SMA and ALMA

Eric Keto
Project Scientist Submillimeter Array

ALMA is a Hubble class observatory

Cost in Billions
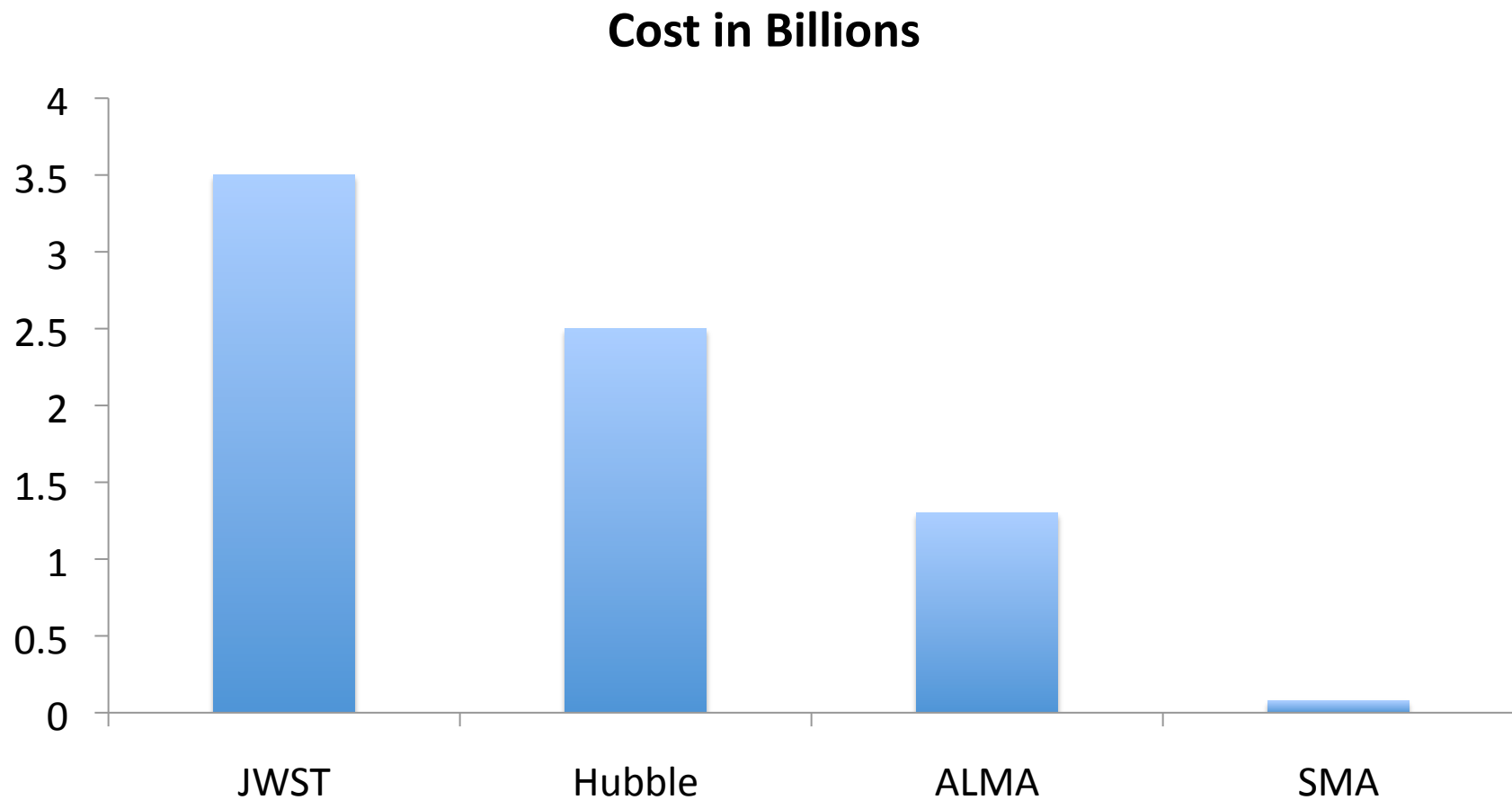
More Light – More Power

ALMA	SMA
• 50 Antennas x 12 m	• 8 Antennas x 6 m
• 25 x sensitivity	
• 1 weekend	• 1 year

An Existential Challenge

The SMA, CARMA, PdBI cannot compete. Should be closed. Money given to ALMA

→

While smaller telescopes have less power, they offer advantages of access, different science, and rapid technology development

Slowly starve the SMA, use the money elsewhere

→

Continued internal and external support for SMA research, instrumentation, and technology to maintain scientific leadership

What are the stakes?

Scientific Research

- SMA has been unique in high angular resolution imaging and spectroscopy in the submillimeter radio spectrum and is a world leader in submm science

Technology development in radio astronomy

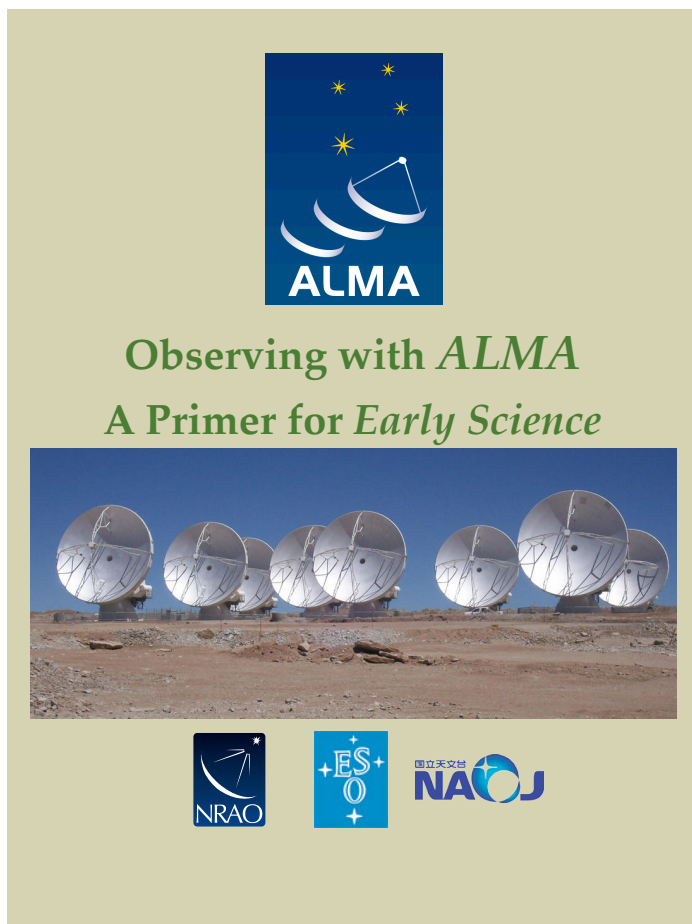- SMA lab leads in wide bandwidth, high frequency radio receivers

Education and training for grad students and post-docs

- Submm astronomy and radio interferometry
- On-site, hands-on, all aspects, observing, operation and development
- In the environment of Harvard University and the CfA

SMA is a scientific leader worldwide

- Since 2004
  - \> 300 refereed publications
  - \> 1000 unique authors

What science is done at the SMA?

- Contains 8 example science projects

- 4 examples from SMA

- All of them addressed by SMA observations and publications

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Wideband waveguide mixers

- 1st generation SMA wide-band, fixed-tuned, SIS waveguide mixers (Blundell *et al.*, 1995)
  - Used in SMA, CARMA, KOSMA.
  - Achieve 10 GHz bandwidth.

- 2nd generation series-connected distributed SIS mixers
  - Achieve > 18 GHz bandwidth (Tong 2005)
  - To be used in SMA bandwidth upgrade
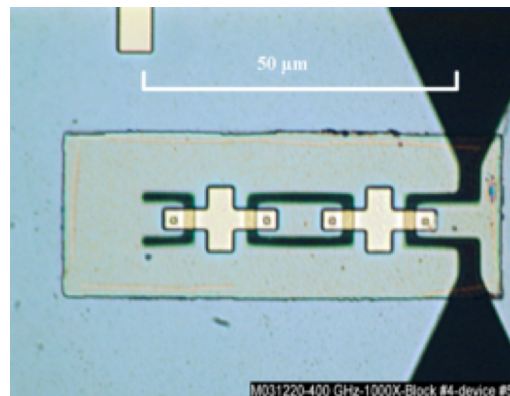
SMA is a leader in low-cost correlator design

Current SMA correlator uses custom designed DSP chips.

New correlator to use generic programmable DSP chips

Cost difference: Saville row bespoke suit versus off-the-rack

- SMA participates in hardware and software design collaborations
  - Reconfigurable Open Architecture Computing Hardware (ROACH)
  - Center for Astronomy Signal Processing and Electronics Research (CASPER)

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Students and Post-docs

51 SMA post docs

22 PhD theses based on SMA data by students at CfA, mostly pre-docs

Other PhD students at sister institutions U. Hawaii and ASIAA

Undergraduate course Harvard Astro 191 Laboratory Astrophysics

- 3 ApJ papers based on A191 observations

Northeastern Univ. co-op students in Receiver Lab

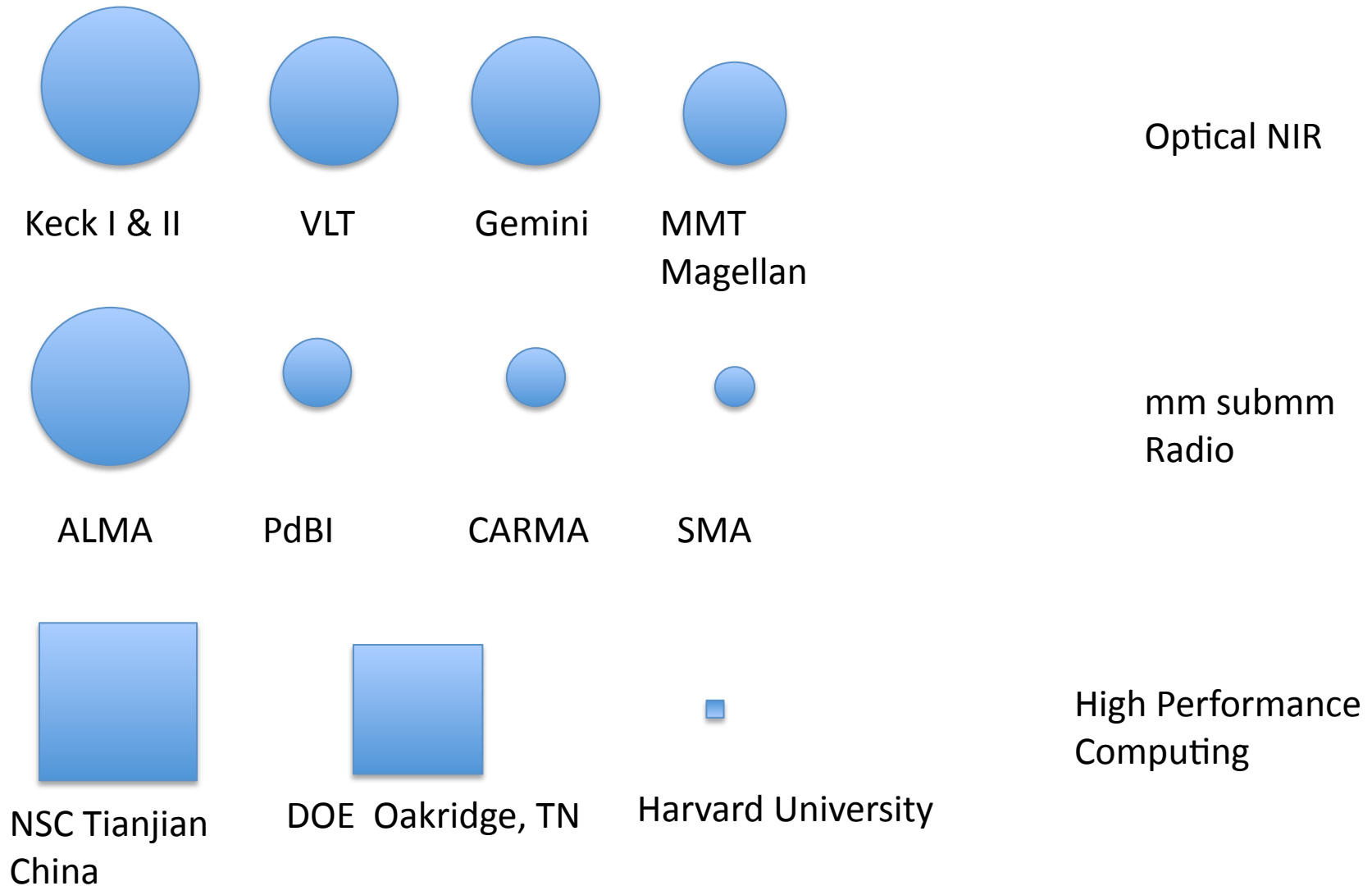# Former SMA grad students and post-docs worldwide
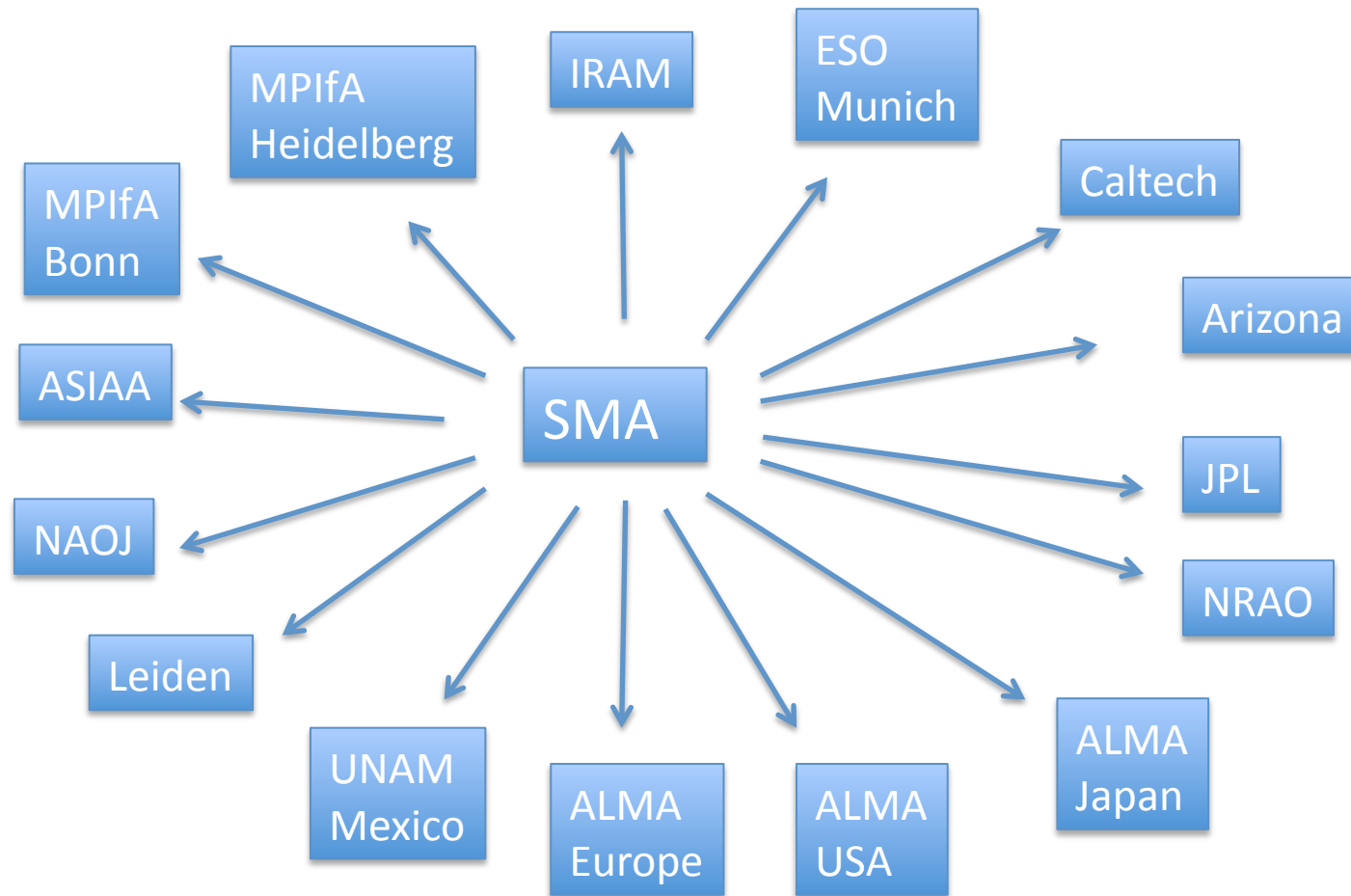
Moving forward: ALMA proposals

- SMA scientists and post-docs are on 75 out of 924 ALMA proposals worldwide

- 23 other CfA scientists are on other ALMA proposals. Not yet sorted, but could equal the SMA involvement.

- Expect that CfA scientists will be on 10 to 15% of the ALMA proposals.

- If we can help out, supporting observations, technical assistance, data processing, let us know.

SMA and ALMA

- At the moment, the SMA and ALMA are not too dissimilar in sensitivity and capability.

- This will change and soon.

- What is the future role of the SMA in the era of ALMA?

Larger facilities collaborate with smaller ones to produce more complete science

Optical NIR

Keck I & II VLT Gemini MMT Magellan

mm submm Radio

ALMA PdBI CARMA SMA

High Performance Computing

NSC Tianjian China DOE Oakridge, TN Harvard University

The SMA-ALMA difference will be too large. What can be done?

Total power = Area x Bandwidth x View
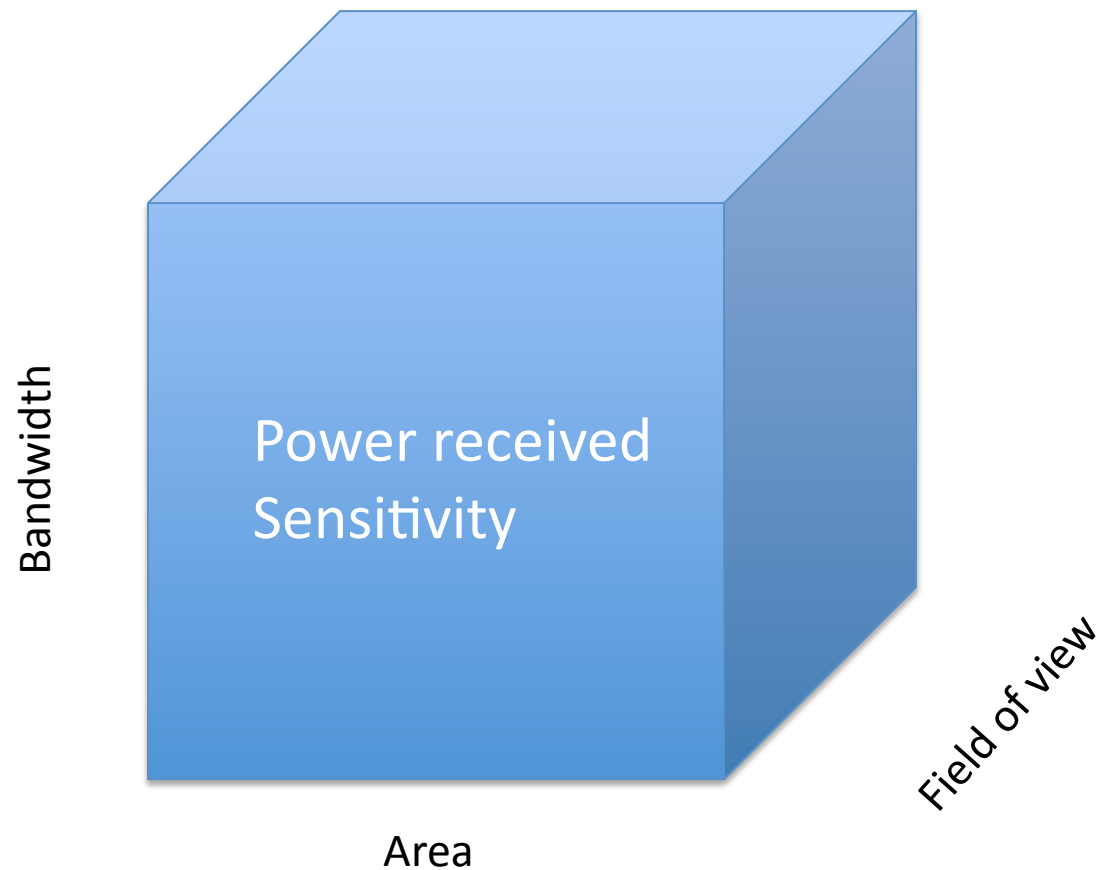
Goal	Option	Feasibility	Design	Implementation

More power more light

- **Bandwidth**
  - Wideband mixers → Series-connected mixers → NSF proposal
  - FPGA correlator → CASPER software ROACH hardware → NSF proposal
- **Field of view**
  - Array receivers Champ+, Hera, Harp, SupCam → Array receiver preliminary design
- **Collecting Area**
  - Additional antennas
  - Increase diameter
  - Take over CSO, JCMT
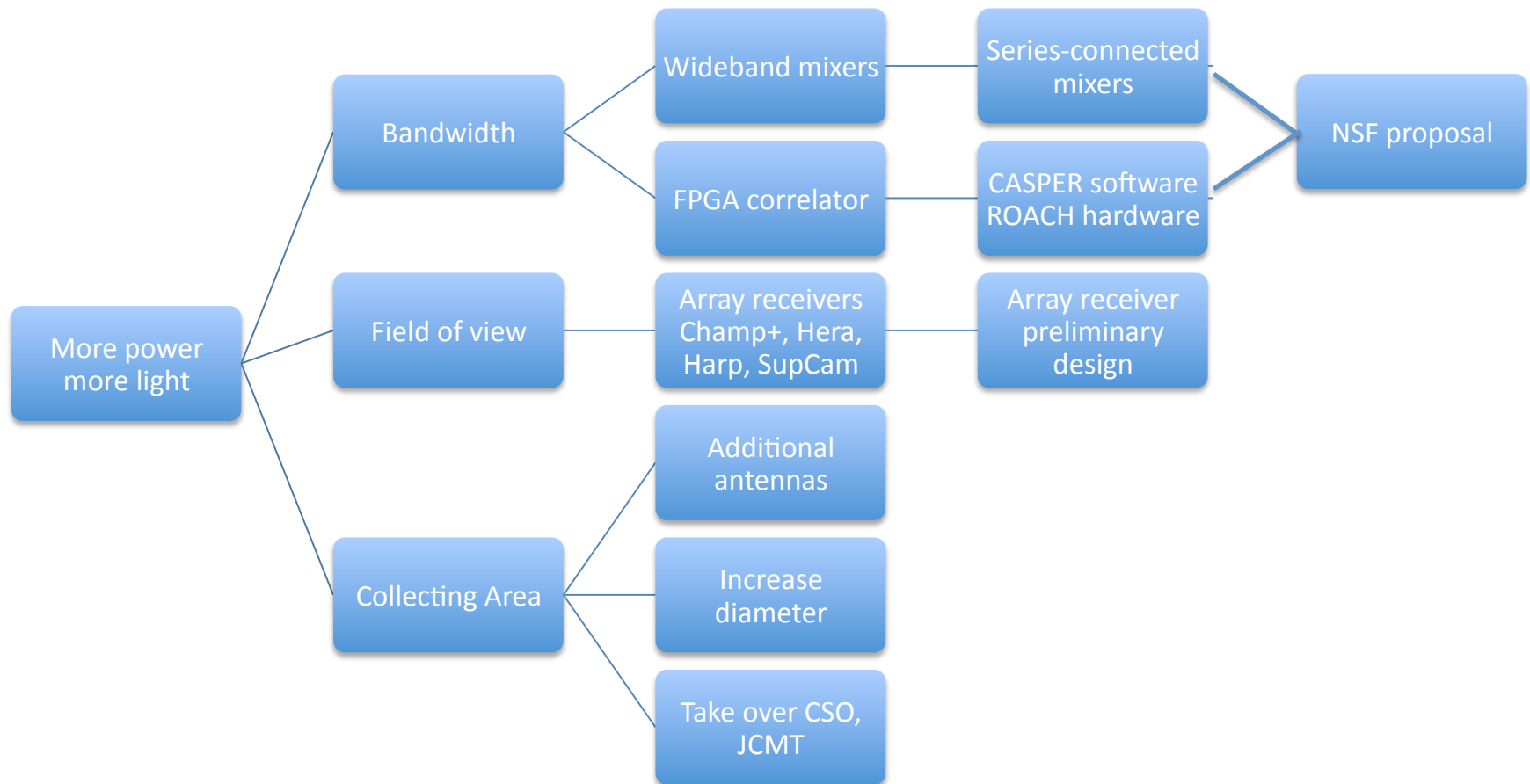
Multi-Pixel Array Receivers

- SMA optics can take a 7 pixel array 2-3-2, same configuration as CHAMP+ on APEX. No problem with antennas.

- Other details to work out.

- Requires 7 x the capacity of the planned correlator upgrade. Cost estimate $30M
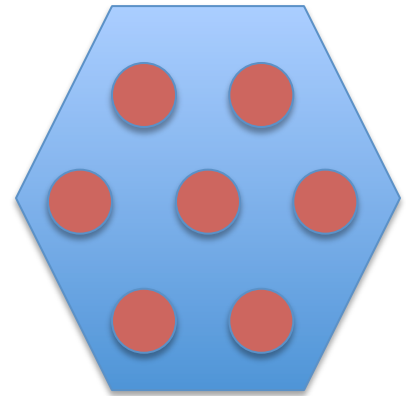
What science can the SMA* do?

- In the Future Planning Committee, Frank Shu proposed the SMA* with a 7 element receiver as a wide field mapper.

SMA*	ALMA
38" FOV	19" FOV
7 lines of sight	1 line of sight
8x7 baselines	50x49 baselines
$6^2 m^2$	$12^2 m^2$
72 GHz bandwidth	8 GHz bandwidth x 2
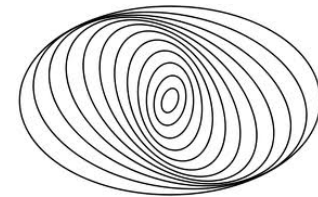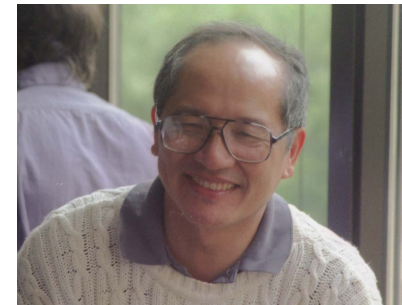
SMA* = 1/6 the speed of ALMA for a single spectral line

SMA* = 2/3 the speed of ALMA for dust continuum

SMA* *same* speed as ALMA for complete spectral line coverage in wide field mapping

72 GHz

SMA survey of IRC10216 (Patel et al 2011)

IRC+10216 (440 lines)
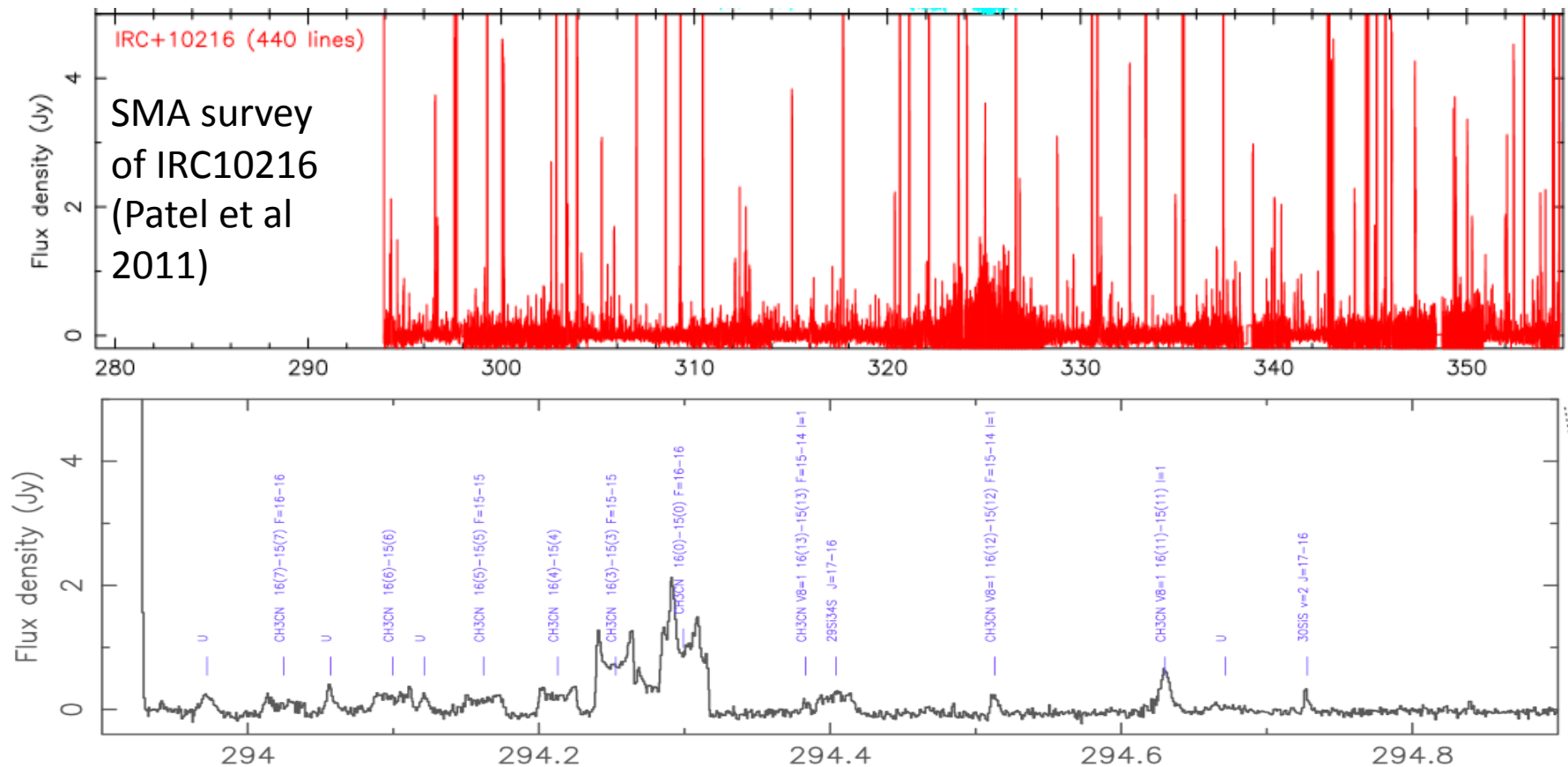
Right now: New scientific capability for the SMA ?

- The SMA, ALMA, and Herschel satellite teams need to develop the capability to interpret broadband spectroscopy in terms of astrochemical models.

- The capability to exploit most of the information in the spectrum does not yet exist anywhere .

- Synergy at the CfA with:
  – Other CfA ALMA observers, SWAS, + Spitzer satellite teams
  – Pat Thaddeus and Mike McCarthy's astrochemistry lab

The Orion bar

- A photo-dissociation region at the edge of Orion nebula is the target of the Herschel HEXOS GTO project for high resolution spectroscopy. Right now, there is an opportunity for collaboration with complementary wavelengths and angular resolutions.
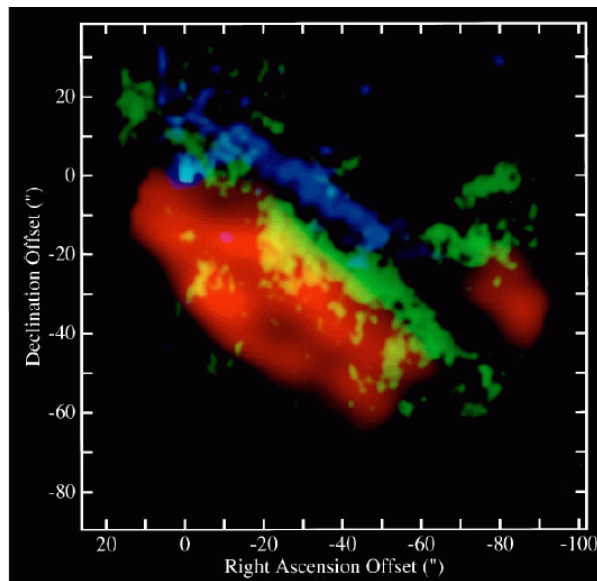
Spitzer IRAC bands
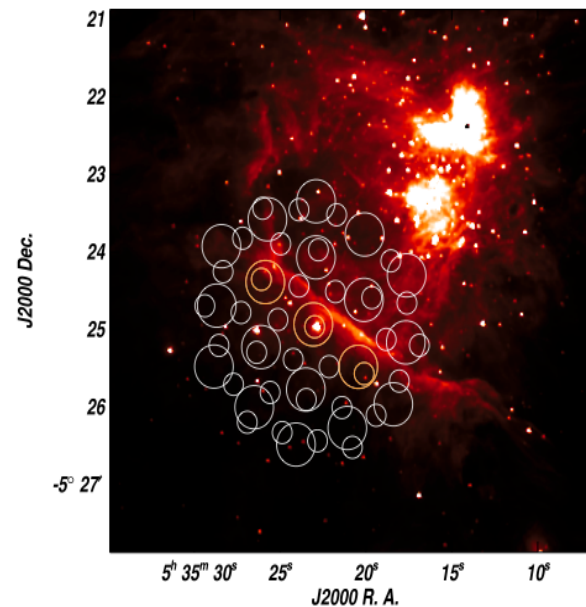
Herschel resolution
Habart et al 2011

M83
Super star-clusters and the origin of globulars
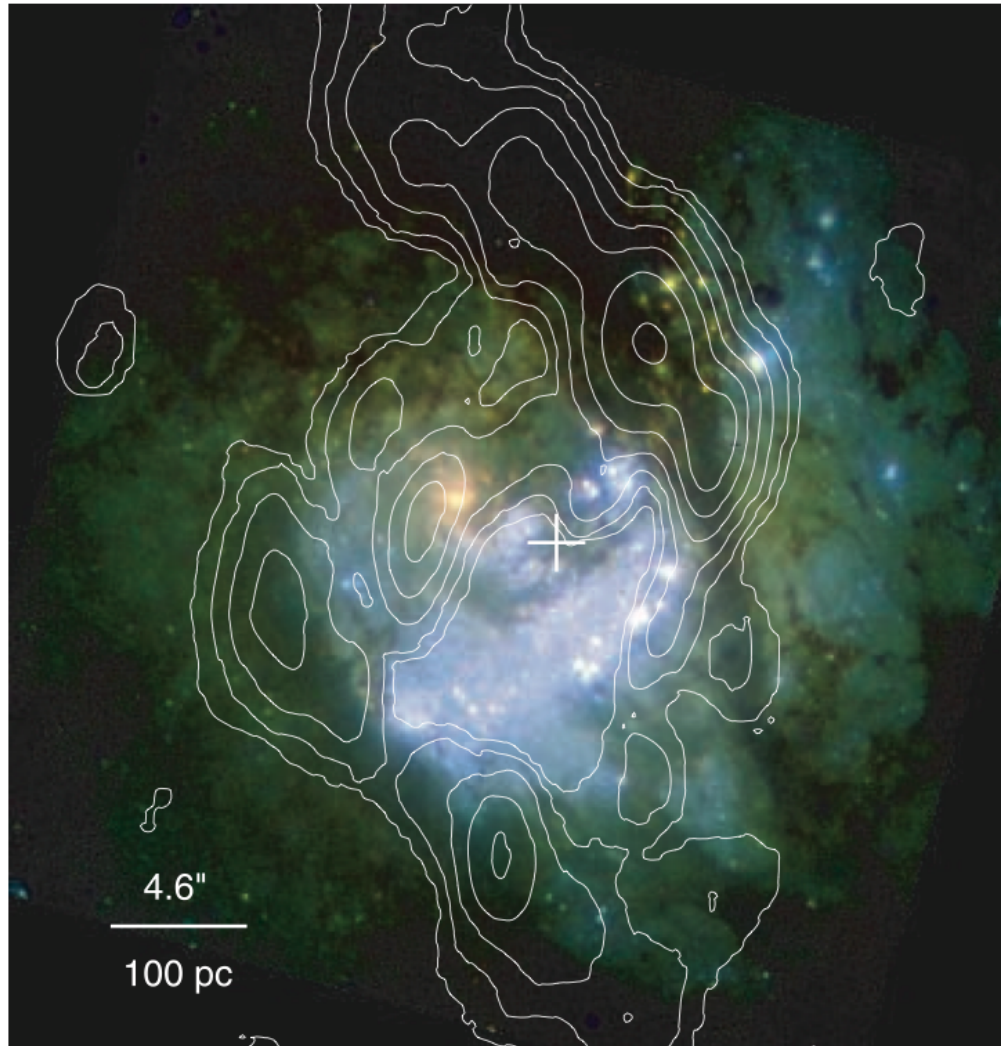
- Super star-clusters are the building blocks of star formation throughout the Universe and the present day analogues of proto-globular clusters.

- SMA shows molecular clouds in the M83 nucleus in both starburst and normal regions (Sakamoto et al 2004).

- Spectral line data could reveal the differences, compression, heat, shocks leading to cluster formation.

- Key is spectral line interpretation.

- SMA – ALMA collaboration on large and small scales.

More SMA science projects can be developed for the era of ALMA
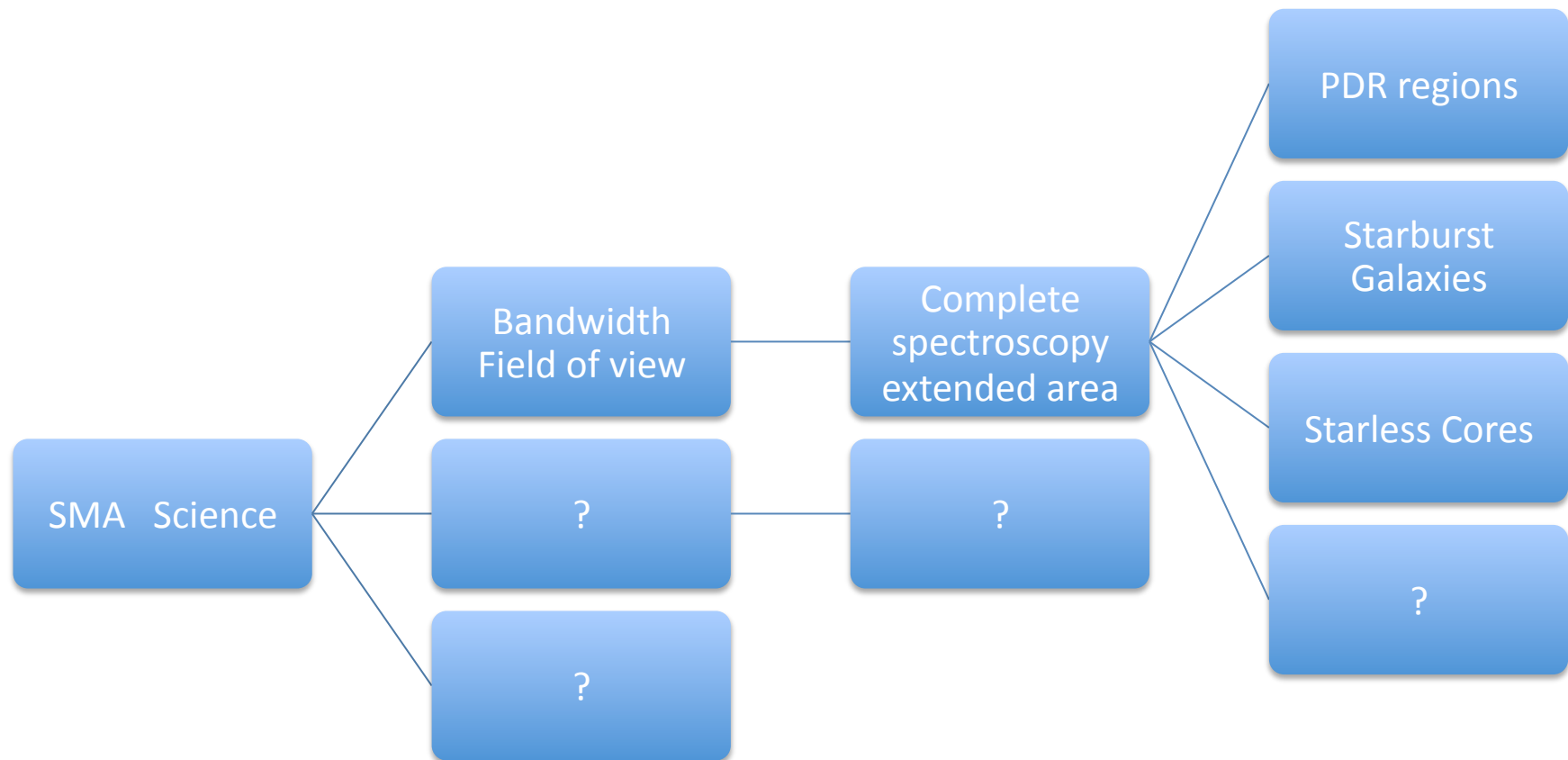
Progress

Short term

- We can accomplish band width upgrade to 72 GHz.
- No technical problems
- $6M from some combination of NSF, SI, ASIAA

Long term

- Multi-pixel receivers + correlator require a significant investment, $30M, with today's technology.
  - Need new source of money and an advance in electronics technology
- Continued scientific leadership requires development of new scientific capabilities.
  - One example:
    - Interpretation of complete spectral coverage
  - Other examples?

More detail in 2 reports

- Future Planning Committee September 2009
- SMA Advisory Committee November 2010