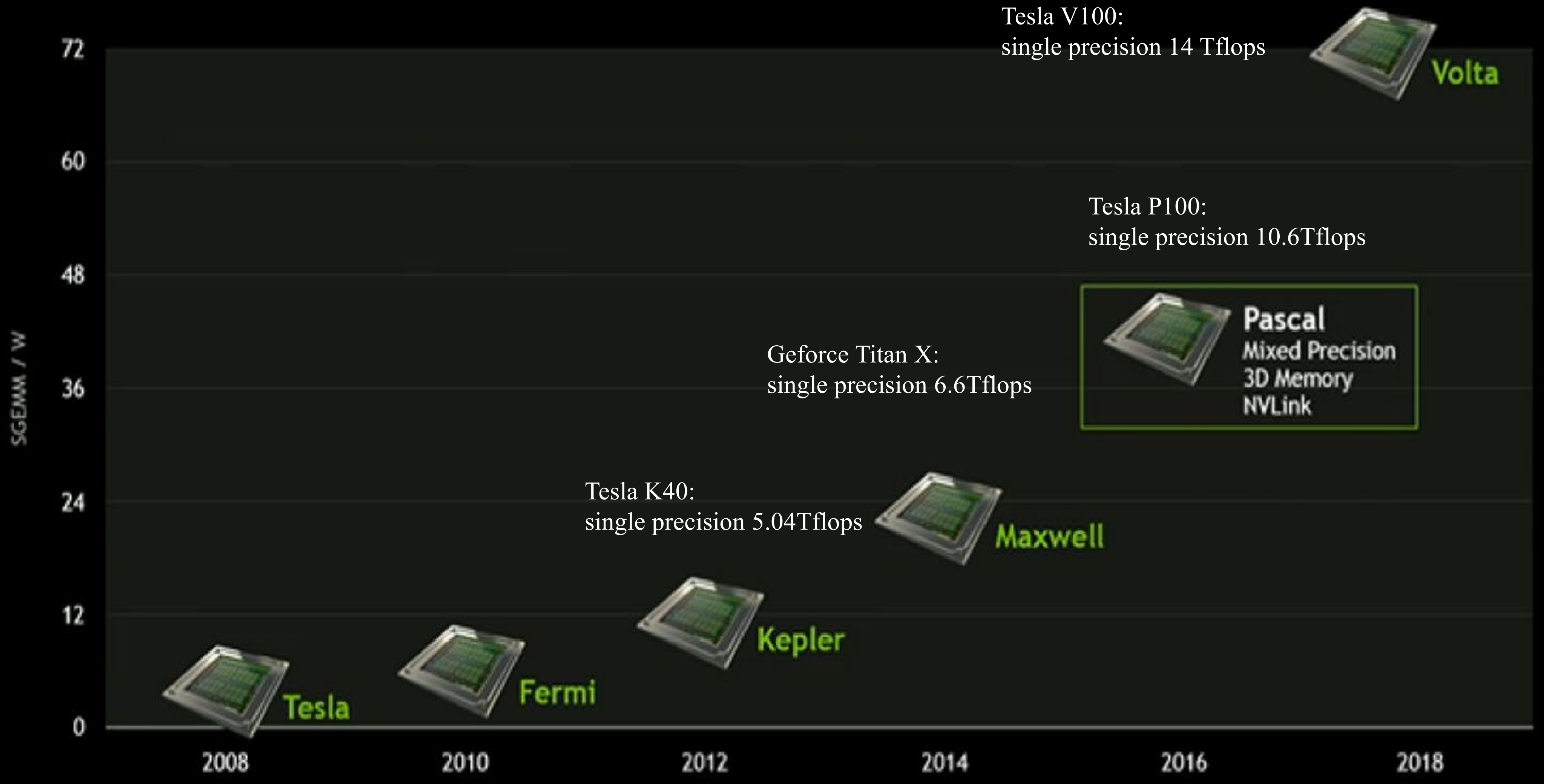
Tesla A100:
single precision 19.5 Tflops

Tesla V100:
single precision 14 Tflops

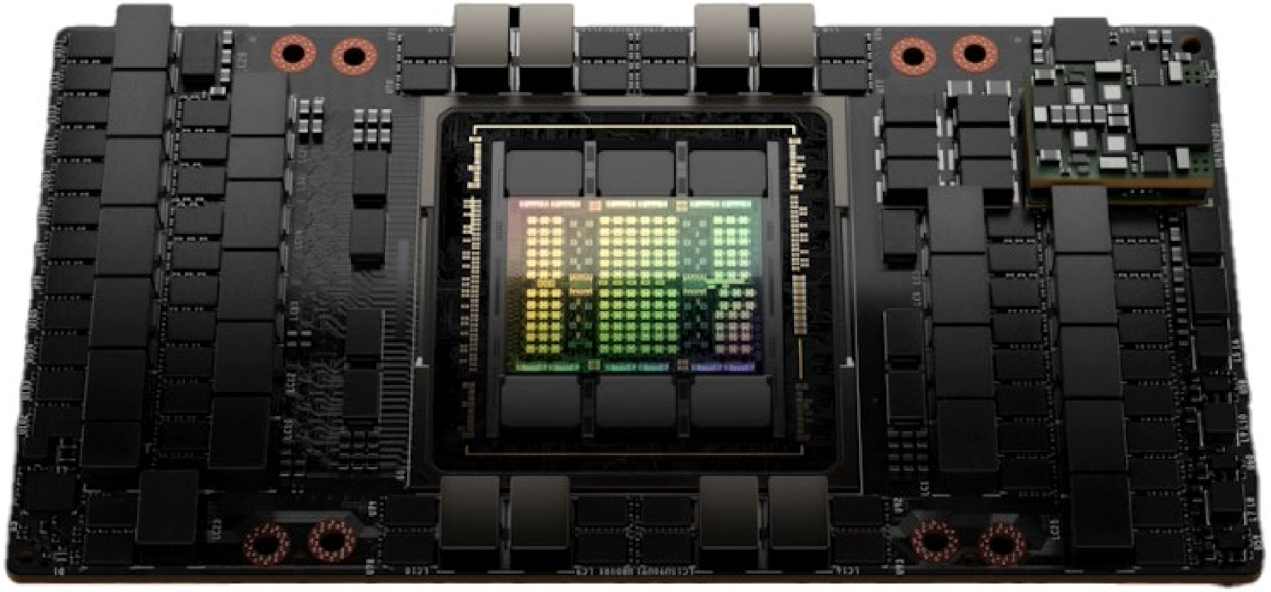
Tesla P100:
single precision 10.6Tflops

Geforce Titan X:
single precision 6.6Tflops

Tesla K40:
single precision 5.04Tflops



NVIDA TESLA H100 SXM5

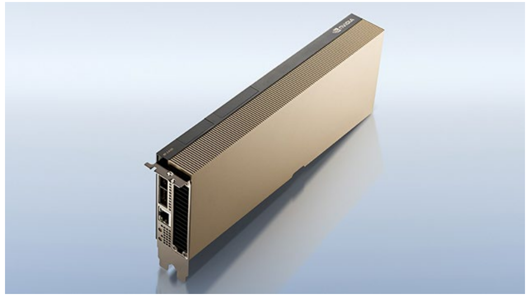


- Hopper Architecture
- Cores: 16896 FP32+432 Tensor
- Memory: 80 GB HBM3
- 4th Gen NVLink: 900 GB/s
- PCIe gen5: 128 GB/s
- Max Power: 700 W

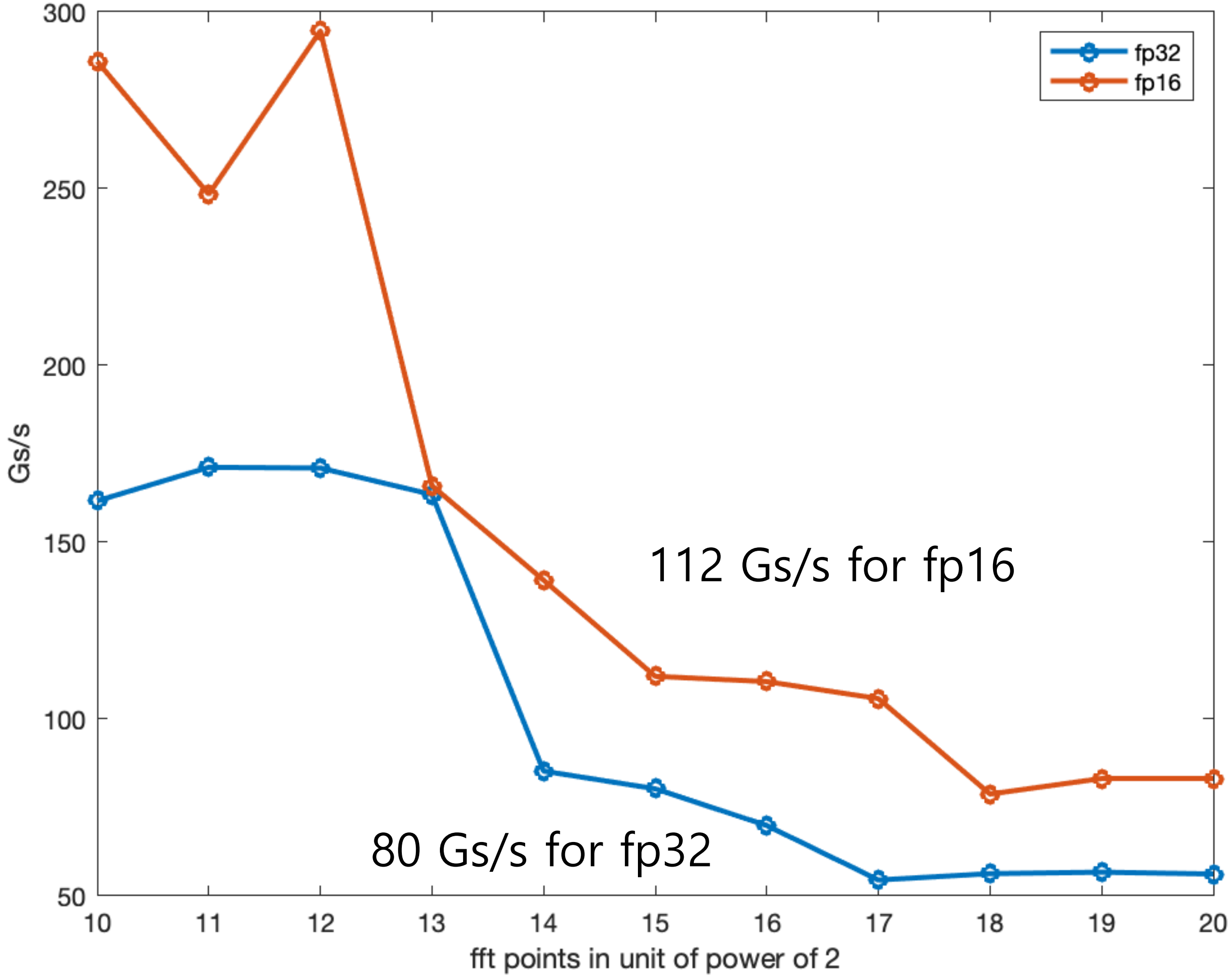
- 30 TFLOPS using FP64
- 60 TFLOPS using FP32
- 120 TFLOPS using FP16
- 500 TFLOPS using FP32 Tensor Core

FFT performance of NVIDIA A100-PCIE-40GB

- The single-precision (ha lf-precision) FFT perfor mance of NVIDIA A100 is 80 (112) Gsamples/s with 32768 FFT points.



NVIDIA A100-PCIE-40GB



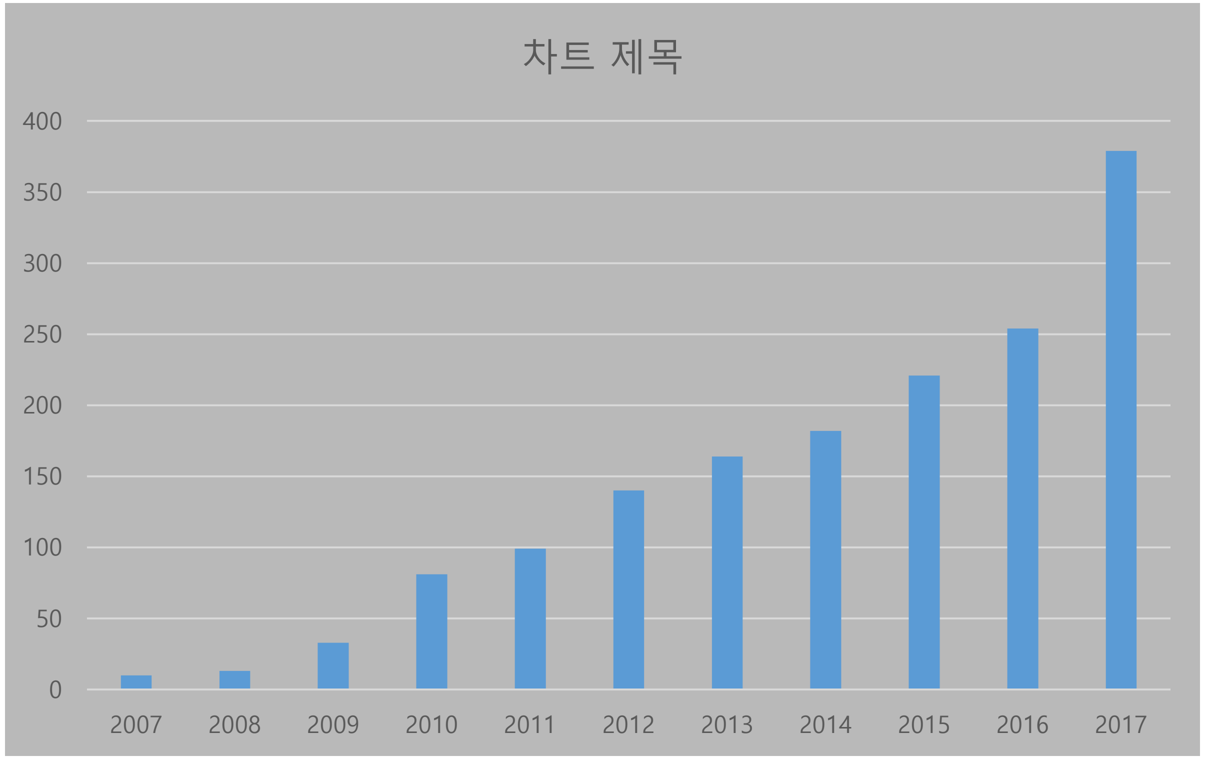
1024

32768

1048576

Astronomy Applications of GPU

- N-body simulations
- Fluid HD and MHD simulations
- Radiative Transfer
- Data processing, e.g., radio astronomy
- etc…
- ADS (search “GPU” in abstract)
    - 10 papers in 2007
    - 13 papers in 2008
    - 33 papers in 2009
    - 81 papers in 2010
    - 99 papers in 2011
    - 140 papers in 2012
    - 164 papers in 2013
    - 182 papers in 2014
    - 221 papers in 2015
    - 254 papers in 2016
    - 379 papers in 2017



Expected Benefit

- Operational Advantage:
  - The TP array will be operated independently from other arrays, which increases the observing efficiency of the TP array. For example, science operations on the TP array can continue without being affected by the downtime of the ACA Correlator (ACACORR).
- 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:
  - 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.

Past and Future Milestones of ACA Spectrometer

- Concept Design Review at Indian Wells,
  - September 24, 2016
- Preliminary Design Review at KASI
  - February 20~21, 2017
- Critical Design and Manufacturing Review at KASI
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- Acceptance on-Site Review
  - July, 2022
- Commission and Science Verification
  - April and May 2022
- ACA Spectrometer will be used from Cycle 10

List of Documents

DOCUMENTATION - Correlator
64 ACA Spectrometer
11. ACA Spectrometer Subsystem Design Description

2020-09-30_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.pdf
File length: 2584 KB
Tetsuhiro Minamidani Posted on 2019-10-13 18:08
Modified by Jongsoo Kim on 2020-09-30 06:01

In response to RID-1400, JK corrected typos in several places.

Author: Jongsoo Kim
Modification Group:
Document Number: CORL-64.00.00.00-0008-A-DSN
Status: Draft
Latest Version: Document is latest version...

Keywords: ACA Spectrometer CDMR

Previous versions:

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2	2019-10-17_CORL-64.00.00.00-004-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.docx	Tetsuhiro Minamidani	2019-10-17 11:18	(15126 KB)
3	2019-10-17_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.docx	Manabu Watanabe	2019-10-31 21:25	(15124 KB)
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5	2019-11-26_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.docx	Manabu Watanabe	2019-11-26 21:48	(15296 KB)
6	2020-03-31_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.docx	Jongsoo Kim	2020-03-31 03:22	(17745 KB)
7	2020-05-13_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.pdf	Manabu Watanabe	2020-05-14 04:34	(2248 KB)
8	2020-05-18_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.pdf	Manabu Watanabe	2020-05-20 22:36	(4213 KB)
9	2020-05-27_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.docx	Jongsoo Kim	2020-05-26 22:34	(16601 KB)
10	2020-06-10_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.docx	Jongsoo Kim	2020-06-10 03:05	(16605 KB)
11	2020-08-22_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.docx	Jongsoo Kim	2020-08-22 22:42	(16610 KB)
12	2020-08-23_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.pdf	Jongsoo Kim	2020-09-04 09:43	(7499 KB)

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2020-08-23_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.docx	2020-09-04 09:45	(16646 KB)
2020-09-30_CORL-64.00.00.00-0008-A-DSN_ACA_Spectrometer_Subsystem_Design_Description.docx	2020-09-30 06:01	(16633 KB)

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DOCUMENTATION - Correlator
64 ACA Spectrometer

- 64.10 ACA Spectrometer Module (ASM) Software
- 64.20 ACA Spectrometer Module (ASM) Server
- ACAS Electrical AOSTB related works
- Acceptance Reviews
- Critical Design and Manufacturing Readiness Review
- Preliminary Acceptance In-house (PAI)
- Preliminary Design Review (PDR)
- Technical Specifications and ICDs

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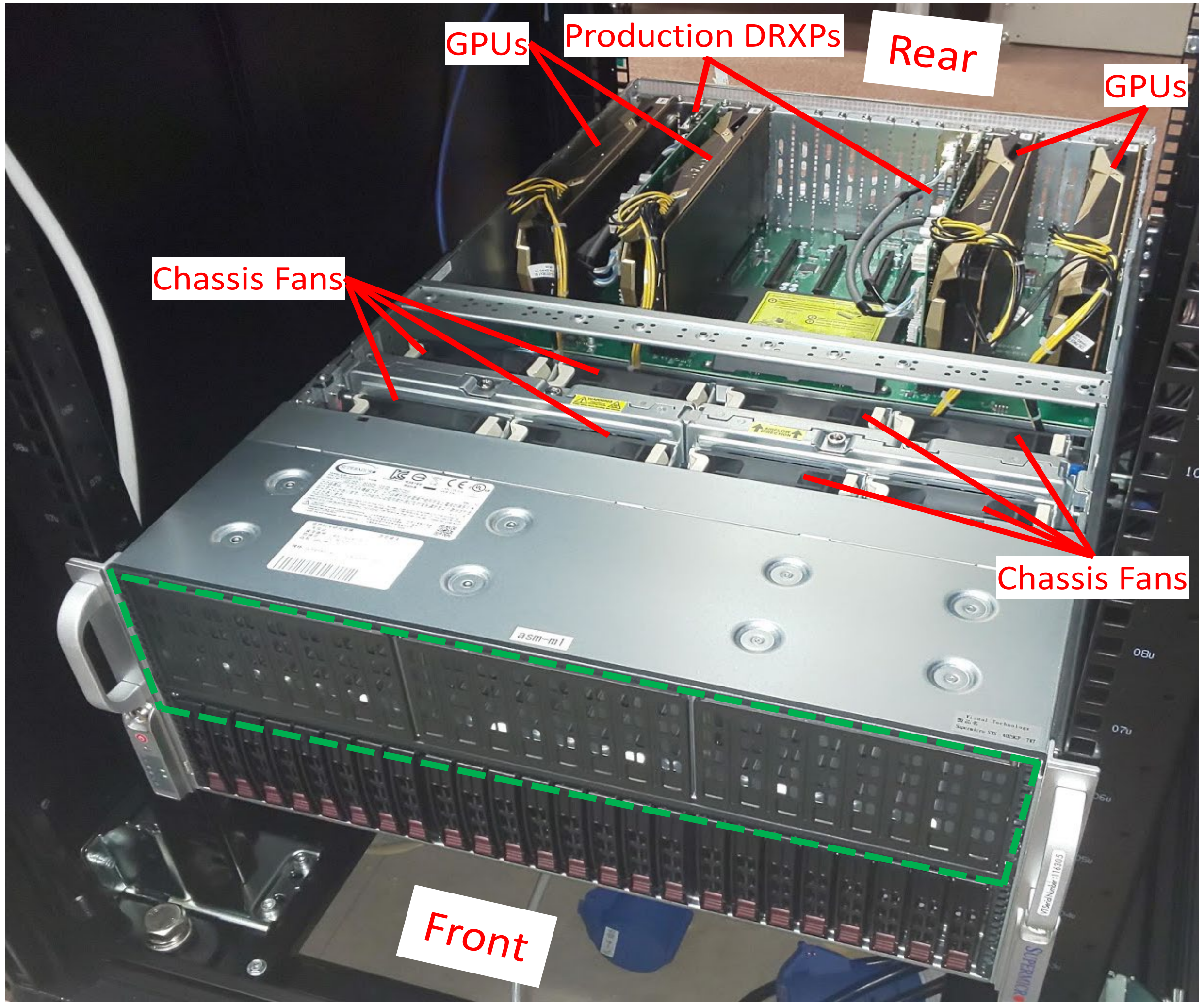
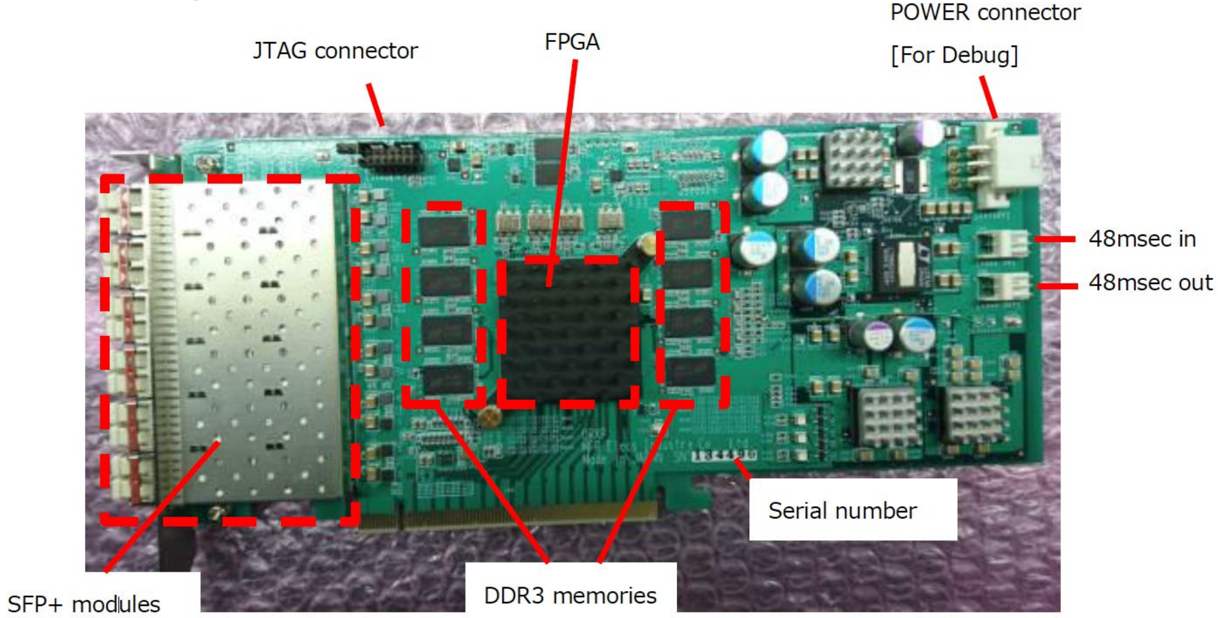
Unseen	Type	Task	Number	Number	Title	Author	Status	Replies	Activity date
			14.	CORL-64.00.00.00-0017-A-PLA	ACA Spectrometer Development/Production Plans	Manabu Watanabe	Released	(1)	2020-09-09 09:02
			11.	CORL-64.00.00.00-0008-A-DSN	ACA Spectrometer Subsystem Design Description	Jongsoo Kim	Draft	(3)	2020-09-30 06:01
			10.	ALMA-64.00.00.00-0012-A-REP	ACA Spectrometer Structural Analysis Report	Takashi Nakamoto	Draft		2020-09-04 09:48
			9.	CORL-64.00.00.00-0021-A-REP	ACA Spectrometer Module Timestamping Accuracy	Takashi Nakamoto	Draft		2020-09-04 10:08
			8.	CORL-64.00.00.00-0013-A-REP	Study Report on Cooling Capacity of ACA Correlator Room for ACA Spectrometer	Takashi Nakamoto	Draft		2020-09-04 09:51
			7.	CORL-64.00.00.00-0016-A-REP	ACA Spectrometer Compliance Matrix	Jongsoo Kim	Draft		2021-11-23 20:31
			5.	CORL-64.00.00.00-0015-A-REP	ACA Spectrometer Safety Report	Takashi Nakamoto	Draft		2021-11-05 19:43
			4.	CORL-64.00.00.00-0006-B-SOW	ACA Spectrometer Subsystem Statement of Work	Tetsuhiro Minamidani	Released		2020-04-30 19:18
			3.	CORL-64.00.00.00-0007-A-PLA	ACA Spectrometer Subsystem Management Plan	Tetsuhiro MINAMIDANI	Draft		2020-09-09 12:21

1 2 3

ASM; DRXP; GPU

Acceptable signal level of a transceiver
-15.5 ~ -1 dBm

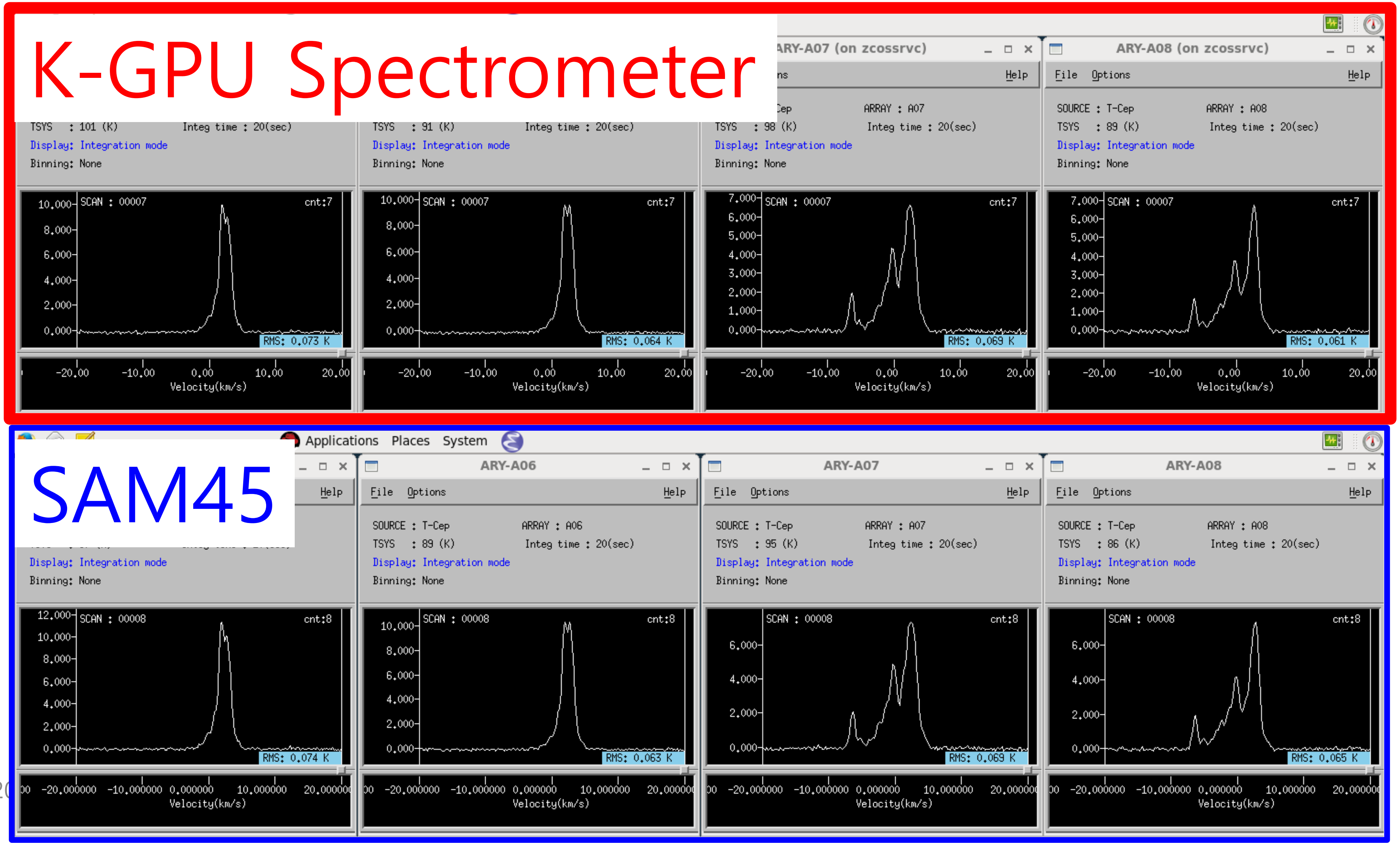




First Spectra with 45-m Telescope (Dec. 25, 2017)

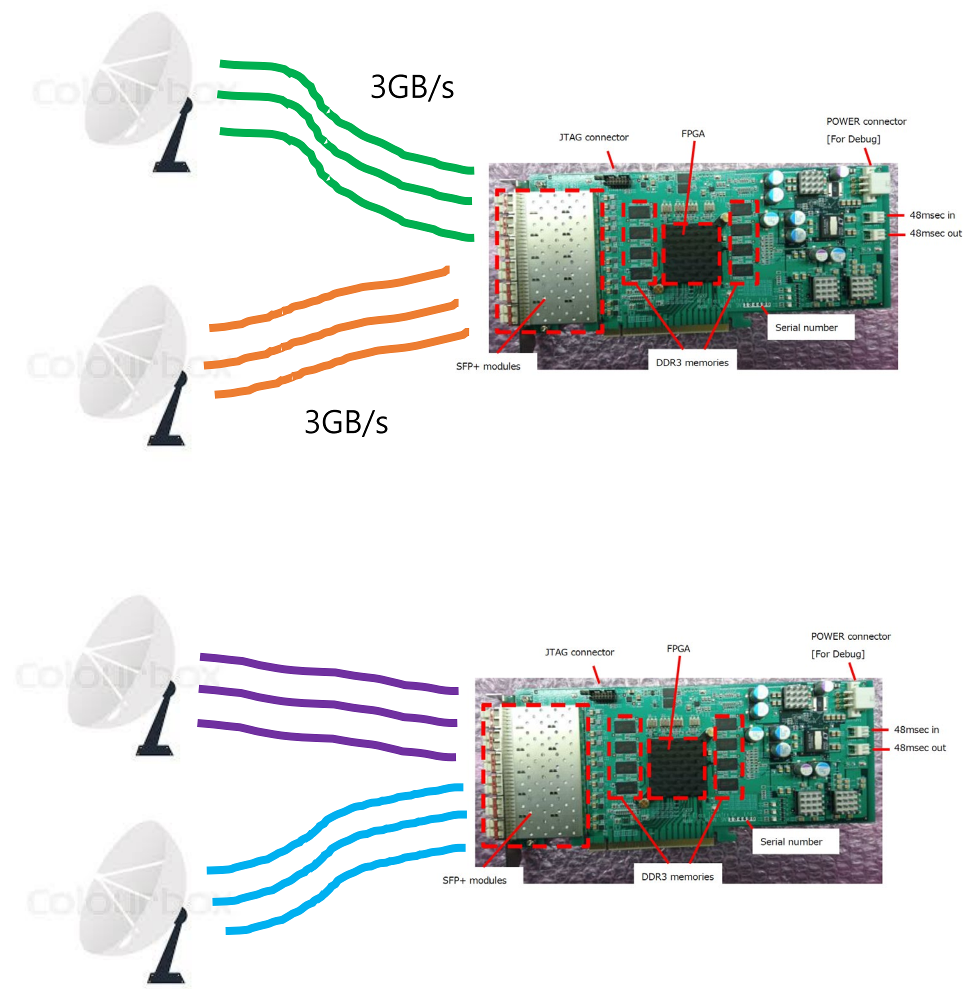
SiO (v=2, J=1-0) @ 42.8GHz

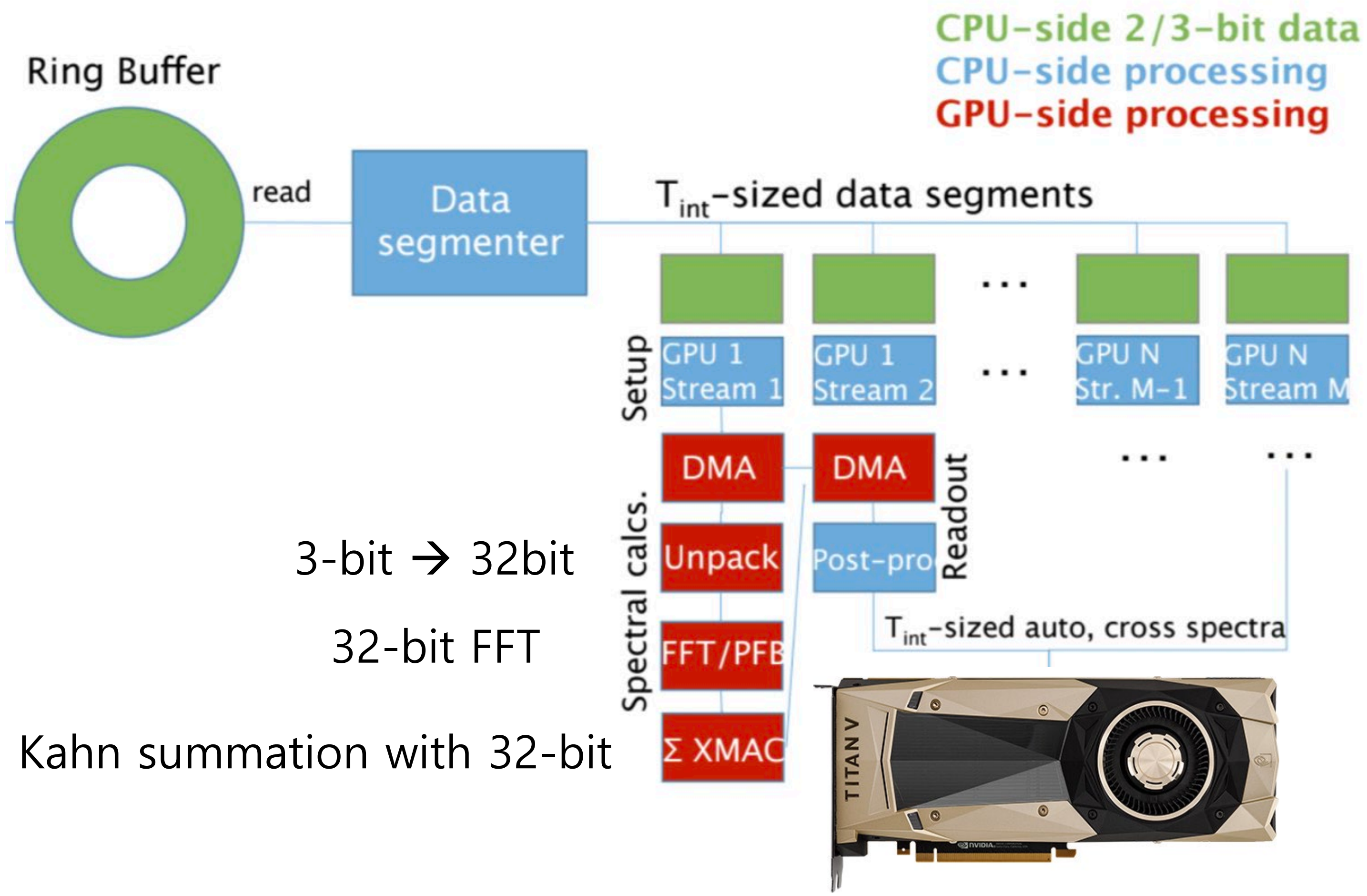
SiO (v=1, J=1-0) @ 43.1GHz



4 TP antennas

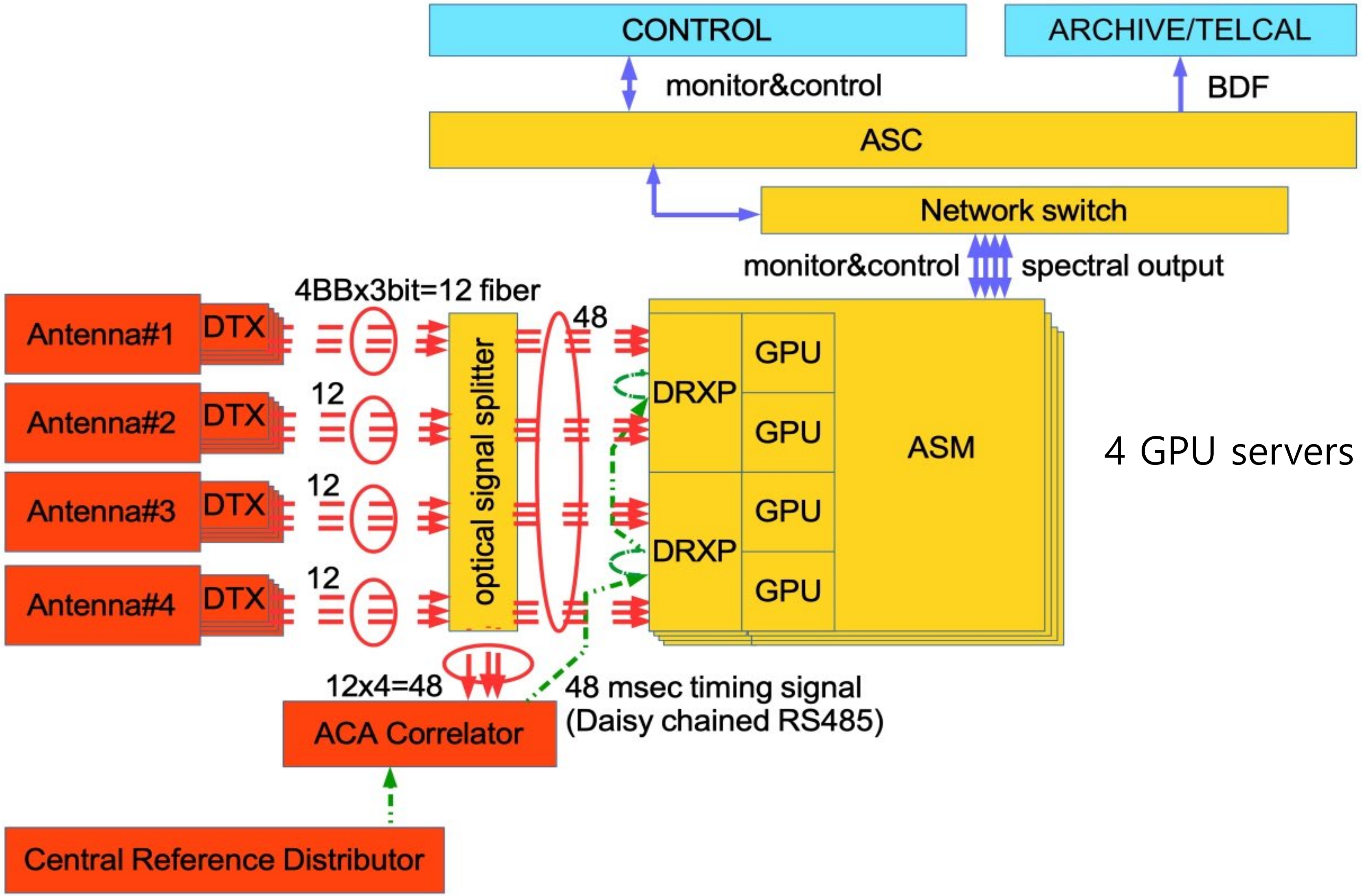
Data streams
from same BB





The Spectrometer is designed to process data streams from one BB from an antenna using one GPU.

High-level view of ACA Spectrometer

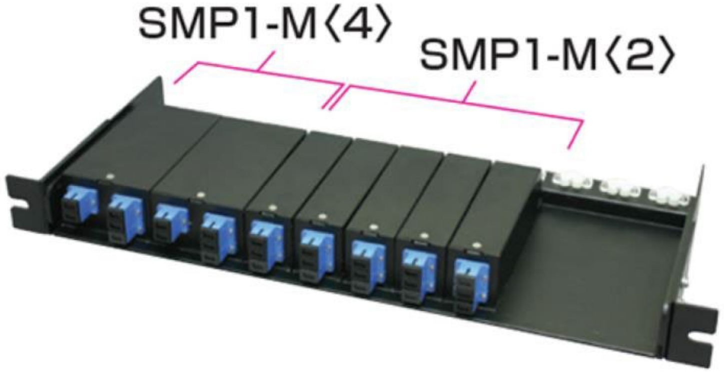


4 GPU servers

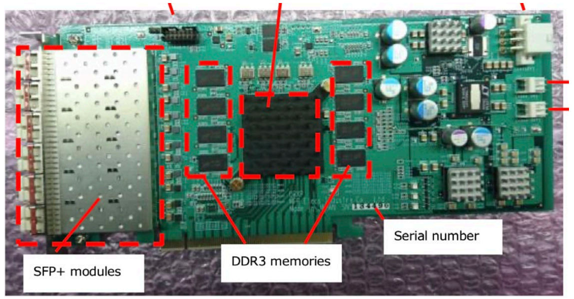
Optical signal paths

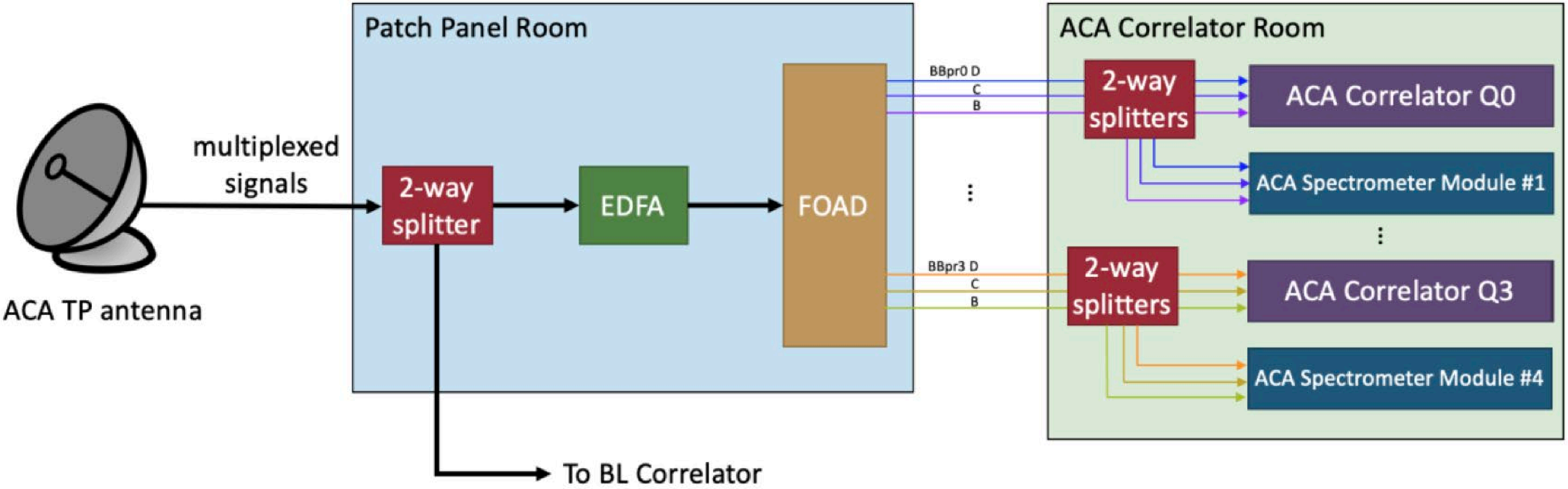
EDFA

EDFA



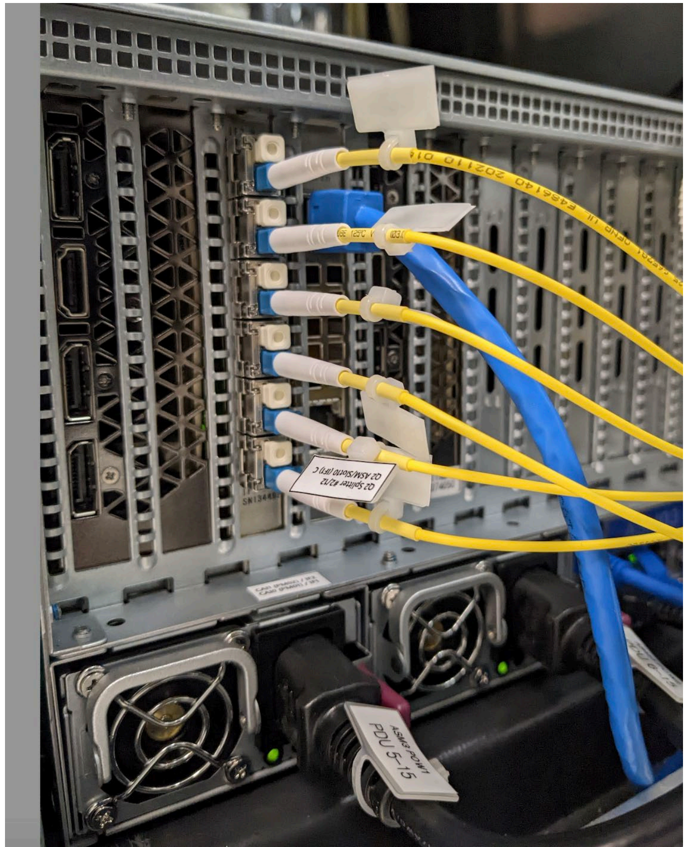
DRXP





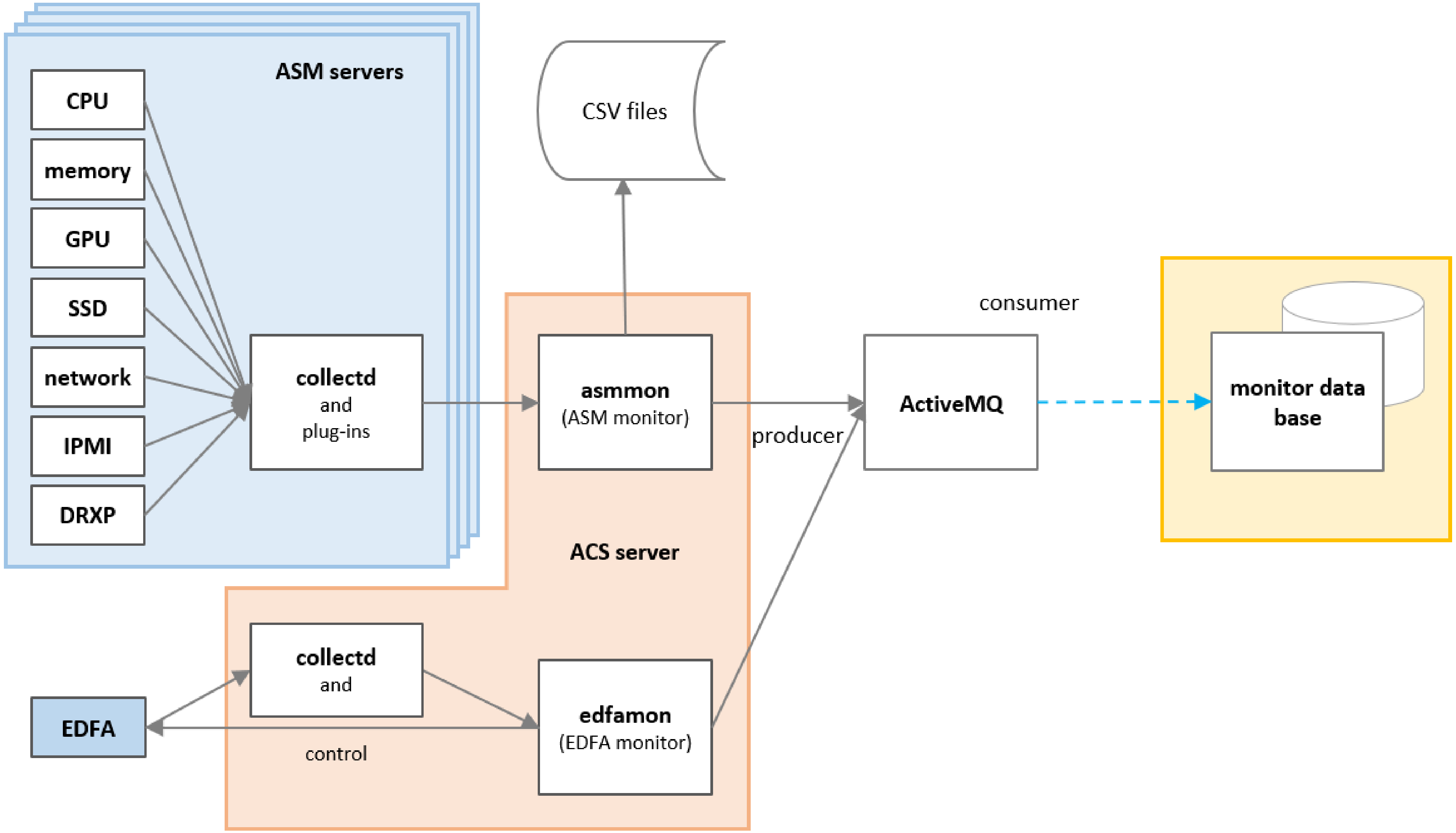
EDFA

Optical Splitter



DRXP

Monitoring



ASM servers
CPU
memory
GPU
SSD
network
IPMI
DRXP
collectd
and
plug-ins
CSV files
asmmon
(ASM monitor)
ACS server
producer
consumer
ActiveMQ
monitor data
base
EDFA
collectd
and
control
edfamon
(EDFA monitor)

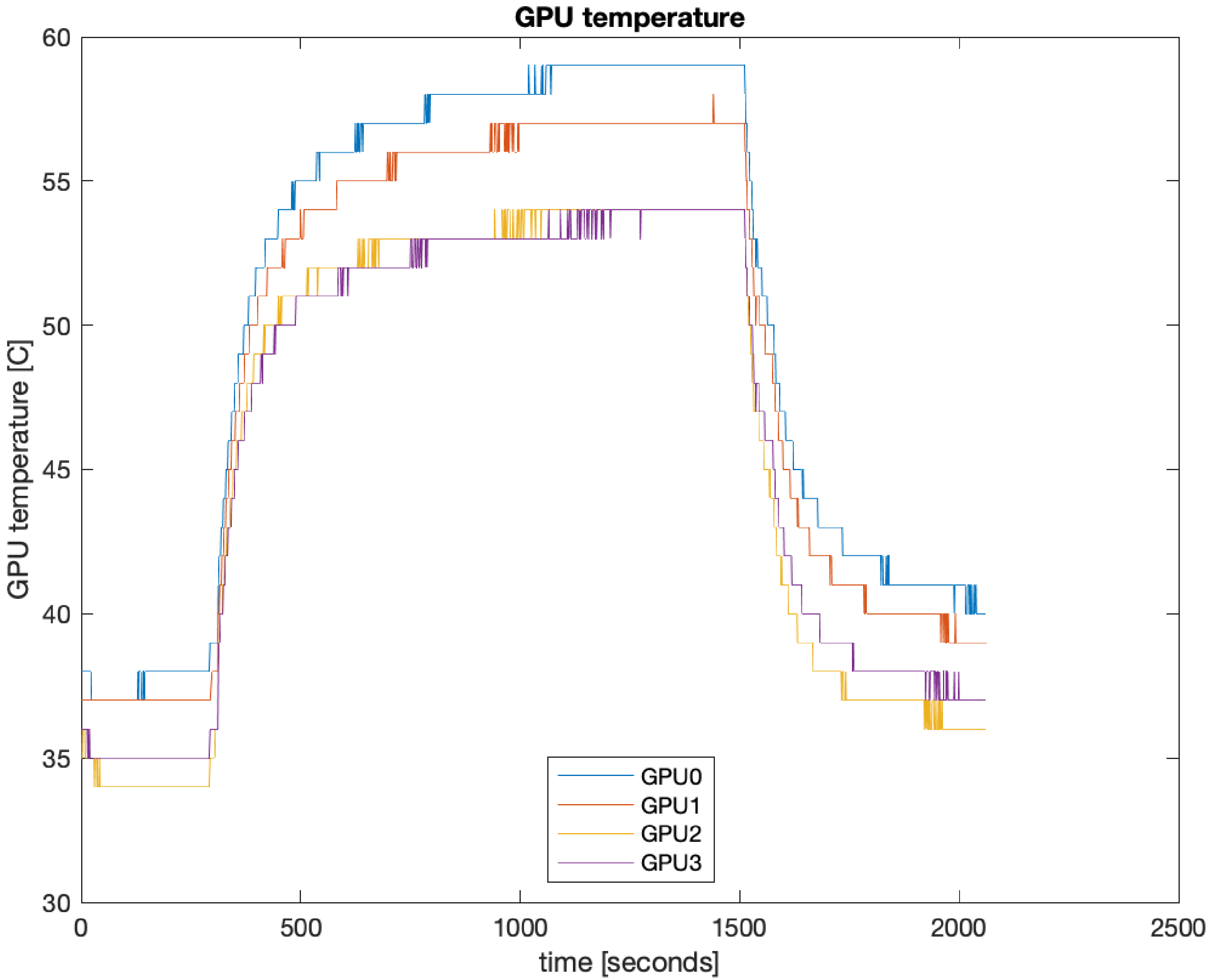
dstat: RT-monitoring GPU, CPU, Power, Fan

- nvidia-gpu-temp : Temperature in degree C.
- nvidia-gpu-util : GPU utilization in %.
- nvidia-gpu-power: Power consumption in watt.

- dcmi-power : Power consumption in Watt
- ipmi-fan : Fan speed in RPM.

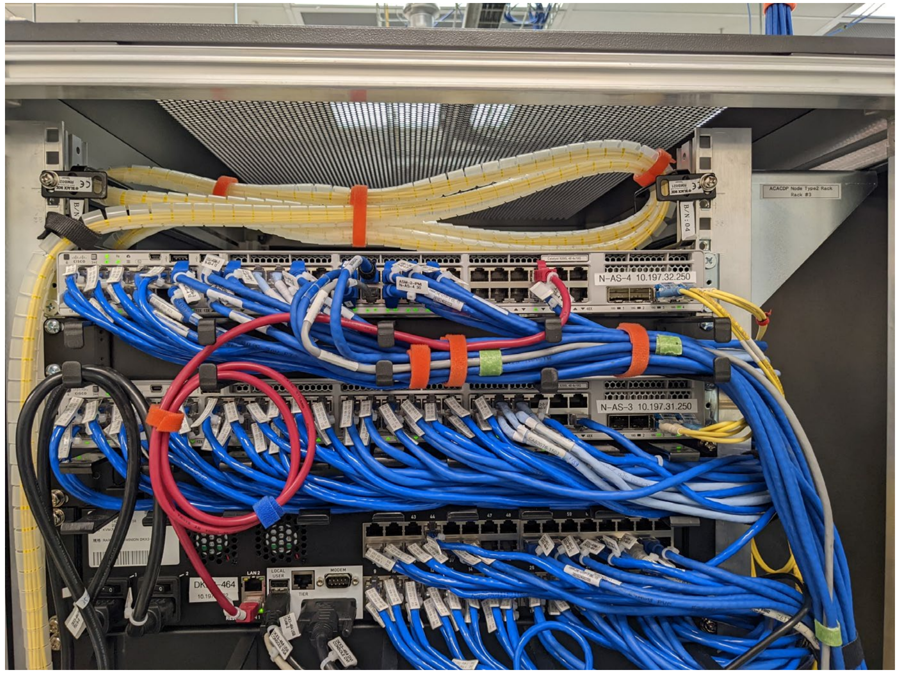
- cpu-freq : CPU clock frequency in Hz.
- ecc : Corrected errors (ce) and uncorrected error (ue) counts.

Temperature of GPUs



Network configuration for ASMs and ASCs

- Allocate a subnet 10.197.32.xxx for the Spectrometer servers
  - We changed the original plan to use a subnet 10.197.31.xxx.
    - Separate traffic of Correlator (31) and Spectrometer (32)
    - No need to install additional network switches
  - IP addresses are defined in two files, SYS-4029GP-TRT_ASM.conf, RX1330M4_ASC.conf, in gns:/etc/dhcpd
  - Hostnames and corresponding IP addresses
    - coj-asm-[1-5]; 10.197.32.[81-85];
    - coj-asc-[1-2], 10.197.32.[86-87];
    - coj-asm-[1-5]-ipmi, 10.197.32.[181-185]
    - coj-asc-[1-2]-ipmi, 10.197.32.[186-187]
  - share a Cisco switch with PDUs



NTP (Network Time Protocol) configuration

- **ACA Spectrometer uses not TE signal but NTP for timestamp.**
- **The error of NTP timestamp should be less than 21 ms (see** CORL-64.00.00.00-0021-A-REP)
- **important configuration option in /etc/ntp.conf**
  - **server ntp.osf.alma.cl minpoll 4 maxpoll 4 (polling interval: 16 seconds)**
- **Output of "ntpstat" from an ASM as of today**
  - synchronised to NTP server (10.195.5.10) at stratum 2
  - time correct to within 2 ms
  - polling server every 16 s
- **Conclusion: The NTP time accuracy is accurate enough for the Spectrometer**
- **We will keep monitoring the error of NTP timestamp.**

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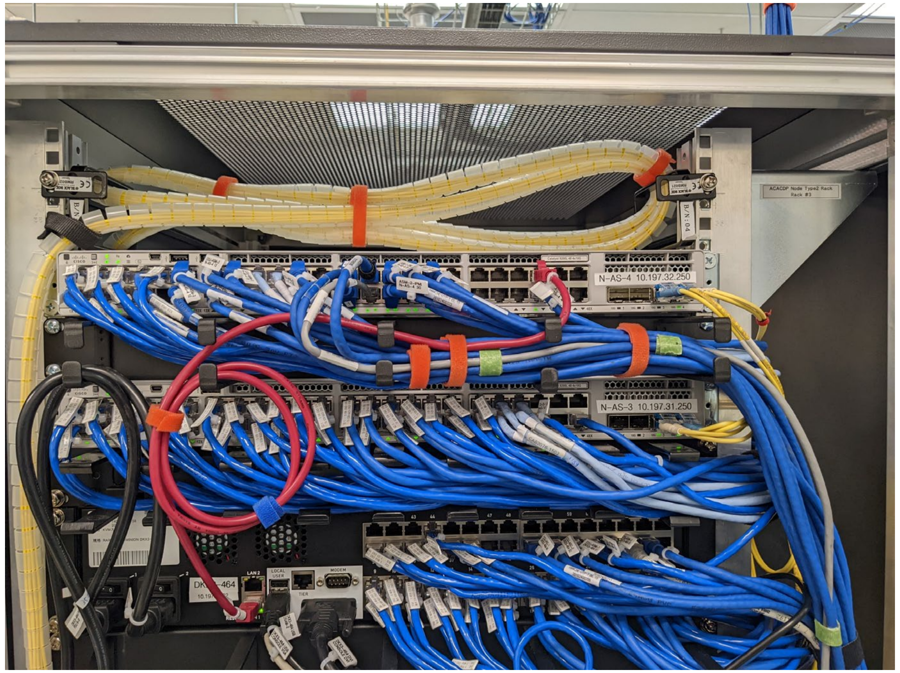

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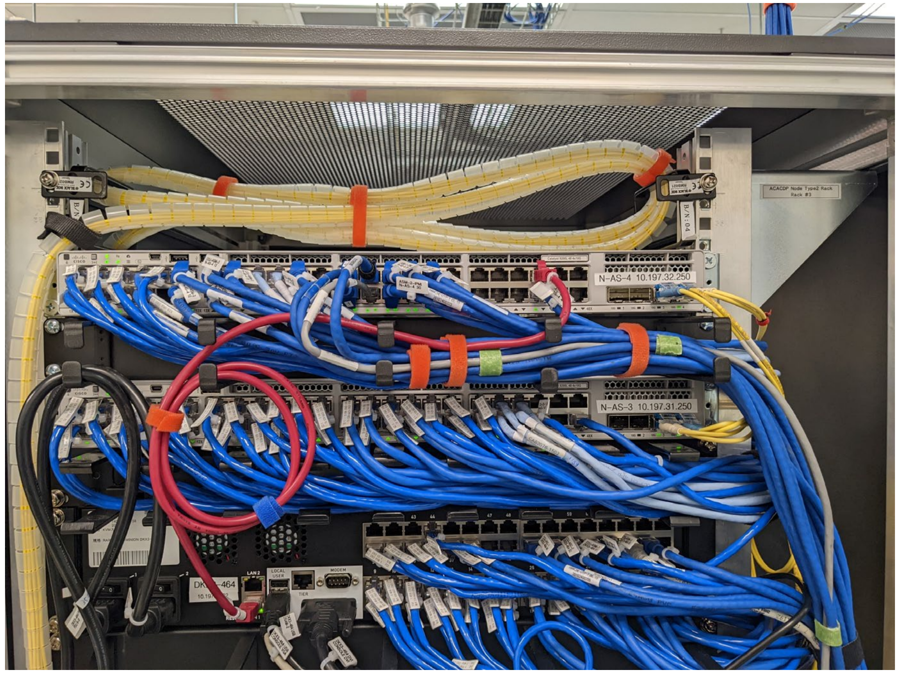

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MonitorData Service

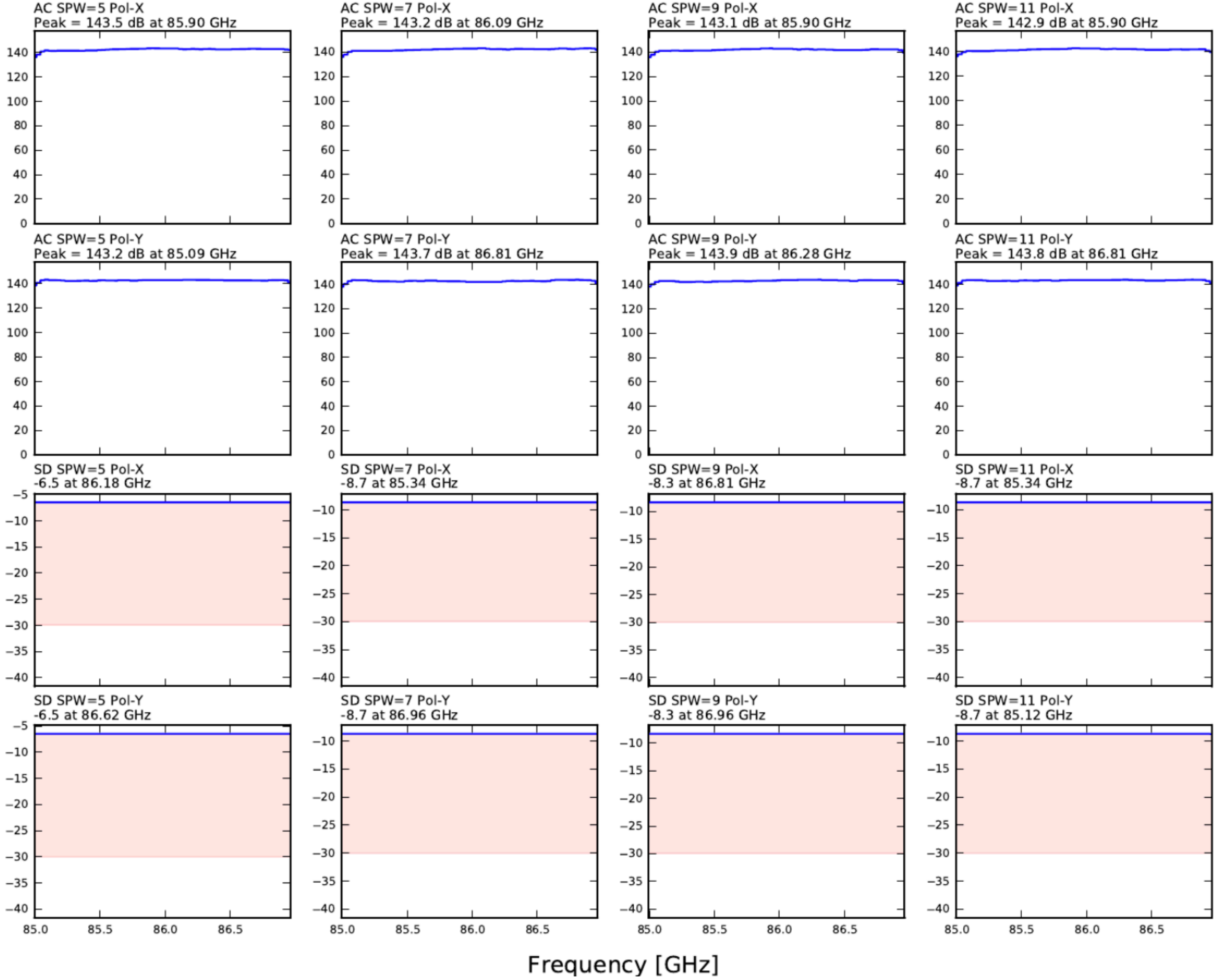
This service creates daily reports about Monitoring Information coming from CONTROL and CORR subsystems.

Directory Listing of /monitordata/2022/02/2022-02-22/

home > 2022 > 02 > 2022-02-22

File	Size	Last Modified
..		
ACACORR_CCC_MONITOR/	-	Feb 22 2022 12:00:54 AM
ACASPEC_ASM1_CPU0/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU1/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU10/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU11/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU12/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU13/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU14/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU15/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU2/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU3/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU4/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU5/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU6/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU7/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU8/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_CPU9/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_DRXP0/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_DRXP1/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_DRXP2/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_DRXP3/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_GPU0/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_GPU1/	-	Feb 22 2022 05:34:13 PM
ACASPEC_ASM1_GPU2/	-	Feb 22 2022 05:34:13 PM

PM04



First spectrum
source: J2253+1608
Observed time:
18-Feb-2022/18:57:42.9(UTC)
Integration time: 0.048s