Introduction to the Harvard-Smithsonian Center for Astrophysics

2nd Annual

Radio Science Symposium

November 8, 2017

Roger Brissenden

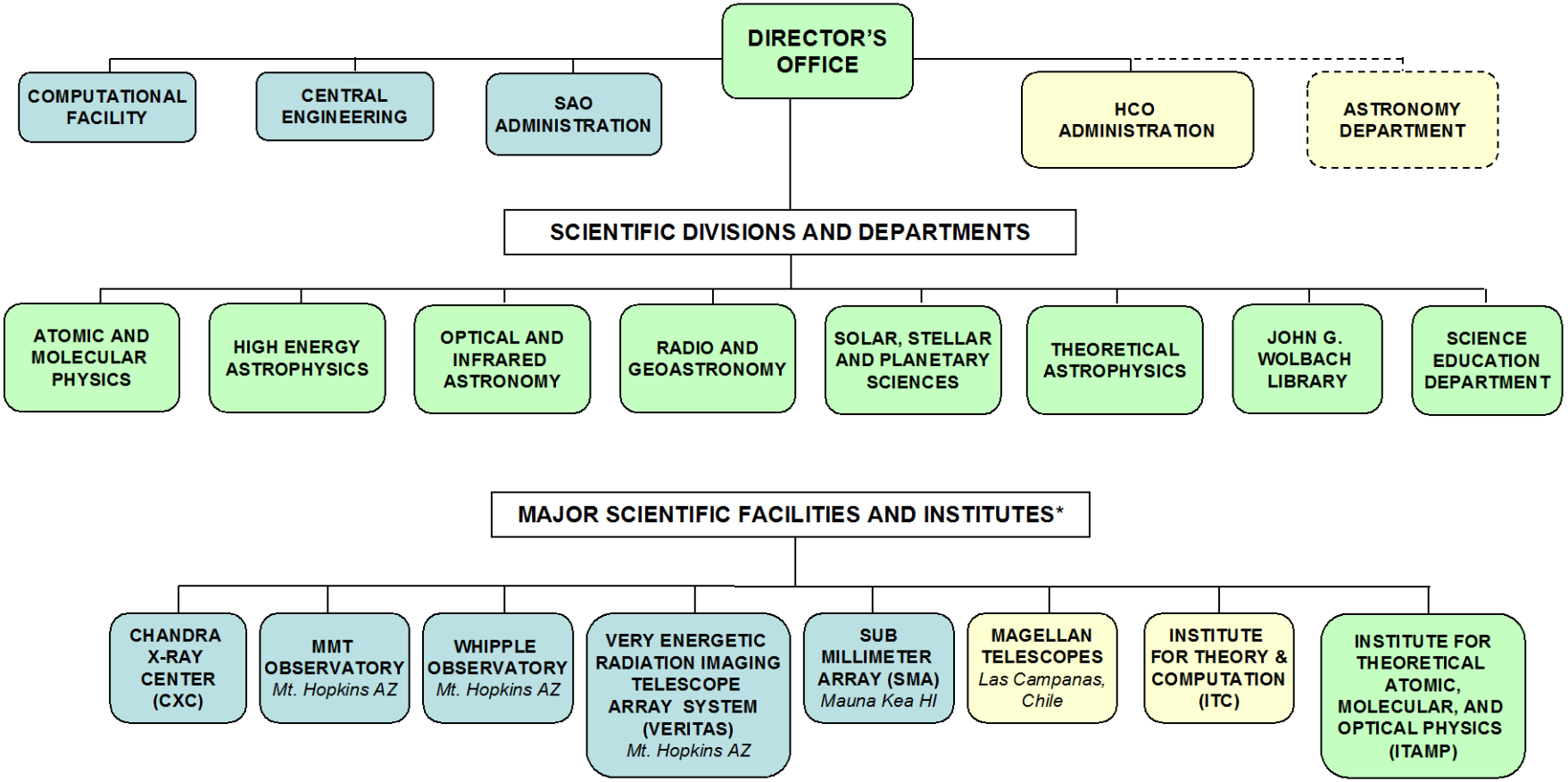
The CfA

- The CfA combines the resources and research facilities of the Harvard College Observatory (HCO) and the Smithsonian Astrophysical Observatory (SAO) under a single director to pursue studies of those basic physical processes that determine the nature and evolution of the universe.
- The CfA is organized around six Scientific Divisions
  - Atomic and Molecular Physics (AMP)
  - High Energy Astrophysics (HEA)
  - Optical and Infrared Astronomy (OIR)
  - Radio and Geoastronomy (RG)
  - Solar, Stellar and Planetary Sciences (SSP)
  - Theoretical Astrophysics (TA)
- The Scientific Divisions are supported by a central engineering department, computation facility and administrative groups

The CfA

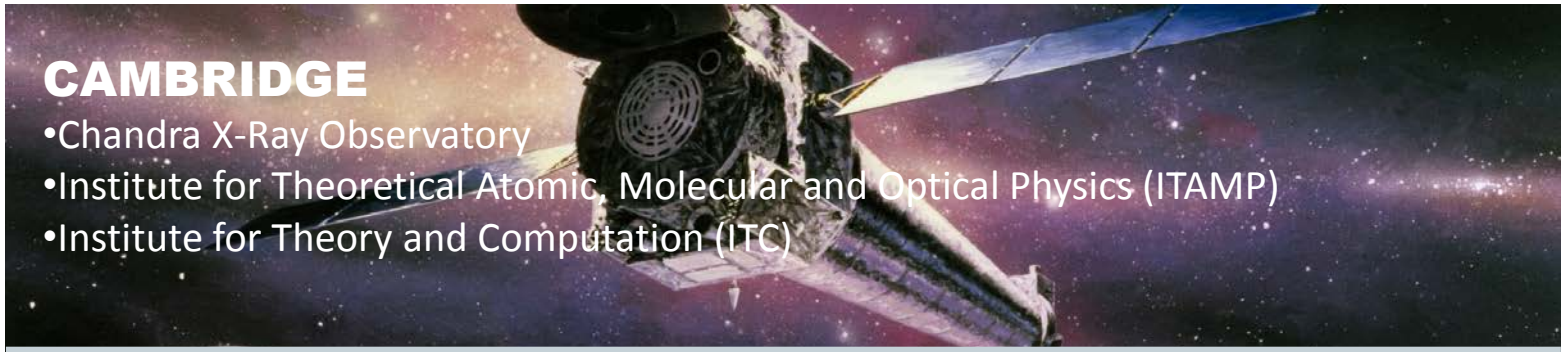
- The CfA is has over 800 staff including 300 scientific staff and postdocs
- Central Engineering department of 50+ engineers covering multiple disciplines supporting development of ground and space-based instrumentation:
  - Systems engineering
  - Electrical and Mechanical engineering
  - Structural Analysis and Design
  - Thermal Analysis and Design
  - Machine Shop
  - Test facilities: high T bakeout ovens, vibration cells

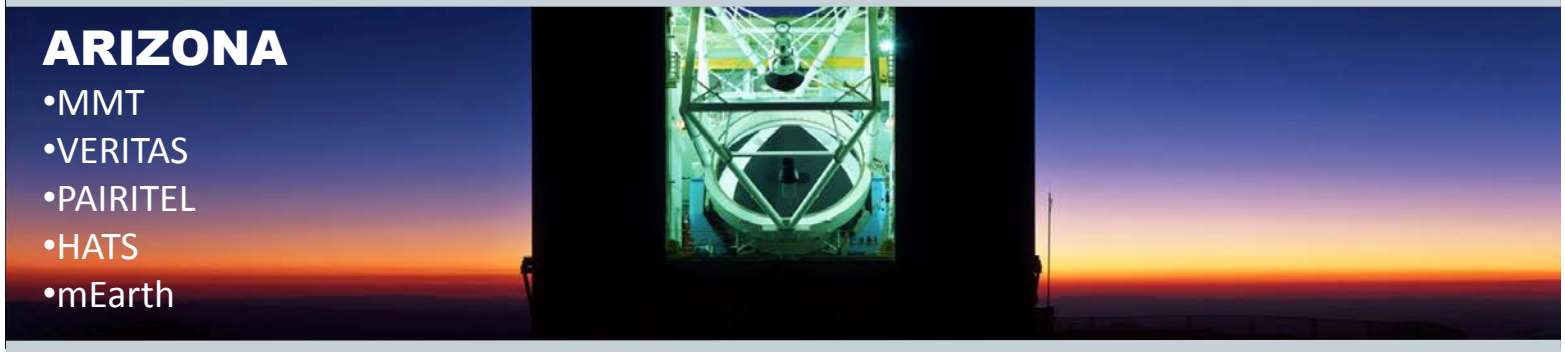
CfA Organization



CfA has over 800 staff including ~300 scientific staff and postdocs

Summary of Facilities & Locations





Missions and Centers

- Chandra X-Ray Observatory (NASA)
- Spitzer Space Telescope, IRAC Camera (NASA)
- Astrophysics Data System (NASA)
- Minor Planet Center (NASA)
- Institute for Theoretical, Atomic, Molecular & Optical Physics (NSF)
- MMT (jointly with U of Arizona) and smaller telescopes (SAO)
- Magellan Telescopes (Harvard)
- Submillimeter Array (jointly with ASIAA)
- Very Energetic Radiation Imaging Telescope Array System (NSF/DOE)
- Hinode (Solar B; NASA)
- Solar Dynamics Observatory (Advanced Imaging Array; NASA)
- Institute for Theory & Computation (Harvard)

Collaboration Opportunities

- SMA – observing and science collaboration [Ray Blundell]
- SAO/SMA receiver lab – mm and sub-mm technology [Ray Blundell]
- Event Horizon Telescope – [Shep Doeleman]
- Greenland Telescope – [Nimesh Patel]
- CMB: BICEP – [John Kovac]
- Low frequency science and technology: LEDA – [Lincoln Greenhill]
- Chandra X-Ray Observatory – [Belinda Wilkes]

Sub-millimeter Array (SMA)

A collaboration between SAO and the Academia Sinica Institute of Astronomy and Astrophysics (Taiwan)

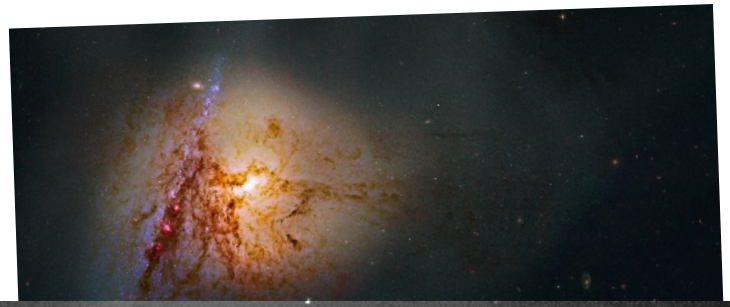
Antennas: 8 antennas of 6 m diameter

Configurations: 24 pads in four rings
baseline lengths 8 - 508 m
sub-arcsecond resolution, best ~0.25'' (at 400 GHz)

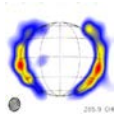
Receivers: max 8 per antenna; always 2 simultaneously, each single pol.
full frequency coverage of atmospheric windows
dual polarization, "A" & "B" combinations allowed
'230' 177-256 GHz (A)
'345' 256-360 GHz (A)
'240' 205-280 GHz (B)
'400' 325-420 GHz (B)

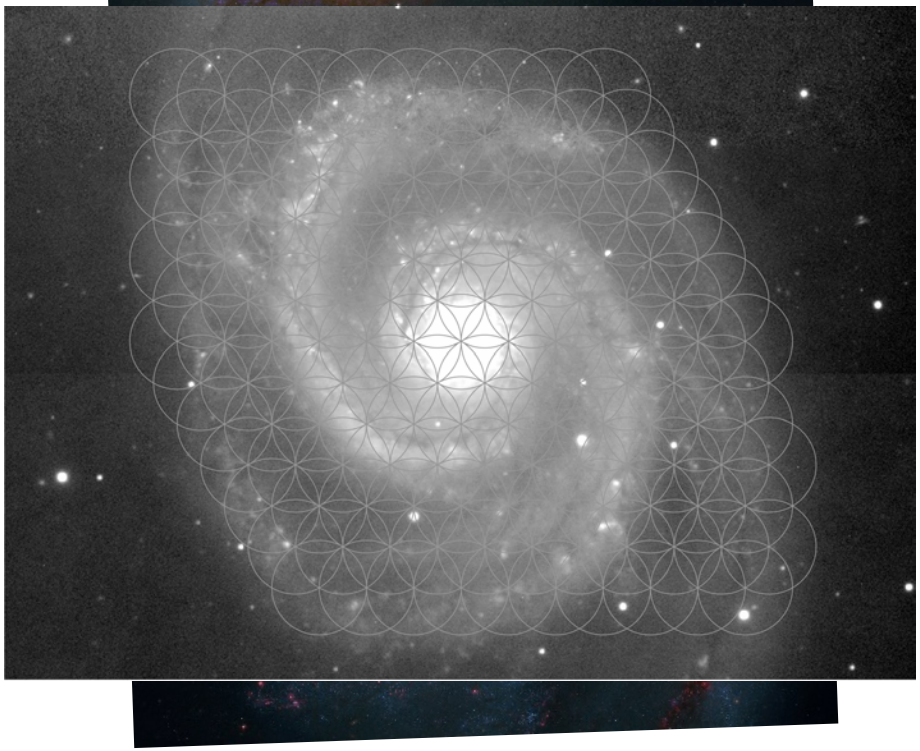
Correlator: Bandwidth: 32 GHz (2 SB x 8 GHz x 2 Rx's)
Uniform 139 kHz resolution at all times!
Every observation is a spectral survey!

Nearby Galaxies



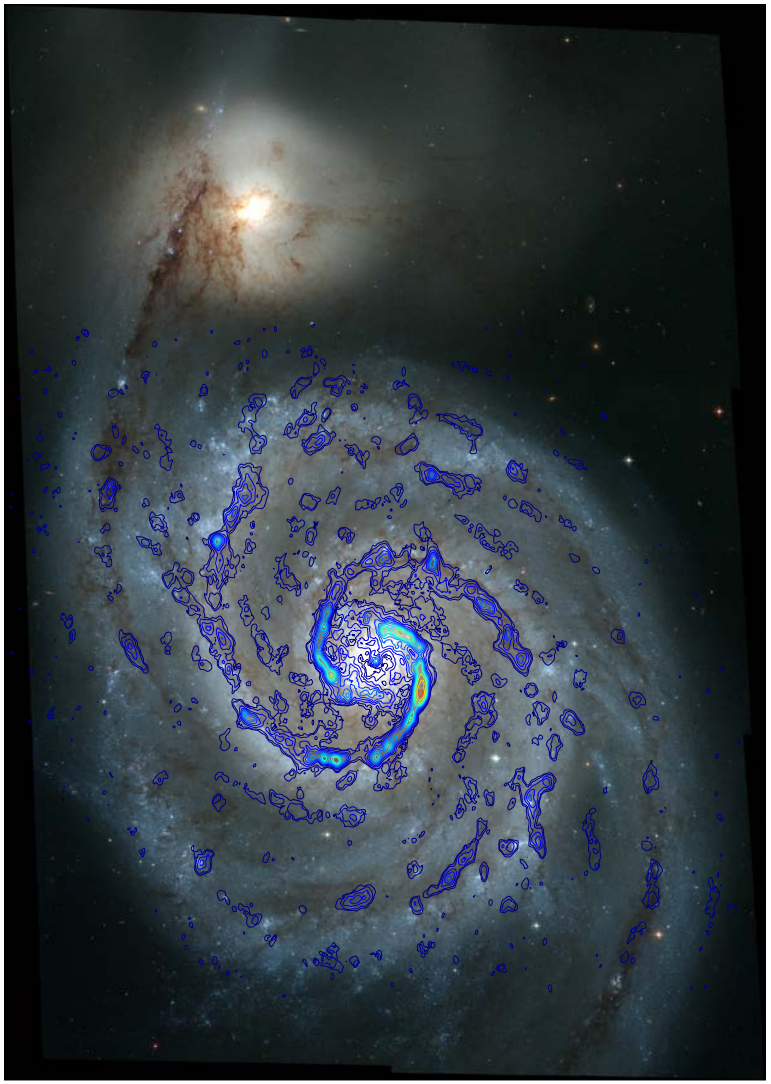
M51 - 1.3mm 127 pointings





~400”x400”

Nearby Galaxies

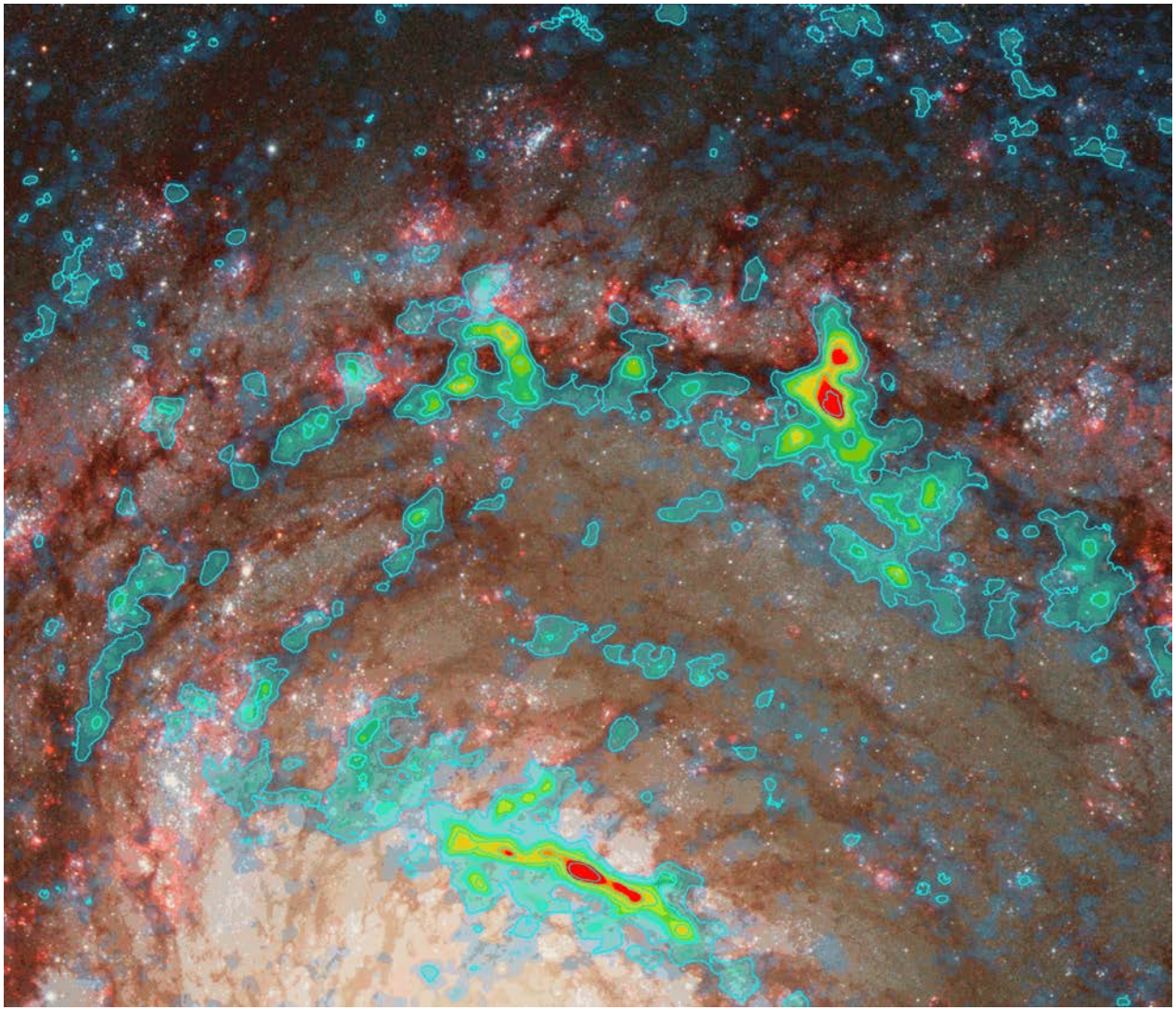


M51 - 1.3mm 127 pointings

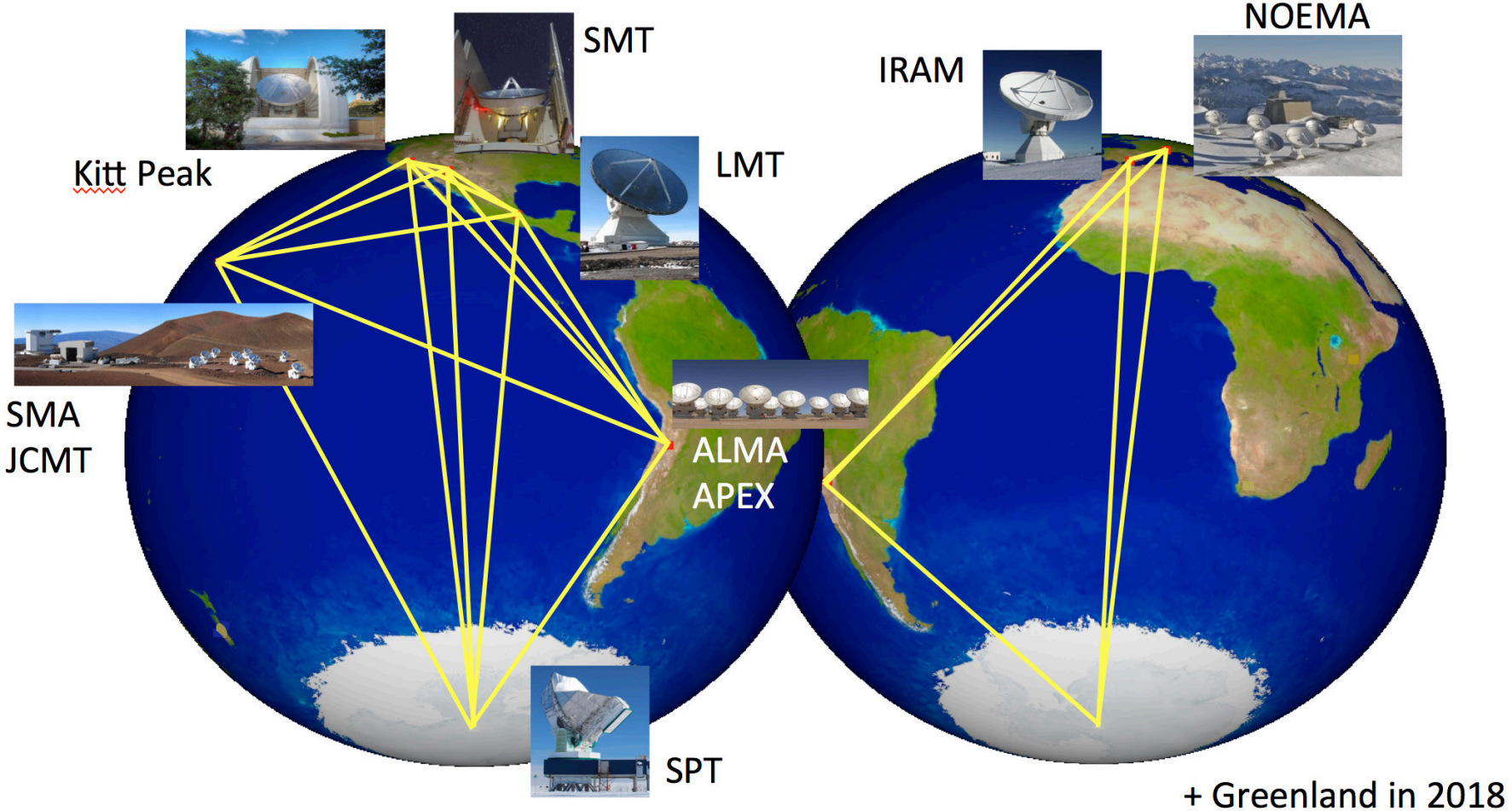
(courtesy Kazimierz Sliwa et al)

~400”x400”

Nearby Galaxies



The Event Horizon Telescope



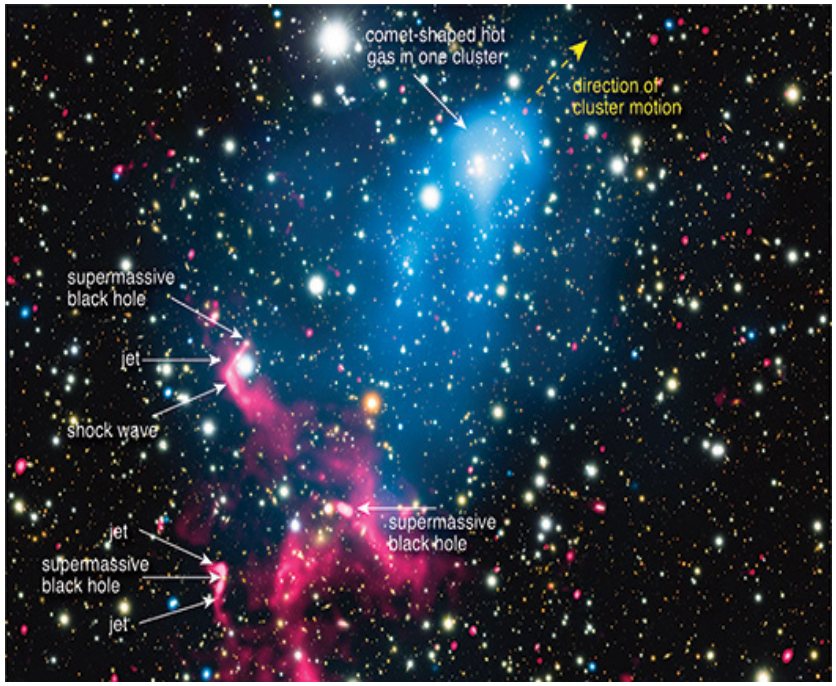
The EHT has already estimated that the emission from Sgr A* arises from a region that is comparable in size to the black hole event horizon. The EHT recently detected ordered magnetic fields with intense variability near the event horizon.

The Greenland Telescope

- SAO collaboration with the Academia Sinica Institute of Astronomy & Astrophysics
- AMLA prototype antenna retrofitted for operation in Greenland
- Shipped and assembled in Thule Air Base with goal of supporting EHT observations of M-87 in Q1 2018
- VLBI and single dish observations at 86 and 230 GHz
- Fringes demonstrated at Maunakea, with SMA + JCMT, using 230 GHz receivers and VLBI backend

Chandra X-ray Observatory

- Synergy between radio and Chandra X-ray observations: a new era of multi-wavelength science
- Key science: radio/X-ray observations of AGN, clusters of galaxies, galaxies, X-ray binaries
- Next annual call for proposals December 15
- Collaboration also through New England Regional Quasar and AGN Meeting (NERQAM)



Abell 3411 and 3412 Merger

X-ray: NASA/CXC/SAO/R. van Weeren et al
Optical: NAOJ/Subaru
Radio: NCRA/TIFR/GMRT

Future: SMA Upgrade - wSMA

Receiver infrastructure > 15 years old

- Opportunity to perform a major upgrade to receiver systems
  - Streamline optical systems
  - Replace cryogenics
  - New front-ends with even wider bandwidth components
  - Upgrade signal transmission system to handle increased bandwidth
  - Add more correlator capacity

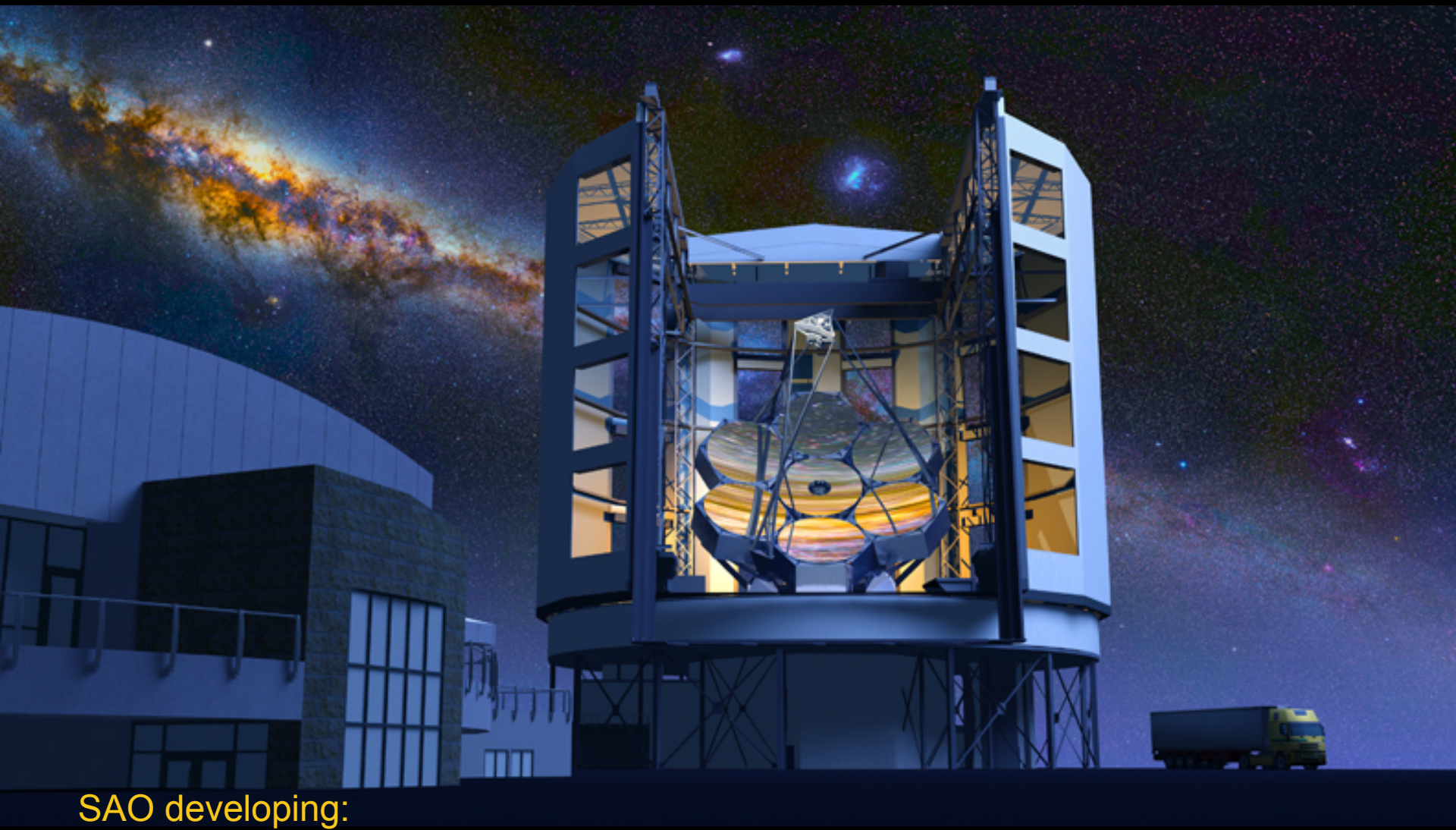
The wSMA

- Dual-polarization Receivers, initially with 4 – 18 GHz IF (1)
- Two band operation: LO tuning 210-270 GHz & 280-360 GHz
- Dedicated space for Guest/PI instrument development and tests

(1) Components specified to 22 GHz


Thank you

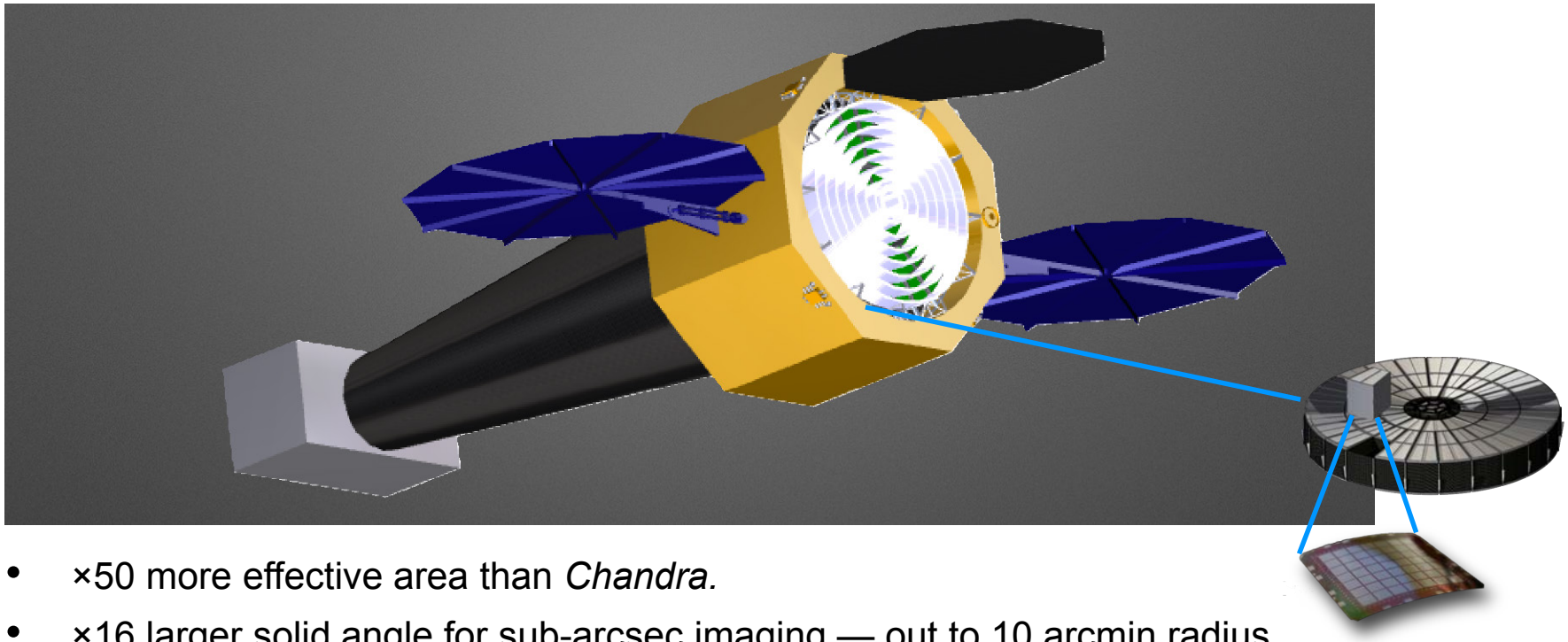
Future: Giant Magellan Telescope



SAO developing:

- The first light G-CLEF instrument
- Acquisition, Guiding, and Wavefront Sensor system

Future: Lynx



- ×50 more effective area than *Chandra.*
- ×16 larger solid angle for sub-arcsec imaging — out to 10 arcmin radius
- x800 survey speed compared to *Chandra*
- Very high resolution spectroscopy with gratings and microcalorimeter
- SAO leading:
  - Lynx Mission Concept Study Office for the decadal study
  - One of the innovative technologies for mirror segments: adjustable optics