Until around 400 million years after the Big Bang, the Universe was a very dark place. There were no stars, and there were no galaxies.

100 million years after the Big Bang

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Swinburne University

CTIO 50th,
May 8, 2013

SWINBURNE UNIVERSITY OF TECHNOLOGY

CAASTRO
ALL-SKY ASTROPHYSICS

Is this talk relevant to the meeting?

- Yes, it's about wide field NIR astronomy
- Yes, it's about bulges, unless you think our bulge is 100% pseudobulge & started forming after a Gyr
- This is an open question with some persuasive dynamical evidence
- and some persuasive stellar populations evidence
- which don't seem to agree on nature of the bulge

Origin of bulges

- **Classical bulges**
  - Formed at high redshift
  - Mergers/accretion/rapid collapse of overdensity
- **Pseudobulges**
  - Secular erosion of disks

Local Group Bulges

Galaxy	Bulge/disk	Ref	M_BH	Ref
M31	0.35	WPS03	1.4×10^8	B+05
Milky Way	0.15	BS80	3×10^6	G+05
M33	0.03	RV94	<1500	G+01
M32	>1	G01	3.4×10^6	vdM+98

This talk focuses on classical bulges and their possible formation in the first few hundred million years

A 10 solar mass star forming 100 Myr after the Big Bang would be seen today with a Balmer Jump at 11μ and a Lyman limit at 2.7μ. Such early stars, if they formed at all, are JWST targets

In luminosity distance the epoch of reionization extends 80 Hubble radii

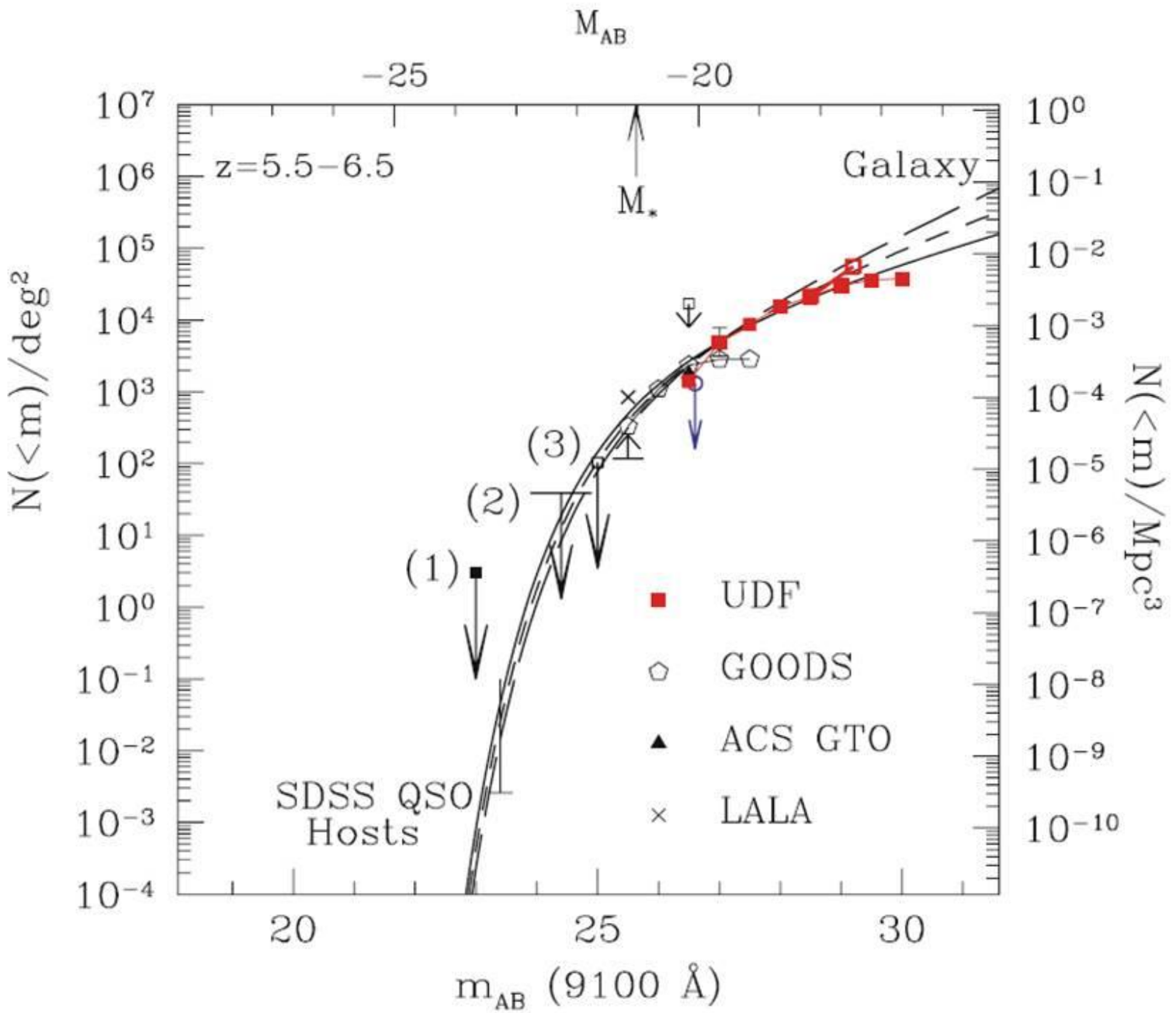
- JWST: powerful, but small field with spectroscopy
- DECam: 1μ and shorter, wide field
- KDUST: 1μ < λ < 3μ, wide field, IR camera TBD
  - optical wavelengths, Gpix camera possible
- Las Campanas Transit Survey: wide field
- TMT high resolution
- SKA: redshifted neutral hydrogen

DECam Deep Fields *goal*

- All 3 are circumpolar
- Chandra Deep Field South (little data)
- Prime Field (great data)
- 16h field (no data)
- *What is doing the reionizing in the EoR ?*

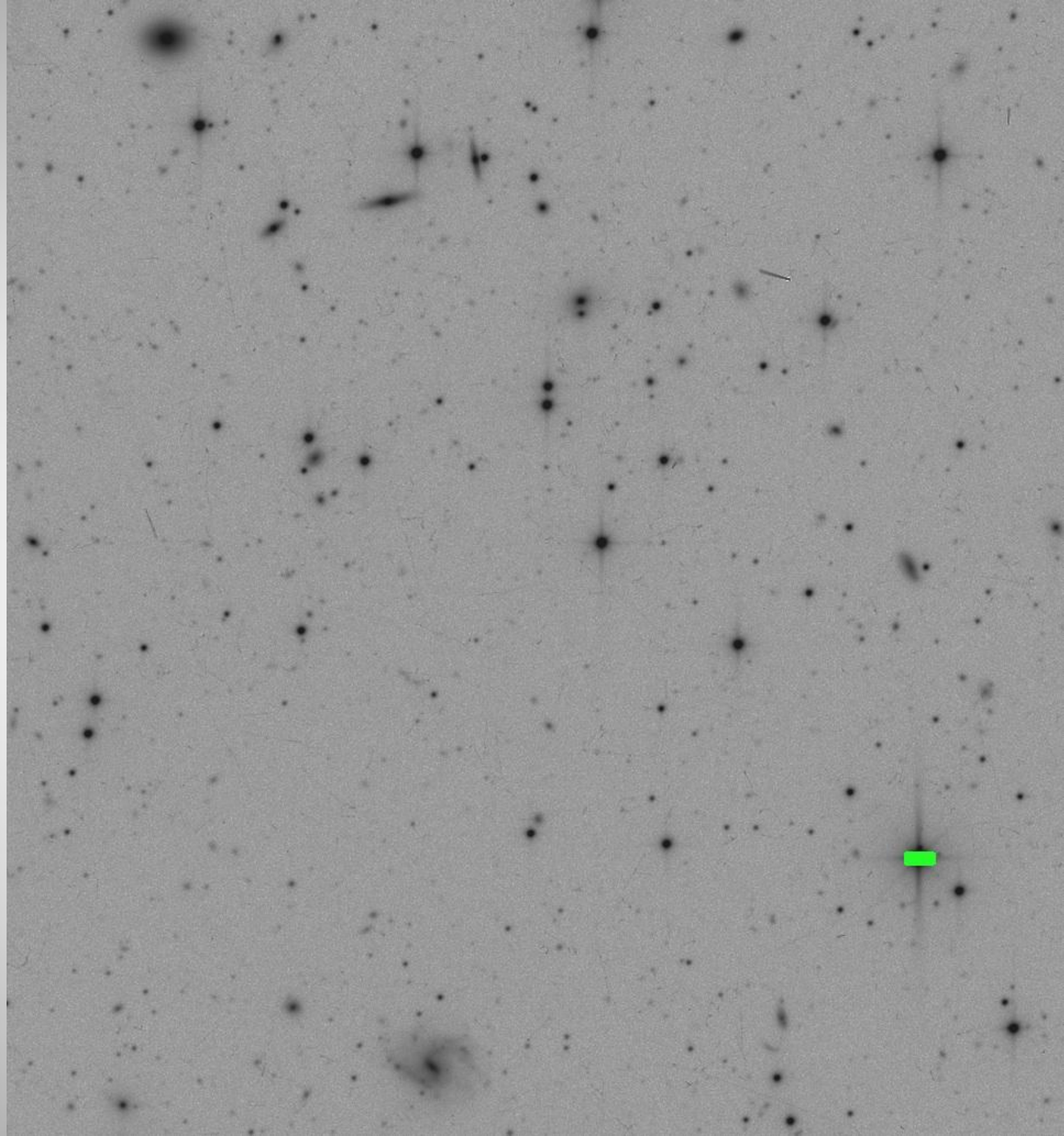
M* at z = 6 is Y = 24.0

Note that m_{AB}-m_{Vega} = 0.634 mag at Y

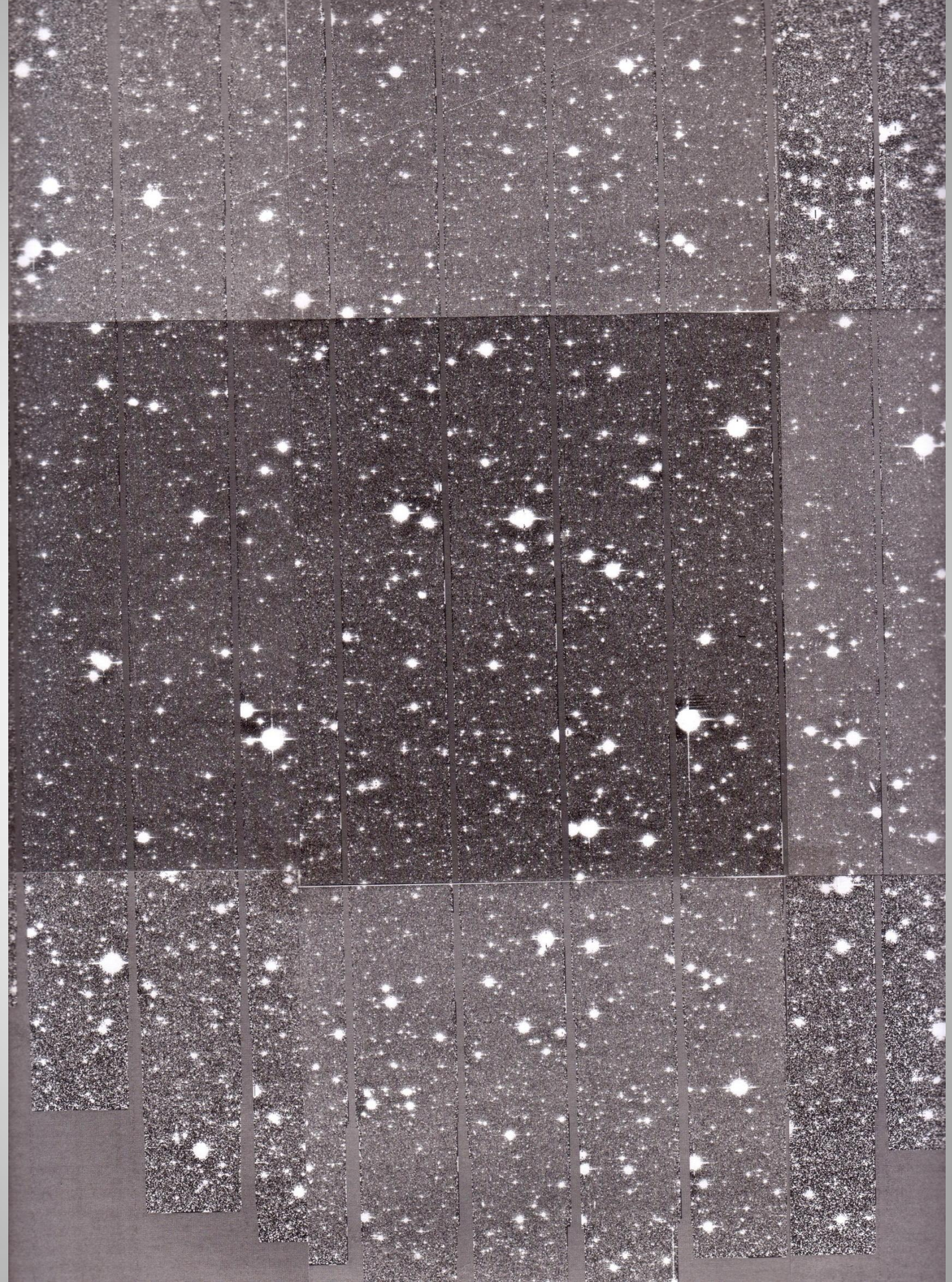


What does 25th mag look like?

140 minutes of DECam at 1.03μ & 0.8” seeing; 2.3σ detections have Y = 25.45

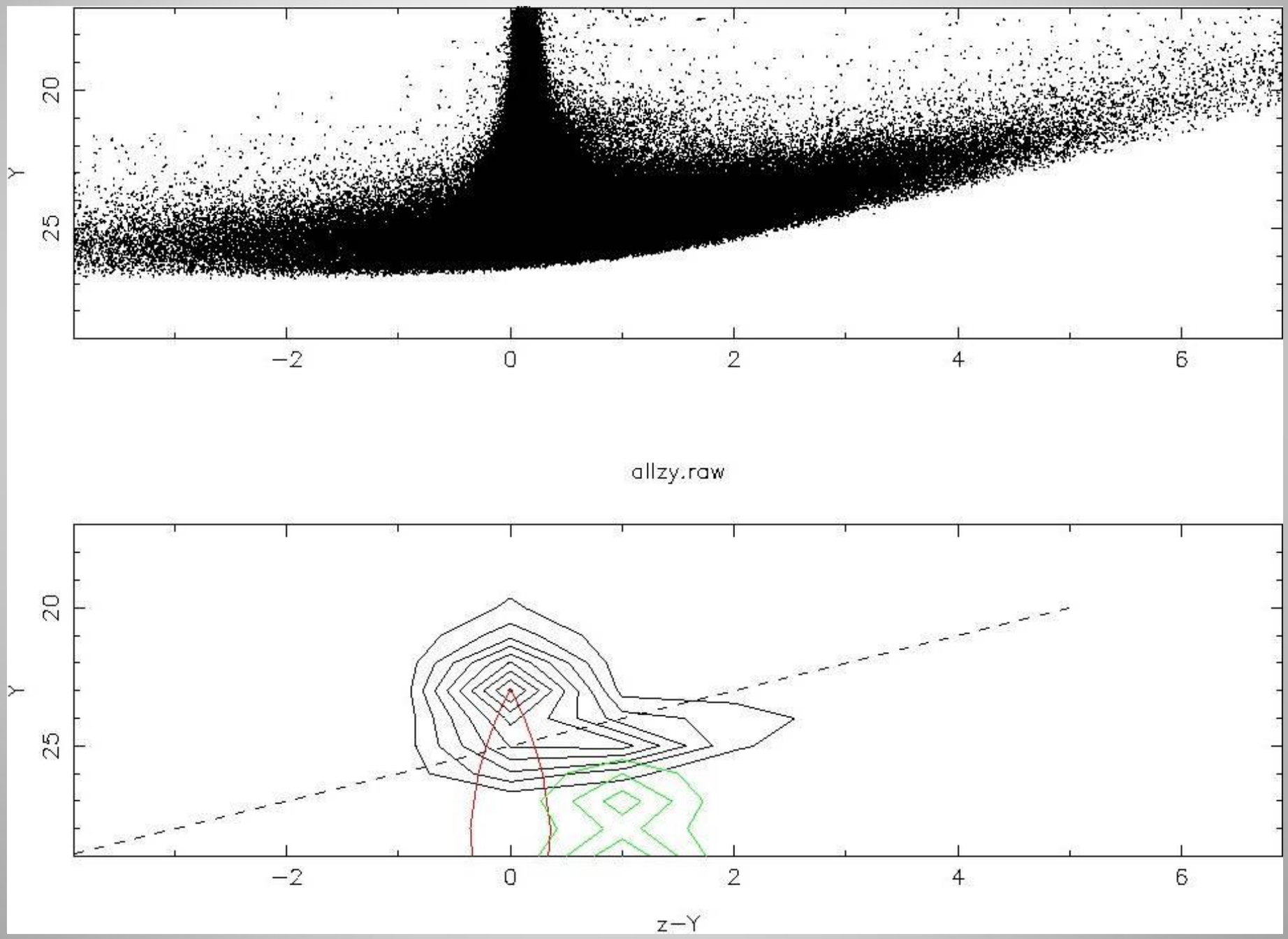


2 degrees of the Prime Field



CMD from aperture photometry

DECam deep field team: Mould, Trenti, Wyithe, Cooke, Lidman Abbott Kunder Koekemoer Tescari Katsianis

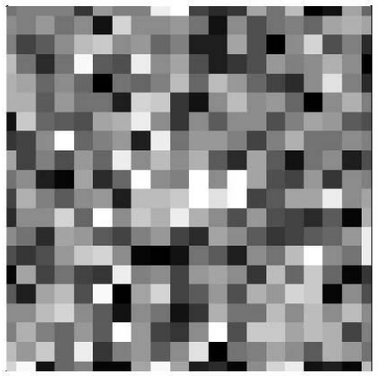


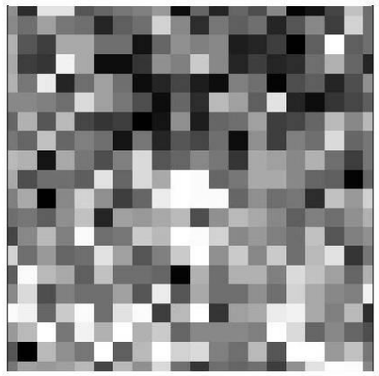
Red is star counts from BS; green is HDF galaxies

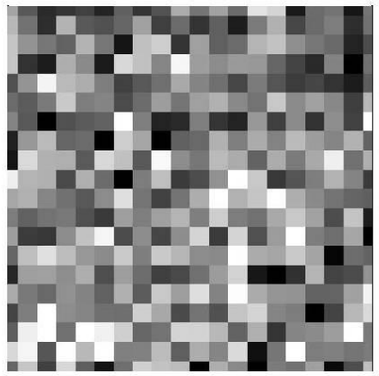
dashed line is z = 25 completeness

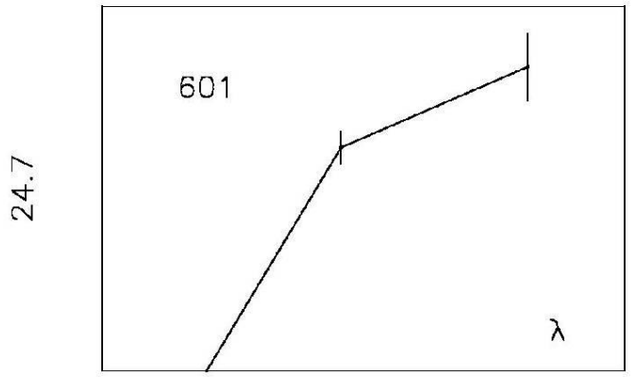
I dropouts are z = 6 candidates

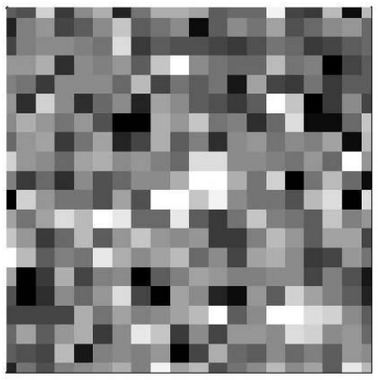
Y z I .

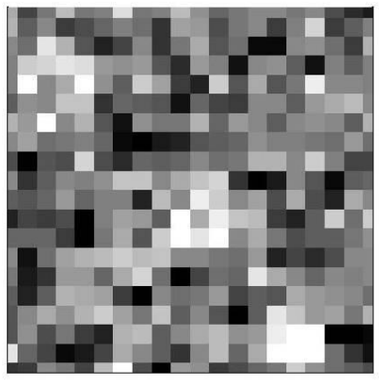


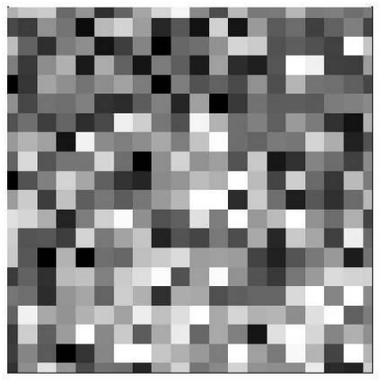


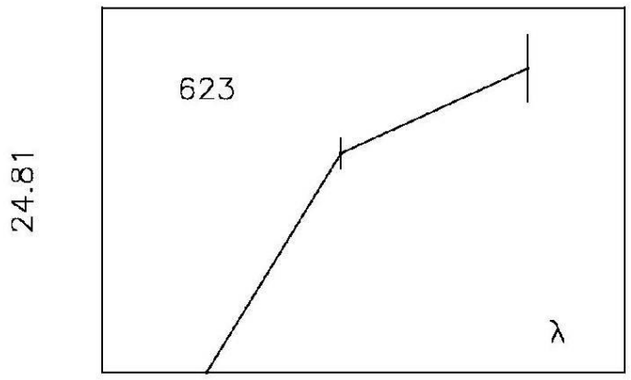




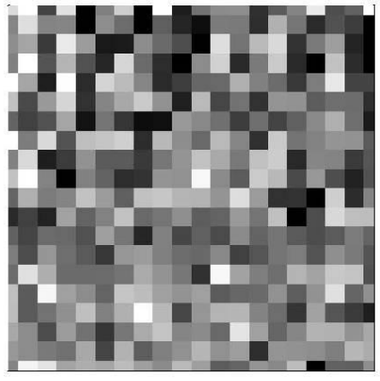


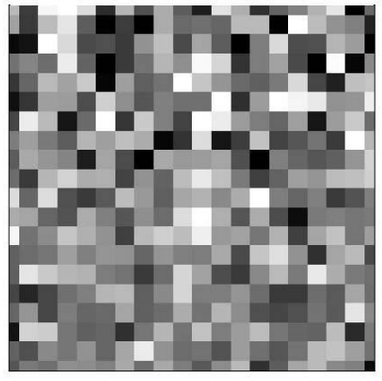


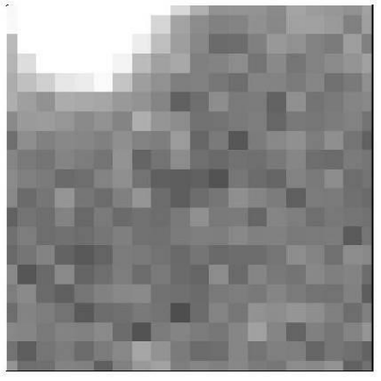




These postage stamps are the Y=24 mag candidates







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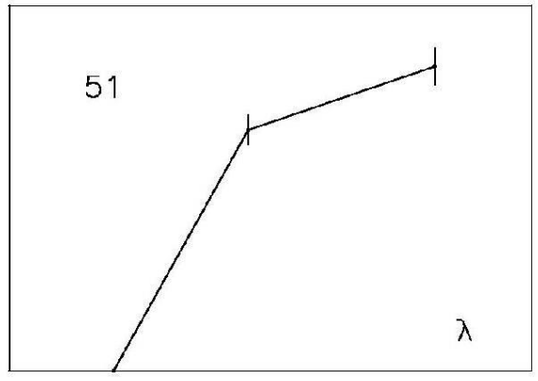

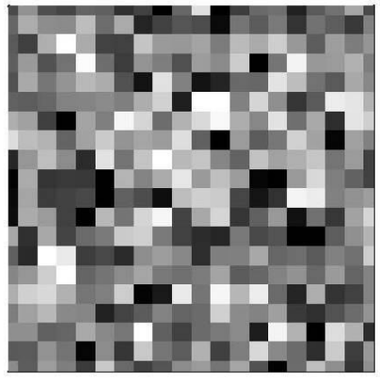

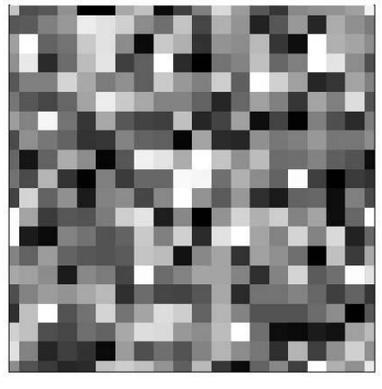

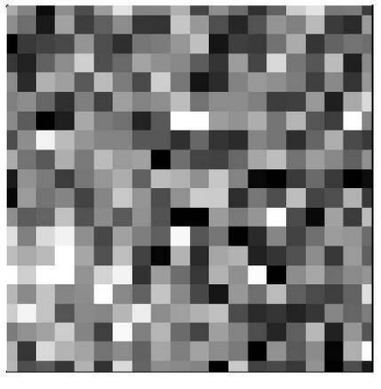

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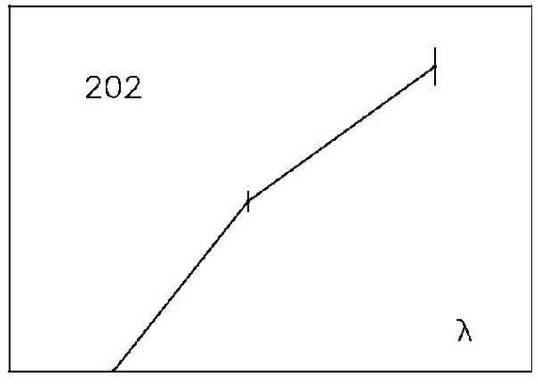

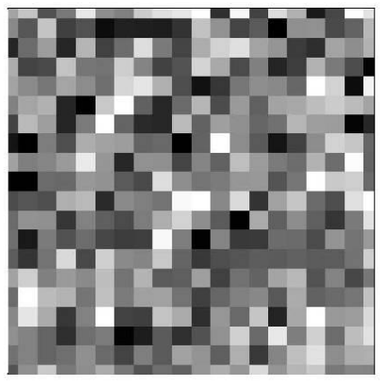

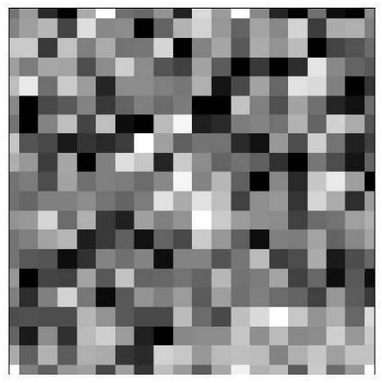

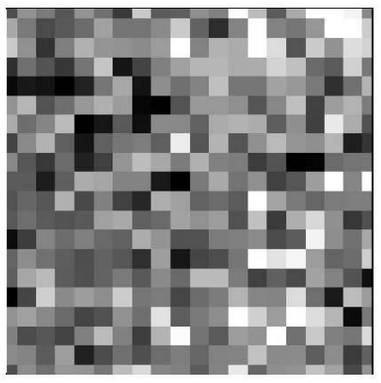

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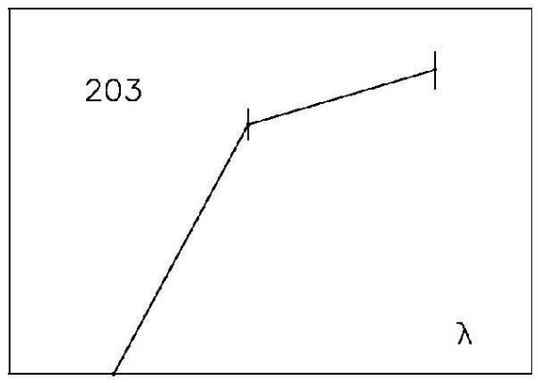

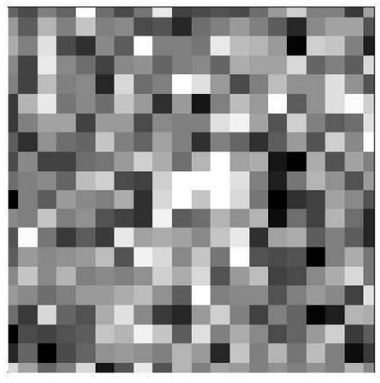

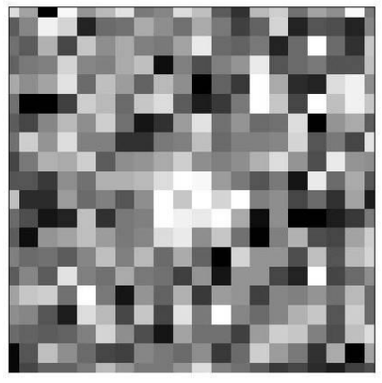

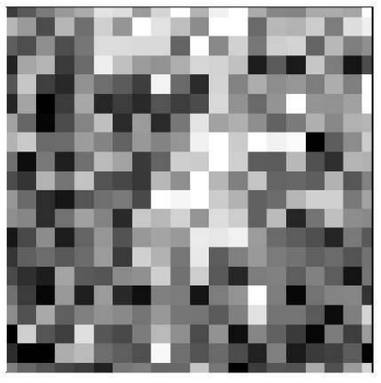

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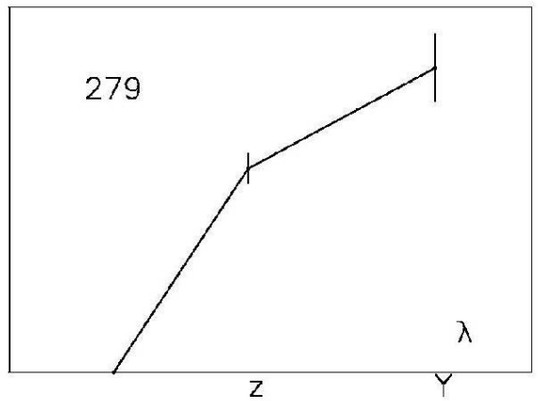

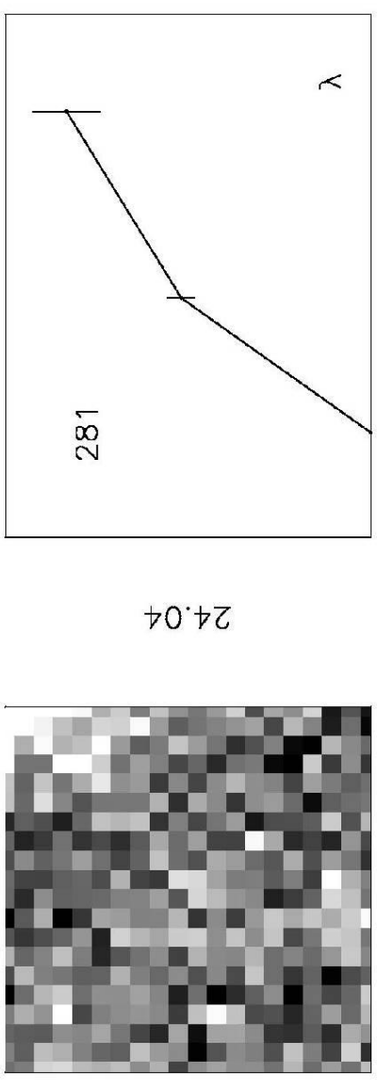

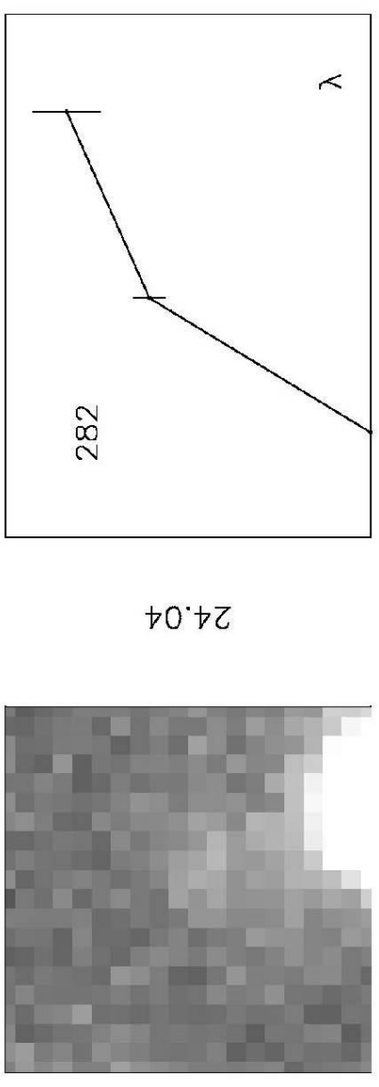

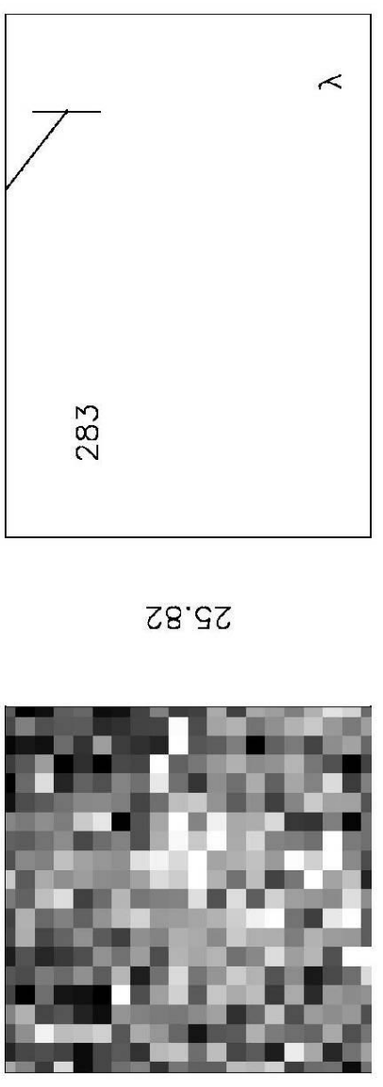

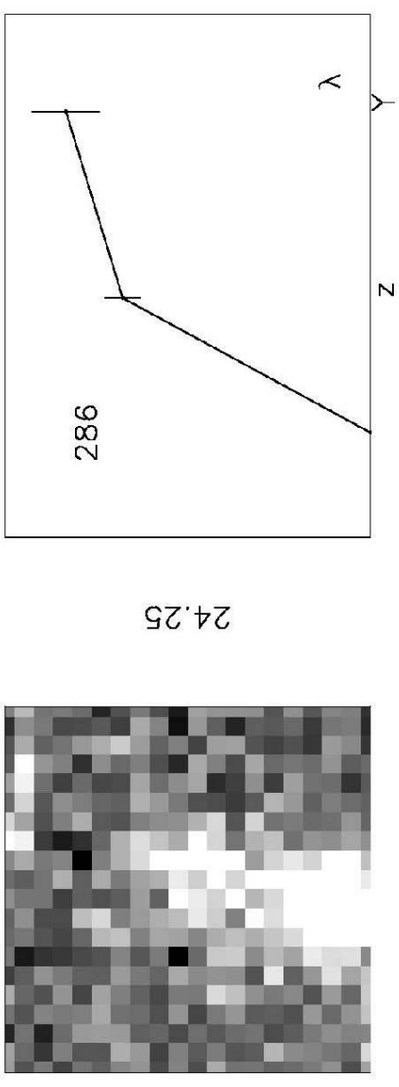

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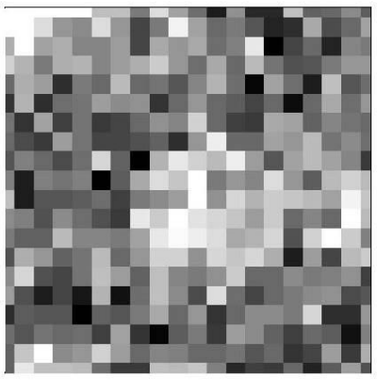

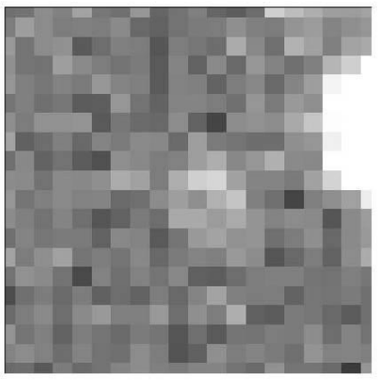

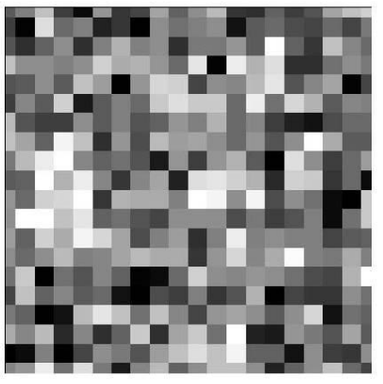

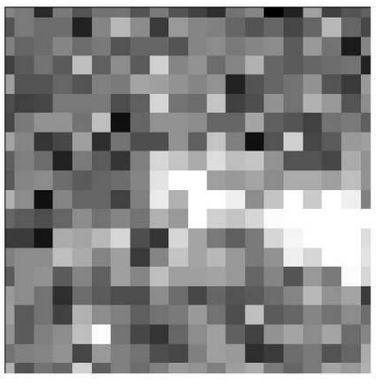

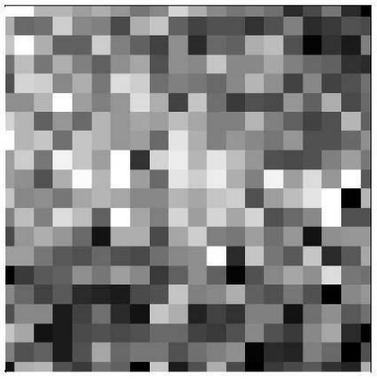

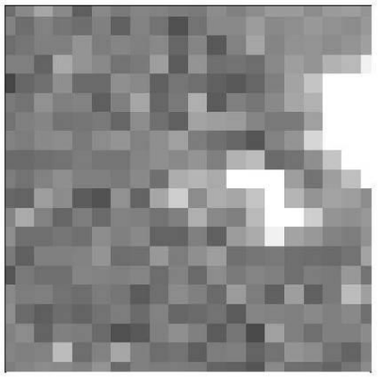

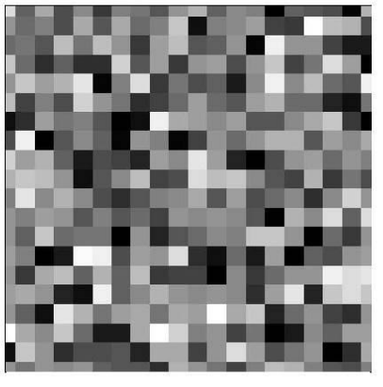

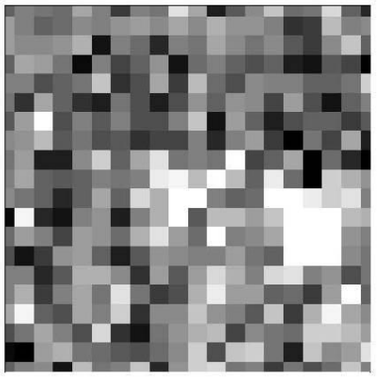

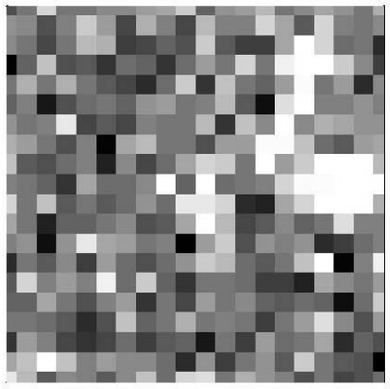

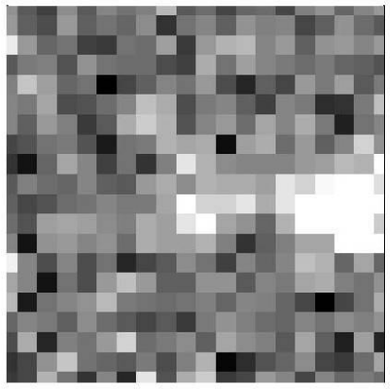

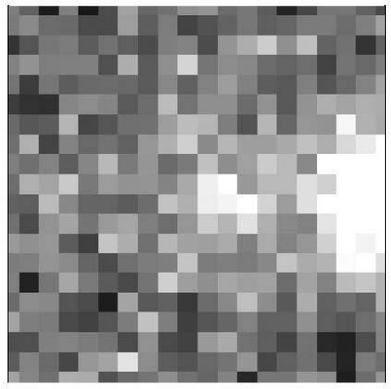

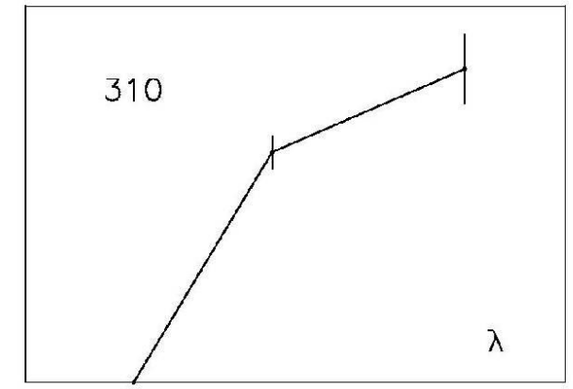

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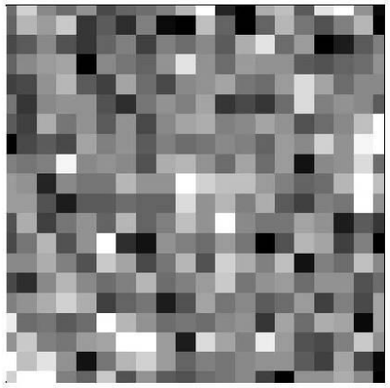

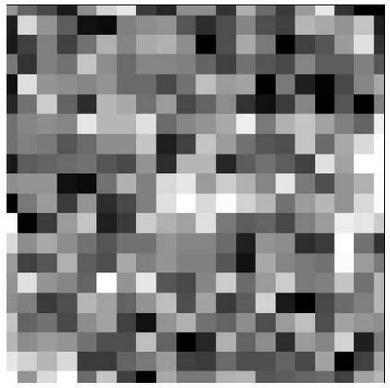

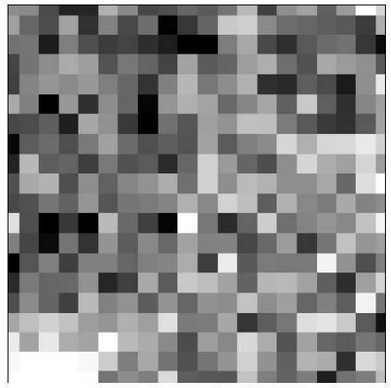

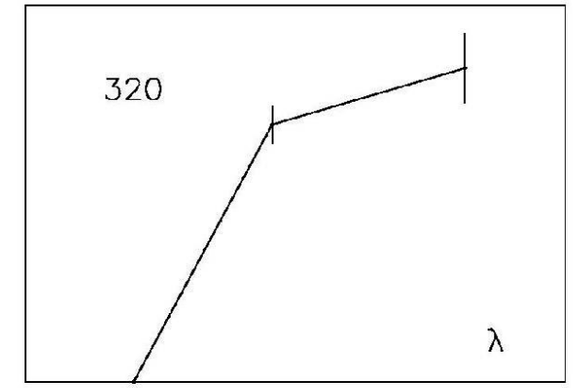

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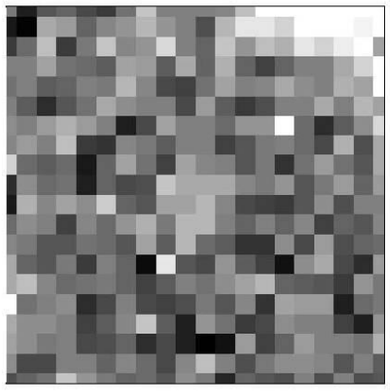

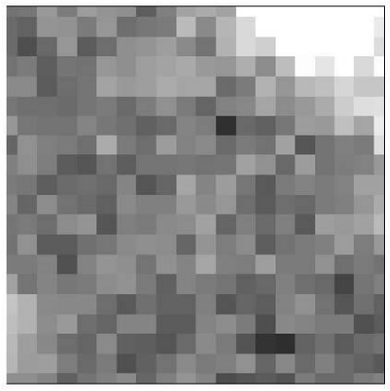

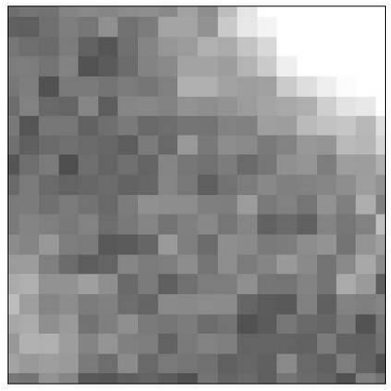

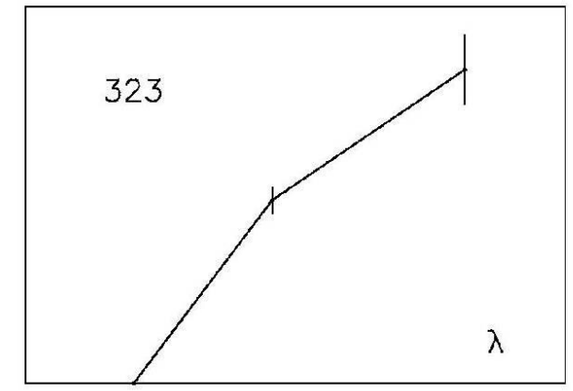

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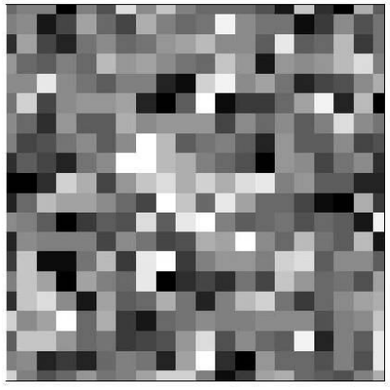

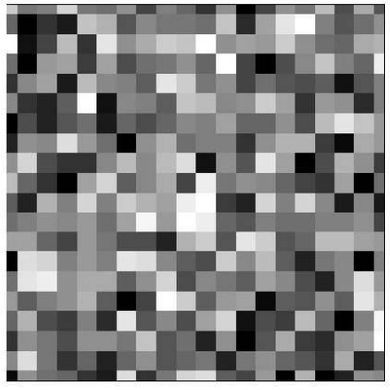

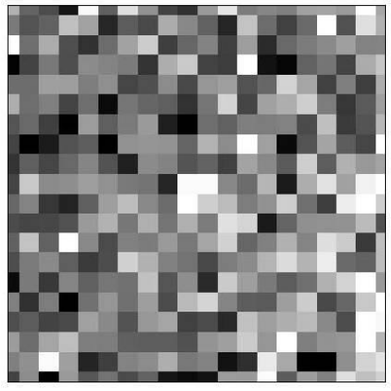

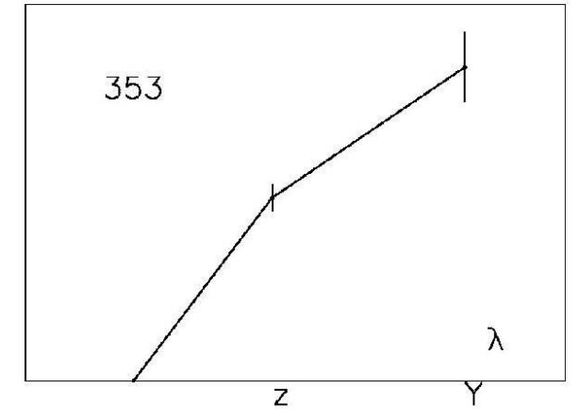

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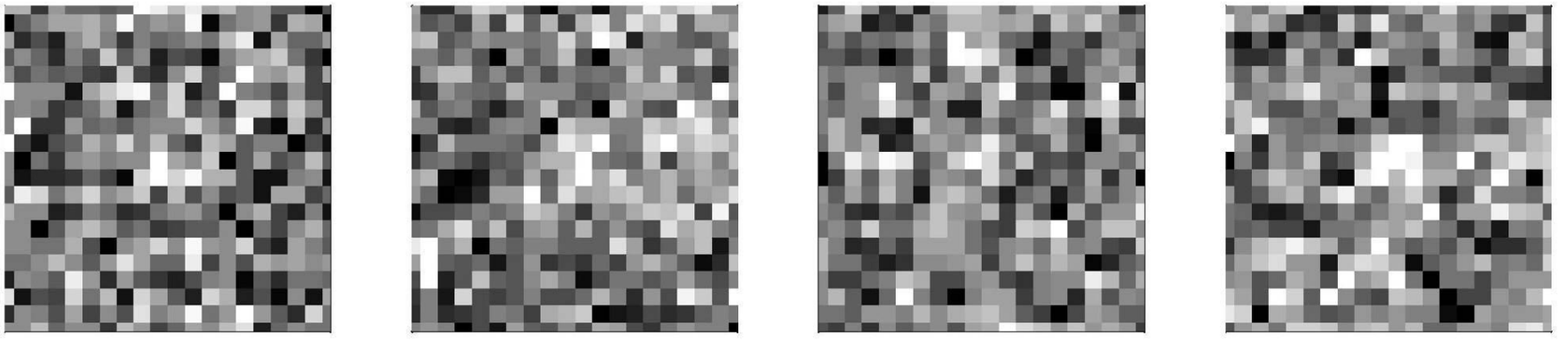

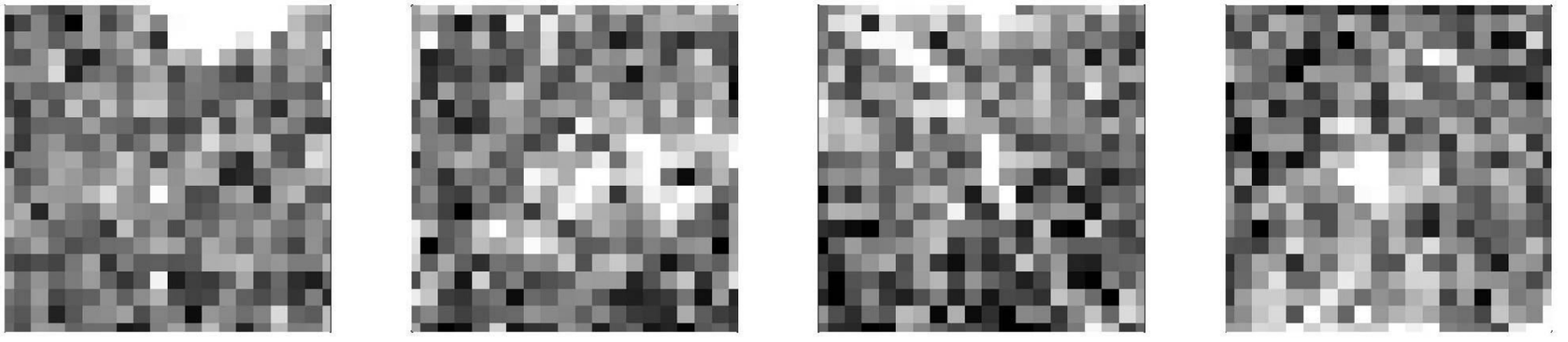

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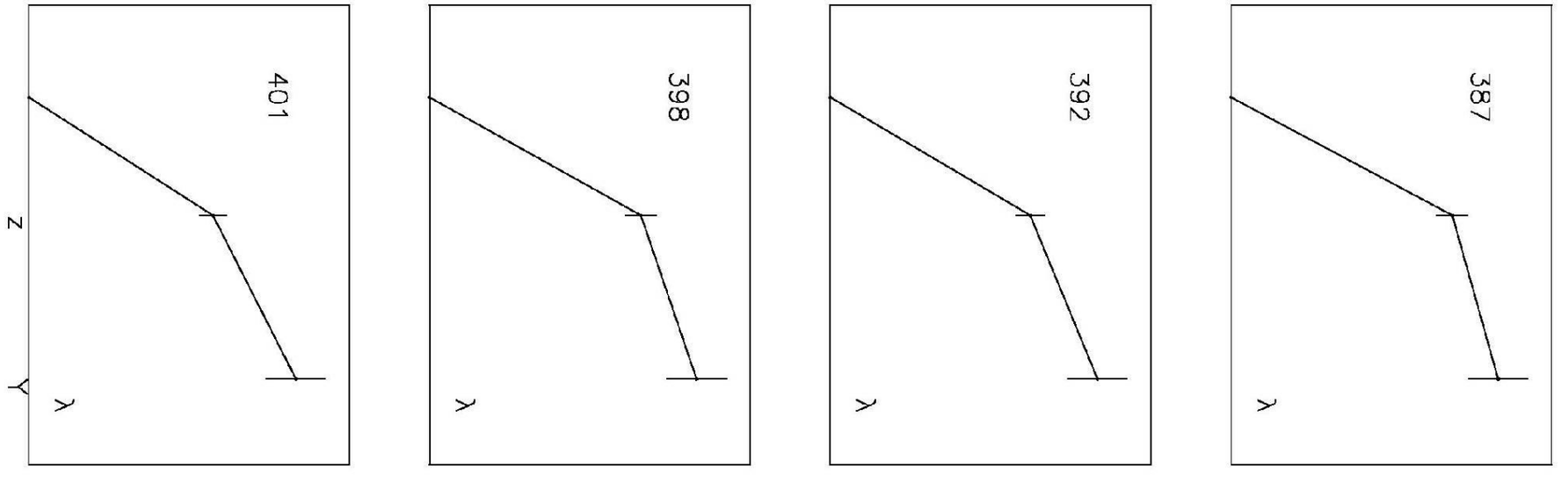

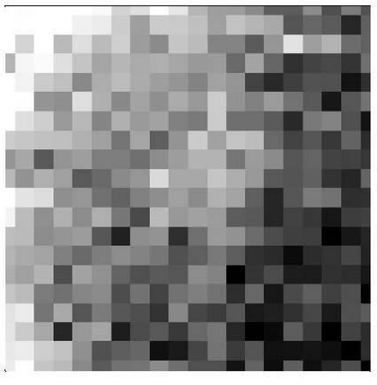

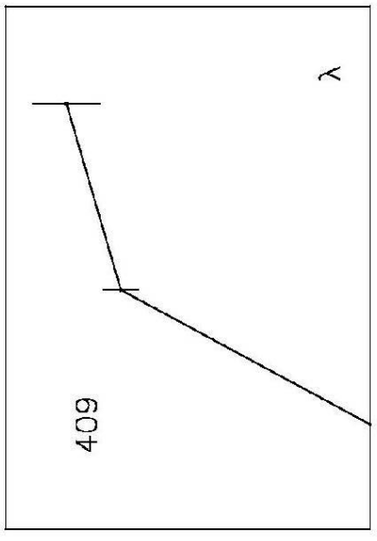

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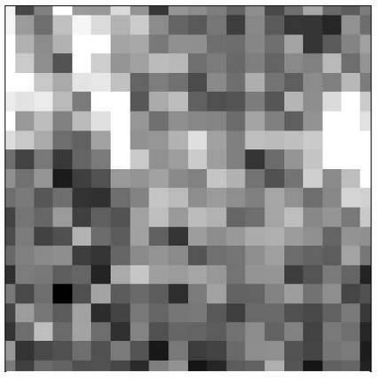

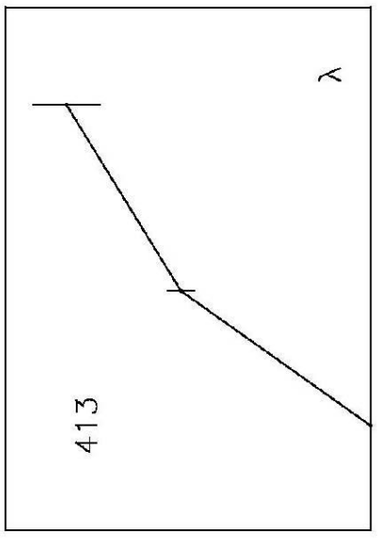

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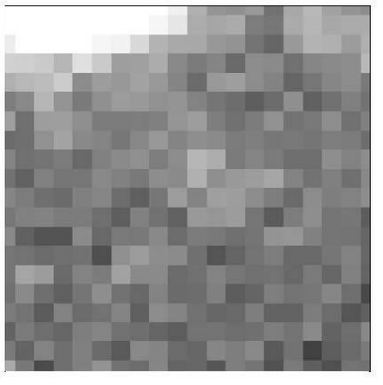

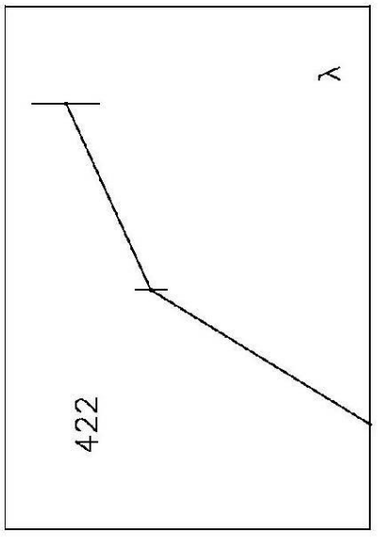

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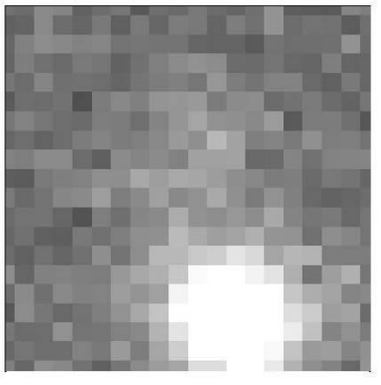

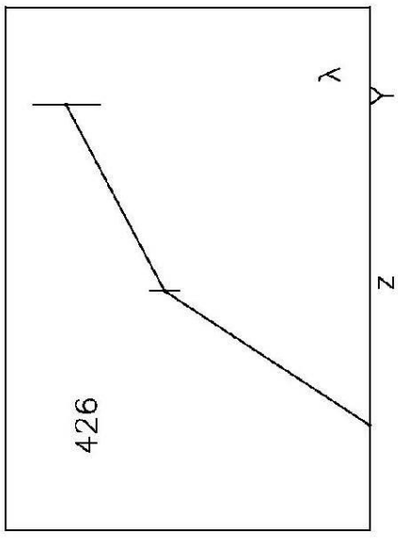

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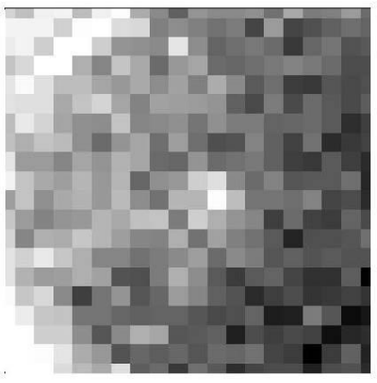

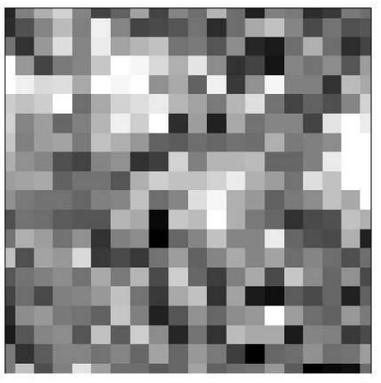

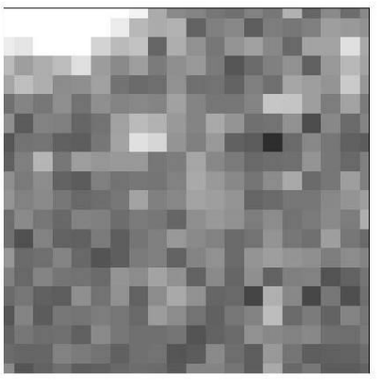

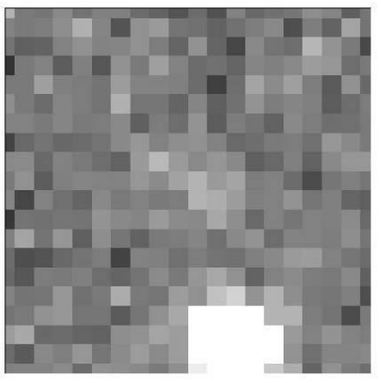

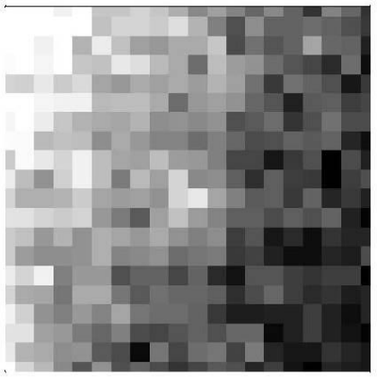

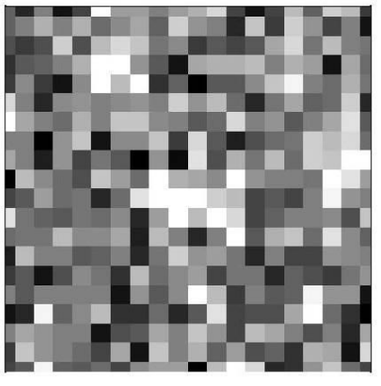

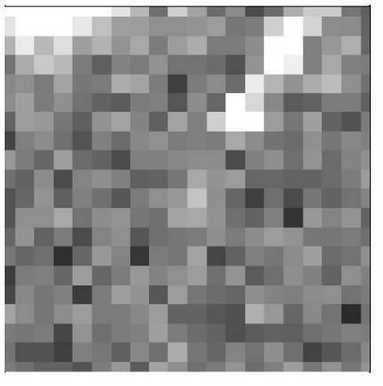

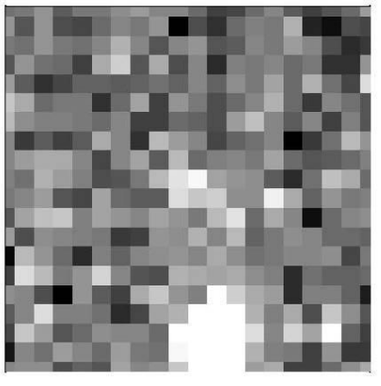

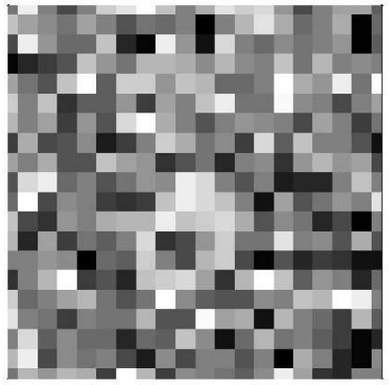

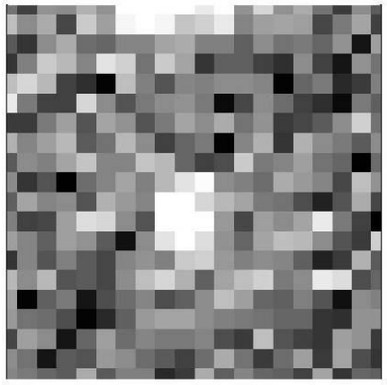

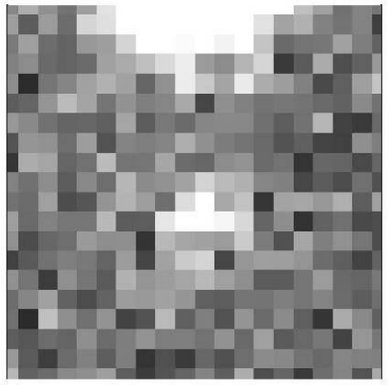

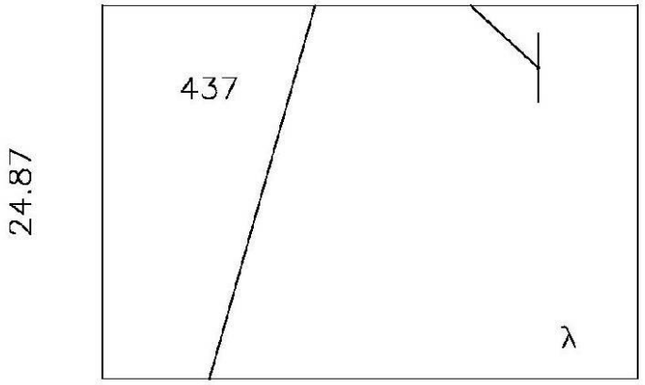
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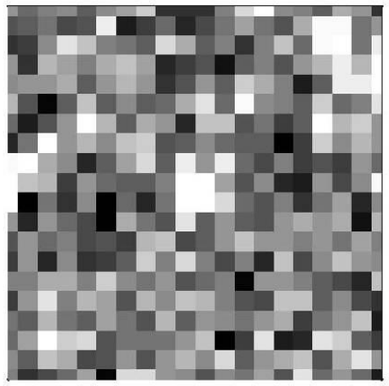

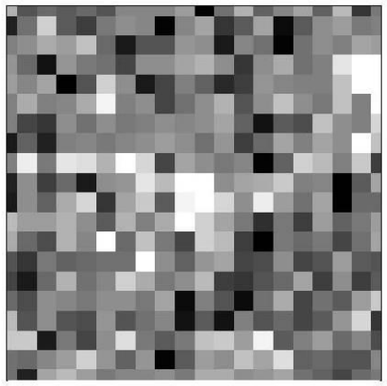

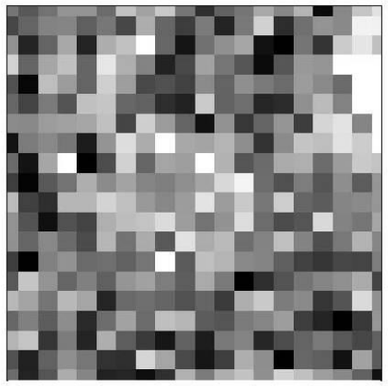

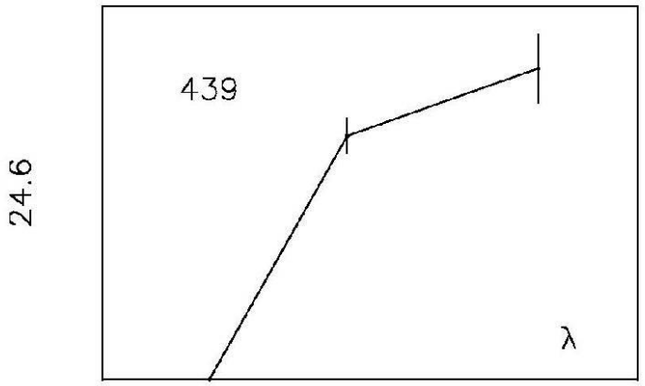
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24.6
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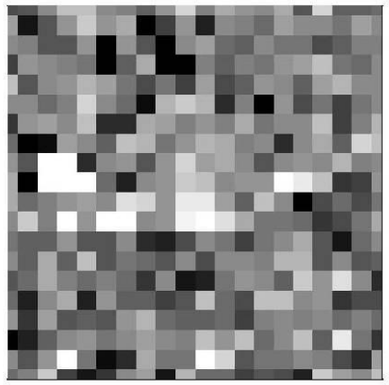

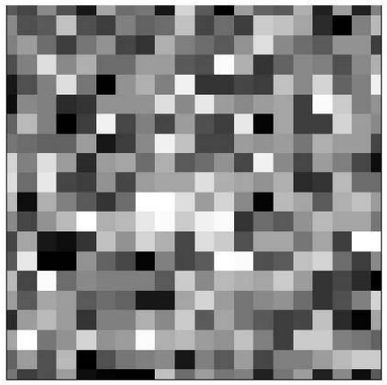

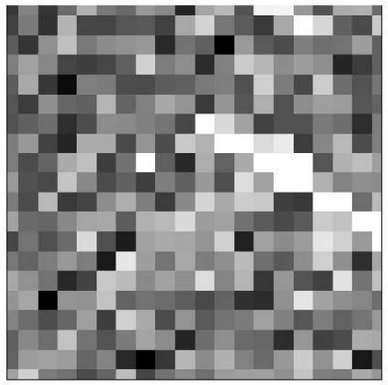

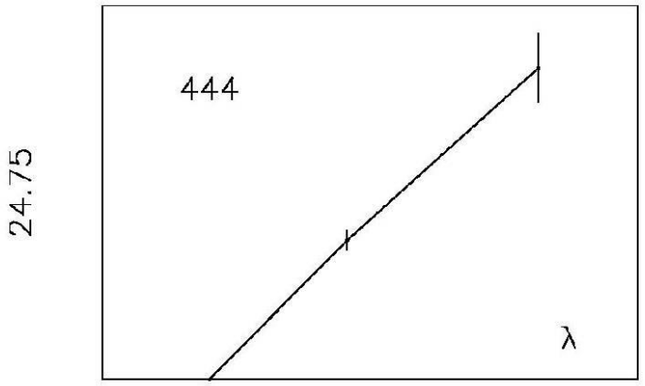
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24.75
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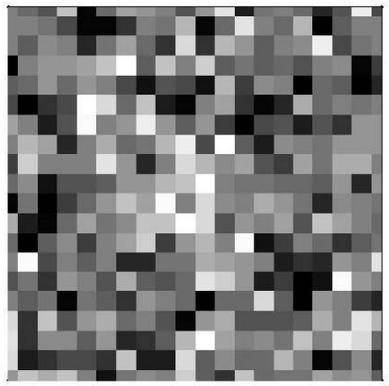
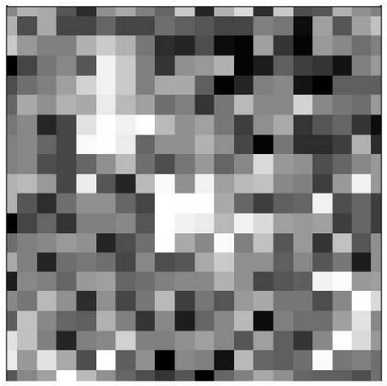
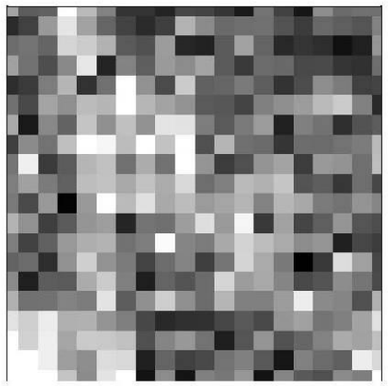
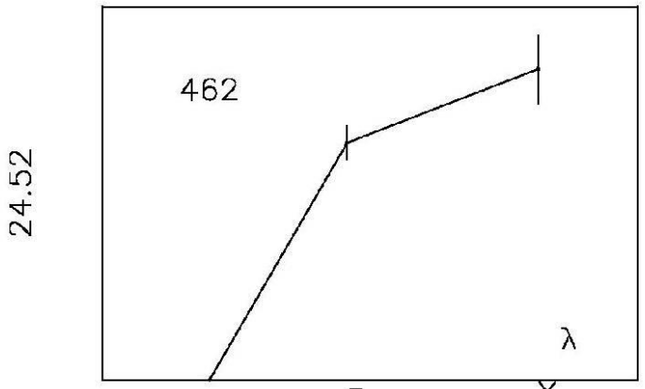
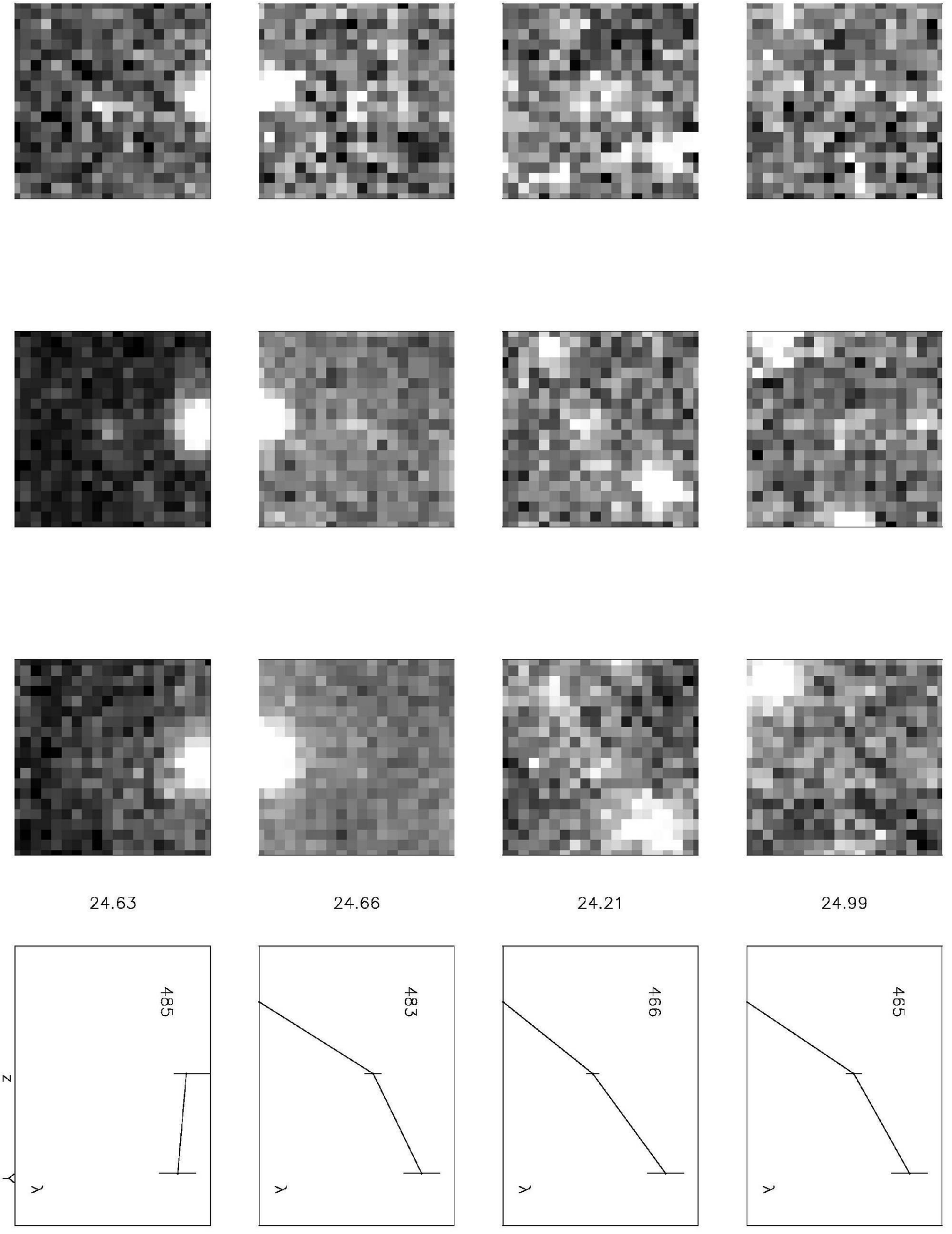







462
24.52
λ
z
Y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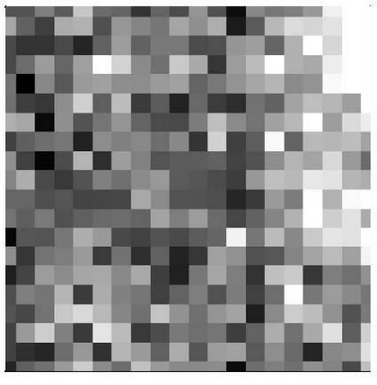
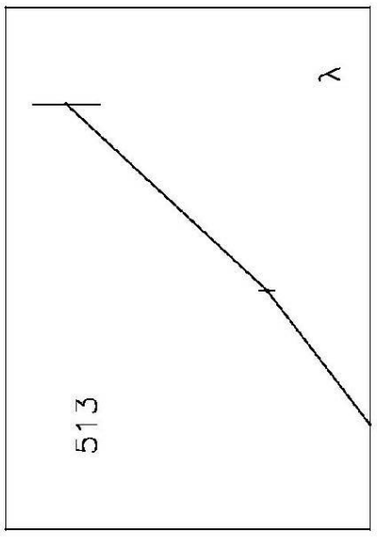
24.21
24.99
485
483
466
465
λ
z
y





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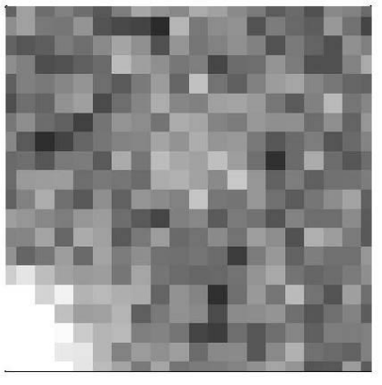

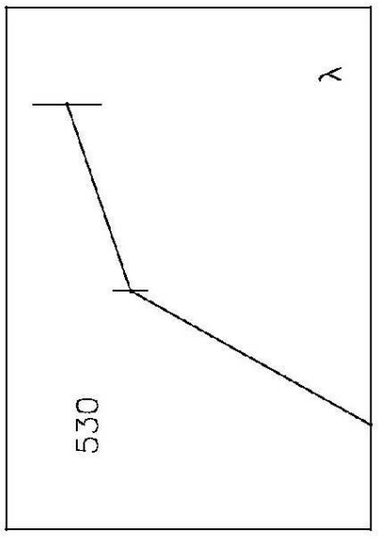

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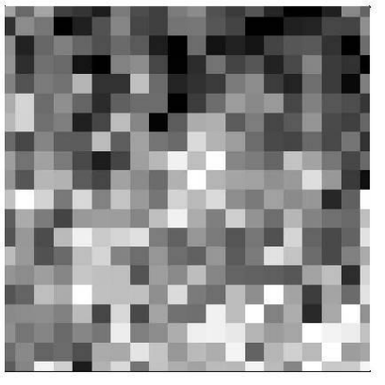

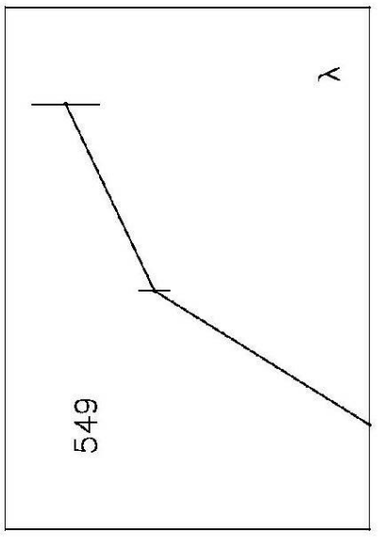

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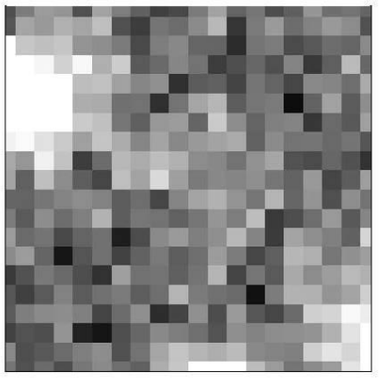

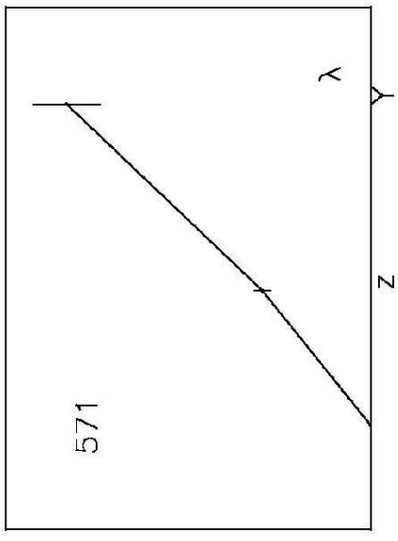

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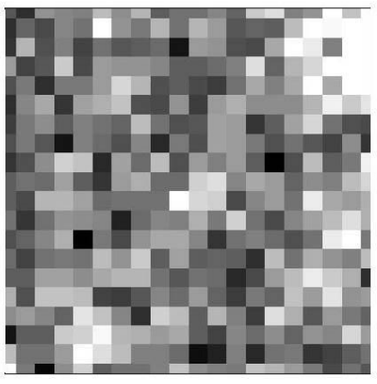
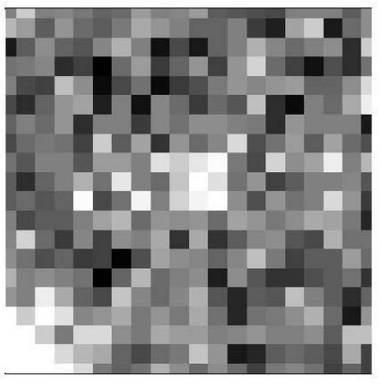
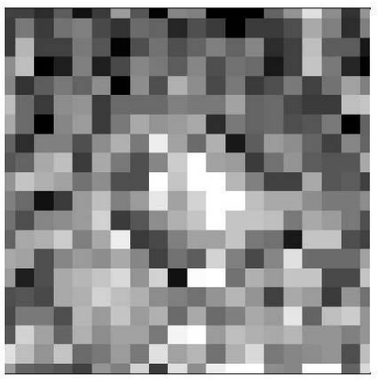
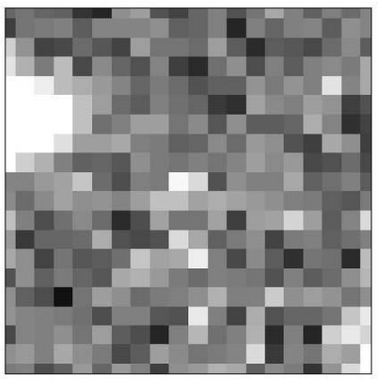
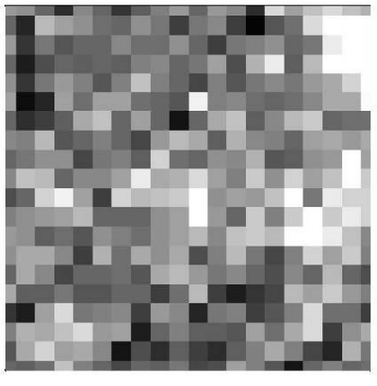
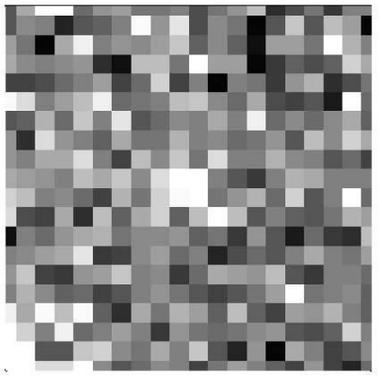


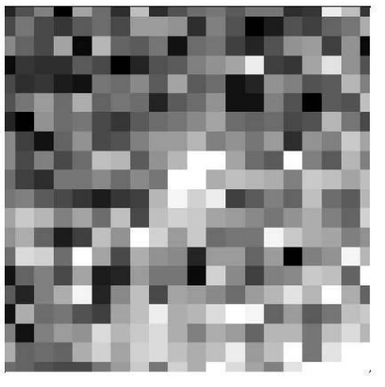


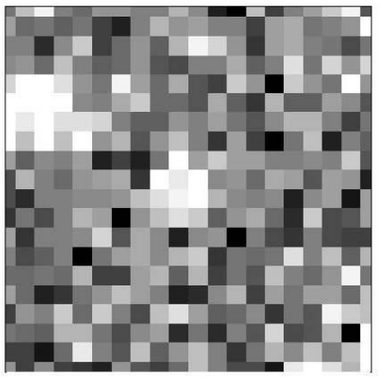












Next steps DECam deep fields

- With about twice the signal to noise we have here we'll have viable target lists for Gemini Flamingos redshifts

- Look for CIV etc all the way to 3727

- We also seek more time to monitor the deep fields for supernovae

Pair Instability Supernovae

- use the highly efficient Lyman break galaxy monitoring technique (that Jeff Cooke has used to find z 2–4 SLSNe) to search for the SLSNe

- SLSNe will rise to peak from 10 – 30 days, stay there for 2 – 20 days, then decline in 20 – 100 days. In the observer frame, this is 75 – 230 day rise, 15 – 150 days near peak, and 150 – 750 day decline for objects at the mean redshift of z 6.5.

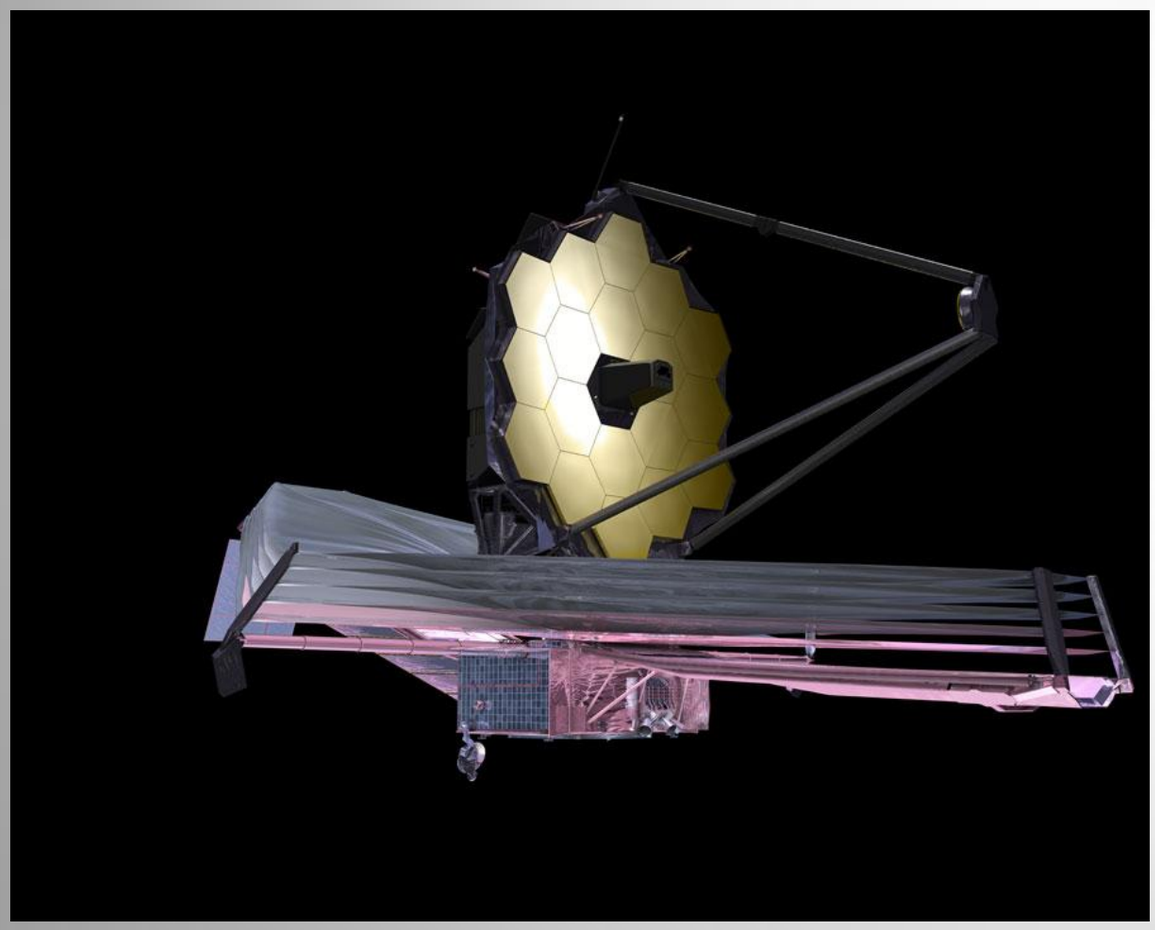
- Rates: several per field

Supermassive SN chemical signature

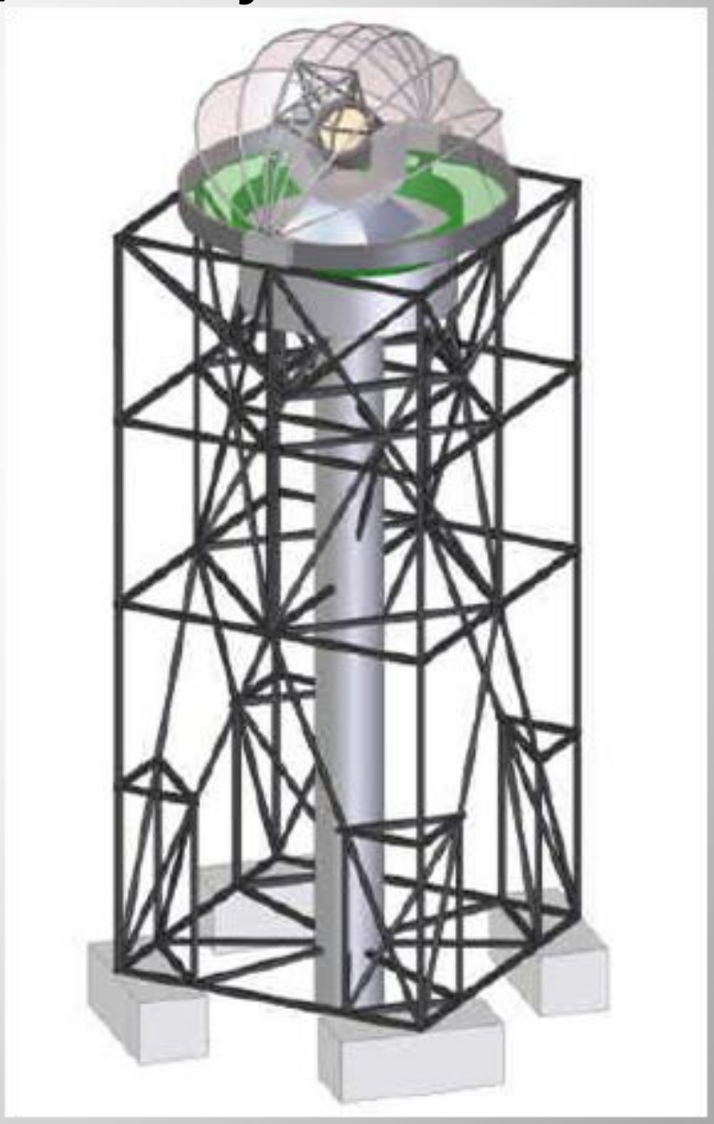
- SMS SNe produce very little nickel-56
  - Heger et al. 2013
- chemical signature may be distinguishable from those of most very massive (i.e. 140–260 M⊙) Pop III explosions (PSNe), which can produce iron-group
  - Heger & Woosley 2002
- Similar to these PSNe, however, SMS SNe would not make any s-process or r-process contributions.

Spectra and images of the first galaxies

JWST



KDUST, formerly PILOT



KDUST

Prioritized science case

	Priority	Field	Competitor	Limit mag
Spatial variation of galaxy LF at z = 6	B	>>HDF	VLT	K = 25
Weak lensing cosmology parameters	A	15000	Euclid	
IMF from 0.1 to 0.01 solar masses	B	10 fields	VLT	
Pair Instability SN at z > 4	A	100	VLT	K = 26
Kuiper belt census and properties	C	20000	LSST/PS	
Cool white dwarfs and Milky Way formation	B	20 fields	VLT	K = 27.5
Planetary transits	?		Kepler	
Clusters of galaxies at z > 2	A	100	SPT	K = 26
Lyman alpha emitters at z > 9	?		VLT	
Formation of globular clusters at z > 6	C		JWST	
Formation of the first SMBH	C		JWST	
Y band dropouts at z = 10	B	100	VLT	K = 26

Speed ratio is D/sqrt(B) assuming no fov difference D is telescope diameter and B is backg
GPC = Gigapixel CCD camera
Theme is evolving universe, dark universe, transient universe, galactic
Anything VLT accessible is priority B but that should be reassessed if 100 sq deg is real
and note that none of the present KDUST collabo
Field is in sq deg except where stated otherwise We assume the KDUST IT camera has a
Volume refers to a one mag range in luminosity distance
The SDSS SN rate is 27000 Sne/yr/Gpc^3 Dilday et al 2010. Massive star Sne may be rarer than that b

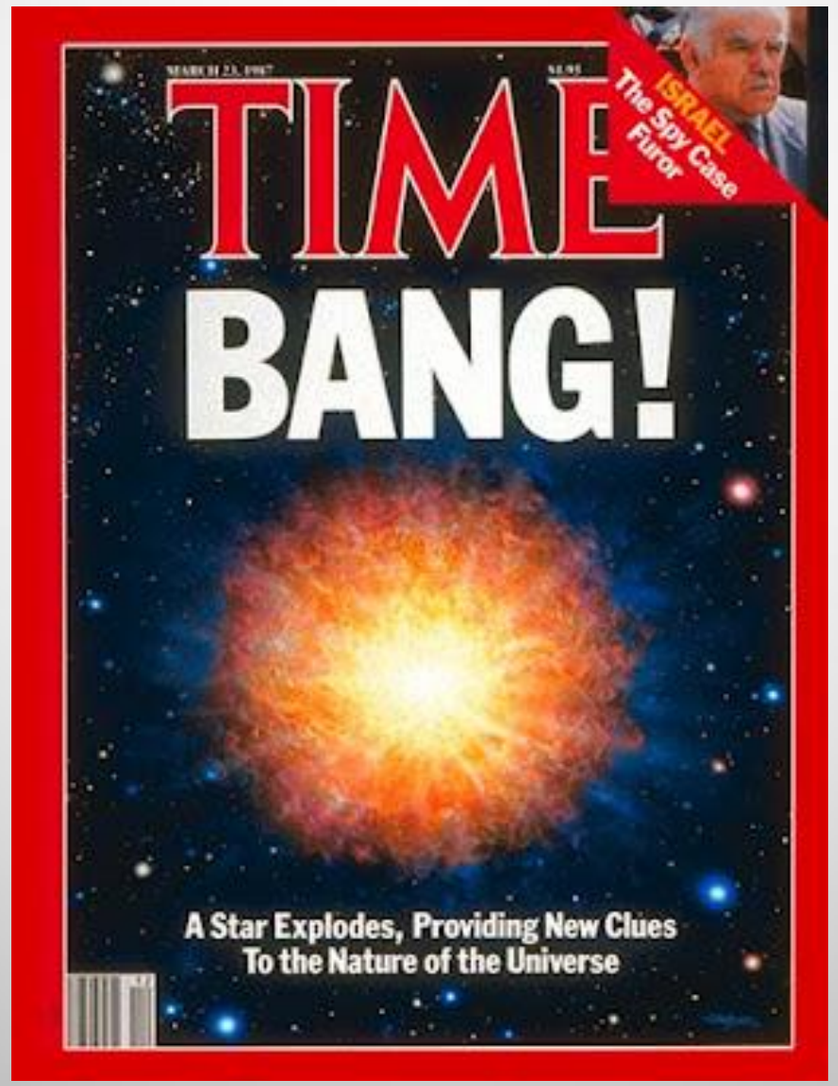
Las CampanasTransit Telescope

- Off axis mirrors 2 and 3 can be turned into transit telescopes
- mounted in a static mirror cell and pointed at zenith
- For f/2 GMT mirror prime focus camera can be positioned on 20 meter tower beside mirror, pointing at mirror center
- GMT mirror 2 soon available (#1 used in SOML test tower)
- If AAO built static mirror cell, and Carnegie transported mirror to Las Campanas Observatory, it could be set up beside Magellan
- Forget 8 meter tower: cantilever camera out from Magellan dome
- Optics need rudimentary protection from bad weather.
- Storage charges in Tucson avoided.
- Note: corrective optics required (not designed yet)

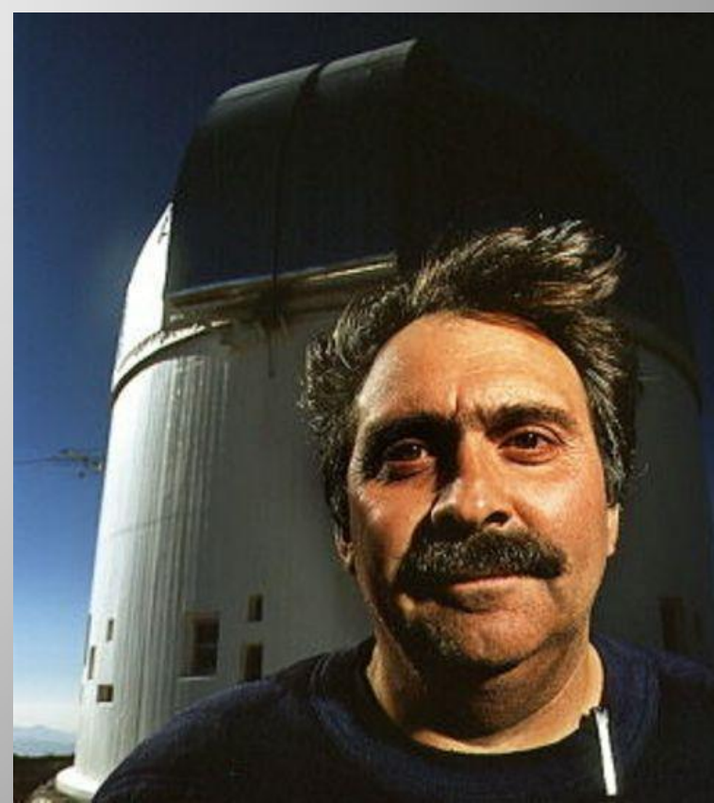
Science goals

- Compare with Palomar Transient Factory for z=1 supernovae
  - with Hubble Deep Field for galaxy evolution.
- Reverberation mapping for any AGN in the field
- Microlensing of galactic bulge stars by brown dwarfs to determine brown dwarf mass function
- During stellar microlensing events trigger exoplanet microlensing alerts to tracking telescopes
  - see Figures 6 & 7 of Green et al astro-ph 1208.4012
- Weak lensing using advantageous off-axis static PSF
  - and LCO half arcsec natural seeing
  - WFIRST also selected unobstructed aperture


SCIENCEphotoLIBRARY

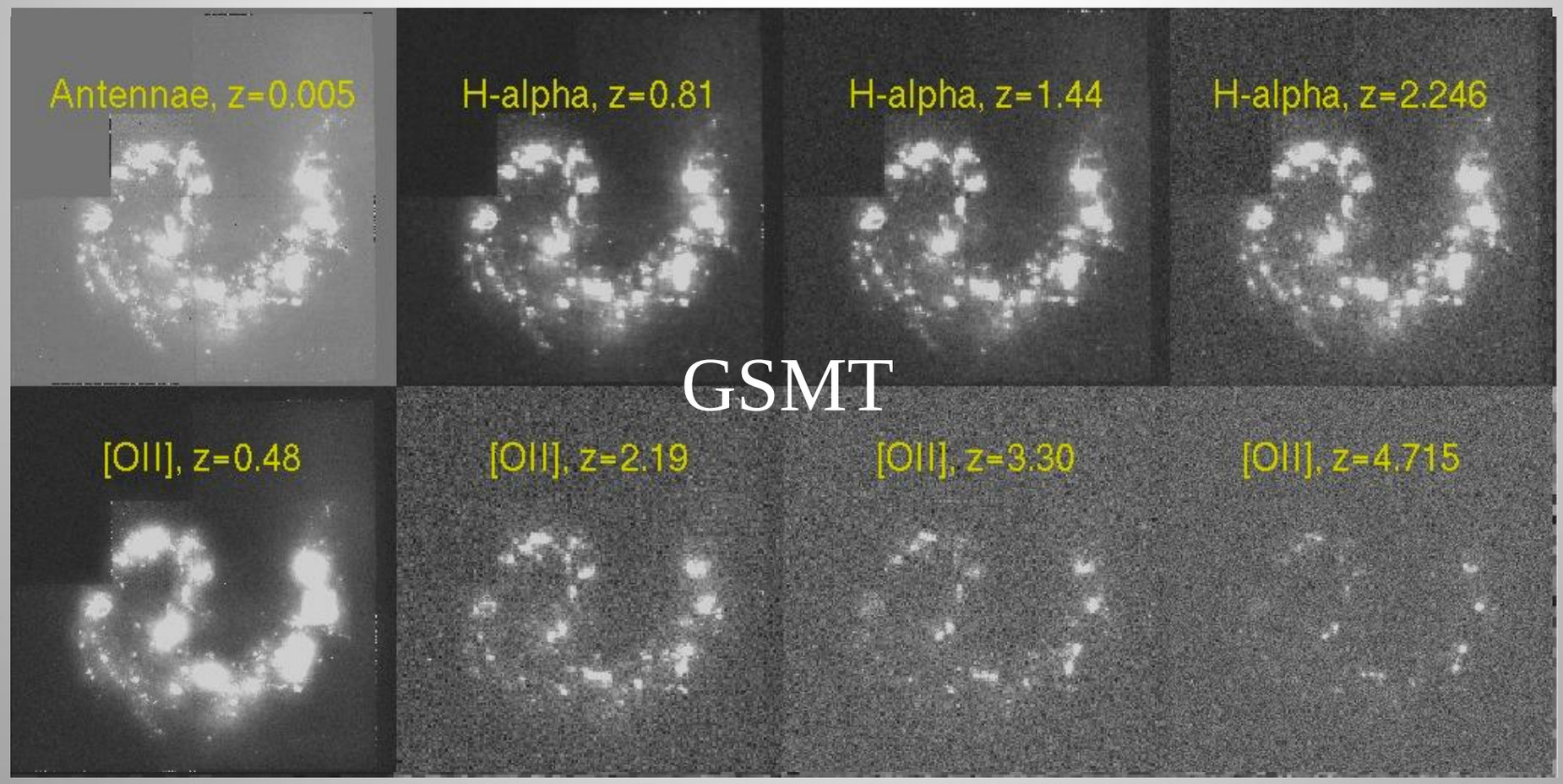

TIME
ISRAEL
The Spy Case
Furor
BANG!
A Star Explodes, Providing New Clues
To the Nature of the Universe


corbis



TMT vs JWST

Simulated monochromatic images of the ‘Antennae’
(local starburst galaxy: 10^5 seconds integration time)
Courtesy: Elizabeth Barton, GSMT SWG



MOS goals in high z universe

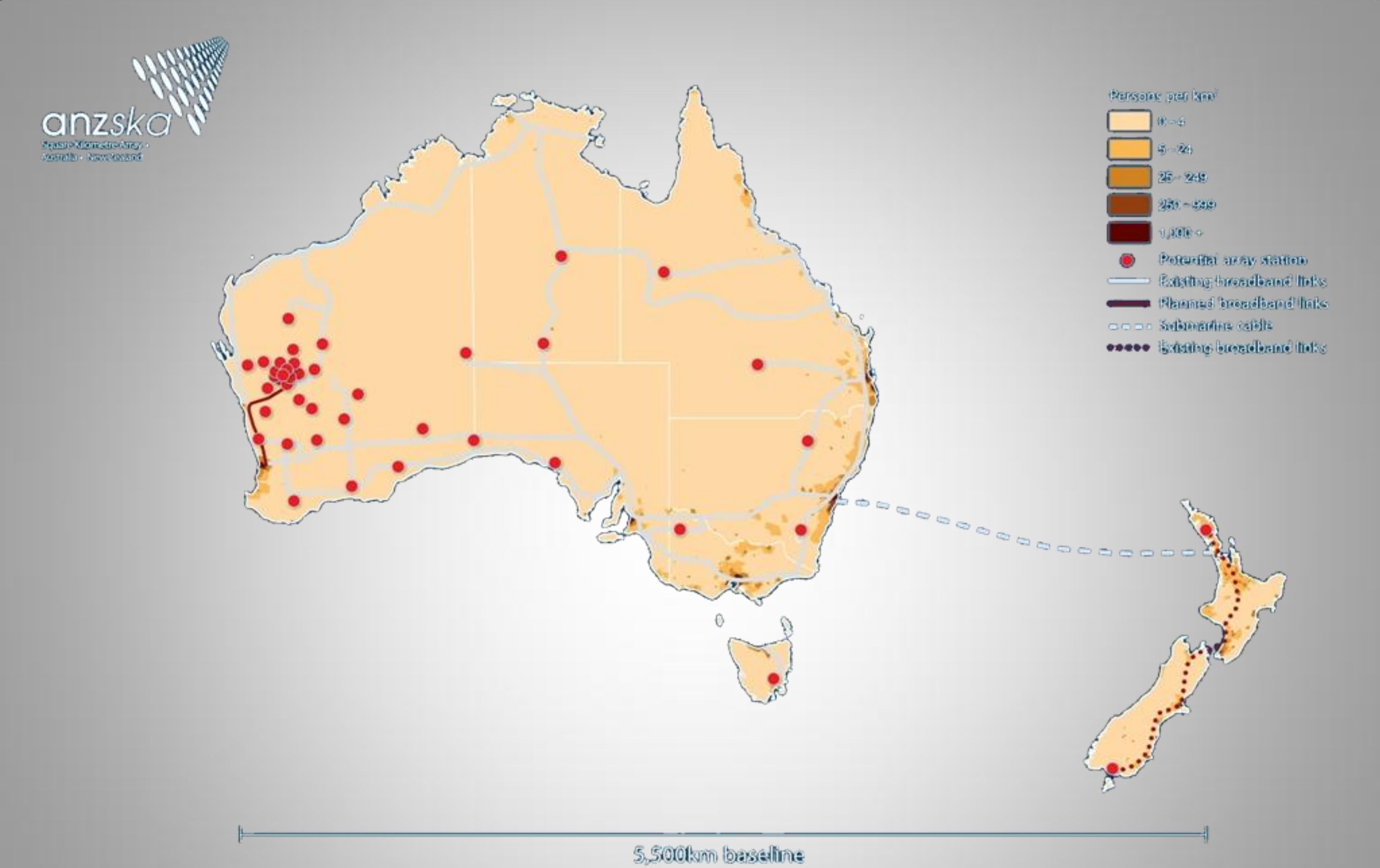
‘FIRST LIGHT’ – SPECTROSCOPY OF MOST DISTANT GALAXIES

- Probing epoch of reionisation: Physical properties of the ‘first-light’ galaxies
- Low-luminosity sources responsible for reionisation
- targets – synergies with other facilities

ELT-MOS white paper
astro-ph 1309.0029

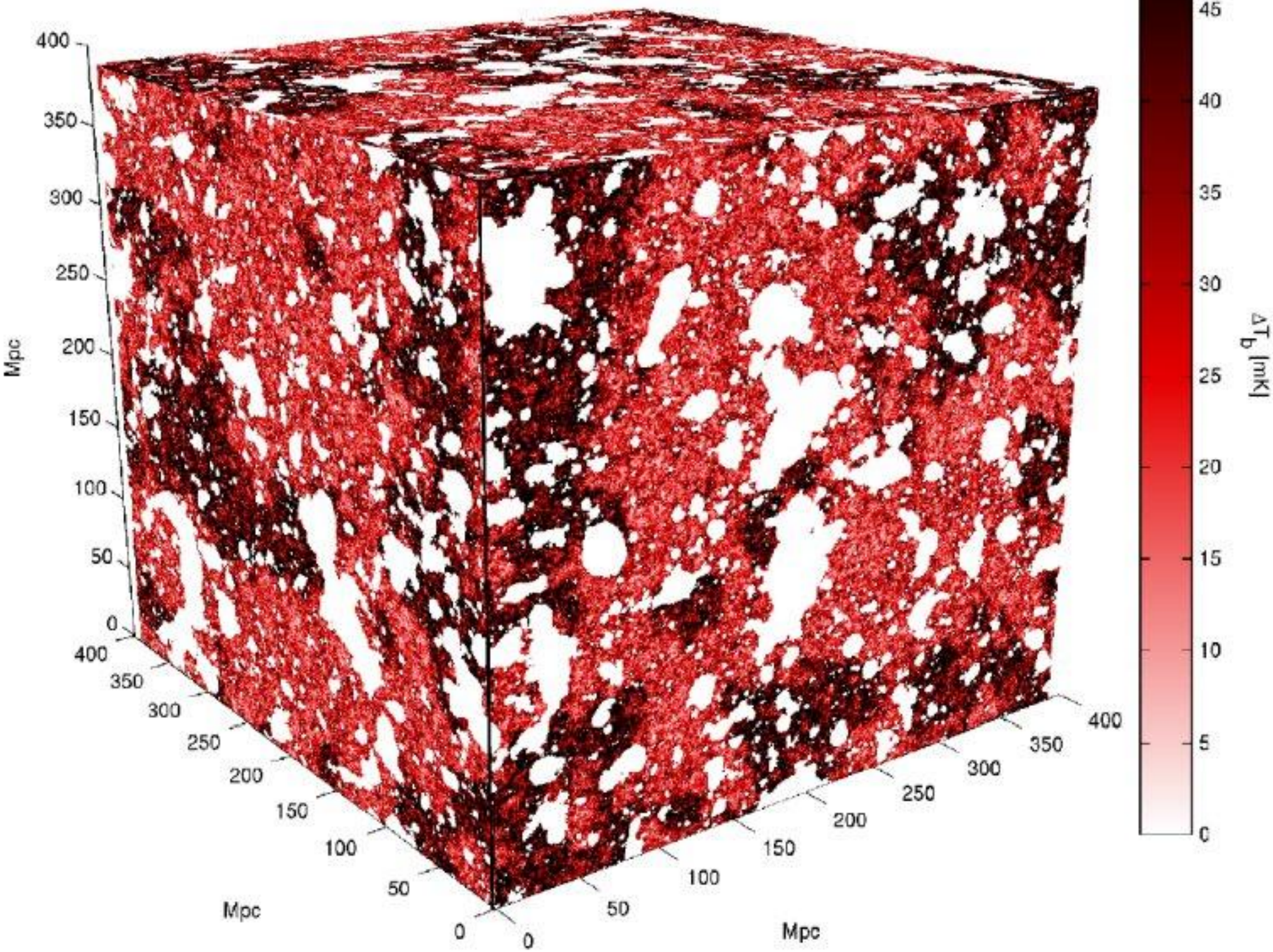
- SPATIALLY-RESOLVED SPECTROSCOPY OF HIGH-Z GALAXIES
  - assembly of galaxy mass as a function of look-back time
- ROLE OF HIGH-Z DWARF GALAXIES IN GALAXY EVOLUTION
  - Impact of LSB Galaxies at high-z, Origin of dwarf galaxies
  - HII galaxies to probe cosmology

- Barbuy et al
- Editors: Evans & Puech



Array antenna locations as of December 2009

Simulated Redshifted 21 cm Brightness Temperature
(Data provided by A. Mesinger and S. Furlanetto)
$z = 8, \quad x_i = 0.3$



What if the EoR looks nothing like this?

- Exactly what was happening in the dark sector during the dark ages ?
- Dark stars? Self Interacting Dark Matter?
- Which astronomy Nobel prizes were given for physics triumphs?
- And which one was given for a physics disaster?
- Is there another one on the horizon for the EoR?

Summary: DECam EoR Deep Fields

- Bulge properties of first-light galaxies
- High redshift AGN
  - SMBH seeds
  - Contribution to reionization
- assembly of galaxy mass as a function of look-back time
- Pair production SNe (massive stars) at $M_K = -23$
- Young globular clusters with 10^6 year free fall times and M/L approaching 10^{-4}

Acknowledgement

- Our DECam time to date was allocated by the Australian Time Allocation Committee
- There is a time exchange agreement between NOAO/CTIO and AAO which makes this possible
- AAO facilities are now reciprocally available to the NOAO user community and appear in the NOAO Newsletter in full detail
- Especially in demand is the AAOmega MultiObject Spectrograph
- Happy Birthday CTIO