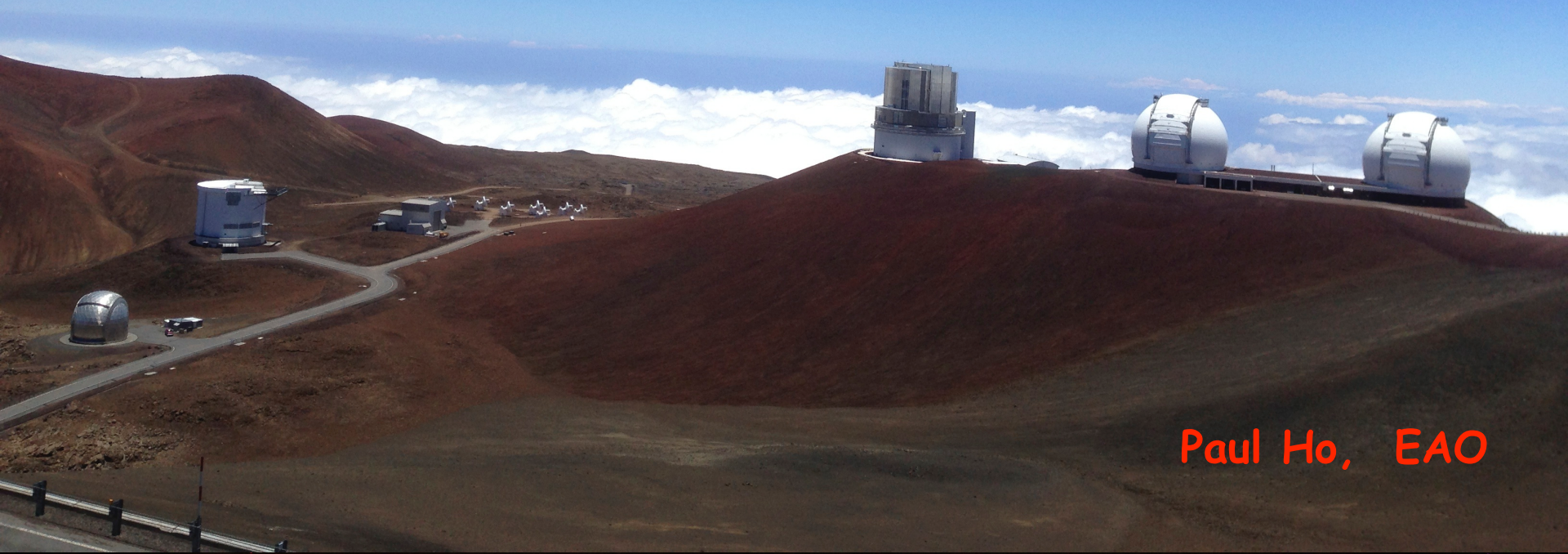


Astrophysics in Asia and the EAO

— *a Joint Dream*



Paul Ho, EAO

Why Astronomy?

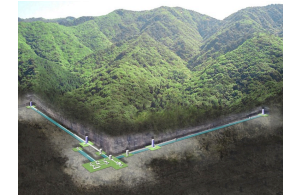
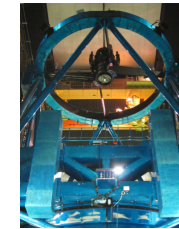
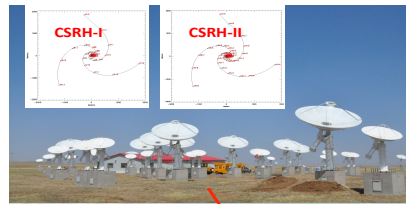
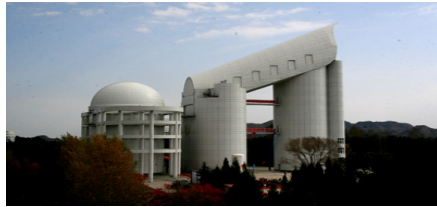
- **Oldest Field of Science — Everywhere**
- **Why? The most fundamental question: Existence**
- **We Study: Largest Volume in Space (all)**
Largest Volume in Time (future and past)
Answers the Questions on “Origin”
- **Our Subjects can be understood/appreciated by**
Public
- **Our Science can stimulate the interests of the**
Youngest
- **Best Stimulus for the Support of**
Science

Asian Astrophysics

- **Well Developed in East Asia during the last 30 years**
- **Key Players: Japan, China, Korea, Taiwan**
 - Strong Theory Tradition: e.g. Hayashi**
 - Strong Facilities Development: In-Country, Abroad**
- **Resources in East Asia:**
 - Fast Economic Growth**
 - Large Population**
 - Industrial Infrastructures**
- **Resources in South East Asia:**
 - Thailand, Vietnam, Malaysia, Indonesia**
- **Main Problems: Coordination, Organization, Competitiveness**

East Asia **already has** Regional Facilities

(10~100M USD)

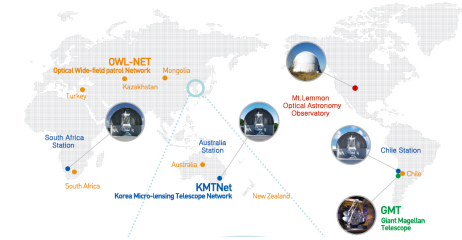
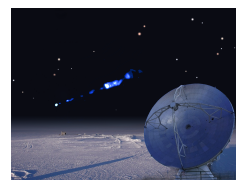
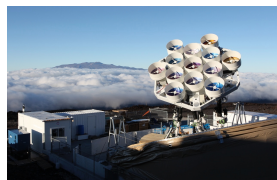
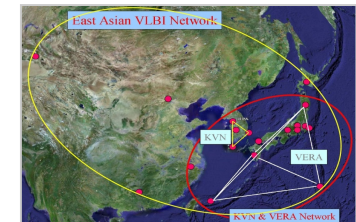


• **China:** LAMOST, FAST, 21CMA, CSRH, Silk Road, ...

• **Japan:** Subaru, Hinode, VERA, KAGRA, Nobeyama, Okayama, Kyoto NTT, TAO,

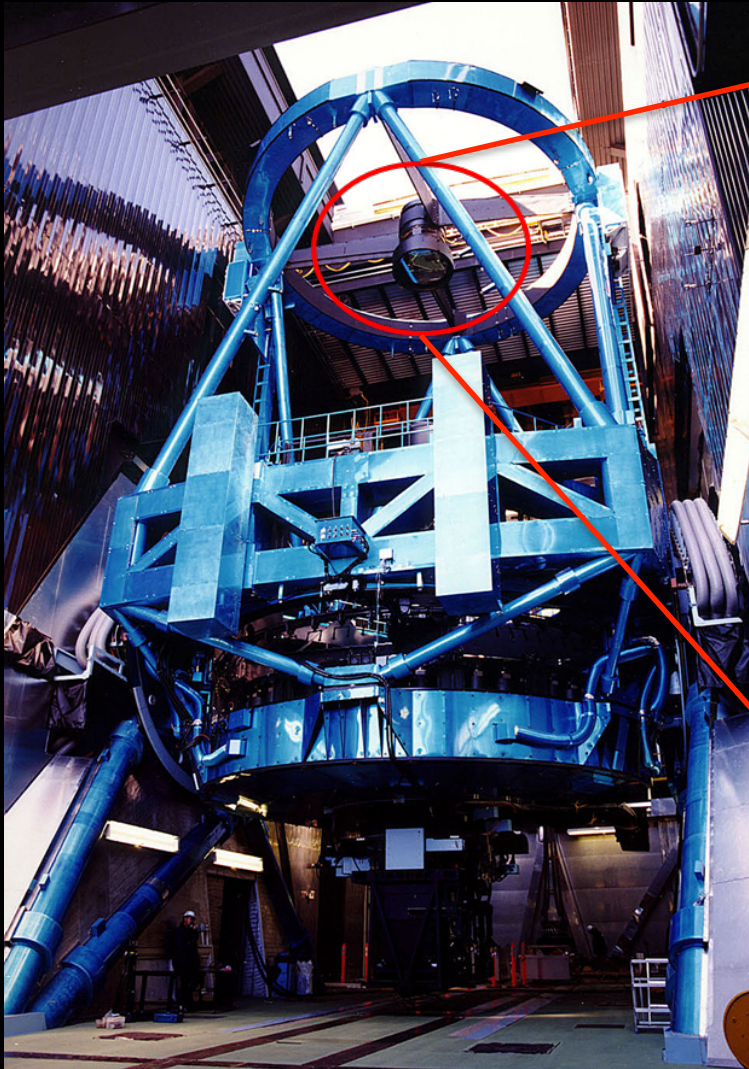
• **Korea:** Bohyunsan OAO, Sobaeksan OAO, KVN, KMTNet, Space Weather, CIBER, OWL,

• **Taiwan:** SMA, AMiBA, TAOS, TAOS-2, GLT, LOT



Subaru is 8.2m Japanese National Telescope

Subaru Hyper-Suprime-Cam (HSC)



HSC

Subaru Wide Field & Deep

- Quicker, Wider, Deeper



HSC
Field of View

Gravitational Weak Lensing



Galaxy Cluster Abell 2218

HST • WFPC2

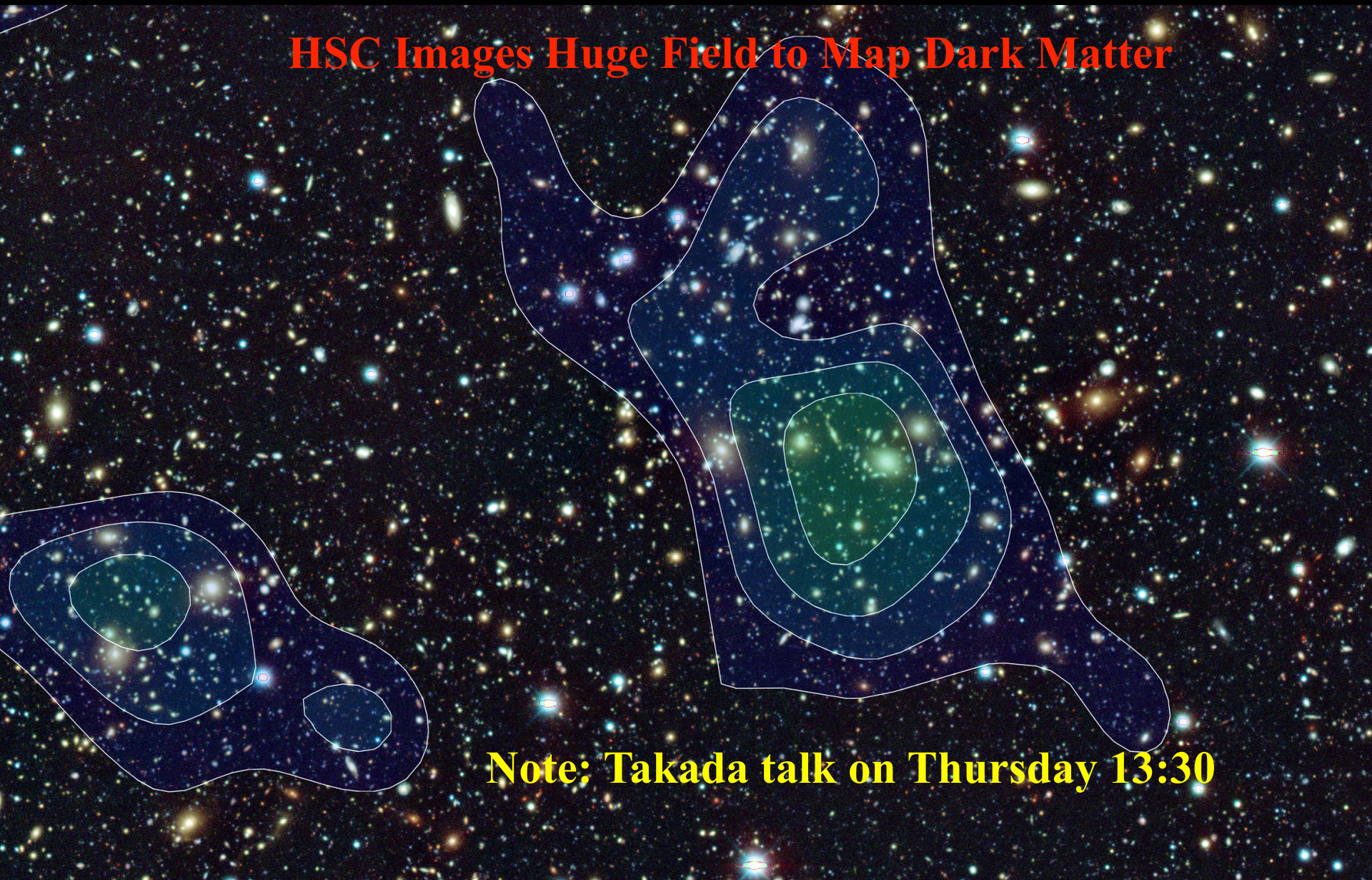
NASA, A. Fruchter and the ERO Team (STScI, STECF) • STScI-PRC00-08

Inverting Lensing Solution probes Total Gravitational Mass Distribution

Dark Matter Distribution via Gravitational Lensing

Miyazaki et al. (2015)

HSC Images Huge Field to Map Dark Matter

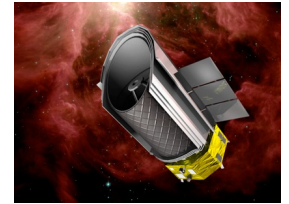
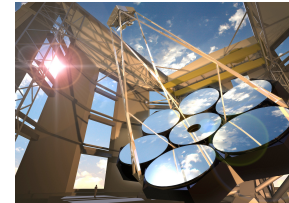
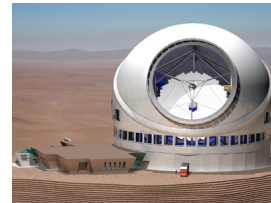


Note: Takada talk on Thursday 13:30

and Regional Large Scale Projects (> 1B USD)



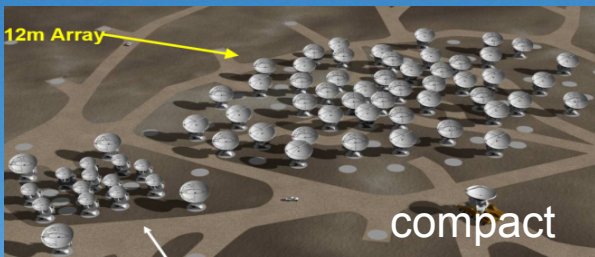
- **ALMA:** Japan, Taiwan, Korea
- **TMT:** Japan, China
- **GMT:** Korea
- **SPICA:** Japan (Korea, Taiwan)
- **SKA:** China, Japan, Korea (Taiwan)



However, Better Coordination Needed

ALMA (Atacama Large Millimeter/submillimeter Array)

An array of 66 antennas,
using aperture synthesis, as a “zoom telescope”
over the *entire accessible mm/submm* wavelength range up to 1 THz



Built to operate
>30 years



At 5000 m (or 16404 feet)

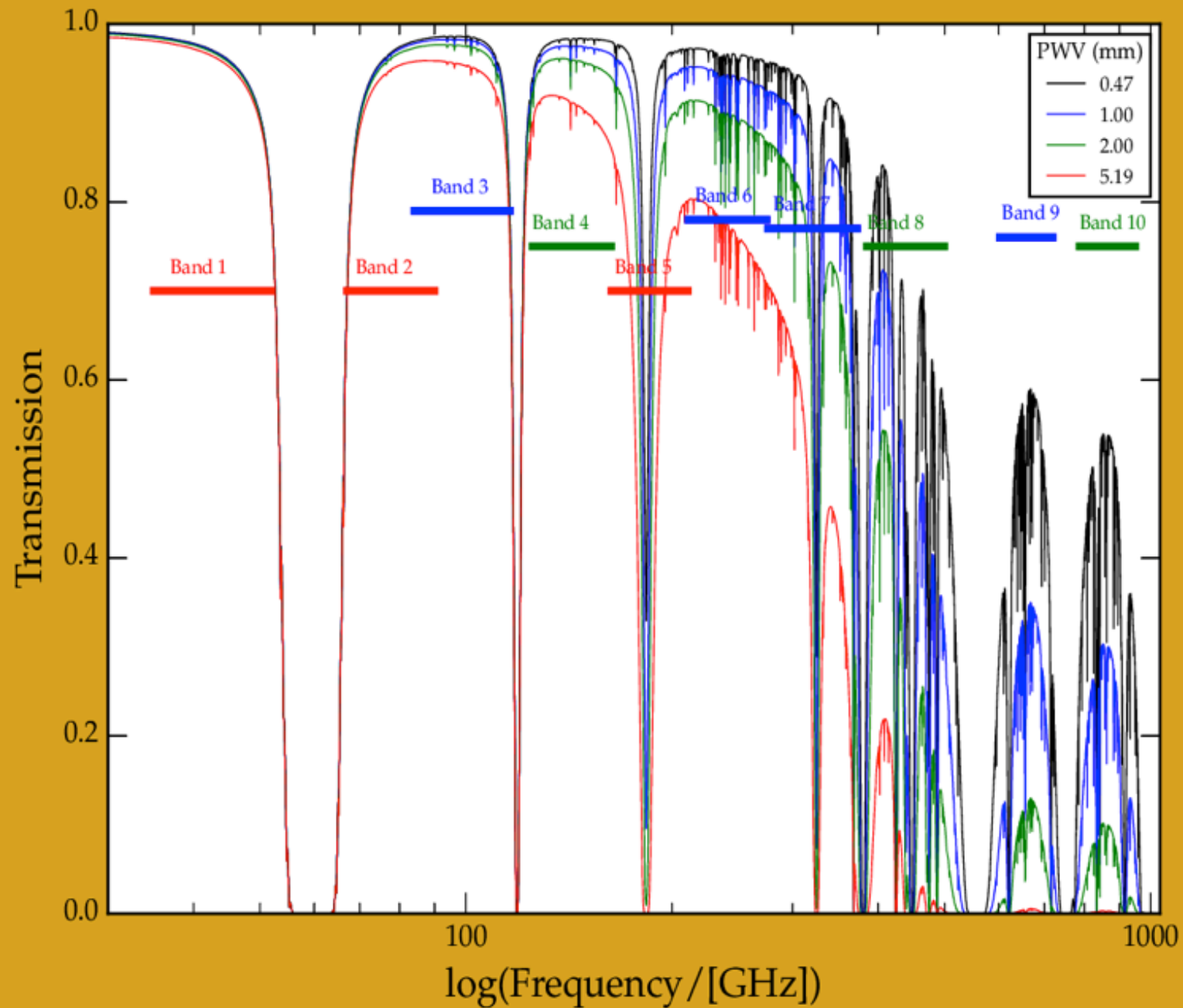


← Remotely operated from
OSF Control room

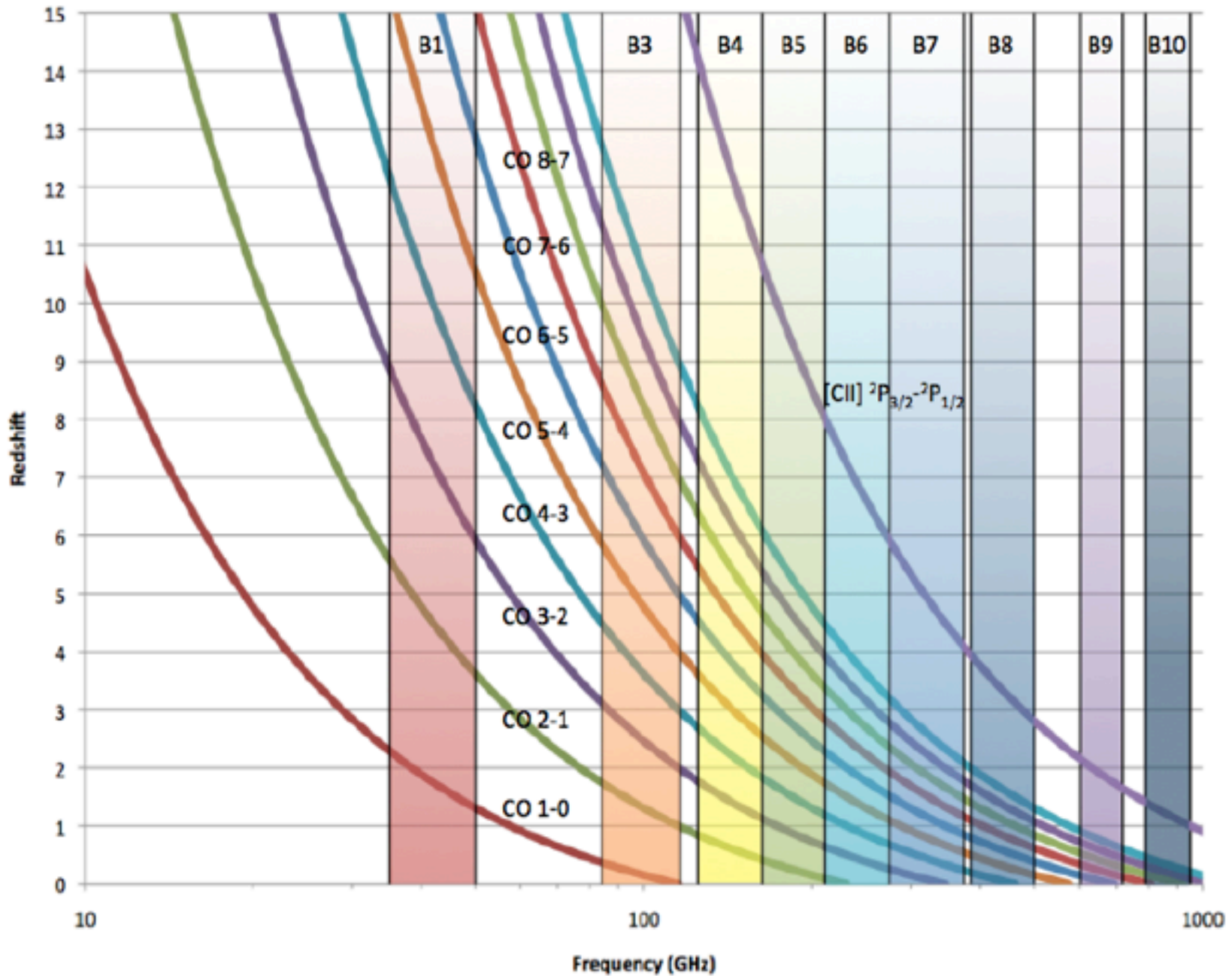
ALMA Completed in 2013



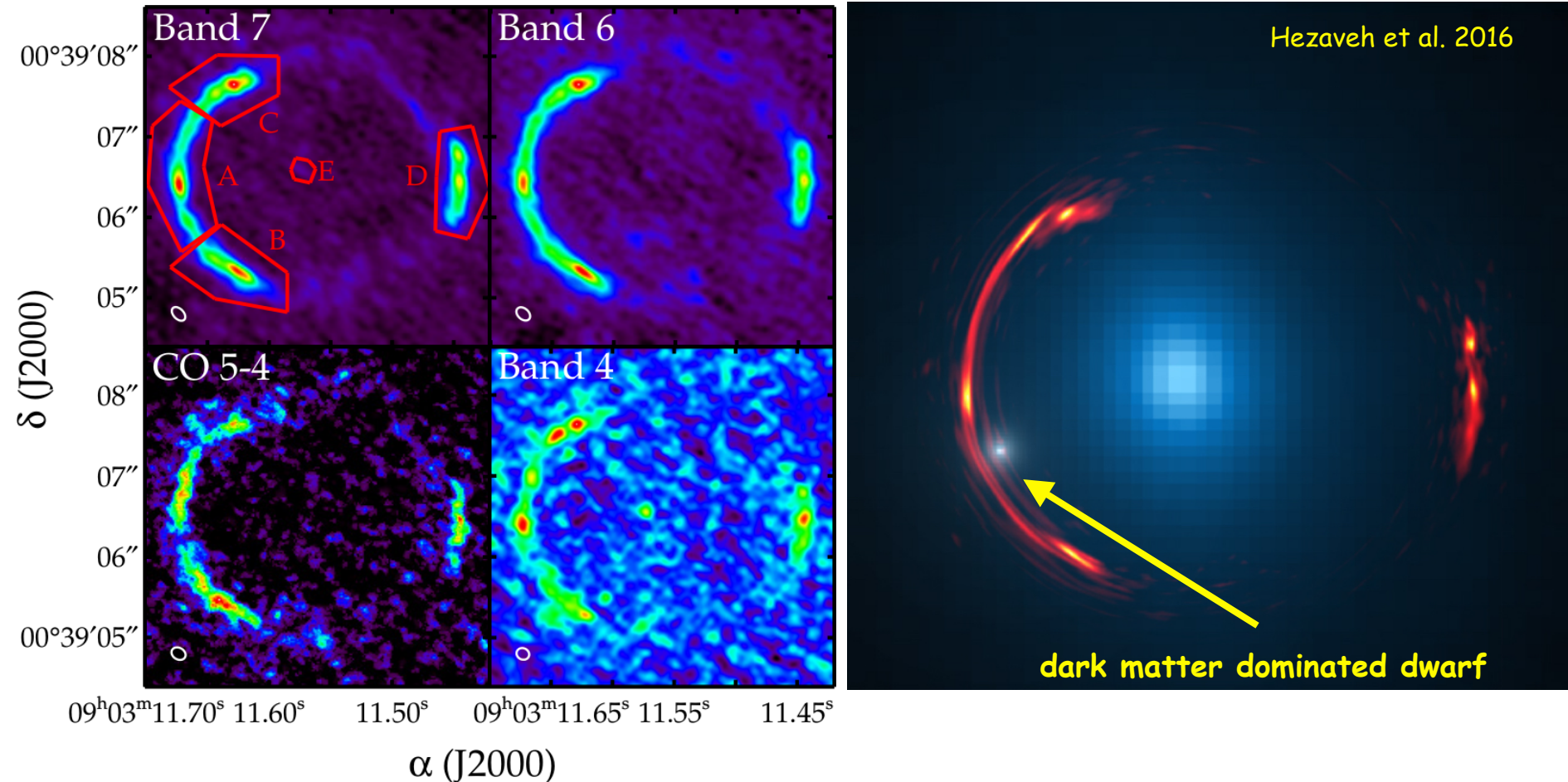
Atmospheric transmission at Chajnantor



No. 1 Science Goal : High z



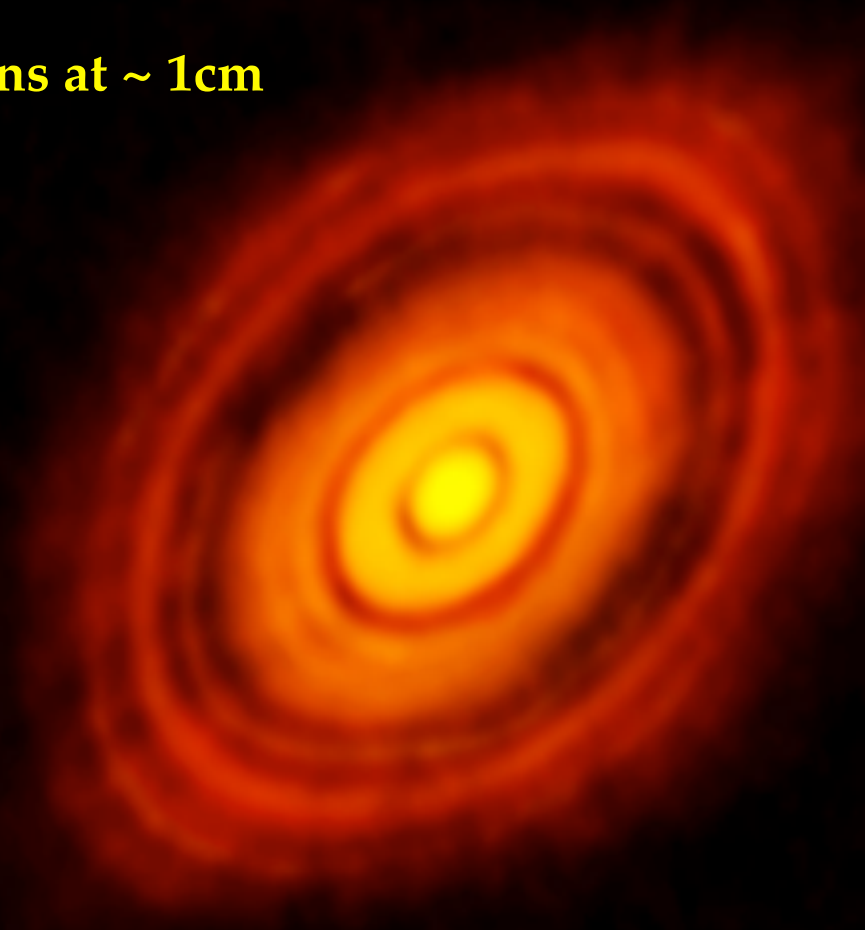
Imaging of High z Galaxies via Lensing



Key: extend lensing studies to higher z to probe even more distant systems

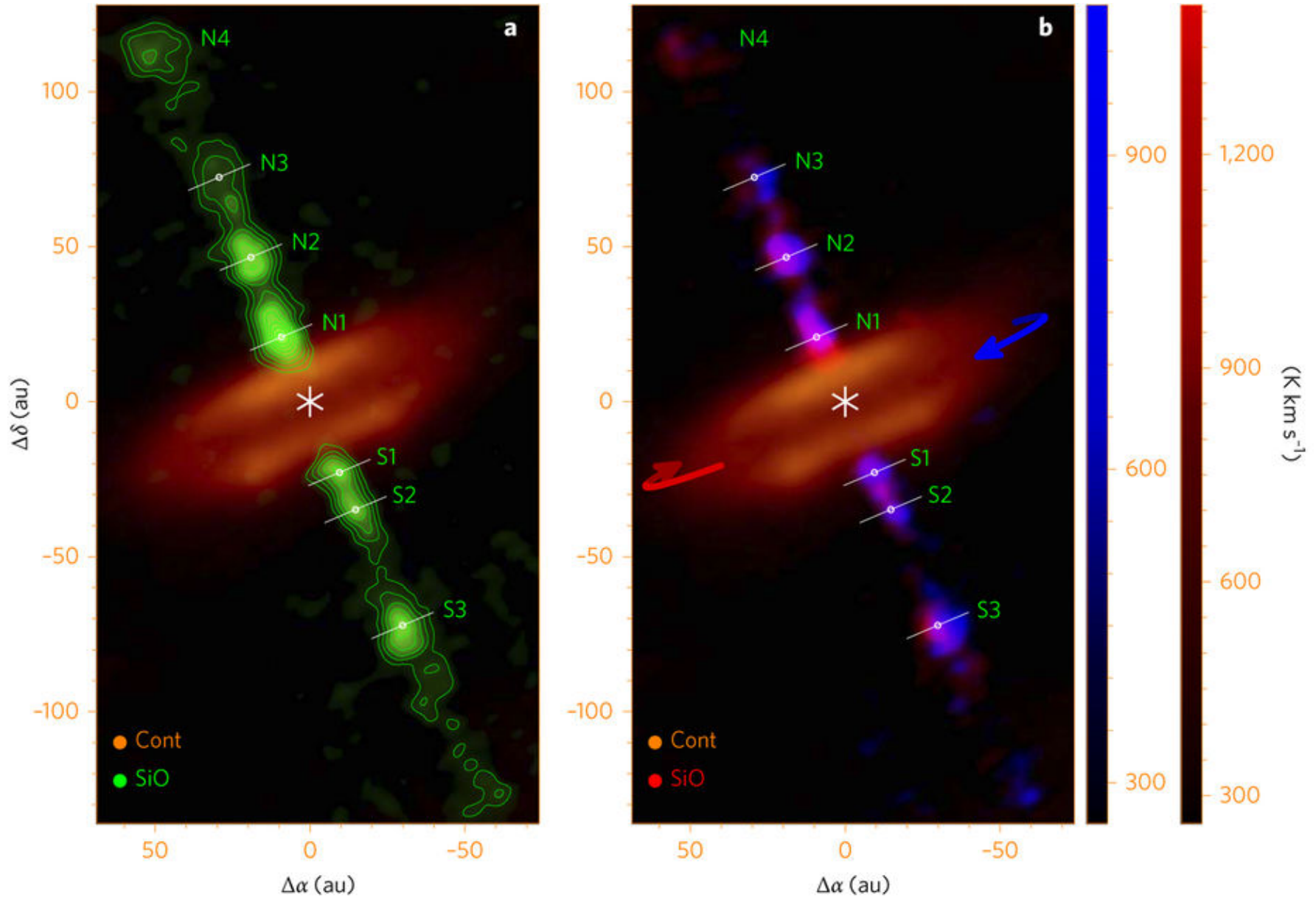
No. 2 Science Goal: Tidal Gaps, Planet Formation

dust grains at $\sim 1\text{cm}$



optically thin dust

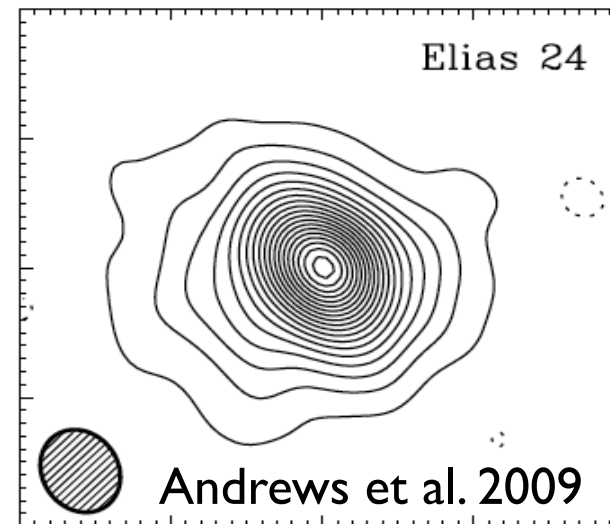
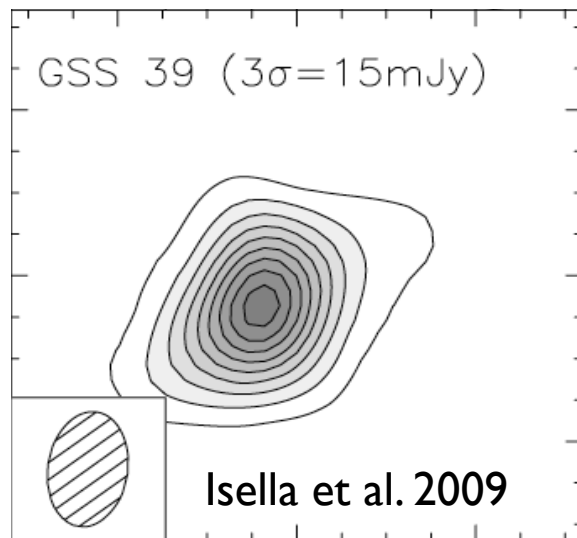
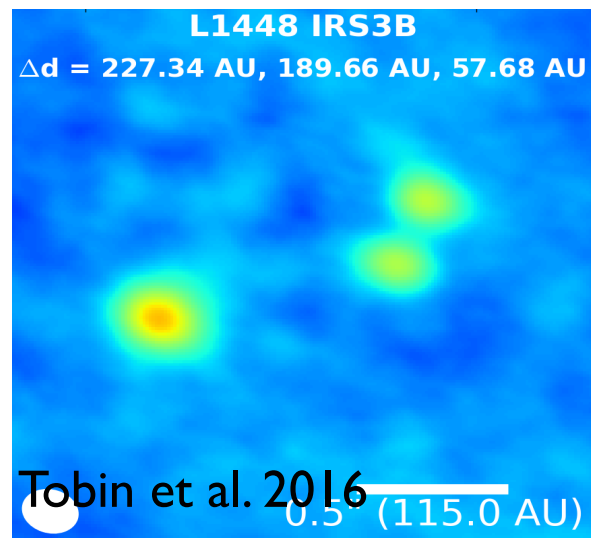
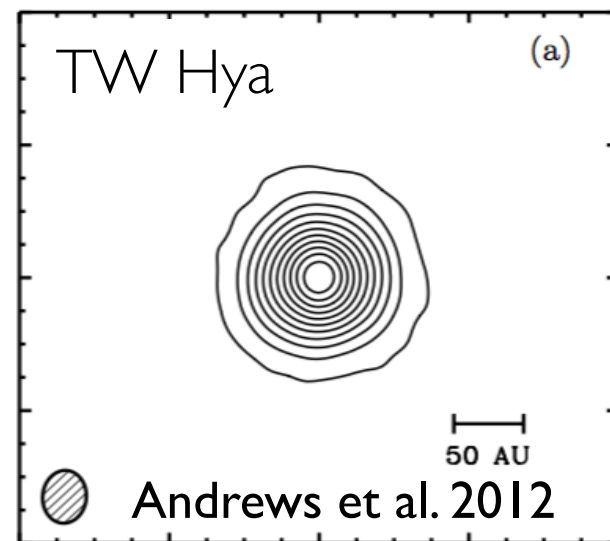
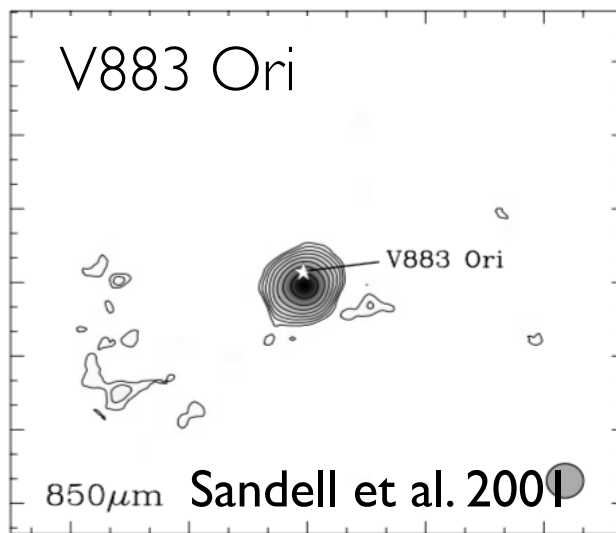
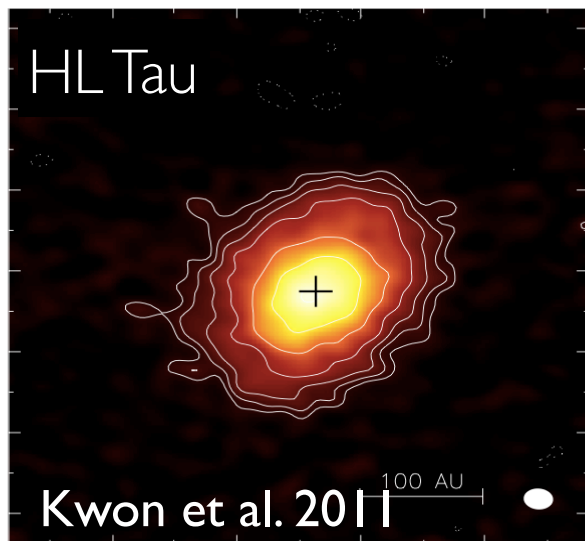
Circumstellar Jet in HH212: (ALMA~0.02'')



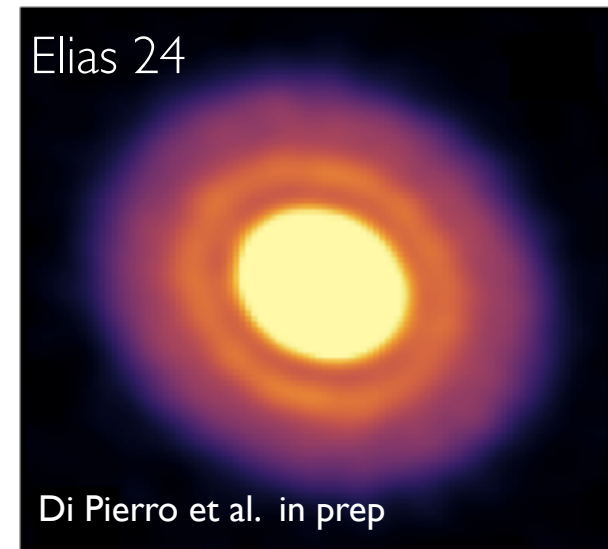
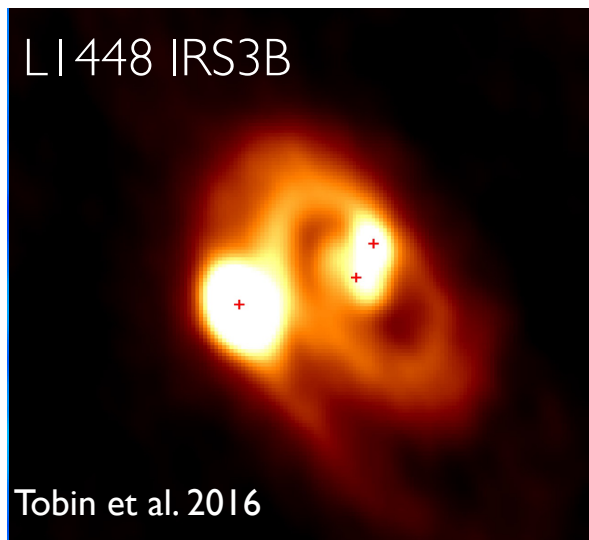
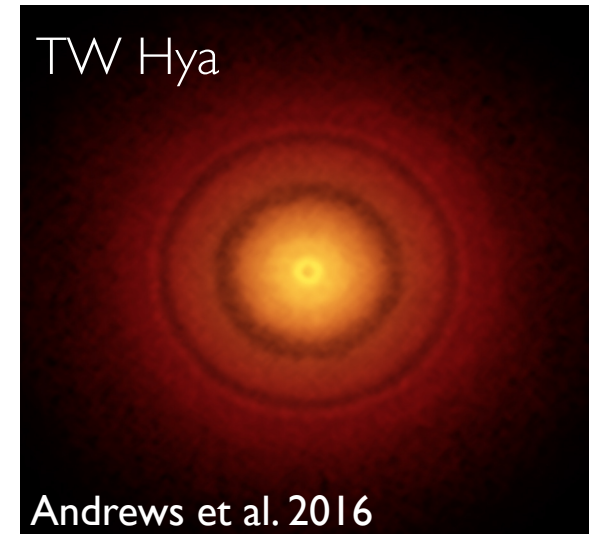
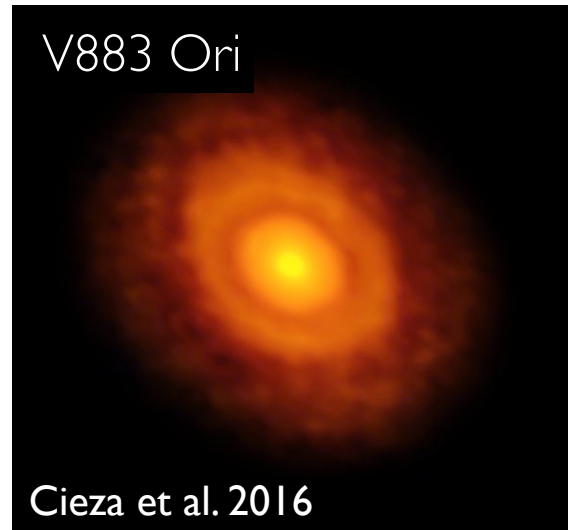
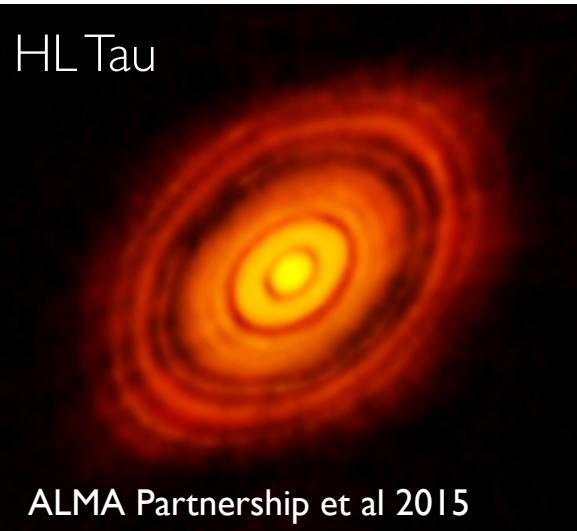
Total Intensity: -14 to 14.5 km s⁻¹

Red: -1 to 4 km s⁻¹; Blue: -10 to -5 km s⁻¹

Protoplanetary disks: pre-ALMA



Protoplanetary disks: ALMA



Why the Development of EAO?

“What is the Role of Asia in the World?”

“Can Asia Participate, Contribute, **Lead?”**

“Can we Improve? How?”

- **Goal:** Compete and Preserve most important “Resource”:
Brain Power
- **How:** Attract **Next** Generation into Exciting Science
- **Method:** **Cross** “Institutional Boundaries”, “Discipline/Field Boundaries”, “Cultural Boundaries”, “National Boundaries”
———*thereby increase possible solutions*———

EAO is a Project of EACOA: EACOA is a Dream for Asia

EACOA: NAOC, NAOJ, KASI, ASIAA



- **Timeline:** EACOA officially formed in 2005
- **Mission:** to Organize and Promote East Asian Astronomy
- **History:** Many Years of Efforts from Norio Kaifu
Cai-Ping Liu, Se-Hyung Cho, & Friends
- **Activities:** Meetings (**EAMA, EAYAM**), Workshops; EA VLBI Network; EA Site Surveys; EACOA Fellows; EACOA-CSO initiative, **East Asian Observatory**
- **Purpose?** **Increase Regional Resources: Funds, Manpower, Jobs**

East Asian Observatory

- **History of Development: Established 2014**
- **Model: Asian Counterpart to ESO**
- **EAO Members: NAOC, NAOJ, KASI, ASIAA**
- **Goals and Aspirations: Jointly Enable Future Dreams**
- **Current Status: Operating JCMT since 2015**
- **Current Plans: Adding more Facilities (SMA, UKIRT, Subaru)**
- **Future Plans: Expand EAO Membership**
(**Vietnam, Thailand**, Malaysia ...)

Vietnam and **Thailand** now Observer Status: Free Access

Vietnam can become Partner in the Future

Malaysia in process of joining as Observer

Goals of EAO

Mission Statement

The EAO (East Asian Observatory) is formed by EACOA (East Asian Core Observatories Association) for the purpose of pursuing joint projects in astronomy within the East Asian region. **In the era of very large scale astronomical instruments, East Asia will be competitive internationally by combining their funding resources, their technical expertise, and their manpower. The intention of EAO is to build and operate facilities, which will enhance and leverage existing and planned regional facilities. The intention of EAO is to raise funding and to build an observatory staff, separate from that of the EACOA institutions. As partners of the EAO, the EACOA institutes will help to establish the funding and to oversee the governance of EAO. The communities represented by the partners in EAO, would have full access to all EAO facilities.**



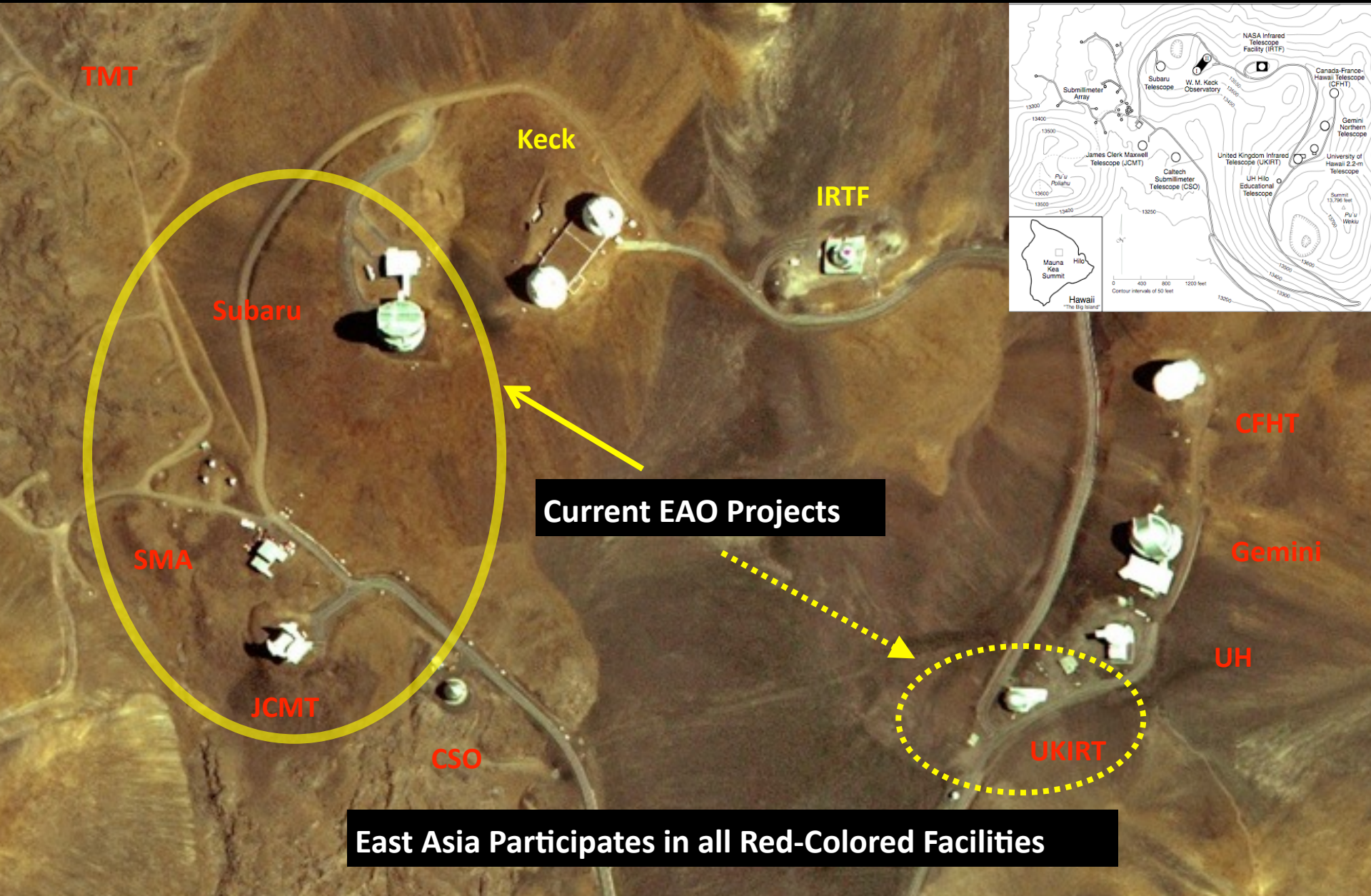
EAO is meant to benefit our regions “together”

Lessons from ESO

- ESO Declaration (1954) predates EEC (1958) and EU (1993)
- ESO is more than 50 years old
- **ESO Annual Budget is at “Government Minister” Level**
- ESO Annual Budget is on the order of NAOJ or NAOC
- ESO Supports Large and Small Facilities
- ESO has “EU” Facilities and “Joint” Facilities (eg ALMA)
- ESO Facilities Complement Member Facilities
- ESO has ~730 staff members
- **EU Scientists are very mobile within EU**
- **ESO Budget : 2018 297M Euro**

- EAO Founding Members are “**Better Prepared**” than ESO Founding Members in 1962 (technically, financially)
 - ➔ We should be moving **FASTER** !
- EAO has ~35 staff, 2018 Budget ~5.0M USD
- **What has EAO achieved in these 3 years?**

EAO Operates on top of Mauna Kea



Current EAO Projects

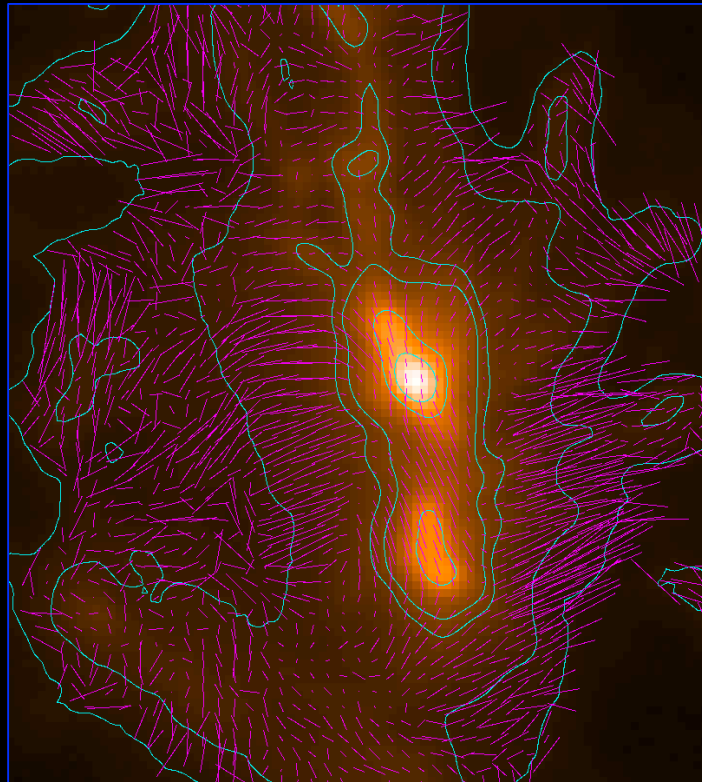
East Asia Participates in all Red-Colored Facilities

**A New EA Submm Community is Built
via the EAO/JCMT**

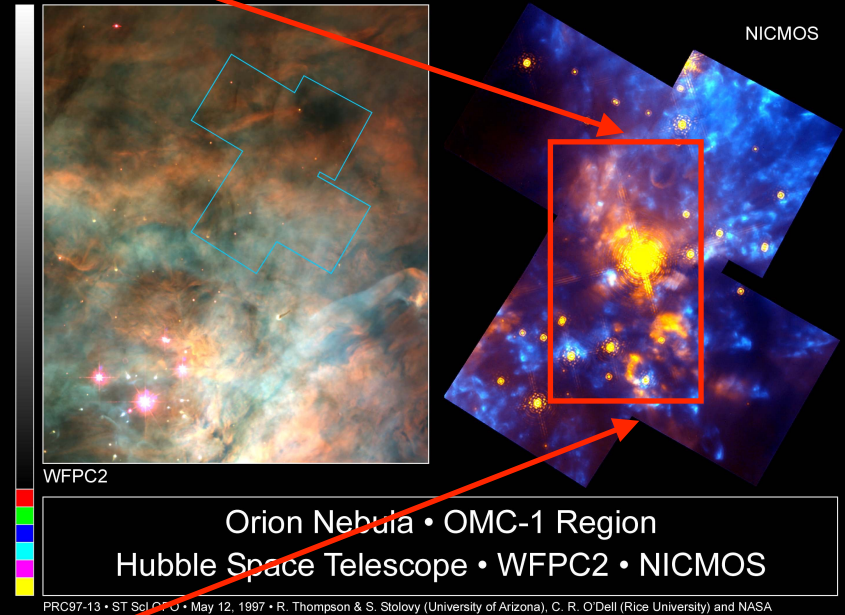


Radio Emission is Polarized

TRACKING MAGNETIC FIELDS via DUST EMISSION



**POL-2 OMC-1
Commissioning Data**

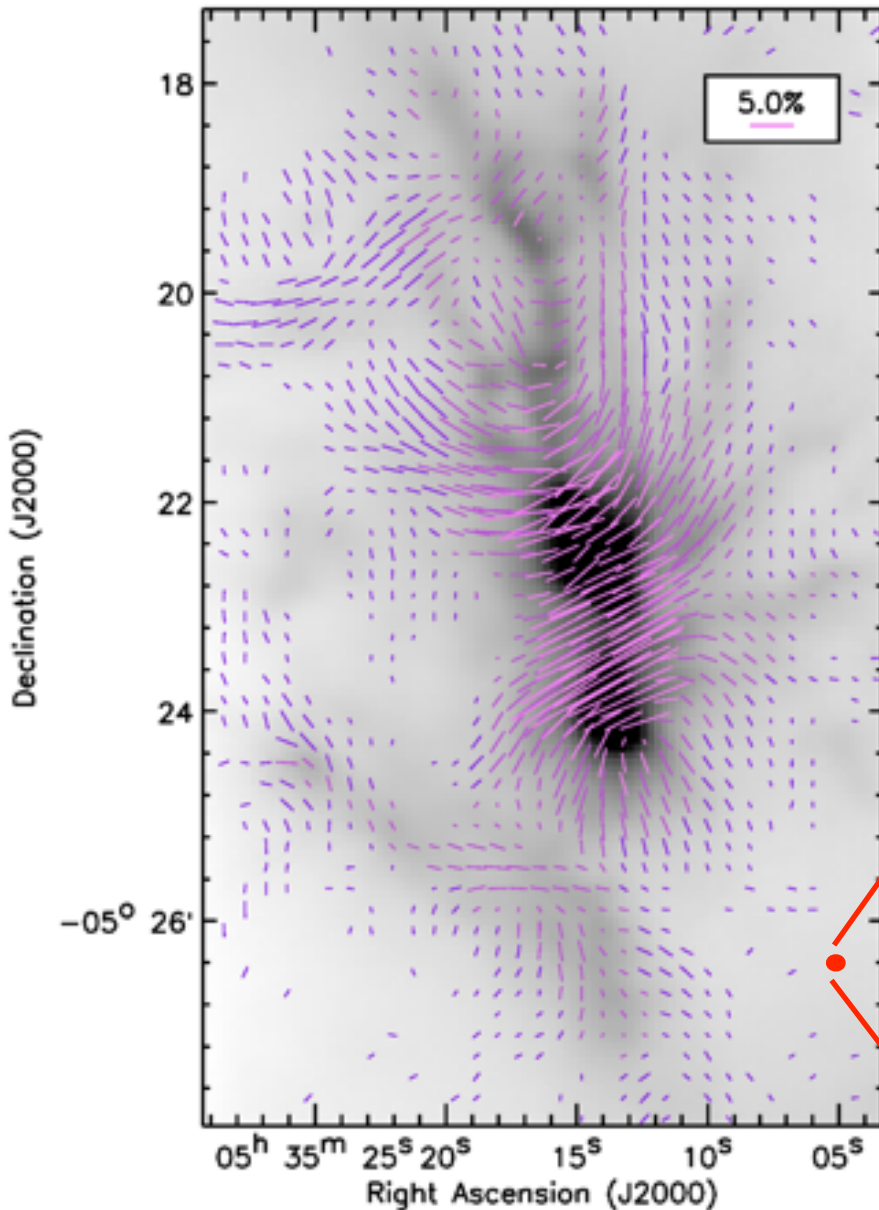


**Hubble Image
STScI Thompson et al**

Dust Grains are elongated, slightly charged, and Aligned by Magnetic Field

Dust Grains are Cold, and radiate in the submm wavelengths

BISTRO: B-Fields in Star-forming Region Observations

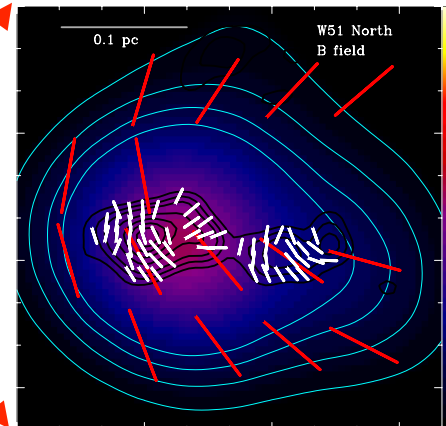


Orion A:

- Survey paper: Ward-Thompson et al. 2017, ApJ in press
- Chandrasekhar-Fermi and energetics analyses: Pattle et al. 2017, ApJ submitted.

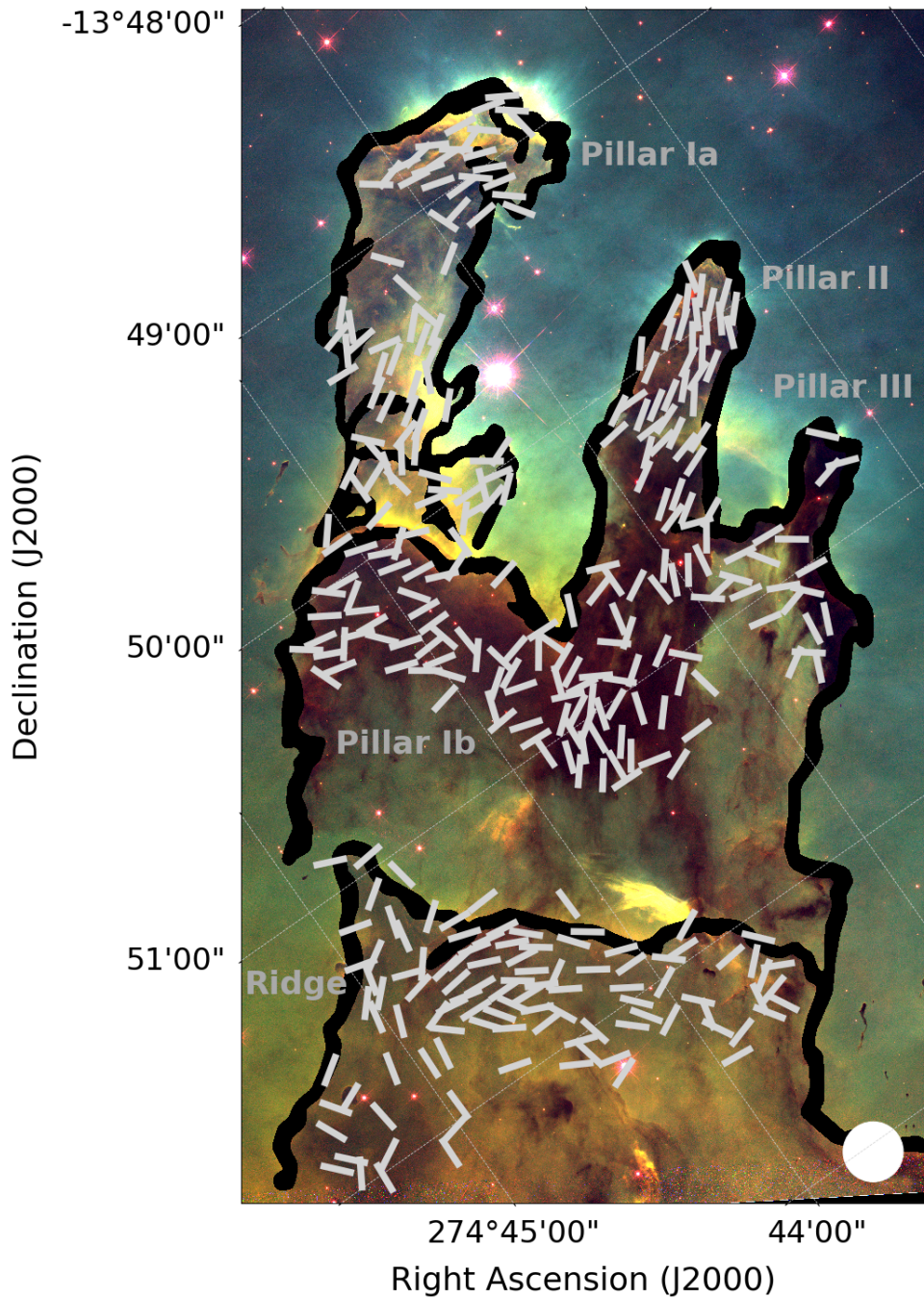
**Tracking B-Fields
into Faint Regions:**

Shaping Molecular Outflows?



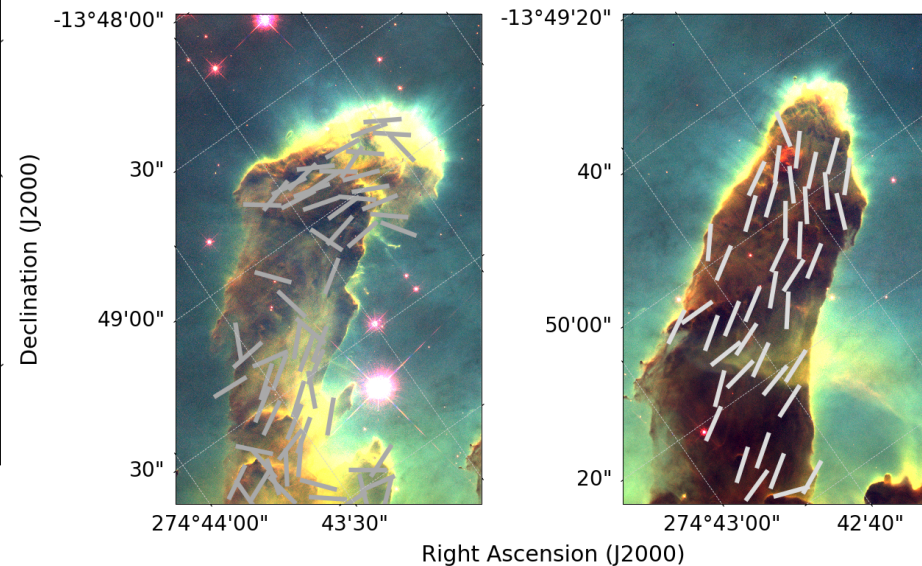
W51: SMA





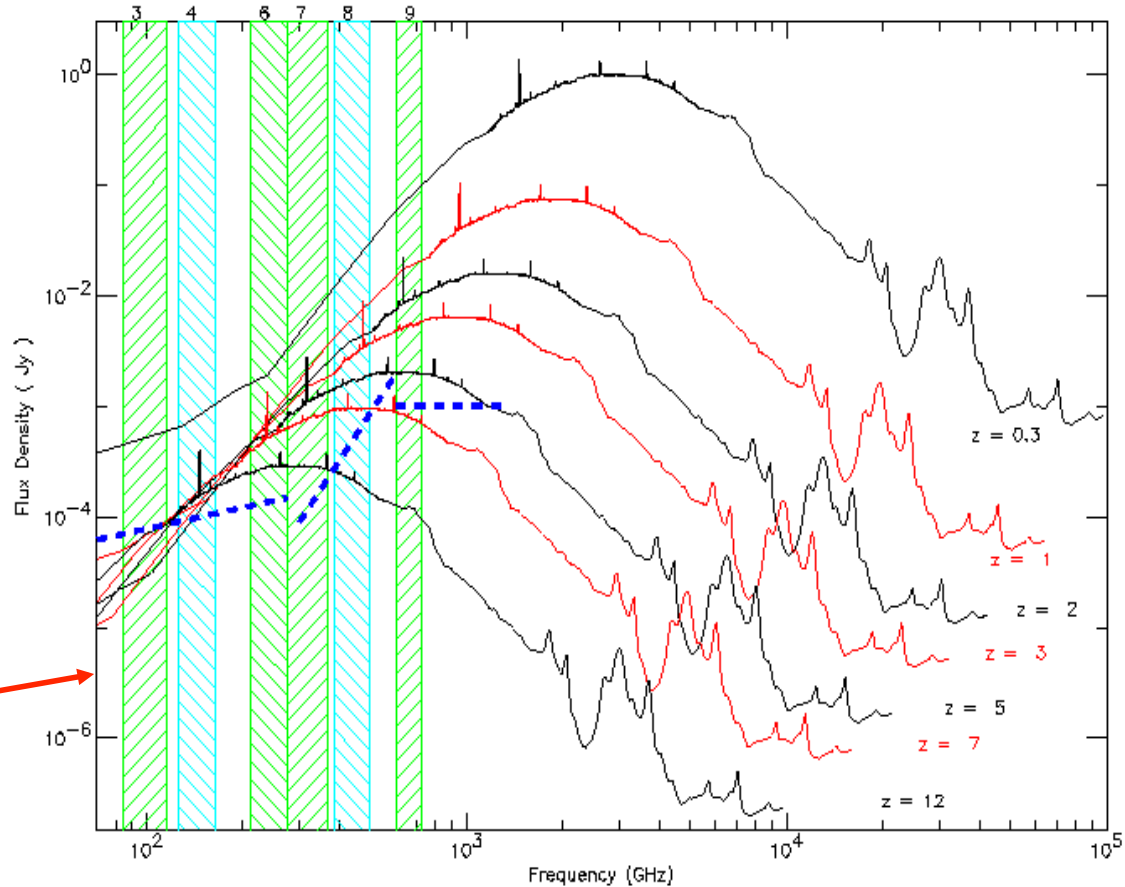
BISTRO-2 results (Pattle et al. 2018)

magnetic field morphology
 observed in the dense gas of the
 Pillars of Creation inside of the
 Eagle Nebula (M16) with
 POL-2, overlaid on the HST
 images



Expansion of Universe

M82 from ISO, (Beelen and Cox,)

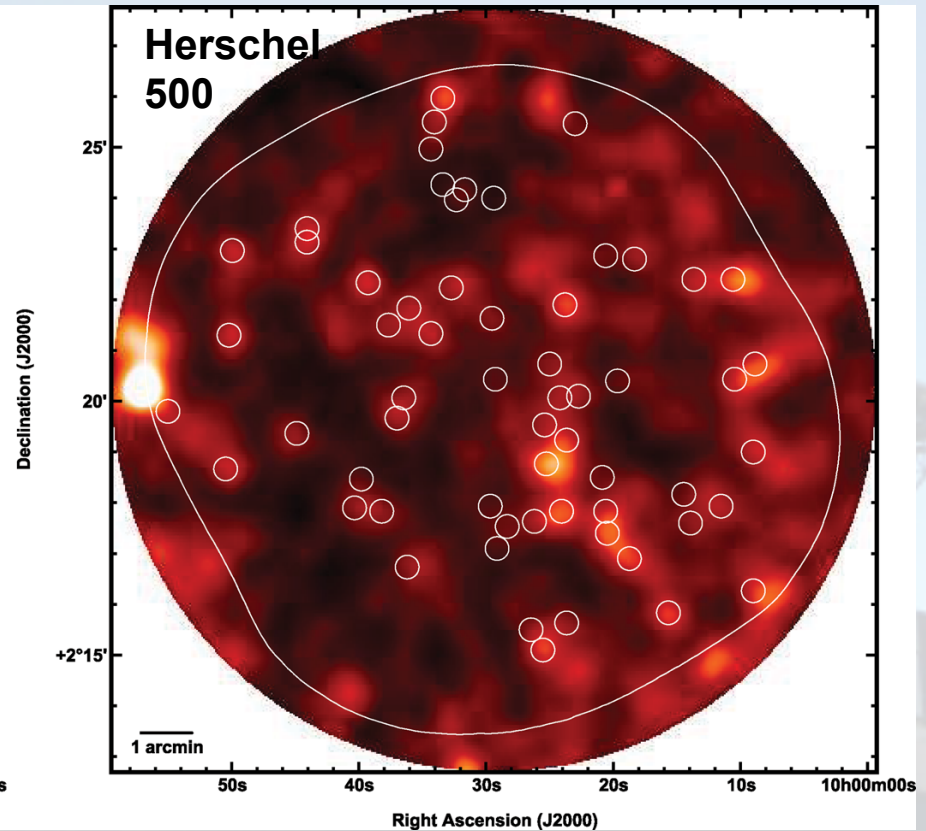
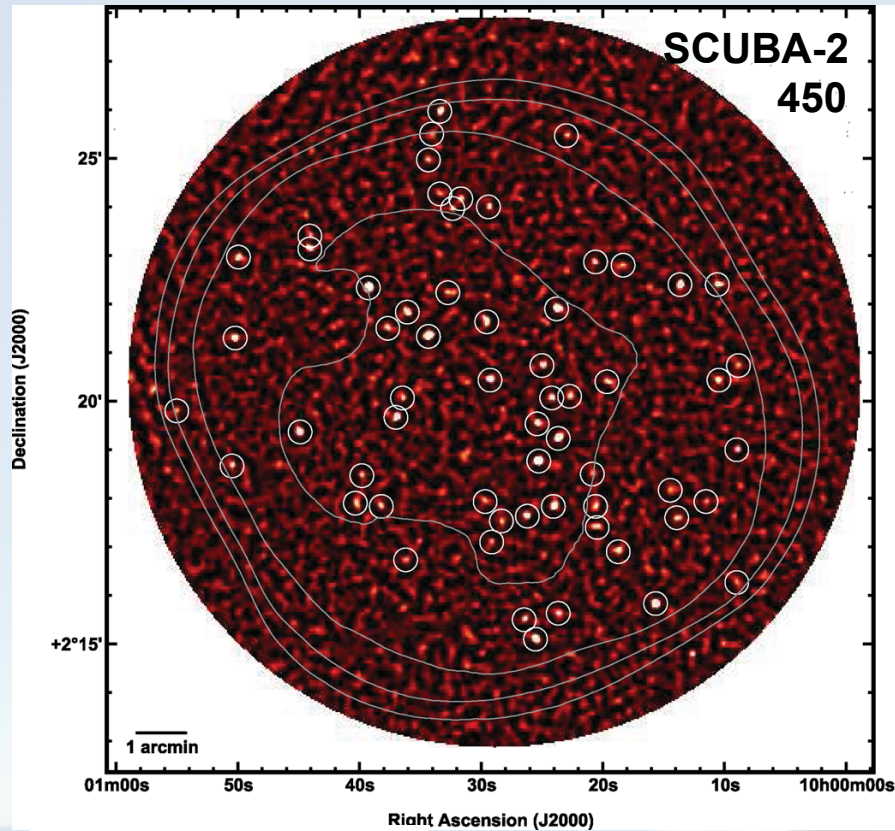


$50 \mu\text{Jy}$

JCMT Window

Optical

JCMT can See Better than a Space Telescope



**JCMT on Mauna Kea can see as clearly as Herschel Space Telescope,
because of the High Transparency at the top of the Mountain even at 450μm**

JCMT is part of EHT

JCMT and EHT participated in ALMA Cycle 4 (Cycle 5)

Calibrated data distributed to EHT Imaging Teams

Event Horizon Telescope

JCMT is part of EHT

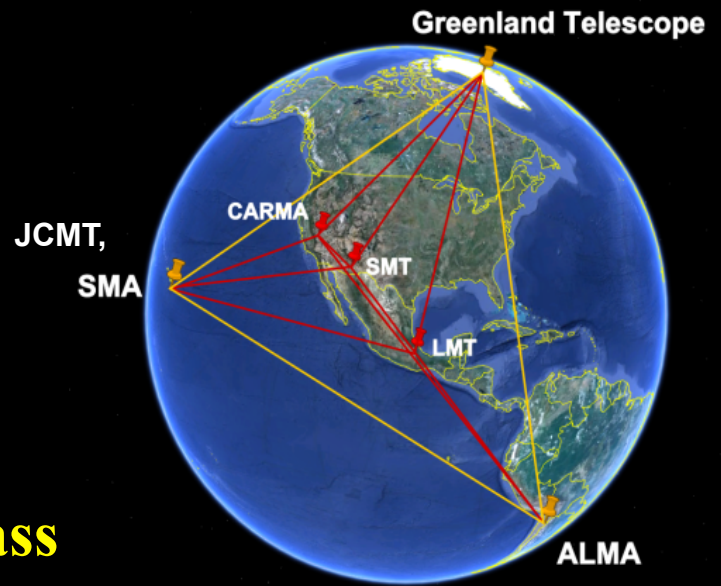
D ~ 9000 km

resolution ~ $10\mu\text{as}$

Goal: Resolve Black Hole

Shadow; measure spin and mass

First Images are Obtained !!



Publication Statistics

2015: 4 out of 108 papers from EA

2016: 19 out of 105 papers from EA

2017: 32 out of 117 papers from EA



In 2017, EA lead 49% of JCMT Partnership 1st Author Papers

2018 (to 04/30)

EAO Status: 2015-2018

- Operate JCMT more efficiently than ever
- Built EA JCMT Submm community (~350 PIs)
- Introduced new JCMT Polarization Capabilities (POL-2)
- JCMT is now part of Event Horizon Telescope consortium
- JCMT Large Programs lead to New Science Initiatives
- By 2017, EA Community leads ~50% of JCMT Partners 1st Author papers
- JCMT operations extended to 2024
- EAO Access to SMA, UKIRT, Subaru
- EAO working with Southeast Asian countries
- **Vietnam** and Thailand are now Observers: Access to all of EAO facilities — Accelerate regional developments

Future: Next EAO Projects?

- **Subaru (for access to 8m to 10m class optical telescope)**
- **SMA (for access to submm interferometry in northern hemisphere, and also to prepare for ALMA)**
- **VLBI (to establish EA VLBI effort to contest for EHT)**
- **UKIRT (to access wide-field IR imaging)**
- **CFHT (for possible participation on MSE)**
- **Instrumentation Projects (improve all receivers in sensitivity by 10 times); detector development**
- **site surveys in Asia, given Mauna Kea situation**

- **ALL SUCH INITIATIVES are in motion**

How EAO Works?

- **Infrastructure Funding aims to be based on ratio of GDP.**
- **Project Funding aims to be based on regional interests.**
- **Regional Manpower are deployed to EAO, either via posting or direct hiring. EAO facilitates visa for international staff.**
- **EAO helps regional scientists to access facilities, prepare science proposals, participate in experiments, reduce data.**
- **EAO helps regional scientists to collaborate on Large Programs.**
- **EAO conducts workshops and schools in the regions.**
- **EAO welcomes regional students and scientists to be in residence at EAO. EAO provides housing support.**
- **EAO welcomes regional participation in instrument development.**
- **What is Role for Vietnam?**

New Partners?

Asian Regional GDP

	2018	2023	5-YR
	GDP (IMF): B \$	Projected GDP	Growth Rate: %
USA	20,413	24,537	20
CHINA	14,093	21,574	53
JAPAN	5,167	5,962	15
SOUTH KOREA	1,693	2,155	27
TAIWAN	613	660	8
INDONESIA	1,075	1,549	44
THAILAND	484	650	34
MALAYSIA	365	568	56
VIETNAM	241	373	55

- South East Asian Economies are Expanding
- South East Asia also has Large Population
- East Asia + South East Asia >> U.S. or EU

Proposed Contributions ~ Ratio of GDPs

Summary:

Accelerating East Asian Astronomy

- **EAO seeks to be the Asian counterpart to ESO**
- **EAO provides a Working Model for “Action” beyond “Planning”**
- **EAO provides a Working Model for Regional Coordination**
- **EAO provides a Working Model for Sharing Cost and Manpower**
- **EAO demonstrates that Joint Efforts can be Competitive with the West**
- **Astronomy in South East Asia can also Grow Rapidly**
- **Astronomy in South East Asia can access Frontier Facilities**
- **EAO seeks to stimulate and support the Growth of Astronomy in all of Asia — in Vietnam**
- **EAO seeks to be a model for Regional Engagement**

Han Mac Tu (1912-1940)

In pure sunlight: dreams dissolve,
A pair of thatched roofs speckled gold.
The teasing wind rustles emerald clothes,
On fragrant arbor. See spring unfold.

Verdant grass waves ripple to the sky.
Around the village, girls singing on high.
—perhaps tomorrow from that youthful throng,
one will follow a husband, bid her game goodbye...

Sound of singing on the mountain,
Soft as words of water and clouds...
Murmuring with those sitting under bamboo,
Such delicate and innocent sounds...

Guests from afar meet at ripe spring,
Hearts and minds suddenly long for home:
—this year, does she still carry rice,
Along the riverbank under the bright blazing sun?



**In pure sunlight: dreams dissolve,
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