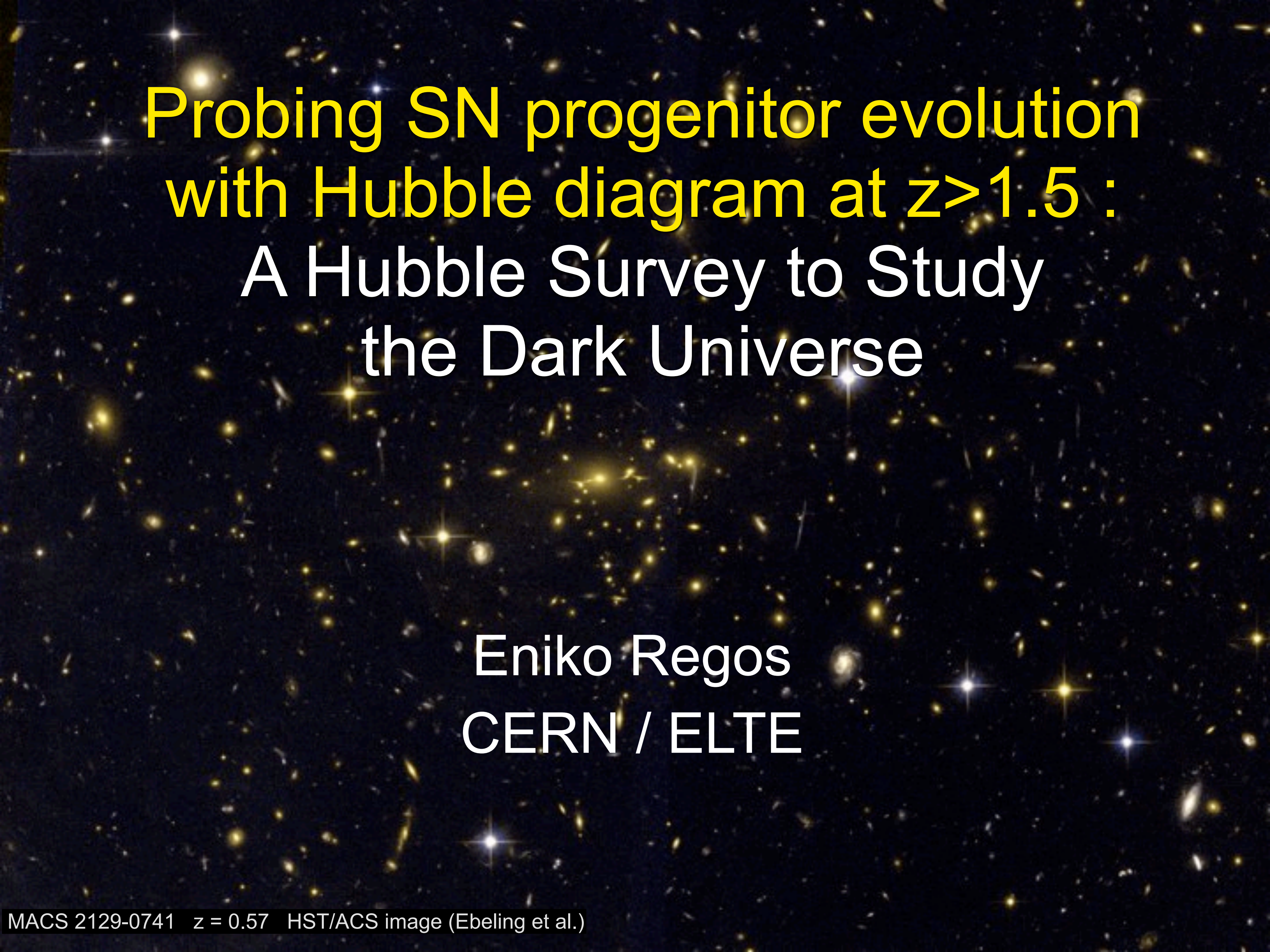
Probing SN progenitor evolution with Hubble diagram at z>1.5 :

A Hubble Survey to Study the Dark Universe

Eniko Regos
CERN / ELTE



MACS 2129-0741   z = 0.57   HST/ACS image (Ebeling et al.)

Fundamental Questions That Remain Unanswered or Unverified

- Why is the expansion of the universe accelerating?
  - Is it something other than Λ?
  - What are the parameters of the dark energy equation of state?
  - What is the time derivative of the equation of state?
  - How standard are our "standard" candles (cosmic distance indicators)? Need better measurements of systematic effects at large lookback times.

$w = P / \rho c^2$

$w = -1$ for Λ=const

$w \neq -1$?

Possible for other models (e.g. Quintessence, k-essence)

Is w a f(z)?

$w(z) = w_o + w_a z/(1+z)$

(see Linder 2003)

CLASH:

Cluster Lensing And Supernova survey with Hubble

An Hubble Space Telescope Multi-Cycle Treasury Program designed to place new constraints on the fundamental components of the cosmos: dark matter, dark energy, and baryons.

To accomplish this, we will use galaxy clusters as cosmic lenses to reveal dark matter and magnify distant galaxies.

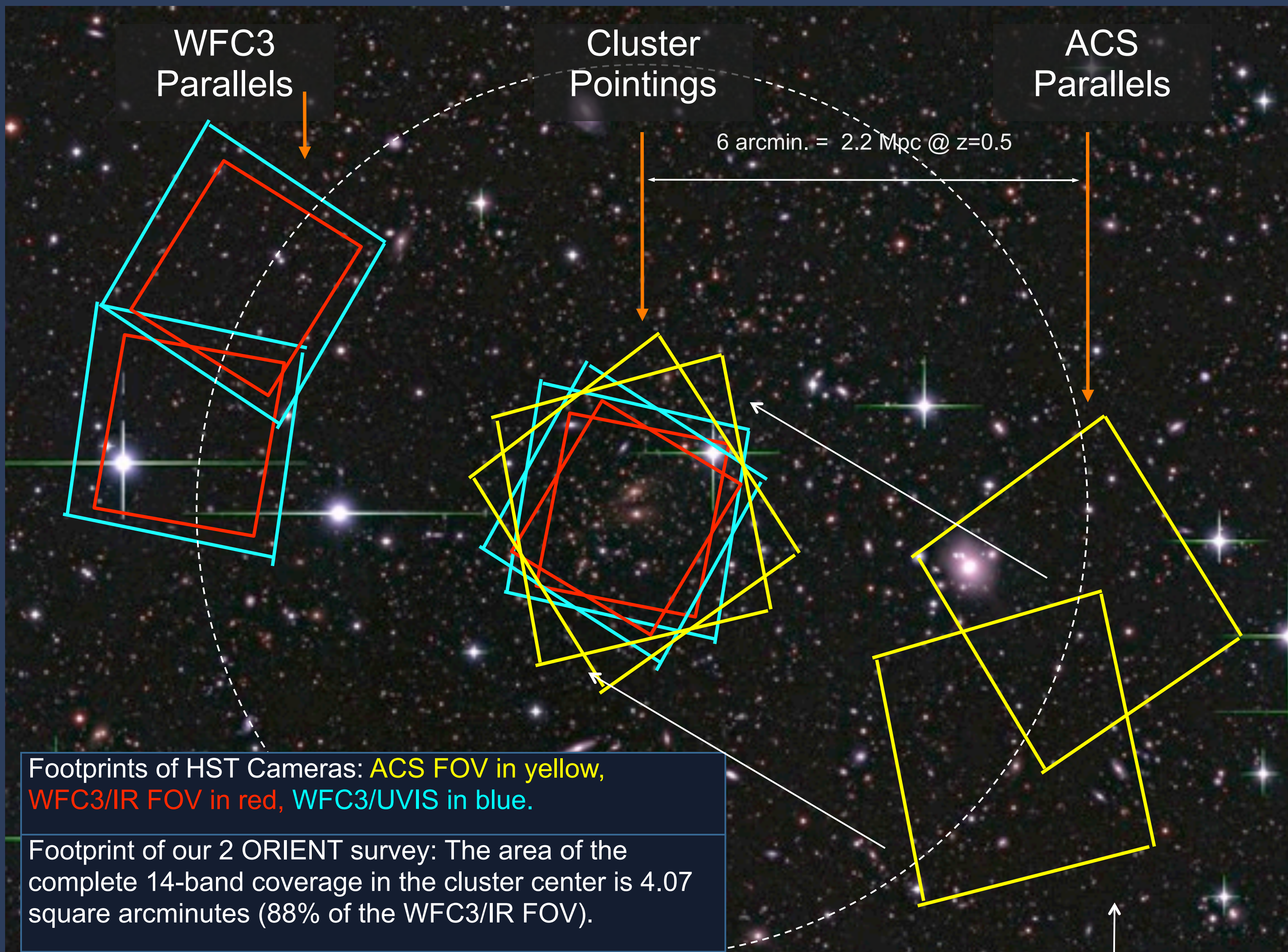
The galaxy clusters are chosen based on their smooth and symmetric x-ray surface brightness profiles: "simpler" lenses to model and minimizes lensing bias. All clusters have masses ranging from ~5 to ~30 x 10^{14} M_{SUN}. Redshift range covered: $0.18 < z < 0.90$ (11.3 Gyr > t_U > 6.3 Gyr).

Multiple epochs enable a $z > 1$ SN search in the surrounding field (where lensing magnification is low). This will allow us to improve the constraints on both the time dependence of the dark energy equation of state and on the amplitude of systematic errors in cosmological parameters.

Marc Postman, P.I.	Space Telescope Science Institute (STScI)
Matthias Bartelmann	Universität Heidelberg
Narciso “Txitxo” Benitez	Instituto de Astrofisica de Andalucia (IAA)
Rychard Bouwens	Leiden University
Larry Bradley	STScI
Thomas Broadhurst	Tel Aviv University (TAU) / IAA
Dan Coe	Jet Propulsion Laboratory (JPL) / Caltech
Megan Donahue	Michigan State University
Rosa Gonzales-Delgado	IAA
Holland Ford, co-P.I.	The Johns Hopkins University (JHU)
Ole Host	University College London (UCL)
Leopoldo Infante	Universidad Católica de Chile
Stephanie Jouvel	UCL
Daniel Kelson	Carnegie Institute of Washington
Ofer Lahav	UCL
Doron Lemze	TAU
Dani Maoz	TAU / Wise Observatory
Elinor Medezinski	TAU
Leonidas Moustakas	JPL / Caltech
Enikö Regös	European Laboratory for Particle Physics (CERN)
Adam Riess	STScI / JHU
Piero Rosati	European Southern Observatory
Stella Seitz	Universitas Sternwarte München
Keiichi Umetsu	Academia Sinica, Institute of Astronomy & Astrophysics
Arjen van der Wel	Max Planck Institüt für Astrophysik
Wei Zheng	JHU
Adi Zitrin	TAU

Post-doc
Grad student

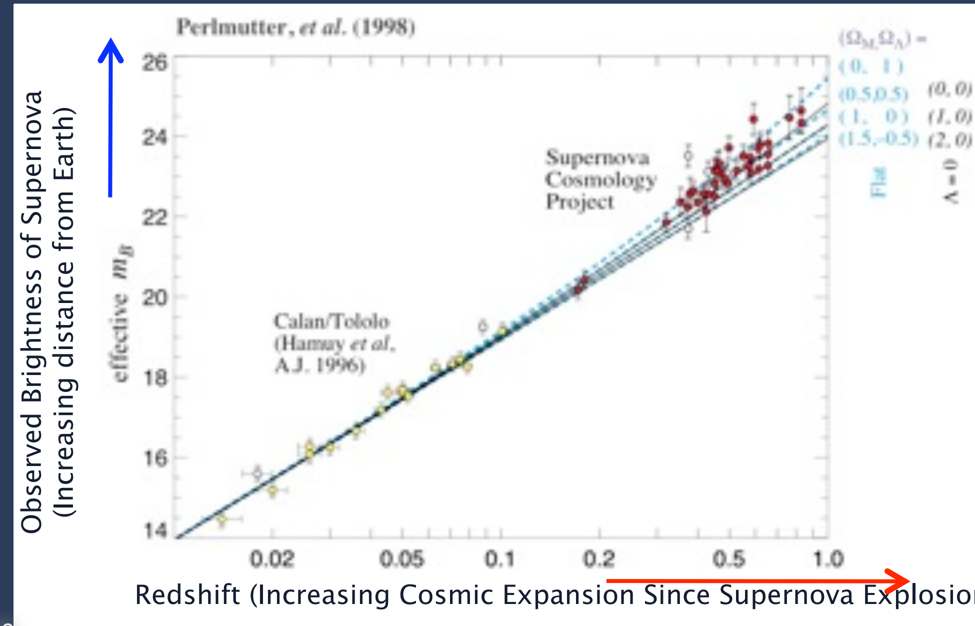
CLASH: An HST Multi-Cycle Treasury Program



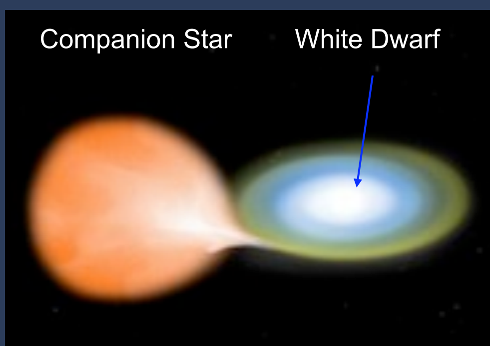
SN search cadence: 10d–14d, 4 epochs per orient

Lensing amplification small at these radii

Constraining Dark Energy by measuring the change in the cosmic scale factor with time



F. Ropke 2009



White Dwarf in binary system. Progenitor of a “Type 1a” supernova.

Accretion of material onto the white dwarf (WD) leads to increase in temperature of WD core. This leads to a runaway thermonuclear deflagration front of Carbon and, eventually, Oxygen burning. WDs are susceptible to runaway fusion as degeneracy pressure is independent of temperature.

The star ultimately explodes when Chandrasekhar mass limit is approached. Homogeneous (few %) explosion mass produces a nearly constant amount of light. Since we know the intrinsic luminosity, distance to the SN (and its host galaxy) can be accurately computed.

Discovering Type Ia SNe at z>1 with HST:

Step 1: Detection:

Pre-explosion image

SN Detection image

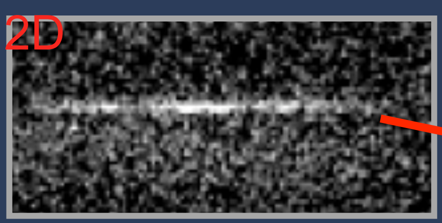
Difference image

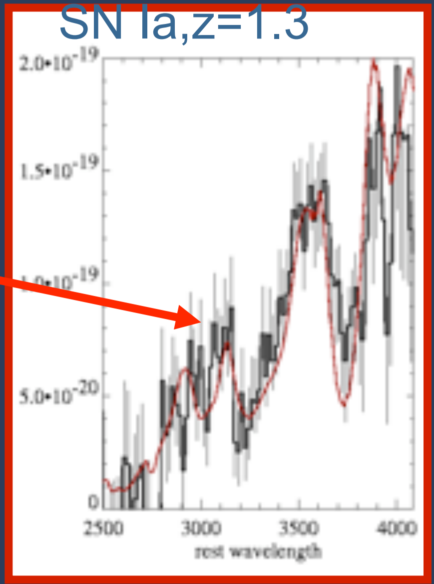
Step 2: Winnowing

SN Ia
are red
in UV

Step 3: Identification, redshift

Obtain HST grism spectrum:



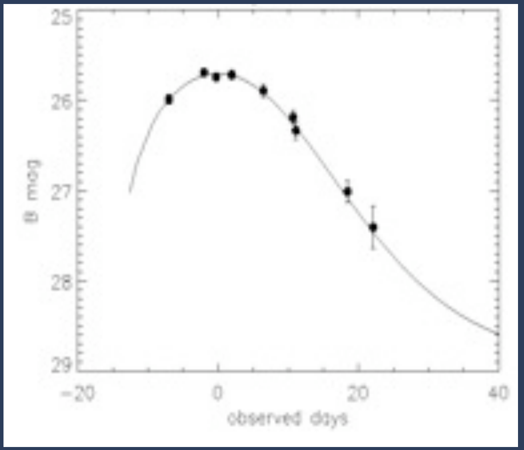


Ground has never measured redshift this high

Step 4: Follow-up, near-IR

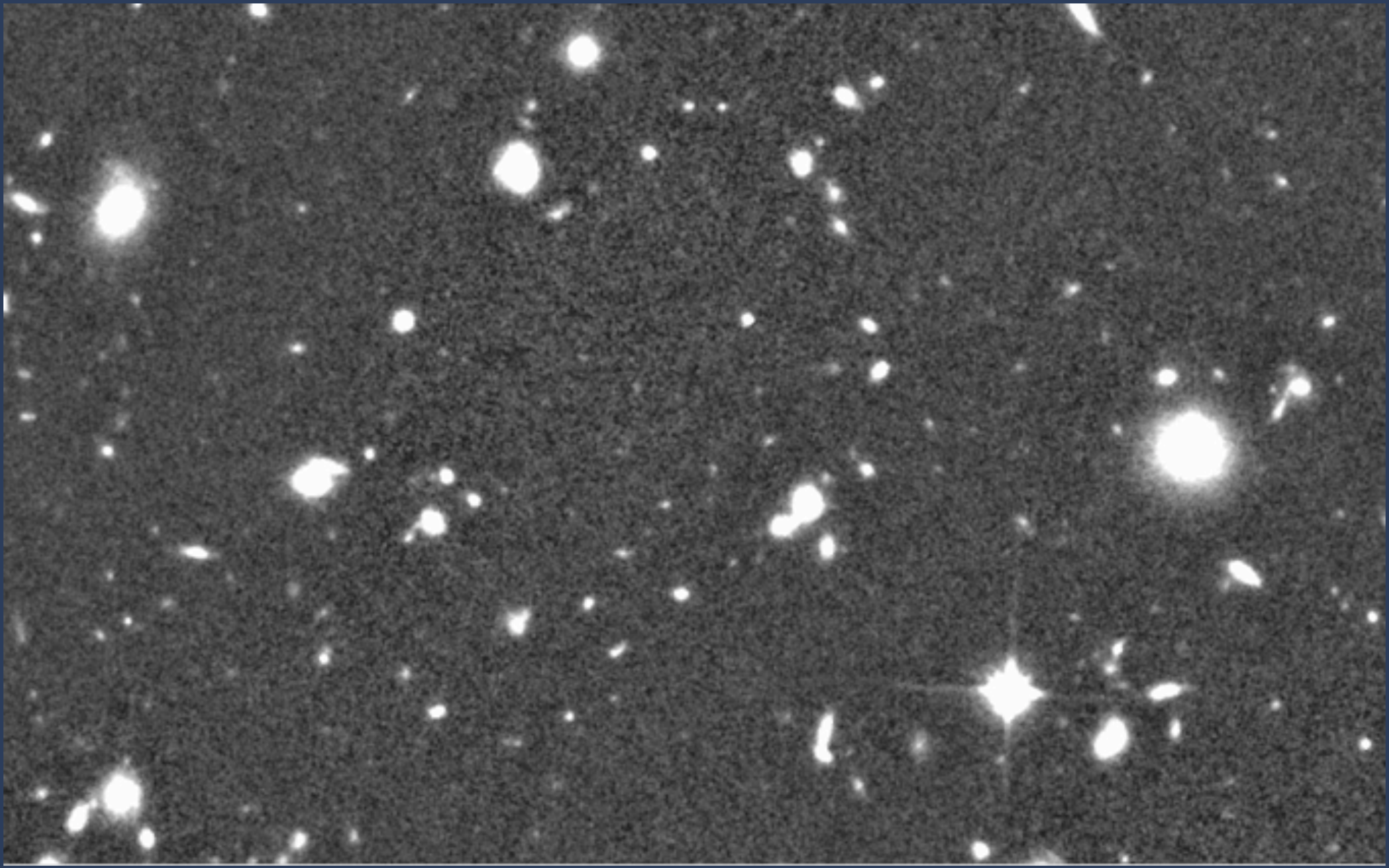
NICMOS:

Light Curve



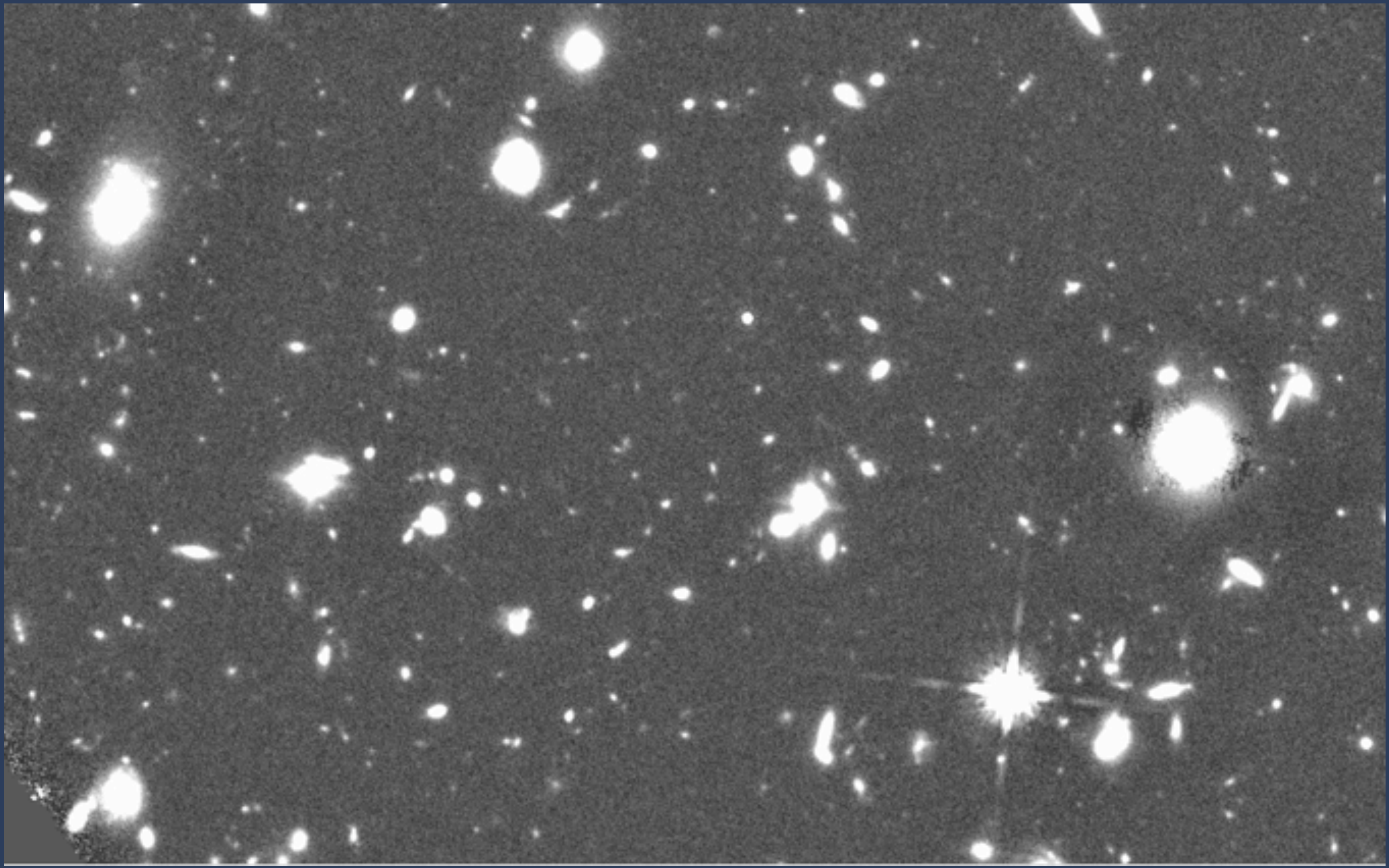
Peak and shape yields distance

Old HST NIR Camera – 72 orbits



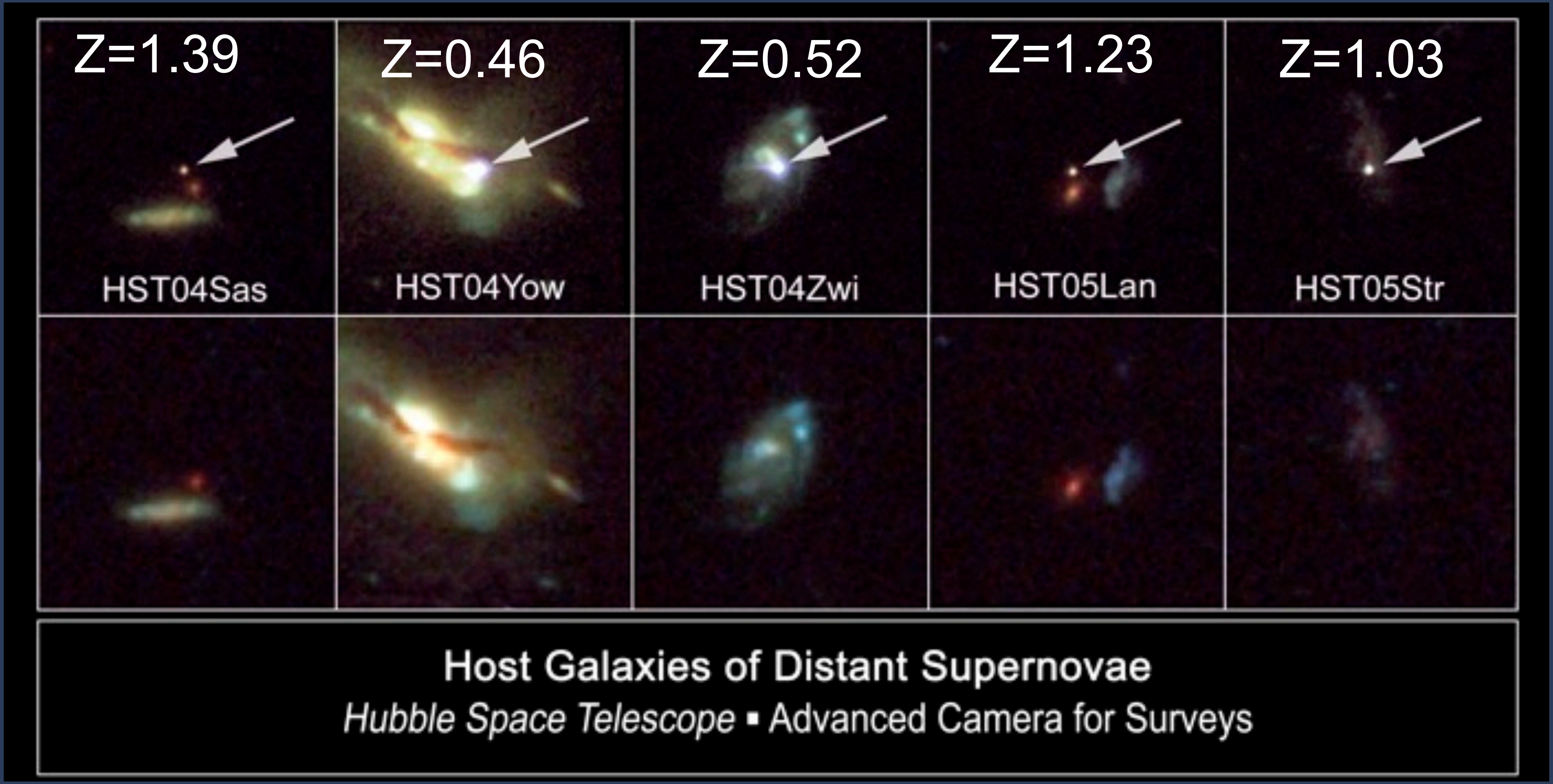
Slide credit: Garth Illingworth, UCSC, Lick Observatory

New HST NIR Camera – 16 orbits

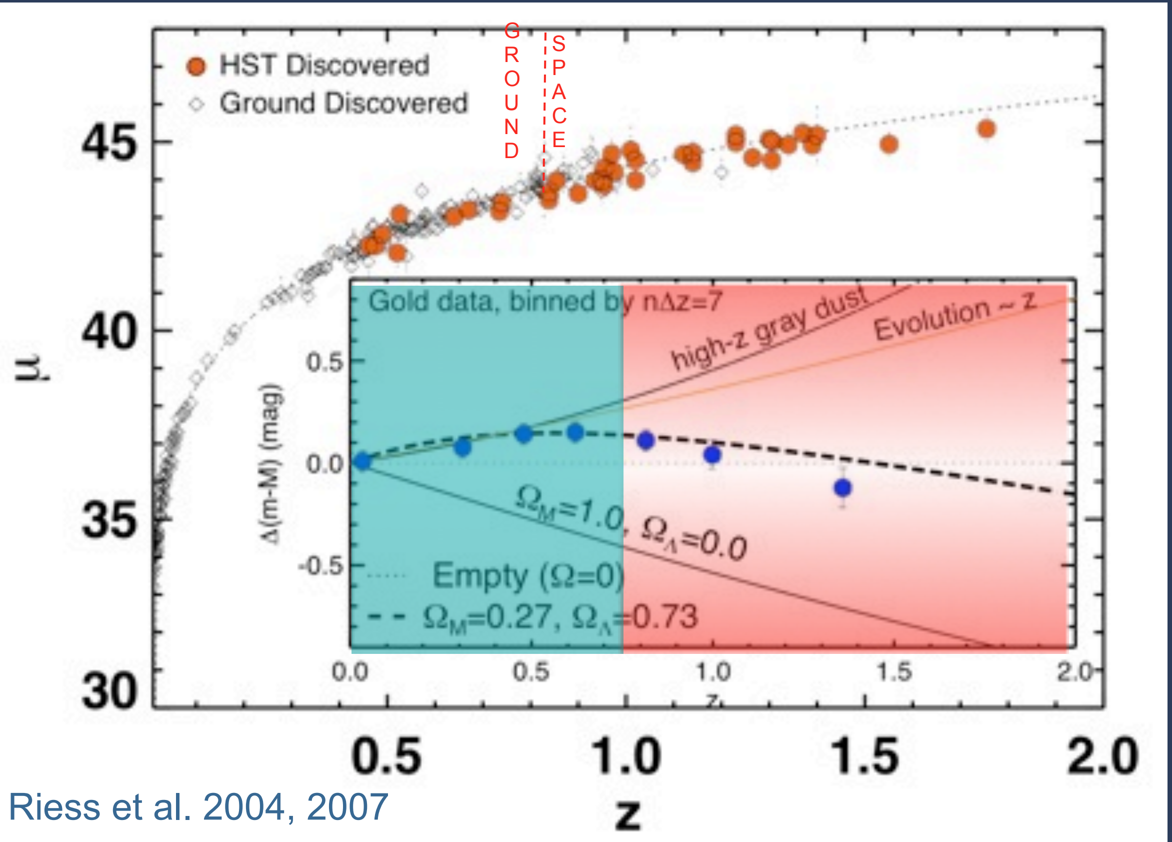


Slide credit: Garth Illingworth, UCSC, Lick Observatory

Higher-z SNe Ia from ACS



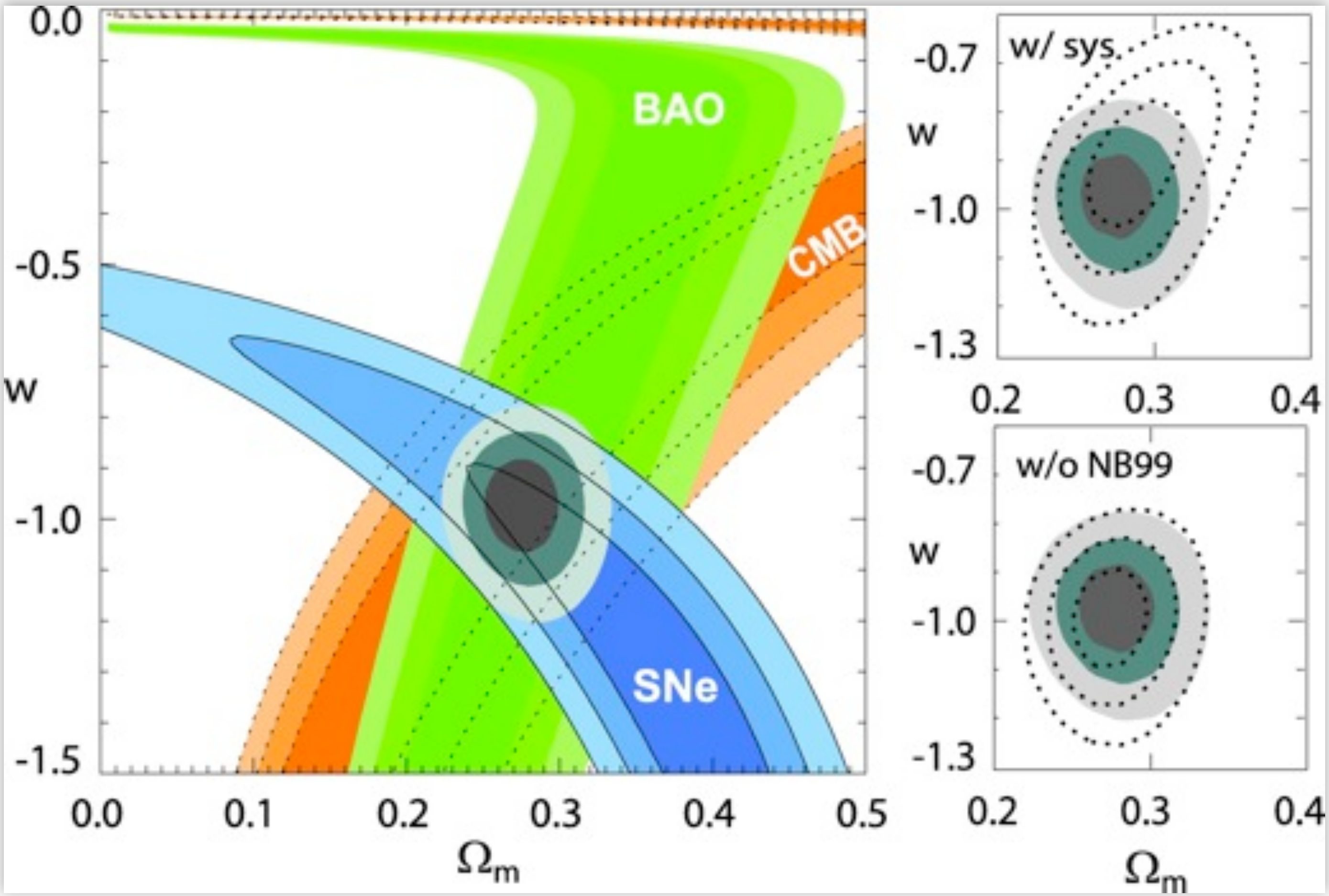
HST: 23 SNe Ia at z>1 Find Past Deceleration, Confirms Dark Energy+Dark Matter Model



Riess et al. 2004, 2007

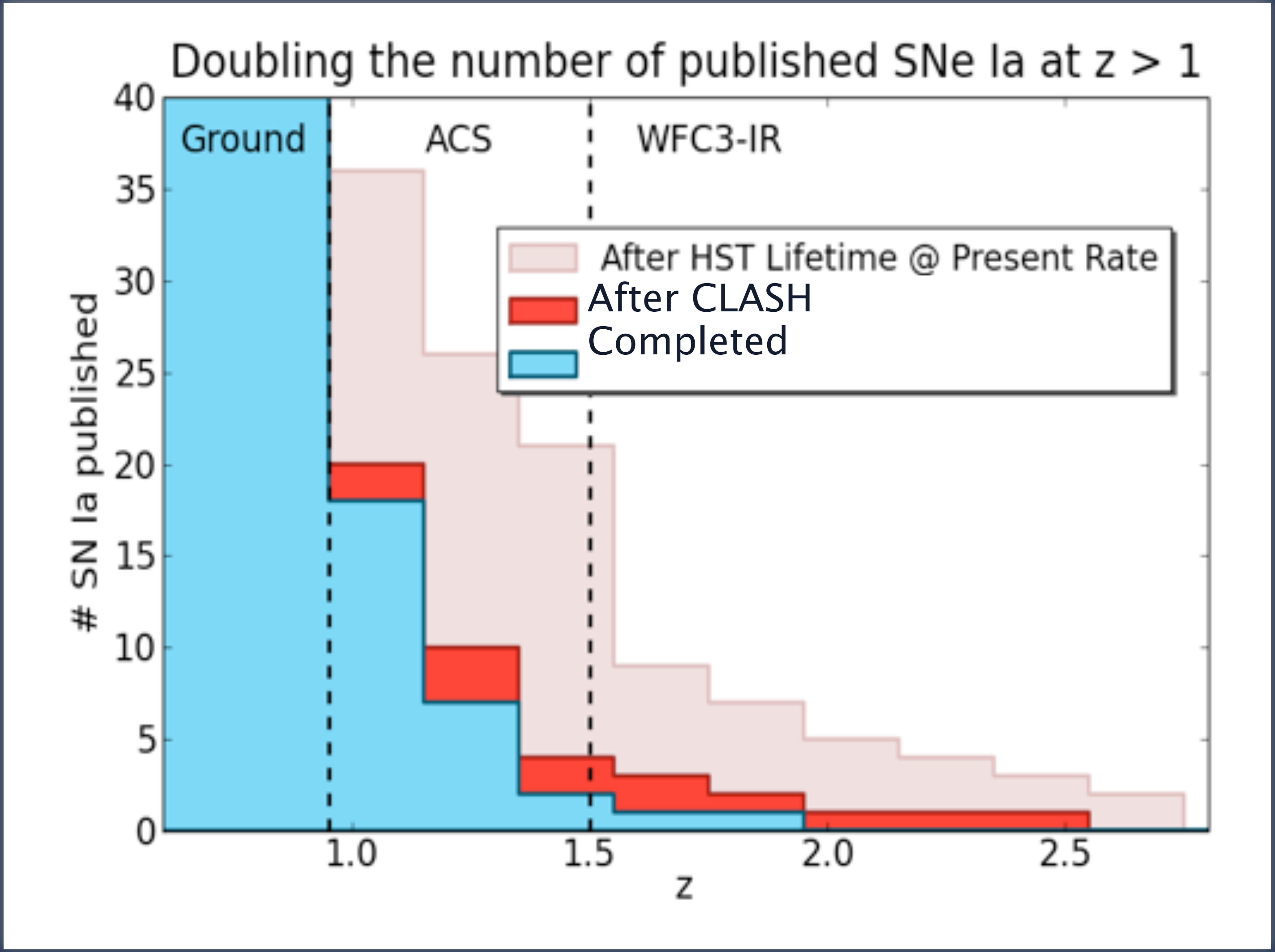
Current Observational Constraints

Kowalski et al. 2008: $w = -0.969^{+0.059}_{-0.063}$ (stat) $^{+0.063}_{-0.066}$ (sys)



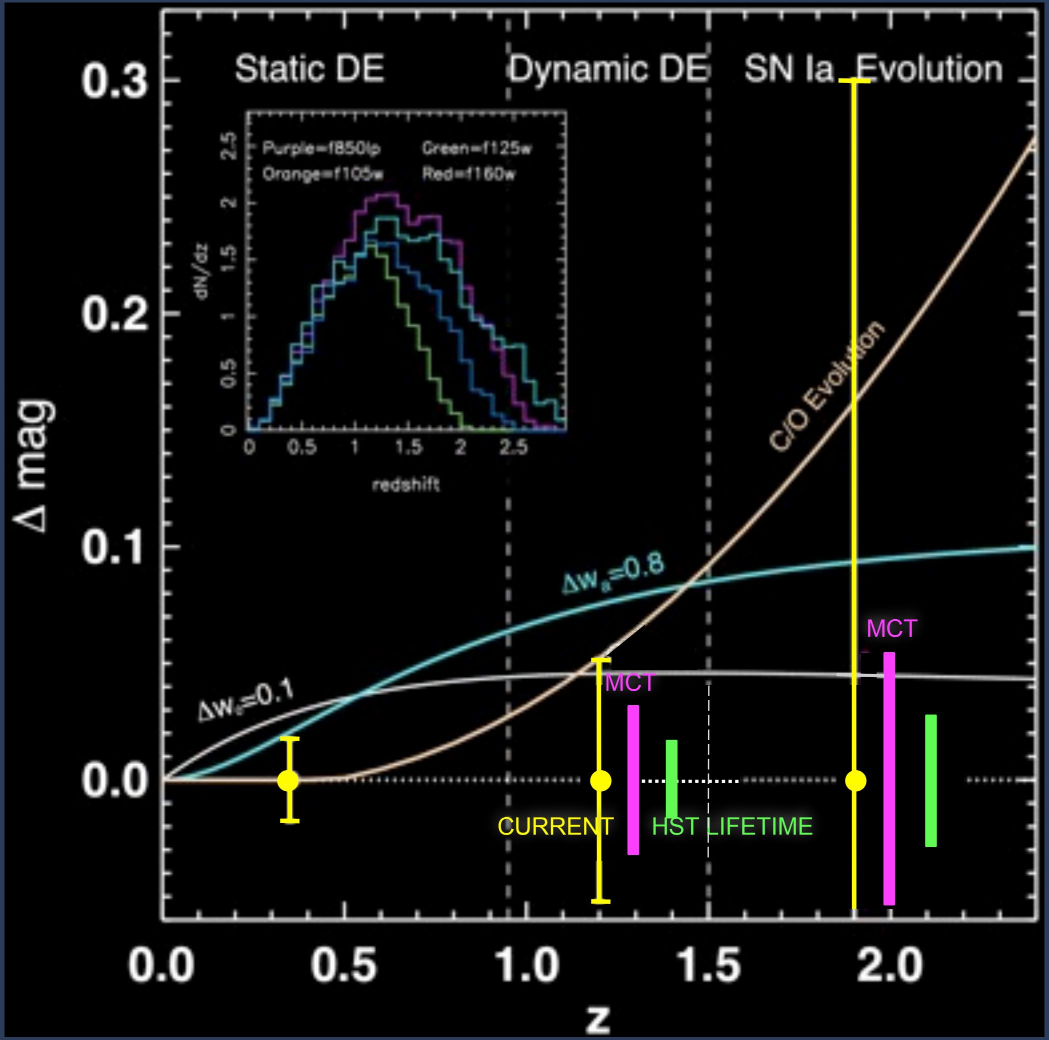
SN data: SNLS, ESSENCE, high-z HST SNe, plus a few other datasets
BAO: SDSS (Eisenstein et al. 2005)
CMB: WMAP 5-year data release (Dunkley et al. 2009)

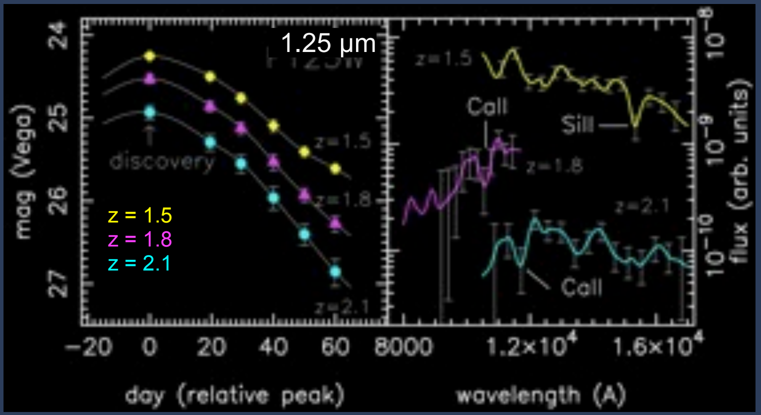
We expect to double the number of Type Ia supernovae at z > 1



Depending on SN delay time, expect to find 10 – 20 SNe at z>1; at least 5 with z > 1.5

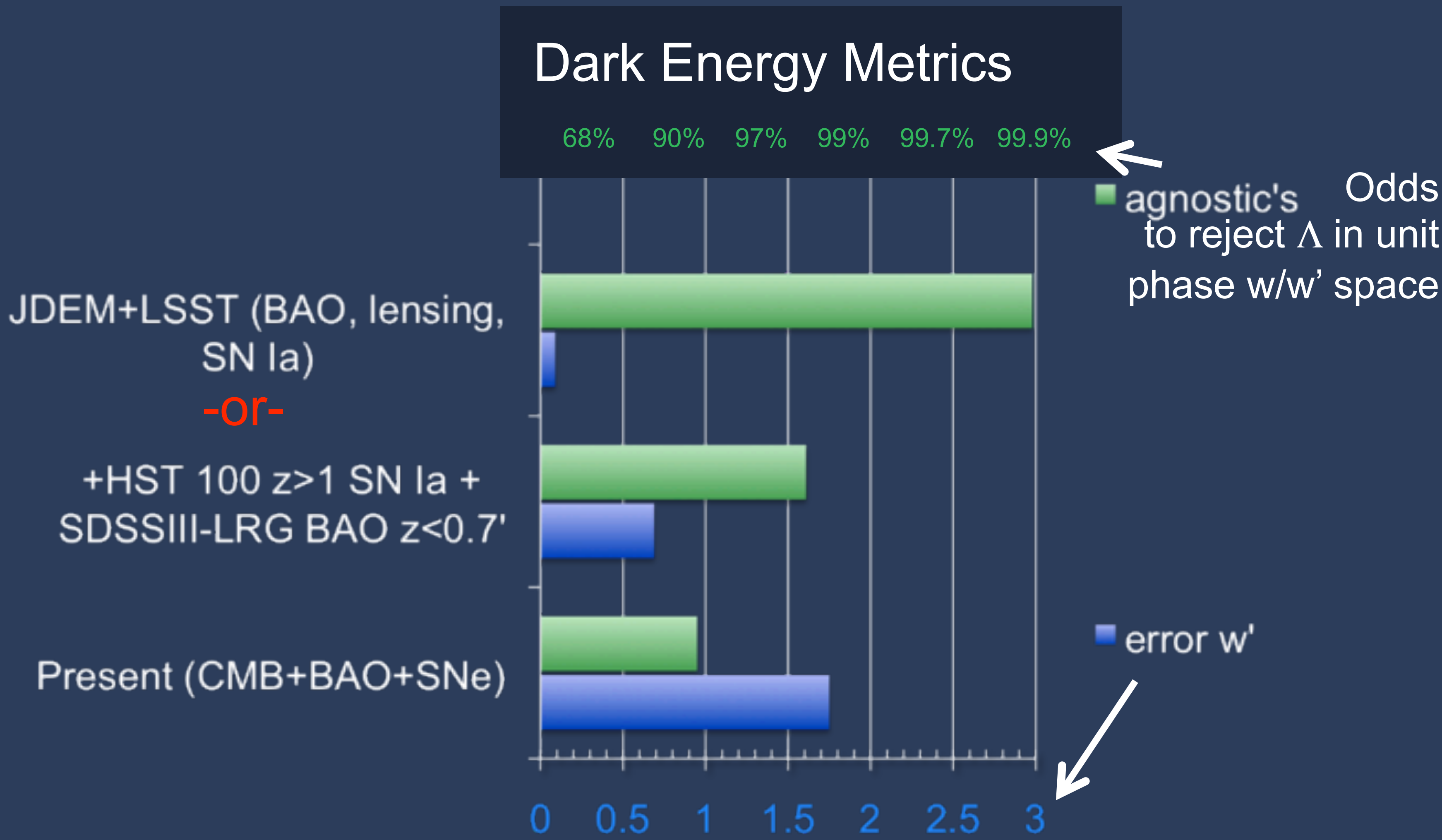
HST & WFC3-IR, Gateway to SNe Ia at z>2





Two MCT HST programs (CLASH + CANDELS) will detect SNe Ia at 1.0 < z < 2.5. They will provide a direct test of systematics in matter-dominated universe (e.g., Riess & Livio 2006).

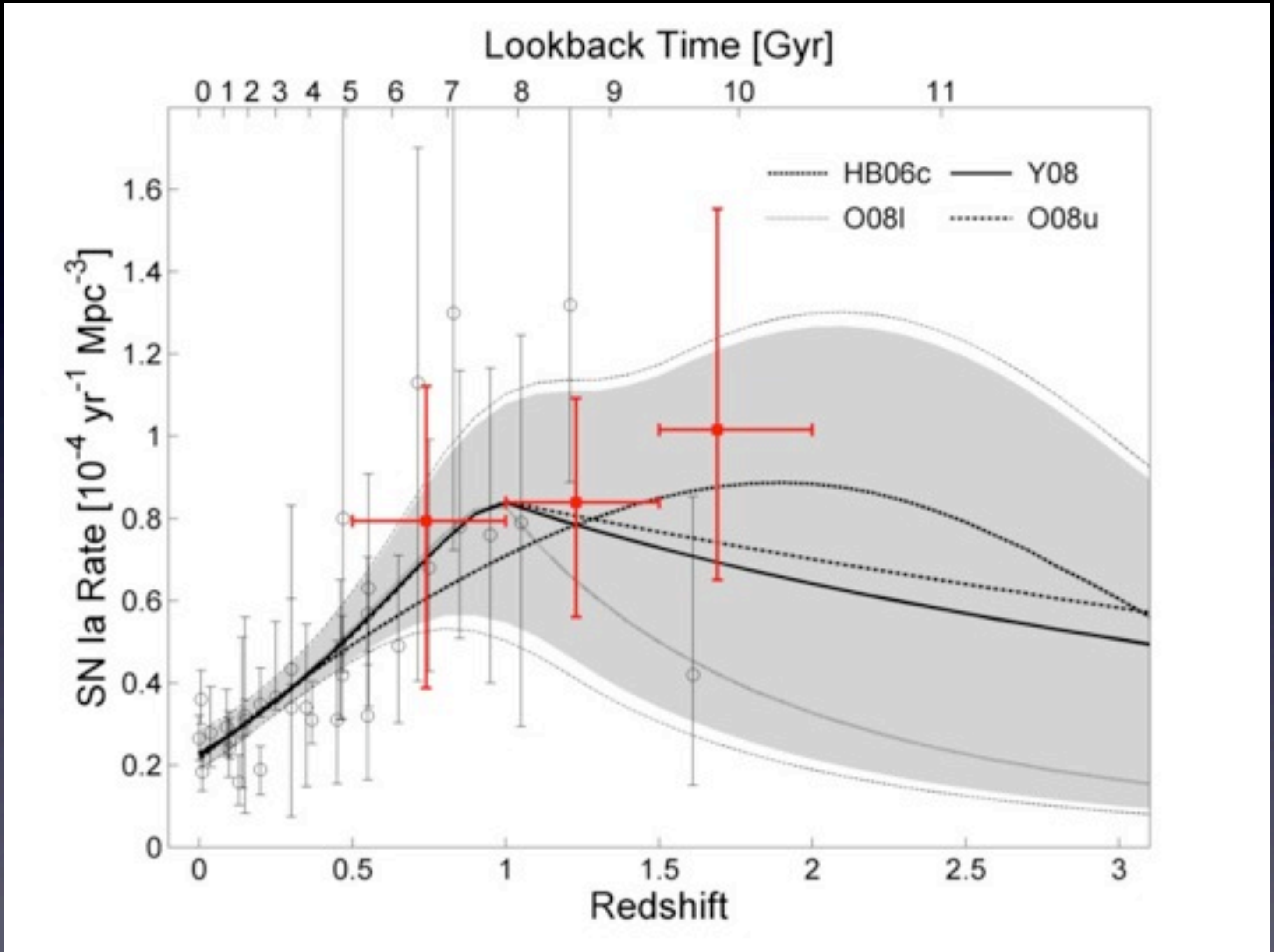
The Future of Dark Energy Measurements



Present=Planck CMB priors, SDSS II BAO, SN World compilation, 5% H_0 prior

Science Goals:

SN Rates



Or Graur

Dan Maoz

Steve Rodney

Tomas Dahlen

Lou Strolger

Predicted

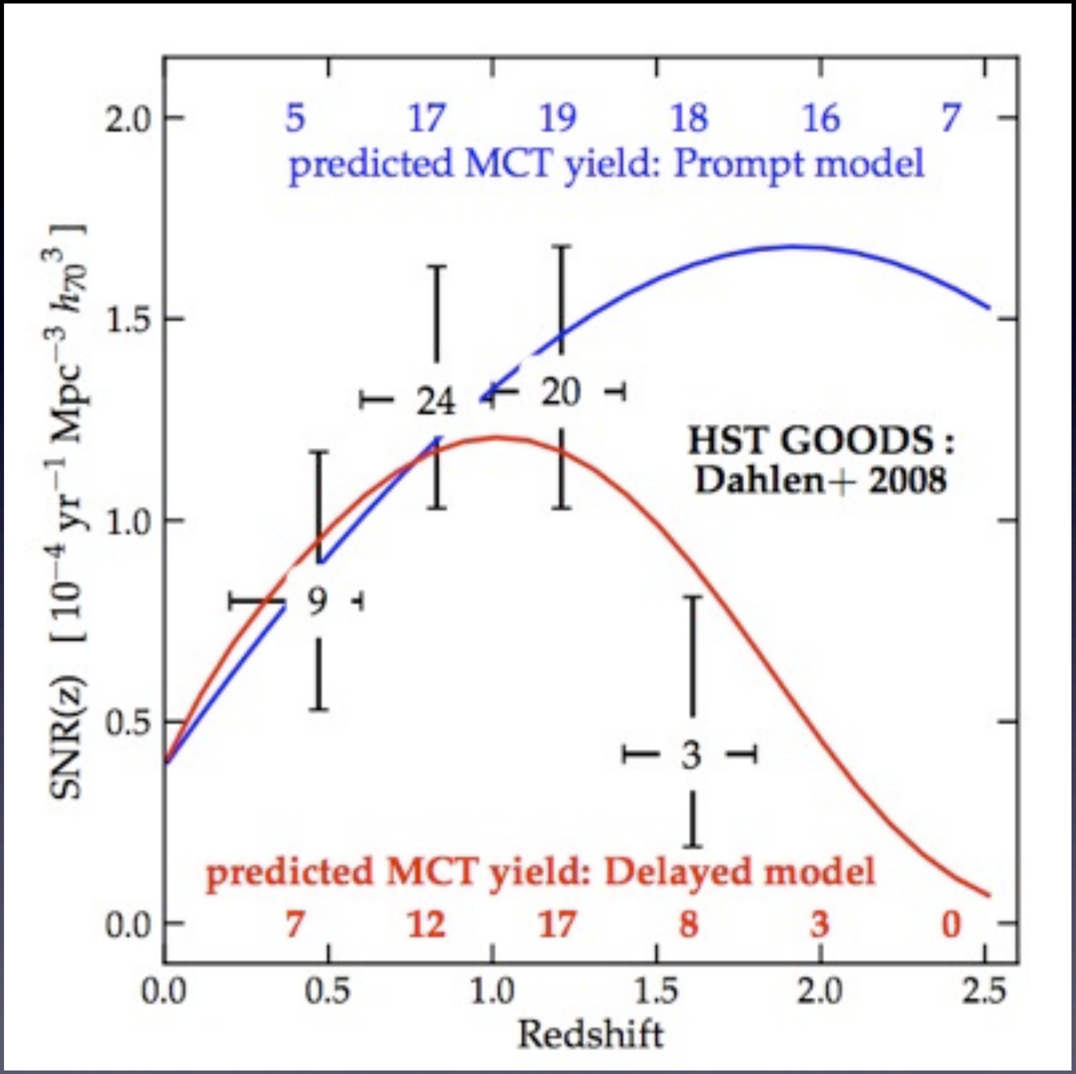
SNIa Yield:

z>1 : 10-30

z>2 : 0-4

Science Goals:

SN Rates



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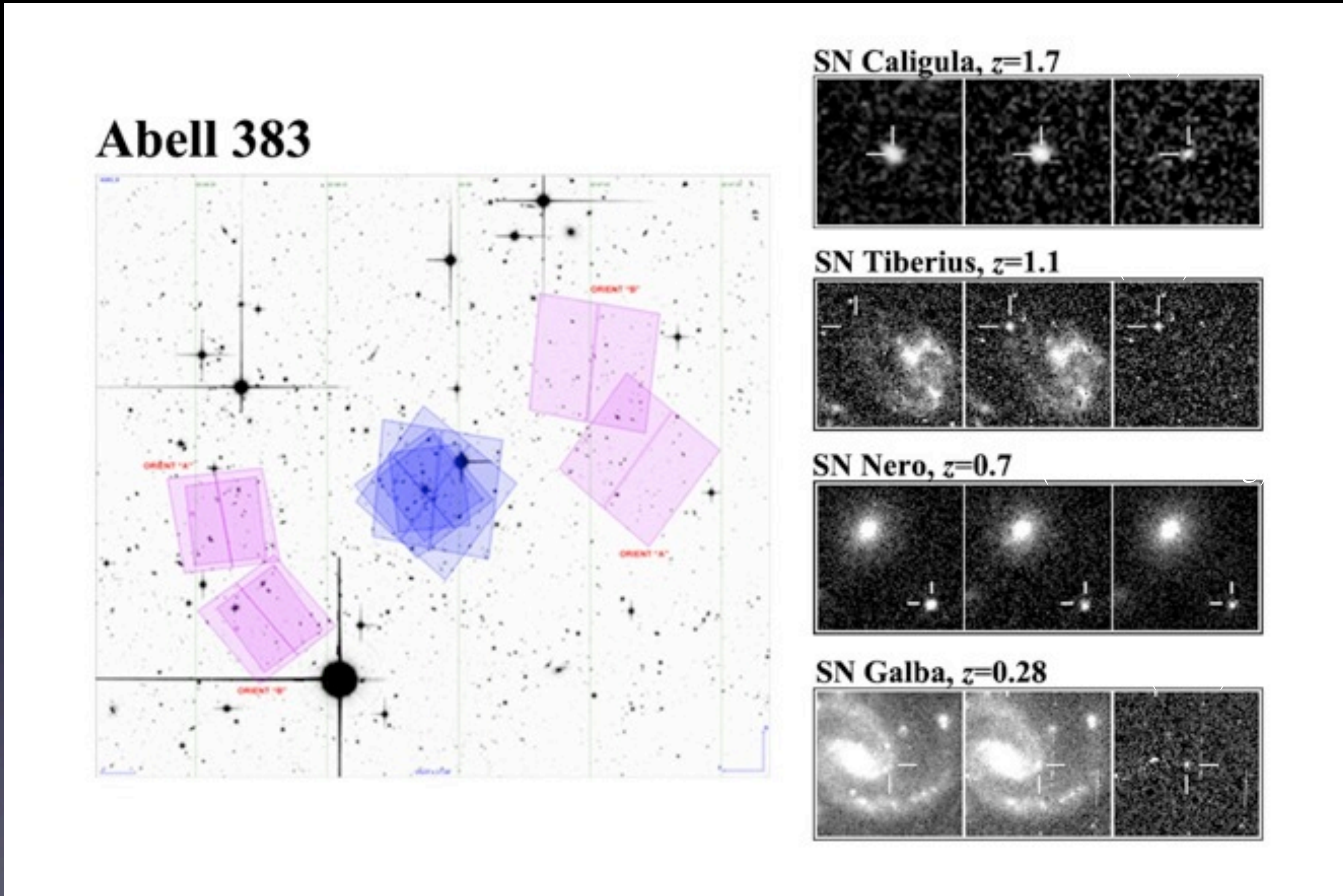
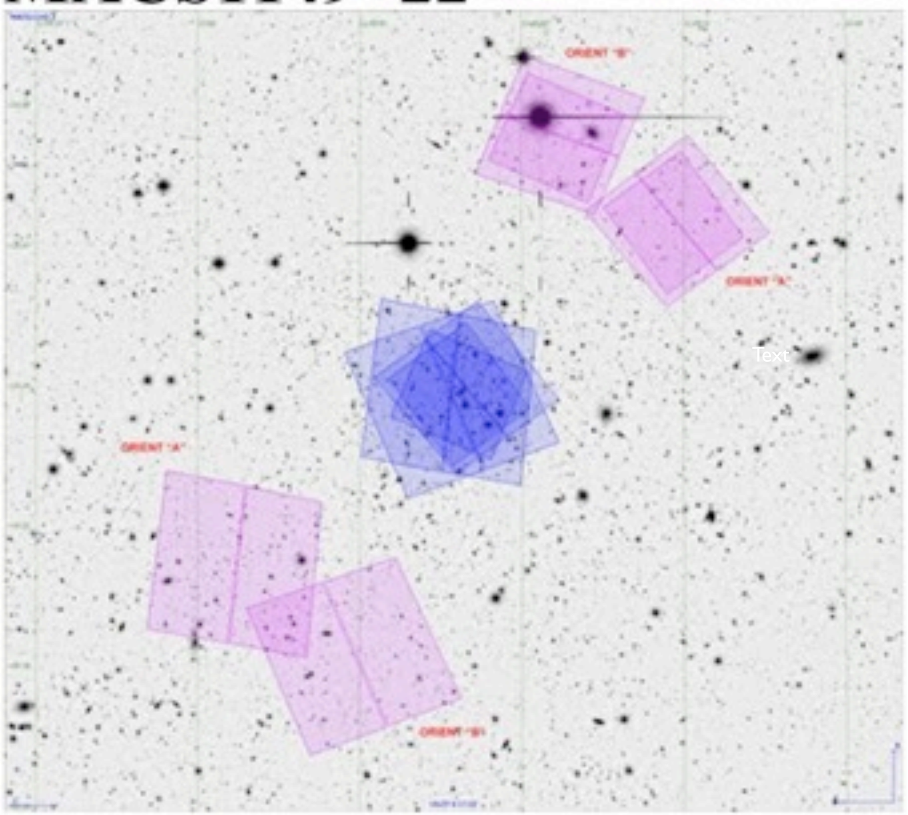
SN Discoveries:

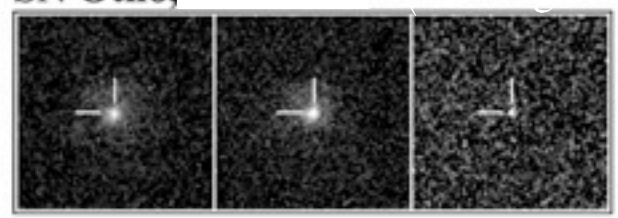


SN Discoveries:

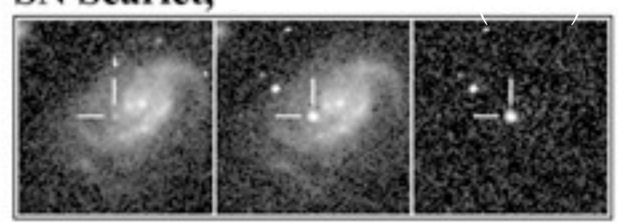
MACS1149+22



SN Otho,



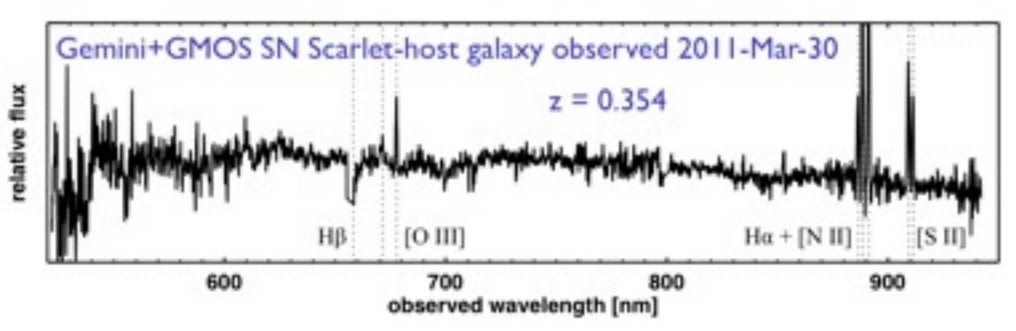
SN Scarlet,

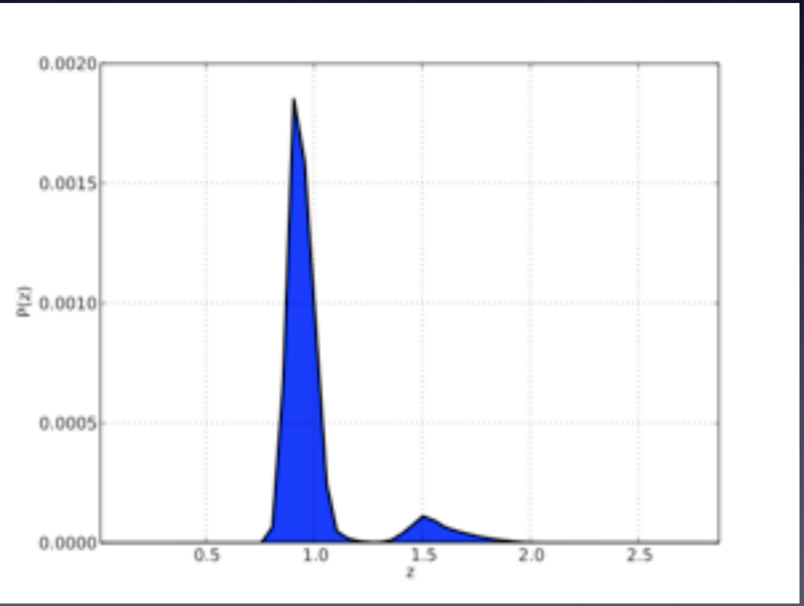


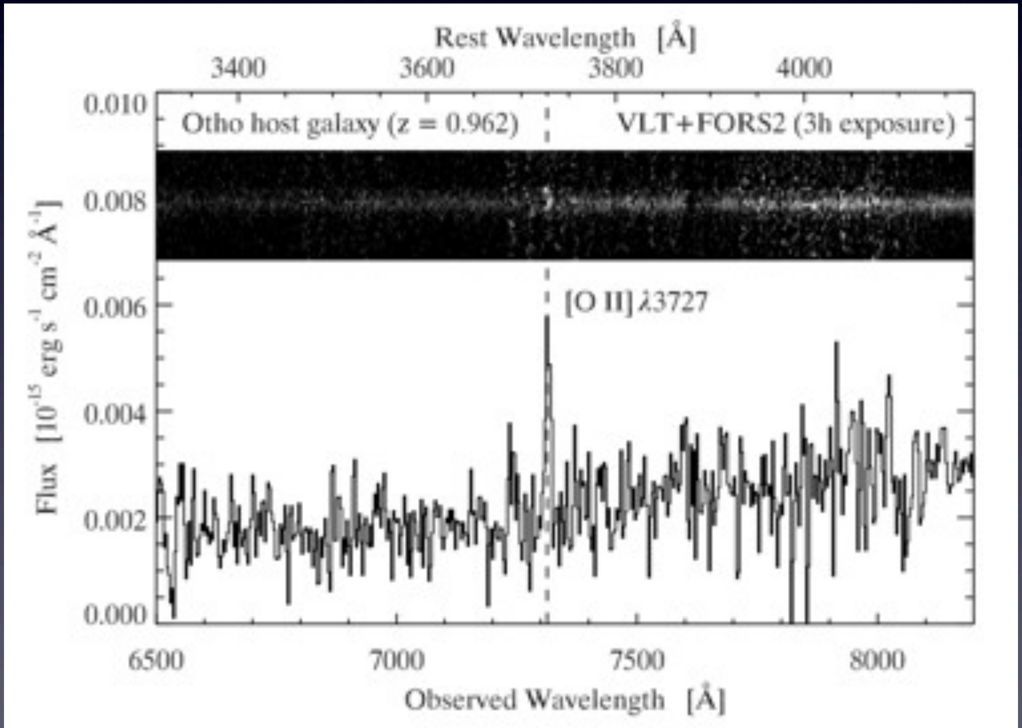
Follow-up:

Otho+Scarlet:

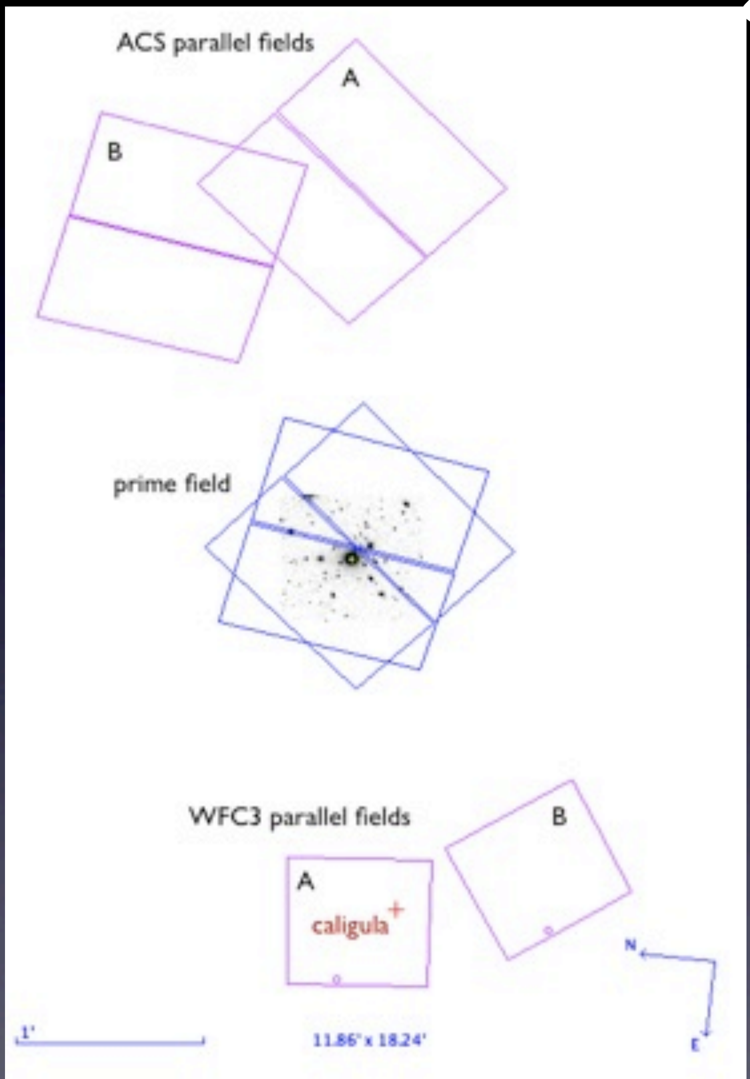
Ground-based spectroscopy confirms the photo-z estimates

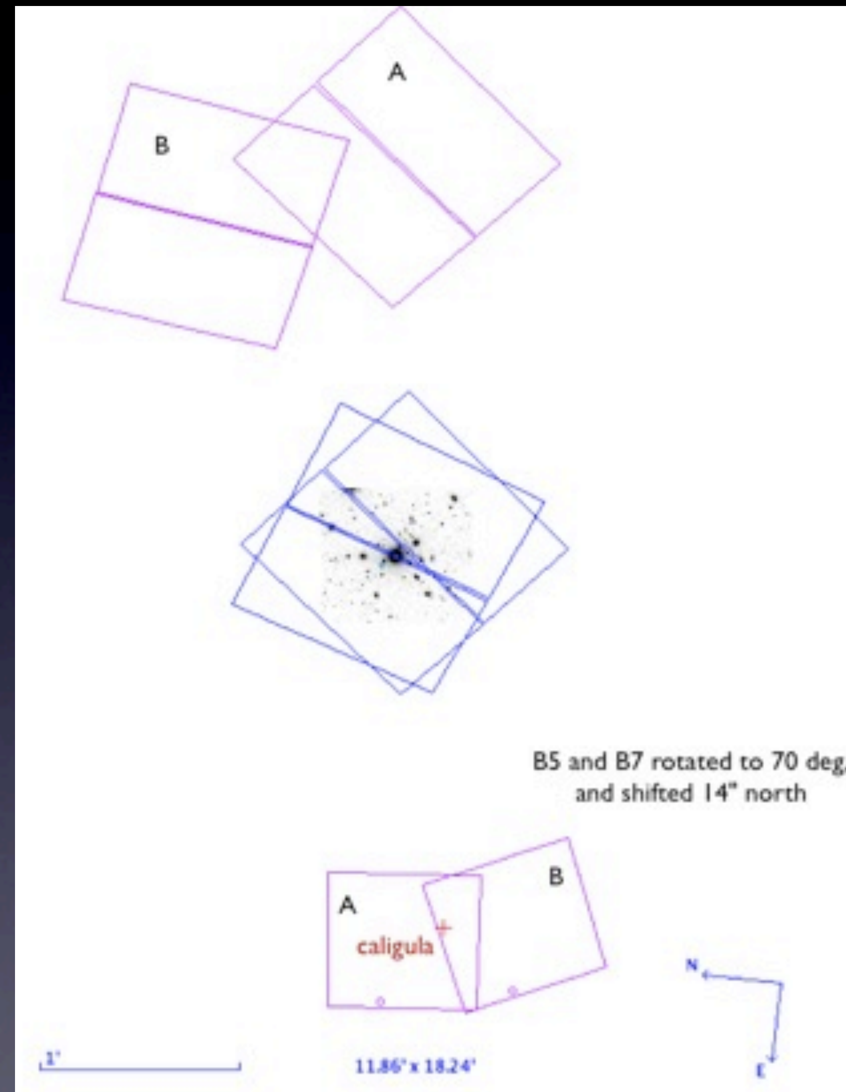






Follow-up: **Caligula** z~1.7, possible SNIa





Follow-up: Caligula

z~1.7, possible SNIa

ToO completed : 1 additional epoch F160W, F814W

ToO Pending : 1 orbit WFC3 F105W, F814W in December 2011