Atacama Large Millimeter/submillimeter Array

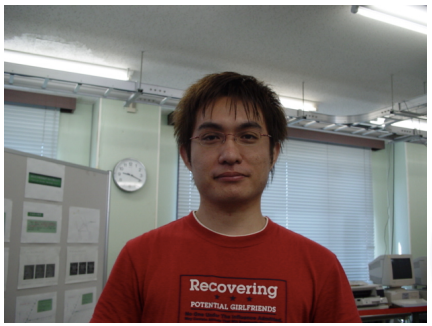
# EA ALMA Future Development - Concept and Status -

Daisuke Iono

National Astronomical Observatory of Japan

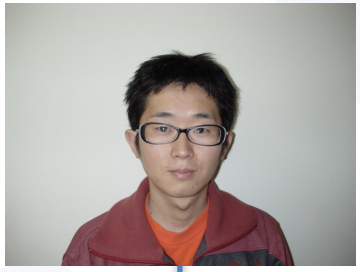

East Asian ARC
ALMA
KASI (Daejeon)
NAOJ
NAOJ (Mitaka)
ASIAA (Taipei)
中央研究院
ACADEMIA SINICA
1928

# NAOJ Future Development Management and Team



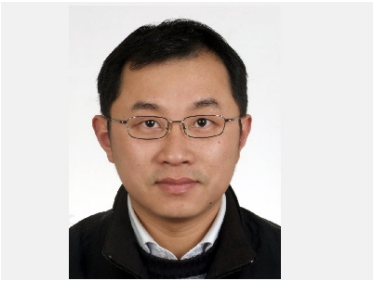

Satoru Iguchi
(EA Project Manager)

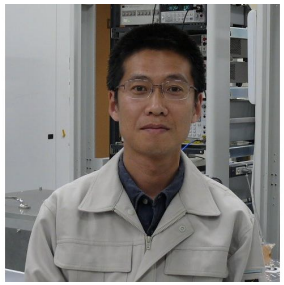
Daisuke Iono
(EA Project Scientist)



Shin'ichiro Asayama
(EA Development Manager)

9 Engineers and Scientists including
Wenlei Shan, Matthias Kroug, Takafumi Kojima, Alvaro Gonzalez, Yasunori Fujii





# Collaboration with Advanced Technology Center (ATC)

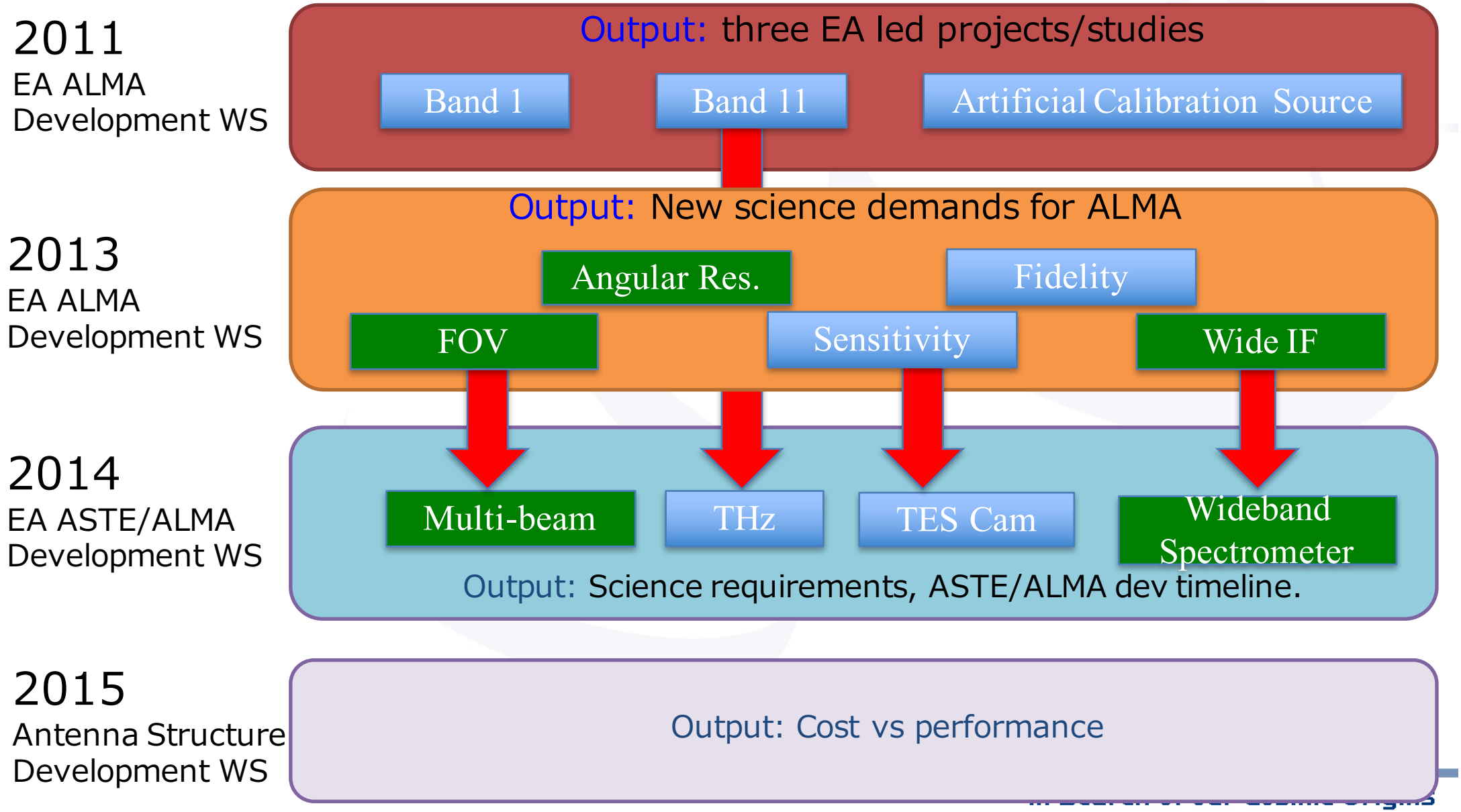

Tight collaboration with ATC

# Collaboration with NRO 45m and ASTE

- Share receiver and spectrometer technologies
- Test-bench for future ALMA development (ASTE)
- Software (e.g. CASA)
- Calibration tests

Talk by Masao Saito

# EA Development Workshops



# 2016 Development Workshops

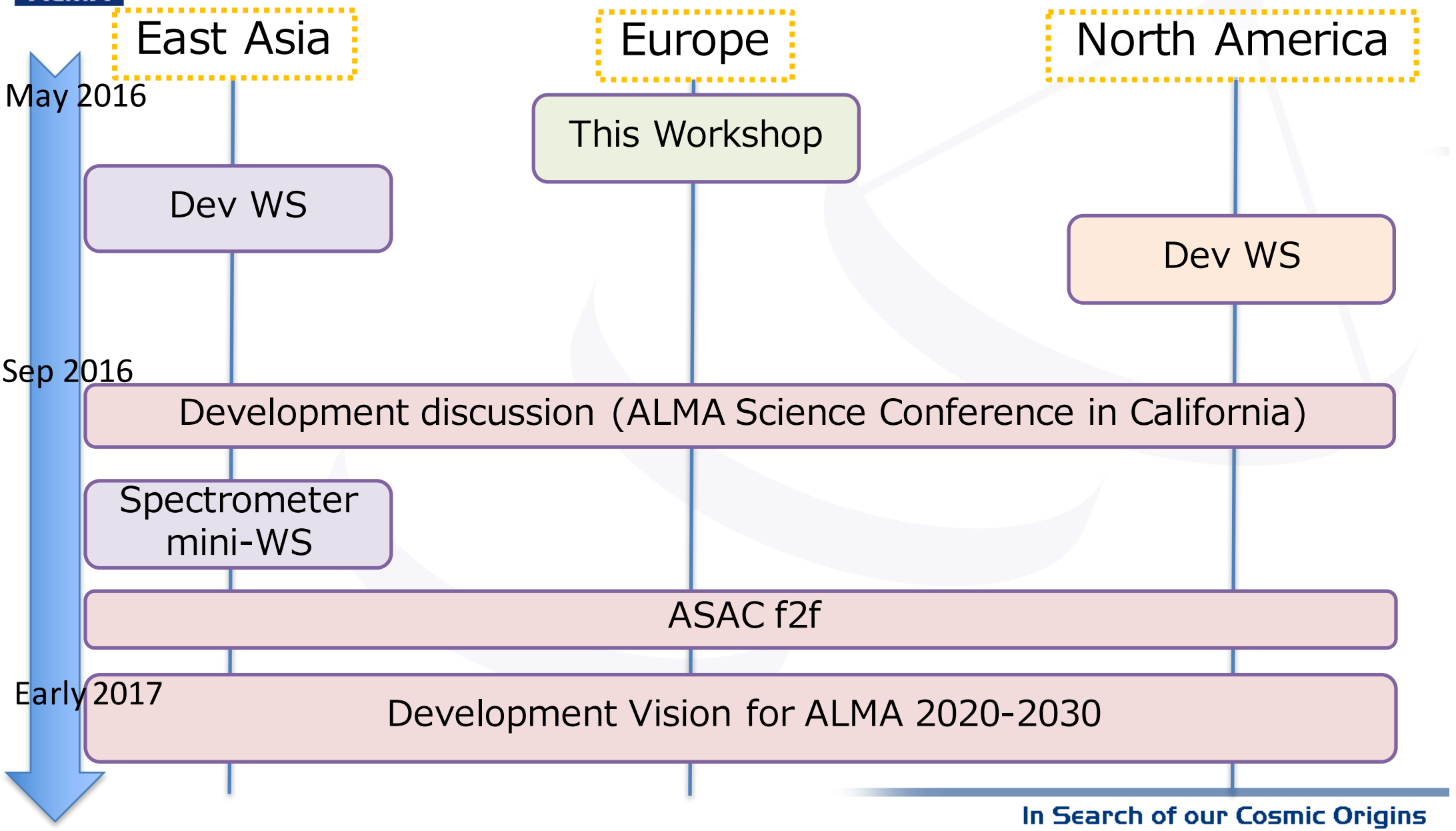
## NRO-ALMA Science Development workshop
July 20-21, 2016

1) Science demands
2) Spectrometer and software development
3) Calibration methods

## ACA Total Power Spectrometer mini-workshop
September 24, 2016

1) Scope and science
2) Conceptual design and technical feasibility
3) Specification and requirements
4) Project plan

# Global Collaboration



# Ongoing Collaboration with EU and NA

Projects

Band 5 (EU)

EA contribution: Front end integration at the OSF

Studies and Small Projects

Band 2 (NA), Combining Band 2 and 3 (EU)

EA contribution: Optics design

Talk by A. Gonzalez

# Current Priorities for EA

Projects

- Band 1 project (lead: ASIAA, Collaboration: NAOJ, U of Chile, NRAO, HIA)

Studies and Small Projects

- ALMA Calibration Source: Calibration at bands 3, 6, 7
- High Critical Current Density (Jc) SIS Junction Device Development
- GPU Spectrometer for TP array (with KASI)

ASTE Development Project (extendable to ALMA)

- Spectrometer & Multi-beam receiver (with KASI)

# Band 1 Science Case

**The Science Cases for Building a Band 1 Receiver Suite for ALMA**

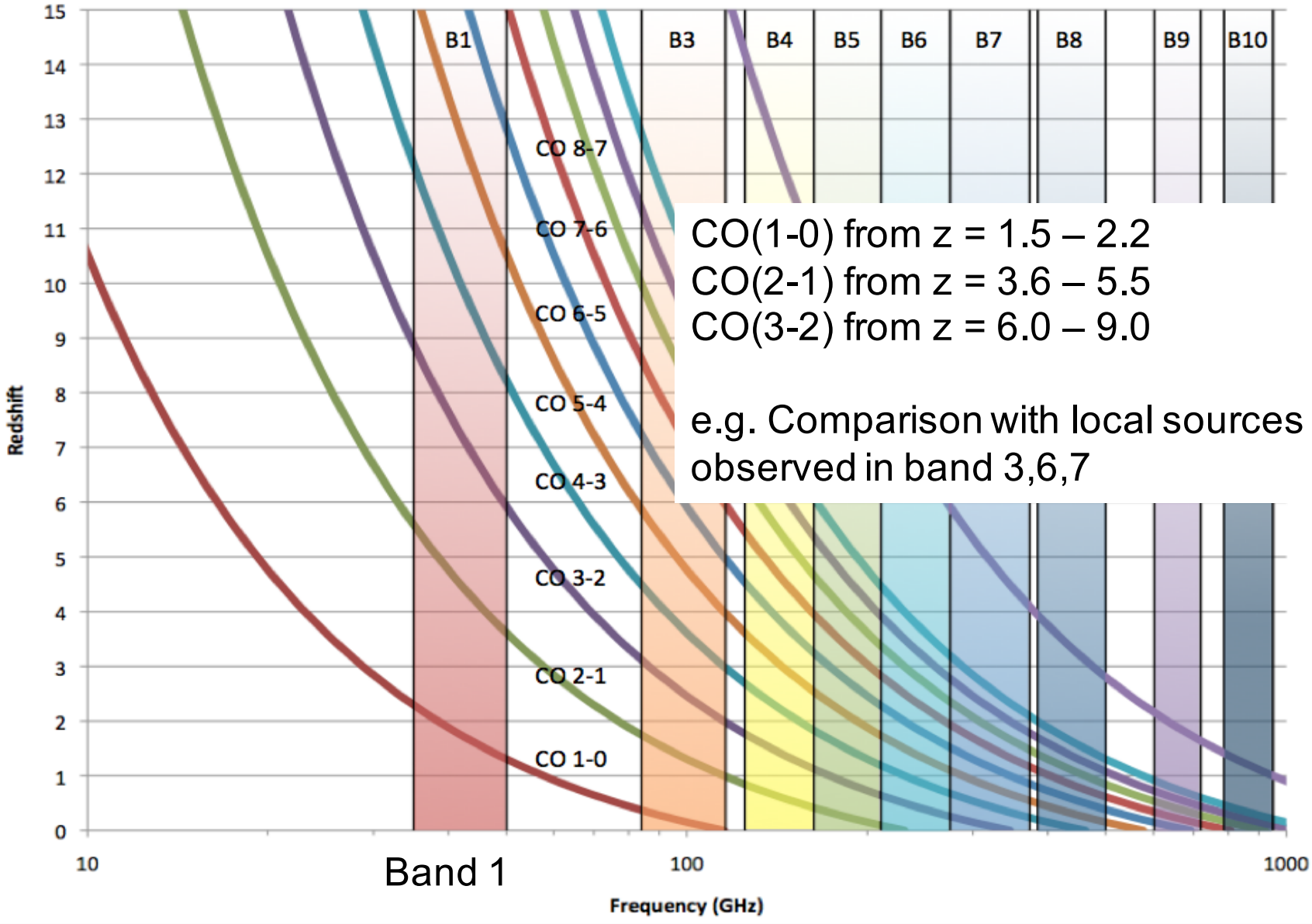
arXiv:1310.1604v3

J. Di Francesco[1,2], D. Johnstone[1,2], B. Matthews[1,2], N. Bartel[3], L. Bronfman[4], S. Casassus[4], S. Chitsazzadeh[2,5], H. Chou[6], M. Cunningham[7], G. Duchêne[8,9], J. Geisbuesch[10], A. Hales[11], P.T.P. Ho[6] M. Houde[5], D. Iono[12], F. Kemper[6], A. Kepley[11], P.M. Koch[6], K. Kohno[13], R. Kothes[10], S-P. Lai[14], K.Y. Lin[6], S.-Y. Liu[6], B. Mason[11], T.J. Maccarone[15], N. Mizuno[12], O. Morata[6], G. Schieven[1], A.M.M. Scaife[16], D. Scott[17], H. Shang[6], M. Shimojo[12], Y.-N. Su[6], S. Takakuwa[6], J. Wagg[18,19], A. Wootten[11], F. Yusef-Zadeh[20]

74 page document that includes various science cases possible with band 1, including;

- Low J CO from high-z sources
- Emission from large dust grains
- Molecular tracers of star formation; large molecules
- SZ effect
- Pulsars and radio supernovae
- Methanol and SiO masers
- Probing magnetic fields with the Zeeman effect
- Solar observing
- Etc, etc …

# Band 1 Science Case
# - High-z -



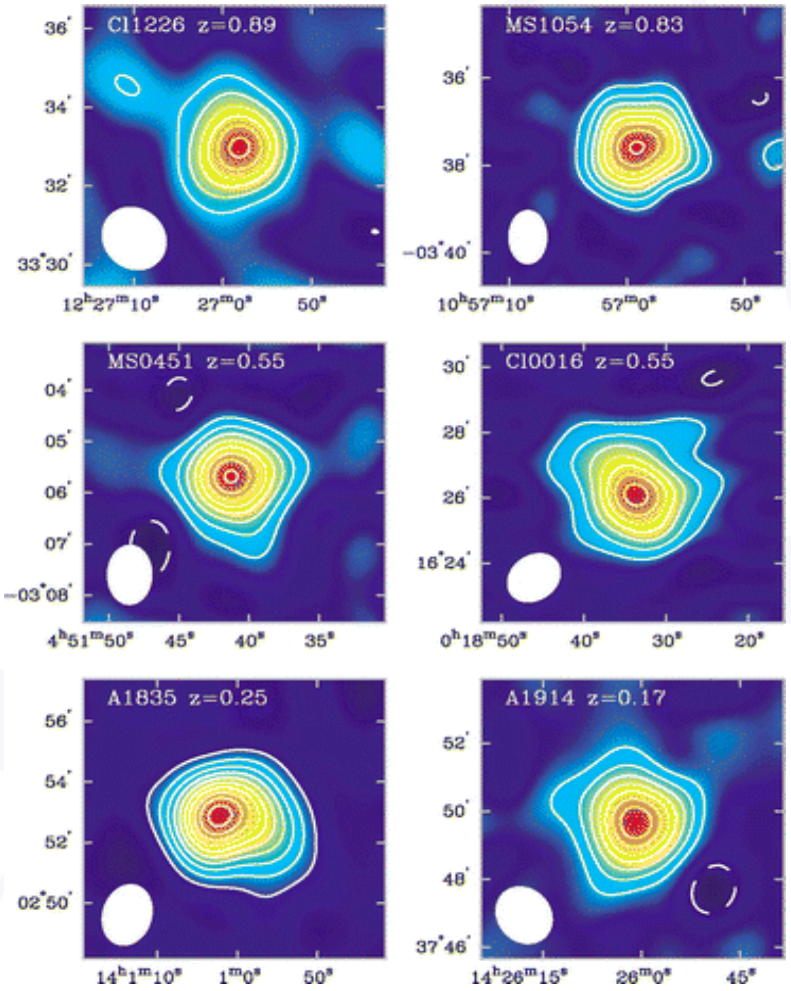

CO(1-0) from z = 1.5 – 2.2
CO(2-1) from z = 3.6 – 5.5
CO(3-2) from z = 6.0 – 9.0

e.g. Comparison with local sources observed in band 3,6,7

# Band 1 Science Case
# - SZ Effect -

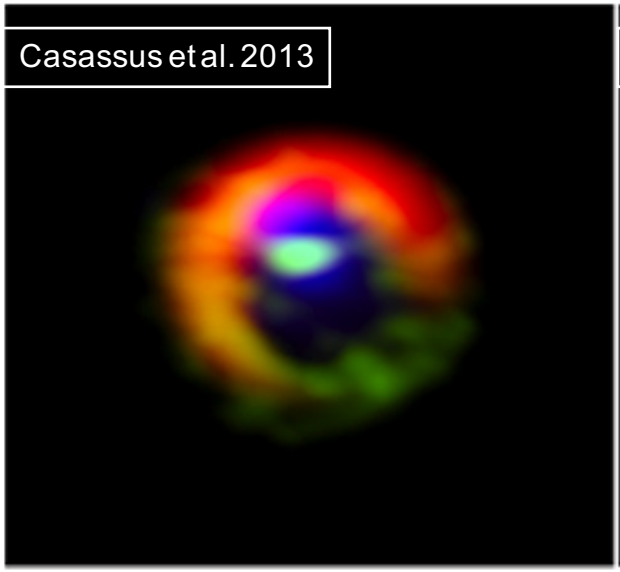
- Follow-up imaging of the large clusters discovered in low resolution (~1') surveys.

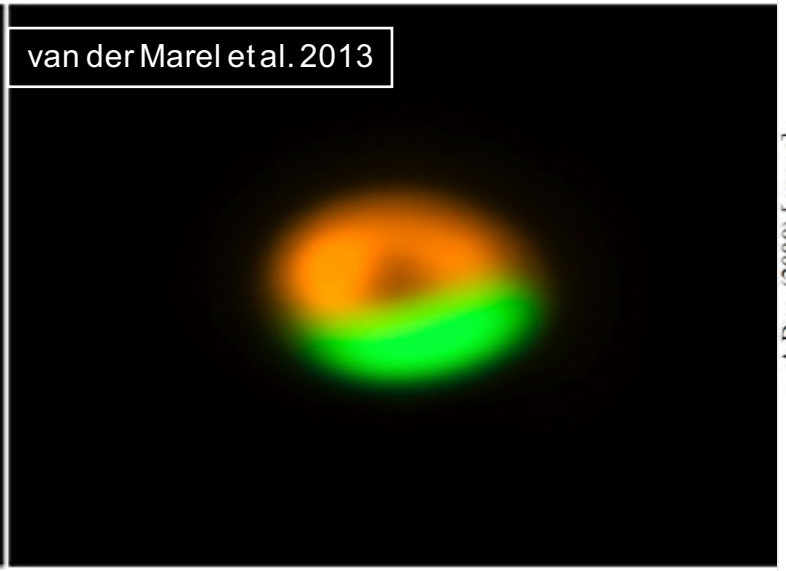
- Allows us to detect shocks, cluster mergers, ICM substructure, physical state of the ICM (electron density, temp).

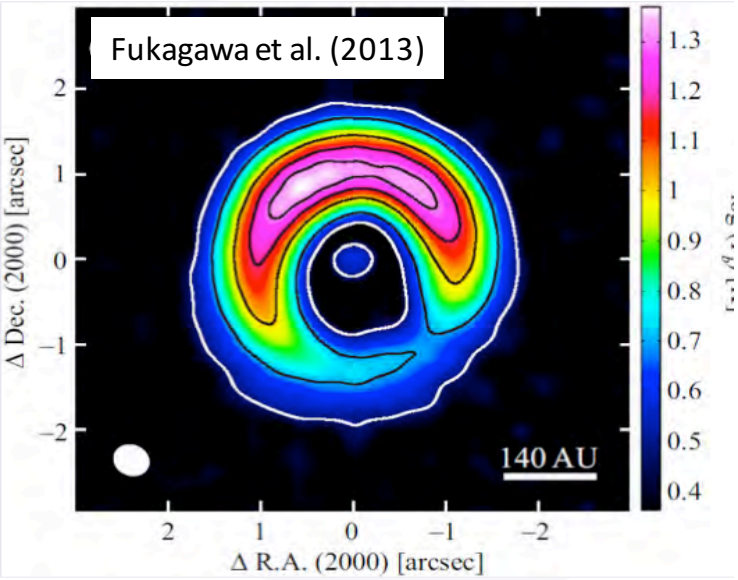



SZ effect (Carlstrom et al. 2002)

# Band 1 Science Case
# - Protoplanetary Disks -




Dust particles emit very inefficiently at wavelengths longer than their size. Band 1 will observe large (cm size) dust particles in proto-planetary disks.

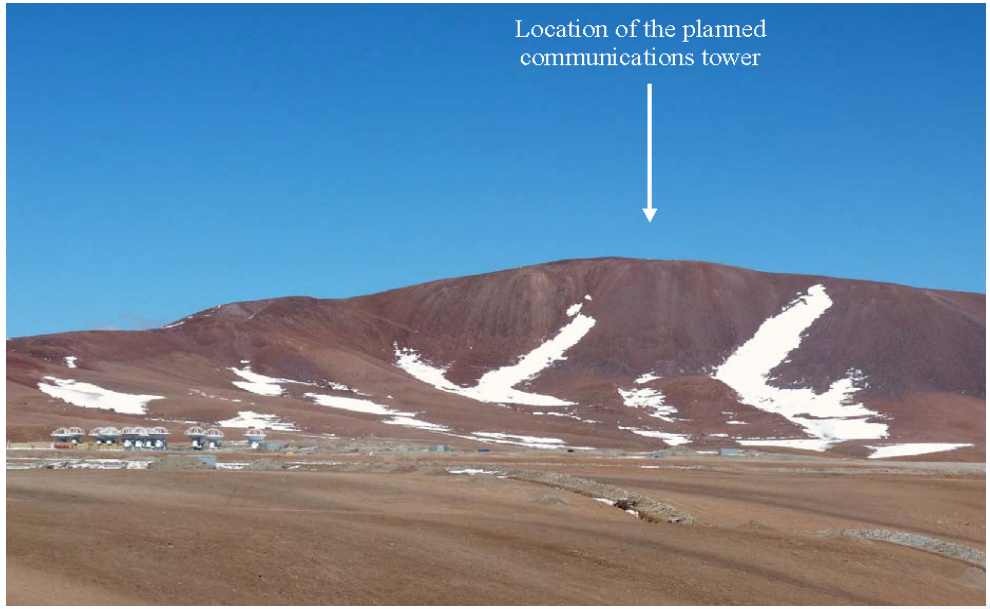
# Band 1 Status

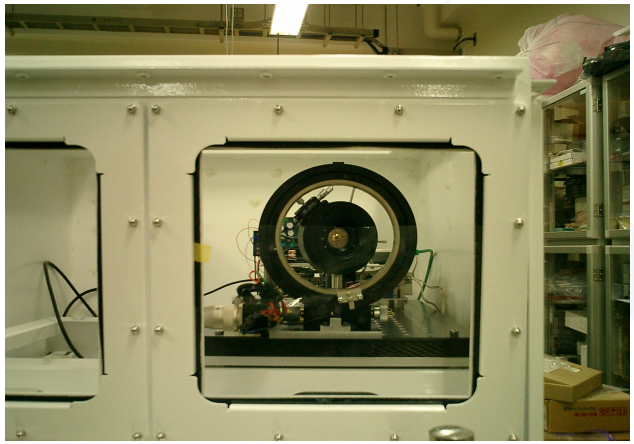
- CDR and project review were held on Jan 19-20, 2016 at ASIAA in Taiwan
- CDR completed, pre-production phase can be initiated. Final document being prepared.
- Positive ASAC reaction on science case
- Board approval for production (May, 2016)
- MRR will be held in late 2016
- AIV in 2019

# Artificial Calibration Source

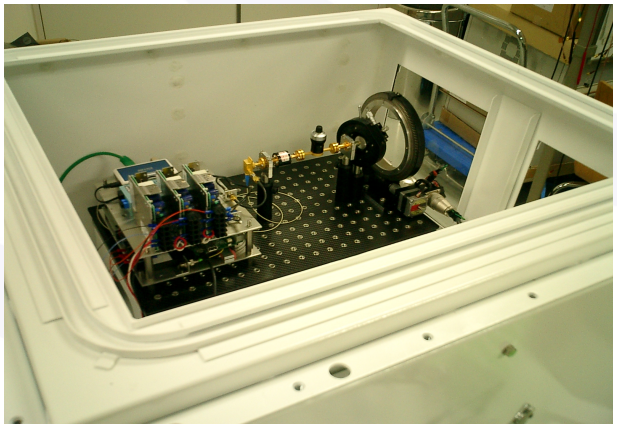
- Lead: Hitoshi Kiuchi (NAOJ)
- Original idea by R. Hills
- Used for calibration purposes
  - Provide a signal for interferometric holography measurements of antenna surface
  - Provide a source of known polarization for calibration
  - Provide a high S/N source to help measure e.g. coherence, phase stability, switching time, stability and sideband ratio.

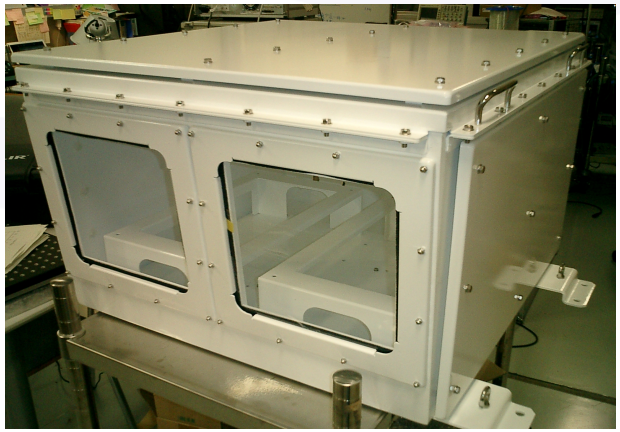
# Artificial Calibration Source



Front face

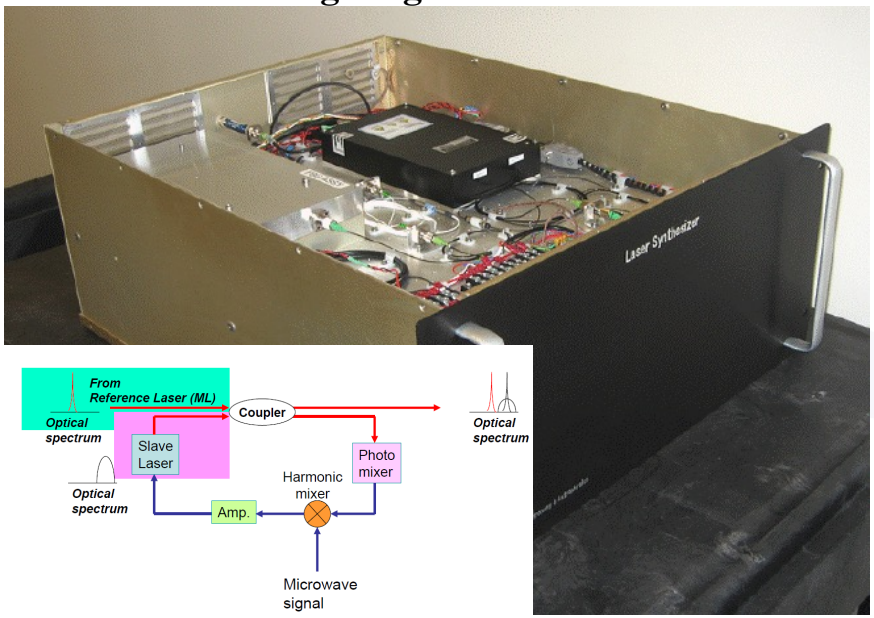




# Artificial Calibration Source

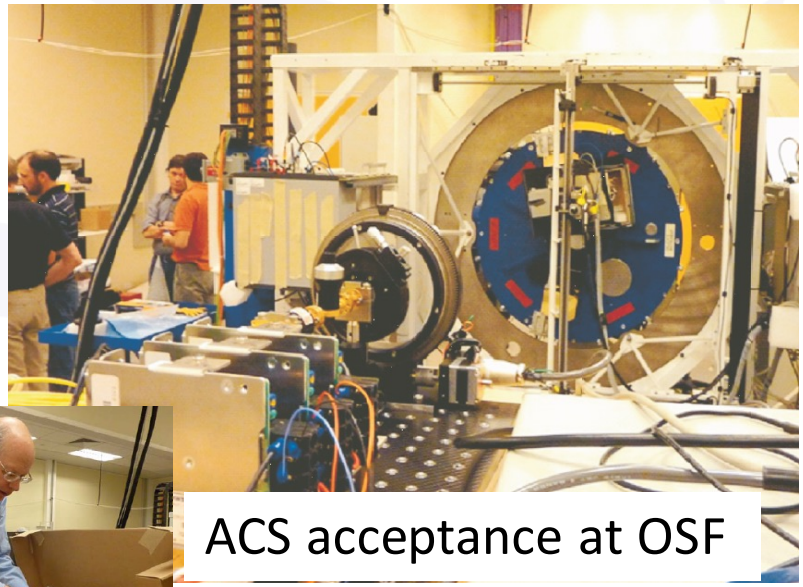
- 100GHz frequency range source has been delivered, and will begin testing in Q4 2016.
- 230/345GHz being developed and will be delivered by 2018.

**Photonic signal generator: MZM-LS**

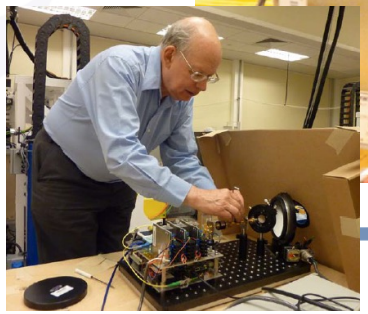






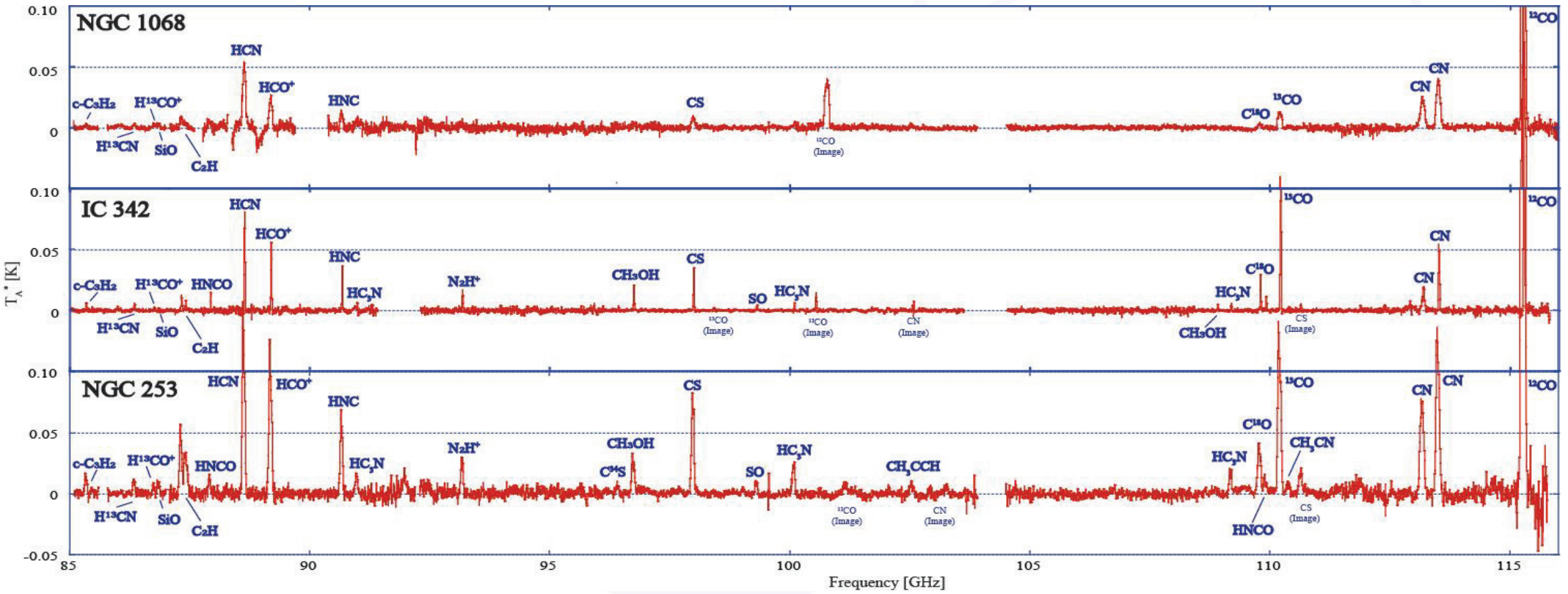


ACS acceptance at OSF



# Wideband Receivers: Science Case

Rich in molecular lines, from 85 – 115 GHz. Wide freq coverage is essential.




Takano et al. (2013)

# Expanding the RF and IF

- (RF) Initial studies for passive components ongoing
  - Orthomode transducer (OMT) for 300-500 GHz (Osaka Prefecture U)
  - Wideband corrugated horn (A. Gonzalez).
- (IF) The components that limit the IF bandwidth are low-noise amplifier and isolator. -> need further studies
- Next step: develop a wideband SIS mixer with high Jc SIS junction components (with KASI).

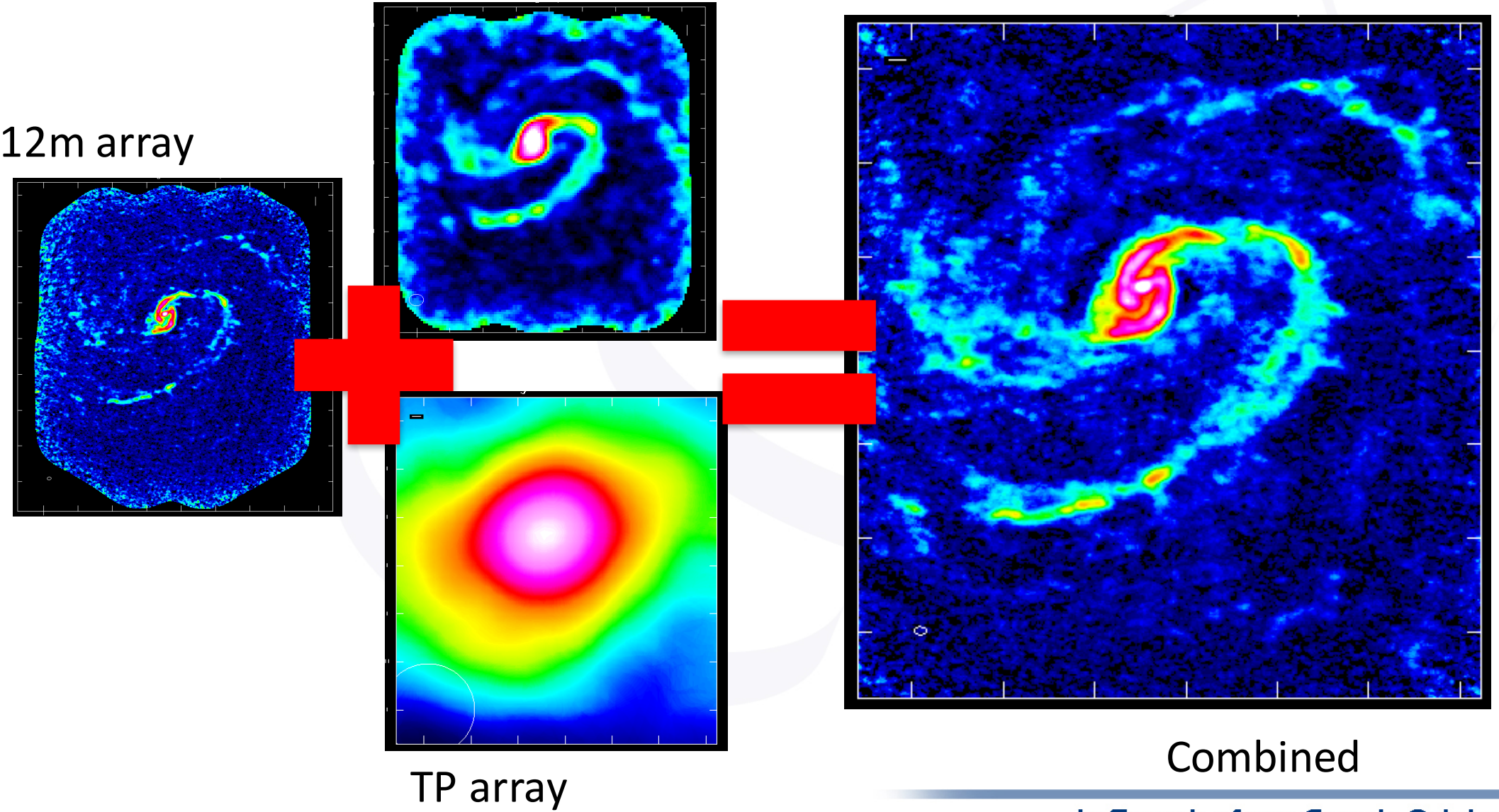
# High Critical Current Density (Jc) SIS Junction Device Development

- High Jc junctions (~30kA/cm$^2$)
  - RF bandwidth to be increased substantially for Ultra-wideband receivers
  - required for THz receivers
- Development and implementation of aluminum nitride (AlN) barriers for SIS devices

# Scientific Importance of the ACA

7m array

12m array



TP array

Combined

# Scientific Importance of the new TP Spectrometer

- Scientific Advantage
  - Higher sensitivity (by eliminating sensitivity loss due to re-quantization)
  - High accuracy (by allowing 16-bit quantization)
- Operational Advantage
  - Improvements in efficiency (by separating 7m with TP array)
  - Simple architecture

# Specifications

- Specs (from ACA correlator)
  - 4 GPU nodes (each for one TP antenna)
  - Sampling bits: 3
  - Bandwidth per baseband: 2GHz
  - Number of basebands: 8
  - Highest spectral resolution < 6 kHz
  - Integration time for autocorrelation: 1ms
  - Spectral dynamic range for a weak line: 10000:1 in strong lines and 1000:1 in strong continuum
  - Full polarization: HH, VV, HV, VH

# Current Status and Timeline

- Held five f2f meetings between NAOJ-KASI
  - Conceptual design and technical feasibility
  - Specification and requirements
  - Project plans
- Workshop in September 24, 2016
- Timeline
  - ASAC (2016/2017)
  - Seek board approval (2016/2017)
  - PDR and CDR (2017)

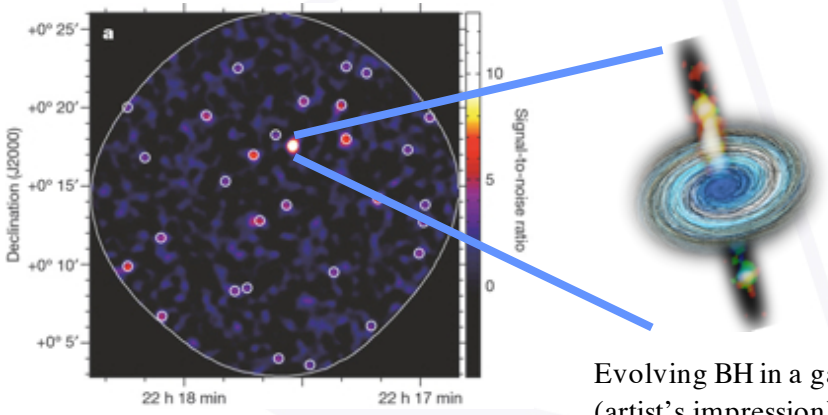
# Idea of the ALMA Extended Array

- Lead: Seiji Kameno (JAO)
- Locate 5 antennas in 300-km range of ALMA
- Observe the thermal universe with VLBI resolution
- Specs
  - Sensitivity: 10microJy (1hour)
  - Tb sensitivity 1000K
  - 0.6 milliarcsec

# Idea of the ALMA Extended Array

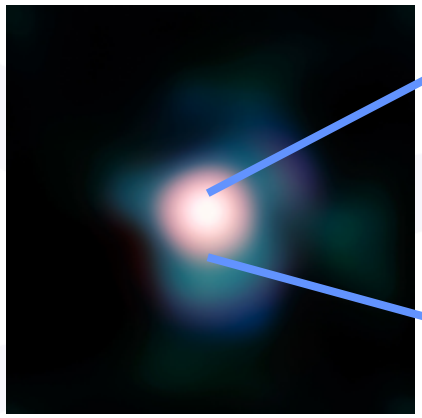
- Science Case
  - Black holes in galaxies
  - Imaging photospheres of nearby stars and stellar size estimates

Sub-mm galaxies discovered with ASTE
(Tamura+09 Nature, 459, 61)

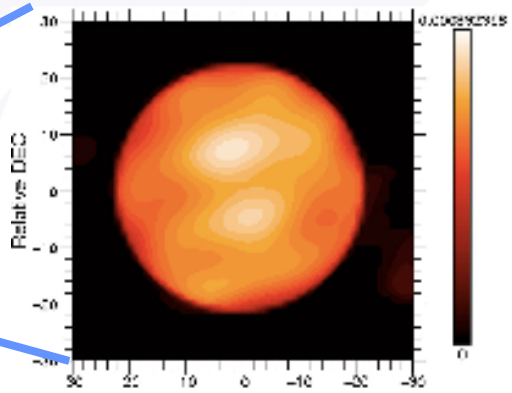





Evolving BH in a galaxy
(artist's impression)



Betelgeuse NIR image (10-mas resolution)
(Kervella+09, A&A, 504, 115)



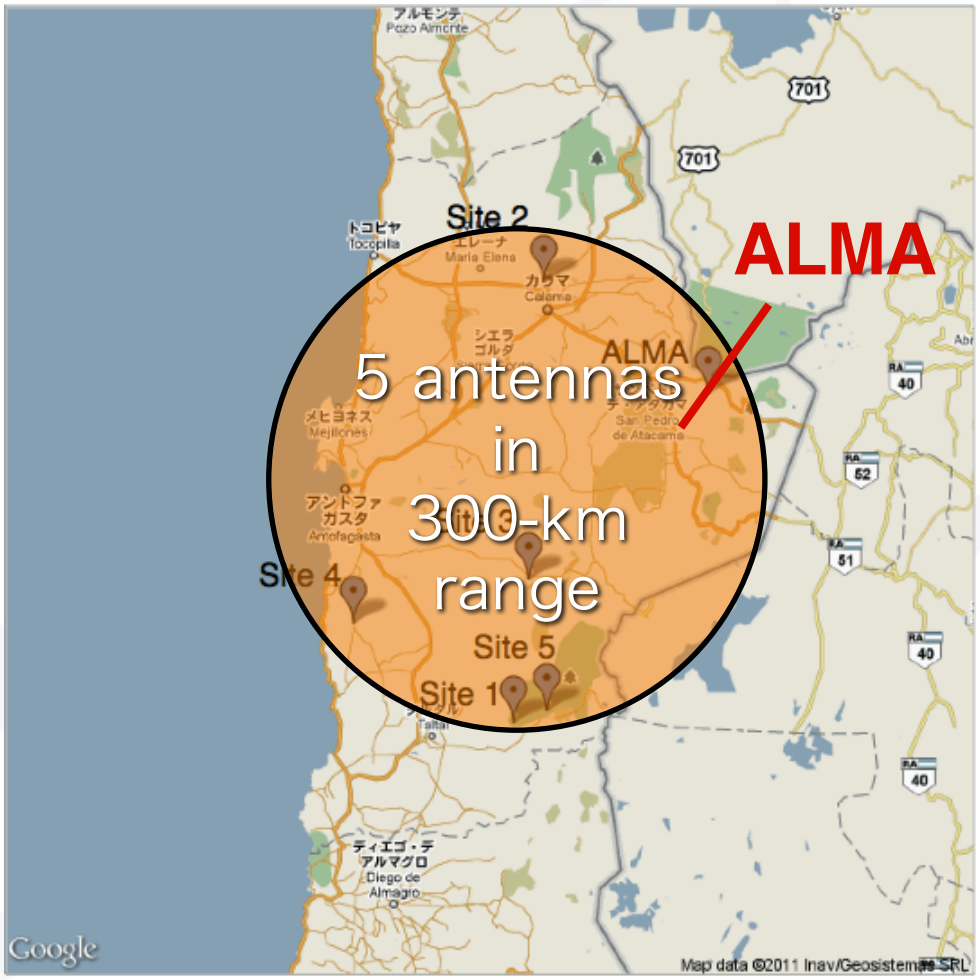

Betelgeuse H-band image (9-mas resolutic
(Haubois+09, A&A, 508, 923)

# ALMA extended configuration

## Tentative site locations … to be surveyed further

| Sites | Altitude | Latitude | Longitude | Distance from ALMA |
|---|---|---|---|---|
| 1 | 4100 | -25.205 | 69.173 | 266 km |
| 2 | 3200 | -22.267 | 68.950 | 134 km |
| 3 | 2900 | -24.253 | 69.057 | 171 km |
| 4 | 2400 | -24.550 | 70.333 | 290 km |
| 5 | 3600 | -25.130 | 68.925 | 248 km |

higher altitude, needed for > 350 GHz




ALMA Extended

Kameno, S., Nakai, N., and Honma, M. (2013), ASP Conf. Ser. 476, 409.

# Japanese Virtual Observatory

- Developed by Advanced Data Center of NAOJ
- http://jvo.nao.ac.jp/portal/alma.do
- Quick look images and spectra of ALMA archive data in only a few clicks
- Users can download the full data for detailed investigation using CASA or their favorite software
- Also available for Subaru data

# Japanese Virtual Observatory




## ALMA Archive

### Using the data for publication

The following statement should be included in the acknowledgment of papers using the ALMA datasets obtained from the JVO portal:

"This paper makes use of the following ALMA data: ADS/JAO.ALMA#<Project code>. ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada) , NSC and ASIAA (Taiwan), and KASI (Republic of Korea), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ."

You can find the project code (e.g. 2011.0.01234.S) on the dataset info page where you download the data.

Please also include the following sentence on the title page as a footnote to the title or in the acknowledgment of the paper.

"[Part of] the data are retrieved from the JVO portal (http://jvo.nao.ac.jp/portal) operated by the NAOJ"

Target Name | **Project Code** | Coords | Frequency | Desktop Viewer

| # | Project Code | # of Data | Title | Last Upate |
|---|---|---|---|---|
| 1 | 2013.A.00023.S | 14 | A New Supernova in the Milky Way Confirmed by ALMA | 2016-05-11 |
| 2 | 2013.1.01312.S | 10 | Wide-field imaging of dense gas in the nearby barred galaxxy M83 | 2016-05-10 |
| 3 | 2013.1.00530.S | 312 | A detailed view to the star-forming gas in dusty Herschel-ATLAS galaxies at 0.03 < z < 0.2 | 2016-05-10 |
| 4 | 2013.1.01358.S | 37 | Galaxies in (and behind) two massive high-redshift clusters) | 2016-05-09 |
| 5 | 2013.1.00662.S | 33 | Orion 2 & 3 mapping | 2016-05-07 |
| 6 | 2013.1.00165.S | 24 | The metamorphoses of Fe and the elusive FeO | 2016-05-07 |
| 7 | 2013.1.00432.S | 62 | A 3mm Line Survey of IRC+10216 : The chemical view of a C-rich object | 2016-05-07 |
| 8 | 2013.1.00718.S | 76 | An ALMA 1.3 mm spectroscopic survey in the Hubble Ultra Deep Field | 2016-05-07 |
| 9 | 2013.1.00806.S | 48 | Needles in the Cosmic Haystack - A Hunt for Massive Starless Cores | 2016-05-07 |
| 10 | 2012.1.00394.S | 123 | Revealing the Evolutionary Status of Candidate First Cores | 2016-05-07 |
| 11 | 2013.1.00993.S | 43 | Resolving structure and physics toward a Photodissociation Region associated with N55 in the Large Magellanic Cloud | 2016-05-07 |
| 12 | 2013.1.00157.S | 41 | Revealing Binarity and the Youngest Disks in Oph | 2016-05-06 |
| 13 | 2013.1.00918.S | 22 | Understanding the Origins and Dynamics of the Multiple Outflows Around IRAS 16293-2422 | 2016-05- |

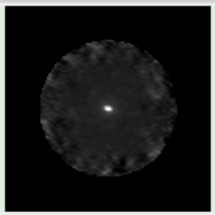
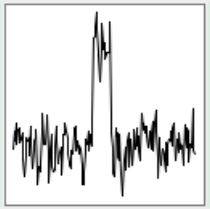
# Japanese Virtual Observatory



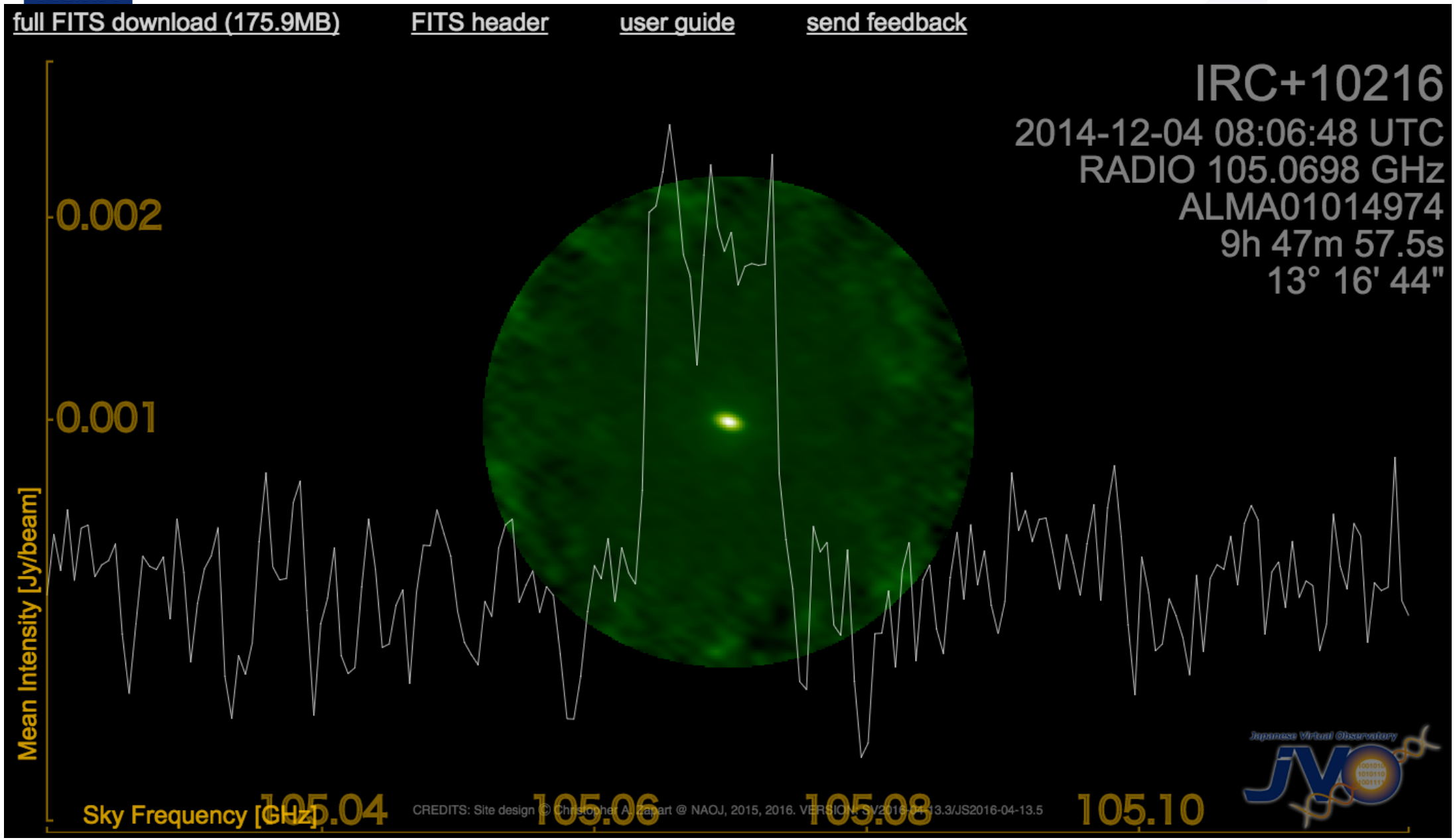
## ALMA Archive : Dataset Info

Summary | Binning Data | Desktop Viewer | Using the data

- **Target**: IRC+10216
- **Dataset ID**: ALMA01014974
- **Coord. (RA/DEC J2000)**: 09h47m57.4+13d16m43
- **Date of Observations**: 2014-12-04
- **Image Size (arcmin2)**: 2.40x2.40
- **Image Resol. (arcsec) (pix, beam)**: 0.30, 3.81x2.22
- **Band Name**: Band3
- **Data Type**: intensity cube
- **Freq. Range. (GHz)**: 105.020 -- 105.120
- **Spectrum Resol. (MHz)**: .500
- **Cube Pix ?**: 480x480x200x1
- **Original Filename**: IRC10216_lineSpw2.image.pbcor.fits
- **3rd(4th) Axis**: frequency
- **Project Code**: 2013.1.00432.S

| data id | image | spect | file size (byte) | Download | WebQL | Readme |
|---|---|---|---|---|---|---|
| ALMA01014974 |  |  | 184,406,400 | Download | WebQLv2 (new) WebQL | Readme |

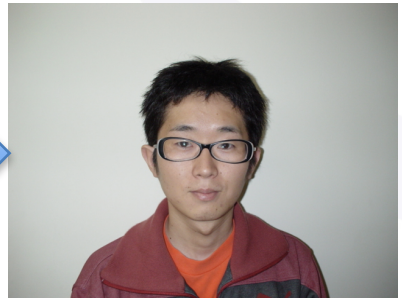
# Japanese Virtual Observatory



# Atacama Submillimeter Telescope Experiment (ASTE)

- Operated by the Chile observatory of NAOJ
- 4860m site in Atacama
- Manager

Takeshi Okuda
(Senior Instrument Engineer (JAO) from April, 2016)



Shin'ichiro Asayama

# ASTE Specs

| | |
|---|---|
| Diameter | 10m |
| Beam | 22” at 350GHz |
| Main Beam Efficiency | 0.60 (350GHz), 0.45 (490GHz) |
| Pointing | RMS ~ 2” (wind < 10 m/s) |
| Receivers | |
| DASH 345 | 321 – 376 GHz, 2SB, 4-8GHz, Tsys(SSB)=250K |
| ASTE Band 8 | 387– 498 GHz, 2SB, 4-8GHz, Tsys(SSB)=600-1000K |
| TES Camera (Commissioning Phase) | 270 (169 pix, BW=50GHz) and 350GHz (271 pix, BW=30GHz) |
| Spectrometer | |
| MAC | BW=128 & 512MHz, Nchan=1024, Res.=0.5 & 0.125 MHz |
| WHSF | BW=32, 64, 2048, 4096 MHz, Nchan=2048, Res.=15.625, 31.25, 1, 2 MHz |

# ASTE Development

## Collaboration within EA ALMA

- Spectrometer: J. Kim (KASI)
- Band 7/8 receiver: J.W. Lee (KASI)
  - Single pixel (2017 -)
  - Multi pixel (2018 -)

→ Poster by J-W. Lee

- TES Camera (270-350GHz camera): T. Oshima (NAOJ)

## Collaboration with Universities

- 230 GHz receiver: T. Sakai (UEC)
- THz receiver: S. Yamamoto (U. Tokyo)
- DESHIMA (On-chip Filterbank Spectrometer): A. Endo (Delft)

# Multi-pixel Array for ASTE

- Technical challenges;
  - Limited cryostat window and space
  - Thermal load (Fitting multiple SIS mixers on a 4 K stage)
  - Developing and distributing a stable LO source signal in a homogeneous way.
- Prototype development (by KASI)
  - Multi-beam receiver system with ultra-wideband SIS mixers from 300 to 500 GHz (TBC) (and spectrometer)

# Summary

- Projects
  - Band 1
- Studies and Small Projects
  - Calibration source
  - High Jc SIS junction device
  - GPU spectrometer for TP array
  - Optics design
- ASTE development project
  - Spectrometer & Multi-beam receiver
- ALMA Extended Array and JVO

Talk by T. Huang, P. Mena
Poster by C.-C. Chiong

Talk by T. Kojima
Poster by M. Kroug

Talk by S. Iguchi

Talk by A. Gonzalez

Poster by
J-W. Lee