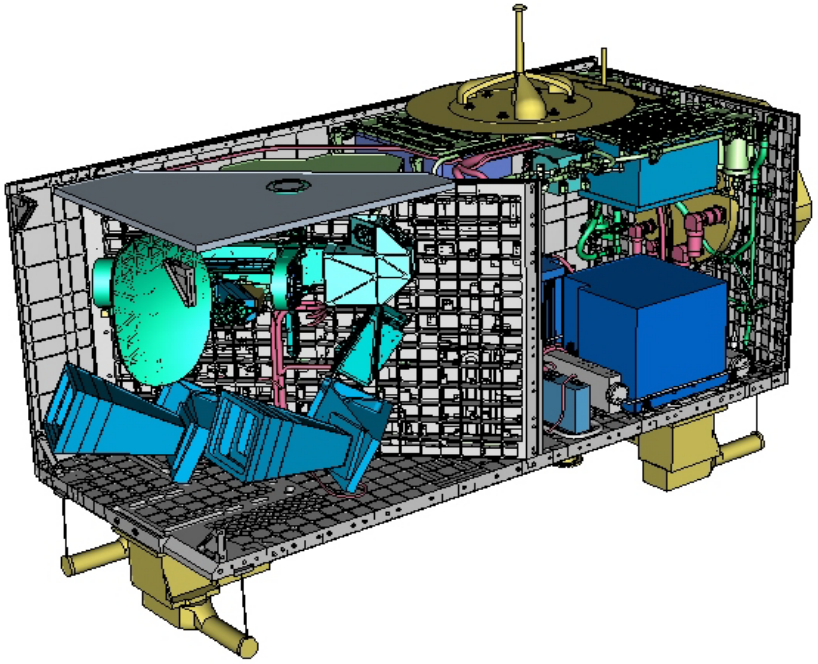
「SMILES による地球大気観測の成果」

- Overview of SMILES Instruments
- Achievements and Future



Engineering Objectives of SMILES

Space Demonstrations of

- Superconducting (SIS) Mixer
- 4-K Mechanical Cooler
- Submillimeter Limb-Emission Sounding

"The engineering usefulness will not be limited within applications to atmospheric sciences. They also will be utilized for future space science missions."

- SMILES Mission Plan (2002)

Why We Need Superconducting Mixer

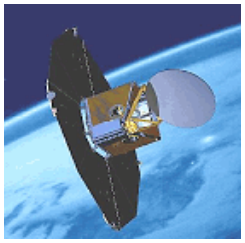
Radiometer Noise:

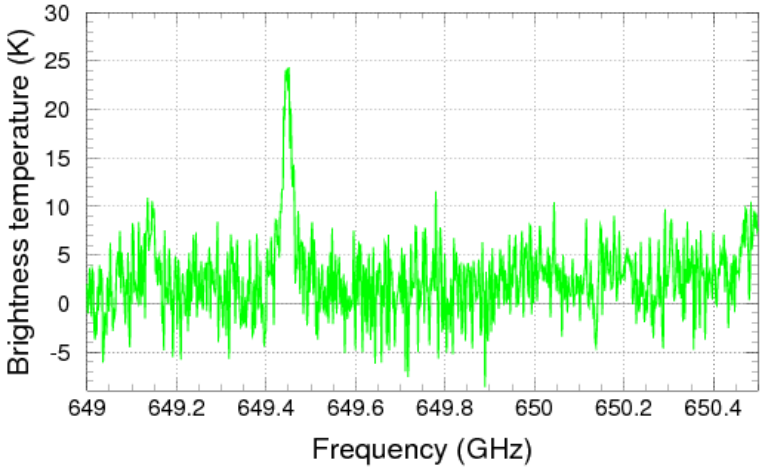
T_{RX} : Input Equivalent Noise [K]
B : Band Width [Hz]
τ : Integration Time [sec]

$$T_\sigma = \frac{T_{RX}}{\sqrt{B\tau}}$$

Odin/SMR (Launch 2001)

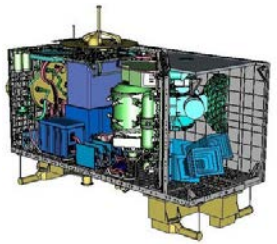
- Cooled Semiconductor Mixer
- Tsys = 3,000 K

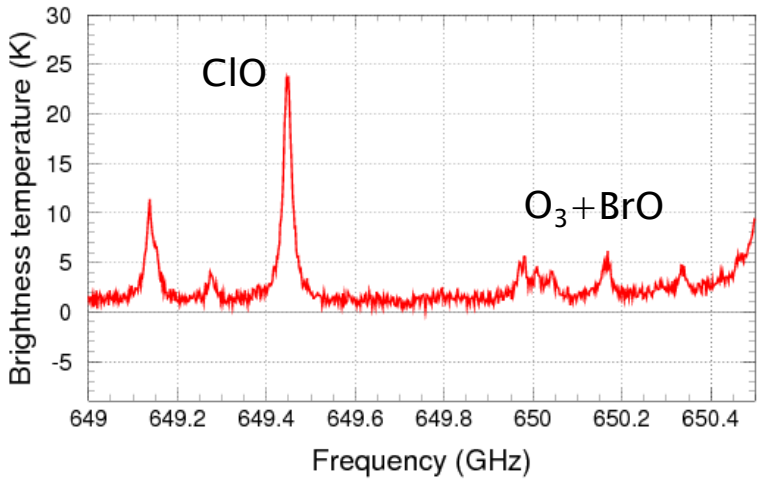




SMILES (Launch 2009)

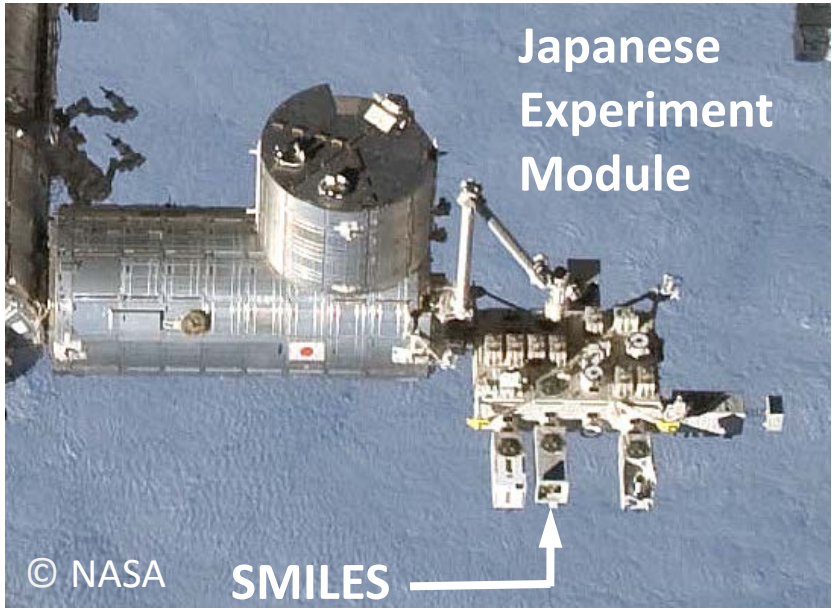
- Superconducting Mixer
- Tsys = 350 K





Current Status of SMILES (1/2)

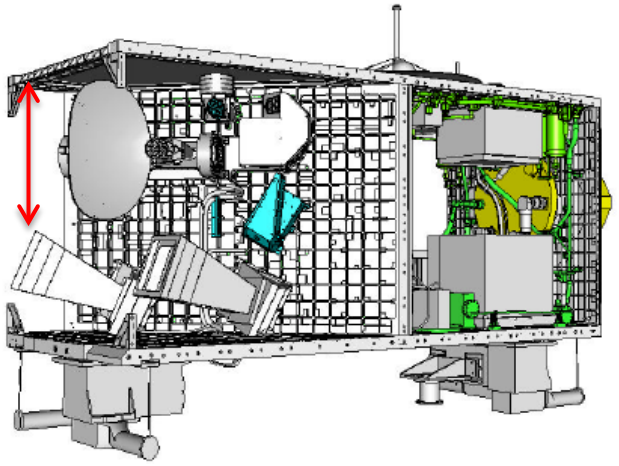
- SMILES is an atmospheric observation mission with a 640-GHz-band SIS receiver.
- Launched on 11 September 2009, started nominal observation from November, at Japanese Experiment Module (JEM) of International Space Station (ISS).



Current Status of SMILES (2/2)

- SMILES was designed to operate for 1-year in orbit. However, Instrumental troubles have prevented SMILES from scientific observation since April 2010.
  - Local oscillator: likely due to a short-circuit fault of a Gunn diode.
  - JT cryocooler: contaminants, possibly CO_2 , block helium gas flow.
- Observation operations had been terminated except for the investigation of cryocoolers.

Block Diagram



Effective Beam-width:
0.096° (3.5-4.1 km)

Submillimeter Antenna (ANT)

Submillimeter Antenna (ANT)
Submm-Wave Limb-Emission Signal
Main Reflector
Calibration Hot Load (CHL)
Cold Sky Terminator (CST)
Star Tracker (STT)
Star Camera Units (CAM)
Star Camera Controller (CAMC)
Payload Bus (BUS)
Thermal Control System (TCS)
Electric Power System (EPS)
JEM Interface Mechanism (JIF)
Data Processing & Control Section (DPC)
SSB Filter
Submm Local Osc. (SLO) 637.32 GHz
SLO Controller (SLOC)
Amb. Temp. Optics (AOPT)
USB SIS Mixer
HEMT Amp.
HEMT Amp.
Amp.
IF: 11GHz - 13GHz
LSB SIS Mixer
HEMT Amp.
HEMT Amp.
Amp.
4K
20K
Cryostat Cryo-Electronics Unit (CRE) 100K
Stirling & JT Drive. Elec. (SJTD)
Helium Gas Compressor (HECP)
CRE Control Electronics (CREC)
Submillimeter Receiver (SRX)
IF Amplification Section (IFA)
D/C
BPF IF Amp
Switching Network
11.8 - 13.0 GHz
1.55 - 2.75 GHz Band C
SW
SW
14.55 GHz
11.8 - 13.0 GHz
1.55 - 2.75 GHz Band A
11.0 - 12.2 GHz
1.55 - 2.75 GHz Band B
9.45 GHz
Comb Generator
CVU
AU-1
AU-2
Radio Spectrometer (AOS)

Submillimeter Receiver (SRX)

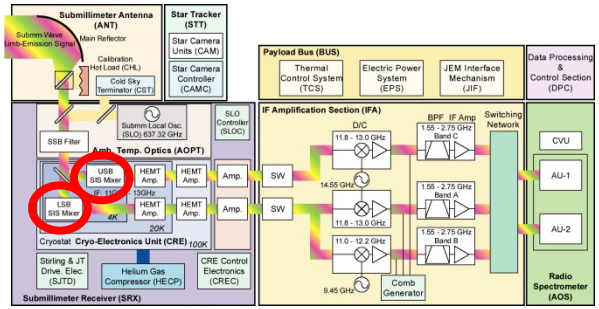
IF Amplification Section (IFA)

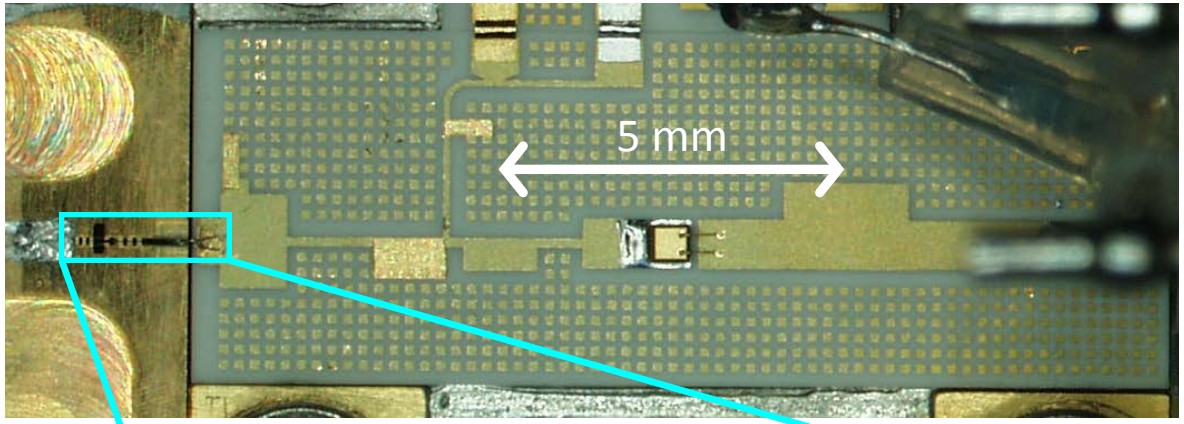
Radio Spectro-meter (AOS)

SIS Mixer

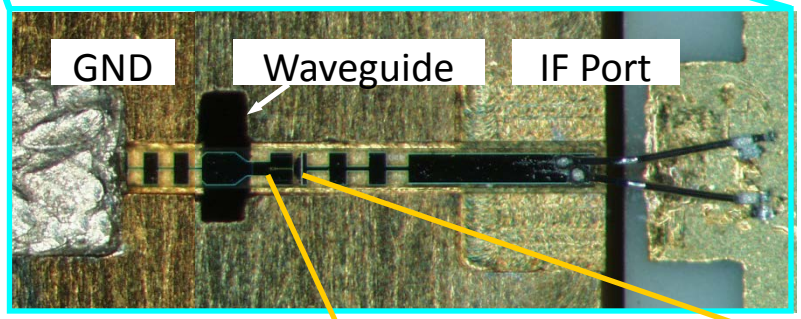
Superconductor-Insulator-Superconductor Mixer

- LO: 637.32 GHz
- IF: 11-13 GHz

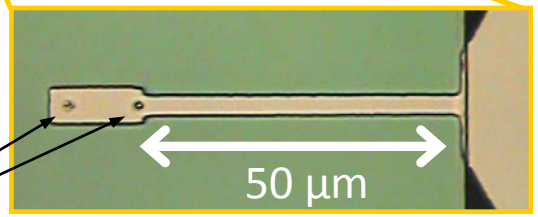




- LO/RF input: Corrugated Horn
- IF output: SMA



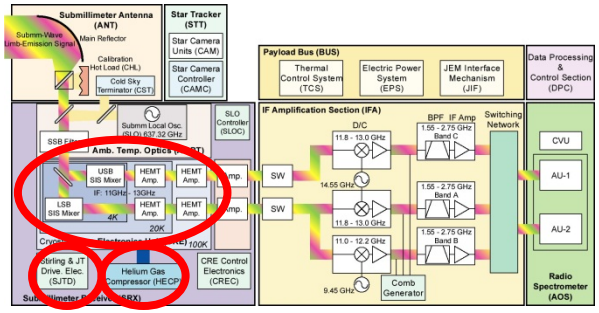
- SIS Junction: Nb/AlOx/Nb
- Junction Size: ~1 x 1 μm^2
- Current Density: 6-7 kA/cm^2
- RF Matching: PCTJ
- Fabricated at Nobeyama Radio Observatory

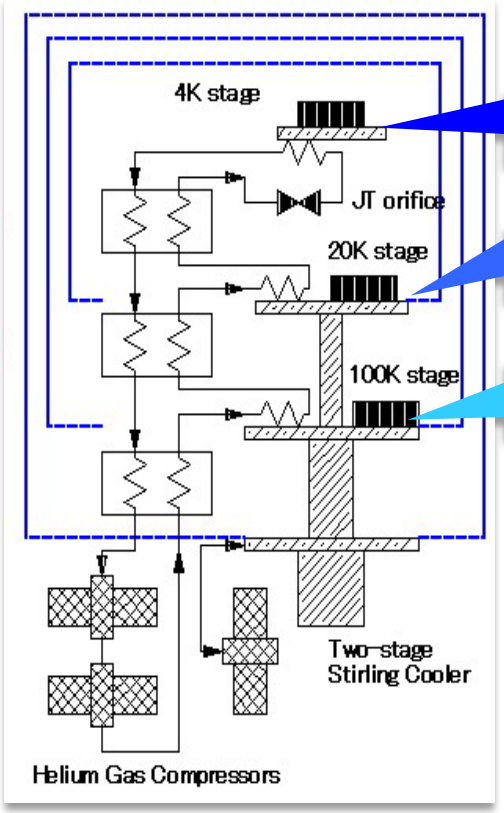


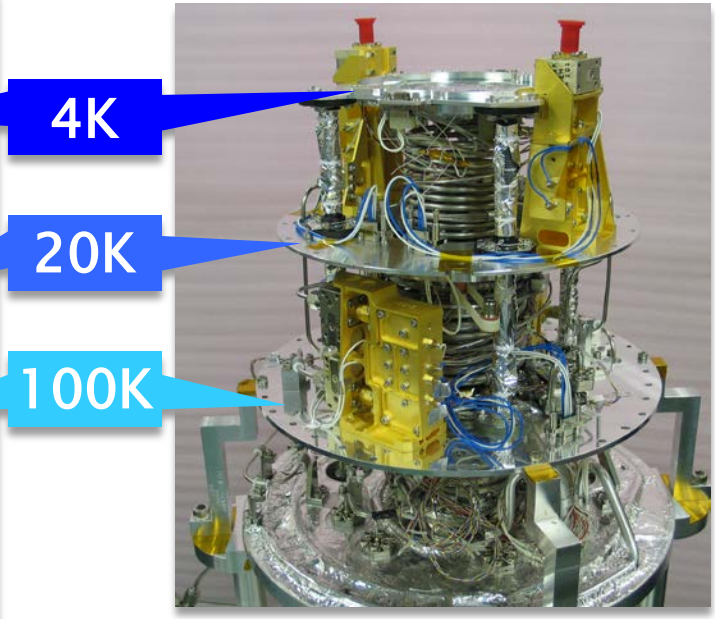
SIS Junctions

4-K Mechanical Cooler

2-Stage Stiring (ST) and Joule-Thomson (JT) coolers







Cooling Capacity:

~20 mW @ 4.5 K

~200 mW @ 20 K

~1000 mW @ 100 K

Mass: 81.6 kg (total)

Cooler 33.2 kg

Cryostat 23.9 kg

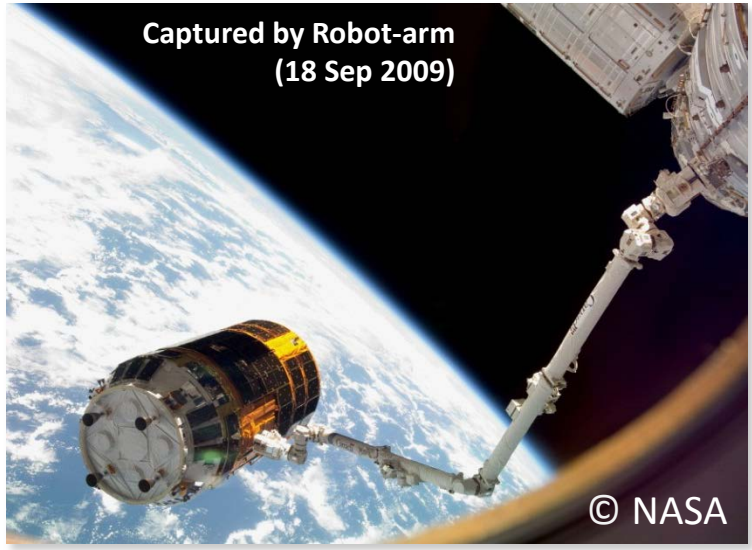
Electronics 24.5 kg

Power Consumption:

Total <304 W @ 125 VDC (ST: <100 W, JT: <60 W)

Developed by Sumitomo Heavy Industries

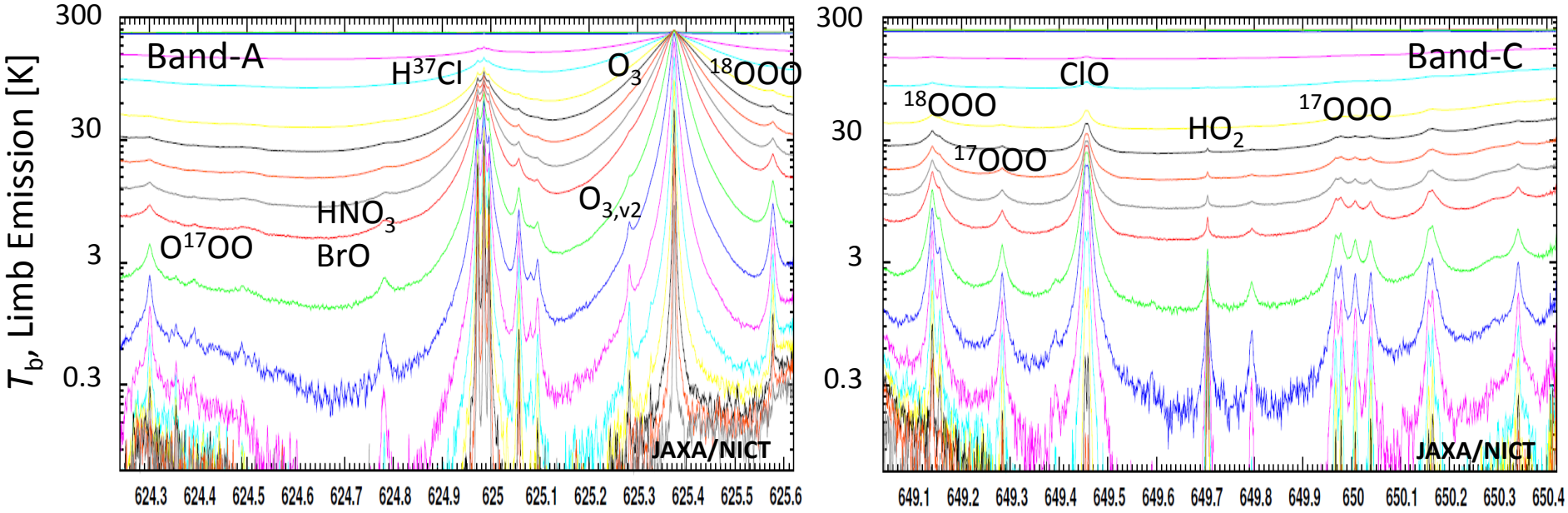
Journey to the International Space Station



In-Orbit Performance (1/2)

Sensitivity (0.5 s integration): 0.30-0.42 K for line spectrum,
0.18-0.27 K for continuum

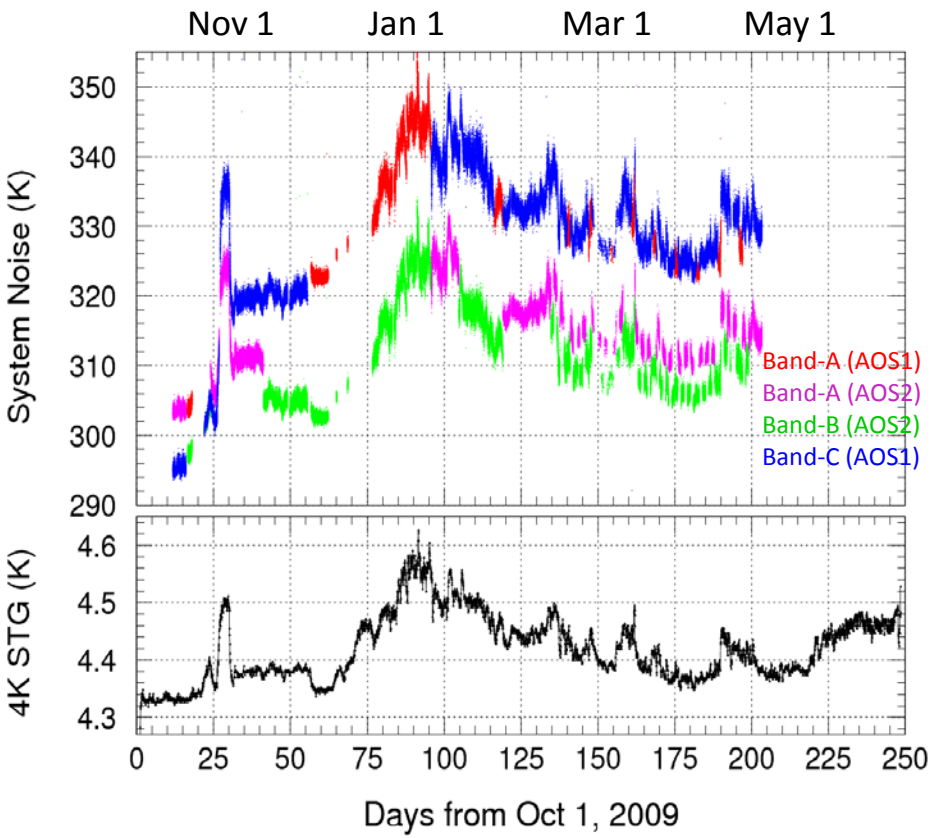
Amplitude of spectrum ripple: <0.07-0.21 K for T_b=245 K

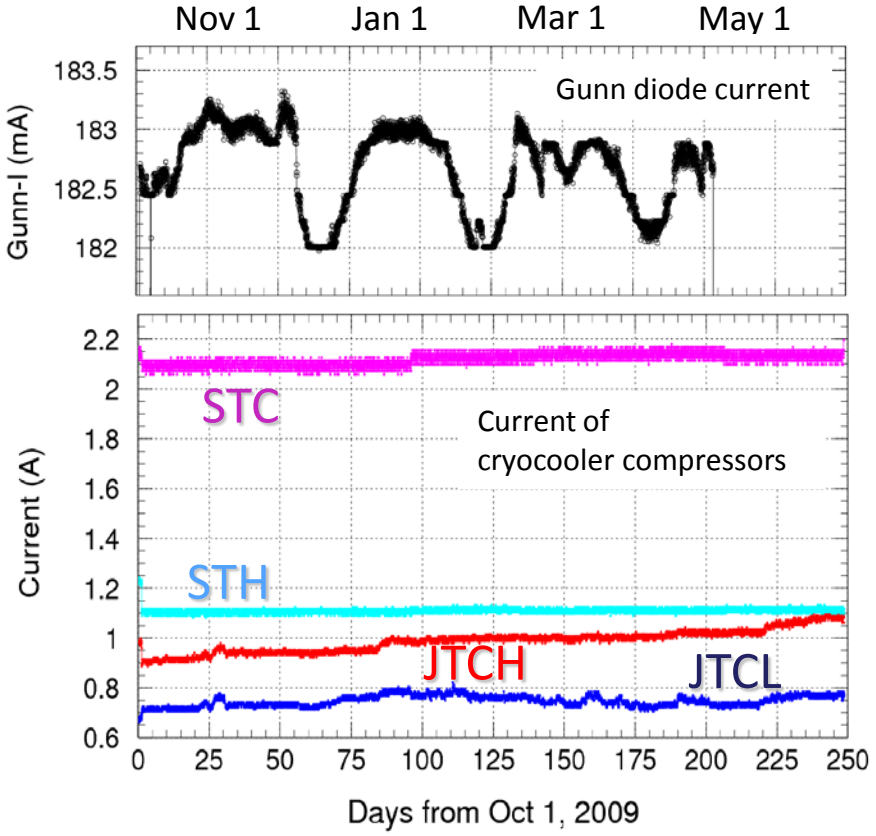


140-scan zonal-mean spectra (15 Oct. 2009)

In-Orbit Performance (2/2)

T_{RX} = 300-350 K throughout the 6-month observation period, without any unexpected degradation.

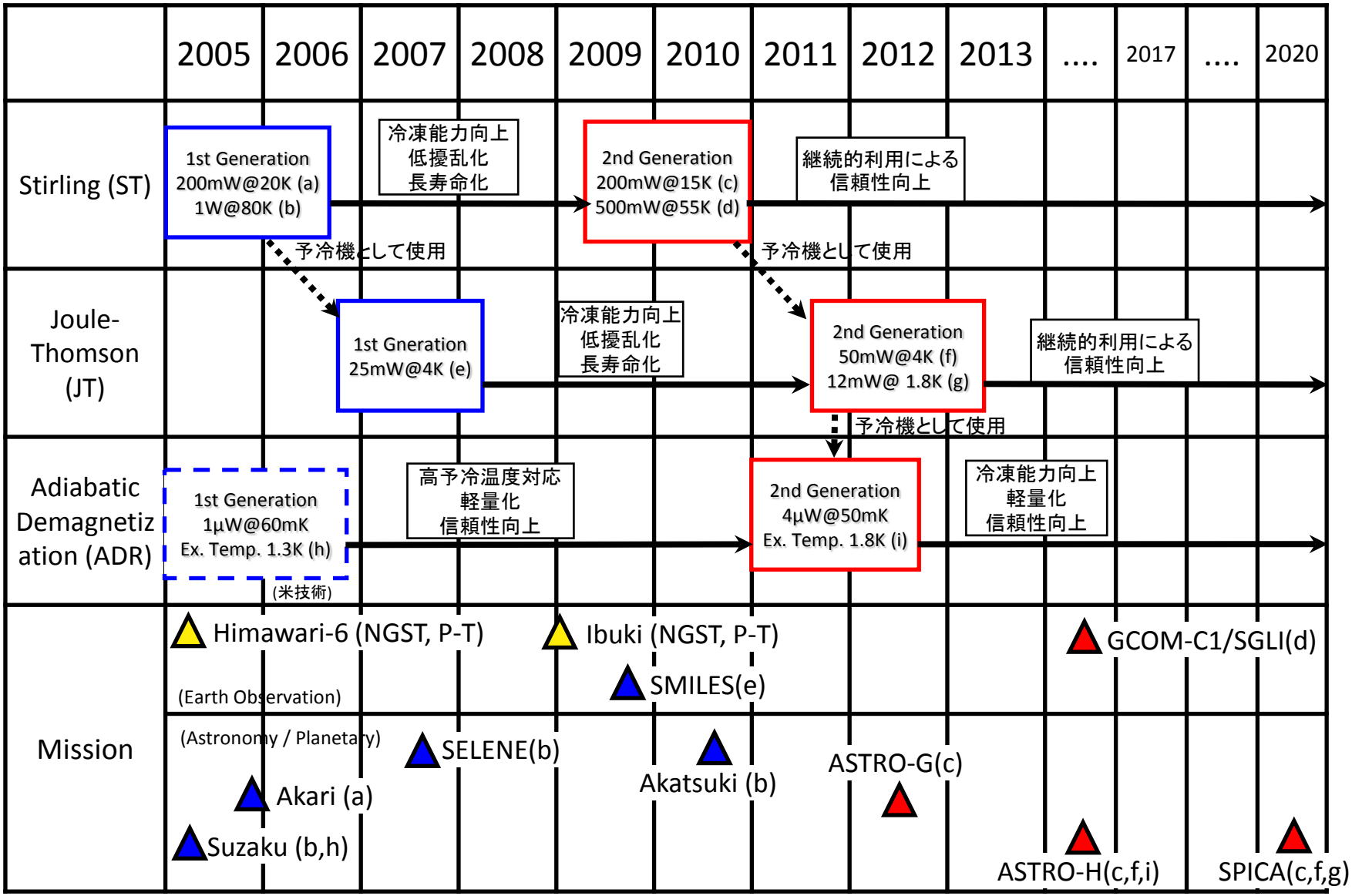




Achievements of SMILES

- Superconducting Mixer
  - Realization of “space-qualified” SIS mixer. The SIS device was fabricated based on NAOJ’s process.
- 4-K Mechanical Cooler
  - Collaboration with future mission team (ASTRO-H, SPICA) to understand and overcome the JT trouble
- Submillimeter Limb-Emission Sounding
  - Demonstration of high-precision submillimeter receiver system in space. Knowledge and skills are accumulating in Japanese community.

Space Cryocooler Roadmap (Japan, 2005-)



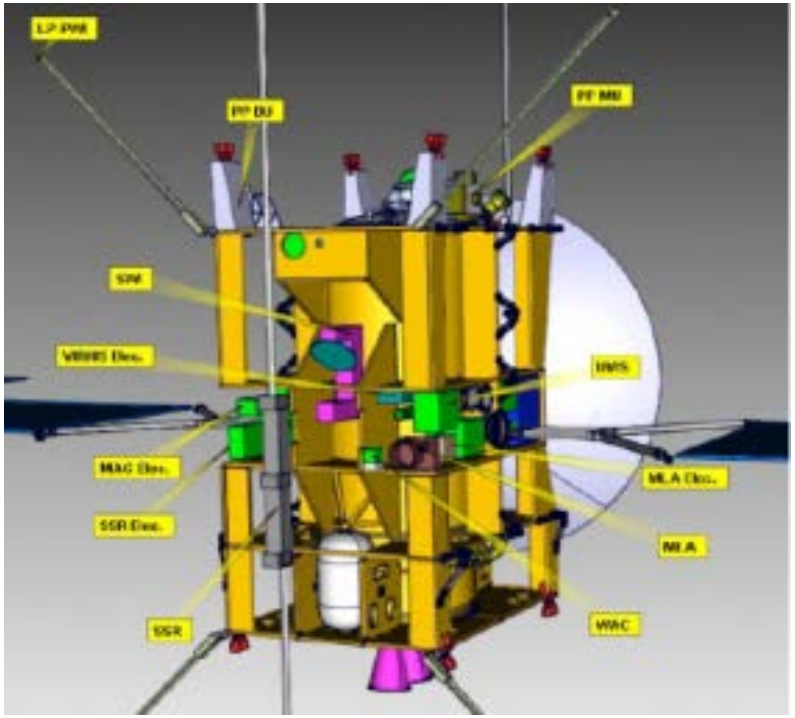
(宇宙研・満田氏提供資料を一部変更)

Future Mission and Technologies

(for Extrasolar Planet Observation)

Jupiter Explore: JUICE (1/2)

- JUICE: JUpiter Icy moon Explorer
  - ESA's L-class mission, launch expected 2022, arriving at Jupiter system in 2030
  - **<u>Science objectives</u>**:
    - Characterizing the habitable environments among the Jovian icy moons (Ganymede, Europa, and Callisto).
    - Investigation of the Jupiter system as an archetype for exoplanetary system.



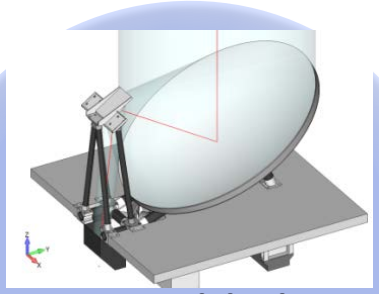
JUICE Assessment Study Report (ESA/SRE(2011)18)

Jupiter Explore: JUICE (2/2)

- SWI: Submillimetre Wave Instrument
  - One of the proposed payloads to be carried by JUICE. Japanese team is proposing to contribute the development of antenna system.
  - **<u>Science objectives</u>**:
    - Investigation of surface and atmosphere of the icy moons (surface permittivity, H_2O isotopomer and ortho/para, temperature structure, …)
    - Understanding the Jovian atmospheric general circulation (CH_4, H_2O, isotpomers, wind, temperature structure, …)
  - **<u>Instrumental challenges</u>**:
    - Ultra-lightweight (~10 kg) and low-power (~50 W)
    - Precise pointing requirement of 5”
    - Highly reliable system to survive long cruising (~8 years) and thermal / radiation environment around Jupiter

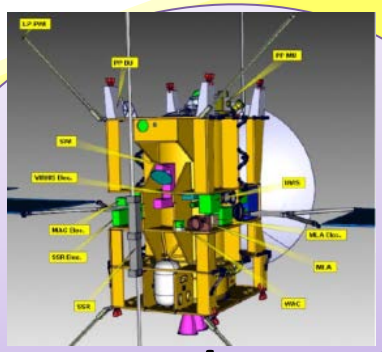
Submillimeter Spectroscopy of Planetary Atmosphere

Understanding the physical processes surrounding planetary atmosphere and surface environment



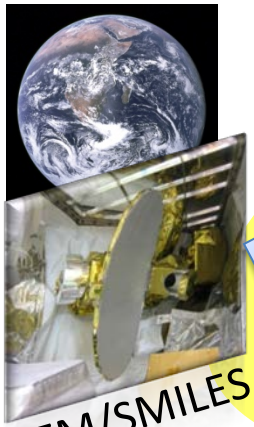
Japan Initiative submillimeter sounder for planetary explorer (Mars, Venus, …)

Accumulate know-how on deep space mission



JUICE/SWI

Rosetta/MIRO



JEM/SMILES

Herschel/HIFI

Planetary Atmos. Science

Submillimeter Spectroscopy

Vis. / IR Observation

Atmospheric Model

In Conclusion

- Hoping that the know-how of the SMILES is of some use for future extrasolar planet science.