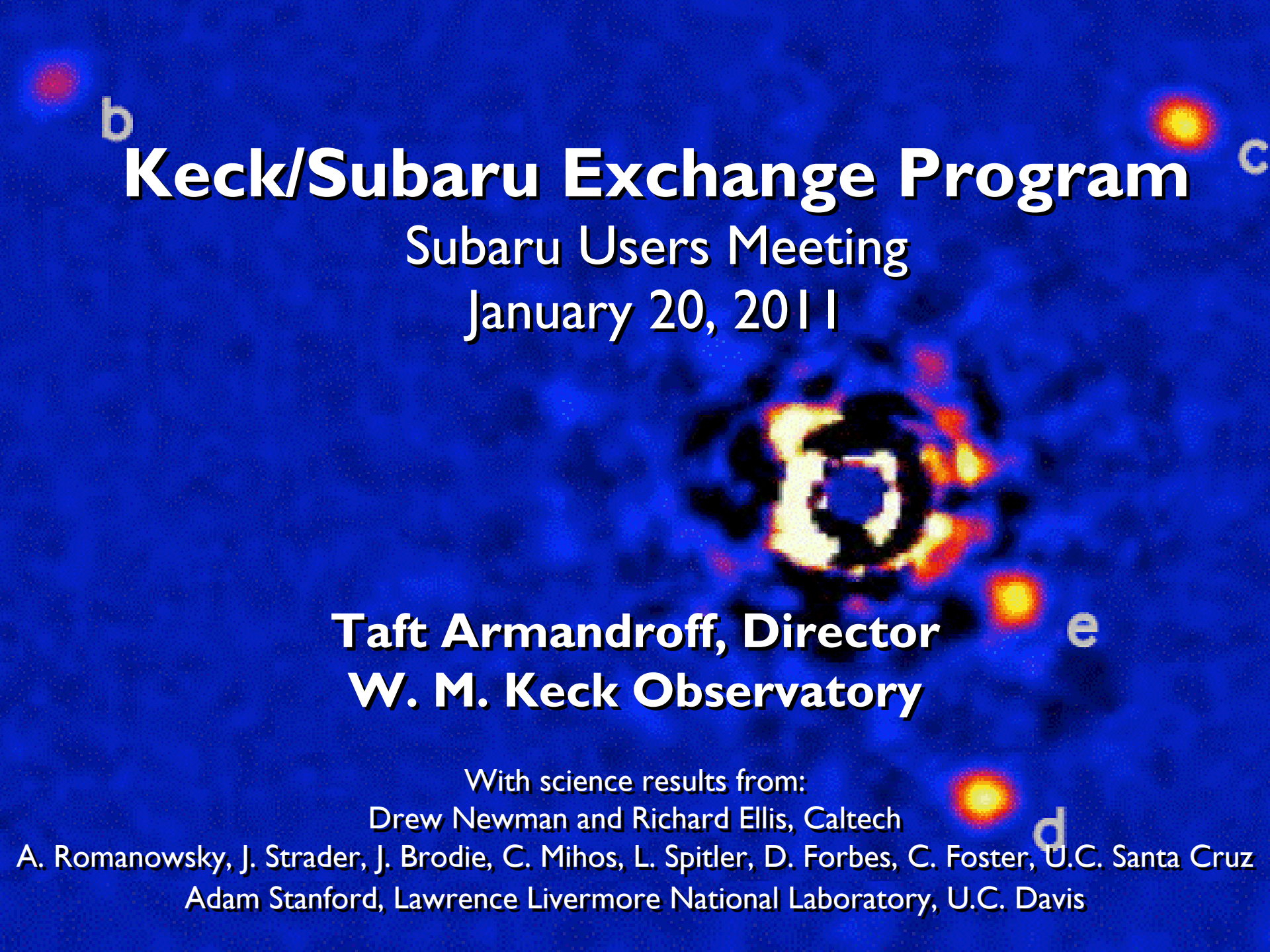


Keck/Subaru Exchange Program

Subaru Users Meeting

January 20, 2011

Taft Armandroff, Director

W. M. Keck Observatory

With science results from:

Drew Newman and Richard Ellis, Caltech

A. Romanowsky, J. Strader, J. Brodie, C. Mihos, L. Spitler, D. Forbes, C. Foster, U.C. Santa Cruz

Adam Stanford, Lawrence Livermore National Laboratory, U.C. Davis

Benefits of Time Exchange

- ★ Expands observing capabilities for each community
  - Subaru's unique wide-field capabilities
  - Keck's powerful spectroscopic & adaptive optics capabilities
- ★ Economical: new instruments are expen$ive
- ★ Brings Keck and Subaru communities closer together
- ★ Creates Mauna Kea Observing System
  - As capable as any on Earth

Subaru-Keck Exchange & Capabilities Offered

★ Subaru

- Initiated in semester 2007B
- Suprime-Cam: wide-field optical imager
- MOIRCS: IR imager & multi-object spectrograph
- Expanded to also include FOCAS, HDS, IRCS (with NGS AO) and COMICS in semester 2010A
- Up to 6 nights / semester

Subaru-Keck Exchange & Capabilities Offered

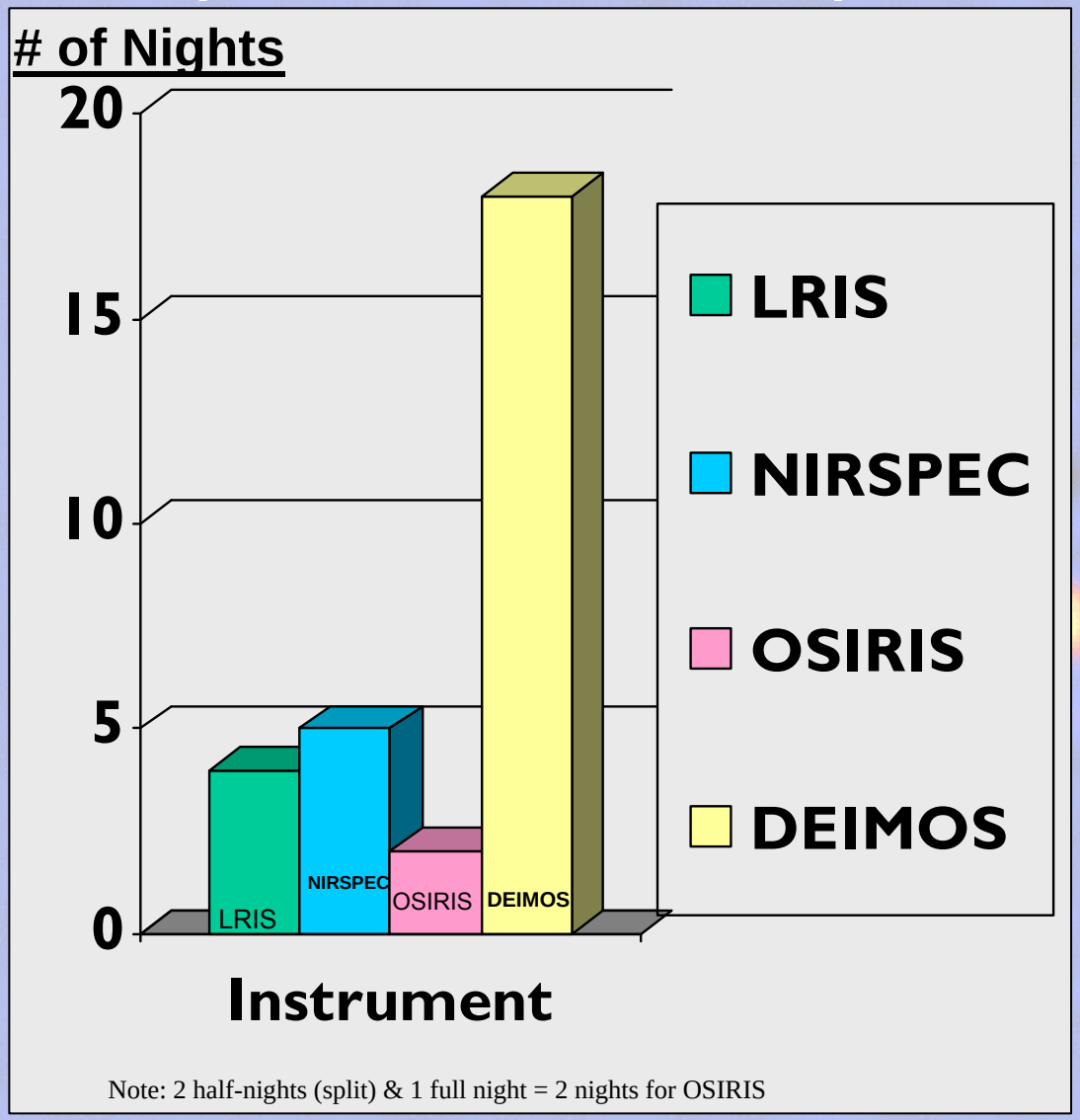
- ★ **Keck I**
  - LRIS:
  - maximum of two Keck I nights
- ★ **Keck II**
  - DEIMOS: wide-field multi-object optical spectrograph
  - ESI: moderate-resolution optical spectrograph
  - NIRSPEC: infrared spectrograph
  - NIRC2: adaptive optics infrared imager (& spectrograph)
  - OSIRIS: adaptive optics near-infrared integral-field spectrograph
  - maximum of four Keck II nights
  - maximum of two laser guide star nights

Keck Community Members with Subaru Time

Semester	PI	Instrument	# of nights
2007B	Brown	Suprime-Cam	2
2007B	Ellis	Suprime-Cam	2
2008A	Brown	Suprime-Cam	2
2008A	Steidel	MOIRCS	2
2008B	Brown	Suprime-Cam	2
2008B	Brodie	Suprime-Cam	2
2009A	Wilson	MOIRCS	1
2009A	Brown	Suprime-Cam	2
2009B	Stanford	Suprime-Cam	2
2009B	Fraser	Suprime-Cam	1
2010A	Stanford	Suprime-Cam	2
2010A	Brodie	Suprime-Cam	1
2010B	Stanford	Suprime-Cam	1
2010B	Steidel	MOIRCS	2
2010B	Brodie	Suprime-Cam	1

Subaru Time on Keck Instruments

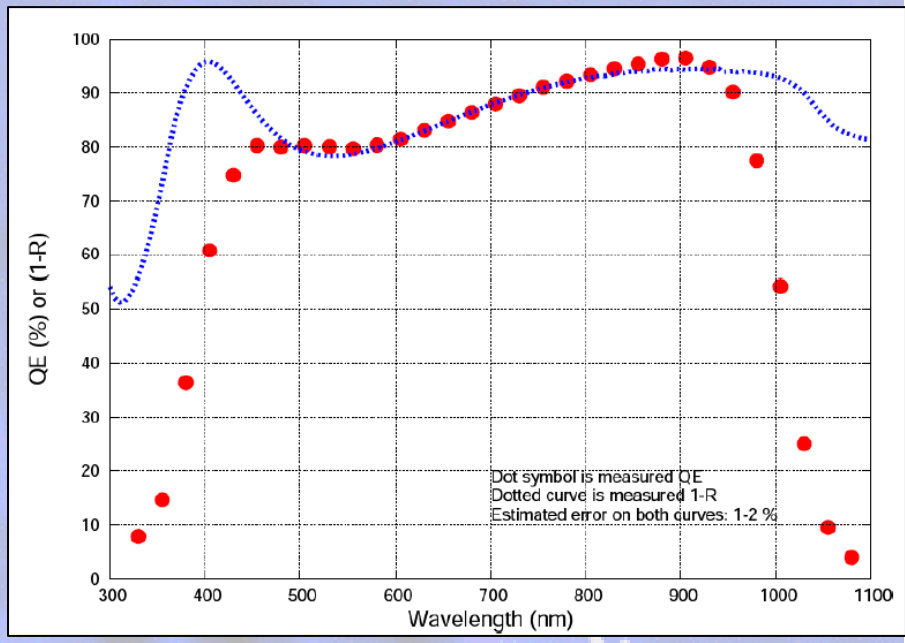
(2007B thru 2011A)



Note: 2 half-nights (split) & 1 full night = 2 nights for OSIRIS

LRIS Red Channel Detector Upgrade

- ★ Upgrade to a mosaic of two 2K x 4K high resistivity, thick substrate detectors (LBNL)
- ★ Dramatically improved sensitivity in red, particularly at longer wavelengths
- ★ No fringing
- ★ 25% more spectral coverage
- ★ New dewar, focus mechanism, CCD electronics & software
- ★ First light 6 June 2009
- ★ LRIS-R now has higher throughput than DEIMOS at λ > 8200 Å
- ★ CCDs replaced again December 2010



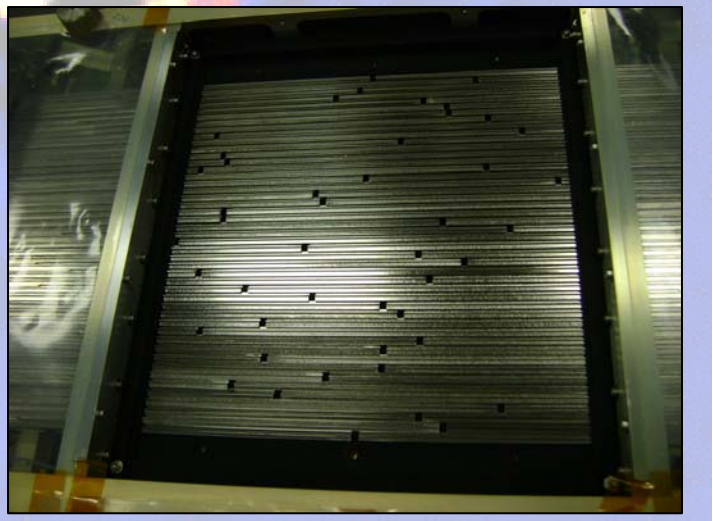
Potential Future Time Exchange Opportunities

- ★ **Subaru**
  - FMOS
  - Hyper Suprime-Cam
  - Prime Focus Spectrograph
- ★ **Keck**
  - MOSFIRE
  - Keck I laser guide star adaptive optics system
  - Instruments in design phase: Next-Generation Adaptive Optics and Keck Cosmic Web Imager
- ★ Both observatories: could expand to additional nights if there is sufficient interest

MOSFIRE

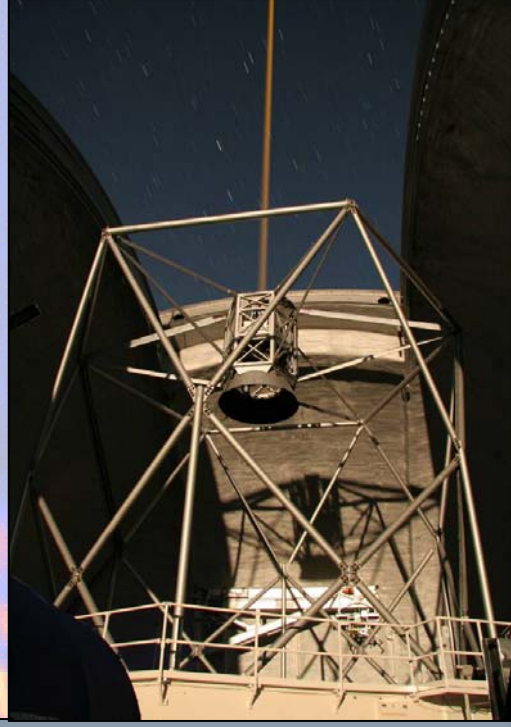
Multi-Object Spectrometer For InfraRed Exploration

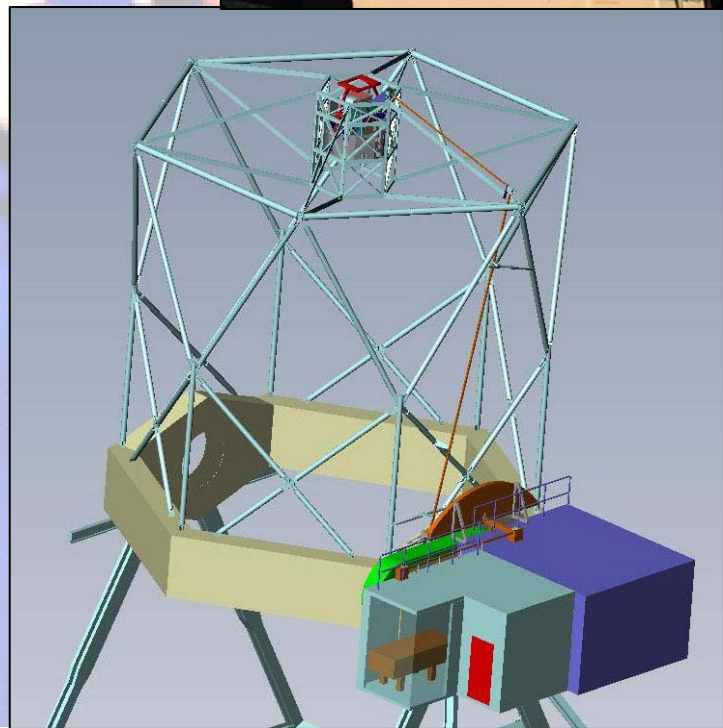
- ★ Near-IR Multi-Object Imaging Spectrometer
  - 0.97 to 2.45 μm
- ★ At Cass focus of Keck I, MOSFIRE will provide:
  - R = 3,270 for a slit width of 0.7"
  - 46 slits over 6.1' x 3' FOV using a remotely configurable slit mask unit
  - Imaging FOV 6.14' diameter with 0.18" pixels
- ★ Acceptance testing underway
- ★ First light planned for April 2011 on Keck I



Keck I Laser Guide Star Adaptive Optics

- ★ Motivation
  - Improved performance relative to KII LGS AO
  - Redundancy
- ★ Brighter LGS AO spot
  - Laser: 35 W (KI) vs. 14 W (KII)
  - Mode-locked CW beam has ~2x better return efficiency compared to Keck II laser
- ★ Better performance from center projection (vs. side projection)
  - Spot elongation reduced by 2x
  - LGS aberrations symmetric
- ★ OSIRIS will move from KII to KI
  - OSIRIS likely relocating during semester 2011B
  - NIRC2 will remain with KII LGS-AO system





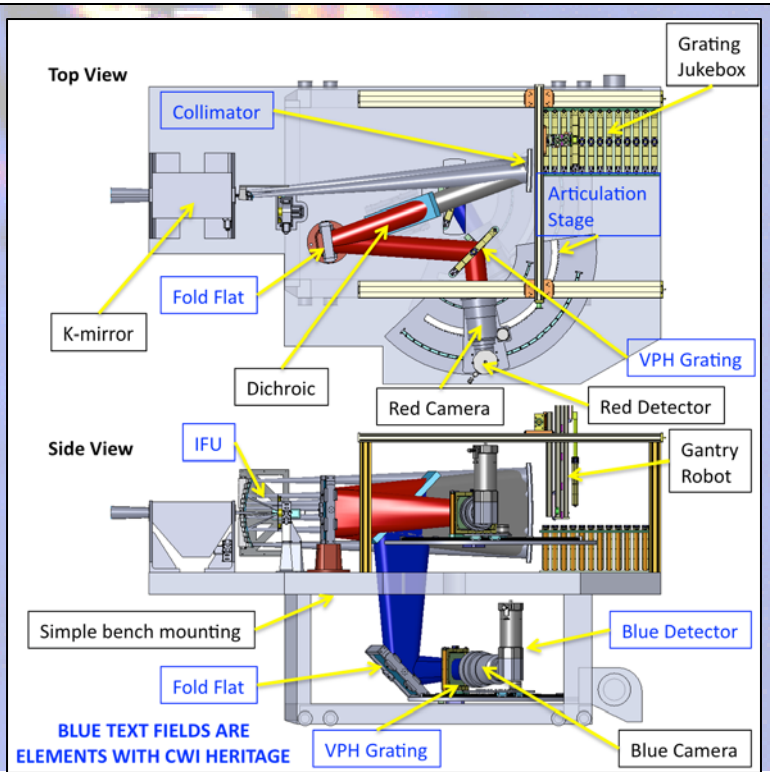
Future: Keck Cosmic Web Imager

3D, Low Surface Brightness Spectroscopy at Keck

Science Applications (examples)

① Map circum-galactic medium 2 < z < 6
② Map circum-QSO medium
③ Map z ~6 reionization bubbles
④ Composition & age of stellar remnants (halos, intracluster light)
⑤ Low mass/surface brightness universe
⑥ Galaxy kinematics & stellar pops
⑦ Strong lens systems
⑧ GRB/SNe host properties
⑨ Galactic superwinds/feedback

★ Integral field spectrograph for 0.35 to 1.0 μm
★ Flexible:
  – FOV from 8" to 30" x 20"
  – Selectable gratings R ~1,000 to 20,000
★ Optimized for very low surface brightness targets & faint emission features
★ High sensitivity
  – 2 wavelength optimized channels
  – Throughput > 25%
  – Precision sky subtraction
★ Keck II Nasmyth mount



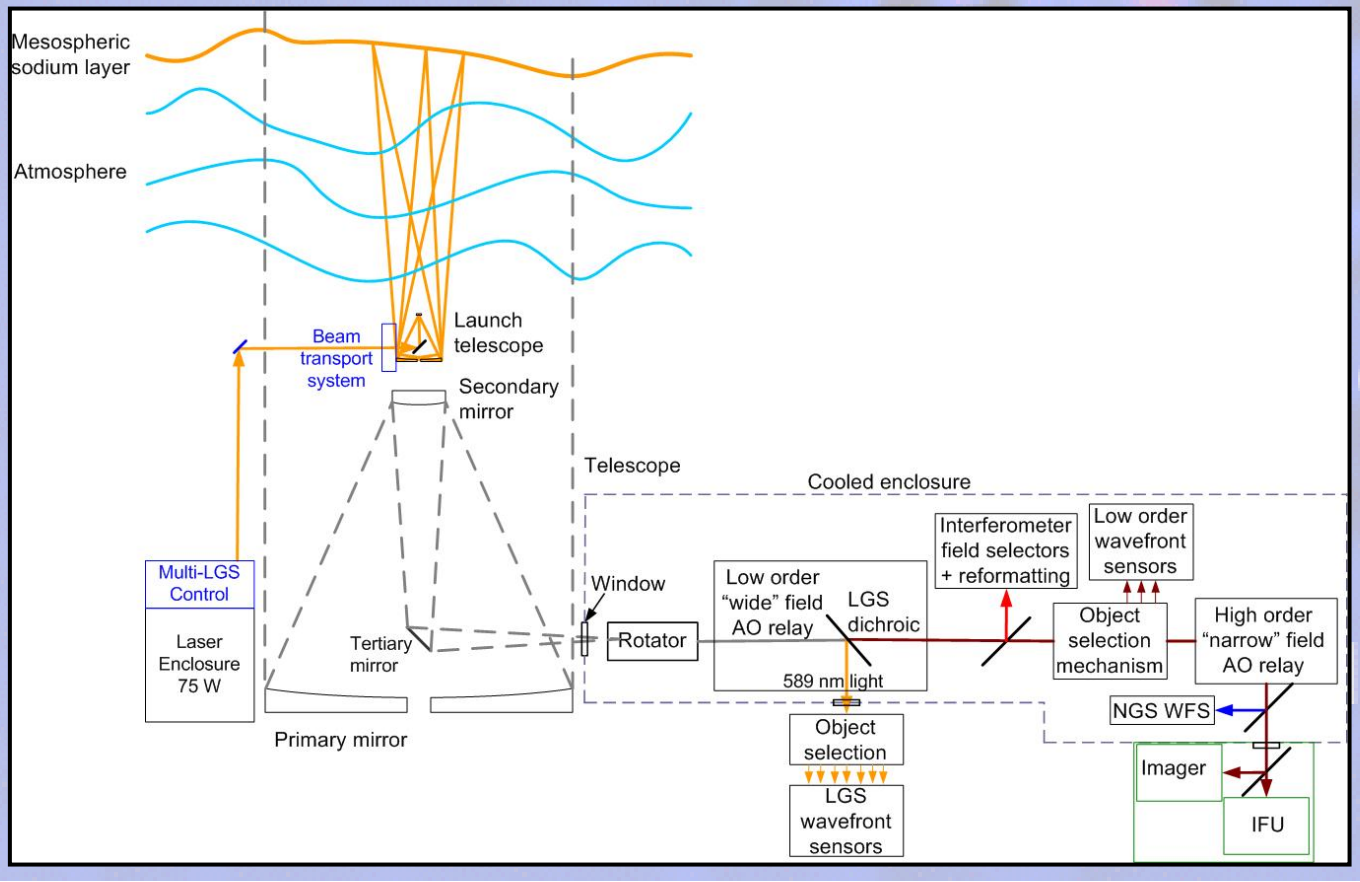
Future: Next Generation Adaptive Optics

Key New Capabilities

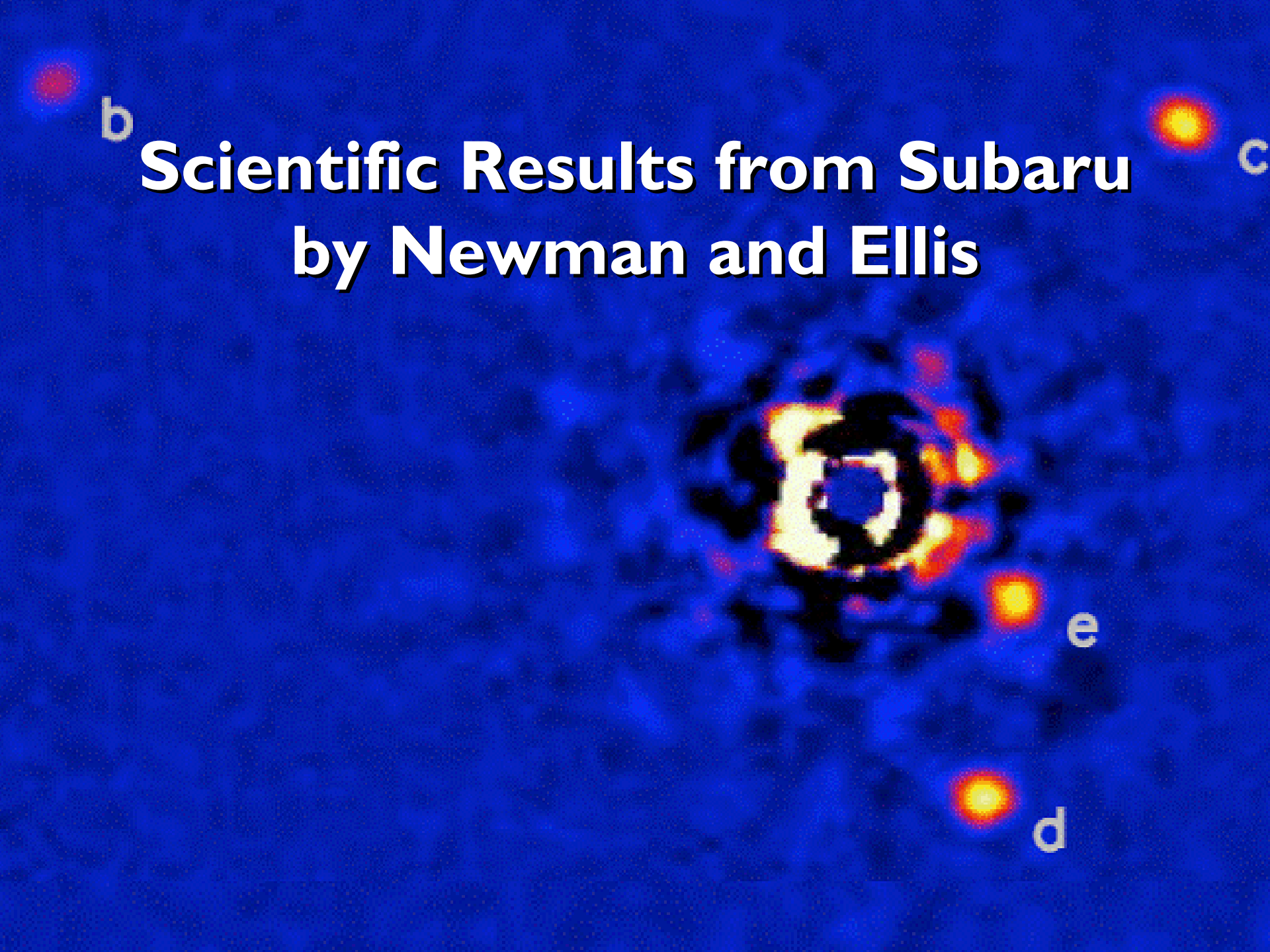
Improved performance (K-Strehl ~80%)

Correction into optical (0.75-1.0 μm)

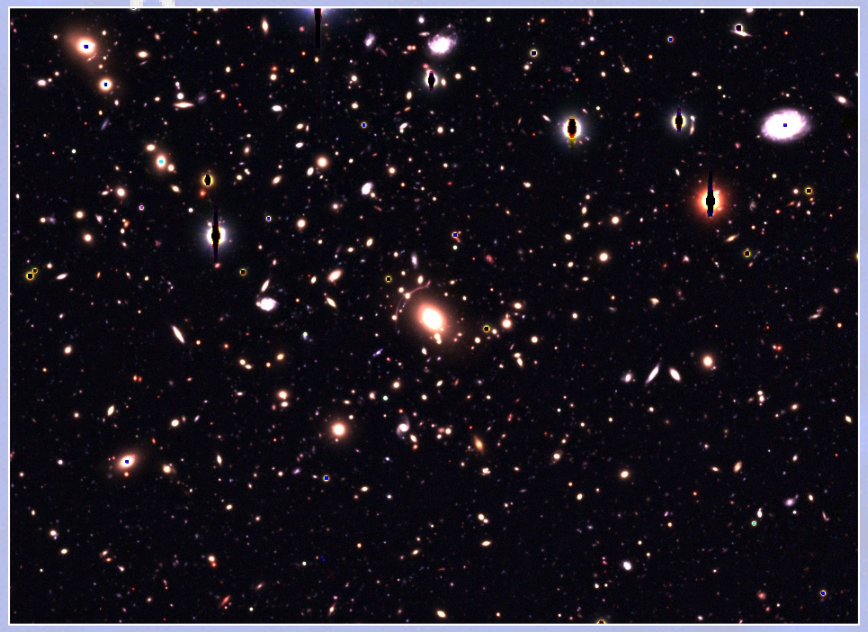
Much Higher Sky Coverage

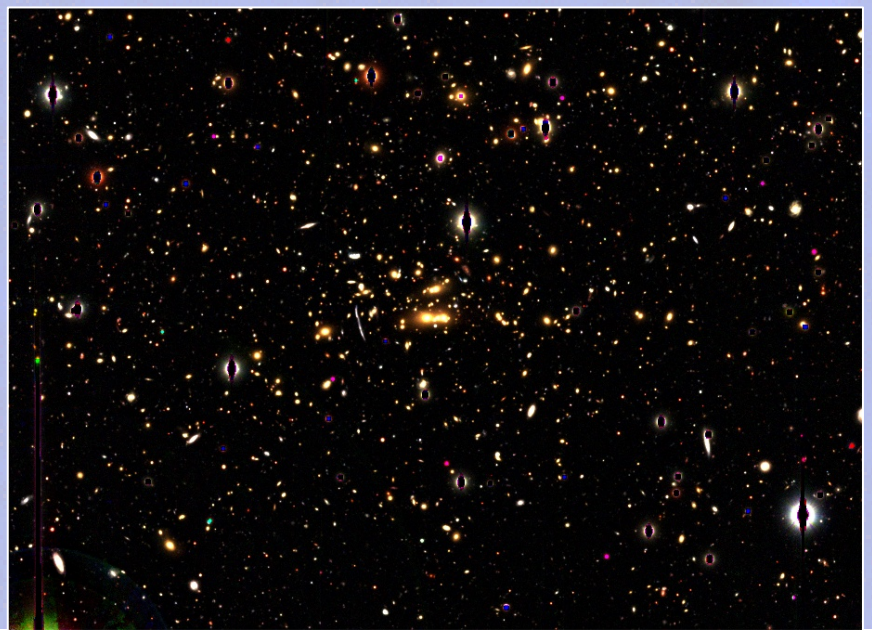


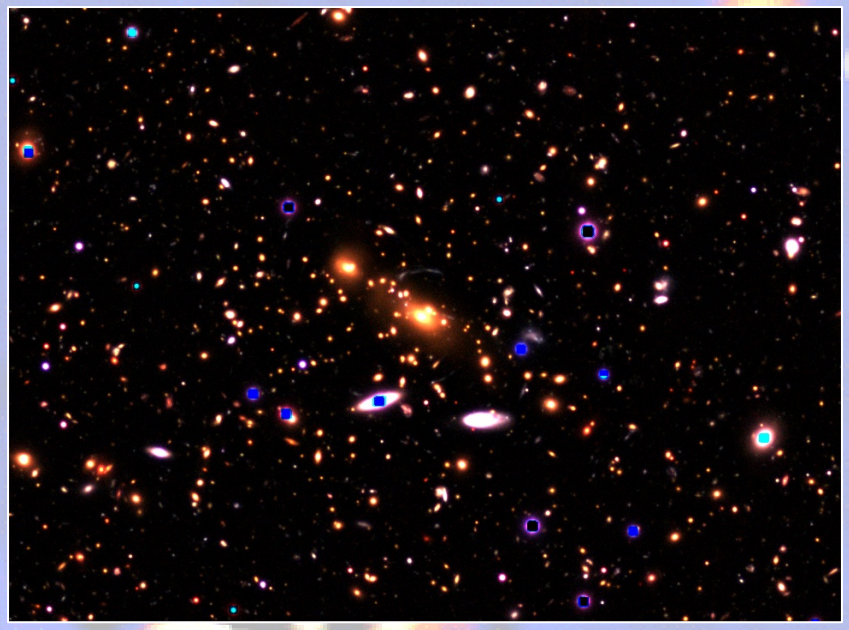
Scientific Results from Subaru by Newman and Ellis



A Detailed View of the Distribution of Dark Matter in Clusters of Galaxies





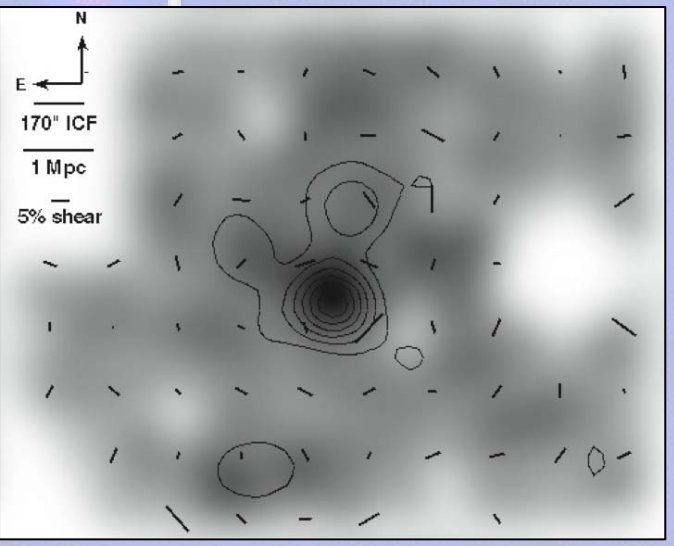


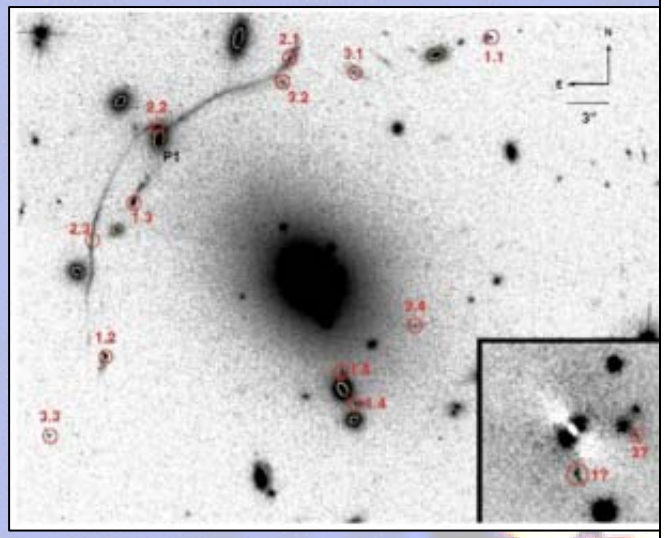
Newman et al (CIT) in collaboration with Miyazaki obtained BVRI SuprimeCam imaging of 9 galaxy clusters providing:

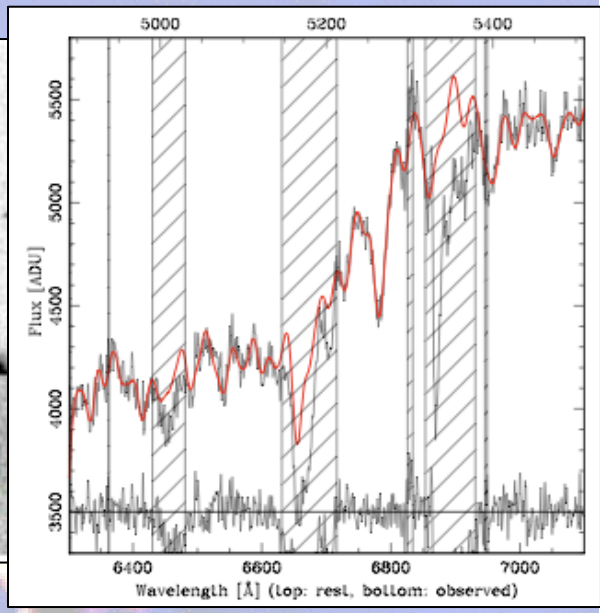
- photometric redshifts to R<25.5
- weak lensing analysis of DM distribution

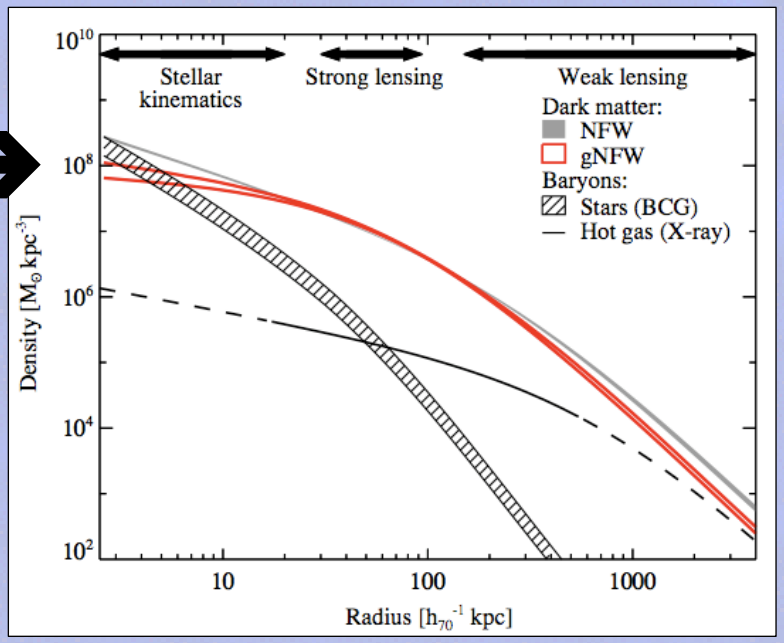
They combined this with HST strong lensing and central galaxy dynamics to test the form of the DM distribution over an unprecedented 3 dex in linear scale.

Subaru (weak Lensing) + HST (strong lensing) + Keck (cD kinematics)









Newman et al Ap J 706, 1078 (2009)

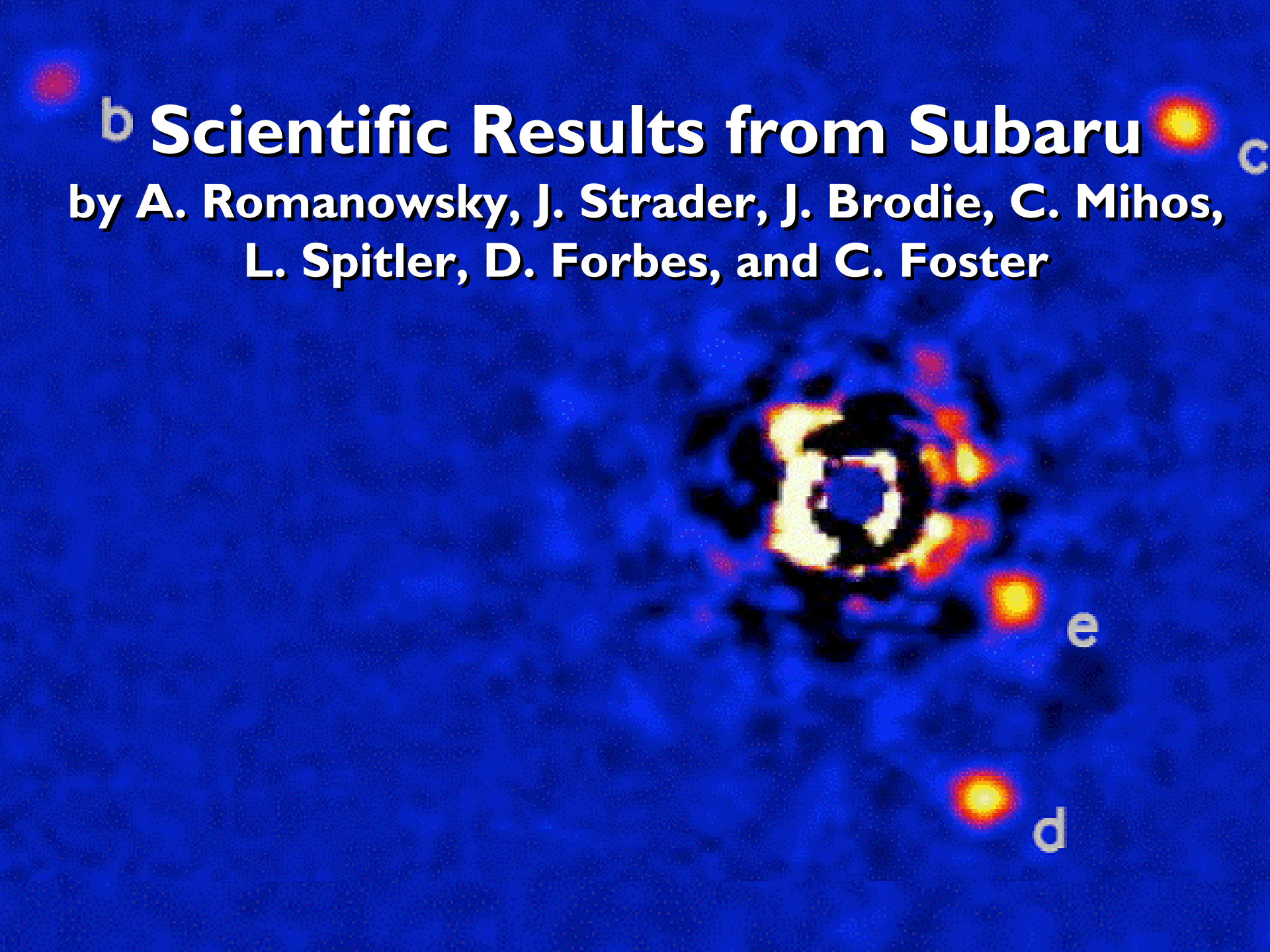
Weak lensing mass maps (Subaru) combine with strong lensing constraints (HST) and resolved stellar velocity dispersions of the cluster cD (Keck) to infer the DM density profile over 3 decades in radius (3 kpc – 3 Mpc)

- **DM distribution is less cuspy than in N-body simulations indicating possible inadequate treatment of baryon-DM interactions.**

- **Full analysis of 9 clusters will test universality of DM profiles and significance of this result.**

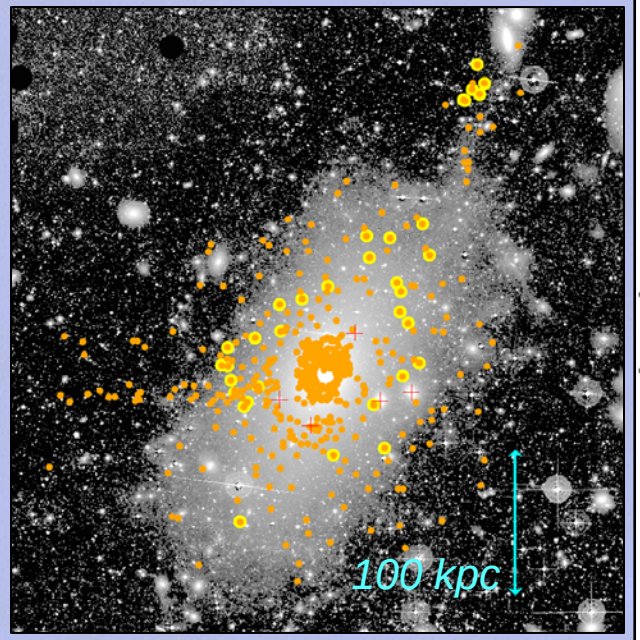
Scientific Results from Subaru

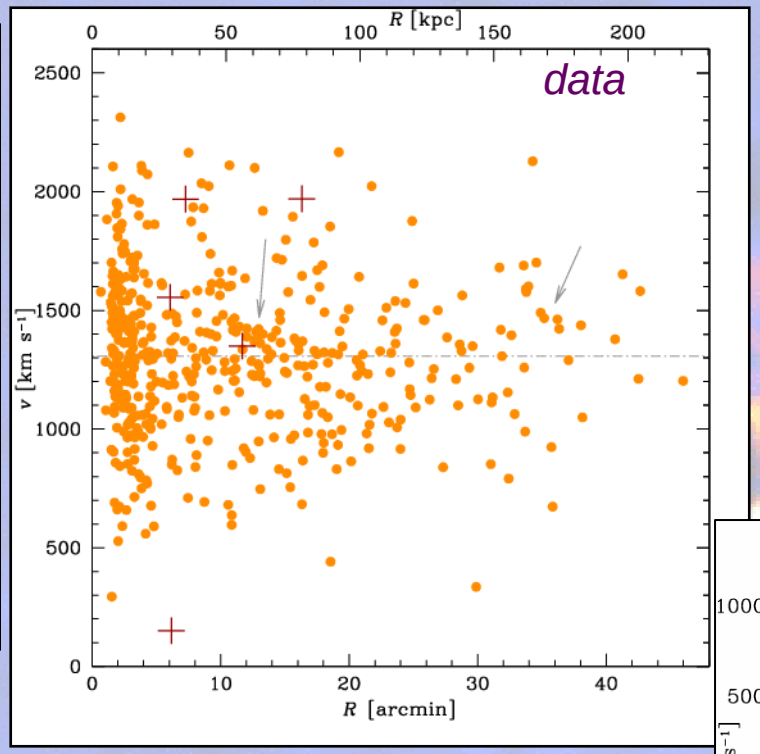
by A. Romanowsky, J. Strader, J. Brodie, C. Mihos, L. Spitler, D. Forbes, and C. Foster



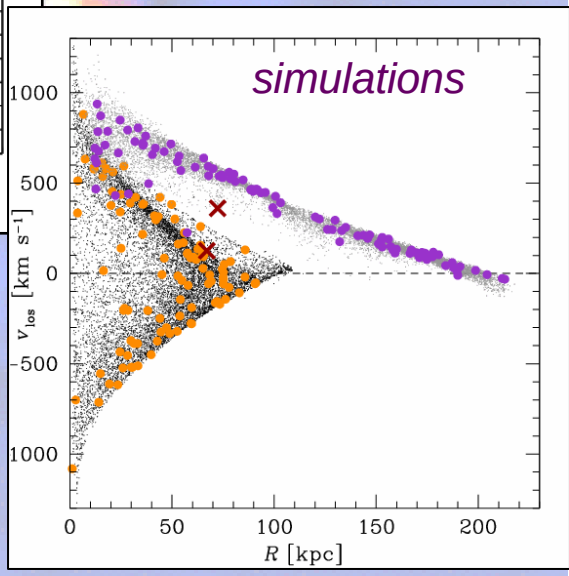
The ongoing assembly of a monster galaxy (M87) revealed by the kinematics of its halo

A. Romanowsky, J. Strader, J. Brodie, C. Mihos, L. Spitler, D. Forbes, C. Foster





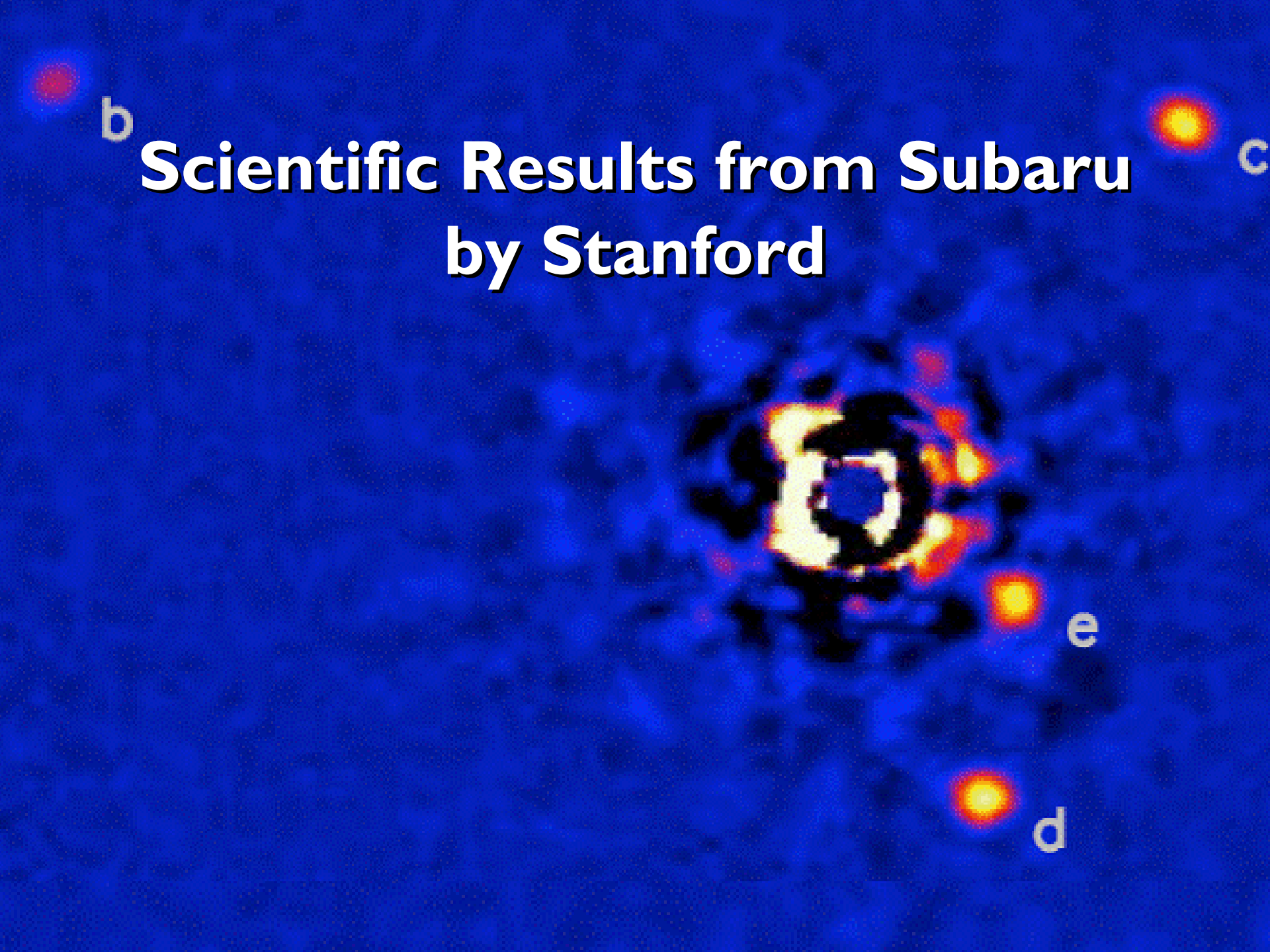
UC SANTA CRUZ



Globular cluster kinematics reveal previously unknown massive shell in phase-space, implying recent accretion event

- *Suprime-Cam ideal for GC photometry, DEIMOS for spectroscopy*

Scientific Results from Subaru by Stanford

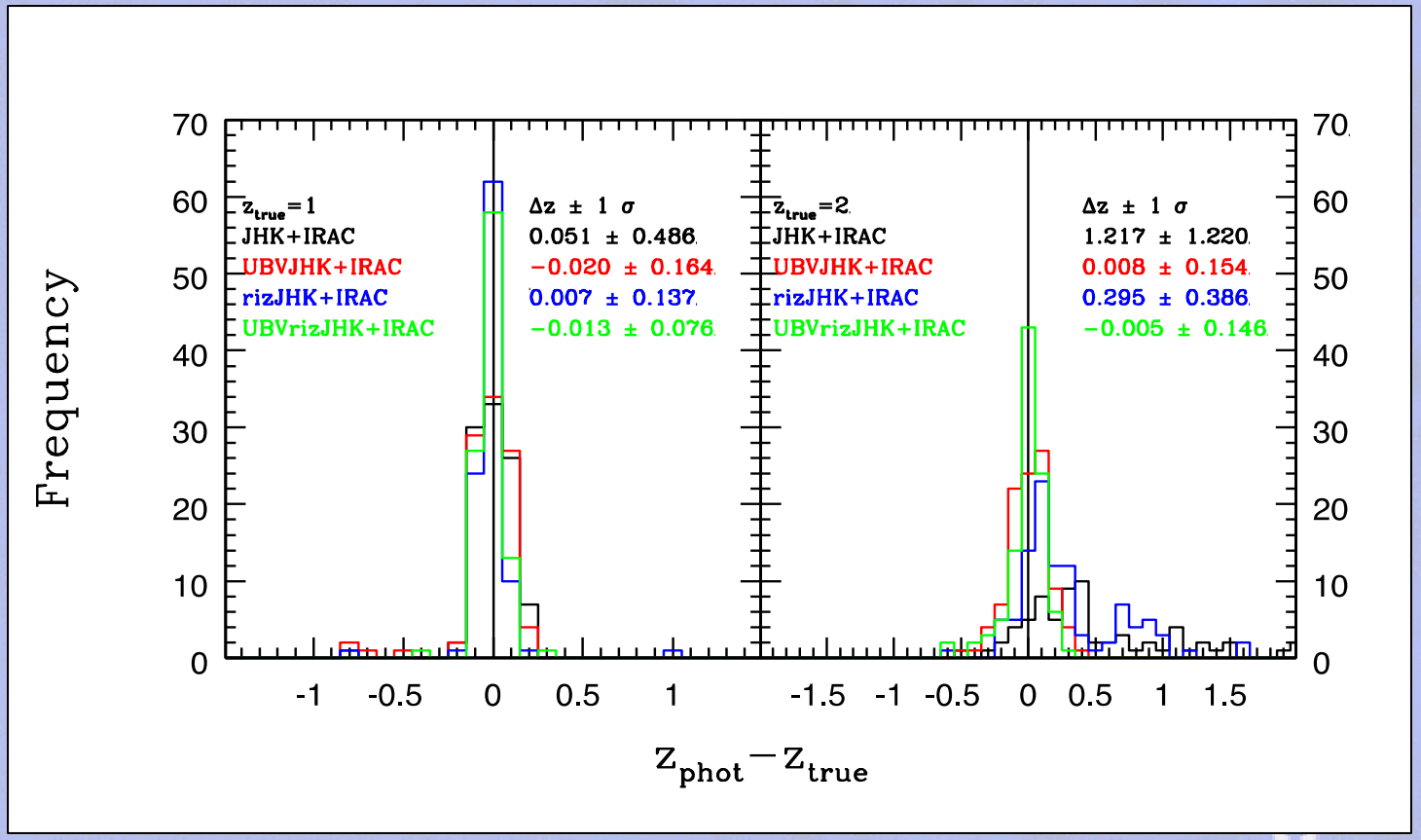


Subaru Observing Time
Adam Stanford, January 2011

- ★ SERVS: Spitzer Extragalactic Representative Volume Survey
  - IRAC Legacy program covering 18 square degrees
- ★ Suprime-Cam optical imaging of three northern fields in riz bands undertaken to enable better photometric redshifts
- ★ 4 nights (1 pending in 2011A), almost all good; covered 5 deg^2 in z, 6 deg^2 in i, and 2 deg^2 in r down to the required depths of riz = 27/26/25 AB mag (10 s).
- ★ Data quality is excellent, as was the observing support

Suprime-Cam Optical Imaging for SERVS

Photometric Redshift Predictions for Galaxies at z=1 (left) and z=2 (right)



Deep riz photometry from Suprime-Cam significantly improves the photometric redshifts of galaxies detected by IRAC at e.g. z~1 and z~2.

Keck Observatory and our science community strongly value our collaboration with Subaru