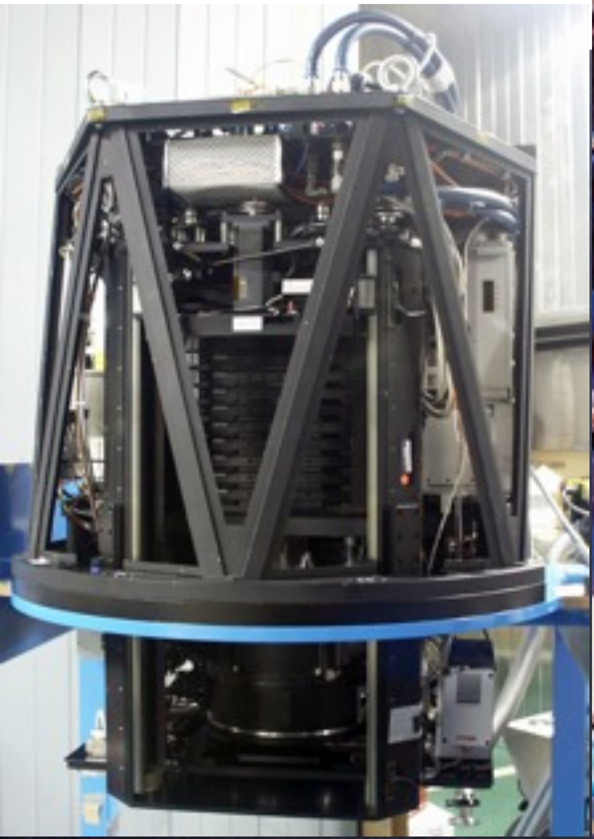
Subaru Wide-Field Variability Survey

Tomoki Morokuma
(University of Tokyo)

MAXI 1st year workshop
Dec. 2, 2010



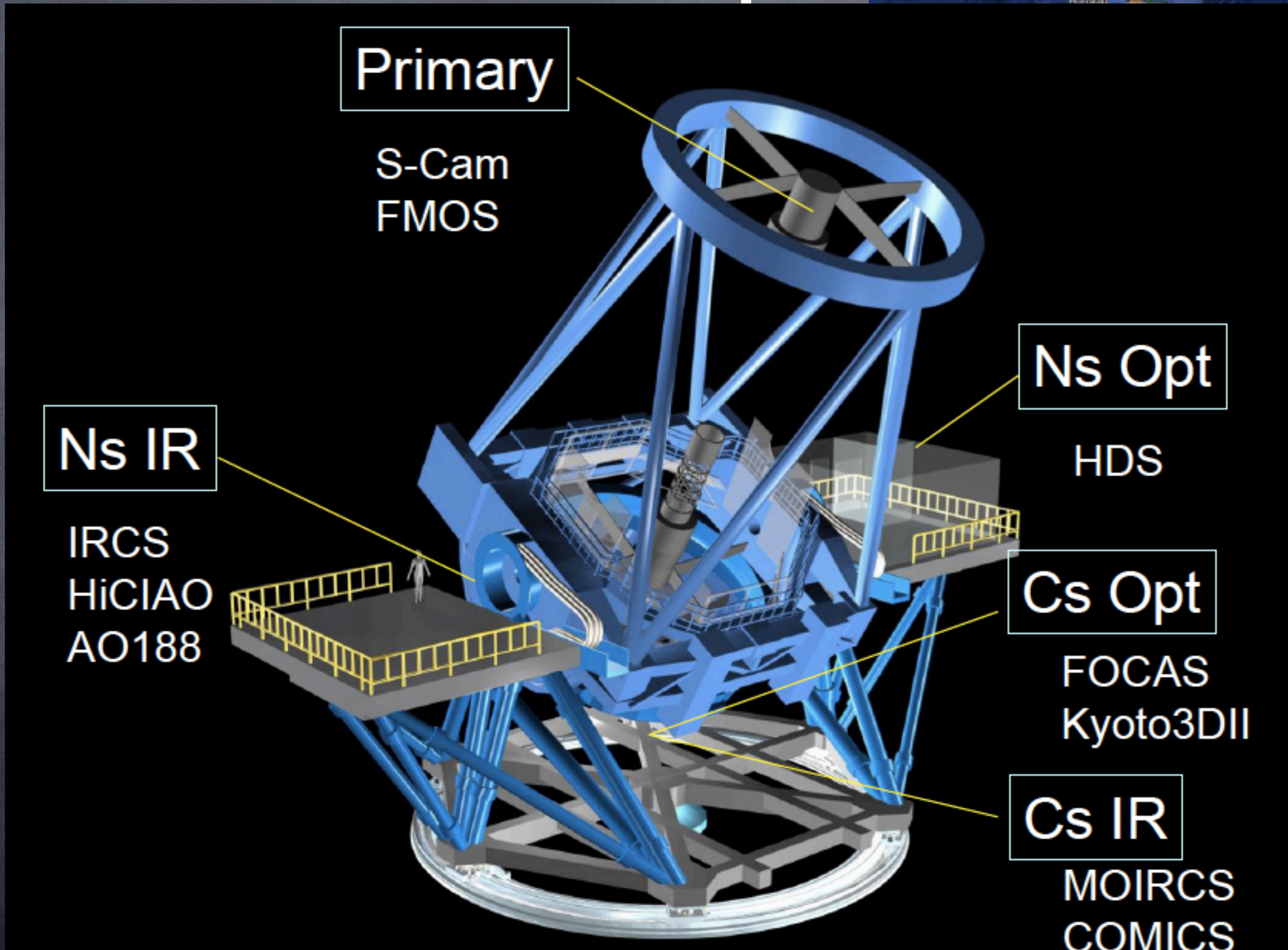
Contents

- Subaru telescope & Suprime-Cam
- Survey for AGN & Distant Supernova via optical variability
- Hyper Suprime-Cam (HSC) & Survey Plan
- Summary

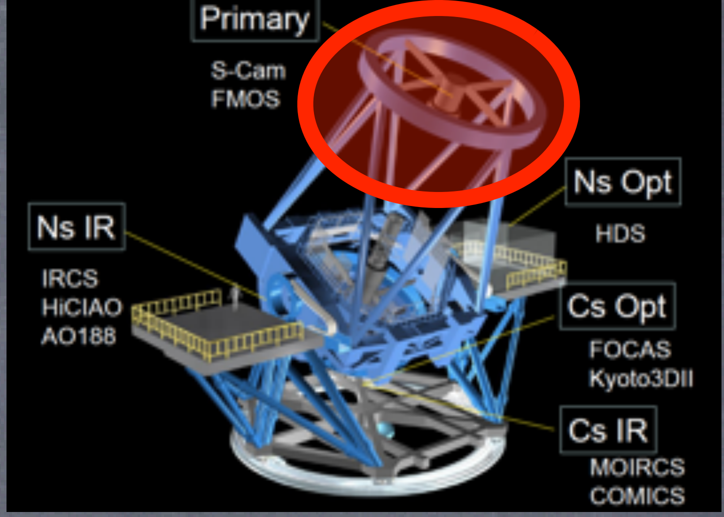
Subaru telescope

- 8.2-m aperture
- Mt. Mauna Kea (~4,200m) in Hawaii Big Island
  - 3 other 8-m class telescopes: Gemini-N, Keckx2
- optical-infrared telescope
- operated by National Astronomical Observatory of Japan (NAOJ)
- multi-purpose: 10 instruments
- first light: 1999

Subaru telescope

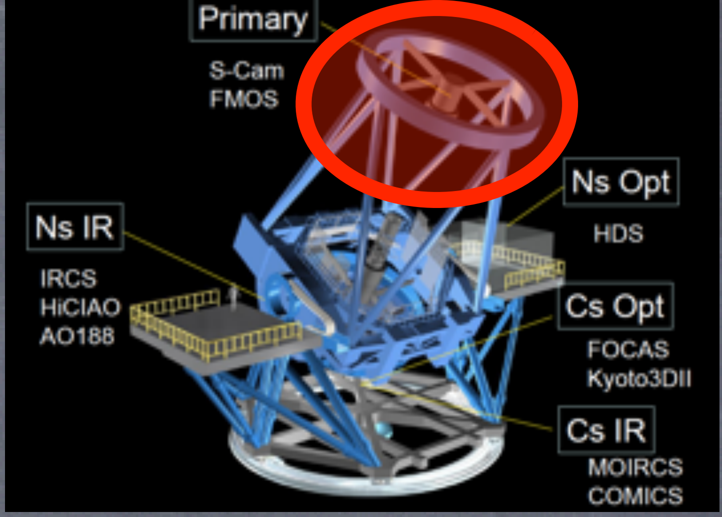


Suprime-Cam

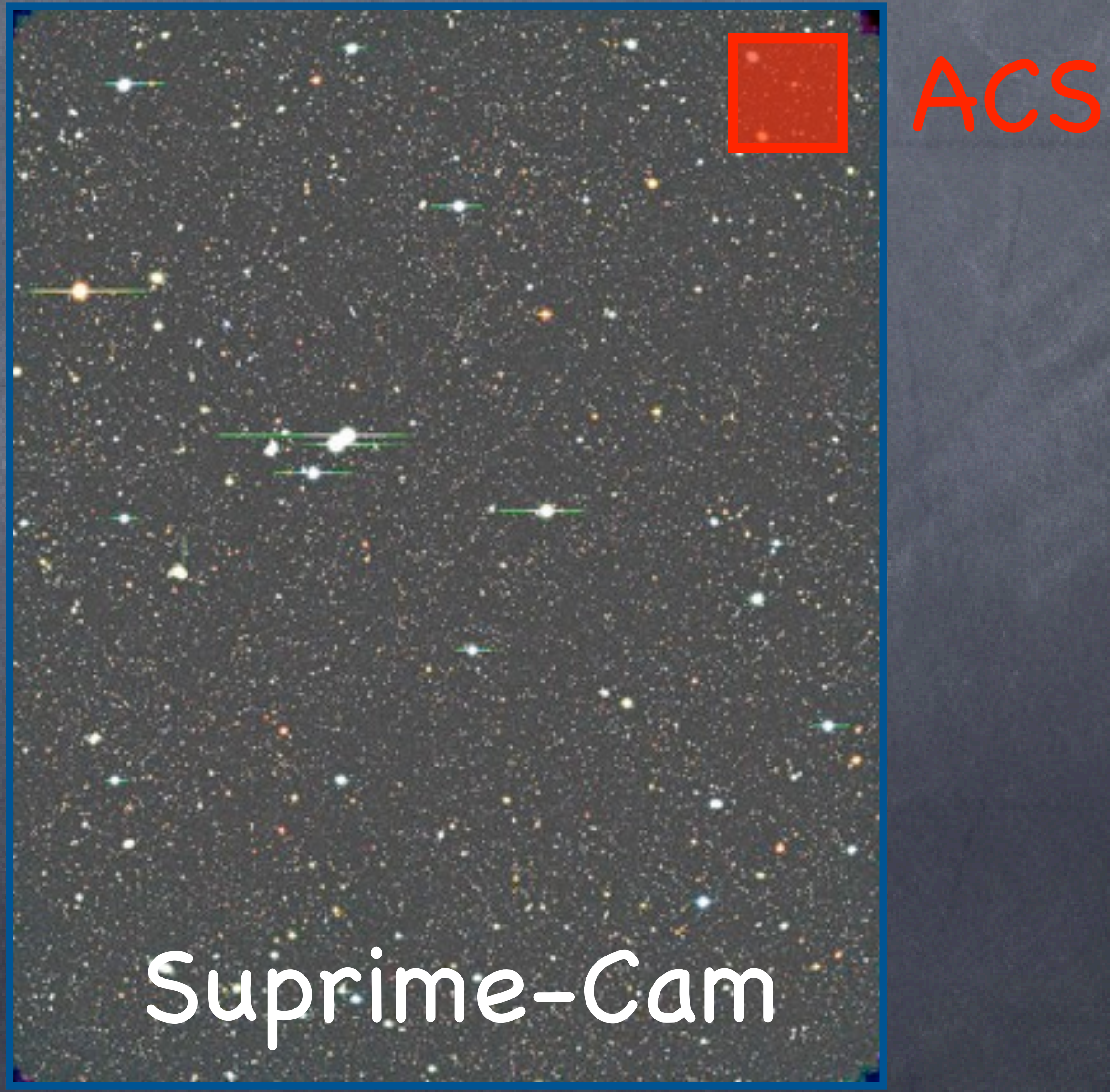


- prime-focus optical imager: 3600-10000A
- based on development experience of mosaic CCD wide-field imagers at Kiso
- much widest field-of-view among 8-m class telescopes: 34`x27' ~ full moon
- 10 Hamamatsu CCDs (upgraded August 2008)
  - QE improvement around ~1um
- most popular instrument: ~20% share

Suprime-Cam

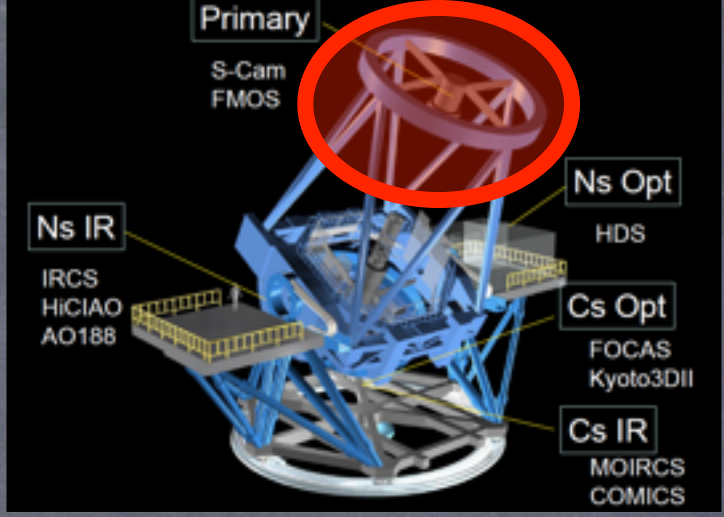


- much widest field-of-view among current 8-m class/ space telescopes: 34'x27' ~ full moon



~1,000,000 objects

Suprime-Cam



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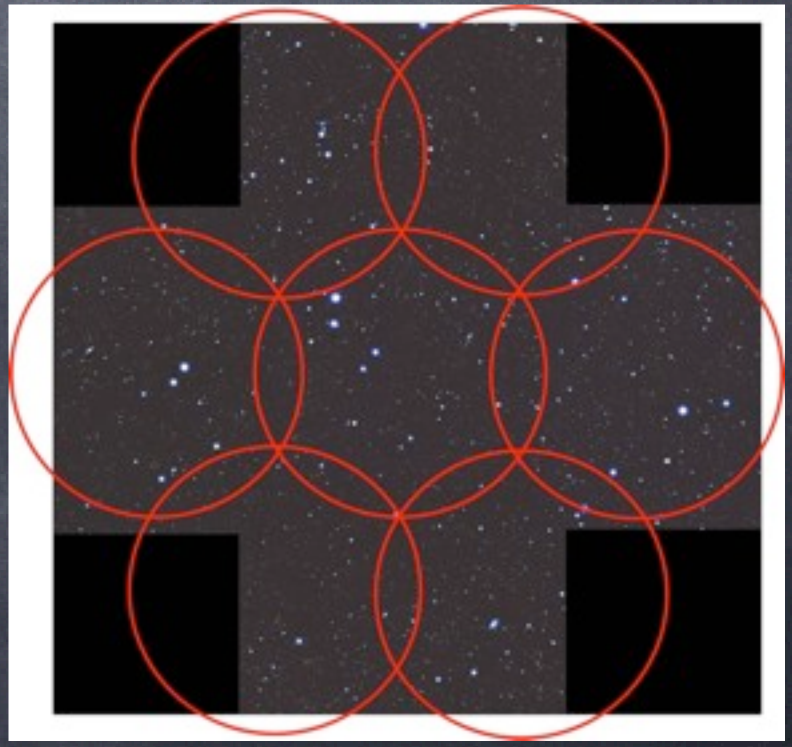
Variable Object Surveys w/ Subaru/Suprime-Cam

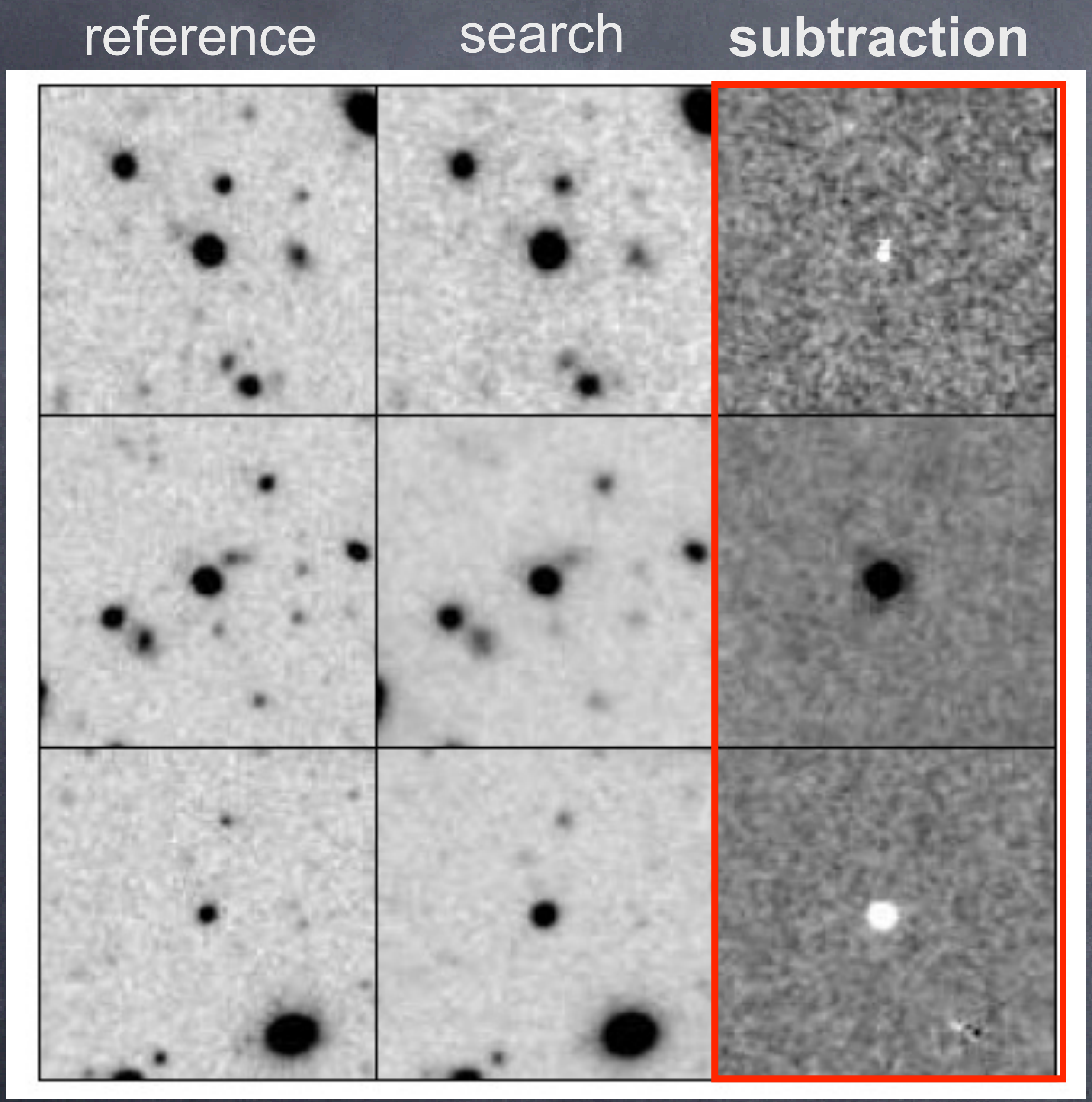
- Subaru is a multi-purpose telescope (10 instruments). Not a dedicated telescope.
- large survey has not been so easy
- but we could conduct variability surveys
  - Subaru Observatory Projects + Intensive Programs since 2001 + Guaranteed Time

Subaru Deep Field (SDF)



Subaru/XMM-Newton Deep Survey (SXDS)

Flux Variability Detection



- simple photometry can NOT detect variability for extended sources such as faint AGN in bright galaxies and supernovae in extended galaxies.
← due to time-varying seeing size (ground-based observation)

Image subtraction method
(Alard & Lupton 1998, Alard 2000)

Survey for Variables

- Variability Survey (TM+2008a)
- Active Galactic Nuclei (AGN)
  - Variability-Selected AGN (TM+2008b)
- Supernovae
  - Supernova Rate (Poznanski+2007)
  - Delay Time Distribution of SNe Ia in early-type galaxies (Totani, TM+2008)
  - Supernova Spectra w/ Subaru/FOCAS (TM+2010)
  - SN Ia Cosmology (Amanullah+2010)
  - Delay Time Distribution of SNe Ia (Okumura, Totani+2010, in prep.)
  - Supernova Rate (Ihara 2010 PhD thesis, Ihara+2010, in prep.)
  - SN Ia Cosmology (Suzuki+2010, in prep.)
- High Proper Motion Stars
  - High Proper Motion Stars 1 (Richmond, TM+2009)
  - High Proper Motion Stars 2 (Richmond, TM+2010)

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Subaru/XMM-Newton Deep Survey (SXDS)

- X-ray (XMM-Newton/EPIC, 50-100ks, Ueda+2009)
  - 1e-15 erg s^{-1} cm^{-2} @0.5-2.0keV
  - 3e-15 erg s^{-1} cm^{-2} @2.0-10.0keV
- mid-infrared (Spitzer/IRAC): 3.6μm-band ~ 22.0mag
- spectroscopic follow-ups with many 8m-class telescopes
- optical (Subaru/Suprime-Cam, Furusawa+2008)
  - B(28.2mag),V(27.2mag),R(27.6mag), i(27.5mag),z(26.5mag)
- optical variability (Subaru/Suprime-Cam,TM+2008a,b)
  - multi-epoch 8-10 times during 2002~2005
  - Timescale: 1 day - 3 years
  - i_{AB}~26mag (each epoch)
  - $i_{AB,vari}$~25.5mag

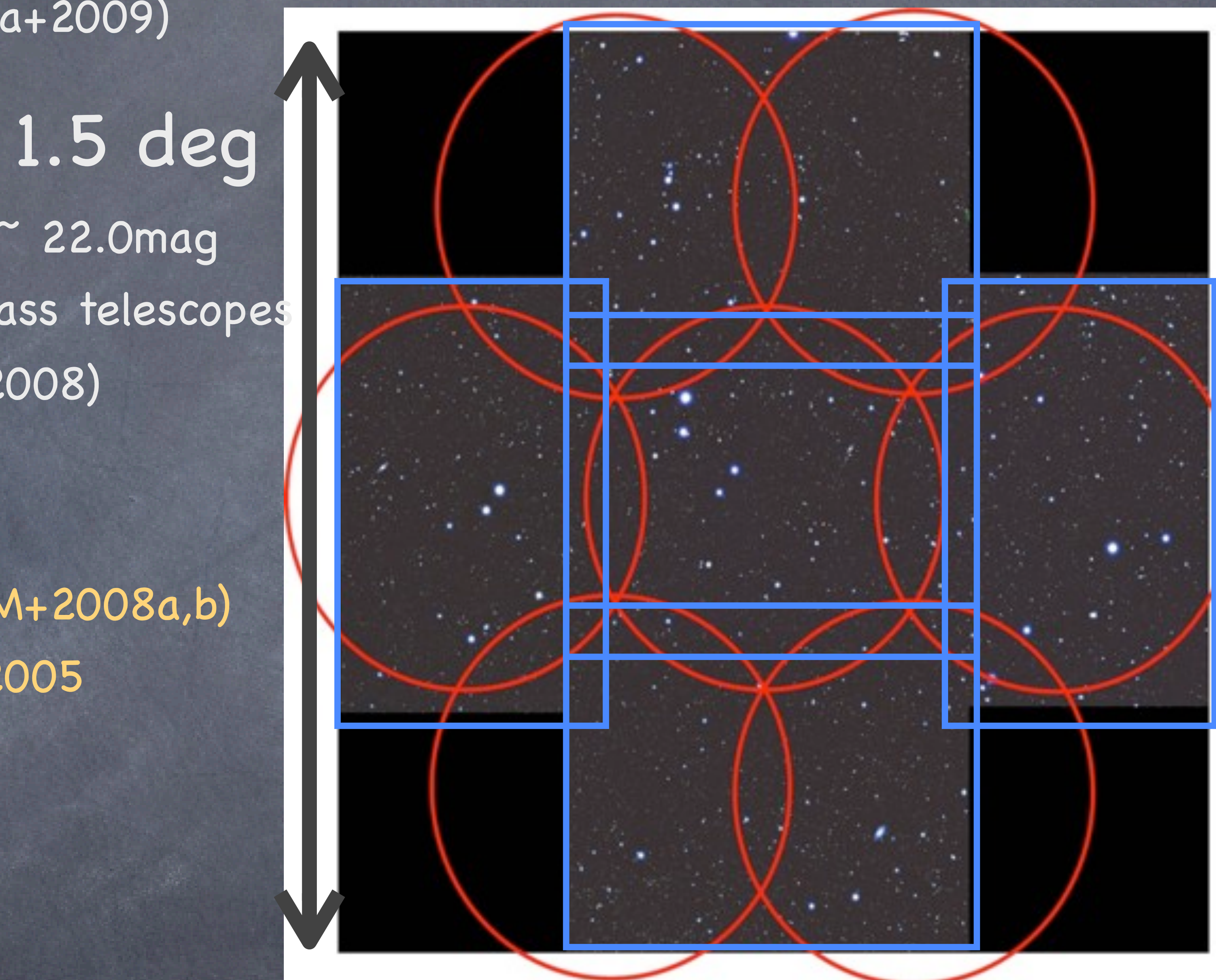
  (flux of variable components

  = flux difference between epochs $\Delta f=|f_1-f_2|$)

1,040 variable objects over 0.918 deg2

~500 AGN selected by optical variability

~50 SNe Ia with good light curves



Suprime-Cam 5 fields

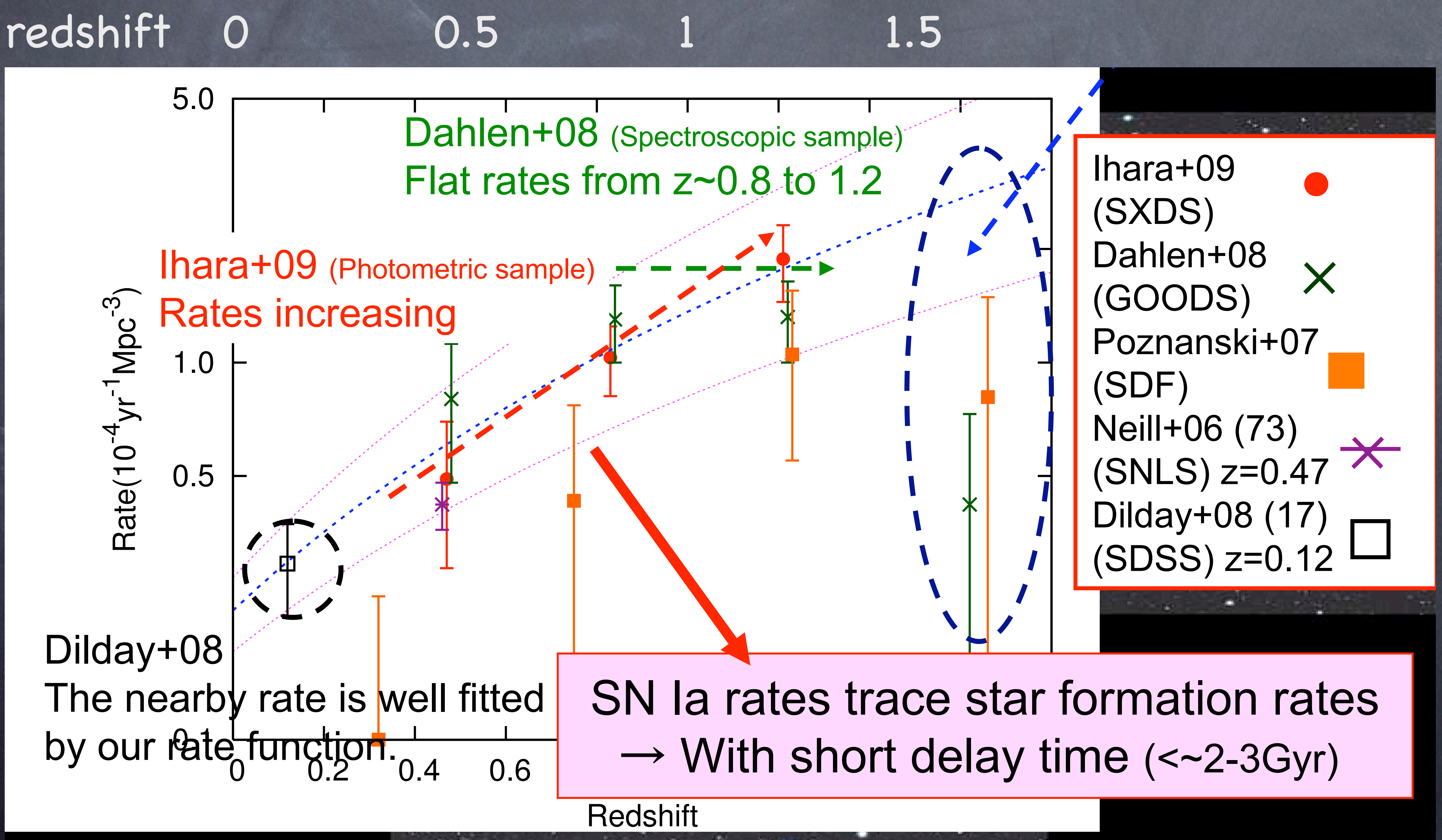
XMM-Newton 7 pointings

(02h18m00s, -05:00:00) in J2000

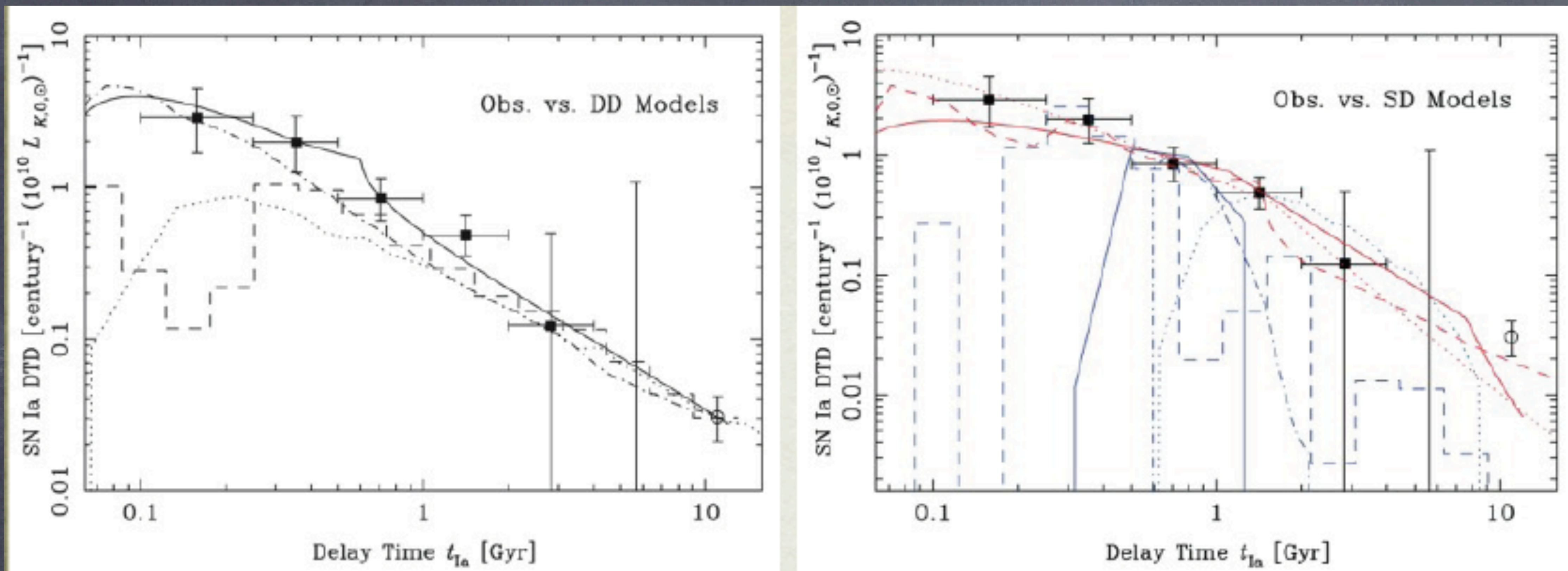
(l,b)=(169°,-60°)

Supernova rates

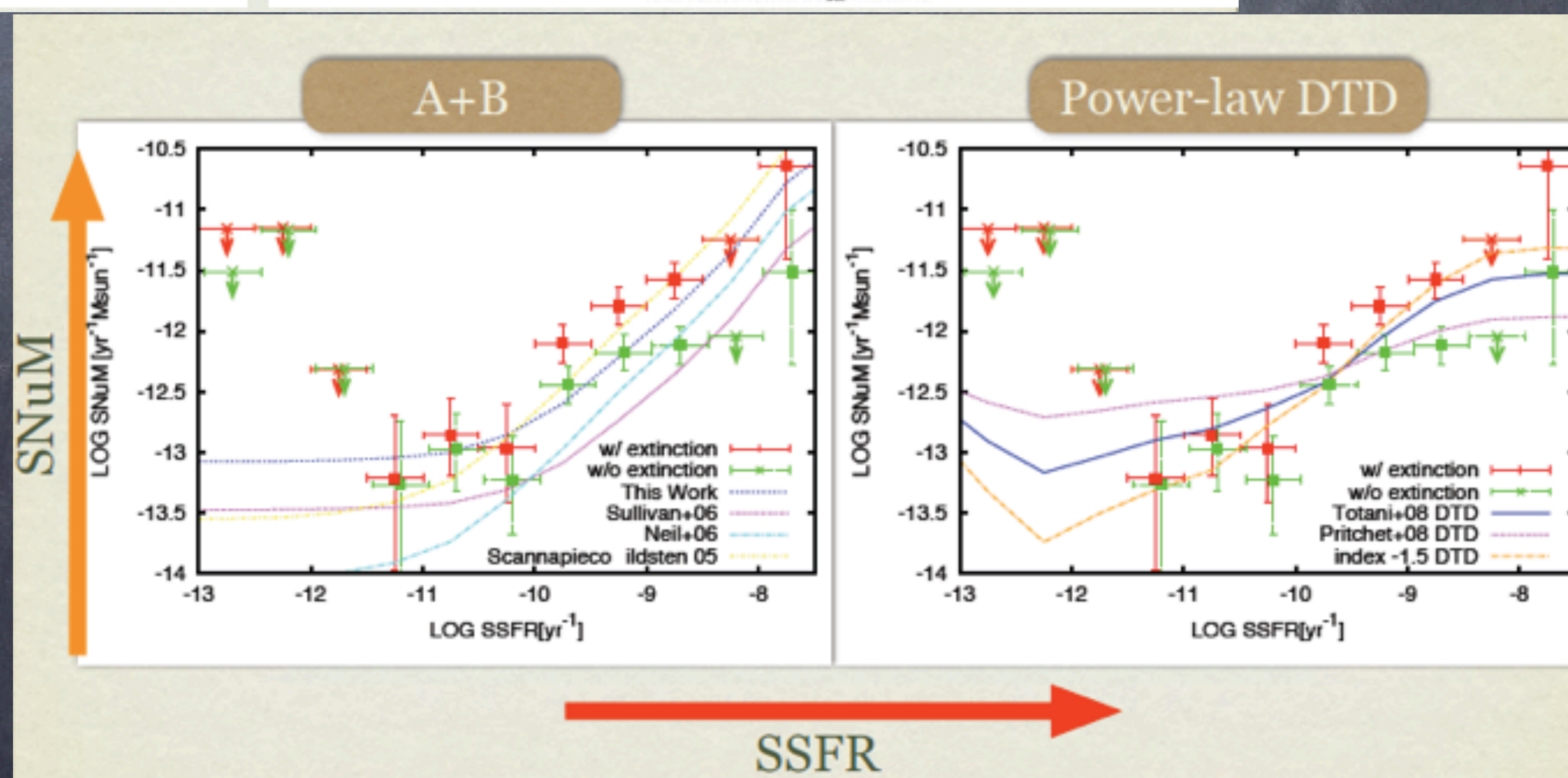
Ihara+2010 in prep.
SXDS (~1 deg2), ~50 SNe Ia by photometric typing



SN Ia Delay Time Distribution



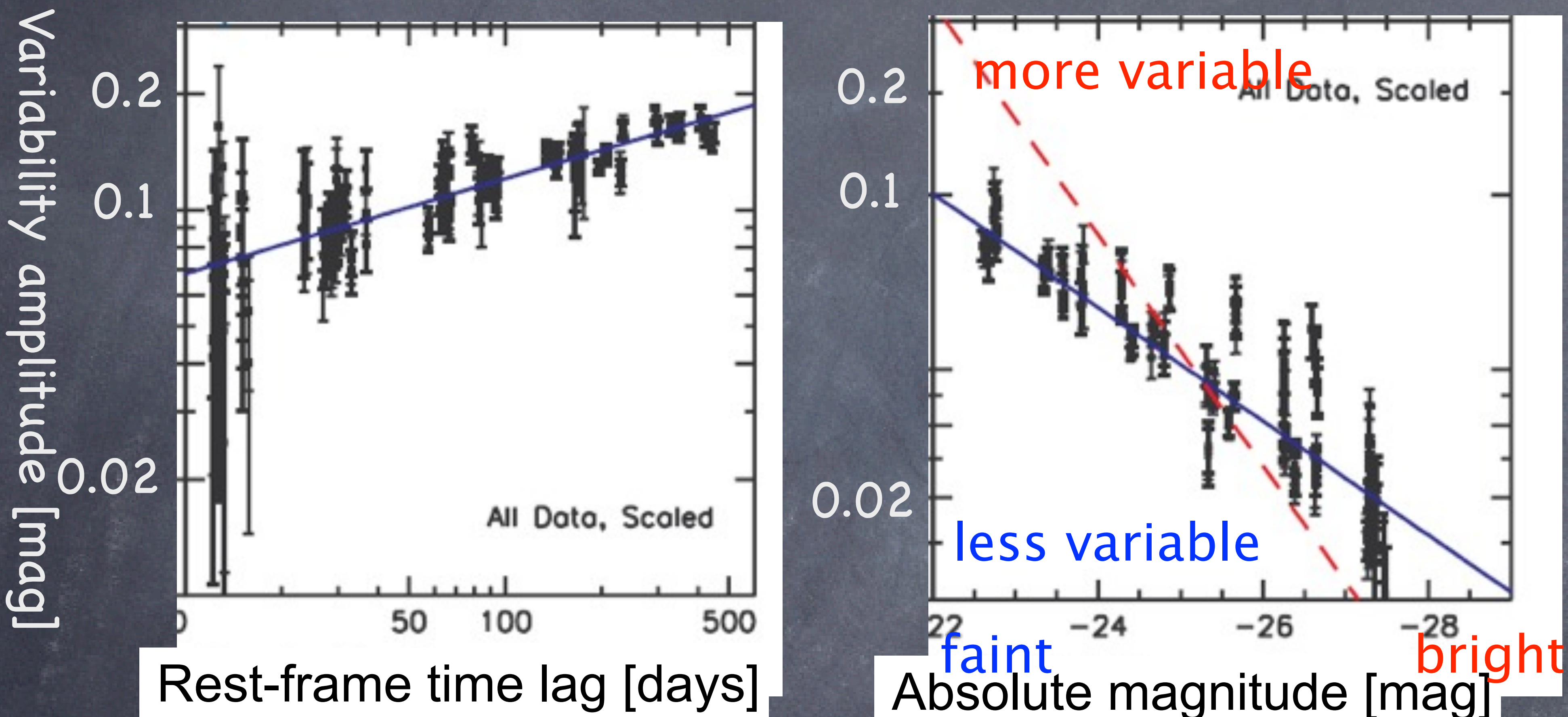
Totani, TM+2008
SN Ia@early-type gals



Okumura+2010, in prep.
SN Ia@all gals

Optical Variability of AGN

- all (type-1) AGN show detectable variability in optical. (Hawkins 1993, Hook+1994, Giveon+1999, many SDSS studies ...).
- fainter AGN show larger variability amplitudes.



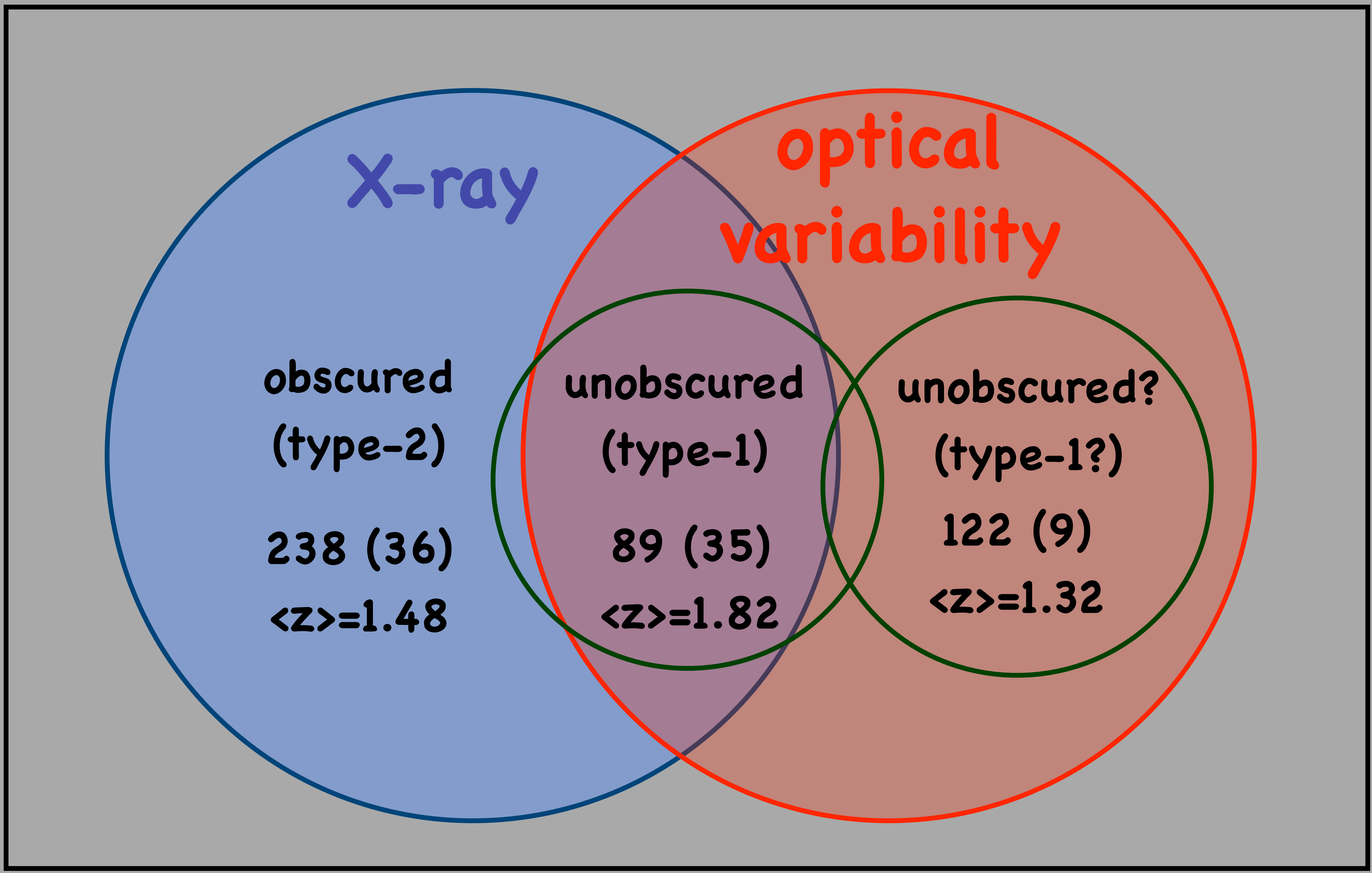
Vanden Berk+2004

classical optical color selection does NOT suit for low-L AGN search.

Optical variability can be a good tracer for low-luminosity AGN.

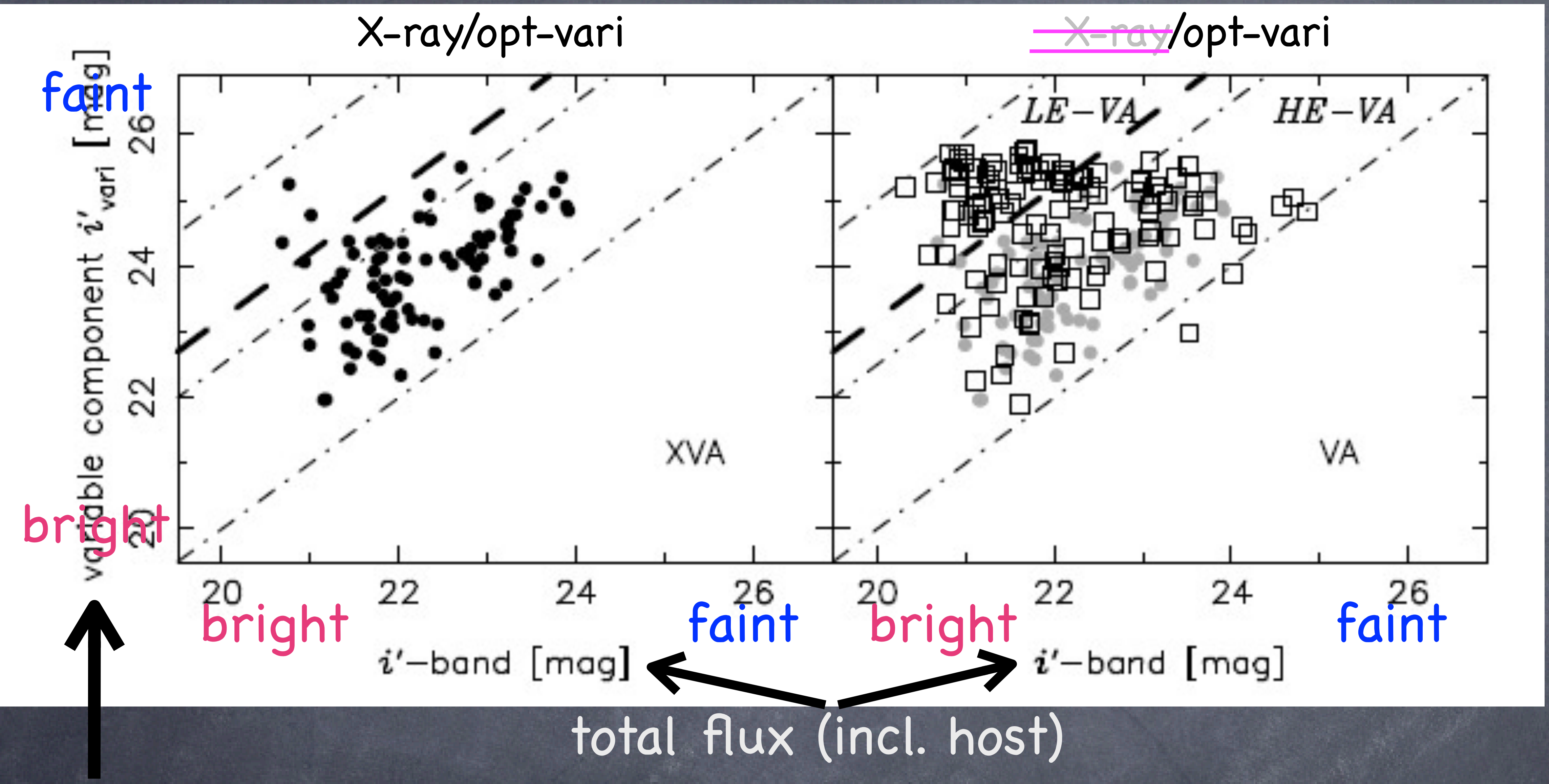
- Subaru (Suprime-Cam): Totani+2005, TM+2008a,b
- HST (WFPC2, ACS): Sarajedini+2000,2003,2006, Cohen+2006
  - (low-luminosity) type-1 AGN (up to z~5)
  - ~580 AGN / deg^2
  - significant fractions (~50%) of AGN w/o X-ray detections

AGN samples



X-ray
optical variability
obscured
(type-2)
238 (36)
<z>=1.48
unobscured
(type-1)
89 (35)
<z>=1.82
unobscured?
(type-1?)
122 (9)
<z>=1.32

properties of variability-selected AGN



differential flux between maximum and minimum

low differential flux ~ low AGN flux

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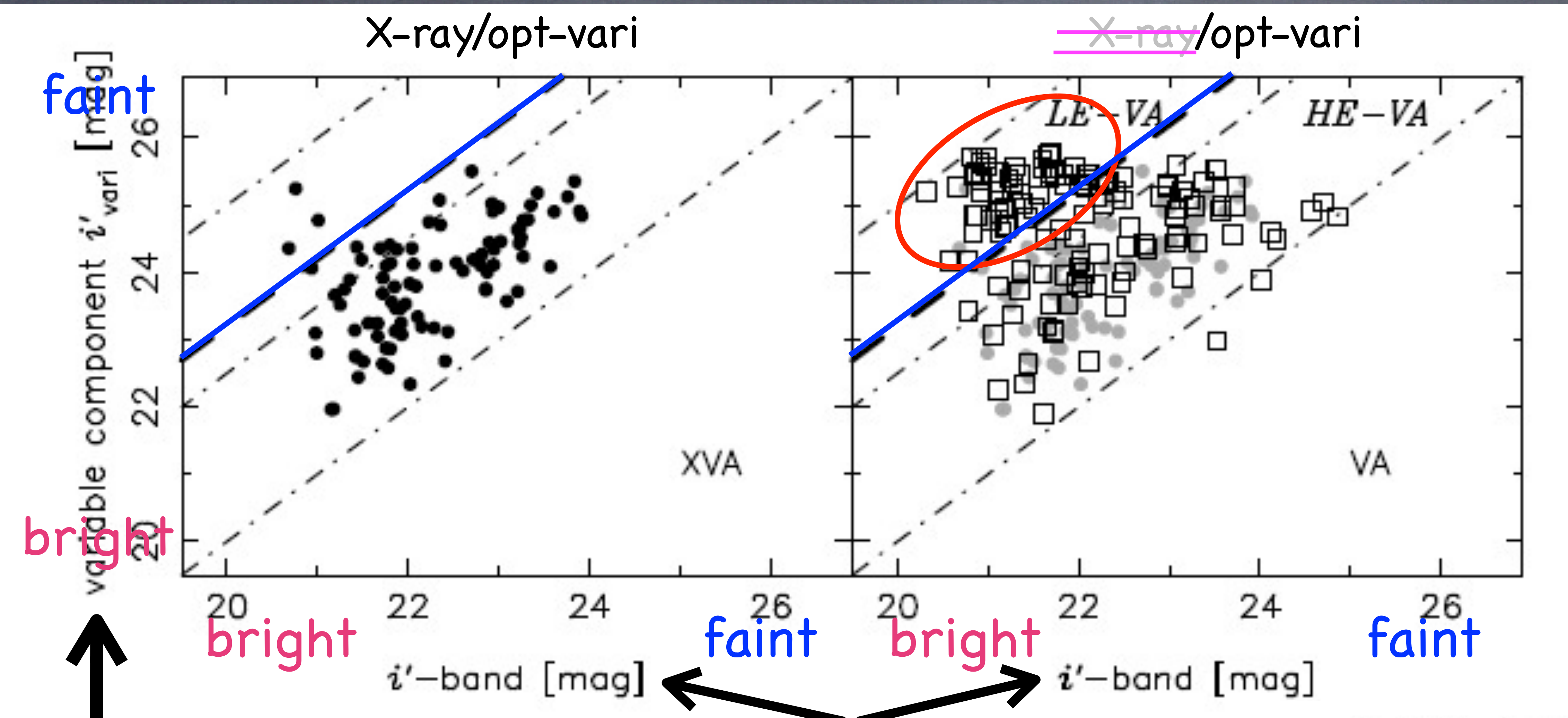
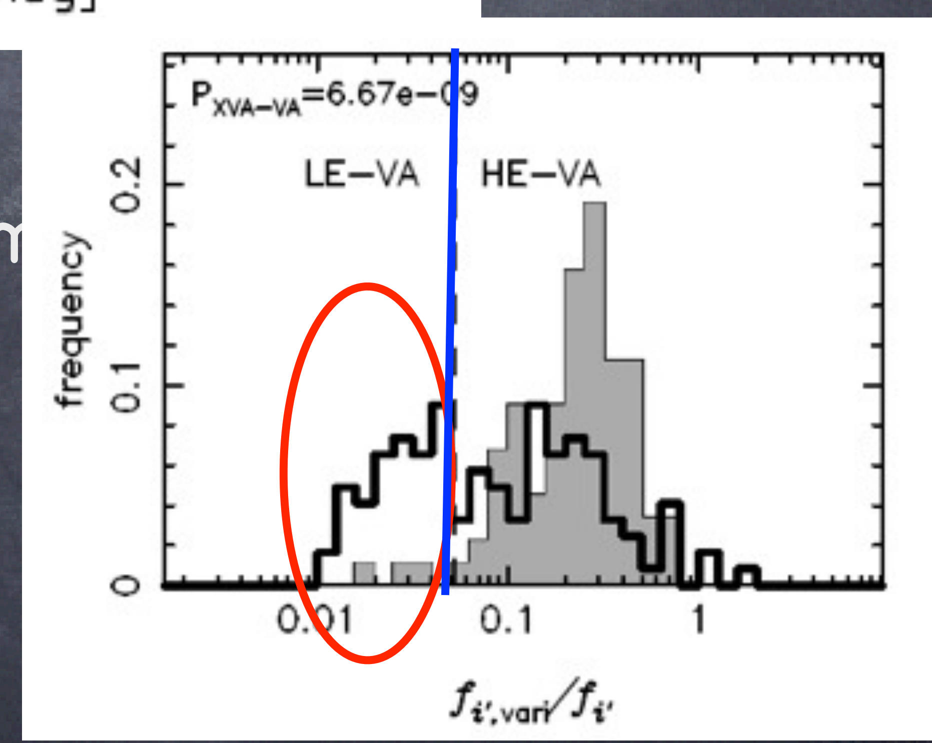


total flux (incl. host)

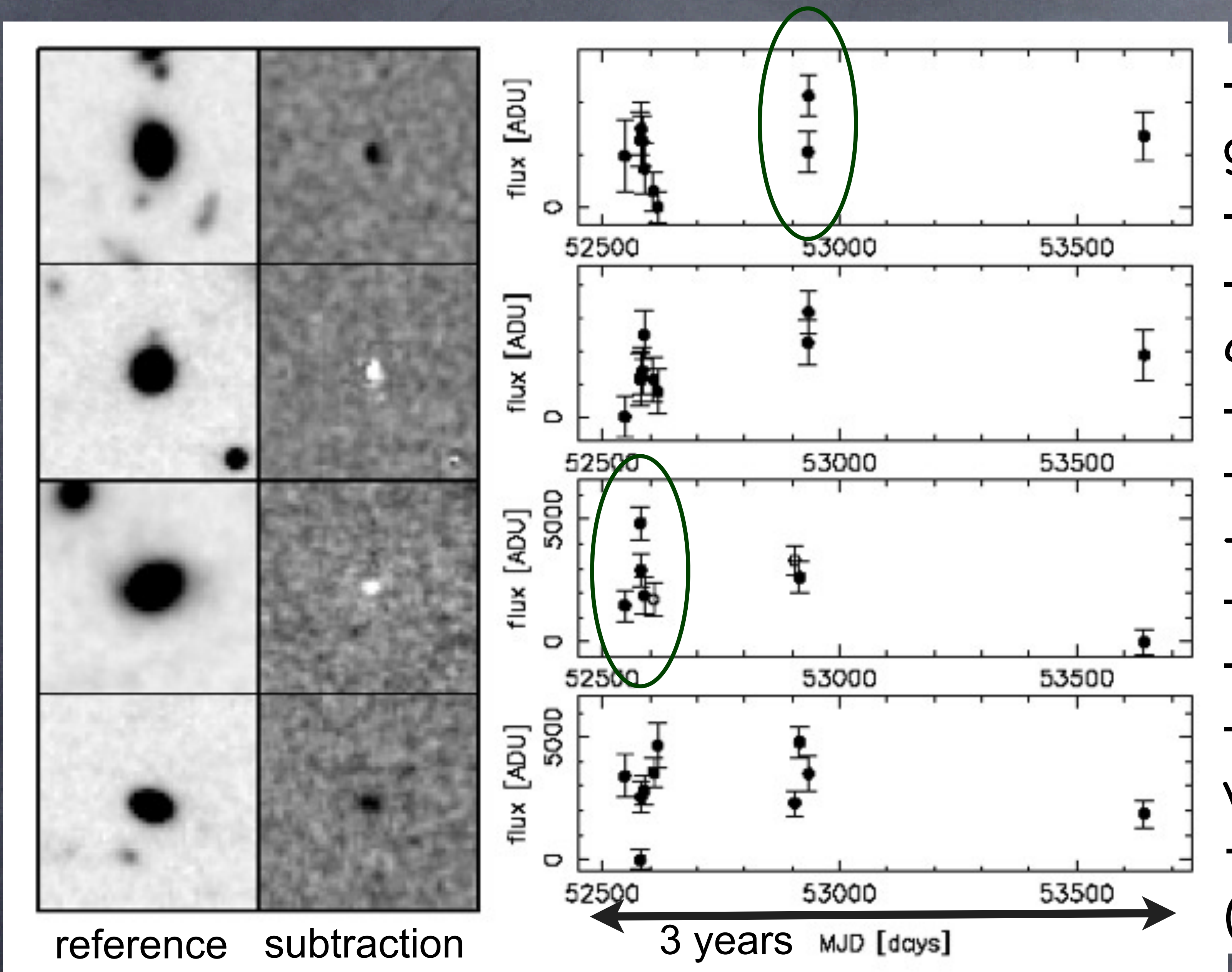
differential flux between maximum and minimum

low differential flux ~ low AGN flux



- X-ray undetected optical-variability-selected AGN
- not optical color selection

Images & Light Curves



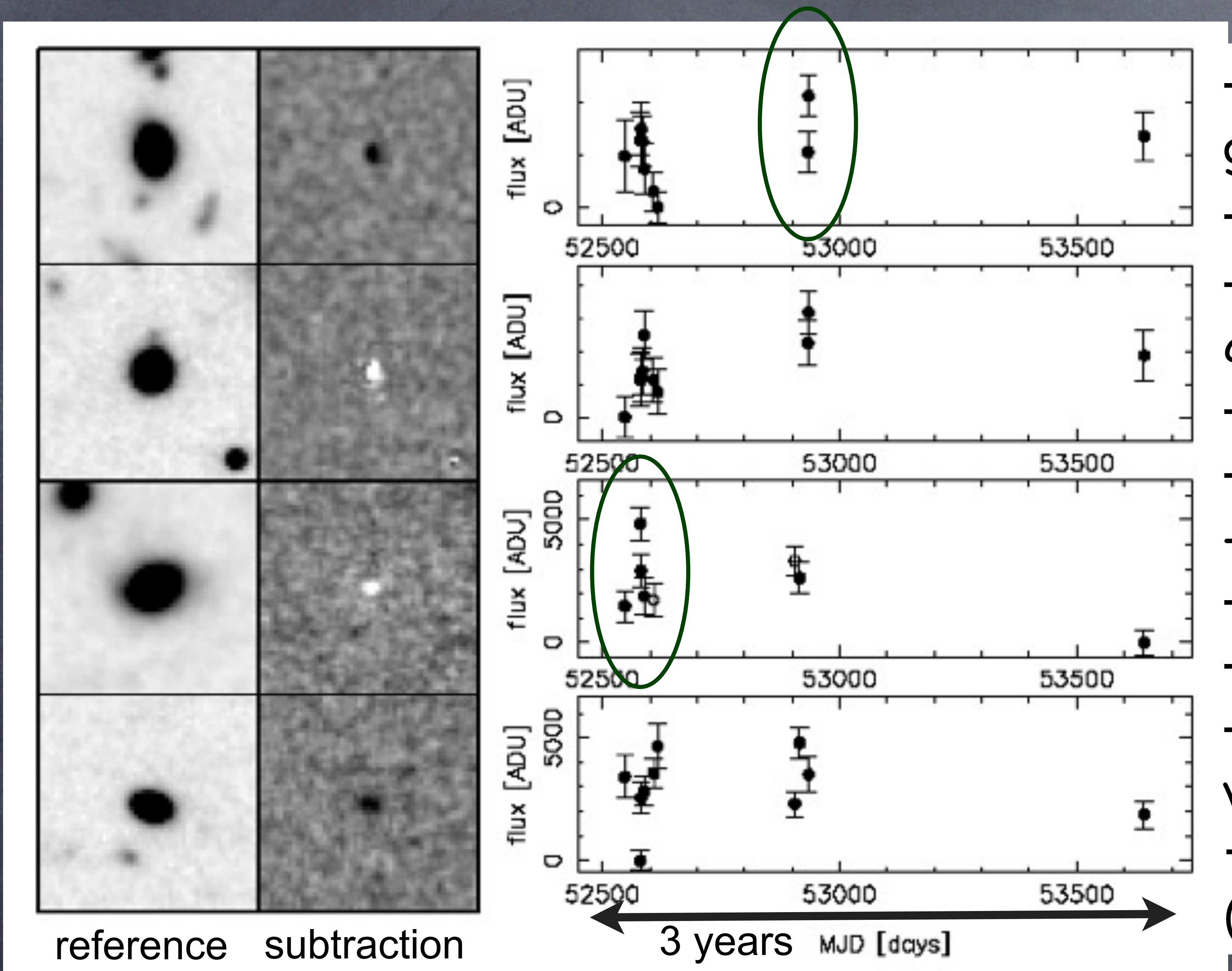
- faint AGN (~-18 mag) in bright galaxies (e.g.Totani+2005)
- elliptical galaxies at z_{photo}~0.5
- flare-up? radiatively inefficient accretion flow (RIAF)?
- radio-mode feedback?
- nearby LINER analogous? (Maoz +2006)
- ~10^8Msun SMBHs
- ending phase of mass accretion?
- 5-10% of bright galaxies show variability

→ several tens percent in total? (unknown detection efficiency...)

What is the nature of this kind of low-luminosity AGN???

- HST imaging
- Deep spectroscopy (maybe stacking analysis necessary) to search for AGN features and also apply AGN identification diagnostics based on emission line ratios.
- environmental dependence?

Images & Light Curves



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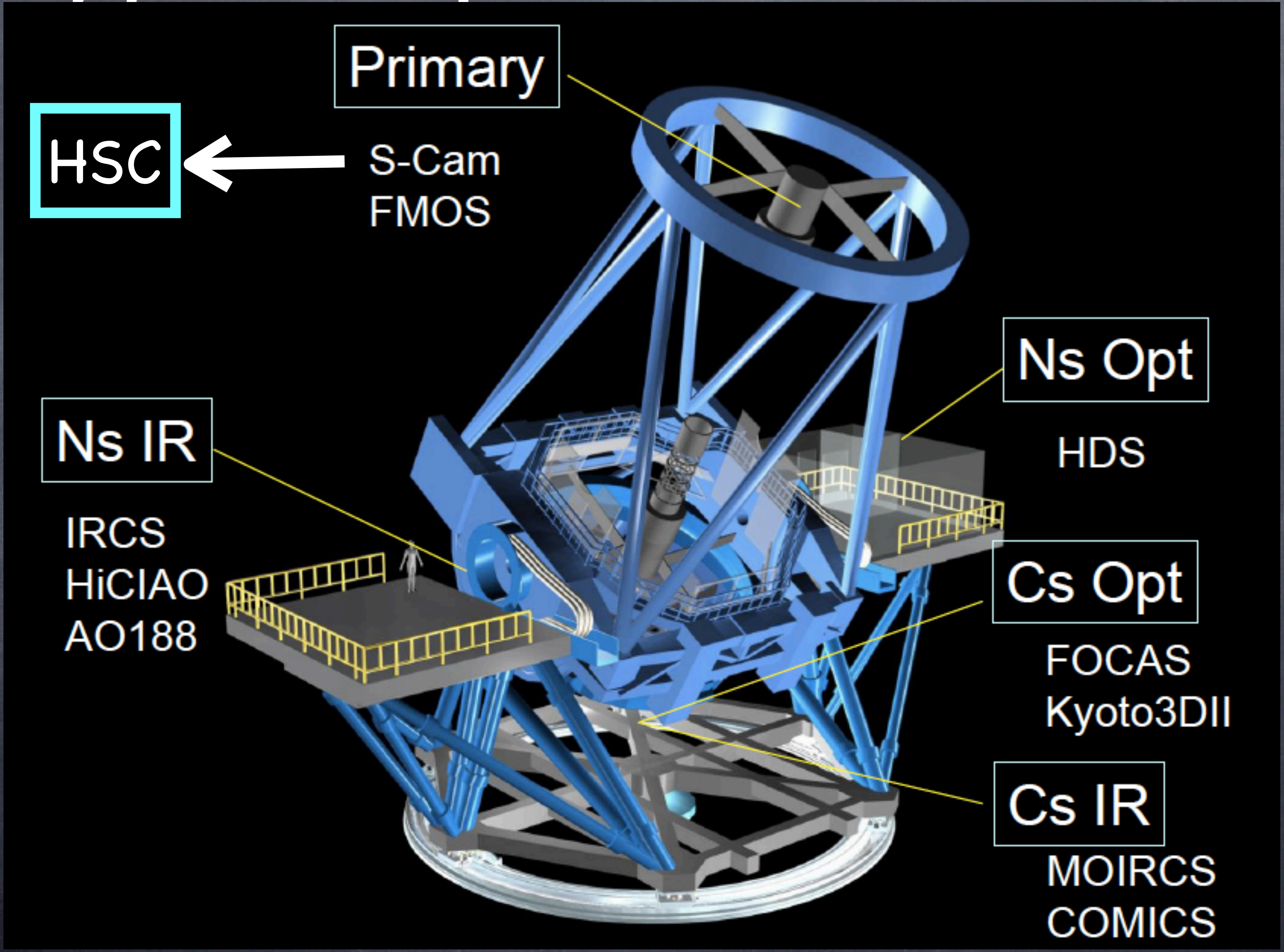
Hyper Suprime-Cam (HSC)



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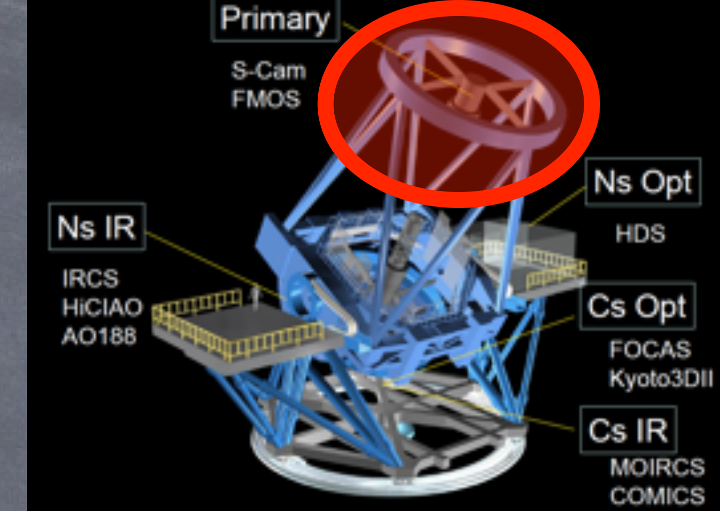

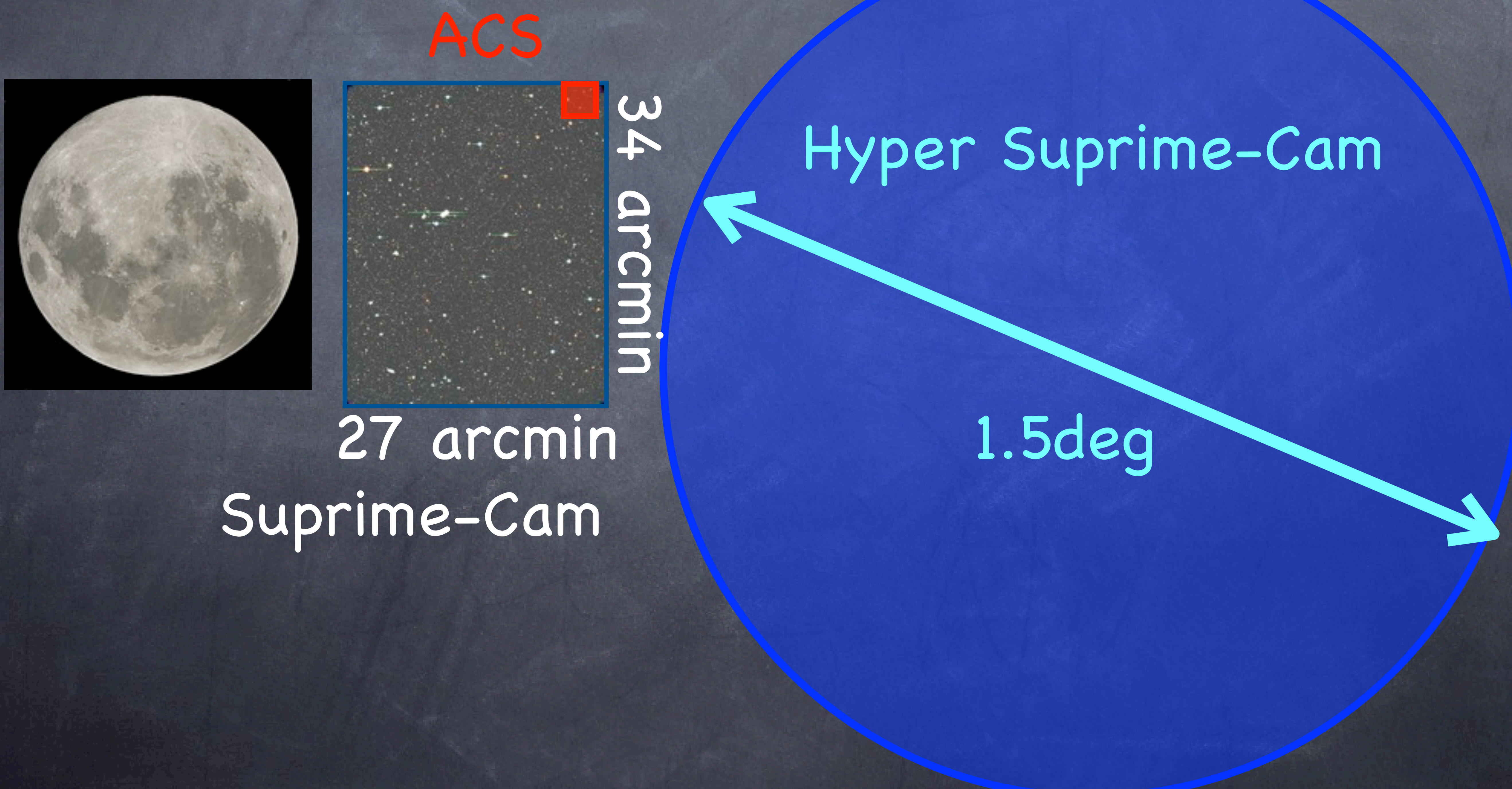

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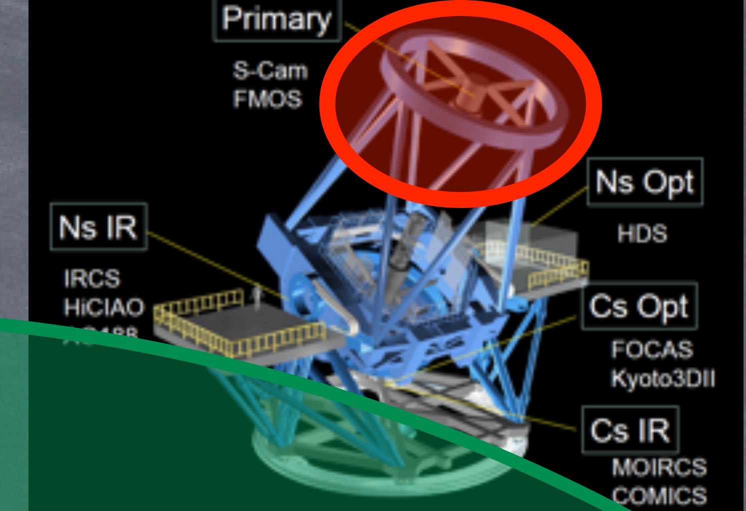
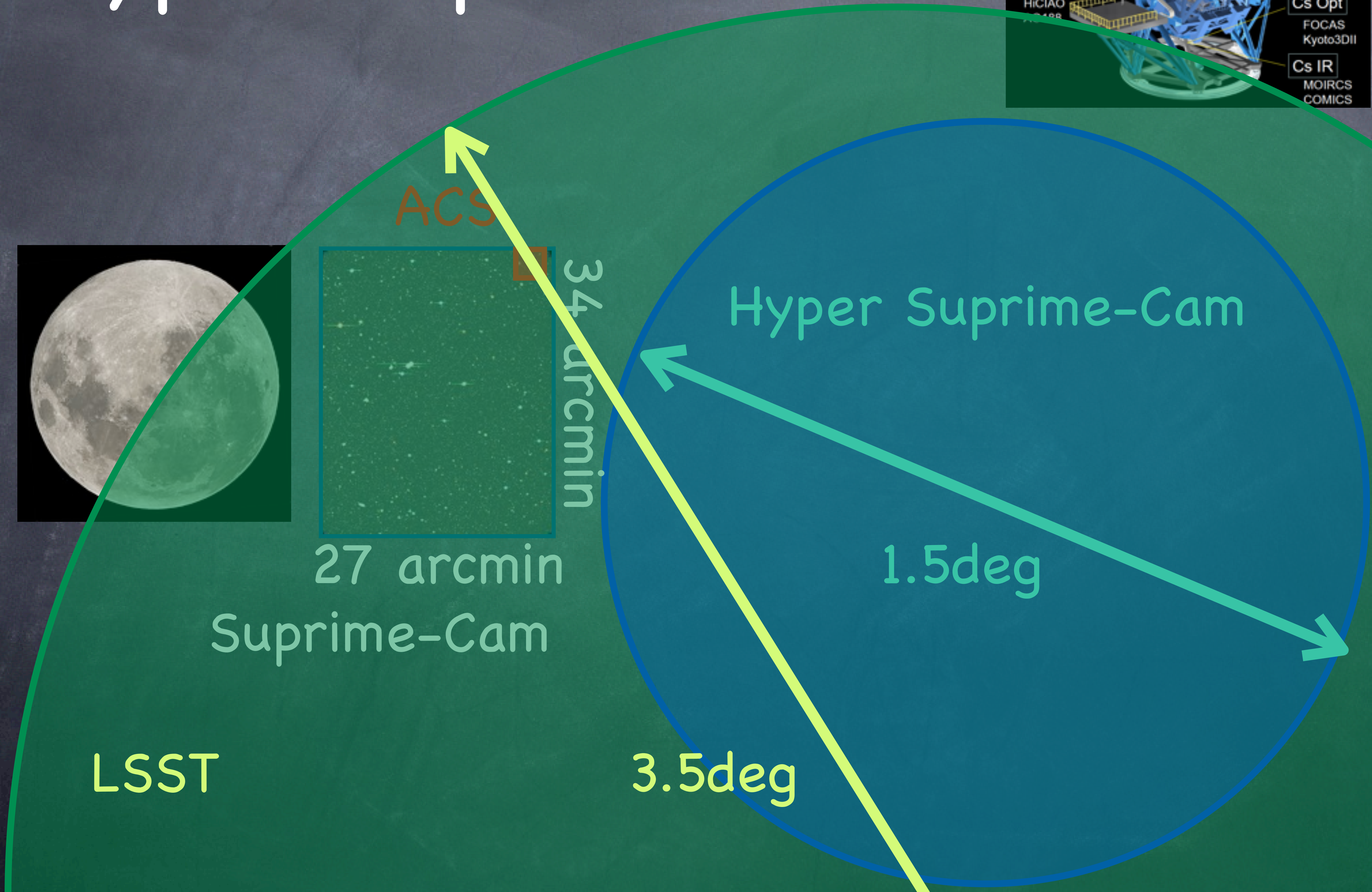
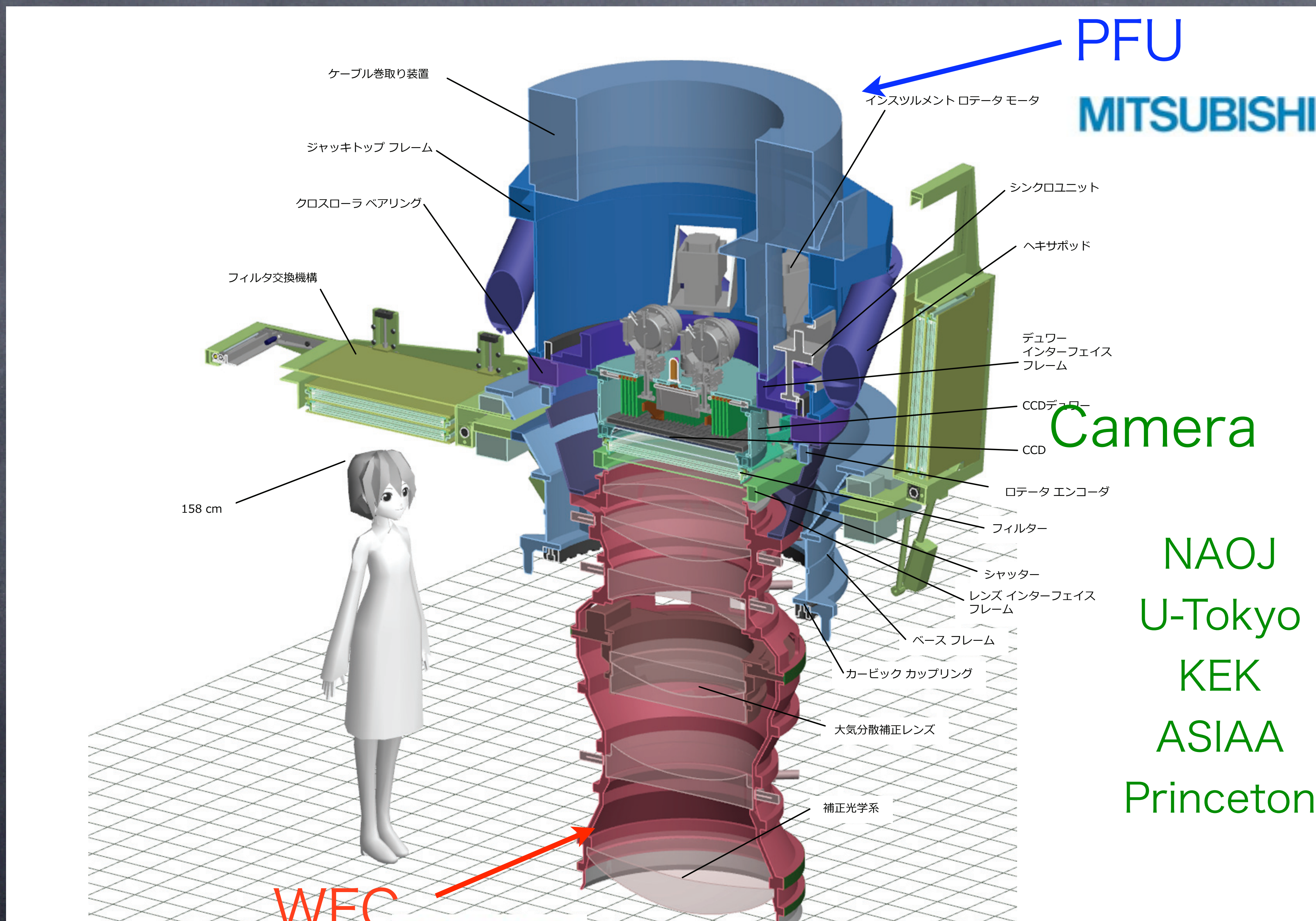




HSC specification

- field-of-view: 1.5 degree in diameter (1.77 deg2)
  - 7 times larger than Suprime-Cam (5 times smaller than LSST...)
- 600mm focal plane
  - 116 CCDs (incl. 4 auto-guider, 8 auto-focus)
  - 1 gigapixel
- 0.17 arcsec/pixel (typical seeing @ MK ~0.7 arcsec)
- high QE CCDs (Hamamatsu)
- readout ~20sec
- 6 broad-band filters (ugrizy) + several narrow-band filters
- seeing-limited image quality
- first light: 2011 fall
- data access?

Hyper Suprime-Cam (HSC)



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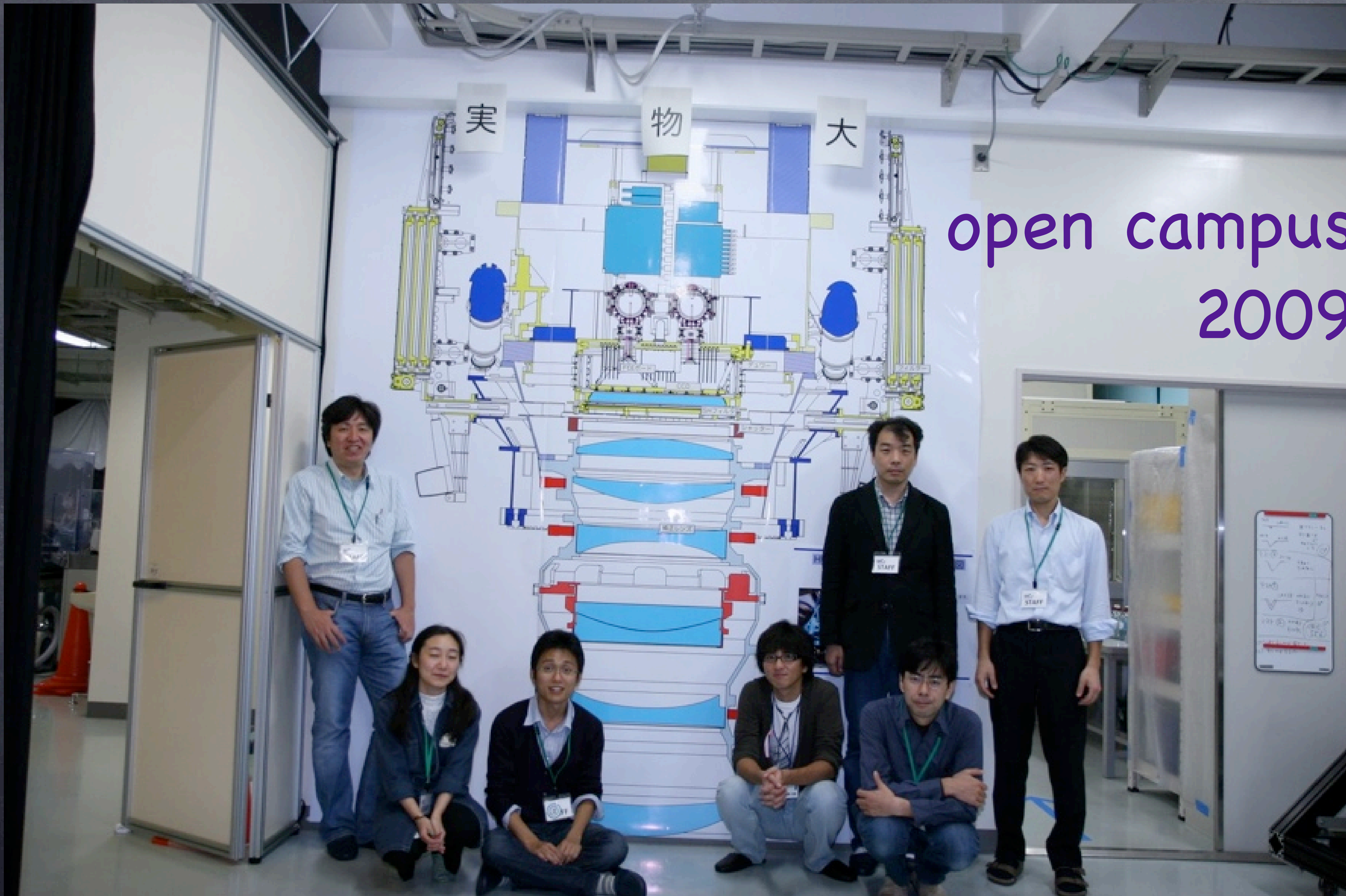
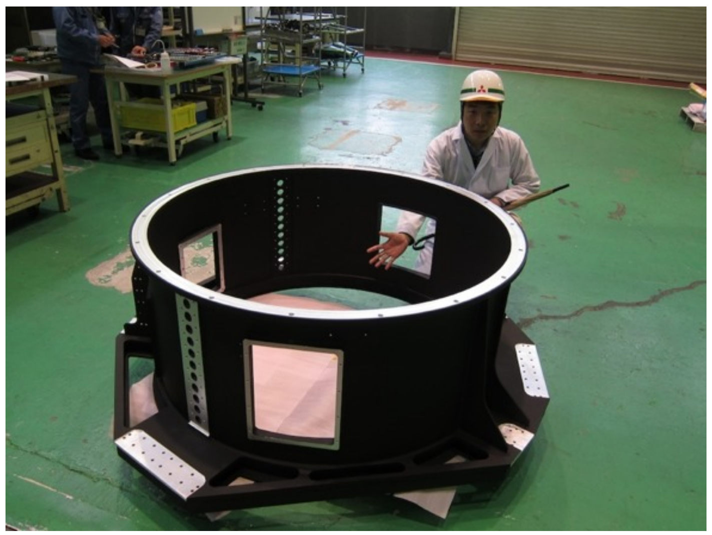


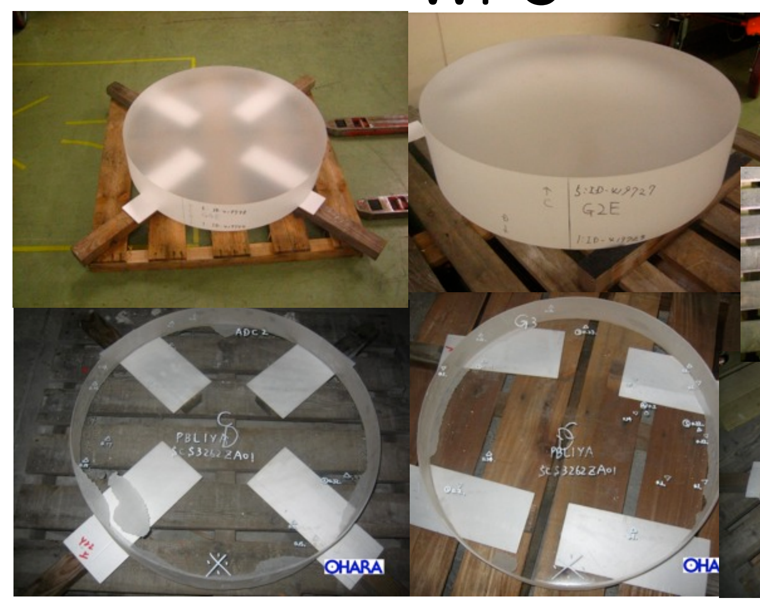
Hyper Suprime-Cam (HSC)

PFU for HSC



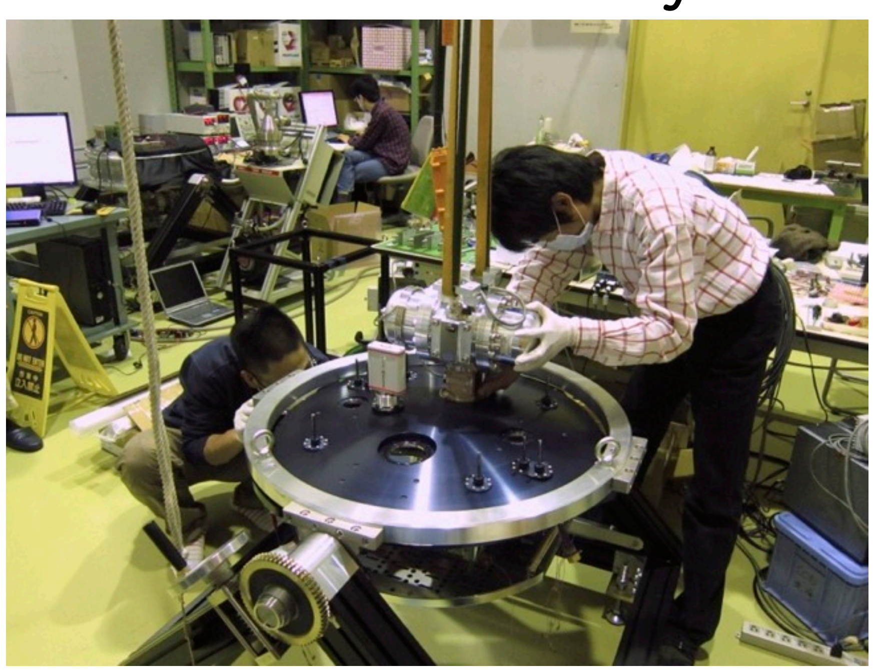
Jack Top Frame

WFC

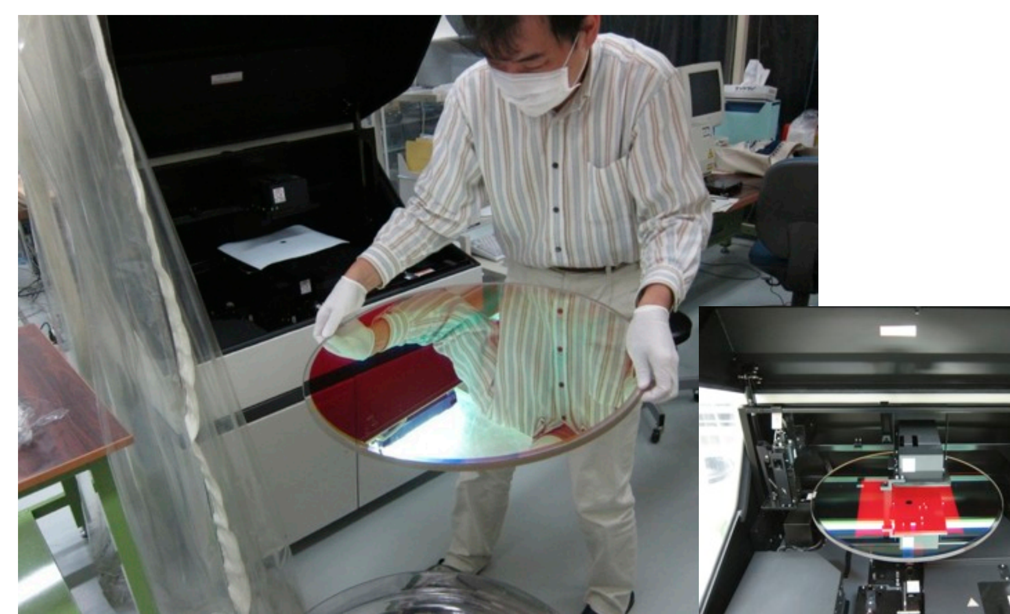


Silica: Corning
i-lines: OHARA
(homo. < 5 ppm)

Dewar Assembly



Filter



i'- filter : Barr

HSC Strategic Observations

- "Legacy" survey
- spend ~300 nights over ~5 years (maximum)
  - can not be achieved by individual proposals
- We will start HSC strategic observation in 2012 summer.
- Japan-Taiwan-Princeton collaboration
  - 3 layers: wide/deep/ultradeep
  - weak lensing, galaxy evolution, SN Ia cosmology, high-z ($z>6.5$) quasars
  - cadence is very important for "us"

HSC Strategic Survey: 3 layers

layer	wide	deep	ultradeep
# of nights	200	50	50
area [deg2] (HSC FoVs)	1300 (734)	28 (16=4x4)	3.5 (2)
filters	grizy	(u)grizy+3NBs	(u)grizy+6NBs
t_exp [min]	10-20	120-180	540-1620
science	weak lensing, galaxy cluster, quasars, ...	high-z galaxy, SNe, quasars, GRBs, ...	high-z galaxy, SNe, GRBs, AGN, ...

all the numbers are tentative.

HSC Strategic Observation (tentative)

	u	g	r	i	z	y	NBs	area
wide	-	10 (26.2)	10 (25.9)	20 (26.2)	20 (25.0)	20 (24.0)	-	1300
deep		120 (27.7)	180 (27.6)	180 (27.2)	120 (25.9)	120 (24.7)	3	28
ultradeep	-	540 (28.5)	540 (28.2)	1080 (28.2)	1620 (27.3)	1620 (26.1)	6	3.5

- wide: weak lensing, galaxy clusters, high-z quasars, ...
  - take all the data during one lunar phase (around new moon)
  - examine variability within a day
- deep: high-z galaxy, supernovae, quasars, GRBs, ...
  - ~10 epochs over 3 years
- ultradeep: high-z galaxy, supernovae, GRBs, AGN, ...
  - ~20 epochs over 5 years

exposure time in minute
area in deg2
limiting magnitude measured within 2 arcsec aperture, 5 sigmas

HSC Science: Transients

time scale: an hour - years

- Supernova
  - type Ia: cosmology, rate, host galaxy, progenitor
  - core-collapse: rate, host galaxy, progenitor(@preimage)
- GRB
  - optical orphan afterglow: mechanism
  - ToO follow-up(?)
- AGN
  - low-L quasar (M1450~-23mag)@z>3: LF, evolution
  - low-L AGN@z<1: environmental effect
- High Proper Motion Stars
- Solay system bodies

Summary

- Subaru/Suprime-Cam variability survey found ~1,000 variable objects over ~1 deg2 (i<26mag).
- SN Ia at z>1. Rate is incresing. Higher-redshift?
- Among the AGN sample (~500 objects), a significant fraction of AGN are not detected in deep X-ray data (XMM-Newton).
- They are low-L AGN without X-ray detection (<10^-15 erg/s/cm2) at z~0.5. LINER analogous?
- Subaru/HSC will be completed and get its first light on 2011 fall.
- HSC Strategic Survey will start on 2012 summer and spend ~300 nights over 5 years (3 layers: wide/deep/ultradeep).
- Many science including SN, GRB, and AGN will be intensively done using Subaru/HSC.

~ End ~

Thank you !!!