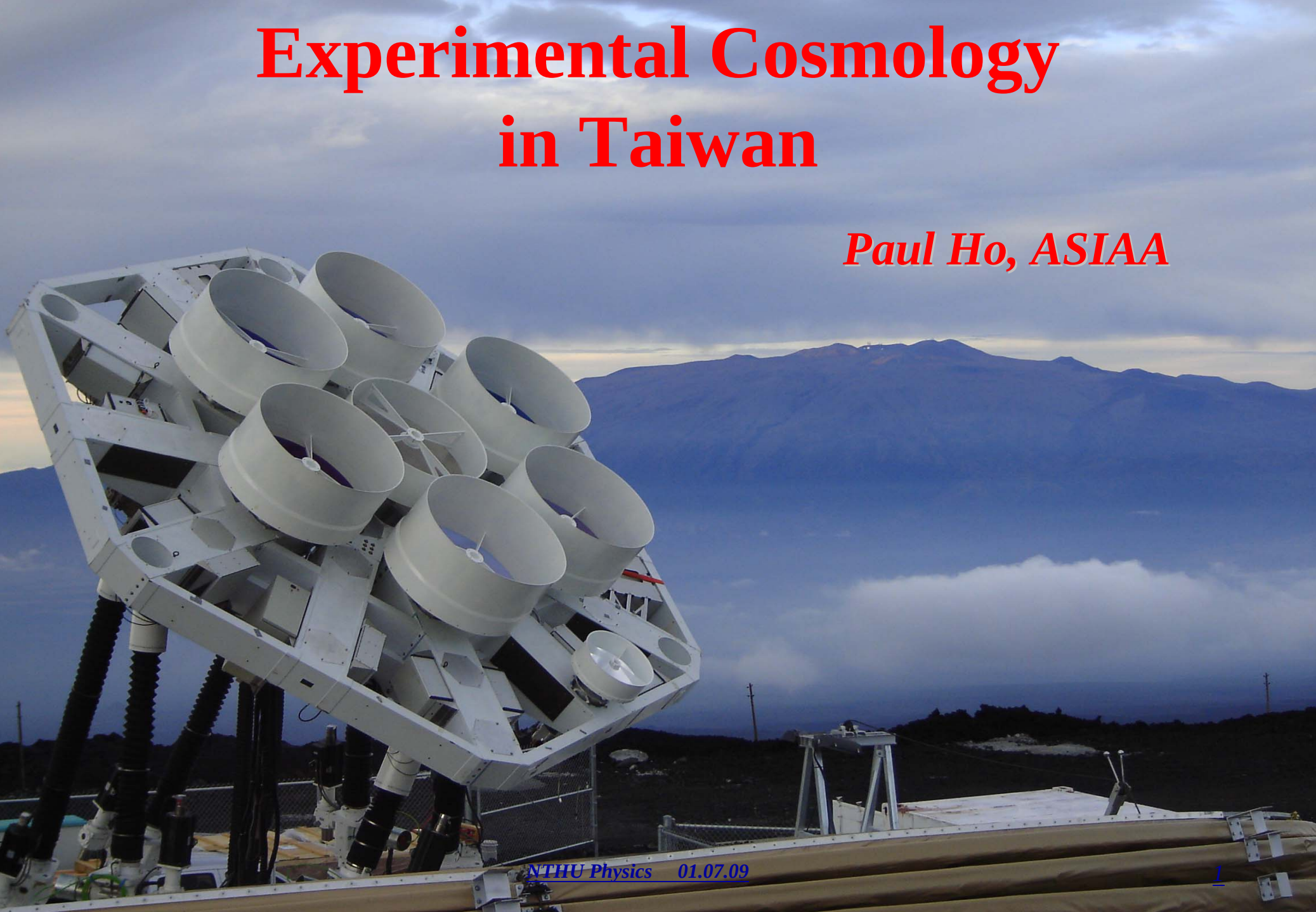
Experimental Cosmology in Taiwan

Paul Ho, ASIAA



Sketch of Talk

- **Astronomy at ASIAA**
- **AMiBA Project**
- **CFHT WIRCam Project**
- **Subaru HSC Project**
- **CMB power spectrum, SZE Cluster physics**
- **High Z Surveys**
- **Weak Gravitational Lensing**
- **GMRT Re-ionization Studies**
- **Baryon Acoustic Oscillations**

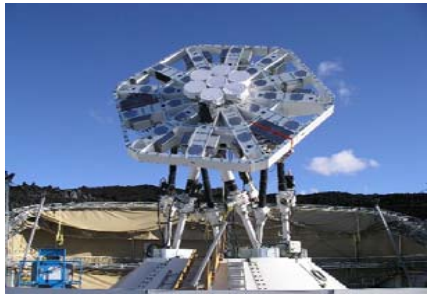
PERSONNEL at ASIAA

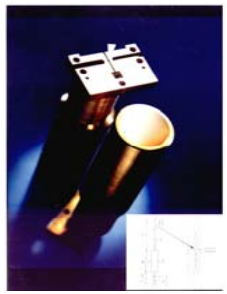
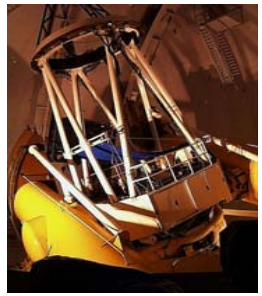
- 31 ASIAA Faculty (22 Regular, 9 Research)
- 11 Adjunct Faculty
- 23 Postdoctoral Fellows
- 14 Visiting Scholars
- 13 Ph.D. Students
- 16 Master Students
- 3 Undergraduate Students
- 7 Research Assistants
- 38 Technical Staff
- 23 Administrative Staff

Working Language: English

Staff: (Australia), Canada, (China), France, India, Japan, (Korea), Mexico, Spain, Switzerland, Taiwan, U.S., Vietnam

MAJOR ASIAA PROJECTS (2008)

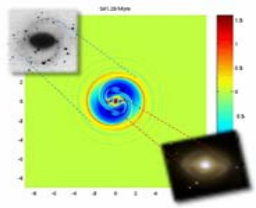



SAO **SMA : Array Completed, Upgrading**

NTU **AMiBA : 7-element Dedicated, 13-element underway**

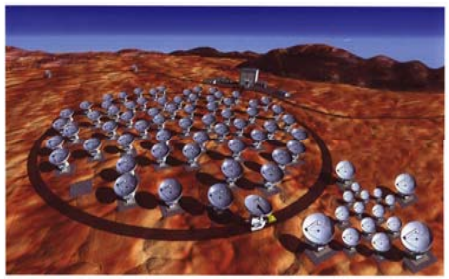
NTHU **TIARA; SIS Junction : 230, 345, 400, 690, 900 GHz**

NAOJ, PMO



NCU **TAOS : 4 Telescopes Working; TAOS-2**

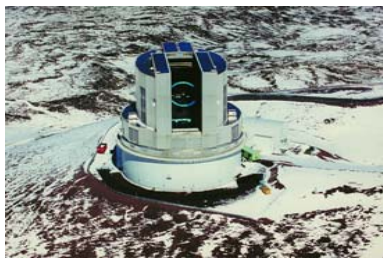
YONSEI, SAO



ASIM **CFD-MHD : 2-D Hydro Codes**

CFHT **WIRCam : Working well on Telescope**

NAOJ **ALMA-J : FEIC started; band-10**



NRAO **ALMA-NA: Approved; (FEHV?)**

NAOJ **Hyper Suprime Cam: Signed MOU**

NTU **ASMAB: on schedule to finish 2009**

AMiBA Summary

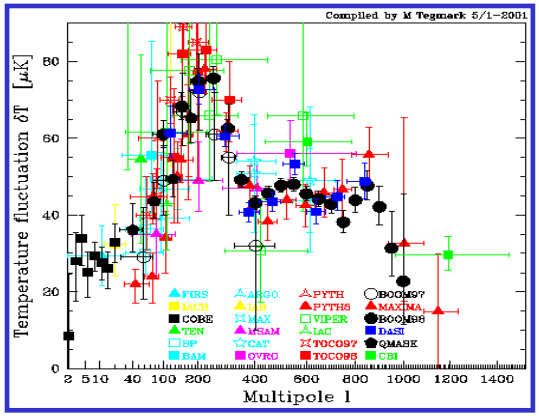
- **AMiBA is 1st CMB Telescope in Asia**
- **AMiBA is 1st Taiwan-Led Big Astronomy Project**
- **AMiBA is MoE CosPA Excellence Initiative**
- **Progress has been Very Fast (6 years)**
- **Project is Flagship of AS-University Partnership**
- **ASIAA Continues Strong Collaboration with NTU Physics and Electrical Engineering**
- **AMiBA is Operational, and currently Upgrading**

PROJECT DESCRIPTION

Goals Set in 2005, after Project Reorganization

- **Science Objectives: CMB at l=800 to 8000**
  - **Polarization Power Spectrum and Structure**
  - **High-Z Cluster Survey via SZE**
  - **Large Scale Structures via SZE**
- **Operations at 3mm (suppress synchrotron, dust)**
- **7-Element Dual Polarization Interferometer**
- **Funding: MOE, AS, NSC, NTU**

Polarization Power Spectrum

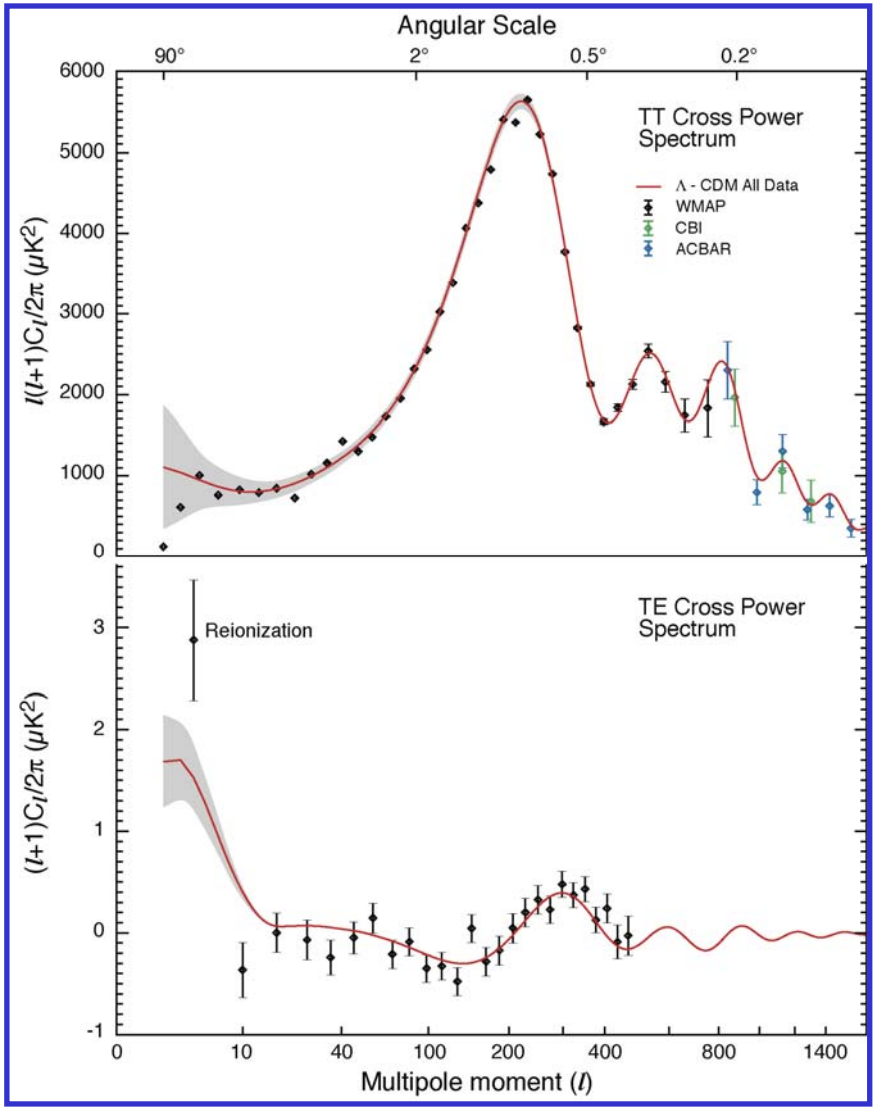


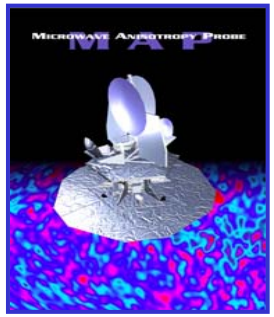
WMAP Samples to l = 500

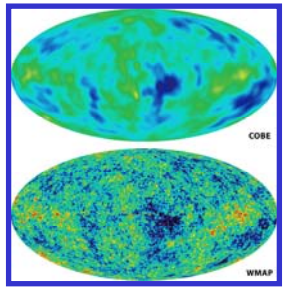
Polarization Consistent With Temperature Structures

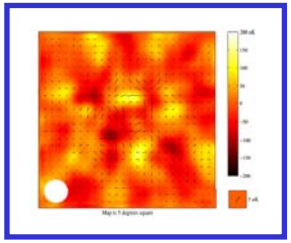
Reionization Signature Seen

AMiBA will sample l = 800 to 8000

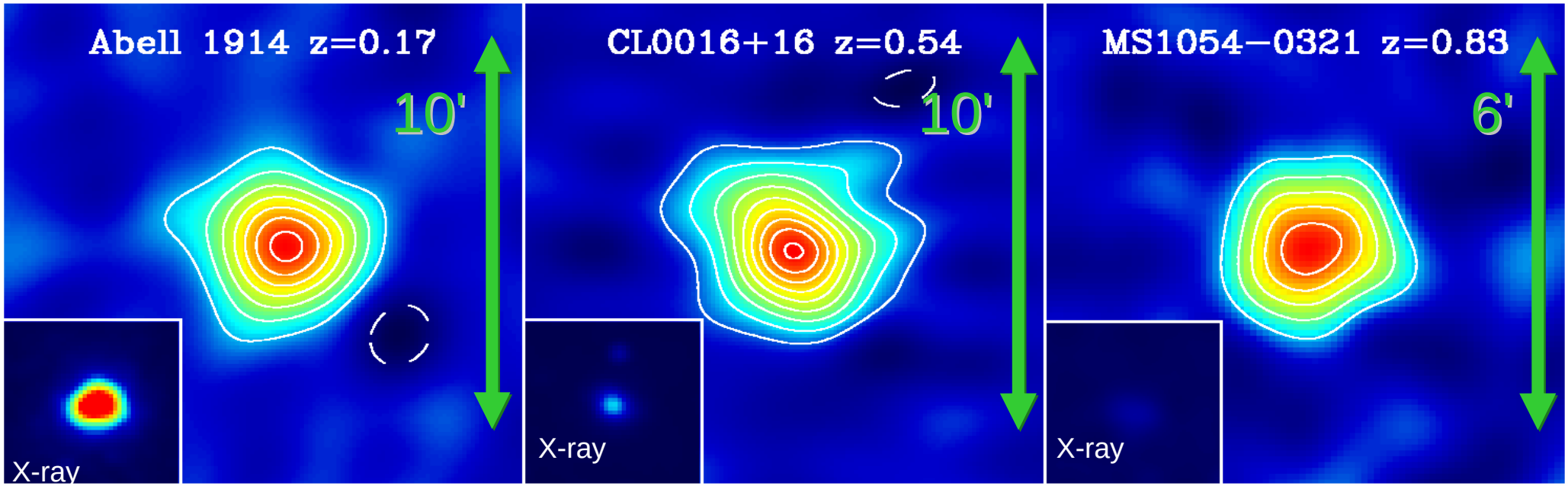








Sunyaev Zel'dovich Effect



SZE brightness independent of distance (z),

while X-ray/Optical/Lensing signal of clusters gets fainter

What we look for is a 10-100 μK weak signal !!

Timeline of AMiBA

- **2000-2004 MoE “Excellence” Funding**
- **2003-2006 AS “Key Project” Funding**
- **2004-2008 NSC “Continuation” Funding**
- **2000-2002 Design, Prototype**
- **2002-2005 Contracting, Construction**
- **2006- Dedication, Operation**
- **2007- First Science Results**
- **2008- Publish or Perish!**
- **2008- Upgrade to 13-elements**
- **2009 10-element operations (30x faster)**
  13-element operations (2x faster)

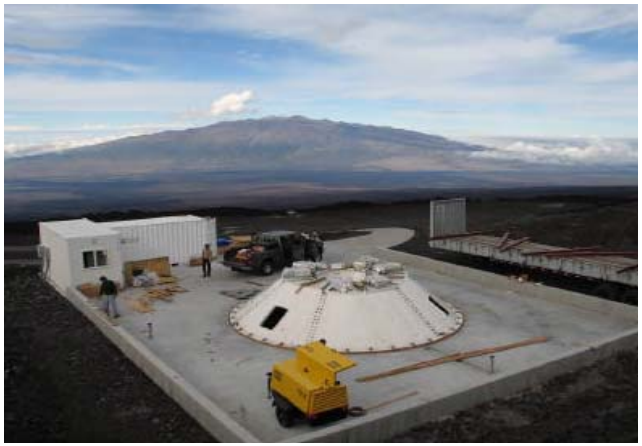
Site Development in Hawaii

AMiBA

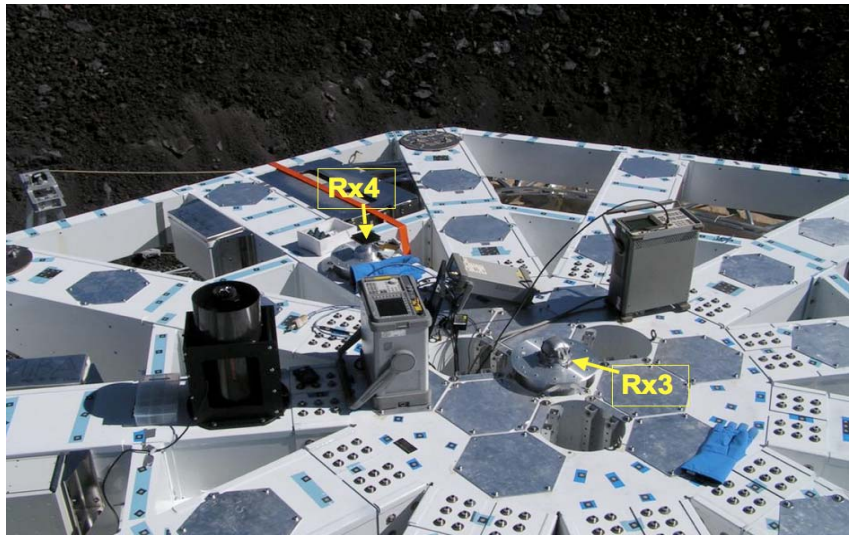
SMA

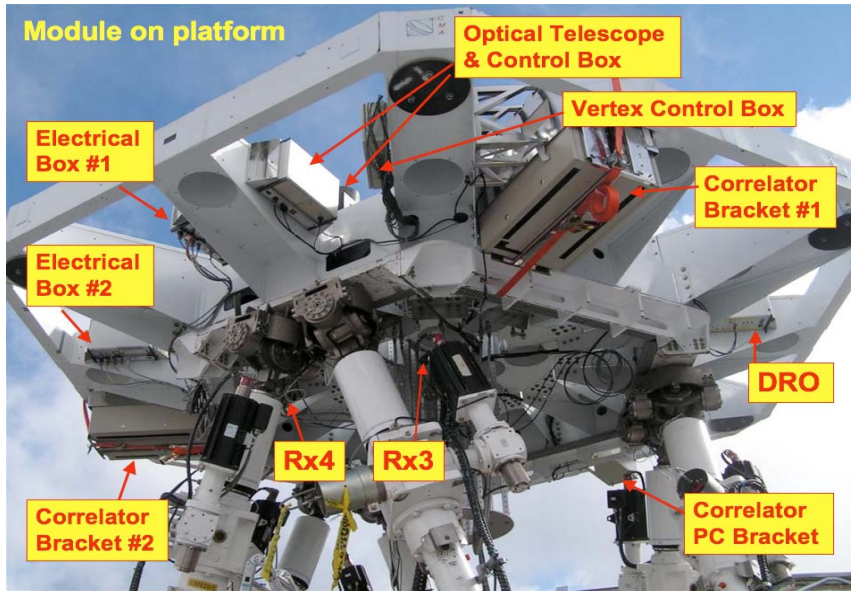
Construction Cost Large

AMiBA Installed on Mauna Loa



Integration on Platform 2006

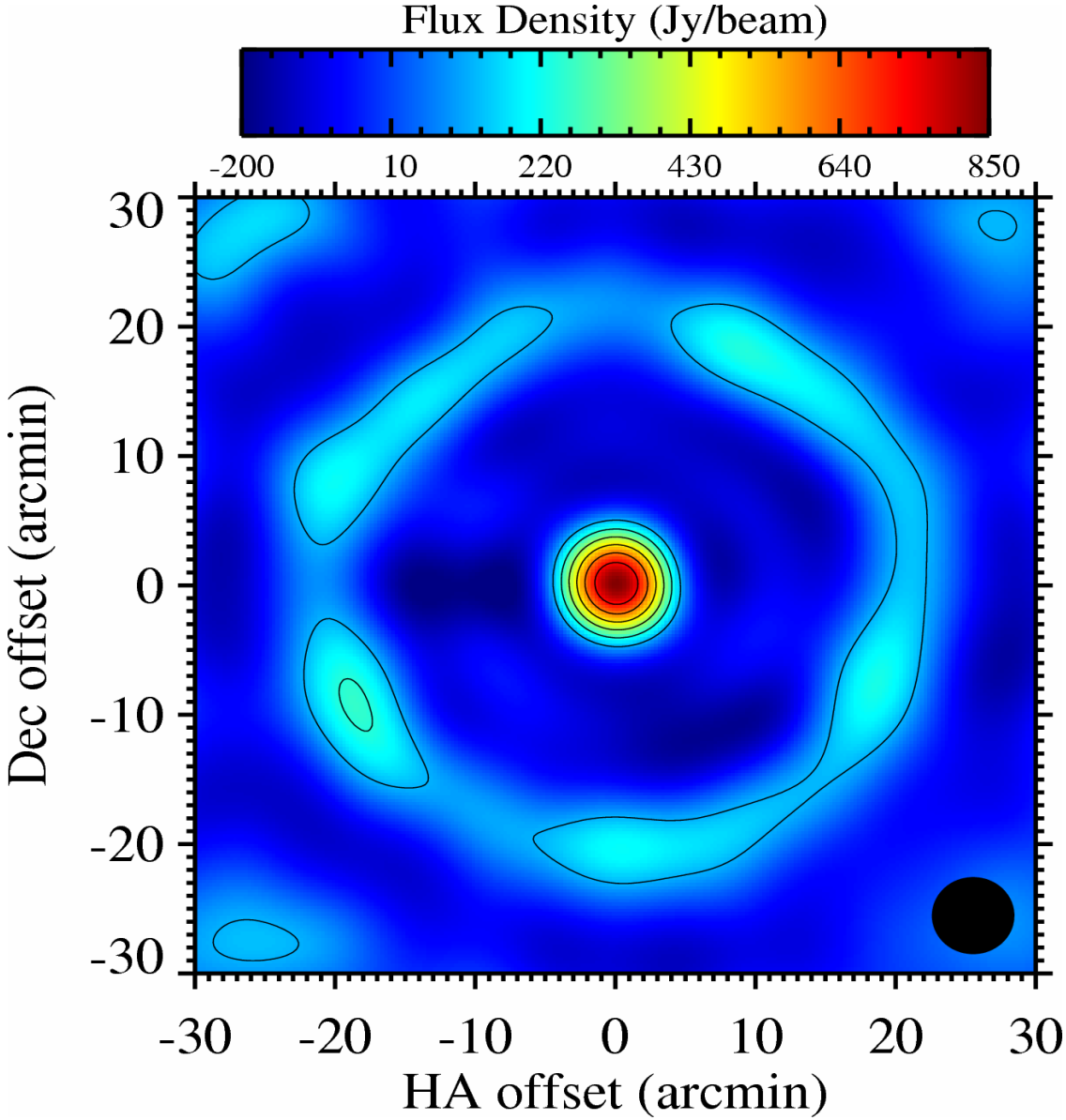




A Nice Day in Hawaii 10.2006

AMiBA Named after Yuan Tseh Lee

AMiBA First Image: Jupiter



Dirty image

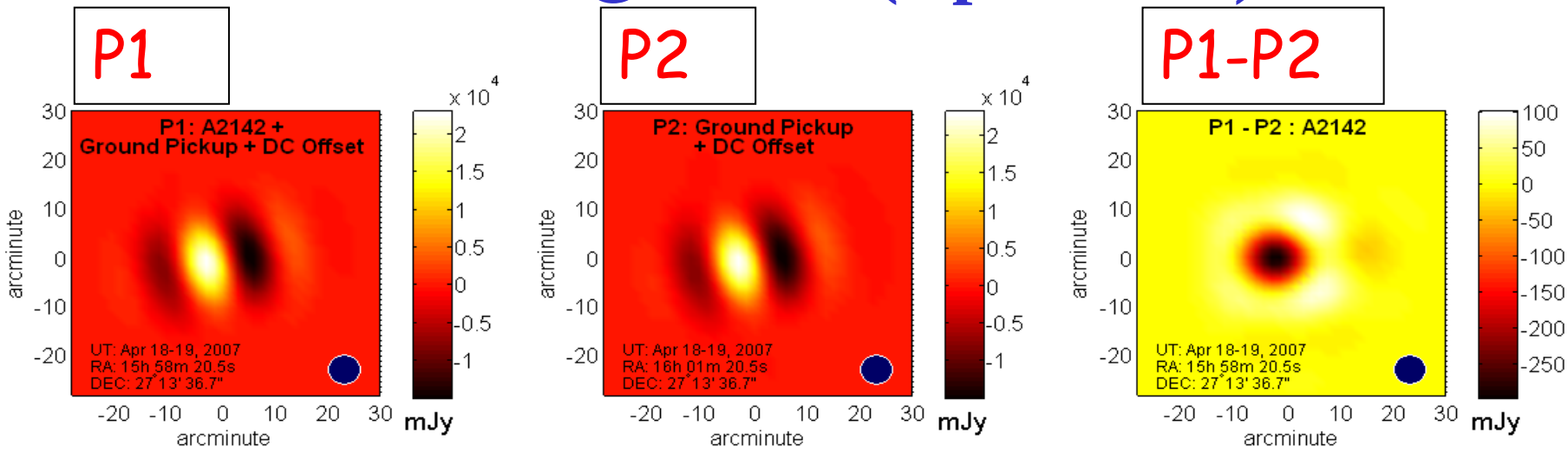
$$I(\vec{x}) = \mathbf{FT}^{-1}[S(\vec{u})V(\vec{u})]$$

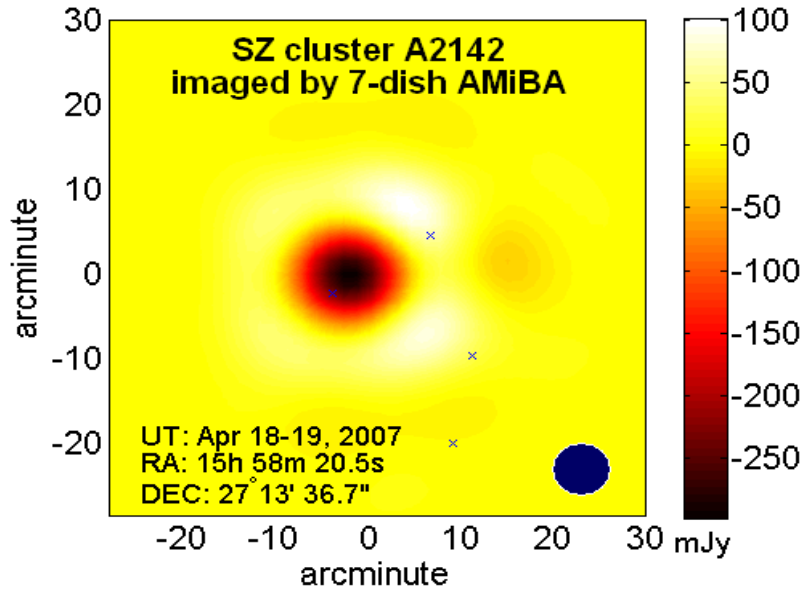
End-to-end verification = hardware + software (calibration, analysis pipelines)

Noise rms =~ 1Jy/beam
(in 12s, 42 baselines)

Synthesized beam FWHM (6')

First SZE Detection towards A2142 @z=0.09 (April 2007)

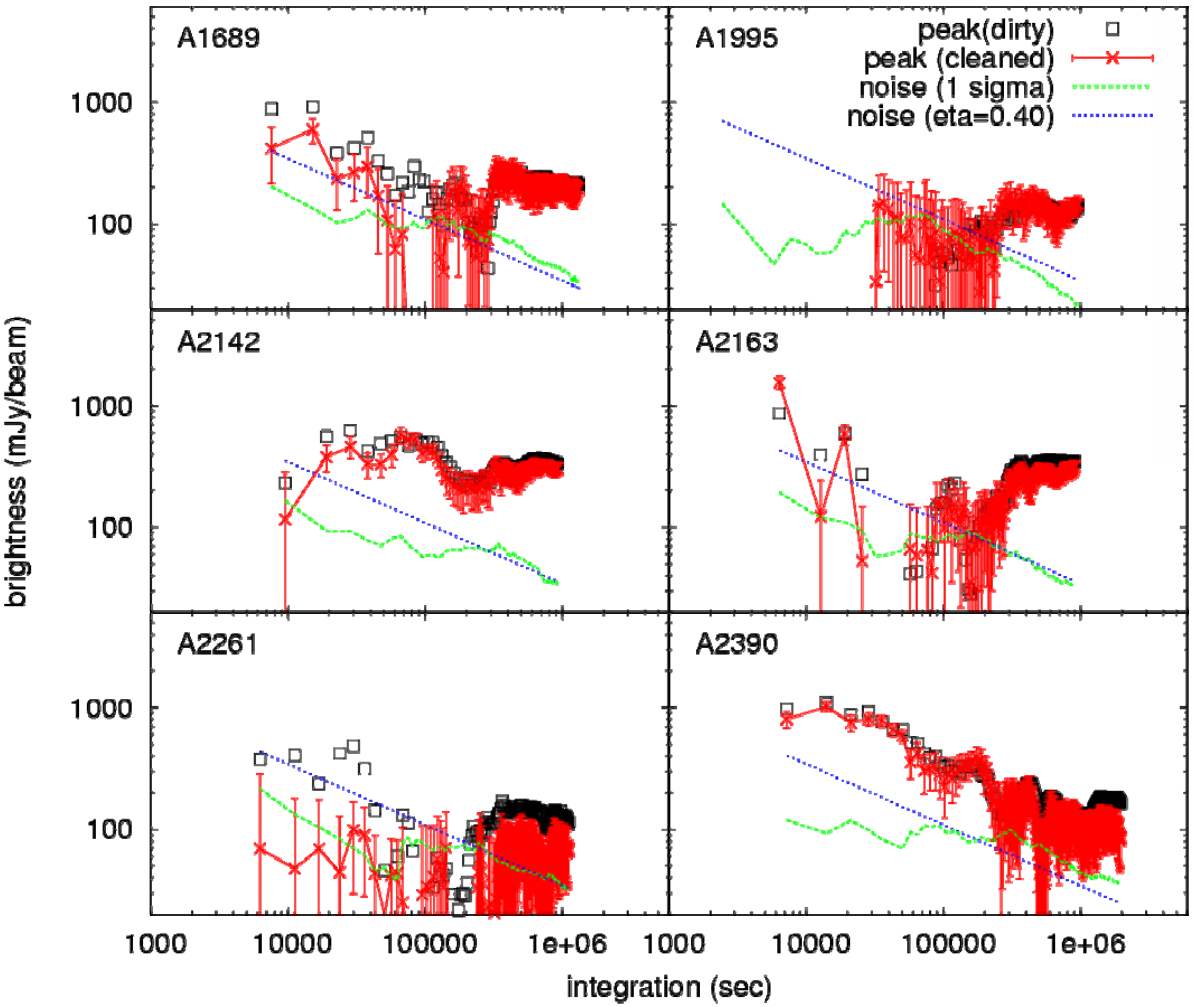


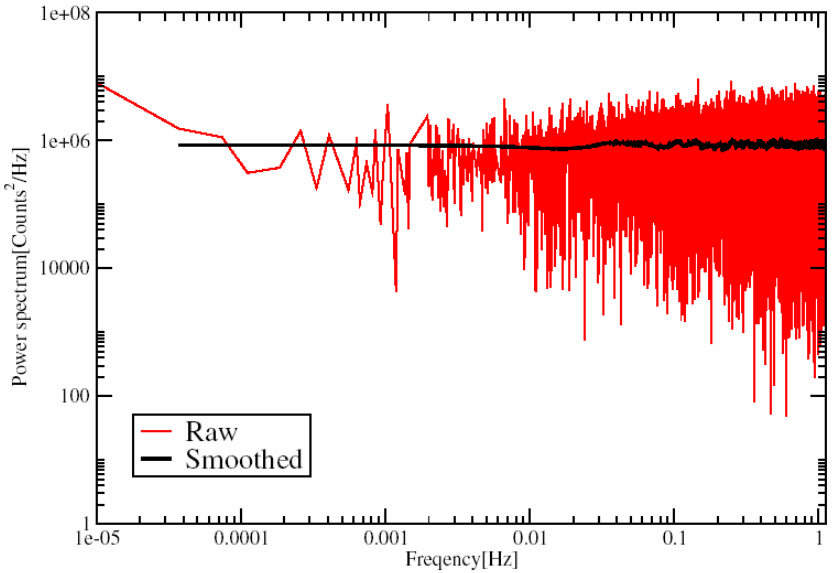


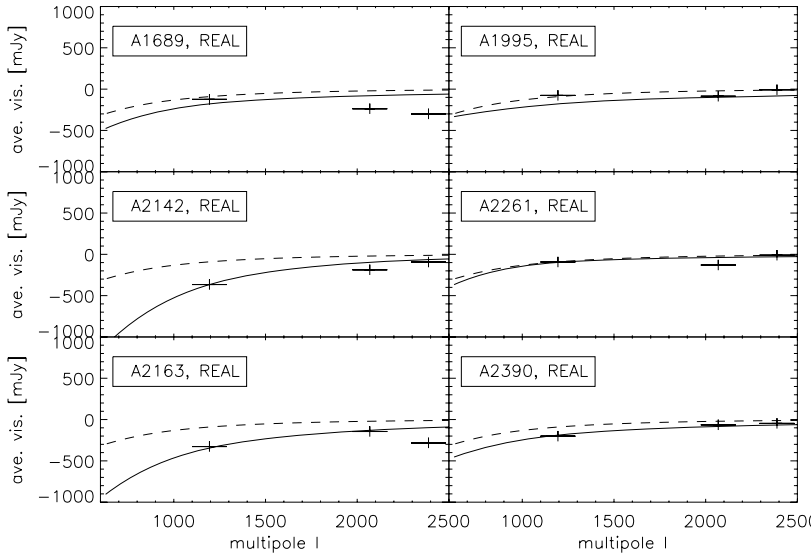
Estimated 3mm flux is about 300mJy, being consistent with the 30GHz observation by VSA at 1cm

About 6σ detection in 5hr x 2-Patch observations (2-3 nights)

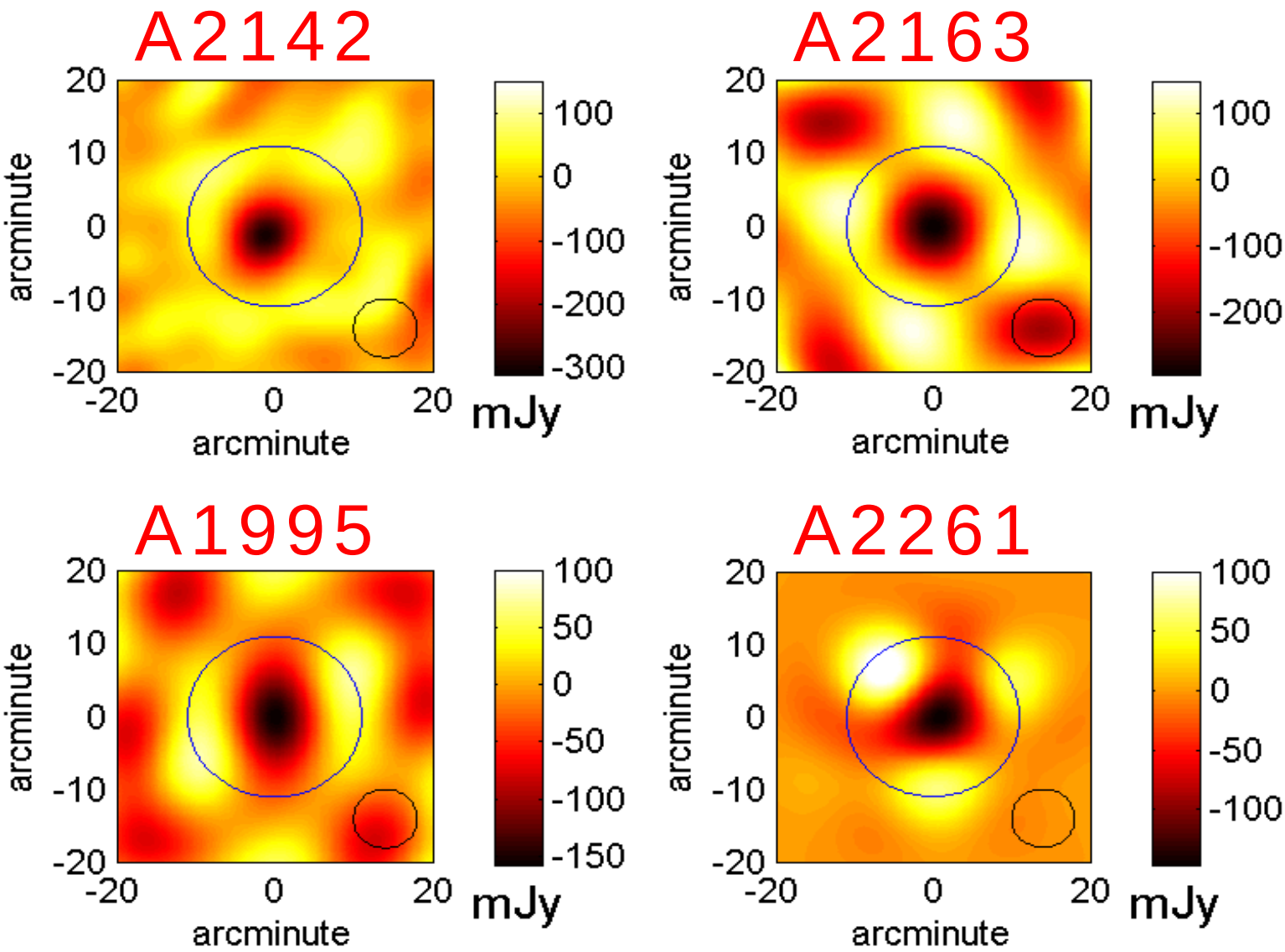
Checking Gaussianity, Contamination, Noise Behavior



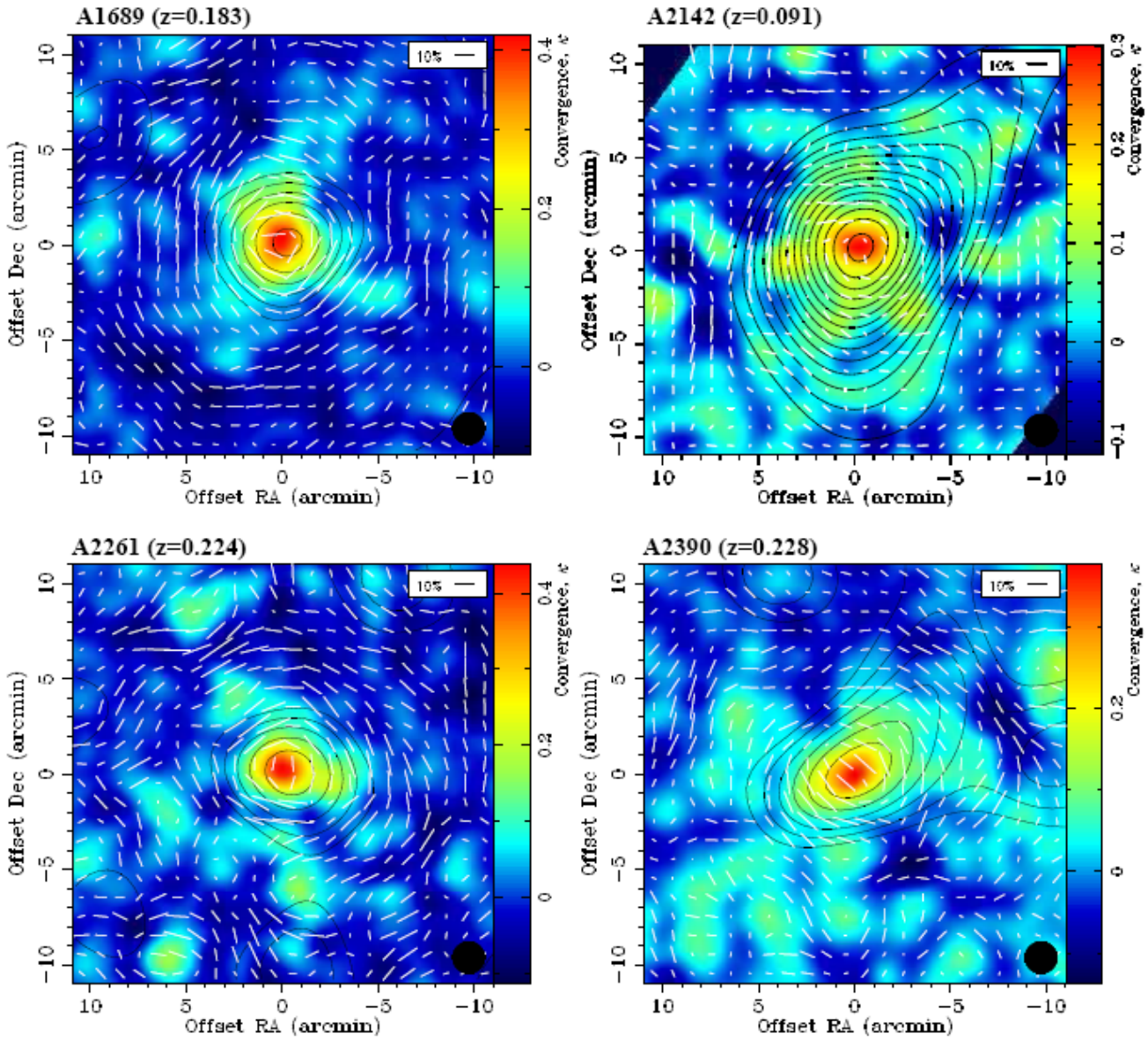




More Clusters



SZE and Dark Matter



Dark Contour:
AMiBA SZE

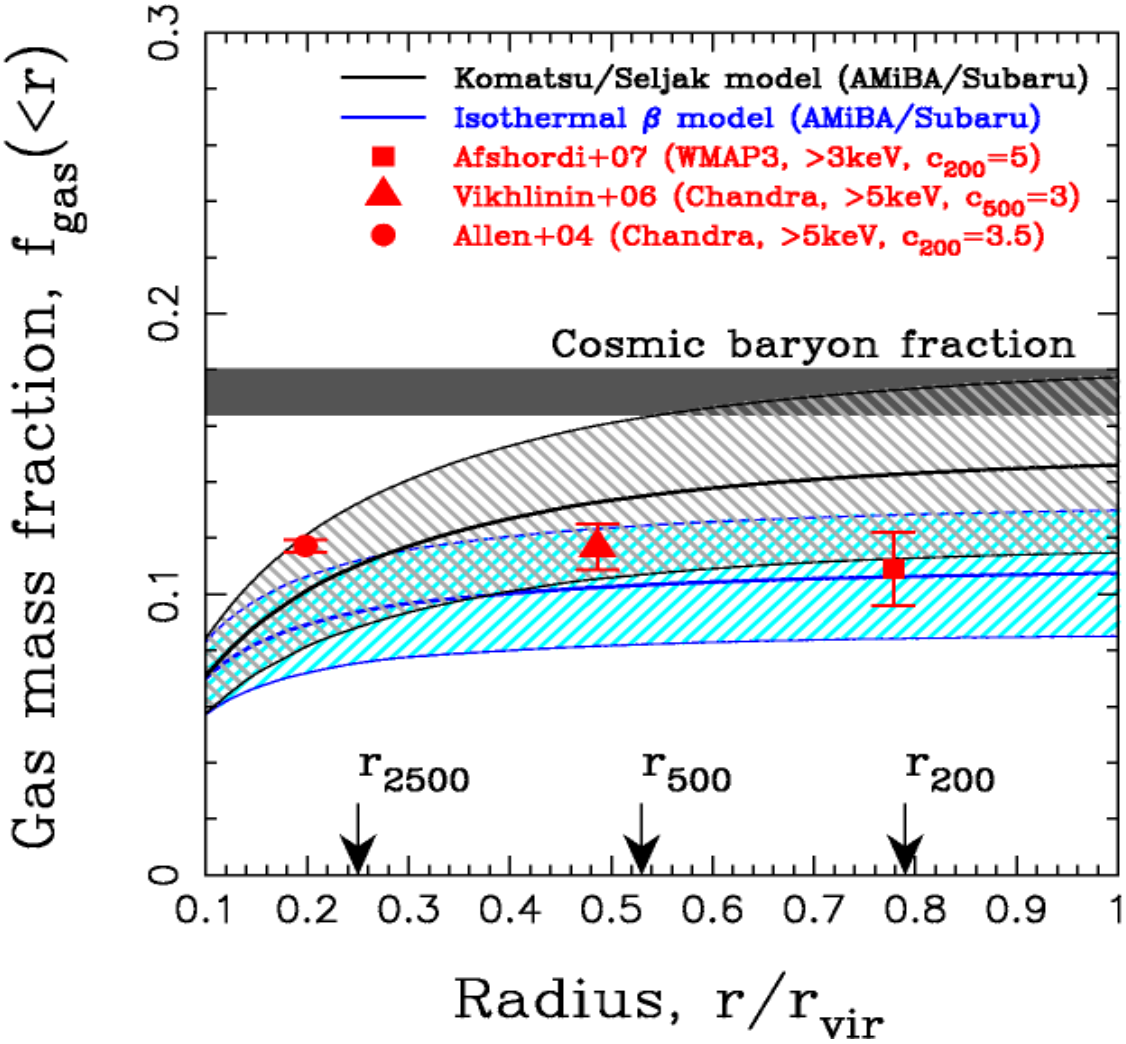
Color Plot:
Gravitational Mass

White Bars:
Gravitational Shape Distortions

85-94% cross correlation found between WL and SZE maps, indicating that the cluster plasmas are tracing the DM potential fairly well.

Cluster Hot-Baryon Fractions from AMiBA SZE & Subaru Weak Lensing

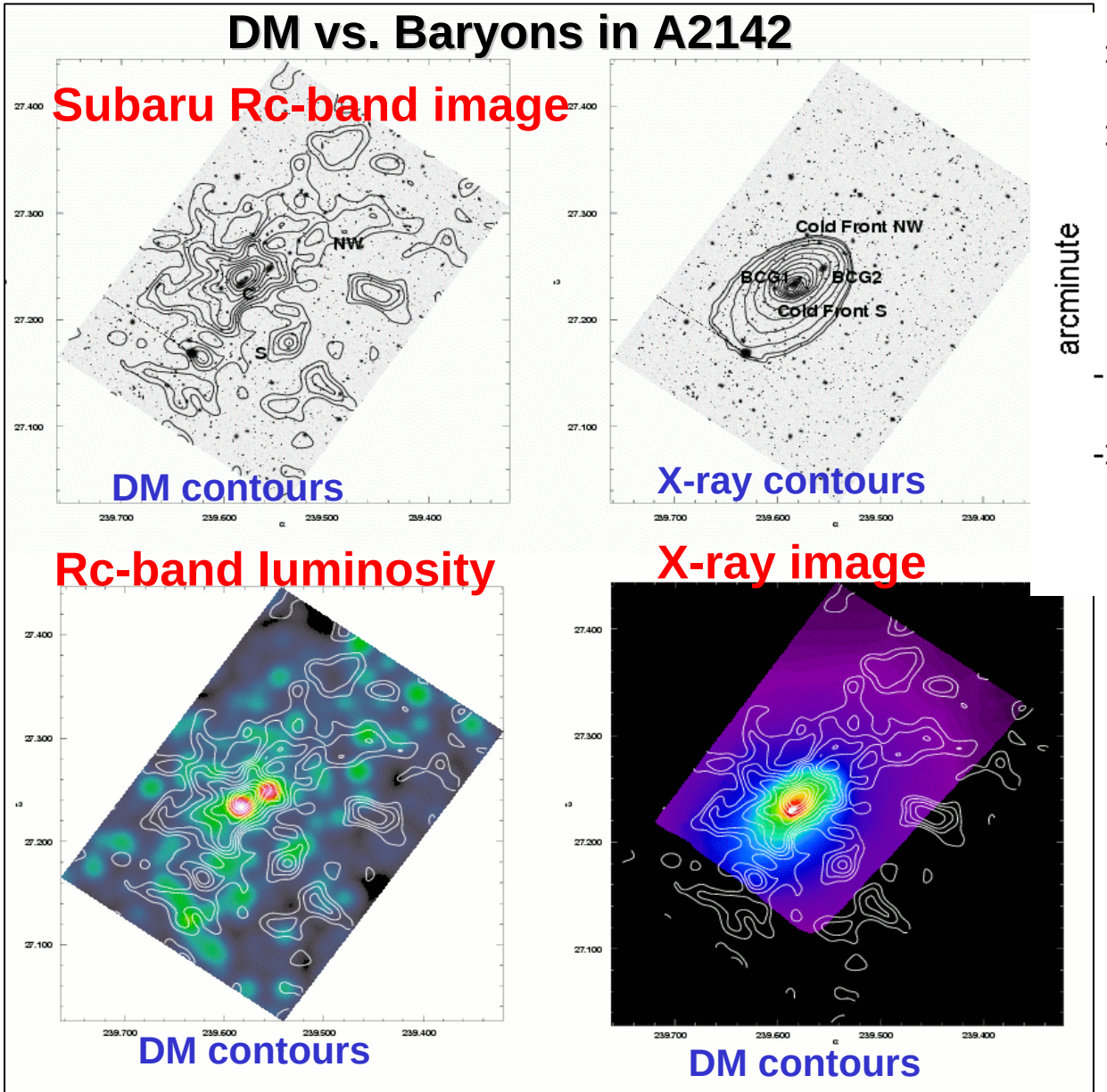
Joint "AMiBA + Subaru" data, probing the gas/DM distribution out to ~80% of the cluster virial radius (r_200 =~ 0.8 * r_vir)

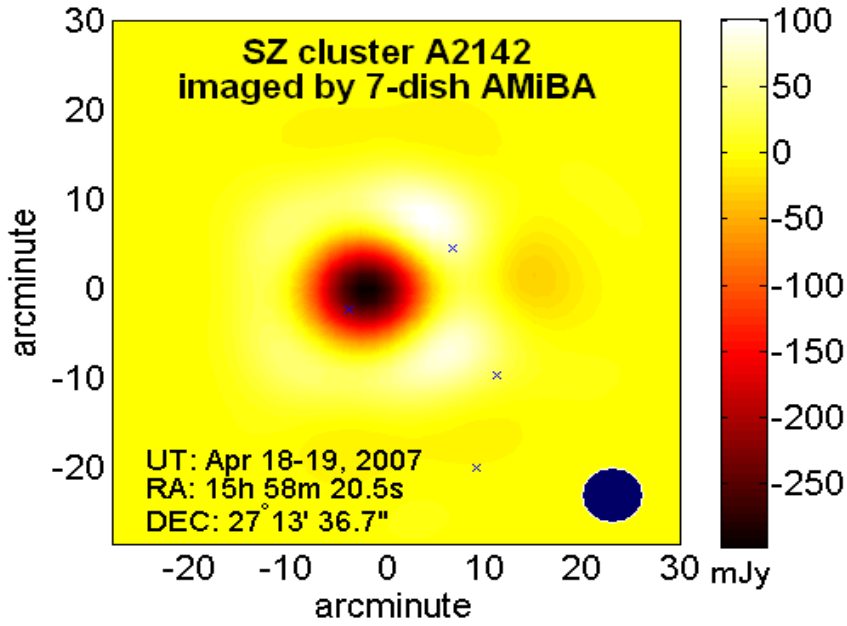


First gas mass fraction measurements out to large radii without assuming the hydro-static equilibrium assumption.

When compared to the WMAP 5yr constraint on the cosmic baryon fraction, our CDM-based halo model (black, cross-hatched) shows that ~83% (+/-18%) of the baryons are in the hot plasma phase of clusters.

AMiBA: "Multi-λ Study of Clusters"



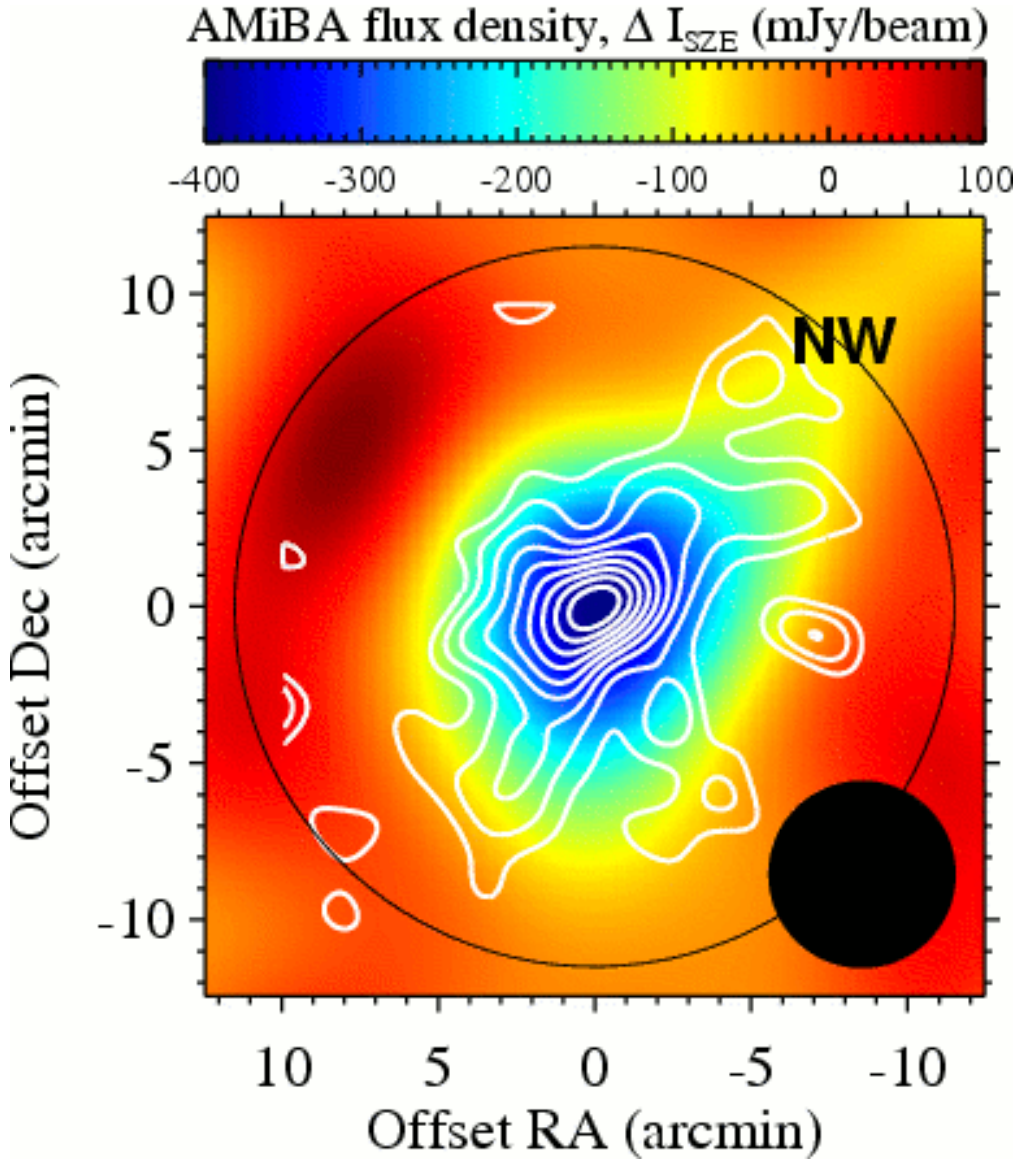


Lensing + X-ray + Optical + SZE, probing the cluster physics

Weak lensing, X-ray, and optical study of 7-merging clusters of galaxies by

Okabe & Umetsu (2007)

A2142 SZE vs Weak Lensing



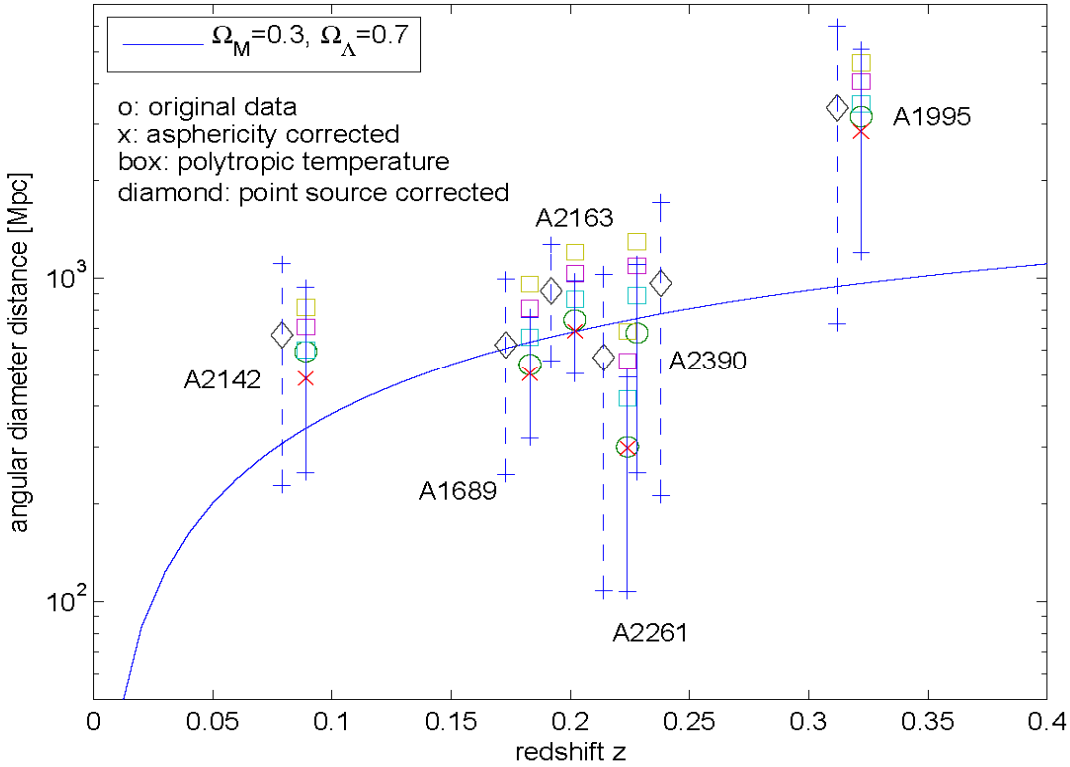
A2142 at z=0.091
FOV = 1.8 Mpc h^{-1}
Merging Cluster with two X-ray cold fronts

At 5' angular resolution SZE shows shape consistent with Dark Matter distribution.

NW enhancement may be overpressure of ICM

SZE more sensitive at edge of cluster to ICM

Hubble Constant:AMiBA SZE + X-ray

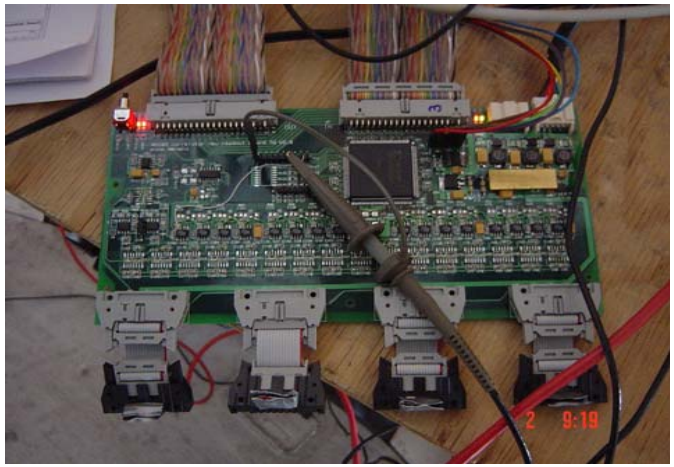


Angular Diameter Distances (D_A) for original data (o) and corrected

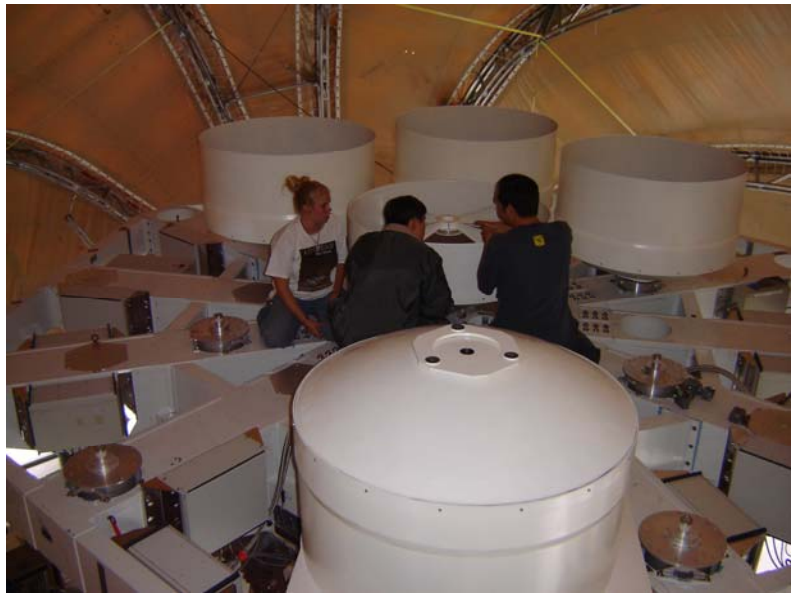
$$H_0 \sim 1/D_A$$

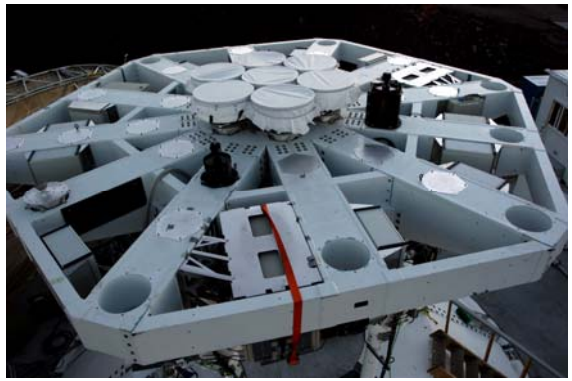
Best-Fit (from asphericity correction): H_0=54±16 km s^{-1} Mpc^{-1} (1 σ error)

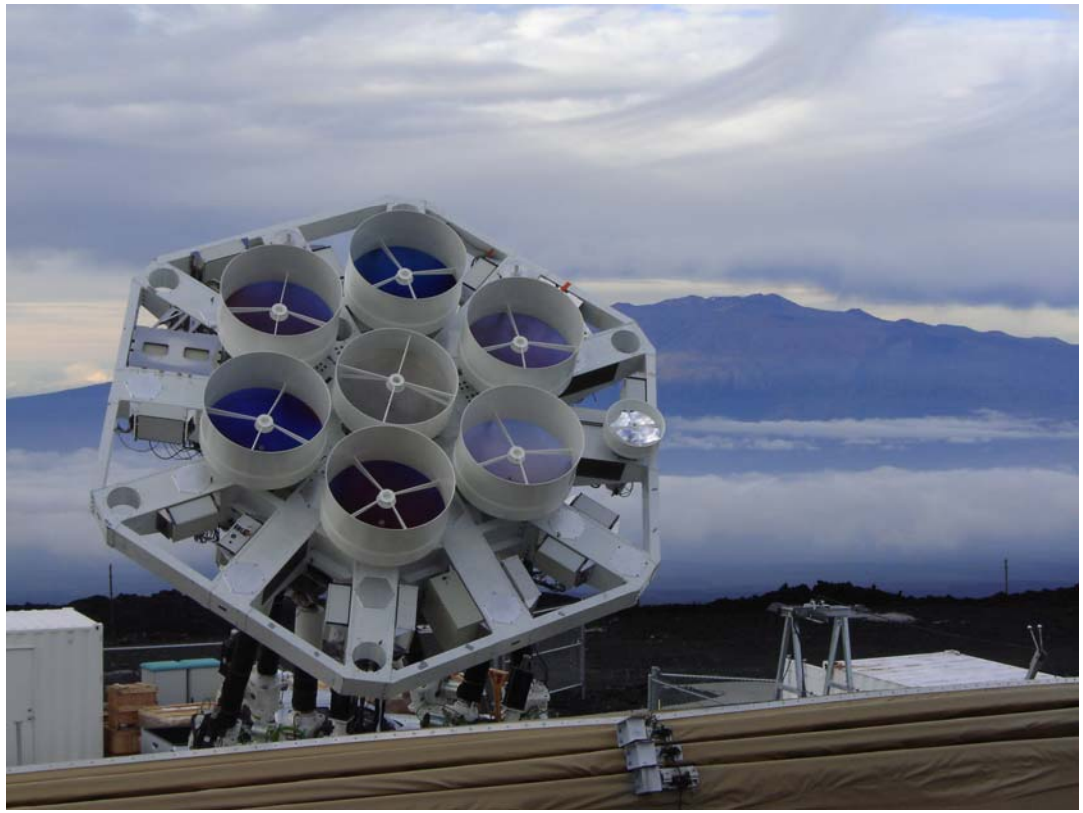
Improve Electronics, Add 6 Rx's Expand Correlator, 1.2m Dishes



7 1.2m Reflectors Installed





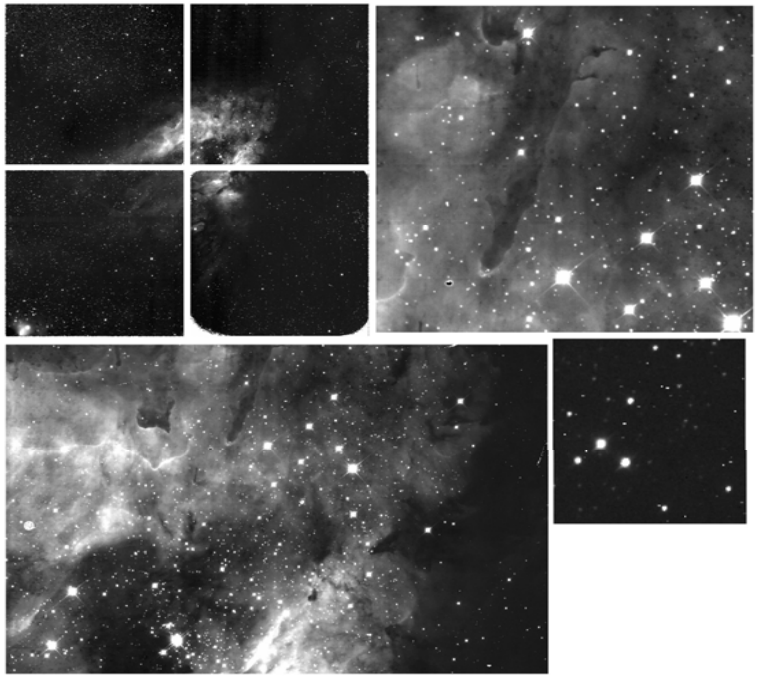


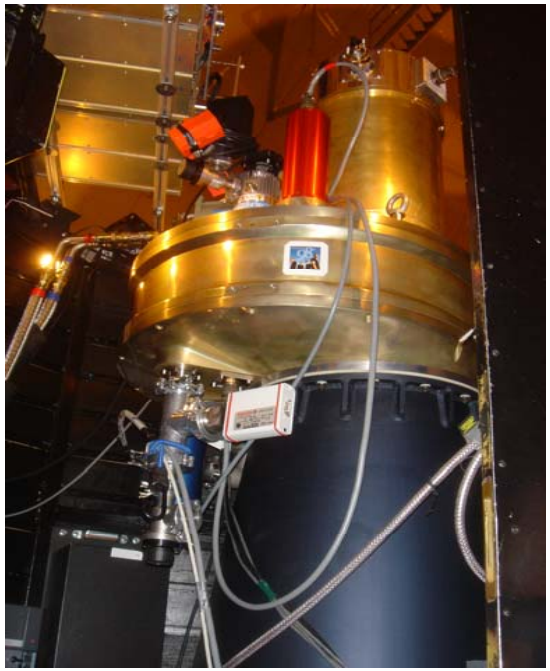
7 1.2m Reflectors Installed

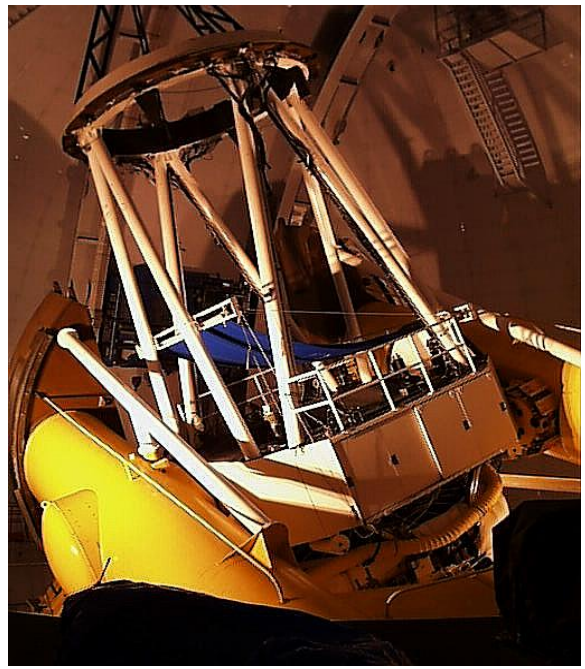
WIRCam Deployed on CFHT 2006

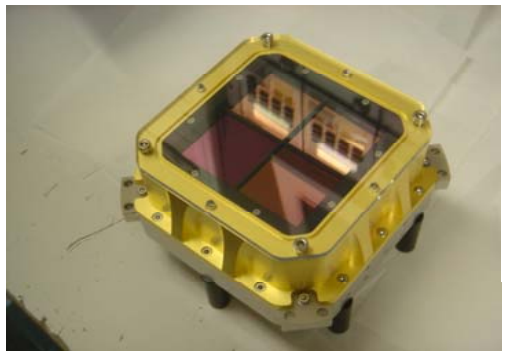
Wide Field (20')

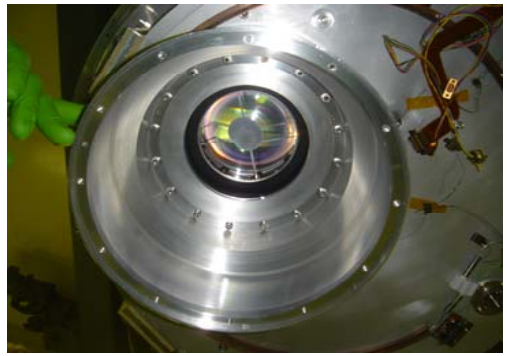
Images with 4 HgCdTd Detector Arrays



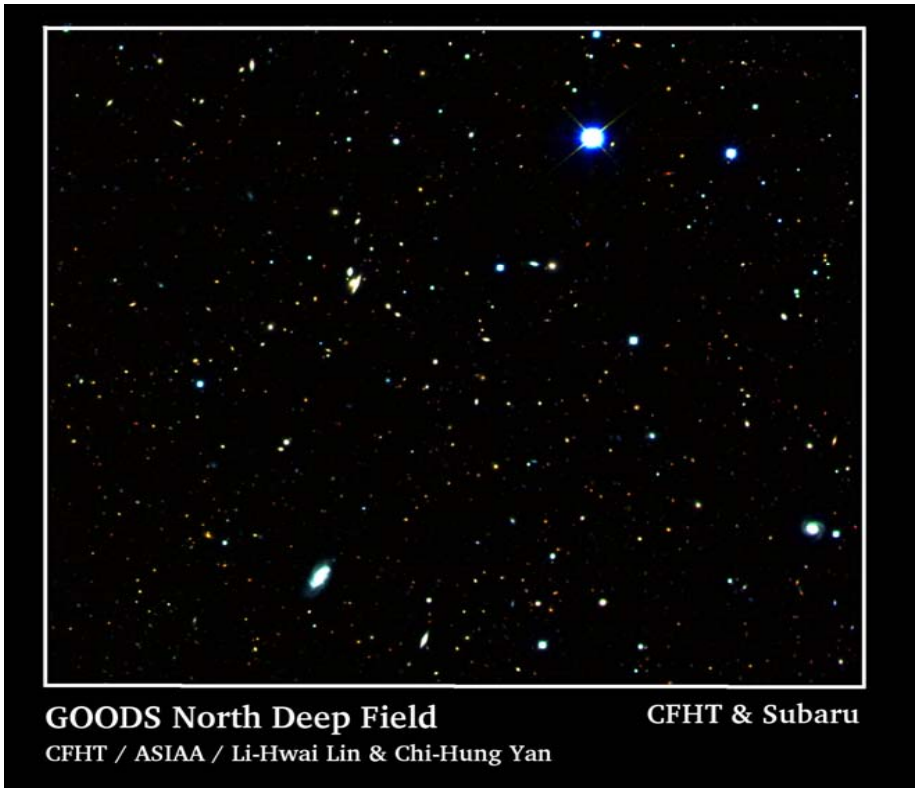


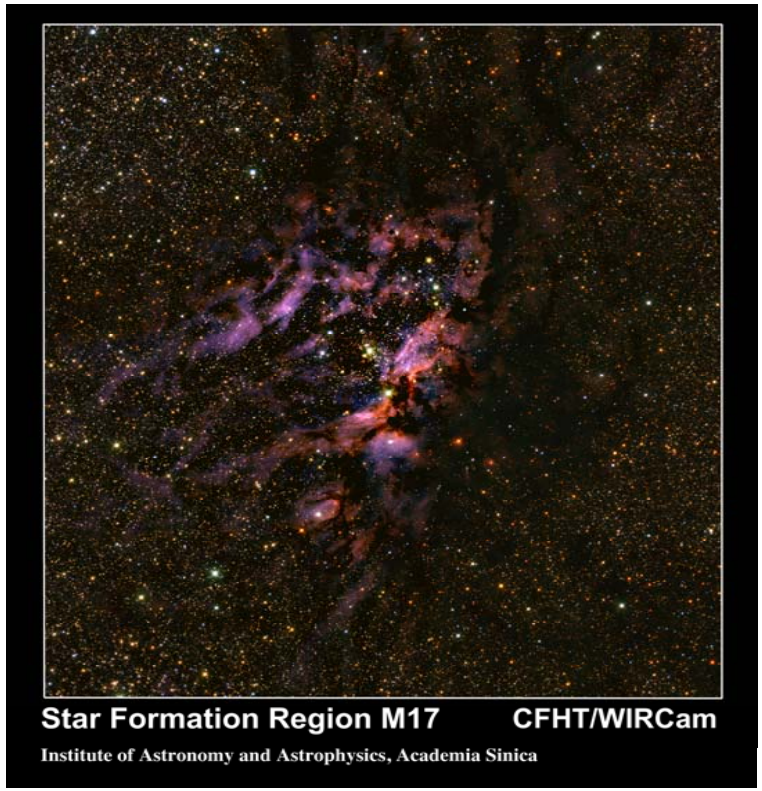






CFHT 2008





Will continue to access CFHT at a minimum of 10 nights per year

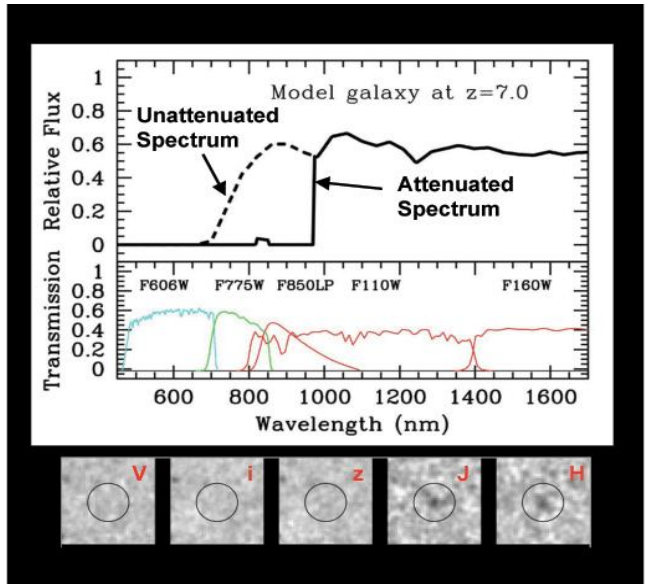
Will continue to work with CFHT on AO, spectro-polarimeter projects

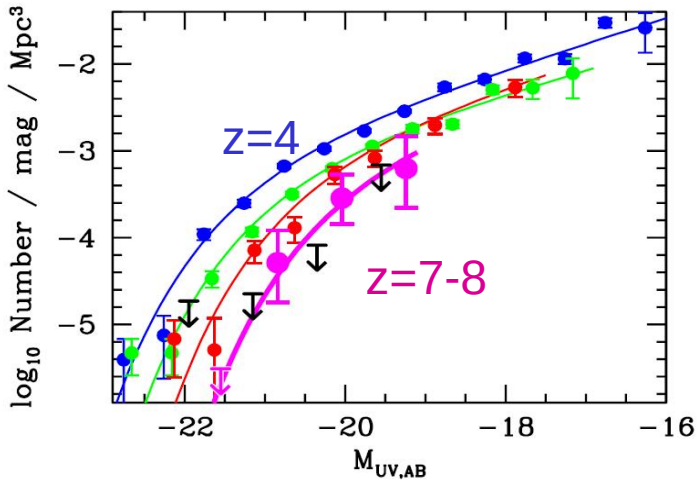
Search for the High-z galaxies

- **Pushing the redshift limits of high-redshift galaxies are essential in:**
  - ✓ **quantifying the contribution of early star formation to cosmic reionization**
  - ✓ **characterizing the history of cosmic star formation rates**
  - ✓ **probing the formation mechanism and evolutionary path of early galaxies**

- **To date most candidates at z>7 are selected in extremely deep pencil beam surveys with very small areas, but none has been spectroscopically-confirmed yet.**

Dropout (or Lyman-Break) Technique





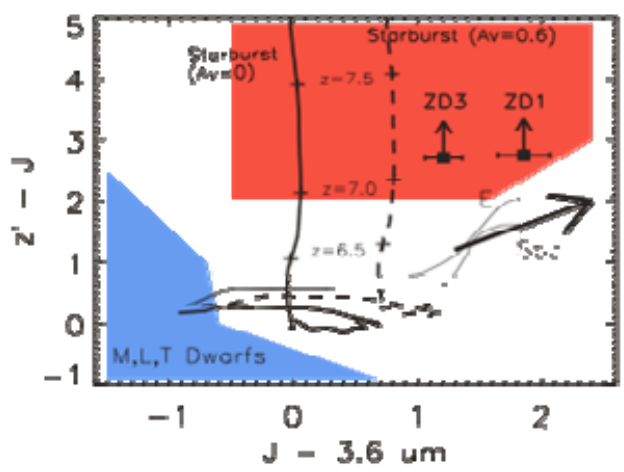
Bouwens et al. 2008

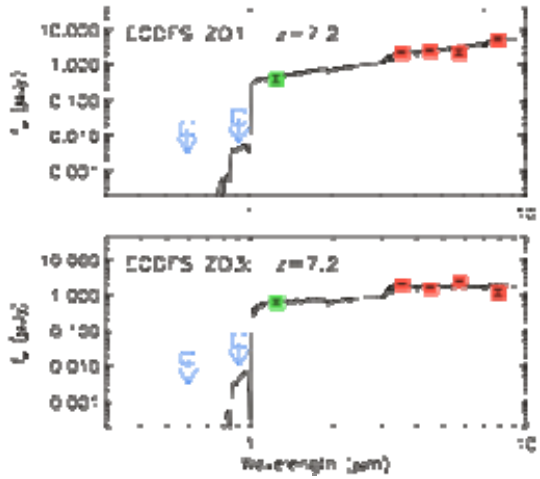
The populations and properties of z>7 galaxies are still poorly understood !

Probing the Dark Age

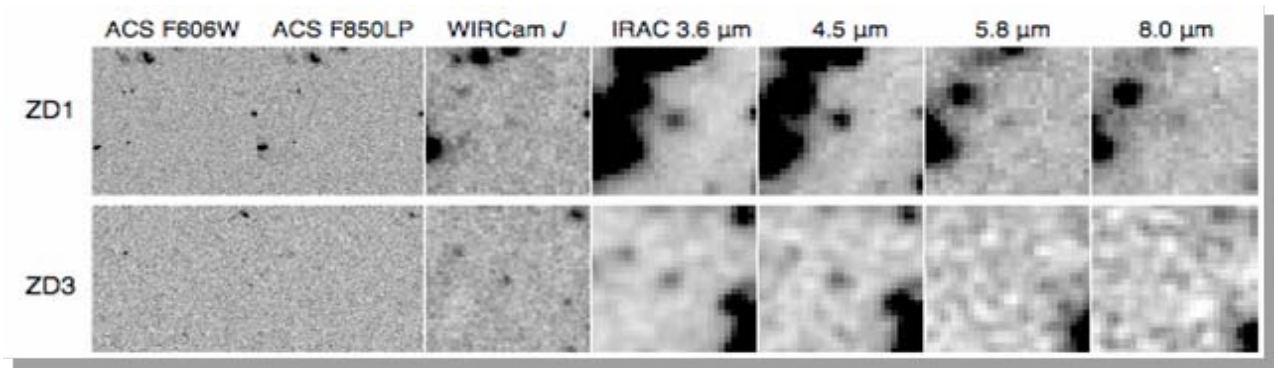
A Deep WIRCAM J Survey for z>7 Galaxies in the ECDF-S

- Search for z'-dropout candidates at z>7
- Field: Extended Chandra Deep Field-South
- 5X wider than published survey
- ACS v & z' band and IRAC data are public
- Contaminators (color-color diagram):
- Galactic objects: blue area
- low-z galaxies: thin solid lines
- Red area for z>7 z'-dropout candidates





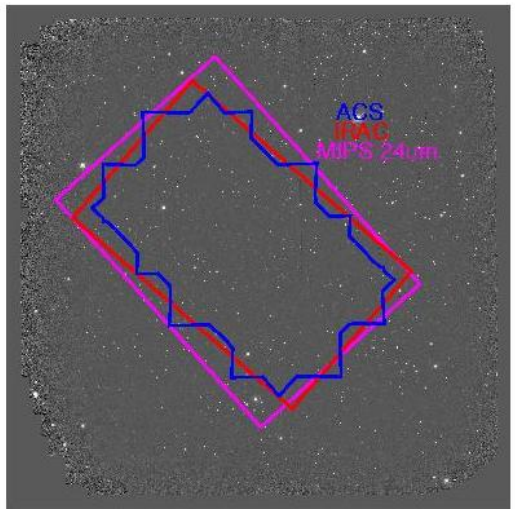
- Two excellent candidates are found
- ECDFS ZD1: J=24.92
- ECDFS ZD3: J=24.42
- Not seen in deep space-based opt data
- detected in all bands redder than z'
- SED fittings give photo-z=7.2
- Estimated stellar mass: $10^{10.3} M_{\odot}$ (not predicted by cosmological model)
- Estimated ages: 100-200 Myrs
- Subaru, HST, and Gemini follow-up



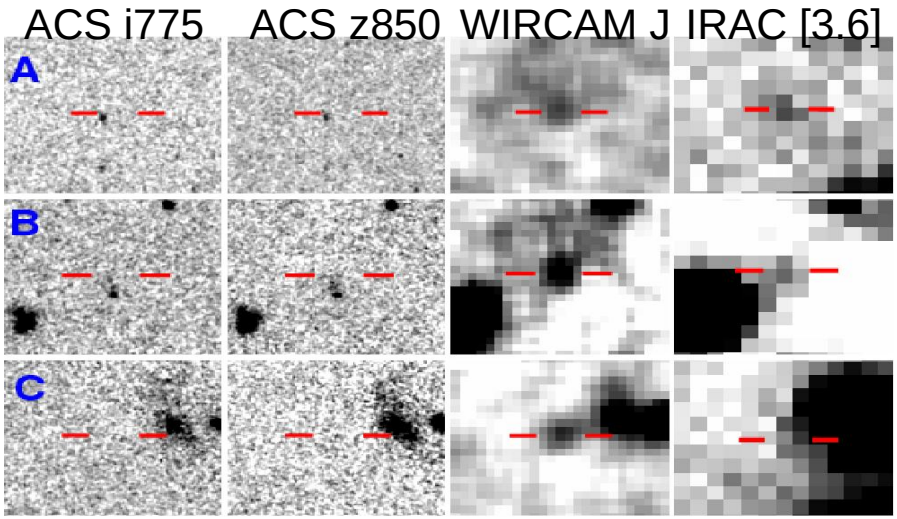
Hsieh et al. (in prep)

z-dropout candidates (z>7 galaxies) found in GOODS-N

- Joint CFHT program between Taiwan and Canadian (06A, 07A, 09A)
  - Taiwan: 52 hrs in J
  - Canada: 10 hrs in K (plus 70+ hrs in K taken by the Hawaiian group)
- People:
  Taiwan: L. Lin, C. Yan, Y. Cheng, S. Wang
  External: H.Yan, M. Dickinson, N. Meger, A. Pope, D. Koo, D. Scott, L. Simard



- Proposing HST/NIC3 study to follow up on these candidates.
  - If null detections: an stringent upper limit of bright z>7 galaxies would be set.
  - If positive detections: we will look for spectroscopic confirmations.



Yan, Lin et al. (in prep)

Red-sequence Cluster Survey 2

International collaboration (Canada, USA, Taiwan, & Chile)

Survey Design

Covering 1000 deg^2

Using CFHT MegaCam (g', r', & z')

10^4 galaxy clusters will be found

Science Goal

Providing constraints in the w-Ω_m plane

Discovering 50-100 strong lensing clusters

Levine et al. 2002, astro-ph/0204273

Supernovae 200

Supernovae 400

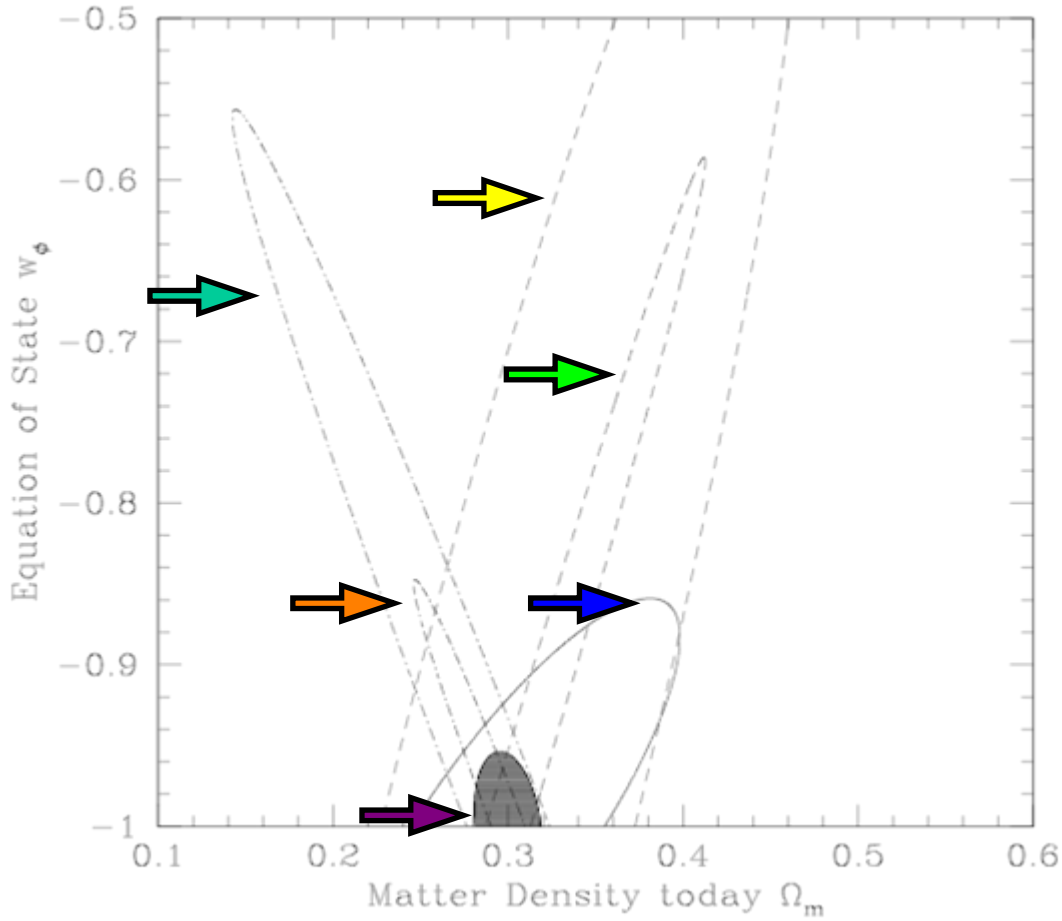
MAP (CMB)

PLANCK (CMB)

Cluster mass function

(z<1.2, 1000 deg^2, Tx>5Kev)

200 SNe + MAP + Clusters

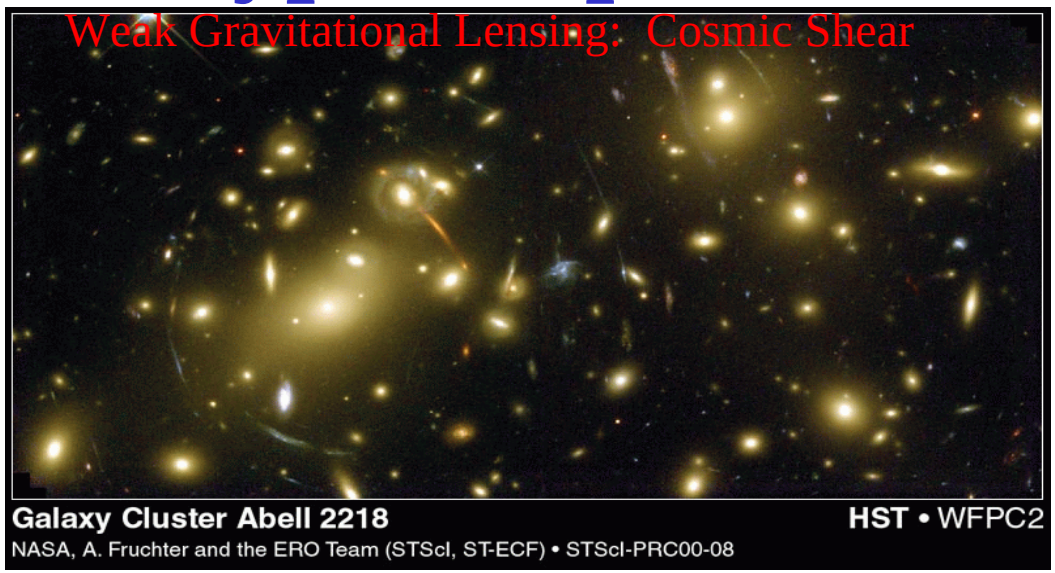


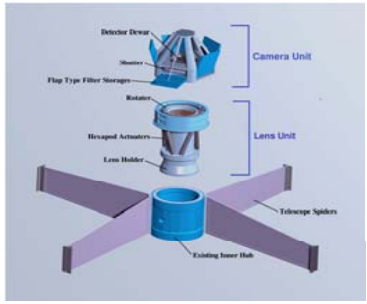
Current Status

Data reduction pipeline is running

First cluster catalog 2009

ASIAA Joins Subaru Hyper SuprimeCam Project 10.08



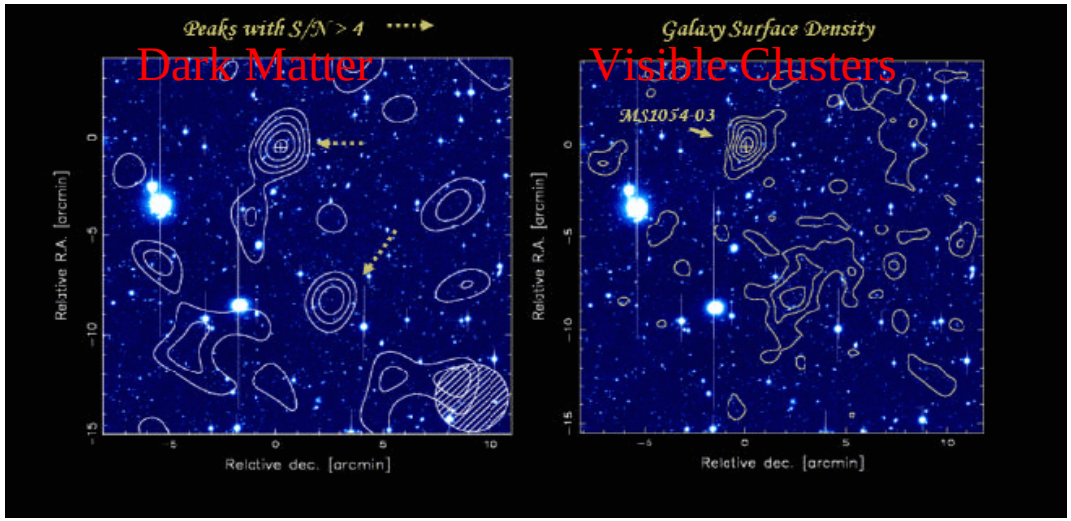


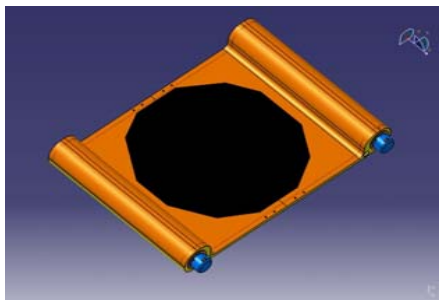
1.5 degree FOV, 10 x FOV (Surpime Camera)

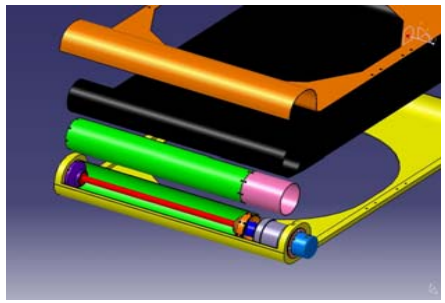
25 M USD Budget (Taiwan 5M) , 5 year timescale

ASIAA: Detector Electronics, Shutter, Filter Exchanger

Weak Lensing Tomography; z>6



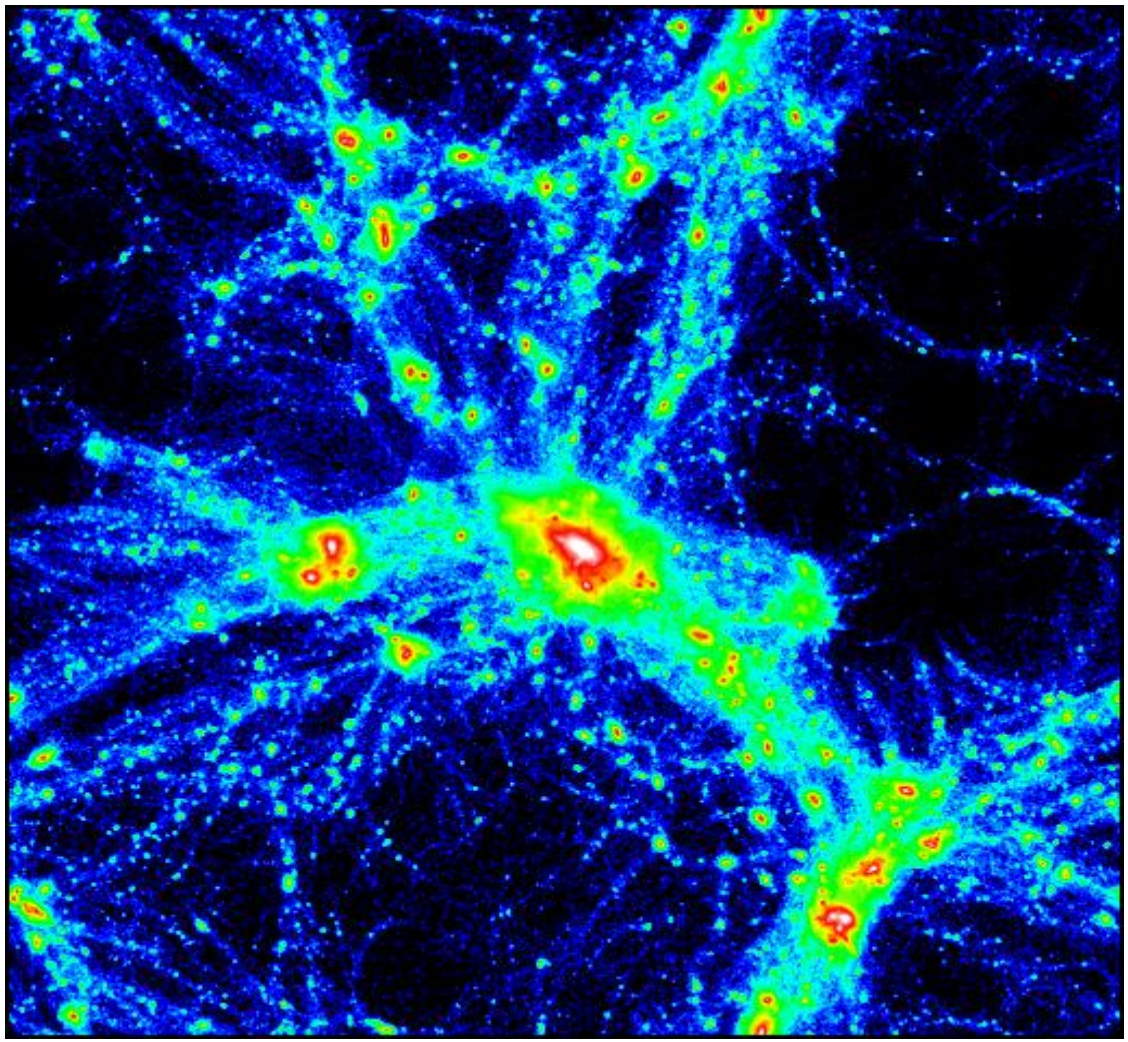


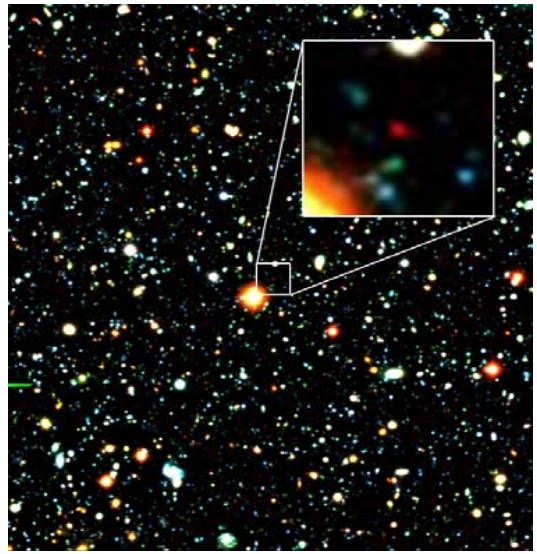


ARL designing shutter, filter exchanger

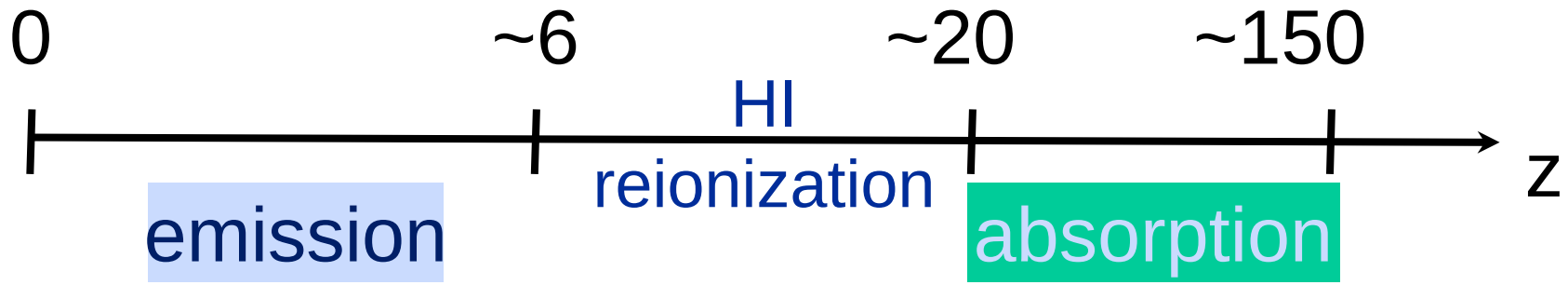
AS IAA procures detectors, do testing

Many Science Targets for HSC





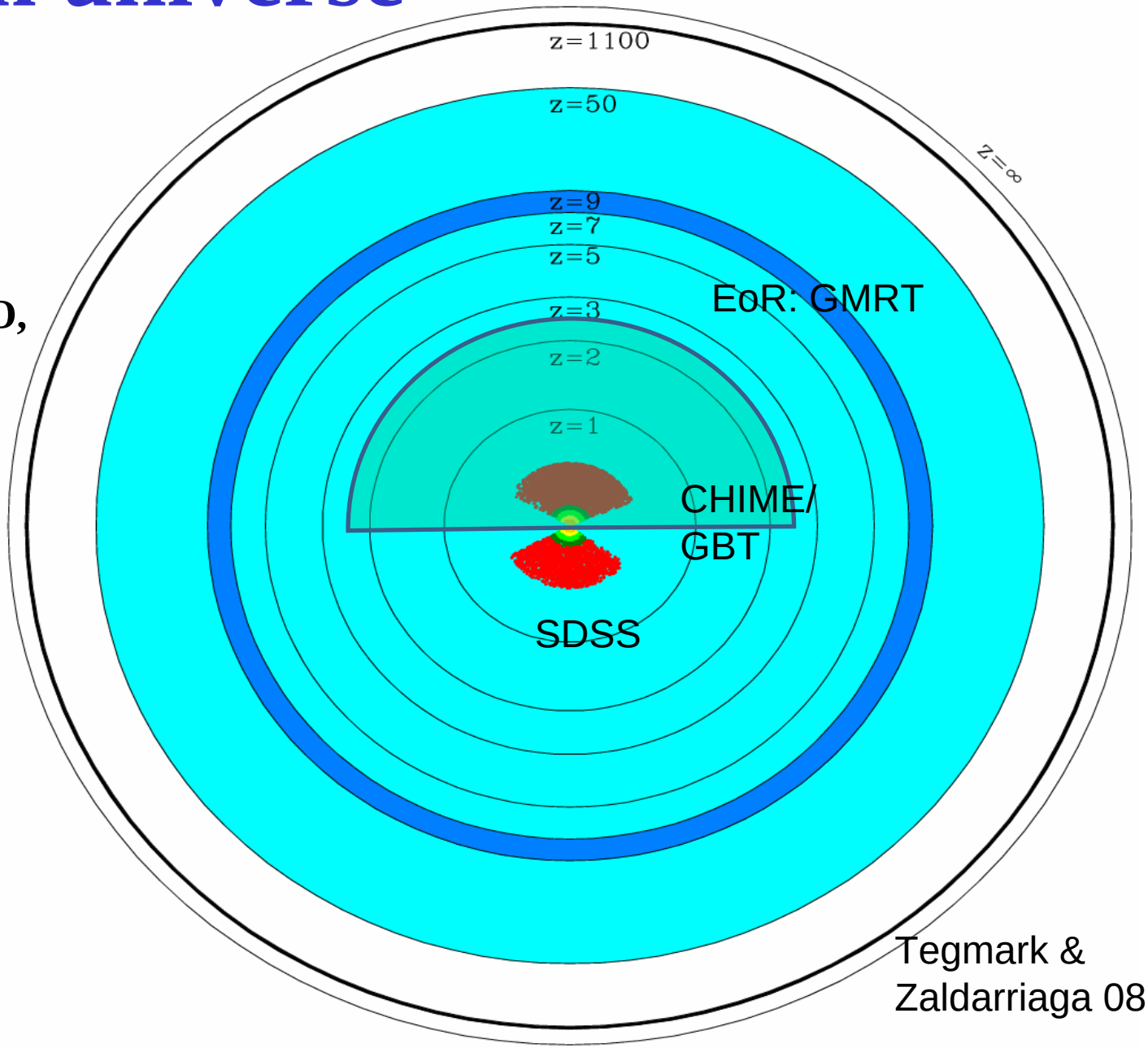
21cm Cosmology



- **neutral hydrogen: most abundant element**
- **optically thin through out the universe**
- **line transition: gives 3D information**
- **visible from 0 < z < ~150, when Ts decouples from Tcmb**
- **~20 < z < 150, Ts < Tcmb, 21cm in absorption**
- **0 < z < ~15, Ts > Tcmb, 21cm in emission**

The 21cm universe

- **Up to 10^{18} modes to z=50 (Hubble/Jeans)^3**
- **Physics: Lensing, gravity waves, primordial NG, BAO, AP**
- **Astrophysics: EoR, galaxy evolution**
- **Experiments NOW**
  - **EoR : GMRT**
  - **BAO : GBT/CHIME**



Tegmark &
Zaldarriaga 08

Why 21cm?

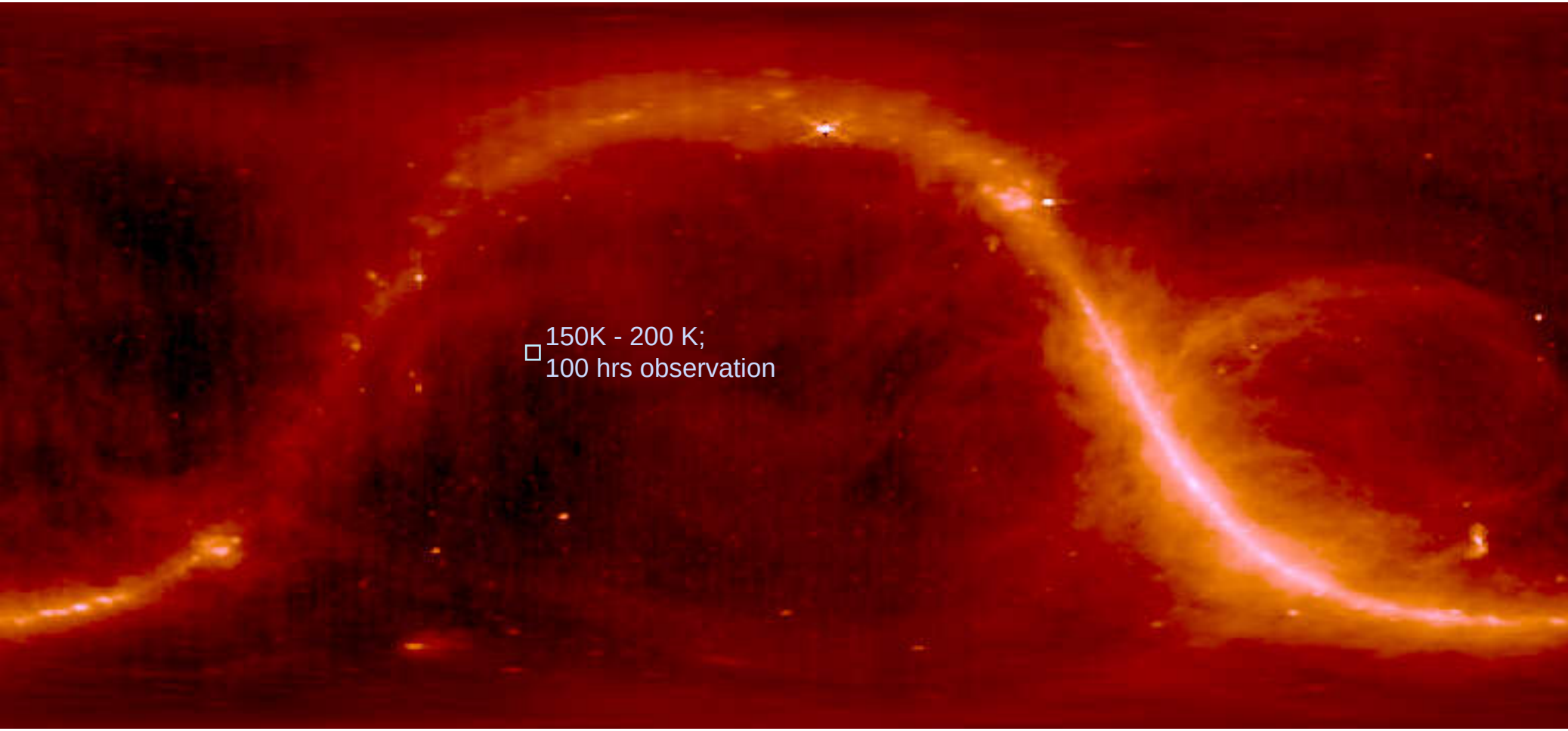
- **Astrophysical -- probing the Epoch of Reionization (EoR):**
  - **Traditional observation can't see anything before there were luminous matter**
  - **Can probe full ionization structure (Ly-alpha saturates except at the end of reionization)**
- **Precision cosmology -- measuring cosmological parameters:**
  - **at high z, pre-reionization: linear, 10^{18} modes; much more than the CMB (10^7), LSS (10^7 at z<1)**
  - **at low z, "ionized": use HI intensity mapping to make an efficient redshift survey: Baryon Acoustic Oscillation measurements; Lensing (T.T. Lu, O. Dore, U. Pen)**

GMRT - Giant Meterwave Radio Telescope

30 antenna; 45-m diameter dish; 1km central core
collecting area ~4e4 m^2, 140-156 MHz, 8 < z < 9

U.-L. Pen, T. Chang, J. Peterson, J. Roy, Y. Gupta, J. Odegova, C. Hirata, K. Sidgurdson, J. Sievers, S. Meyers

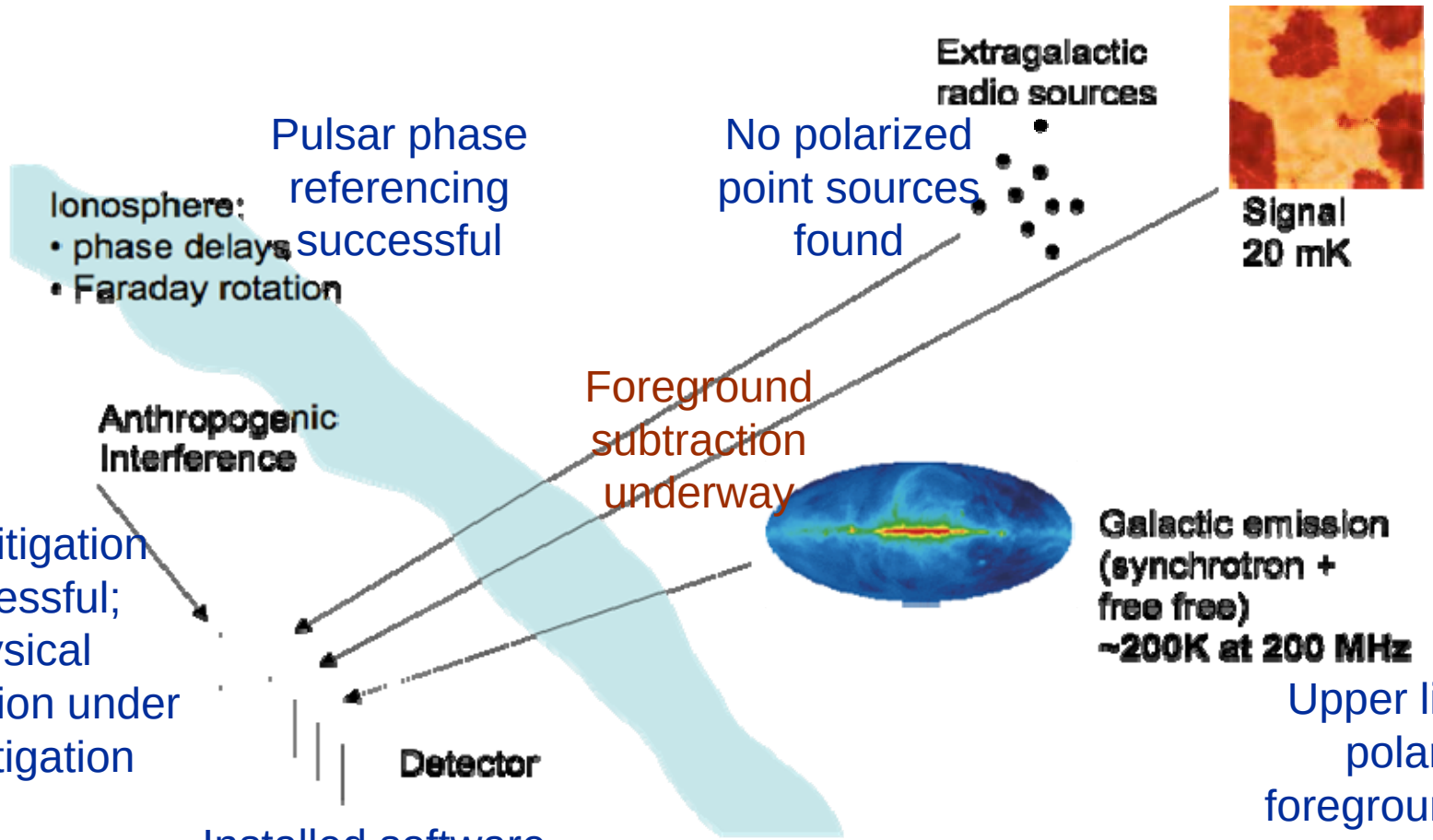
Foregrounds



Haslam 408 MHz

Foregrounds: much brighter than signal, but no spectral structure

GMRT Current Status



Pulsar phase referencing successful

No polarized point sources found

Sensitivity forecast promising

Foreground subtraction underway

RFI mitigation successful; physical elimination under investigation

Upper limits on polarized foregrounds ~ 1K

Installed software correlator; collected a few x 100 hours of data

BAO - Tool for Precision Cosmology

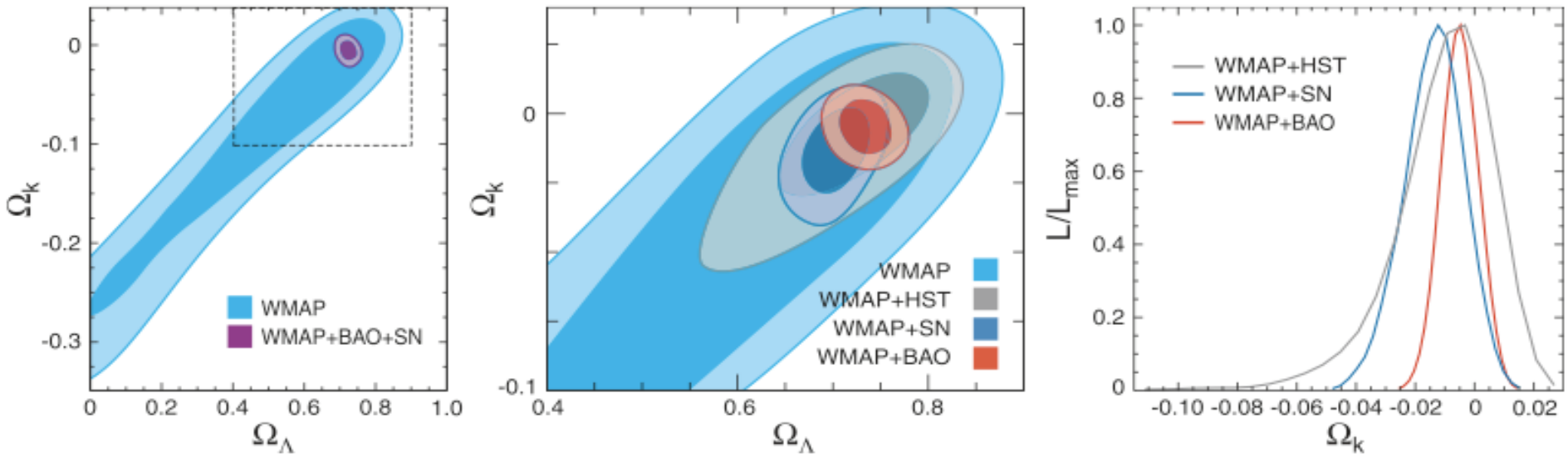


FIG. 6.— Joint two-dimensional marginalized constraint on the vacuum energy density, Ω_Λ, and the spatial curvature parameter, Ω_k (§ 3.4.3). The contours show the 68% and 95% CL. (*Left*) The WMAP-only constraint (light blue) compared with WMAP+BAO+SN (purple). Note that we have a prior on Ω_Λ, $\Omega_\Lambda > 0$. This figure shows how powerful the extra distance information is for constraining Ω_k. (*Middle*) A blow-up of the region within the dashed lines in the left panel, showing WMAP-only (light blue), WMAP+HST (gray), WMAP+SN (dark blue), and WMAP+BAO (red). The BAO provides the most stringent constraint on Ω_k. (*Right*) One-dimensional marginalized constraint on Ω_k from WMAP+HST, WMAP+SN, and WMAP+BAO. We find the best limit, $-0.0181 < \Omega_k < 0.0071$ (95% CL), from WMAP+BAO+SN, which is essentially the same as WMAP+BAO. See Fig. 12 for the constraints on Ω_k when dark energy is dynamical, i.e., $w \neq -1$, with time-independent w.

Komatsu et al. 2008

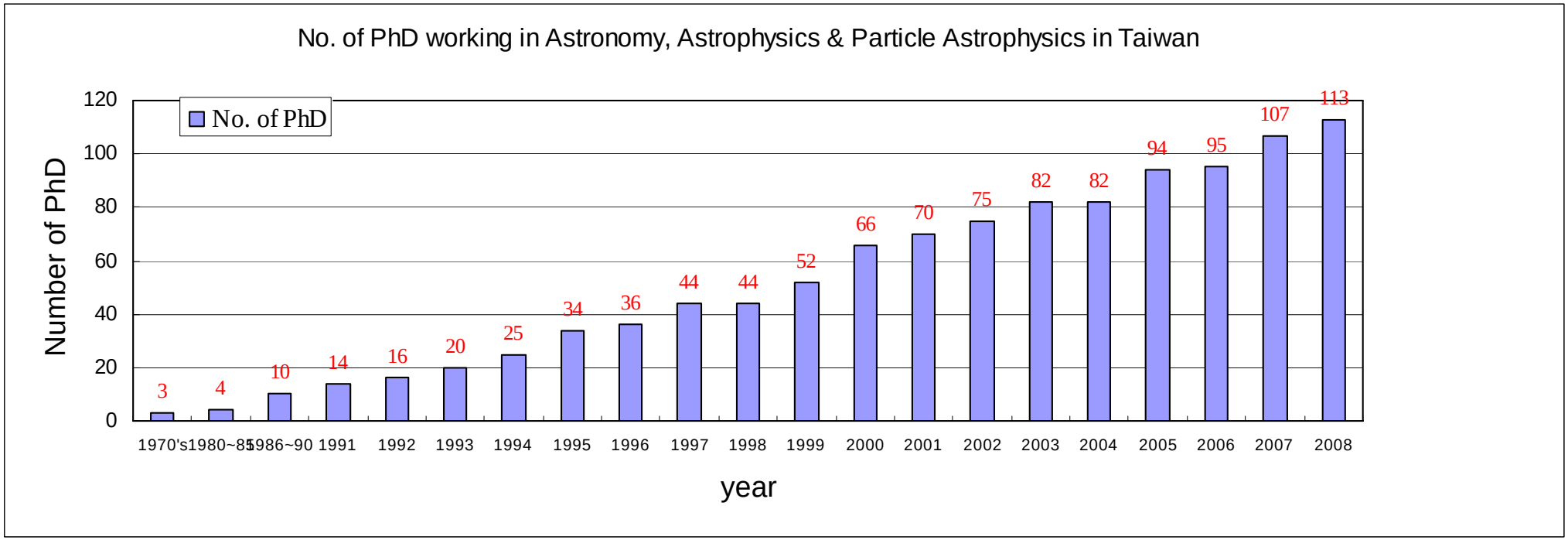
• HI BAO Experiment Prospects

- **CHIME (Canadian Hydrogen Intensity Mapping Experiment); Cosmic Variance limited Hubble Survey**

Chang, Pen, Peterson, McDonald 2008

Pittsburgh Cylinder Prototype

MANPOWER in Taiwan



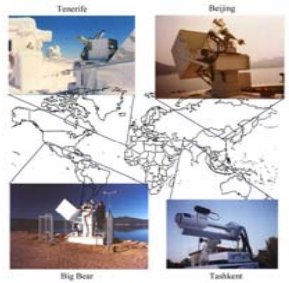
Almost 10 times Growth in Manpower in the last 15 years

Strategy: Invest in Technology; Embed and Train Overseas, then Recover

Taiwan Astronomical Research 2008

Pan-STARRS, 2-m Telescope

- National Central University (NCU)
  - Institute of Astronomy, 1992
- Academia Sinica (AS)
  - ASIAA, 1993
- National Tsinghua University (NTHU)
  - Institute of Astronomy, 2000
- Normal, Cheng-kung, Tamkang, Chiaoda
  - Geology, Physics departments ...
- National Taiwan University (Taida)
  - Institute of Astrophysics, 2002



Taiwan Oscillation Network (TON), (EAST), Compton

Leung Cosmology Center