Lecture on near-IR astronomy

- A brief history of near-IR history
- Some science drivers for observing in the near-IR
  - Galactic center astrometry
  - Dust clouds mass estimation
  - Photo-z
  - Brown dwarfs
- Instrumentation
  - Reading out images
  - Hardware

Part 1
25min

- The Near-IR Sky
  - OH- emission lines.
  - Thermal emission.
  - Definition of filter bands - the Mauna Kea system.
  - Sky brightness variations - in J,H,K from WIRCam data.
  - Sky brightness variations - 2MASS movies.
- Strategy to remove the sky background.
  - The classical dithering strategy.
  - The nodding strategy on extended targets.
  - Golden rules.

Part 2
25min

- 'I'iwi (pronounced e-e-vee) at a glance
- Detrending steps in more details
  - Non-linearity correction
  - Dark subtraction
  - Flat fielding
  - Bad pixel masking
  - Sky construction and subtraction
  - Crosstalk correction
  - Linear astrometry solution
  - Absolute photometry
- Stacking

Part 3
45min

Summary of the lecture today

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In 1799, William Herschel proffered the somewhat tentative suggestion: ‘Radiant heat will at least partly, if not chiefly, consist, if I may be permitted the expression, of invisible light.’

- Late 1960s - CALTEC IR photometry (2 micron sky survey) Becklin, Neugebauer, etc. using photometers.
- In the early 80s, two-dimensional monolithic detector arrays were starting to find their way into the hands of US astronomers (but could not be exported - ring a bell?).
- In the early 90s, 256x256 NICMOS detectors were introduced (prompted by HST project).
- MONICA at CFHT among the first scientifically usefull cameras, used with PUEO adaptive optics.
- 1024x1024 HAWAII detectors at the end of the 90s.
- 2048x2048 HAWAII-2 in ~2005.

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- Lower extinction. Interstellar extinction is a very steep function of wavelength. Heavily obscured regions, such as the centres of galaxies and star formation regions, cannot be observed at optical wavelengths but are readily studied in the infrared.

- The ability to see warm (as opposed to hot) objects. Planets, circumstellar discs, protostars and other warm objects emit negligible flux at visible wavelengths, and can therefore only be directly observed at infrared and longer wavelengths.

- Better spatial resolution under seeing-limited conditions. The diameter of an image under seeing-limited conditions goes as $\lambda{-}1/5$. In addition, adaptive optics correction becomes much simpler and much more effective as the wavelength increases.

- Unique phenomena. In any spectral region there will be phenomena that can be observed at other wavelengths only with difficulty, or perhaps not at all. In the infrared region, for example, lie almost all of the molecular vibrational transitions, plus the rotational lines of molecular hydrogen and HD.

- Red-shifted spectral features. Important diagnostic lines whose rest-frame wavelengths are in the optical or ultraviolet are shifted into the infrared at high z .

- (taken from: John W. V. Storey, Infrared Astronomy: In the Heat of the Night The 1999 Ellery Lecture)

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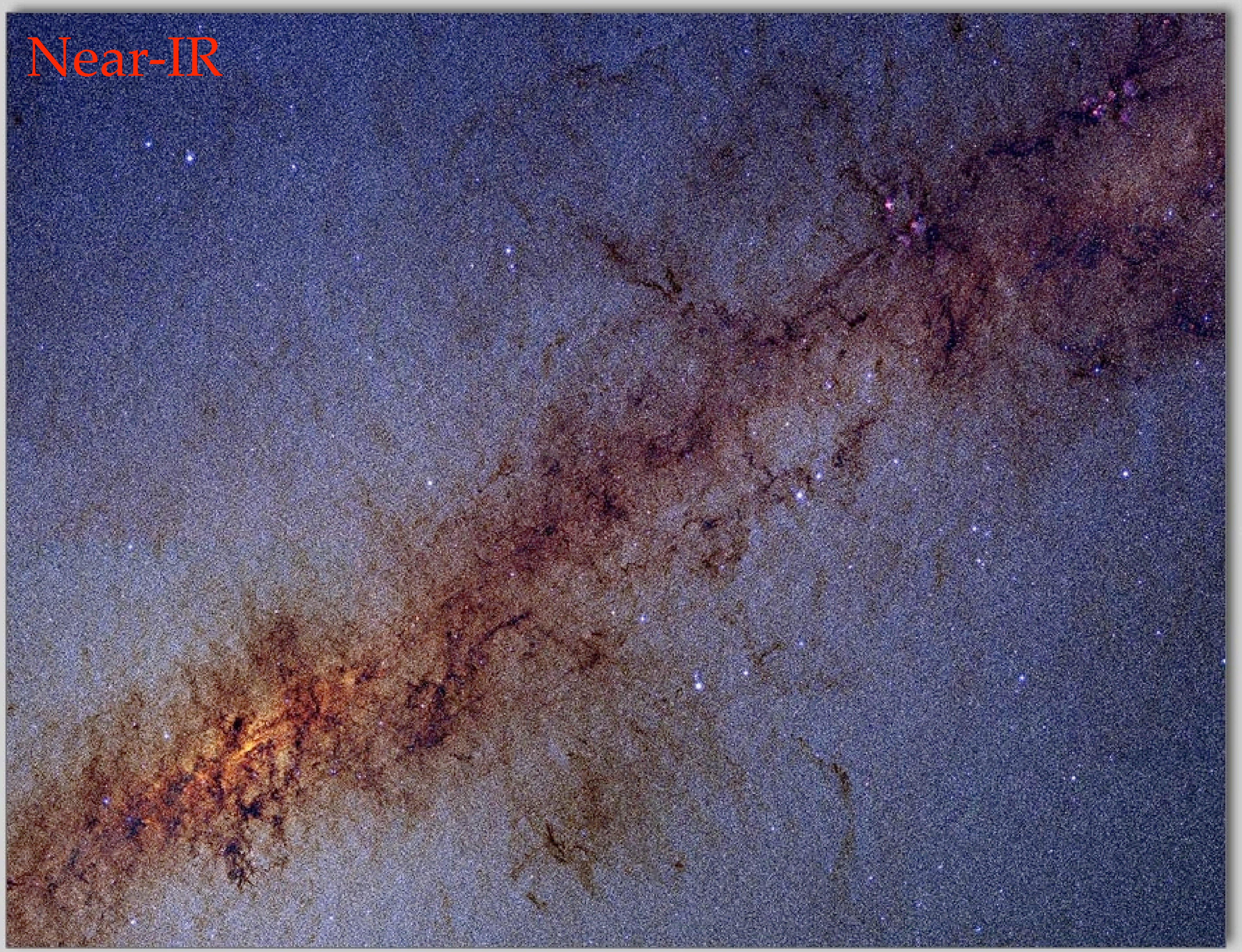
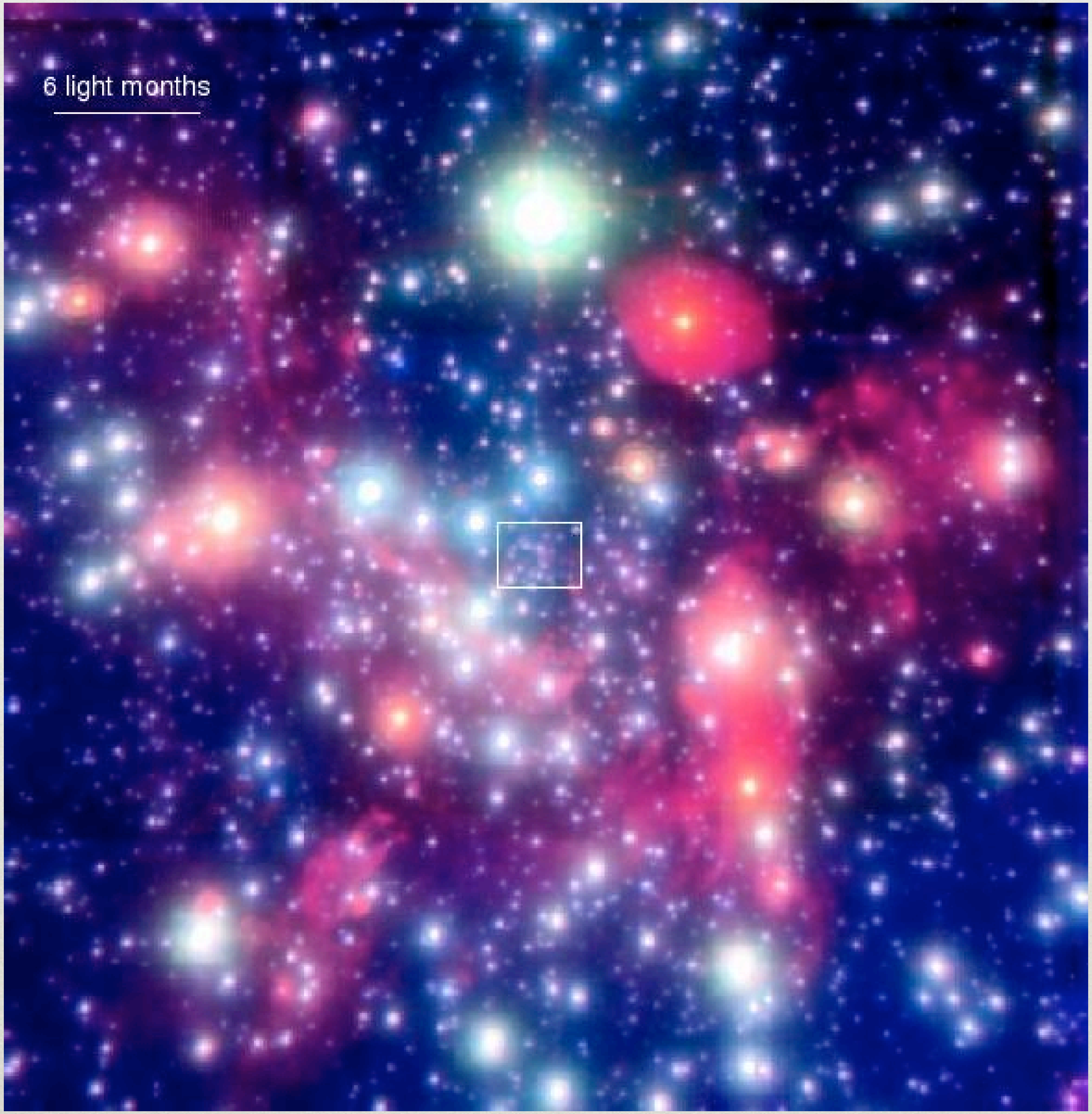
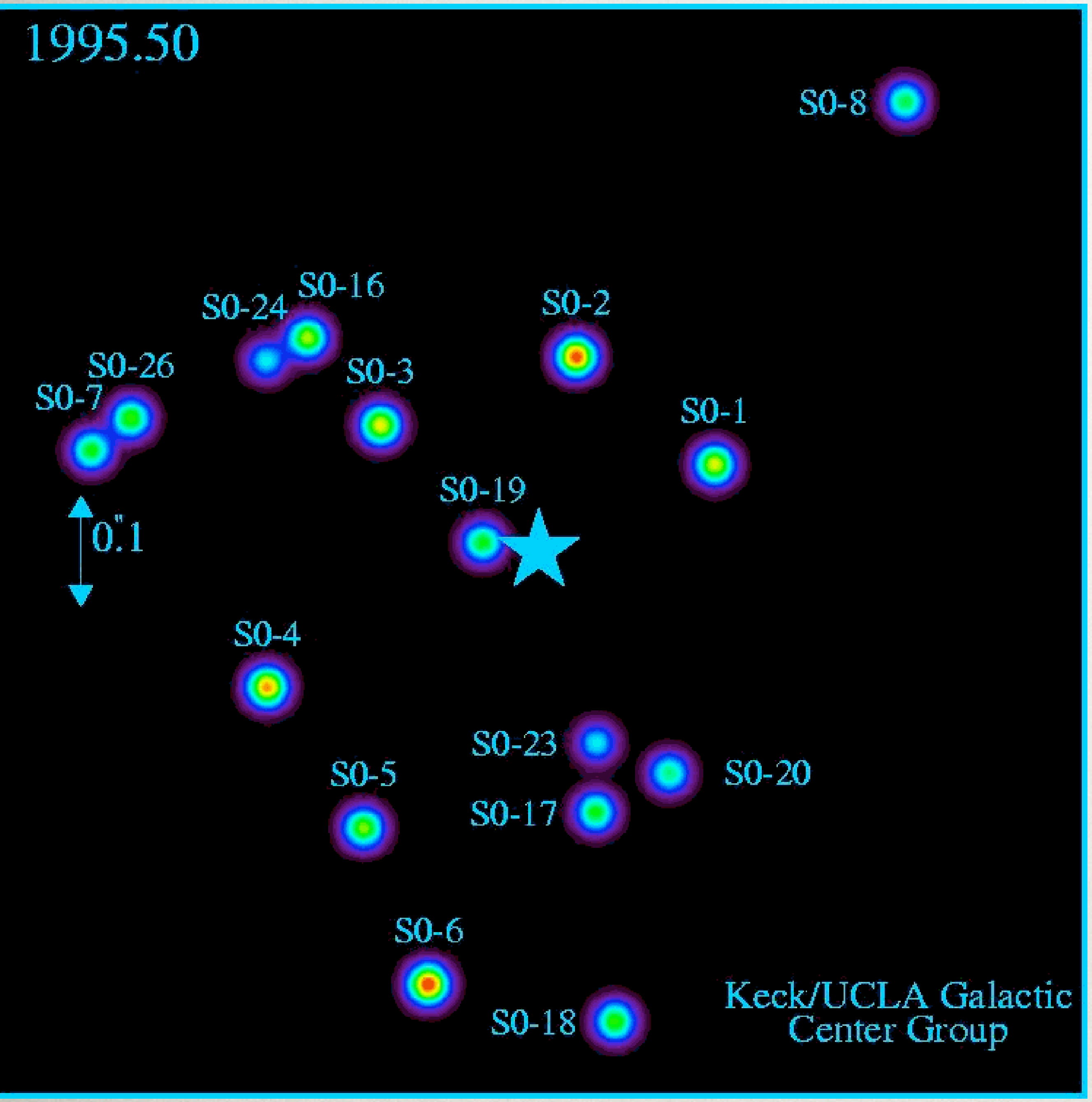
optical



The Galactic Center Infrared view penetrating to the central star cluster of the Galaxy

2MASS*Showcase*


6 light months


1995.50
S0-8
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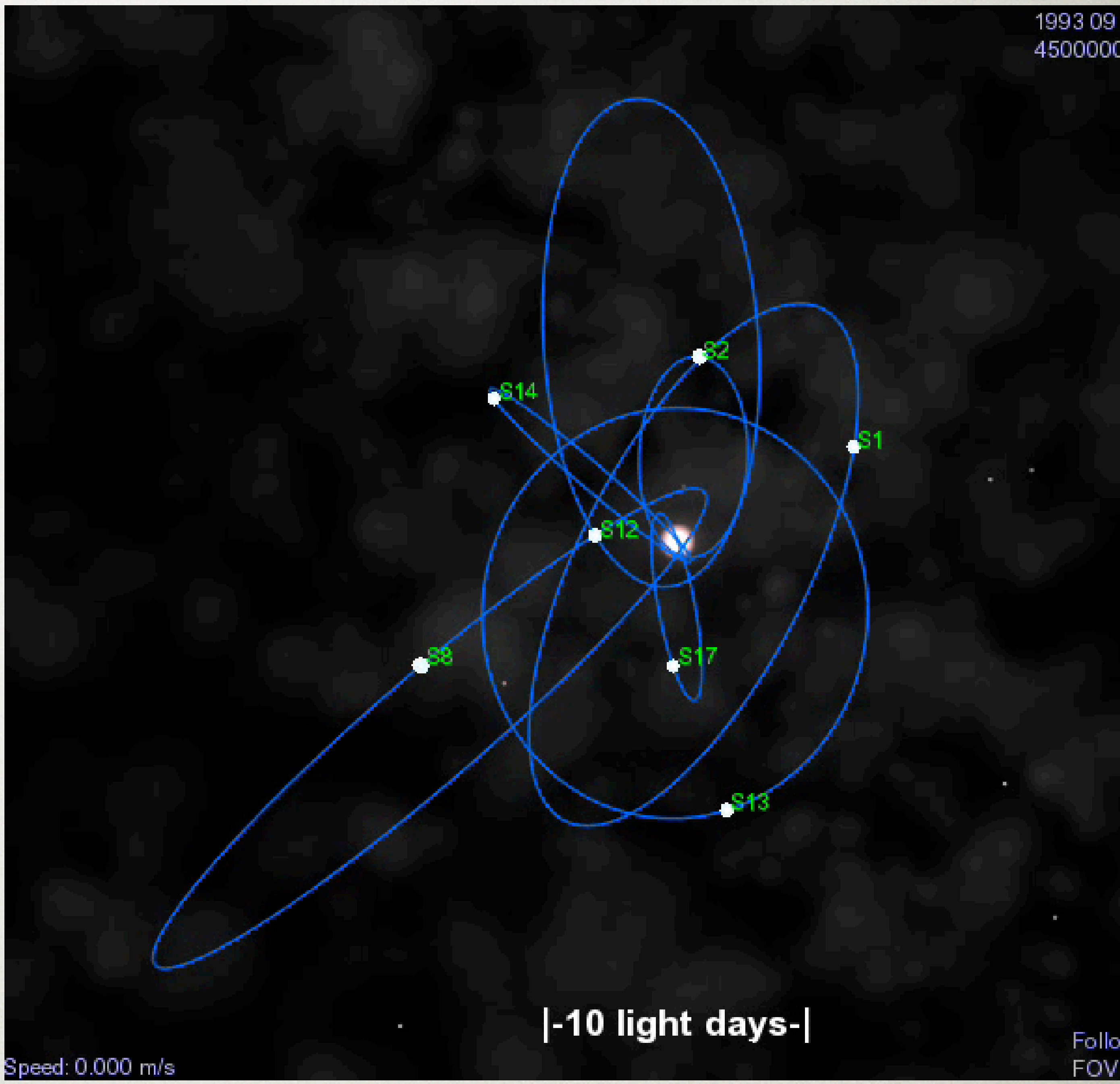
S0-18
Keck/UCLA Galactic Center Group


S2
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S1
S12
S8
S17
S13
|-10 light days-|
Speed: 0.000 m/s

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UV & Optical

- $\lambda \approx a$, Mie theory

-Scattering of light by dielectric particles (a).

-Particle size distribution is important.

IR

- $\lambda >> a$, Rayleigh scattering

-Scattering of light by dust.

-Efficiency prop. to λ^{-4}.

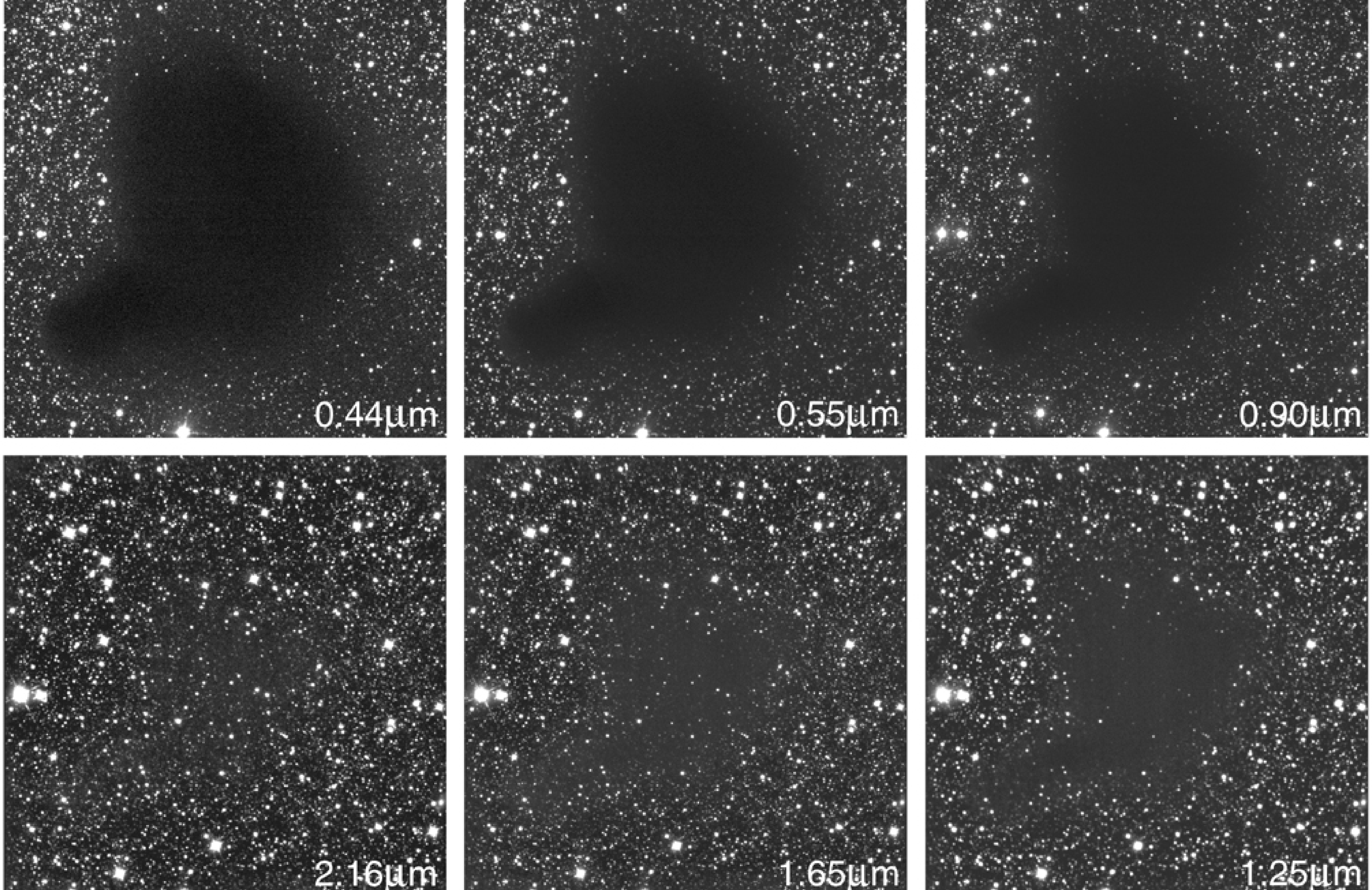
-Particle size distribution not important.

Color excess = $(A_\lambda - A_V)/E_{B-V}$

Extinction (A_λ)

Band	λ (um)	A_λ(mag)
V	0.55	1.00
R	0.64	0.78
I	0.79	0.59
J	1.21	0.28
H	1.65	0.18
K	2.20	0.11
L	3.45	0.06

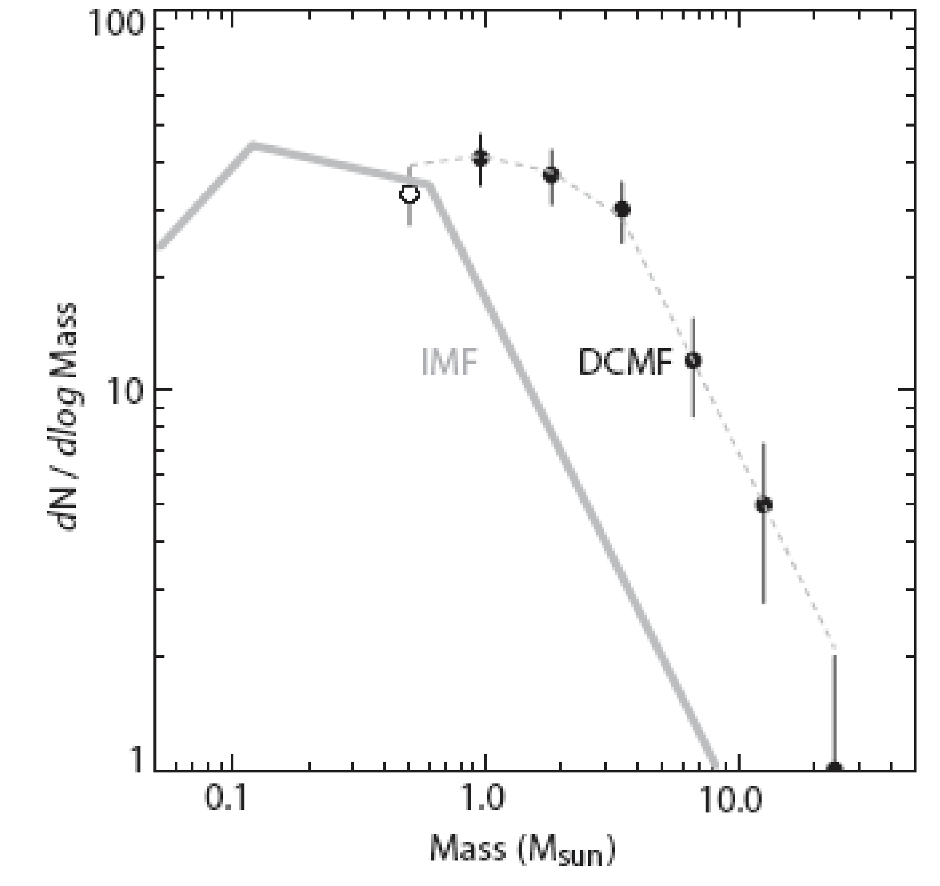
$A_\lambda \propto \lambda^{-1.75}$



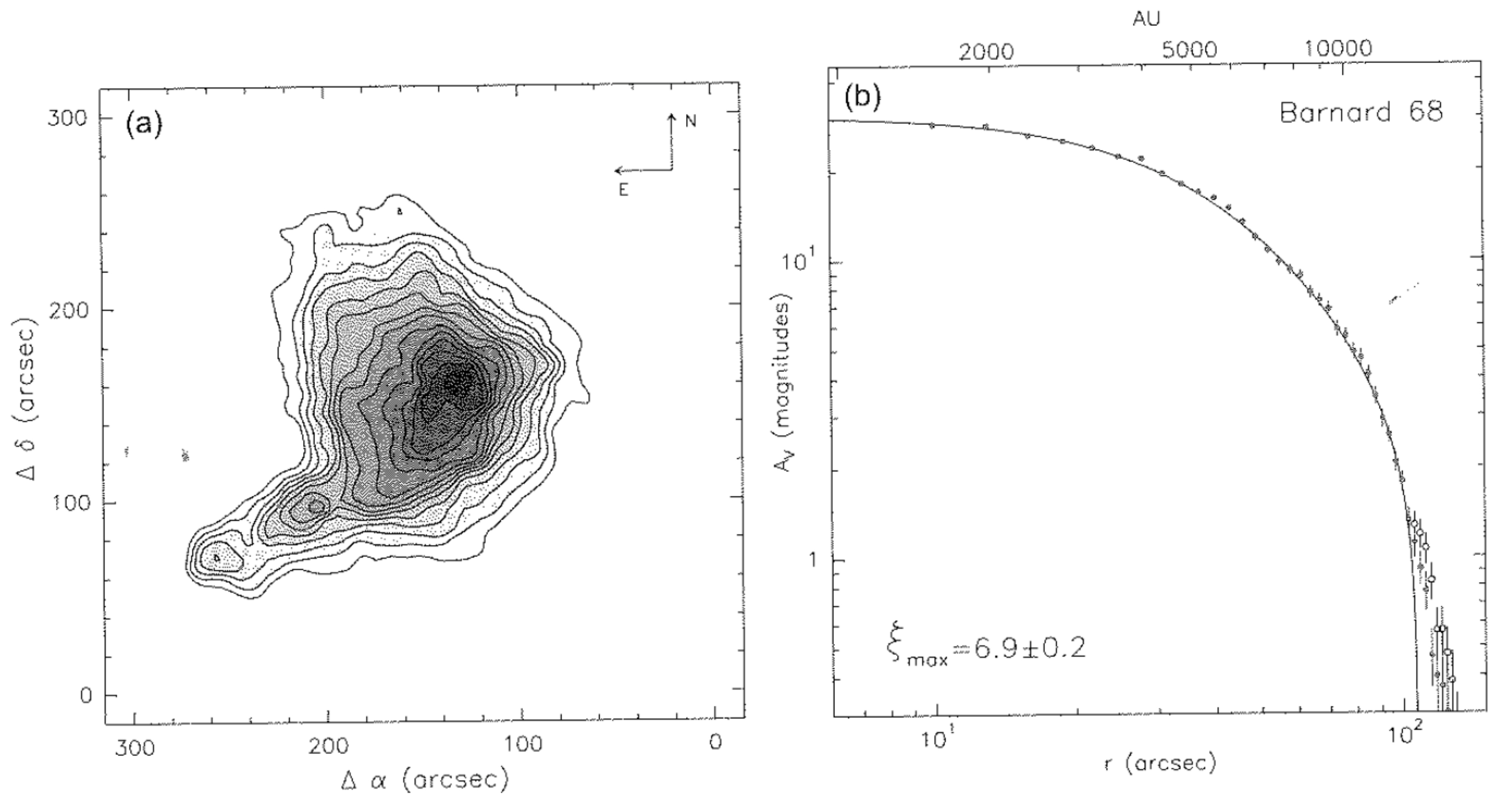
The Dark Cloud B68 at Different Wavelengths (NTT + SOFI)

ESO PR Photo 29b/99 (2 July 1999)

Alves, Lombardi, Lada, 2006, A&A



Lada & Alves, 2006, PPV



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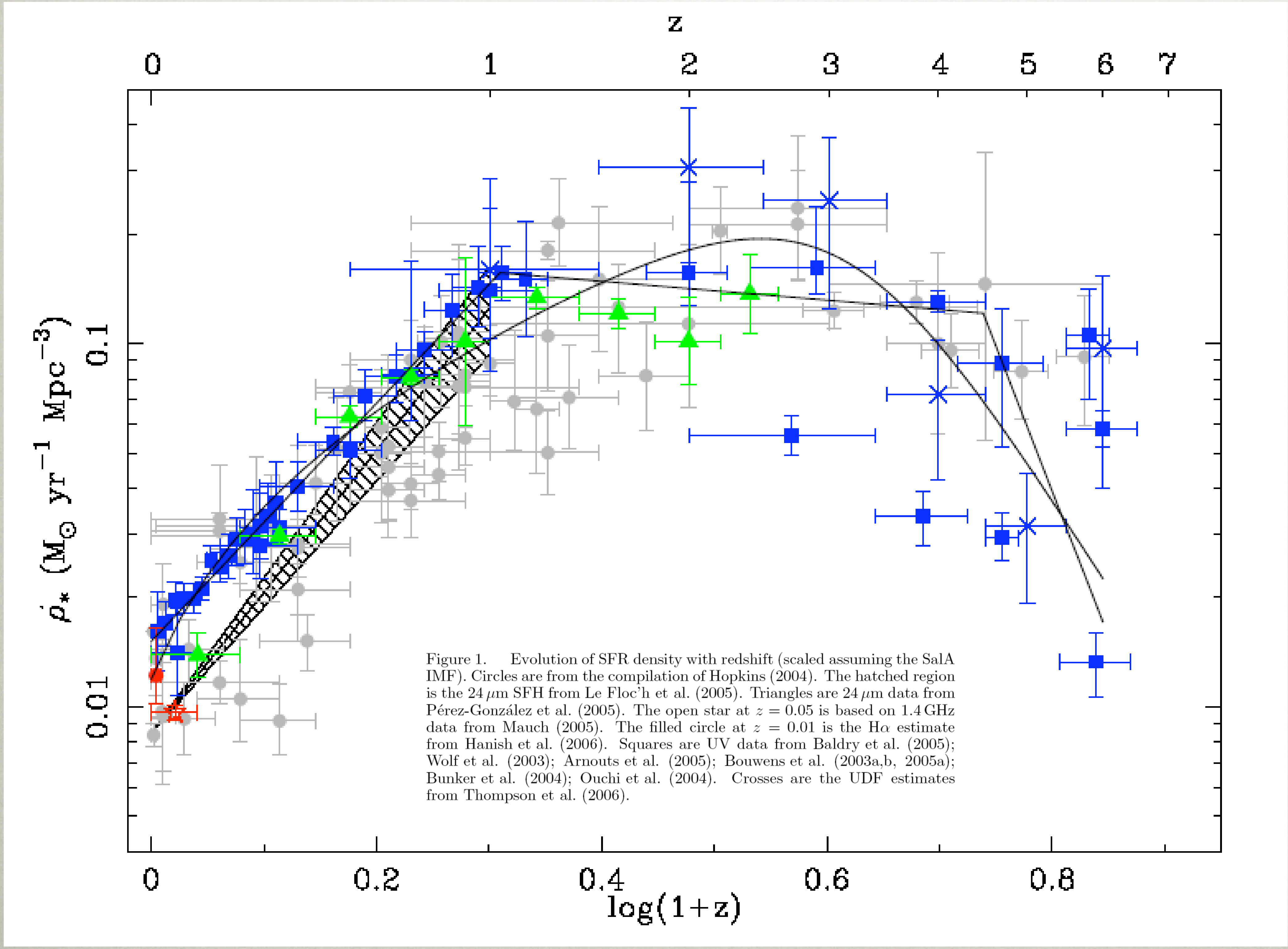
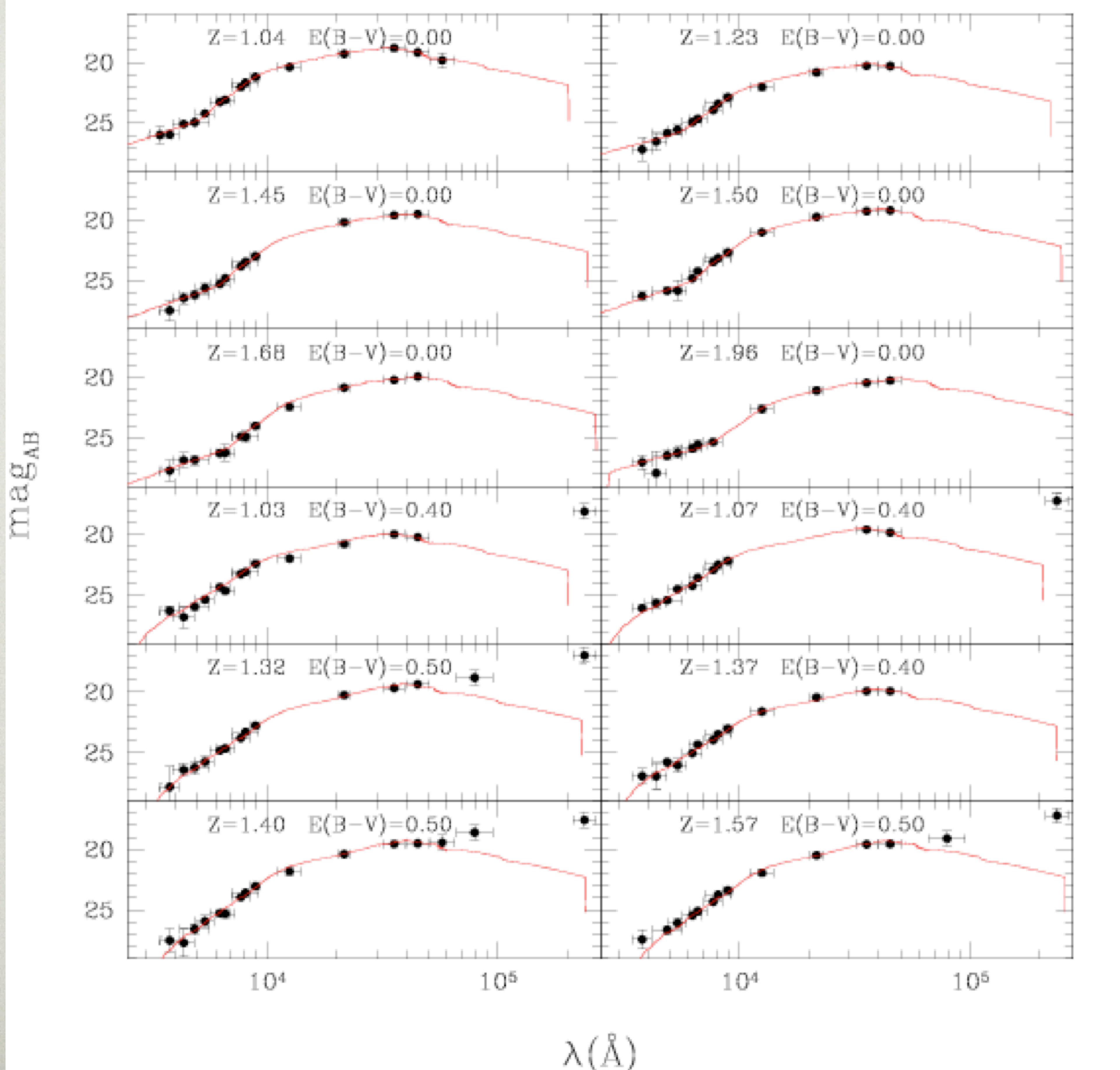
Star Formation History of the Universe

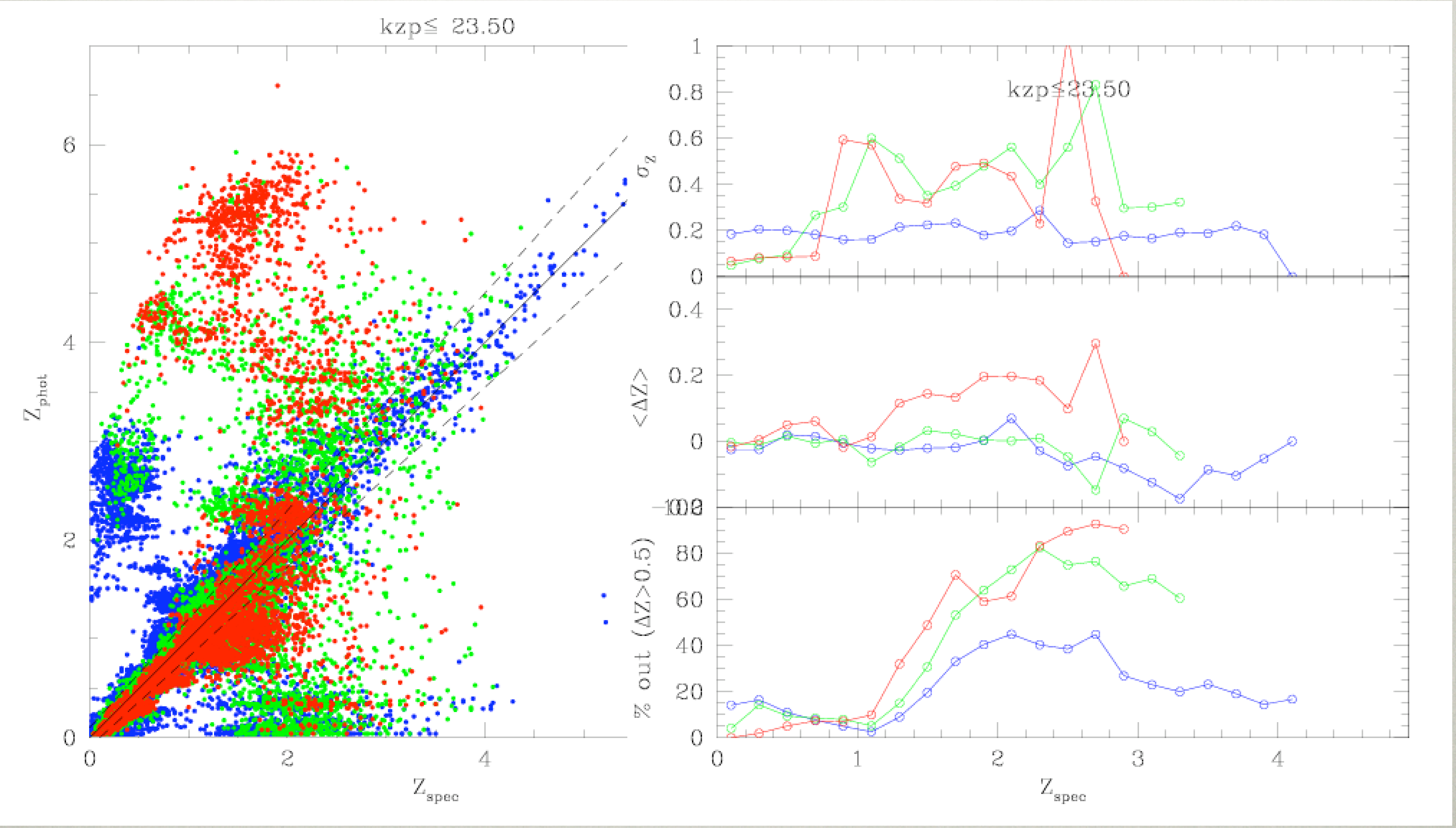


Hopkins et al. 2006, astro-ph 11283

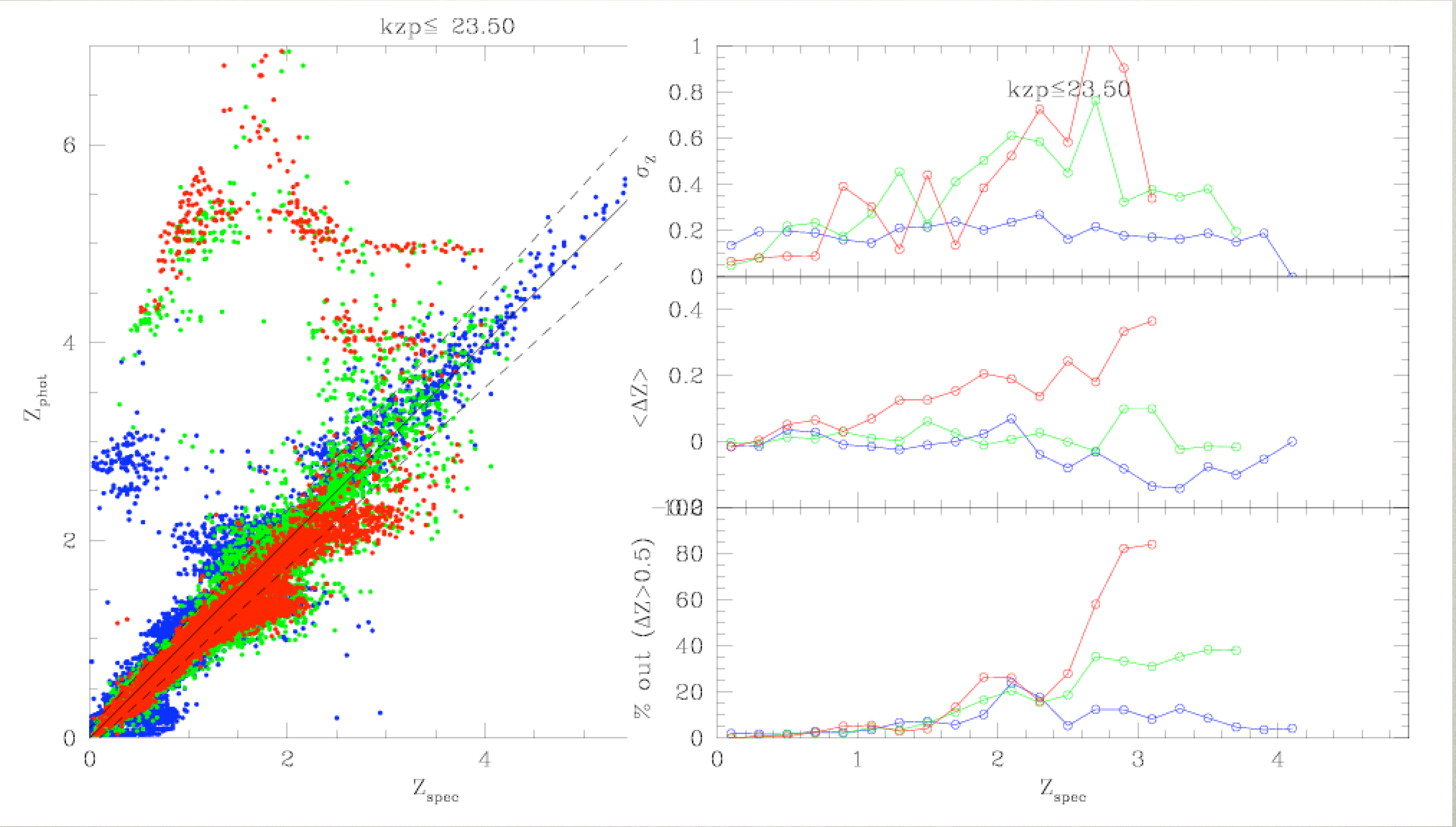
Accurate SED fitting at high Z



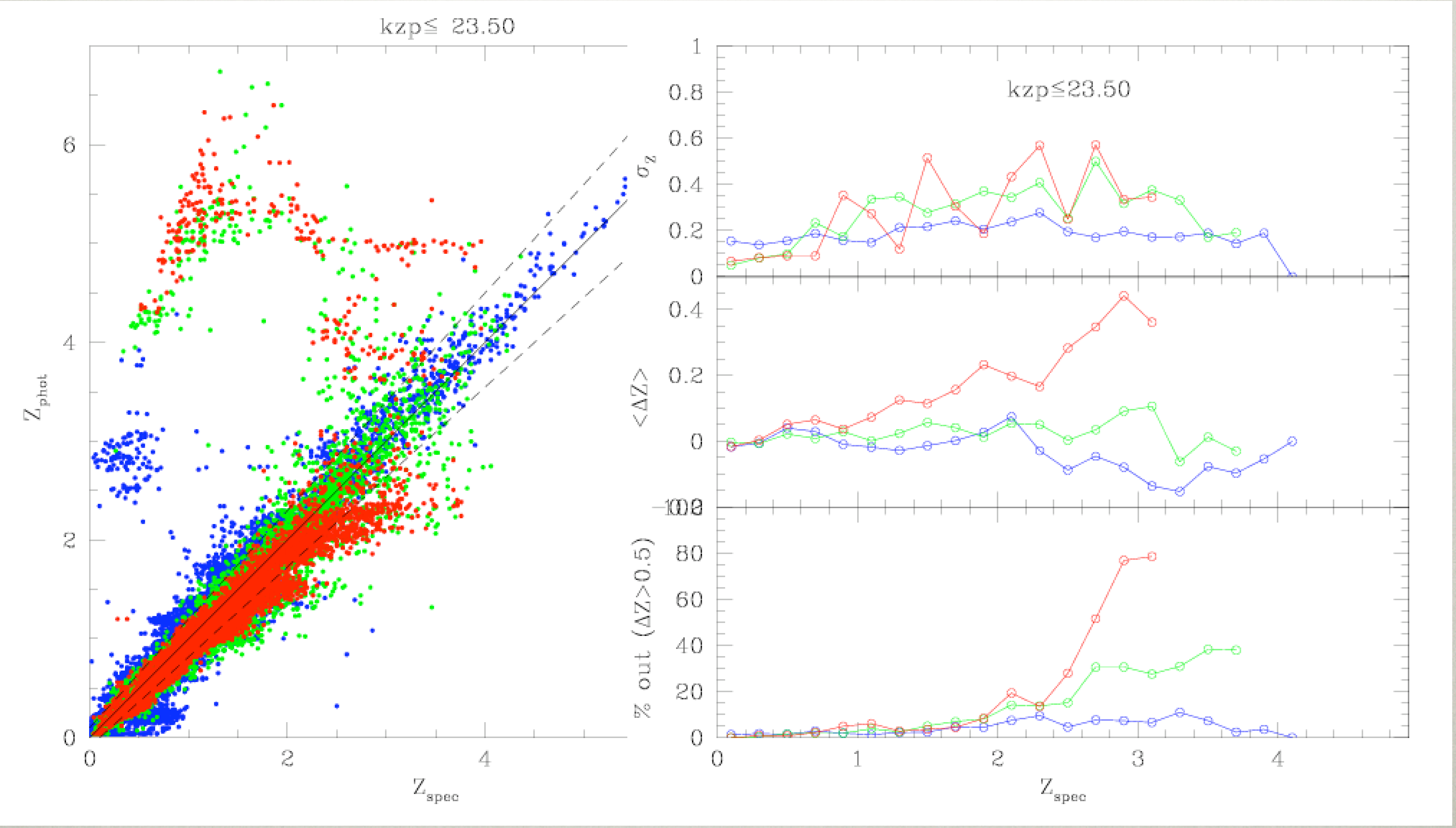
GALEX + CFHTLS



GALEX + CFHTLS+JK

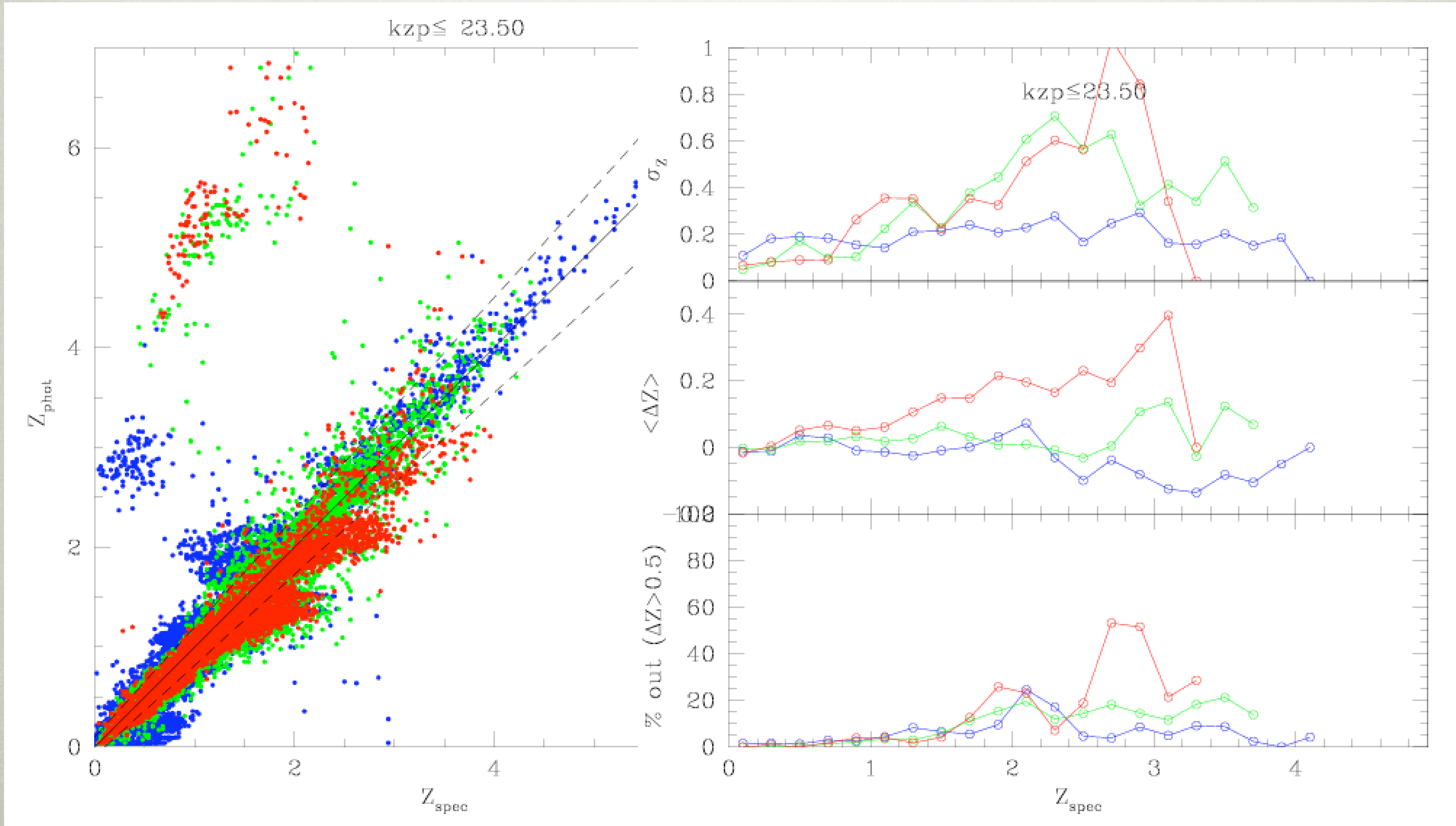


GALEX + CFHTLS+YJK



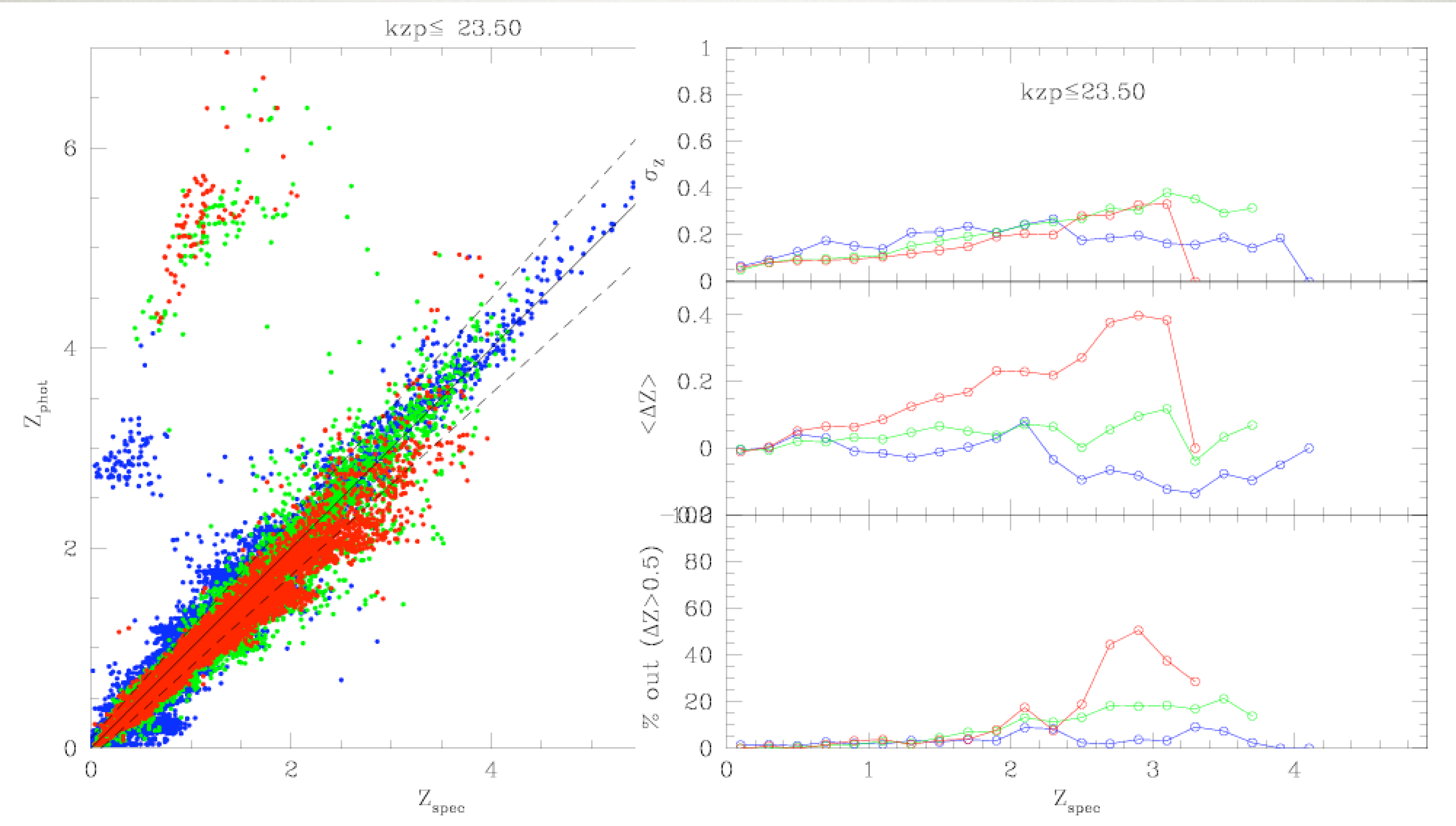
Y improves Zphot around z=1-2

GALEX + CFHTLS+JHK



H improves Zphot at z>2

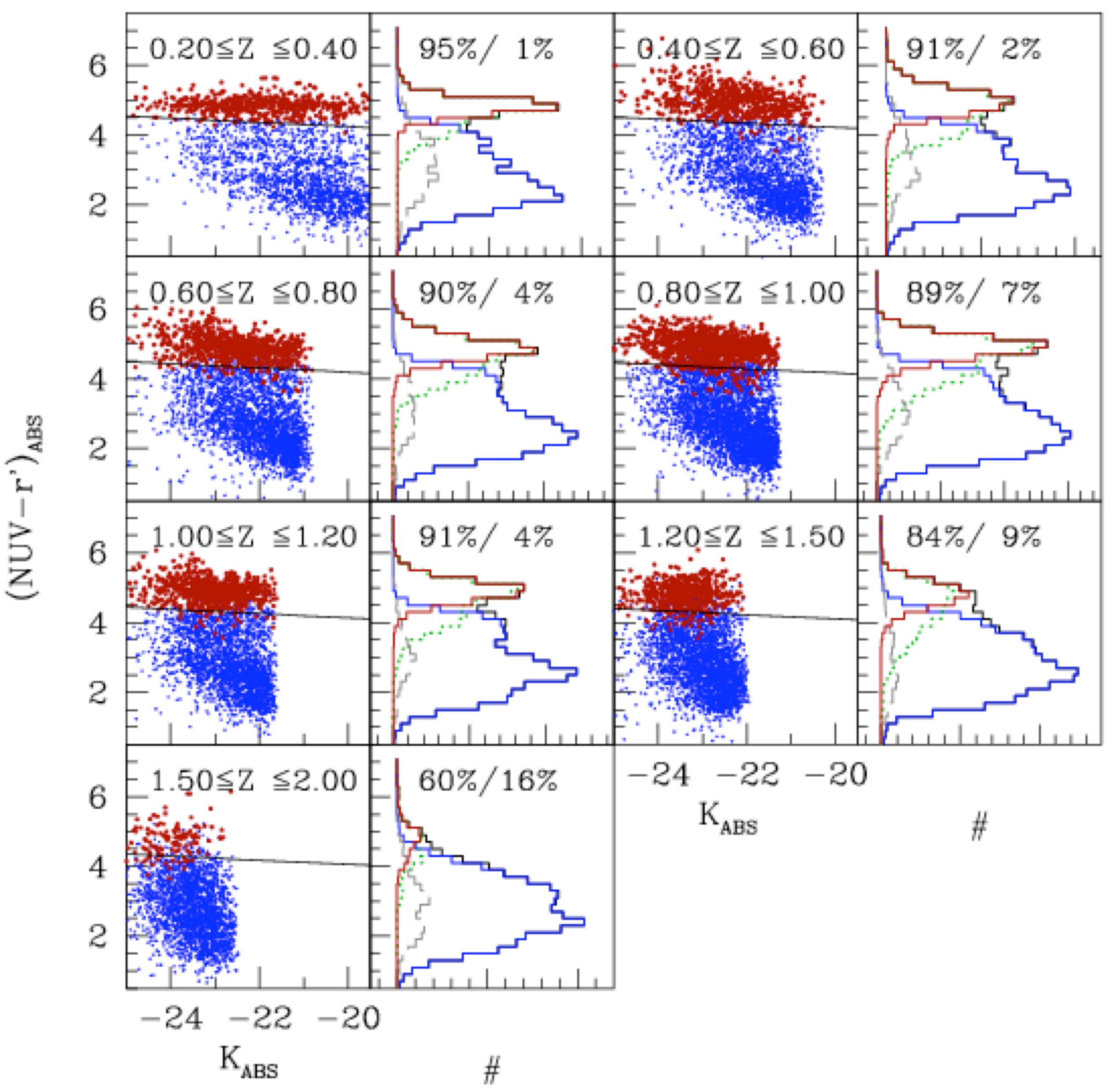
GALEX + CFHTLS+YJHK



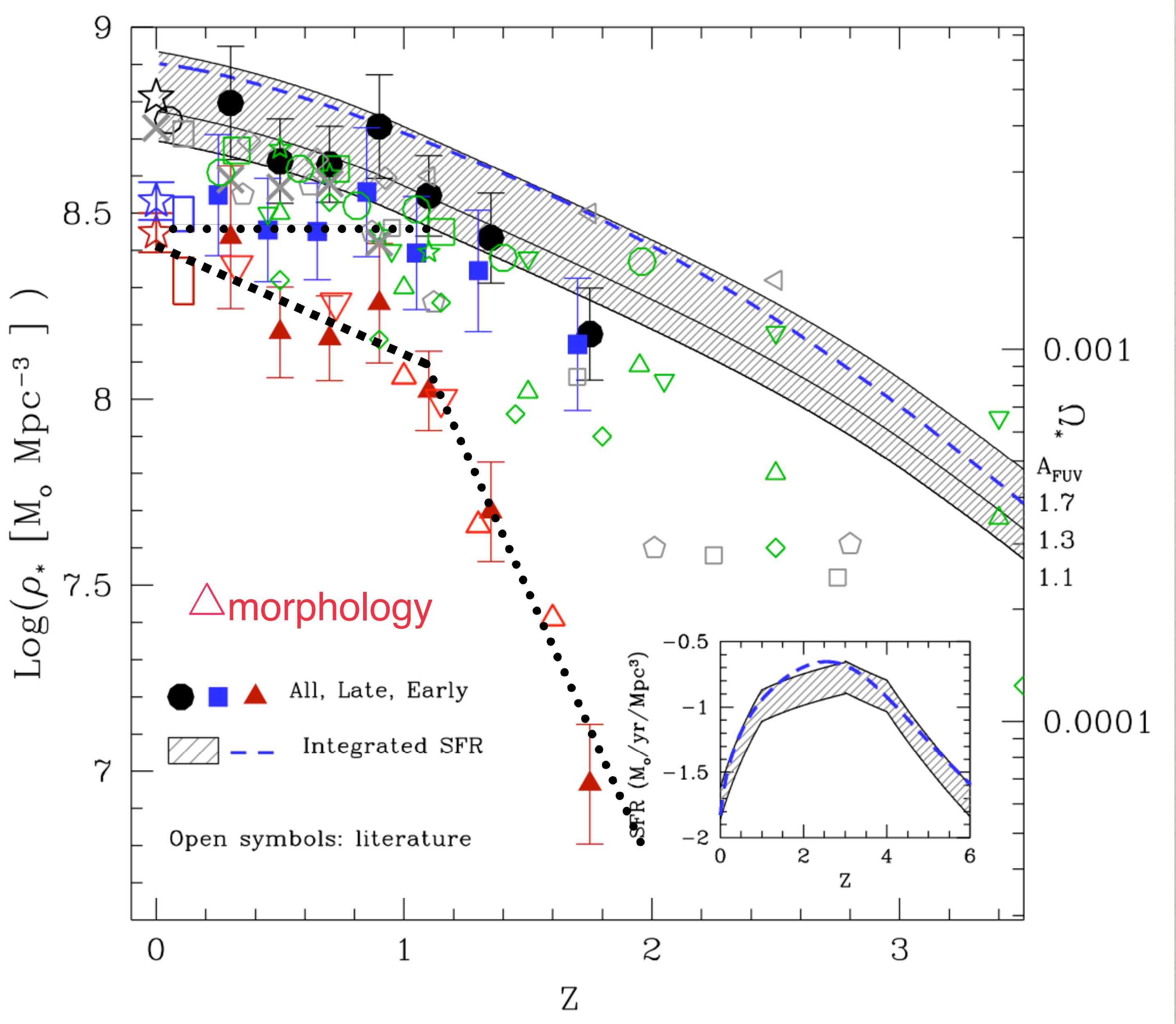
Obviously the best. σ(z) ∝ 0.1 x (1+z)

Stellar Mass Assembly History

Red sequence evolution using (NUV-r')



Origin of the mass growth of Red Sequence



Understand global evolution with individual Galaxy properties

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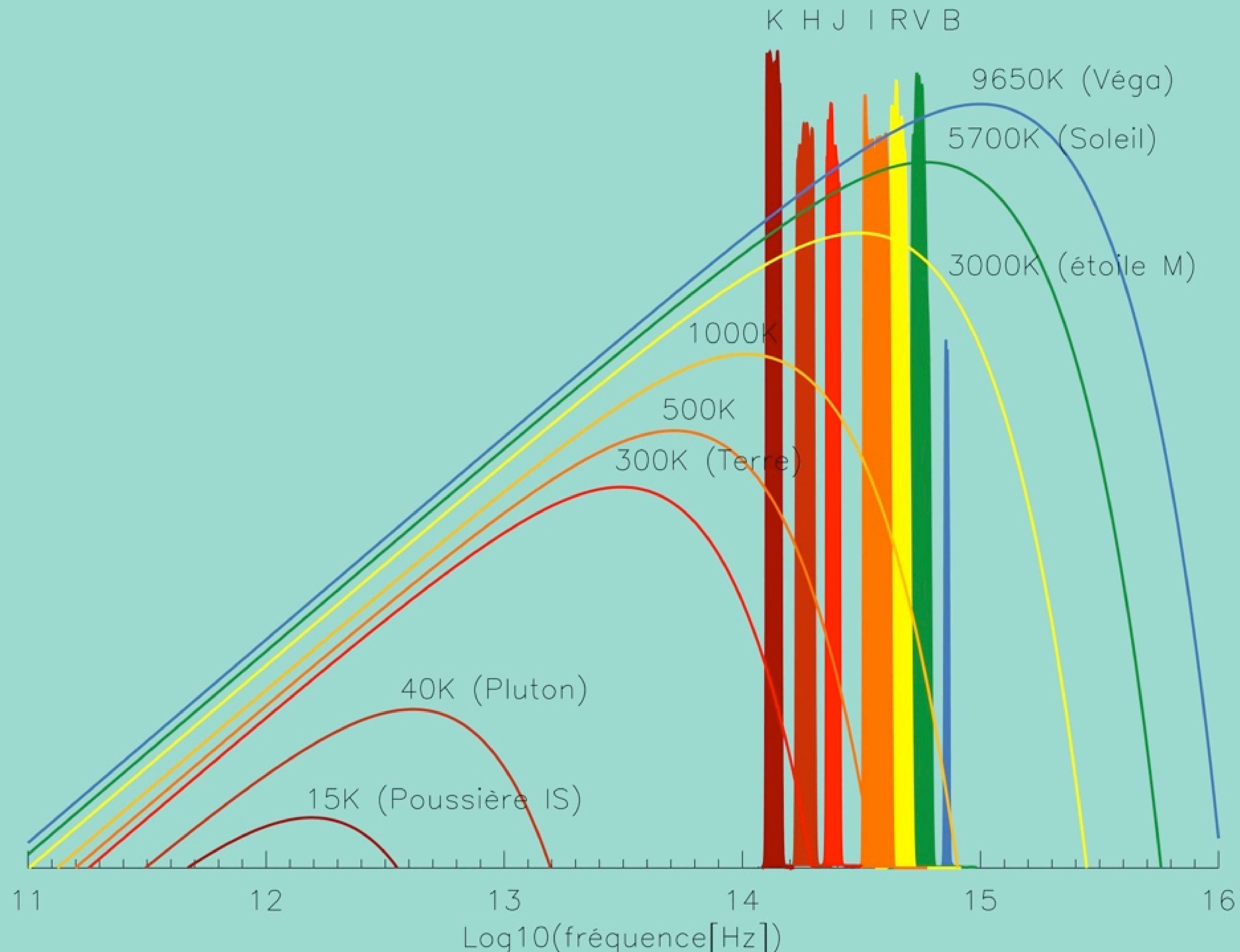
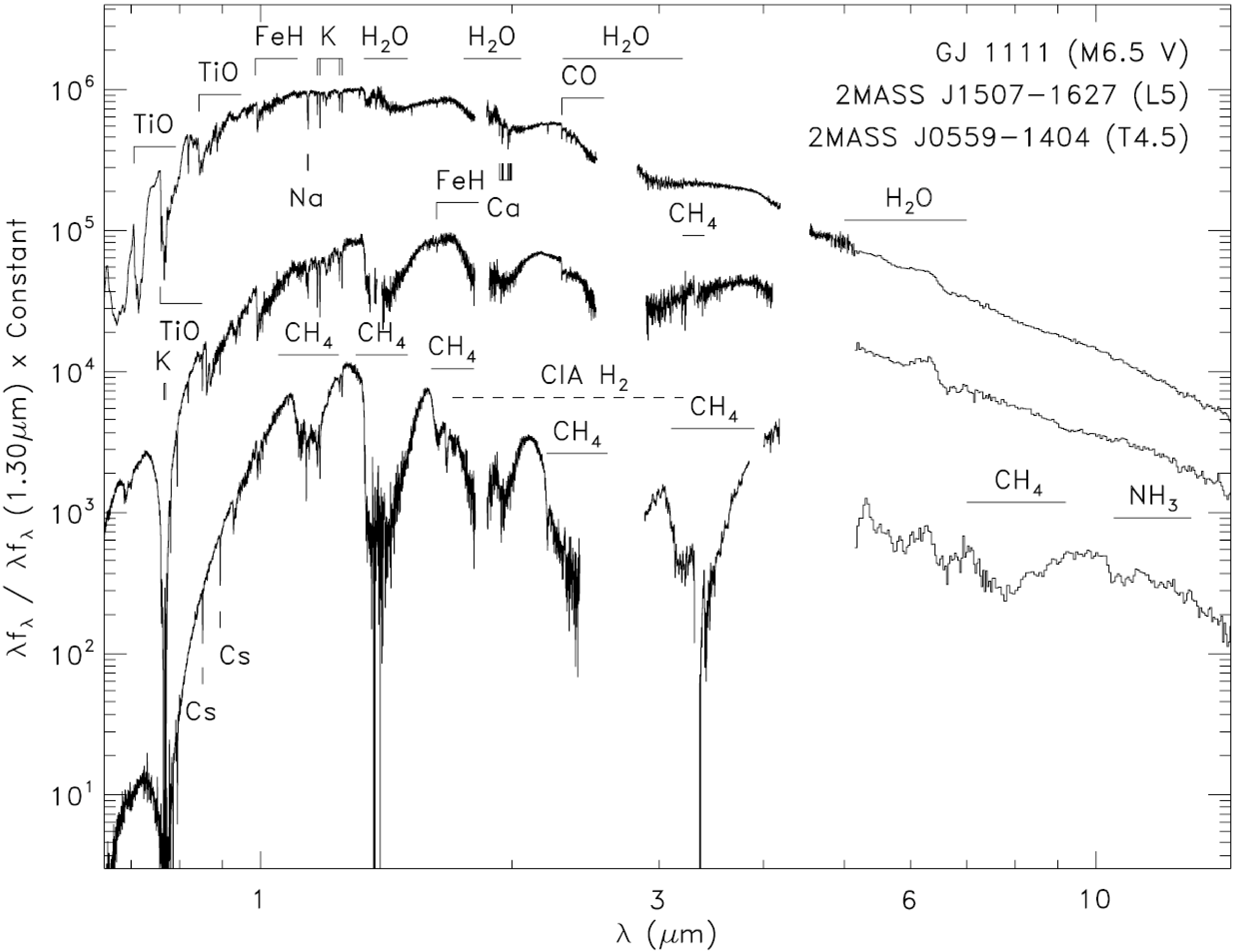
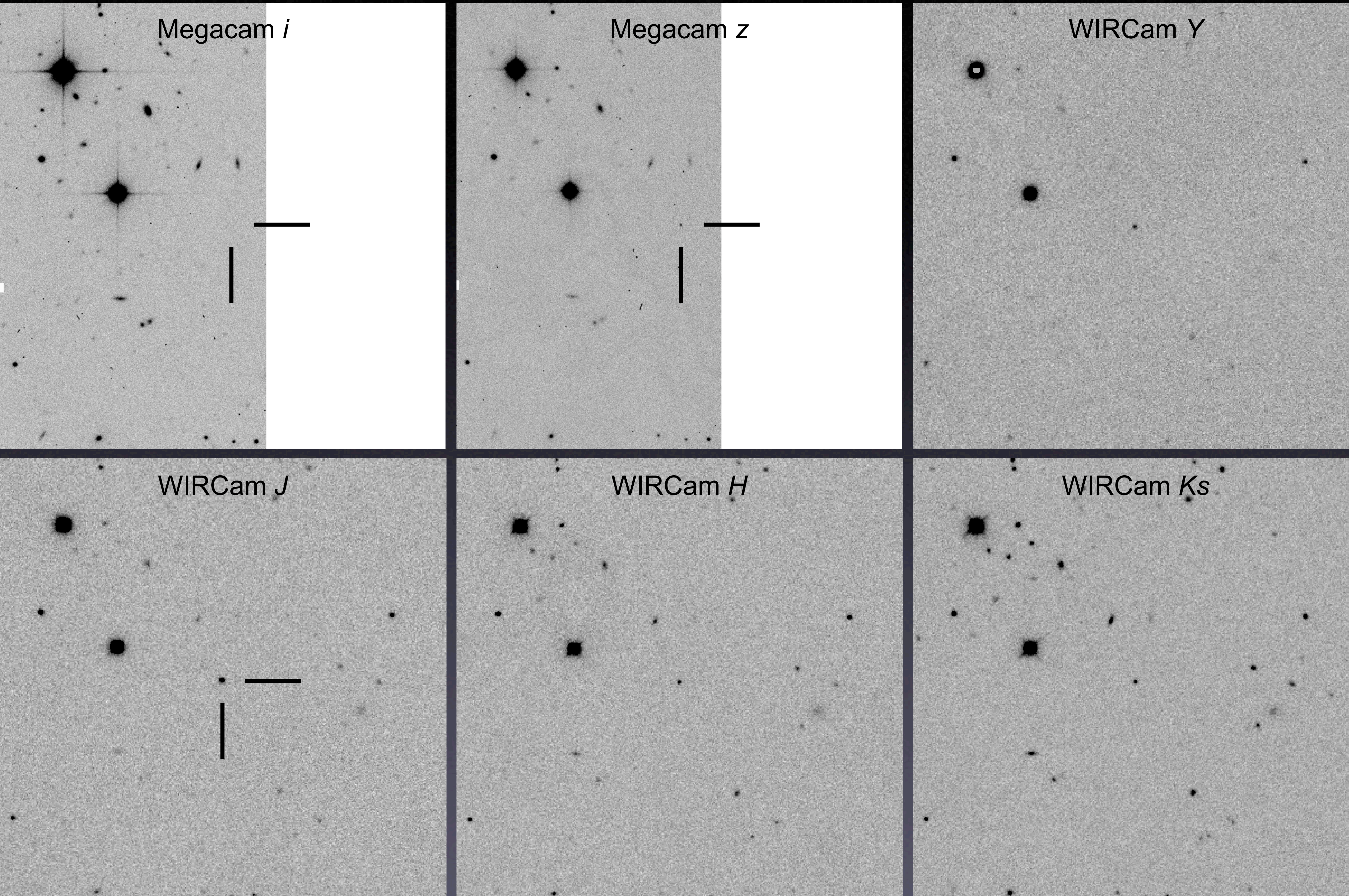
Black Body Thermal Emission

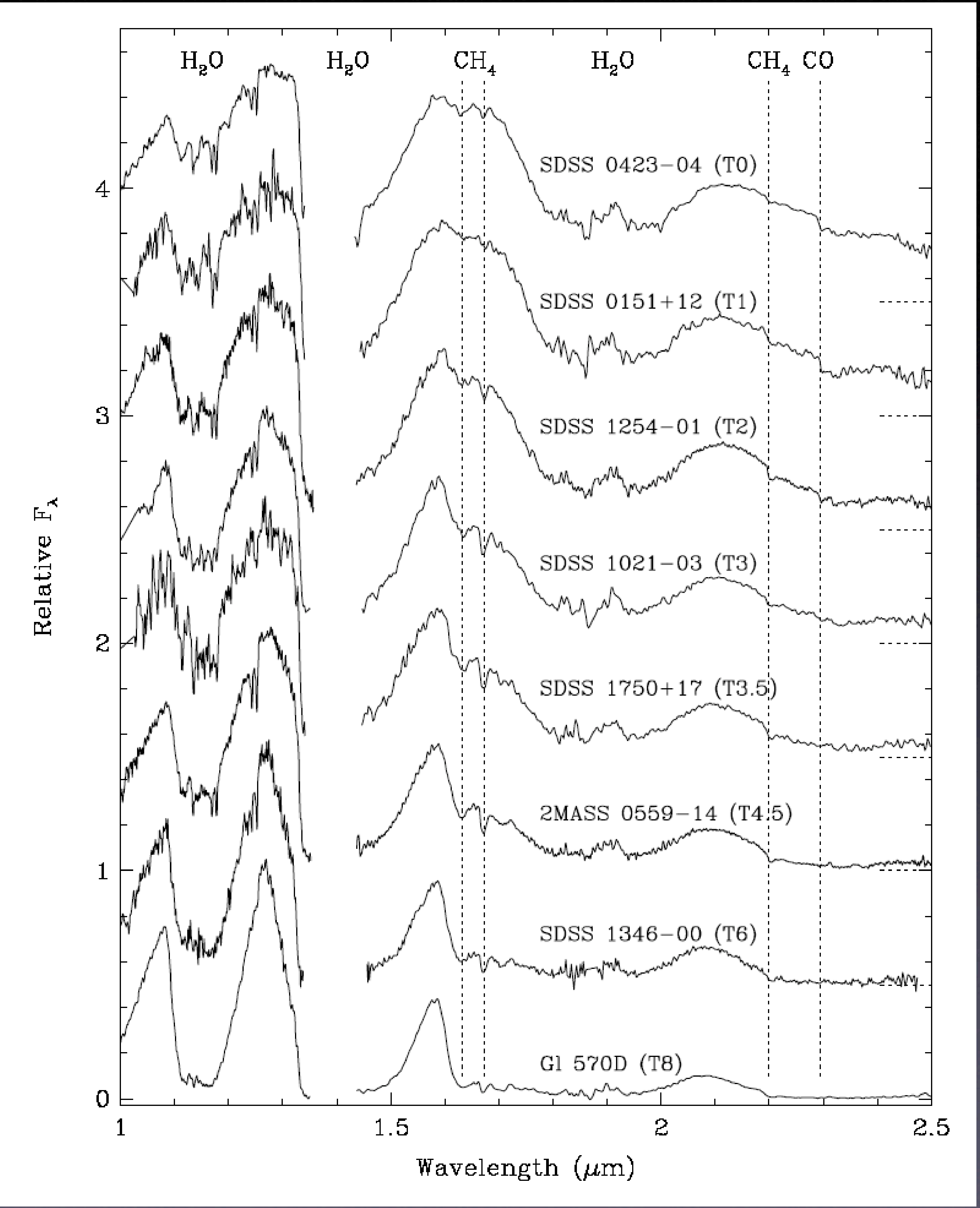


SPECTRAL SEQUENCE OF M, L, AND T DWARFS



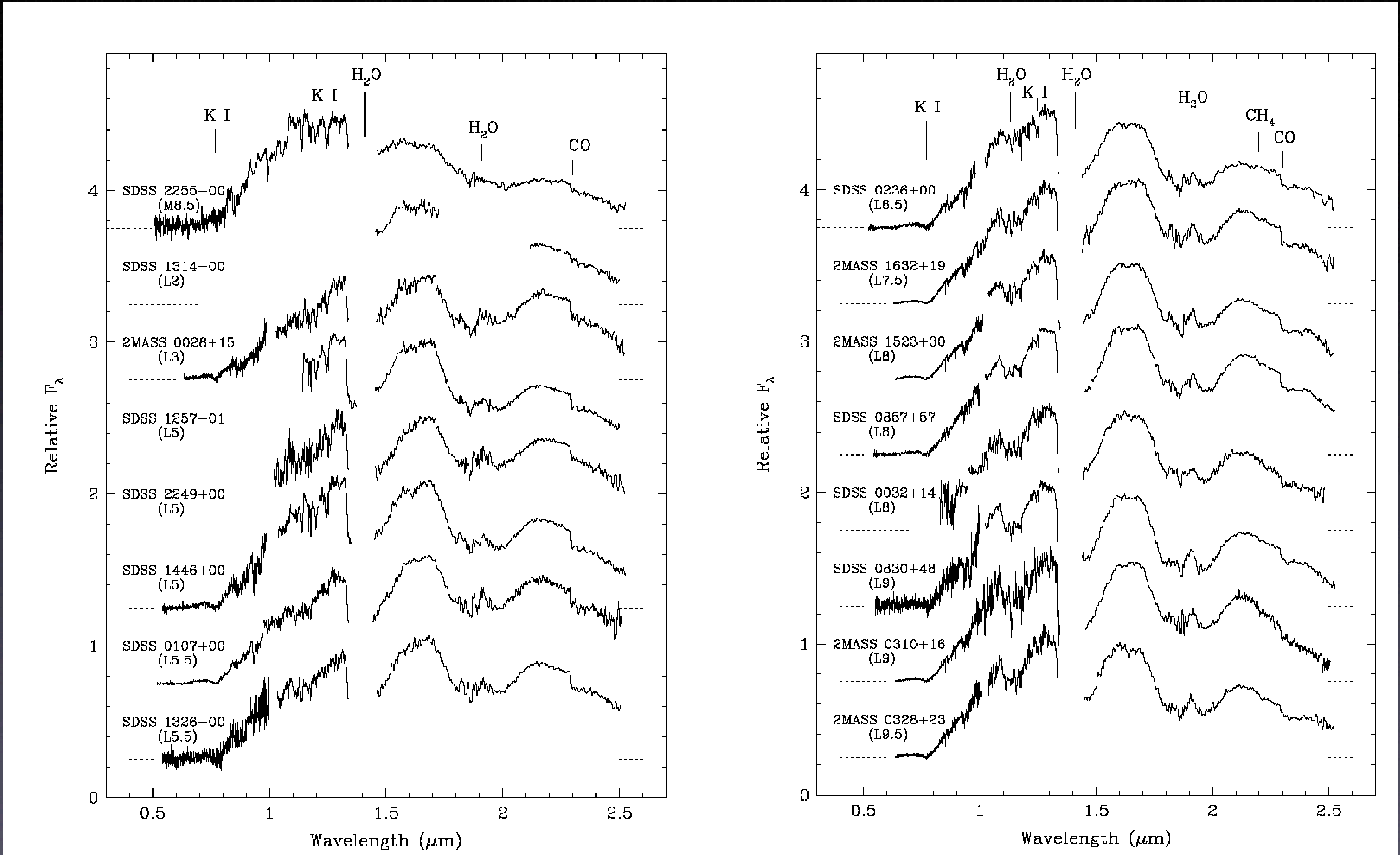


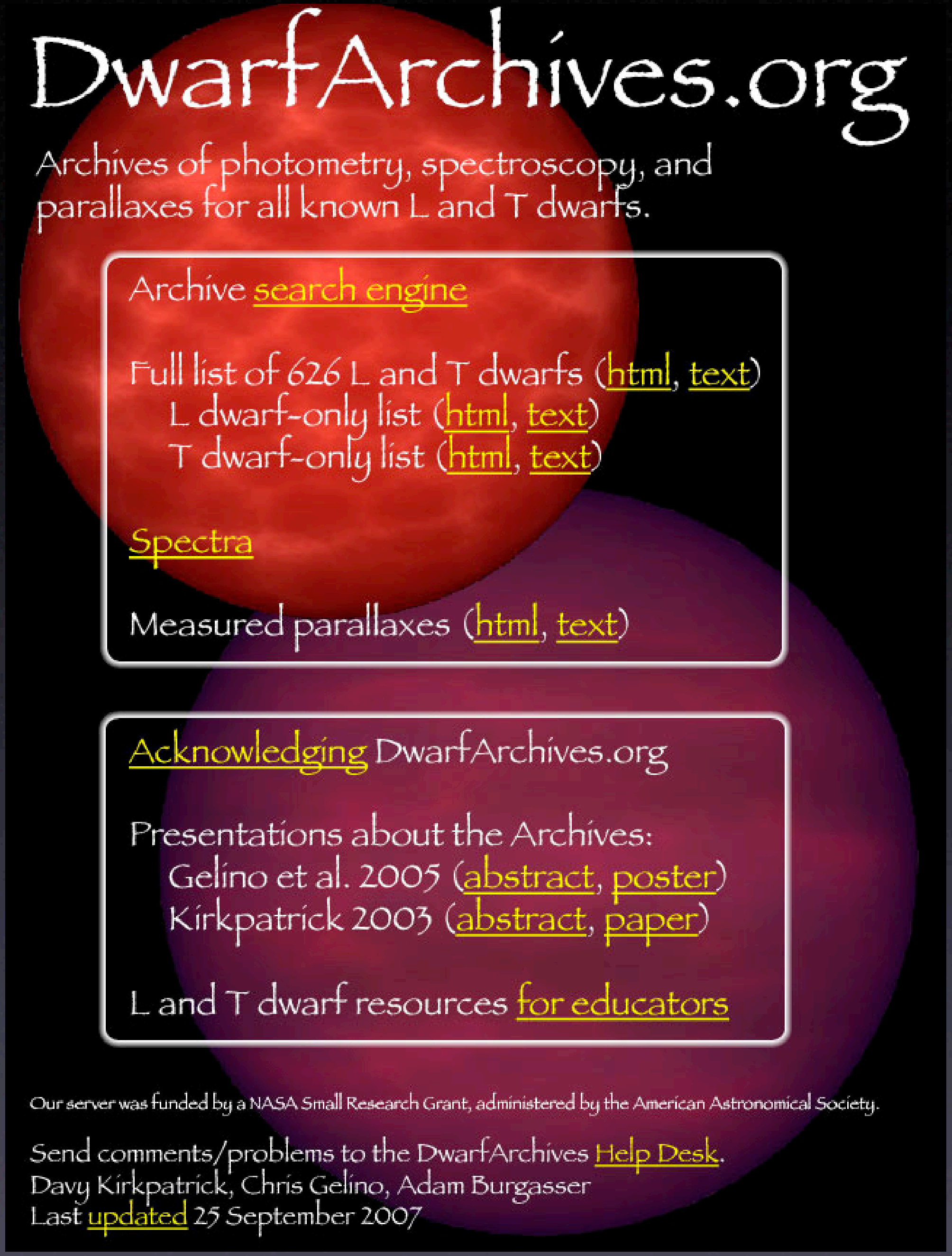
Megacam *i*
Megacam *z*
WIRCam *Y*
WIRCam *J*
WIRCam *H*
WIRCam *Ks*



T spectral type

L spectral type





- 122 T type
- 509 L type
- Most from 2MASSand SDSS surveys
- UKIDSS and CFBDS soon
- BD mass density is 10% that of stars
- BD number density is approx. equal to that of stars
- BD aren't the missing dark matter as was the motivation for their search

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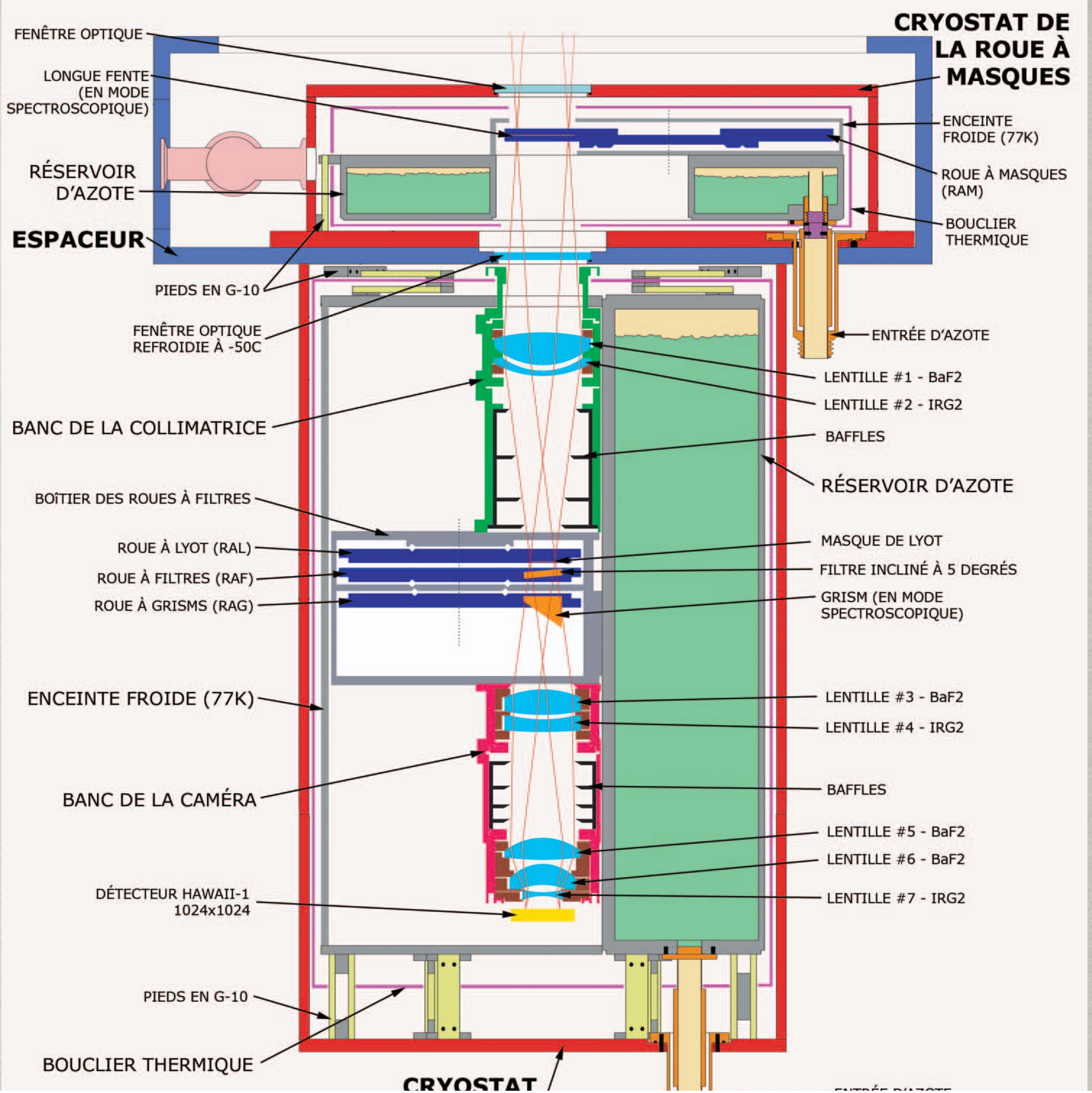
SIMON instrument (Ph. D. thesis, U. of Montreal)

- Instrumental thermal emission. Lyot mask to block it.
- No shutter because shutter emits light anyway and cold mechanisms are prone to failure.
- Detector needs to be cooled to <80K
- Optics needs special NIR-transparent glasses



French lessons will be provided by Chi-Hung Yan after this class...

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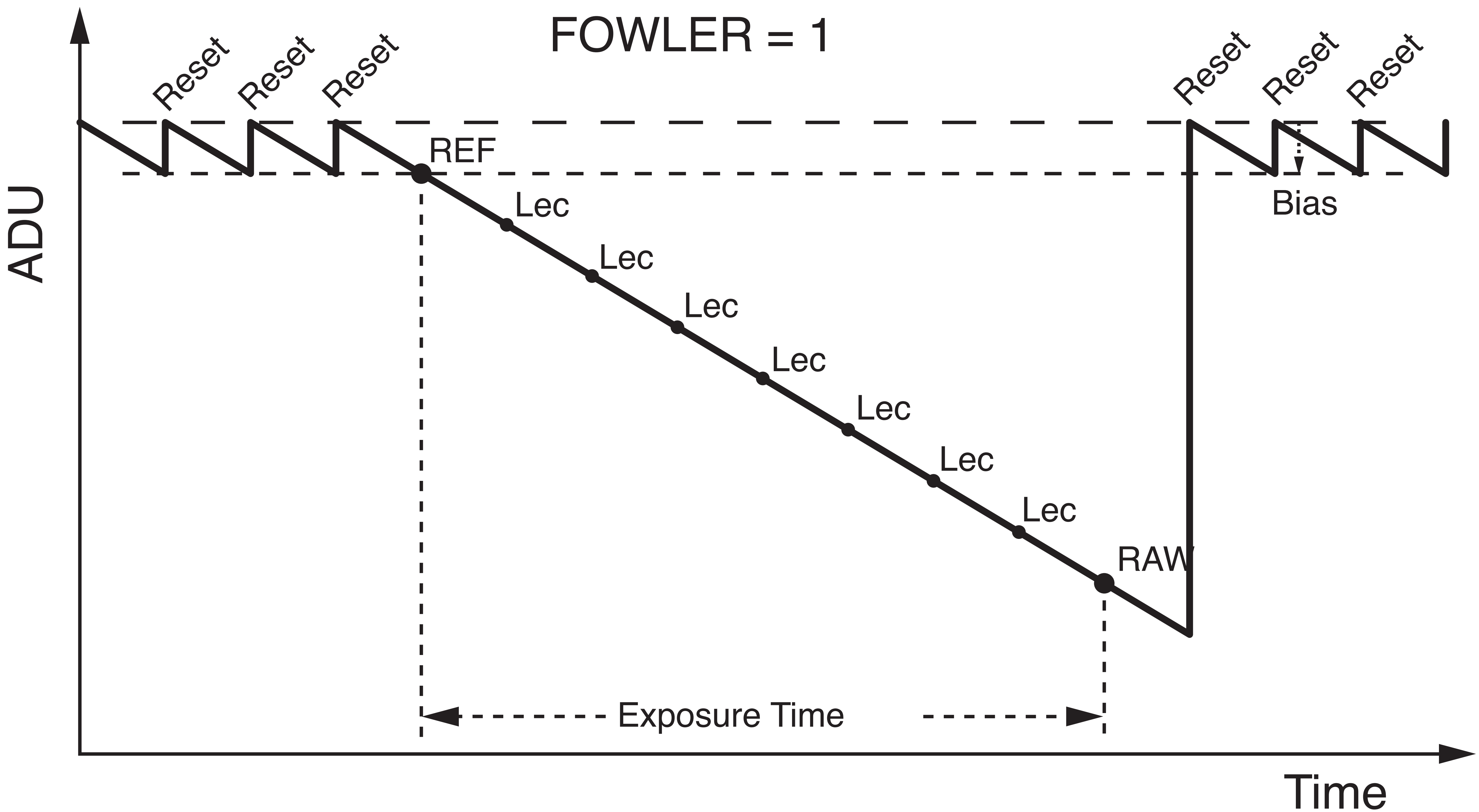
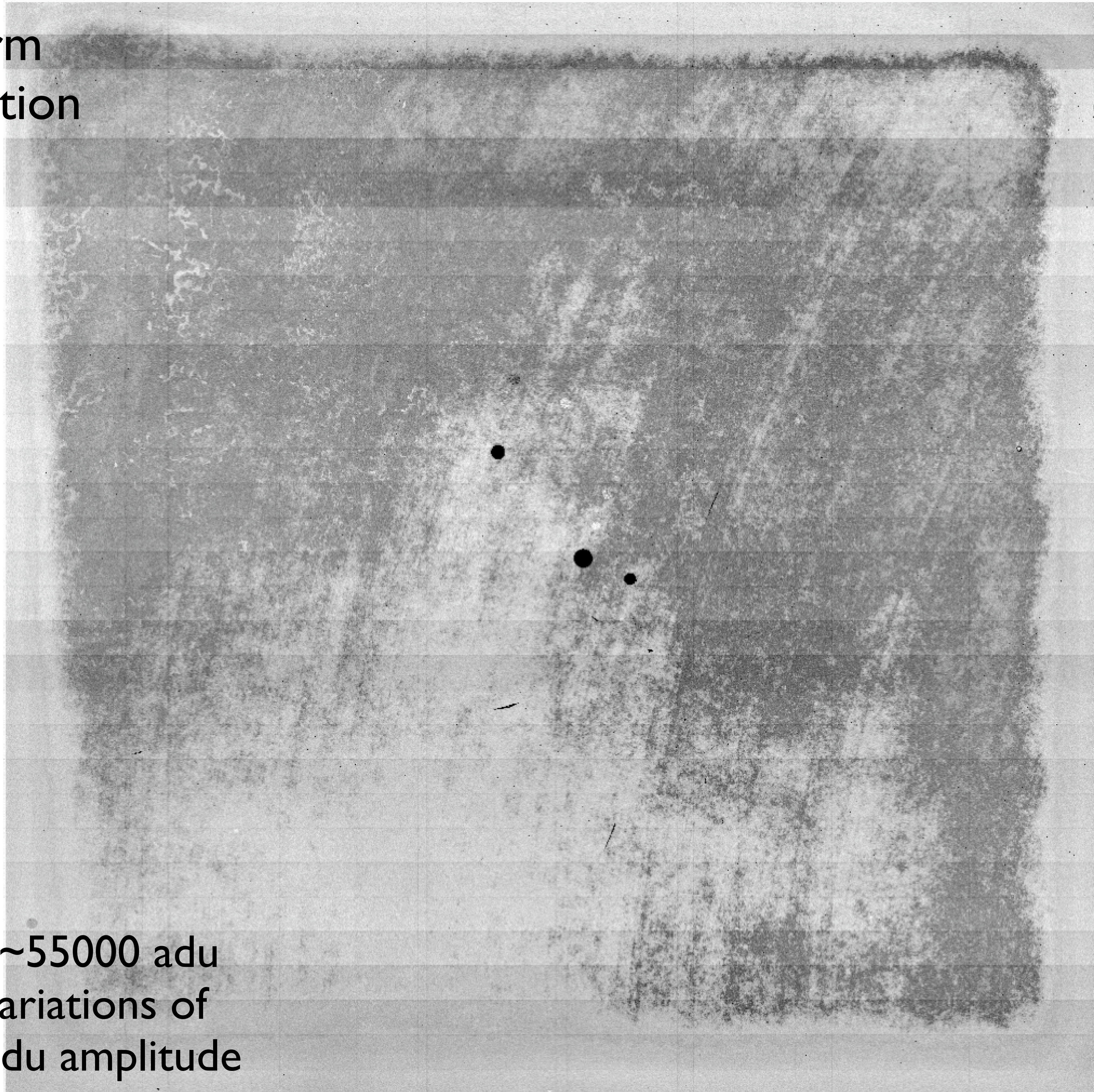
NIR detector readout scheme



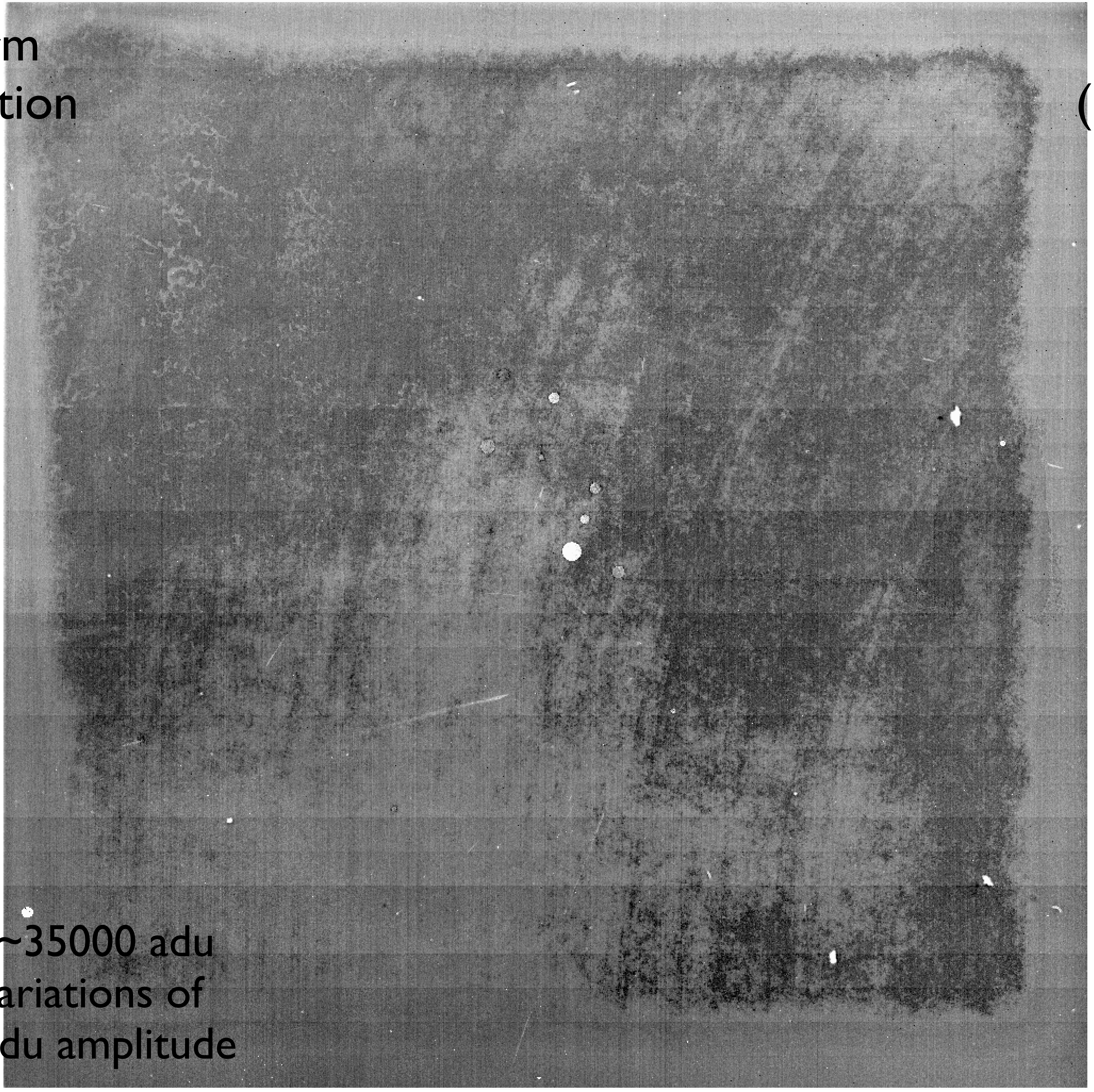
RESET

uniform
illumination

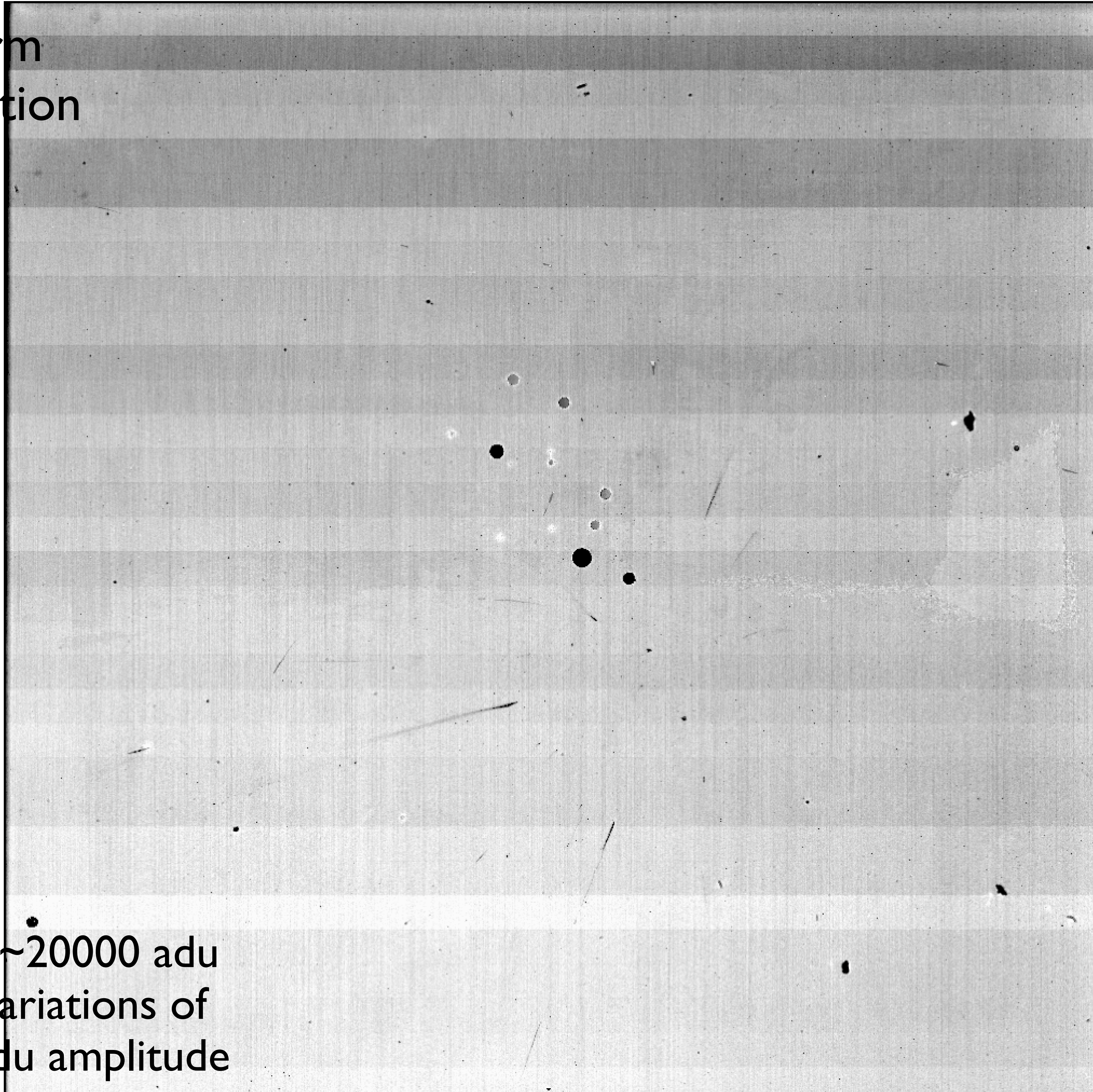
REF
(READ 1)



signal=~55000 adu
with variations of
~5000 adu amplitude


uniform
illumination
RAW
(READ 2)
signal=~35000 adu
with variations of
~5000 adu amplitude

uniform illumination



CDS (READ 2 - READ 1)

signal=~20000 adu with variations of ~100 adu amplitude