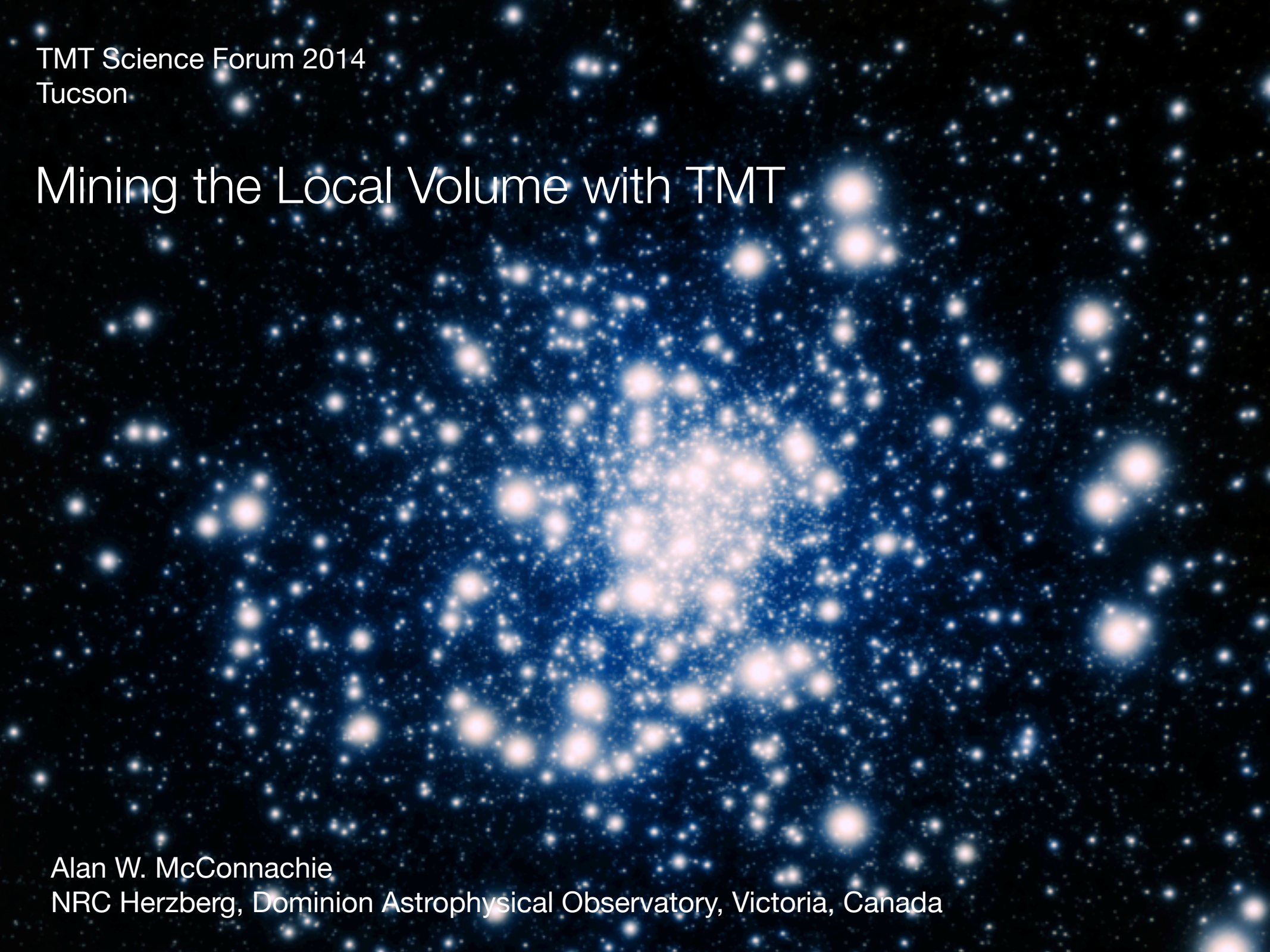
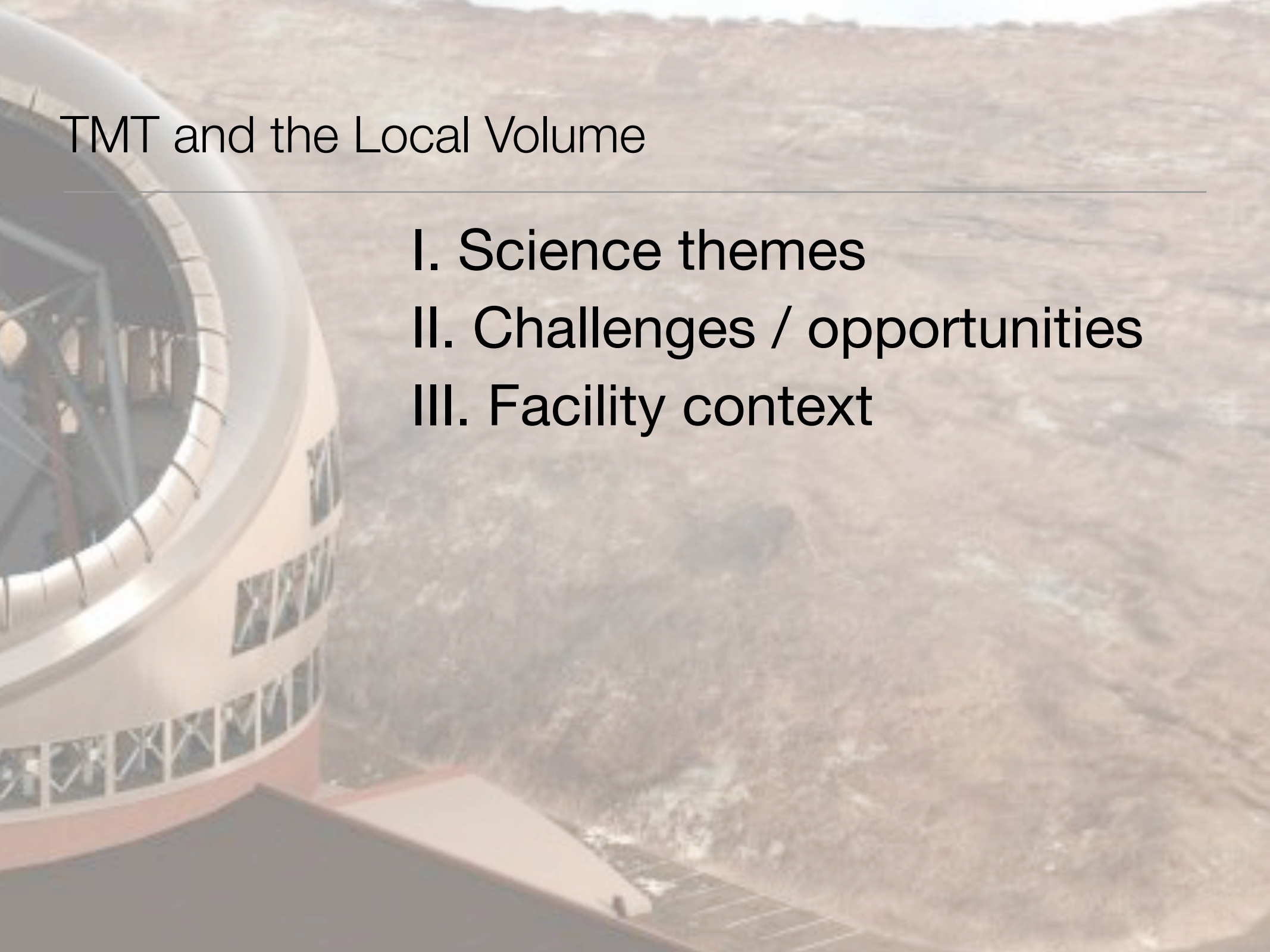


TMT Science Forum 2014
Tucson

Mining the Local Volume with TMT

Alan W. McConnachie
NRC Herzberg, Dominion Astrophysical Observatory, Victoria, Canada



TMT and the Local Volume

I. Science themes

II. Challenges / opportunities

III. Facility context

I: Science themes

- 7.10 Chemical evolution histories in the Local Group and beyond
- 7.17 Resolved stellar populations as tracers of galaxy evolution
- 7.18 Reconstructing the star formation histories of nearby galaxies
- 7.19 The time-resolved history of the galaxies in the Local Volume: the TMT era
- 7.20 LSB and BCD galaxies study with TMT
- 7.21 Resolving extreme star formation environments in LIRGs at low redshift
- 7.22 Kinematics of star forming galaxies at z = 2 - 3

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Themes

- Studies of the resolved populations of large samples of (previously unresolved) galaxies
- Faint and small galaxies
- Connecting the near and far fields

Deeper, further, fainter ---> new science

- Unique insight into the timescales associated with chemical enrichment and the cycling of baryons using resolved stellar population

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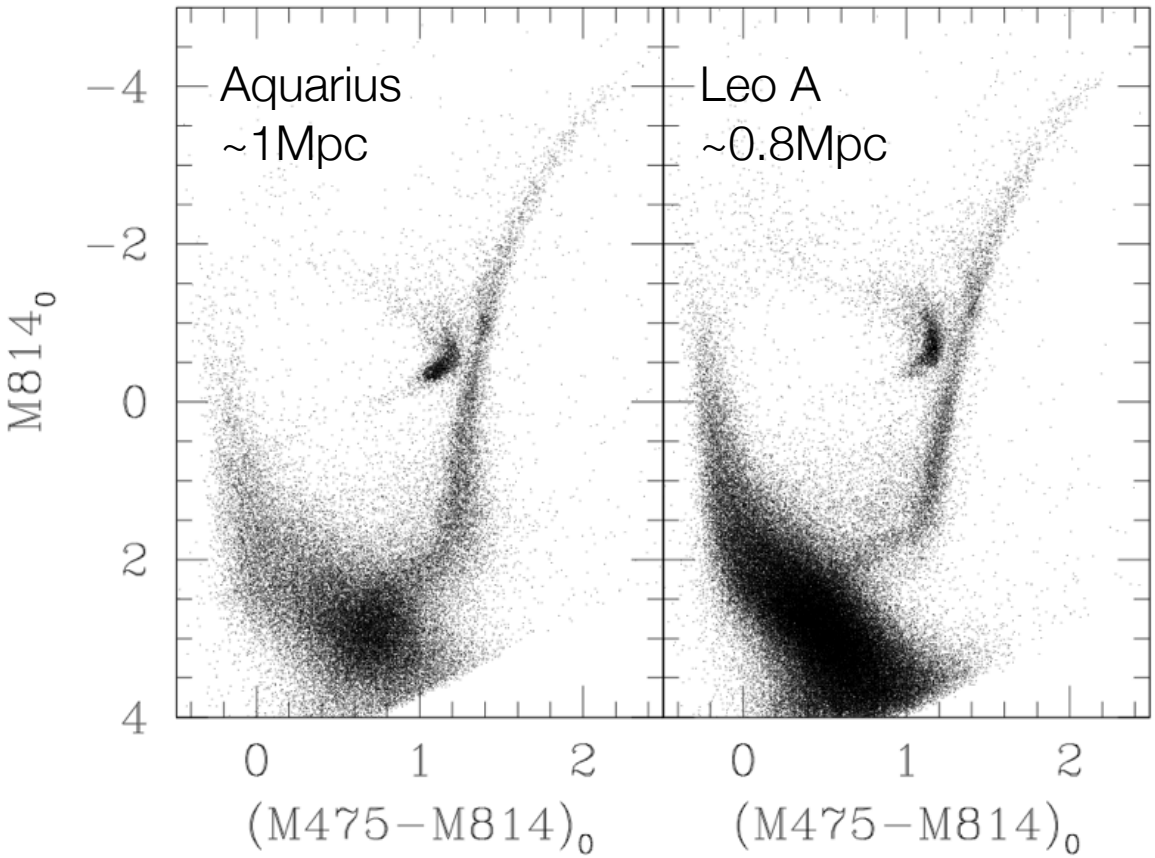

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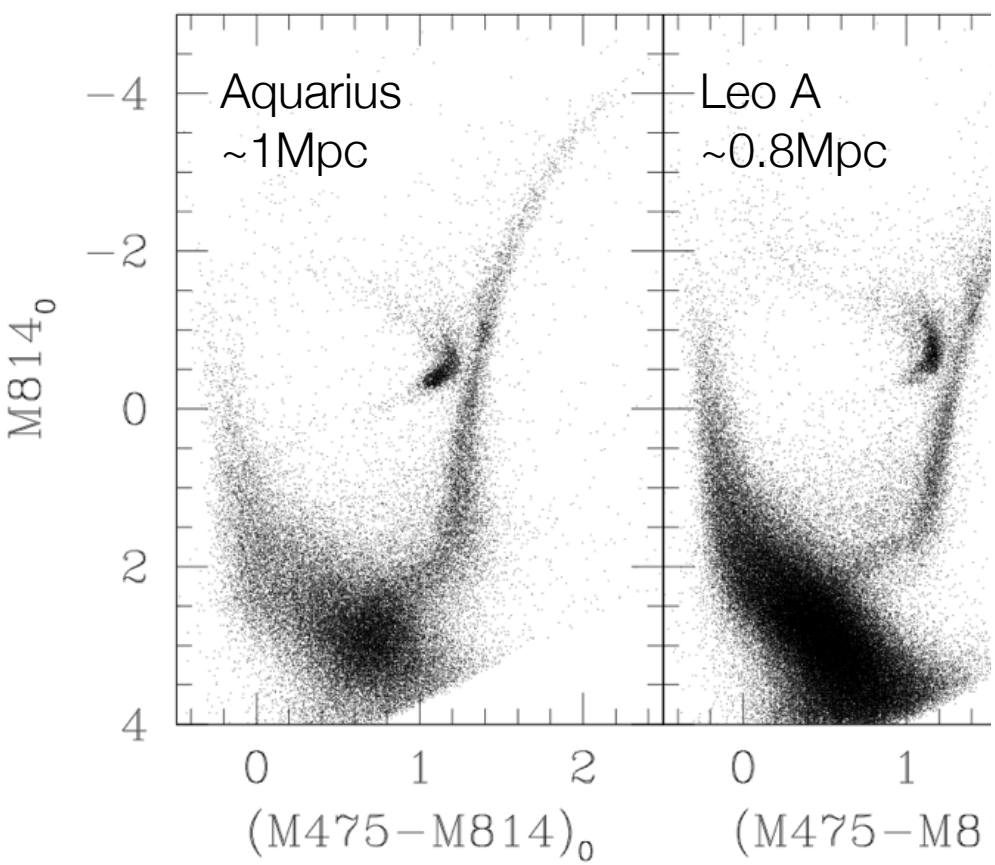

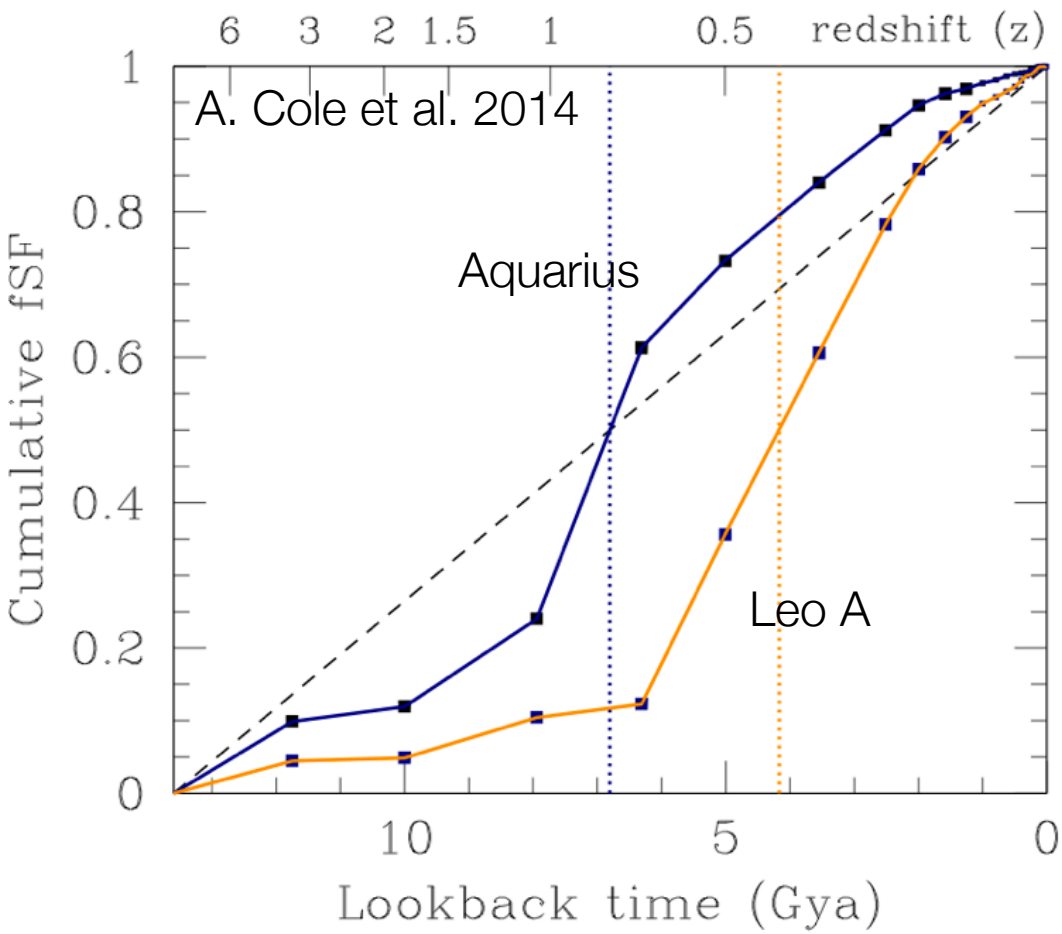

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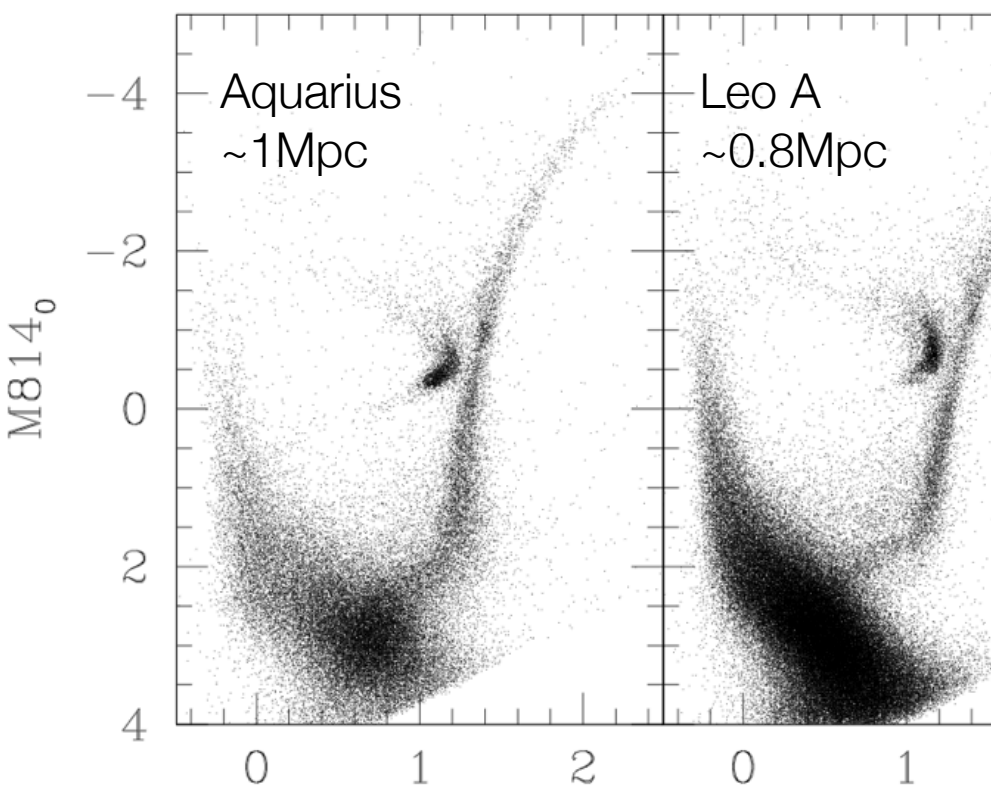
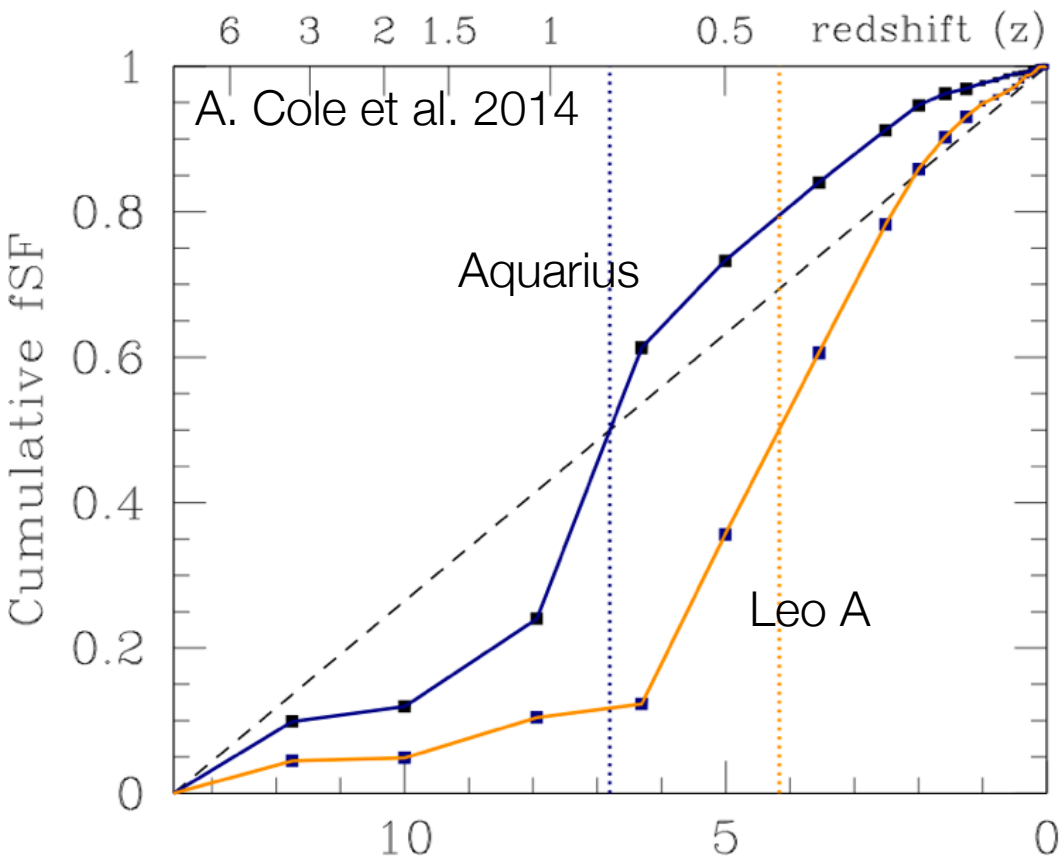
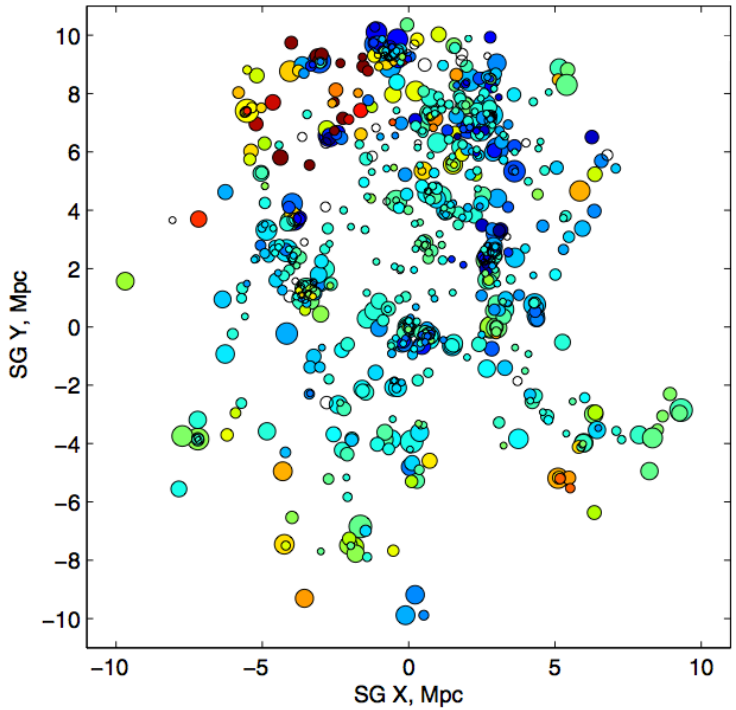
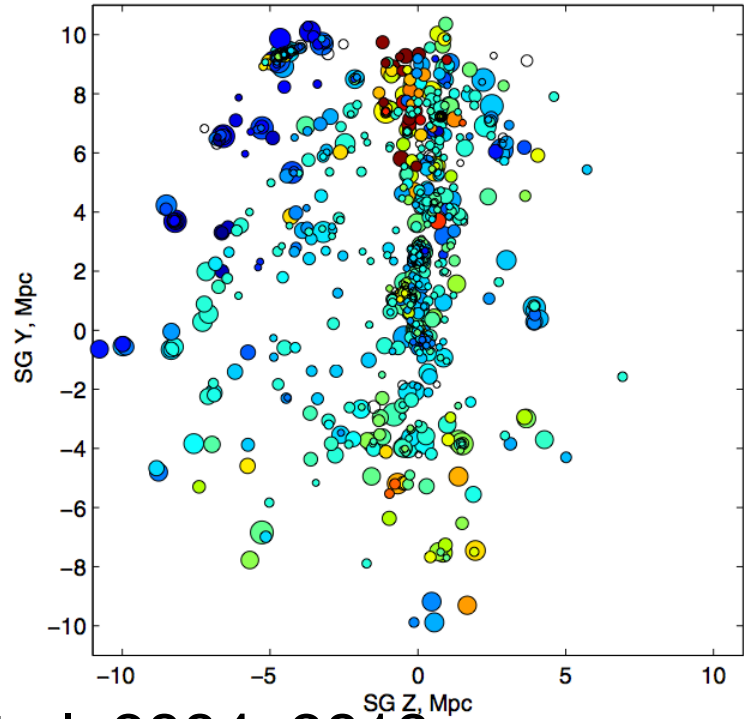




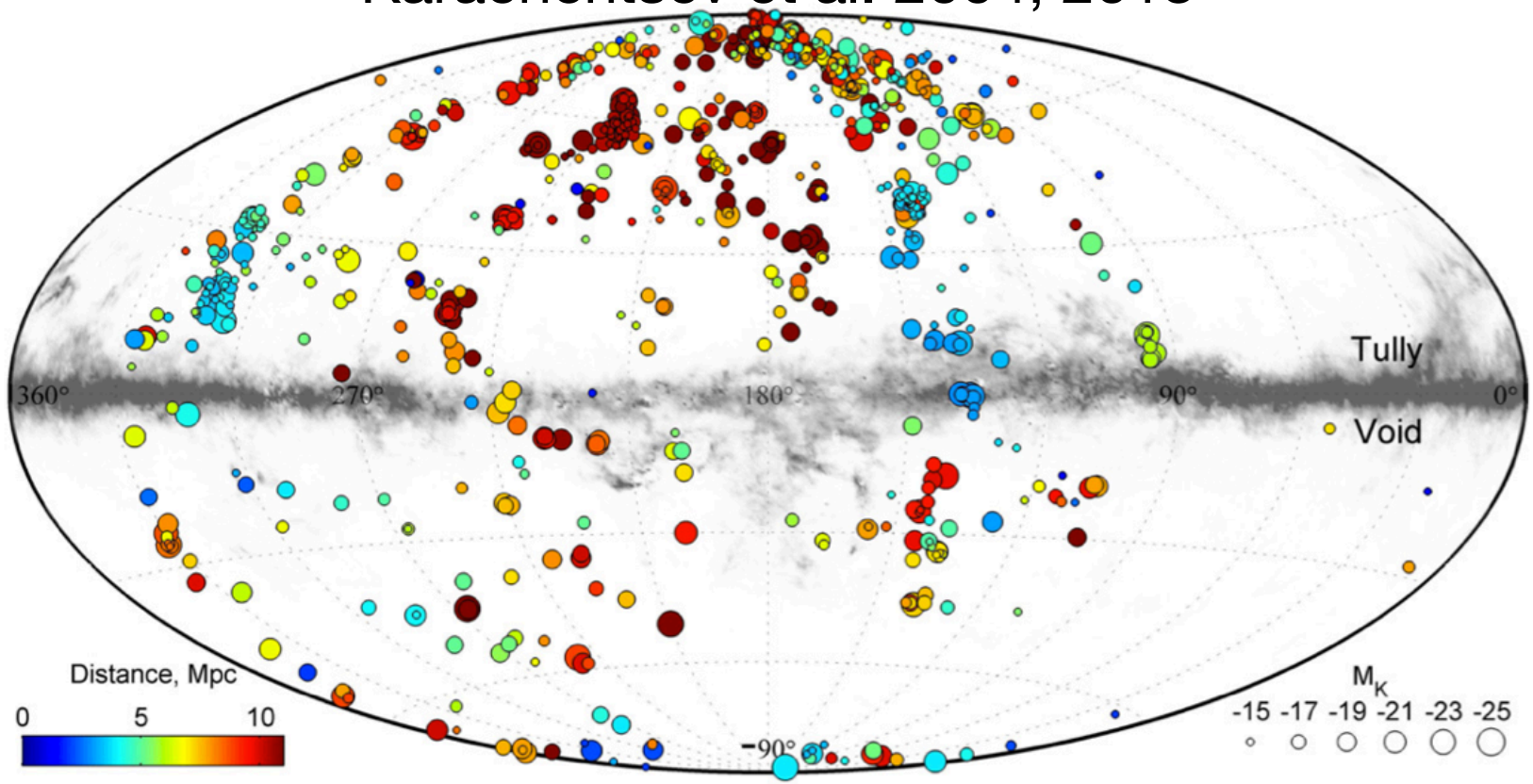
- **In principle**, TMT allows us to view the resolved stellar populations of all galaxies out to the distance of the Virgo cluster
  - *spanning all luminosities, morphologies, regions of the galaxy color-magnitude diagram and across all environments (from voids to loose groups, groups and galaxy clusters)*

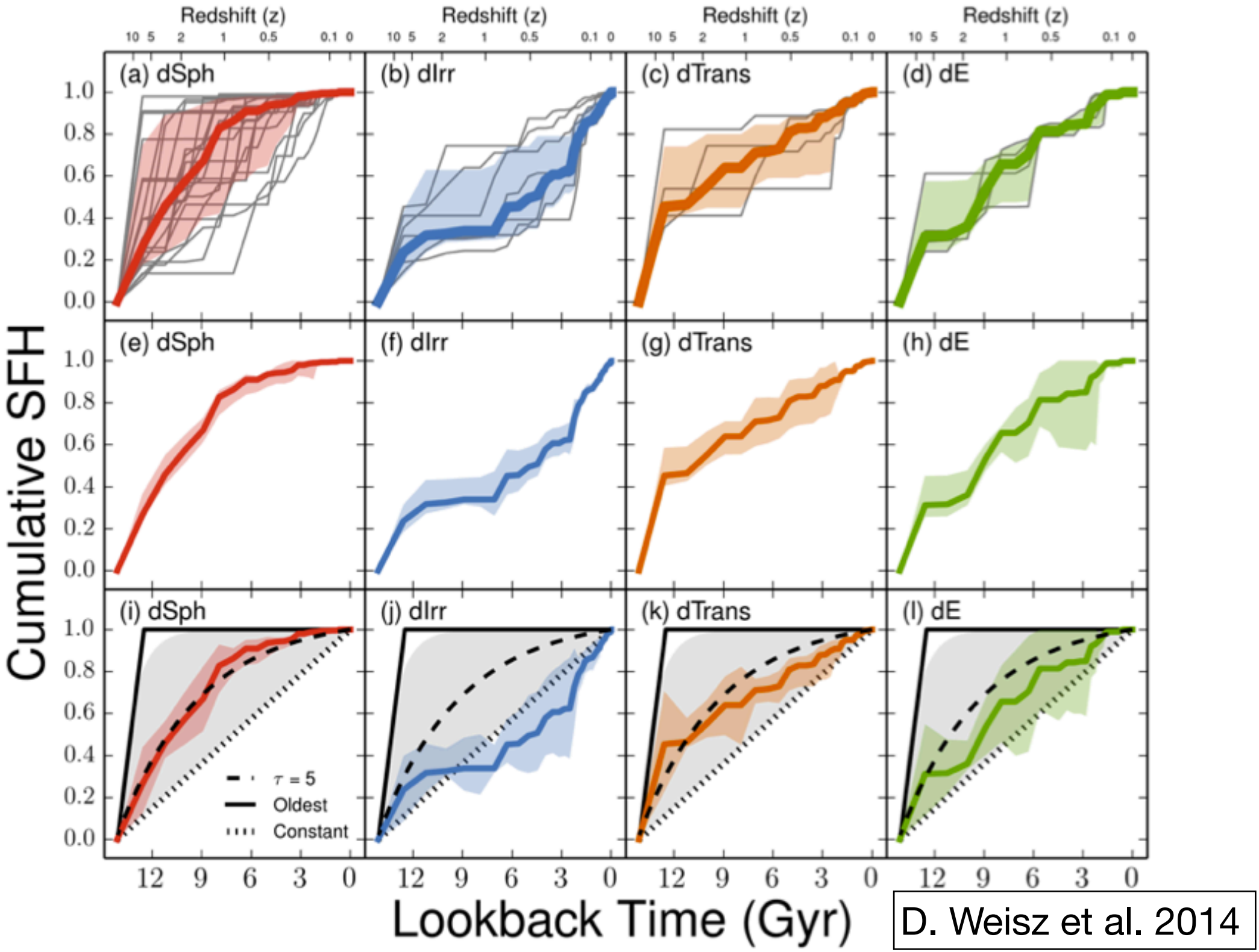
The Local Volume of 879 galaxies (D<11Mpc)



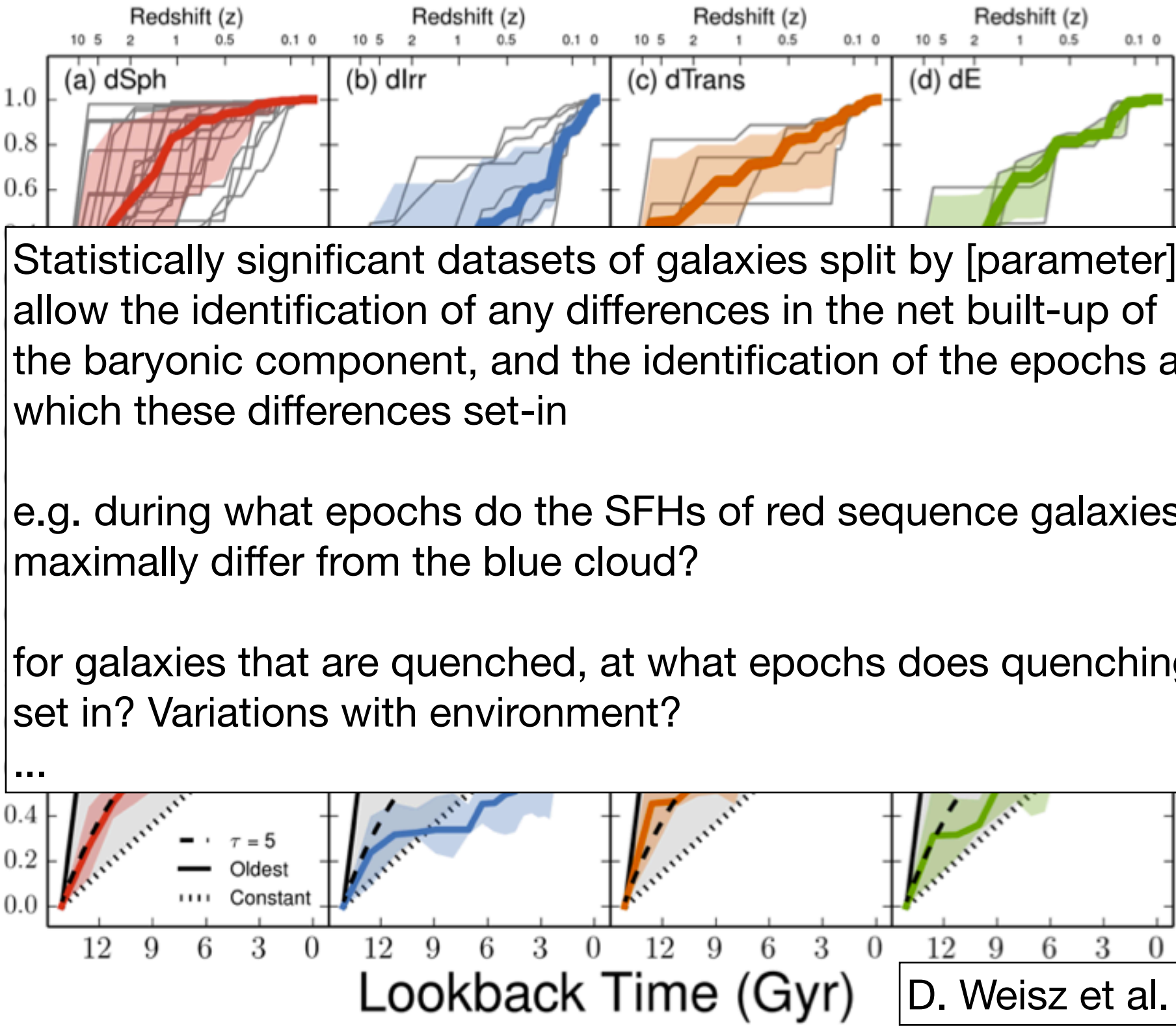


Karachentsev et al. 2004, 2013





D. Weisz et al. 2014



Statistically significant datasets of galaxies split by [parameter] allow the identification of any differences in the net built-up of the baryonic component, and the identification of the epochs at which these differences set-in

e.g. during what epochs do the SFHs of red sequence galaxies maximally differ from the blue cloud?

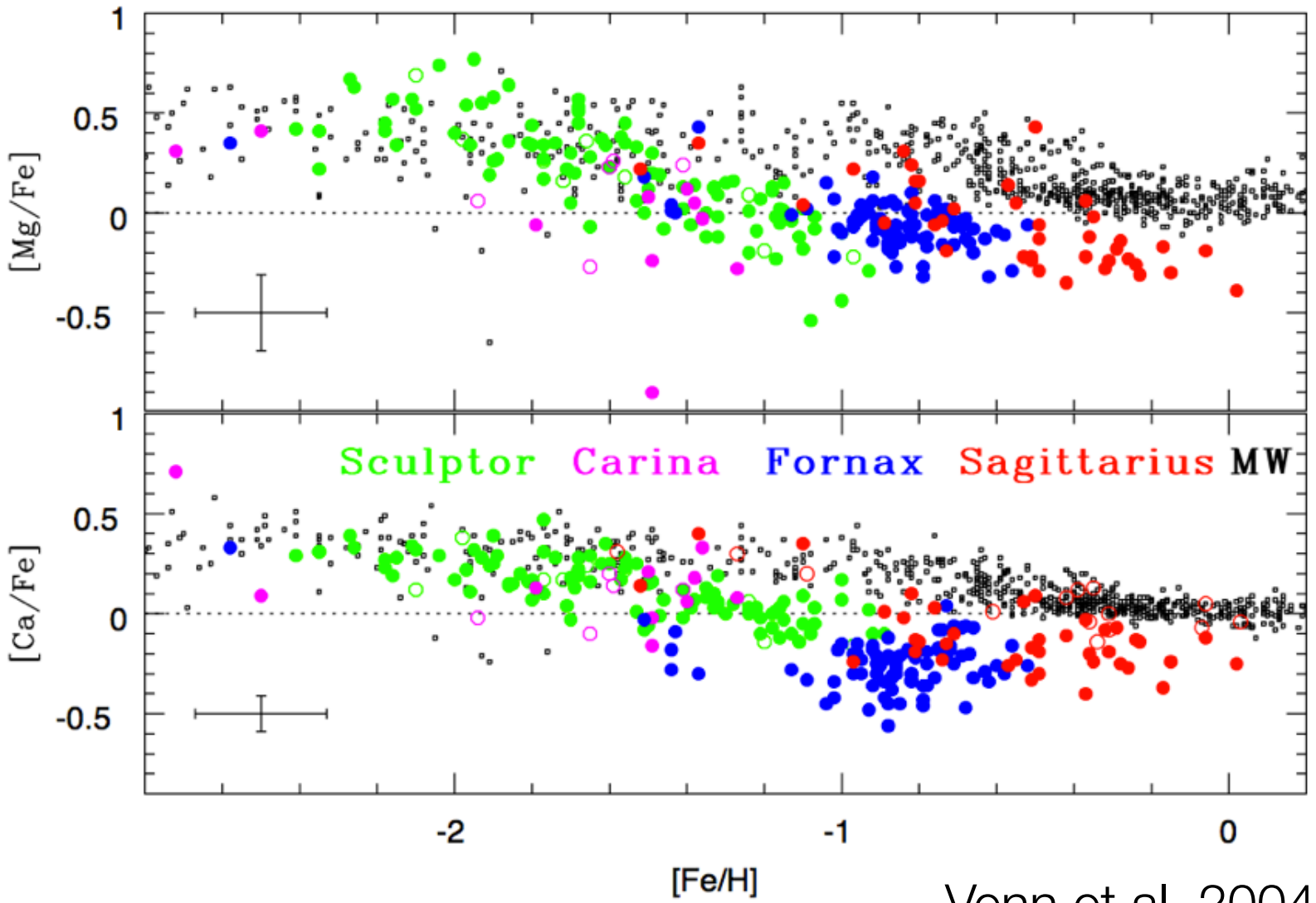
for galaxies that are quenched, at what epochs does quenching set in? Variations with environment?

...

D. Weisz et al. 2014

Spectroscopy in the distant Local Group and nearby

- e.g., alpha element abundance pattern



Venn et al. 2004

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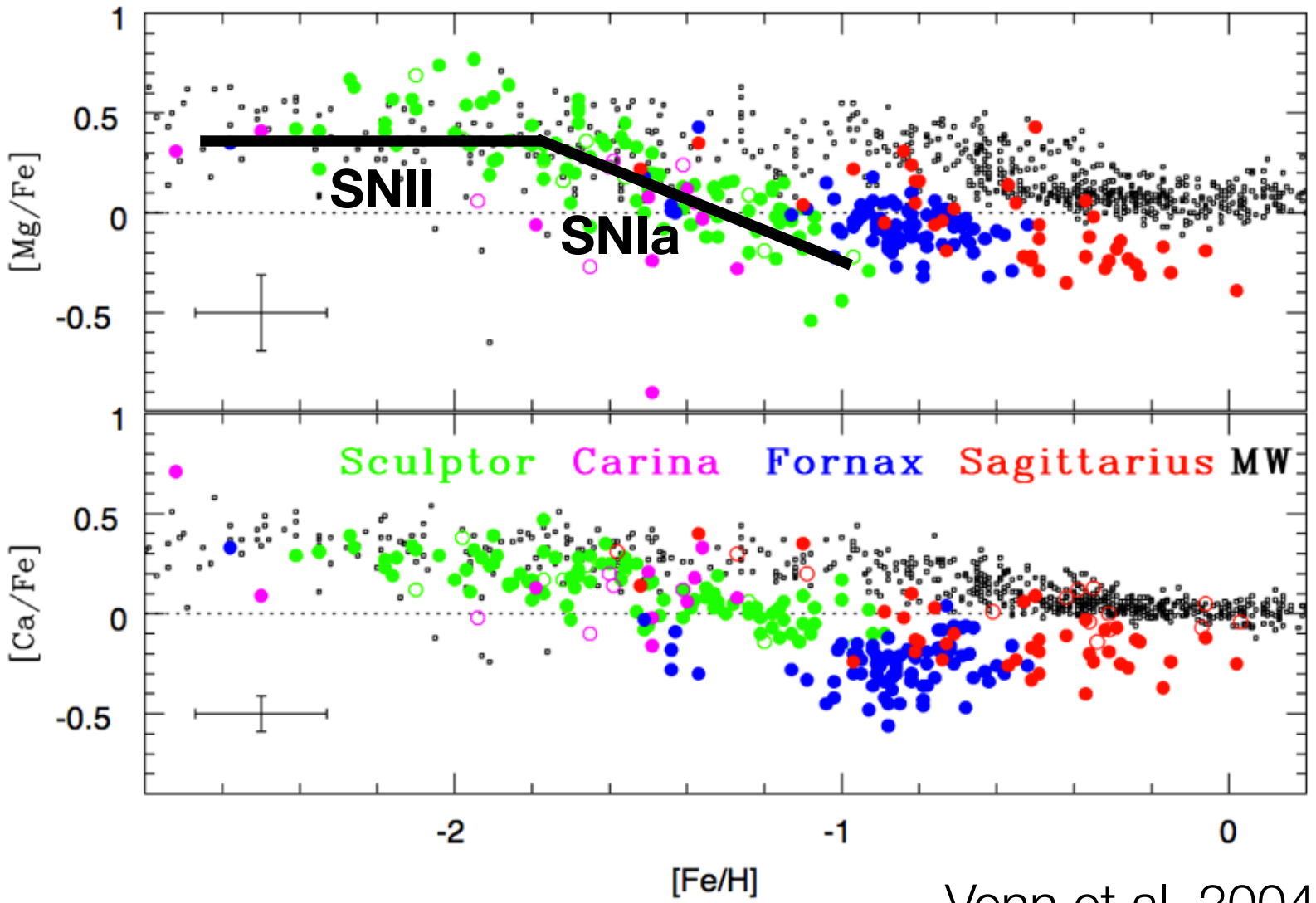

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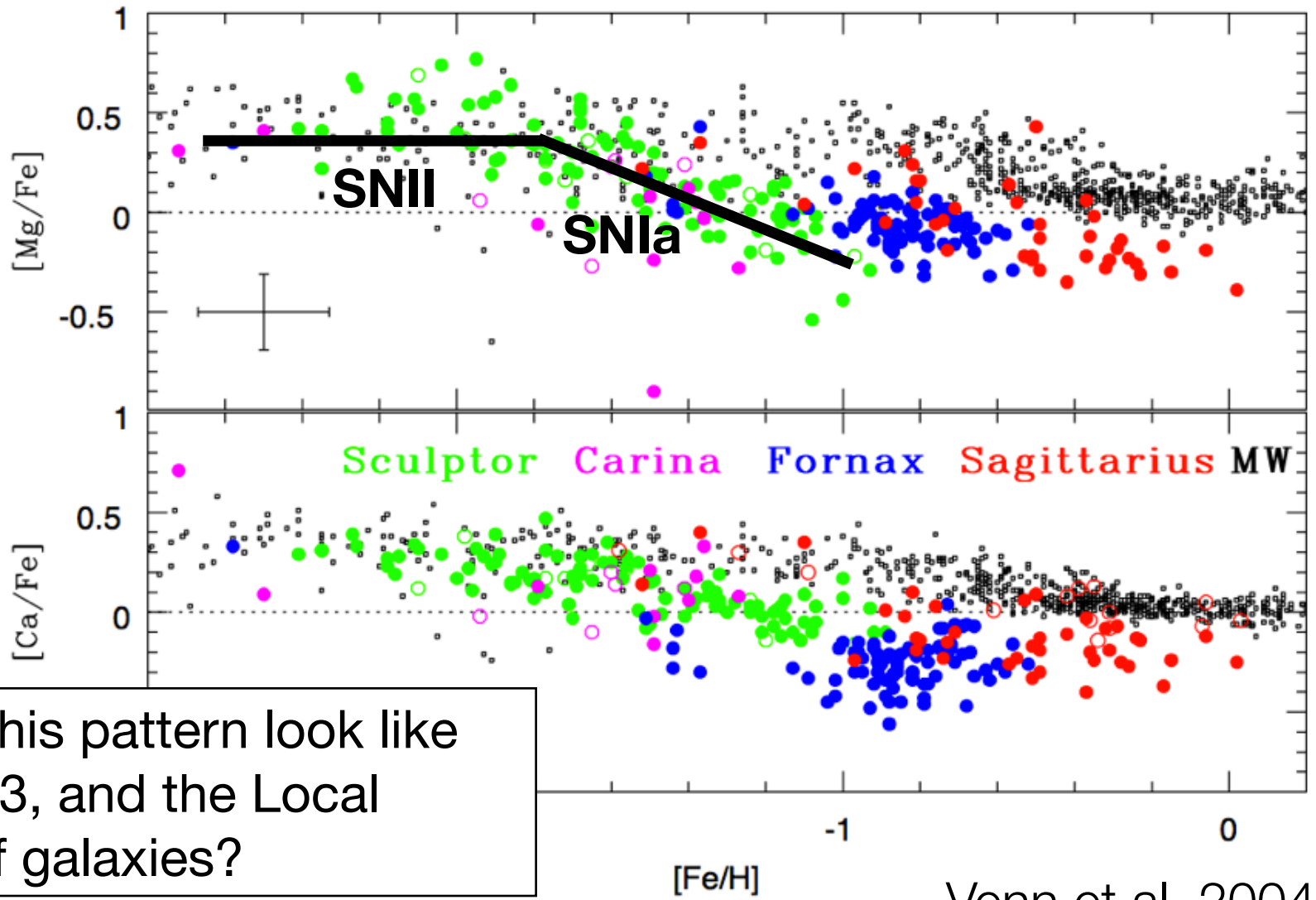


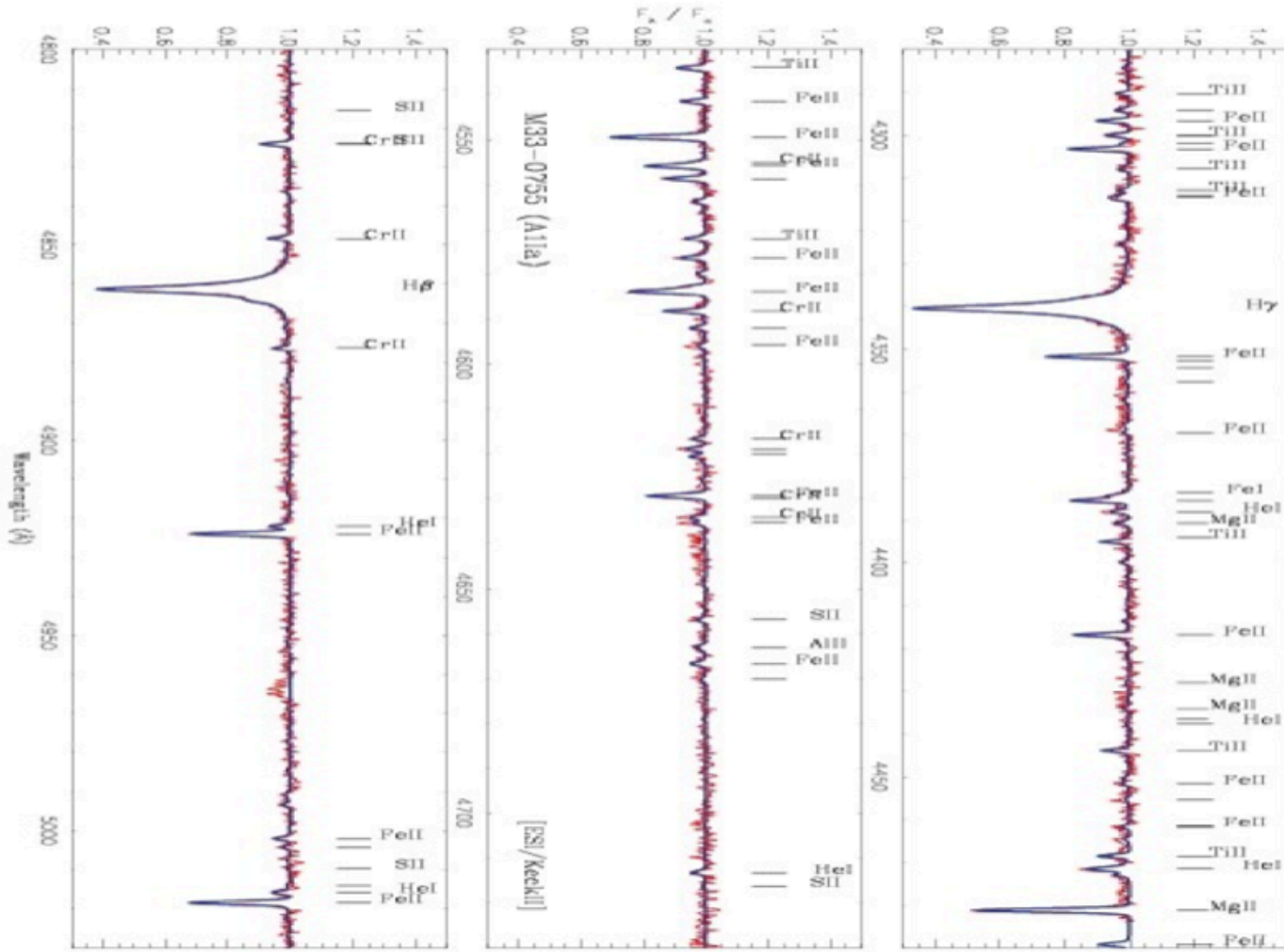
What does this pattern look like for M31, M33, and the Local Group dwarf galaxies?

Venn et al. 2004

Beyond the Local Group

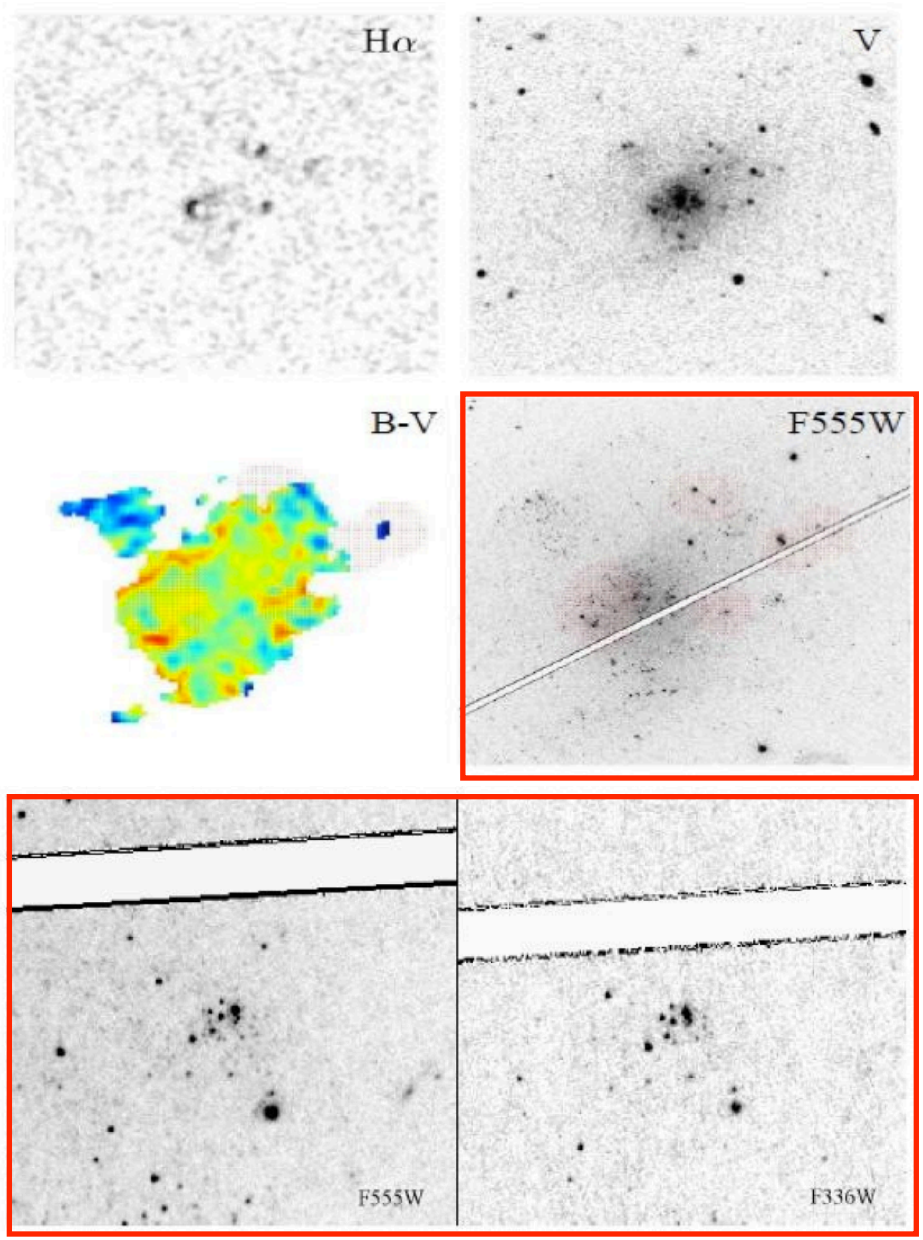
- Spectroscopy of brighter stars possible for many nearby galaxies beyond the Local Group

- Direct probes of star forming galaxies in different environments



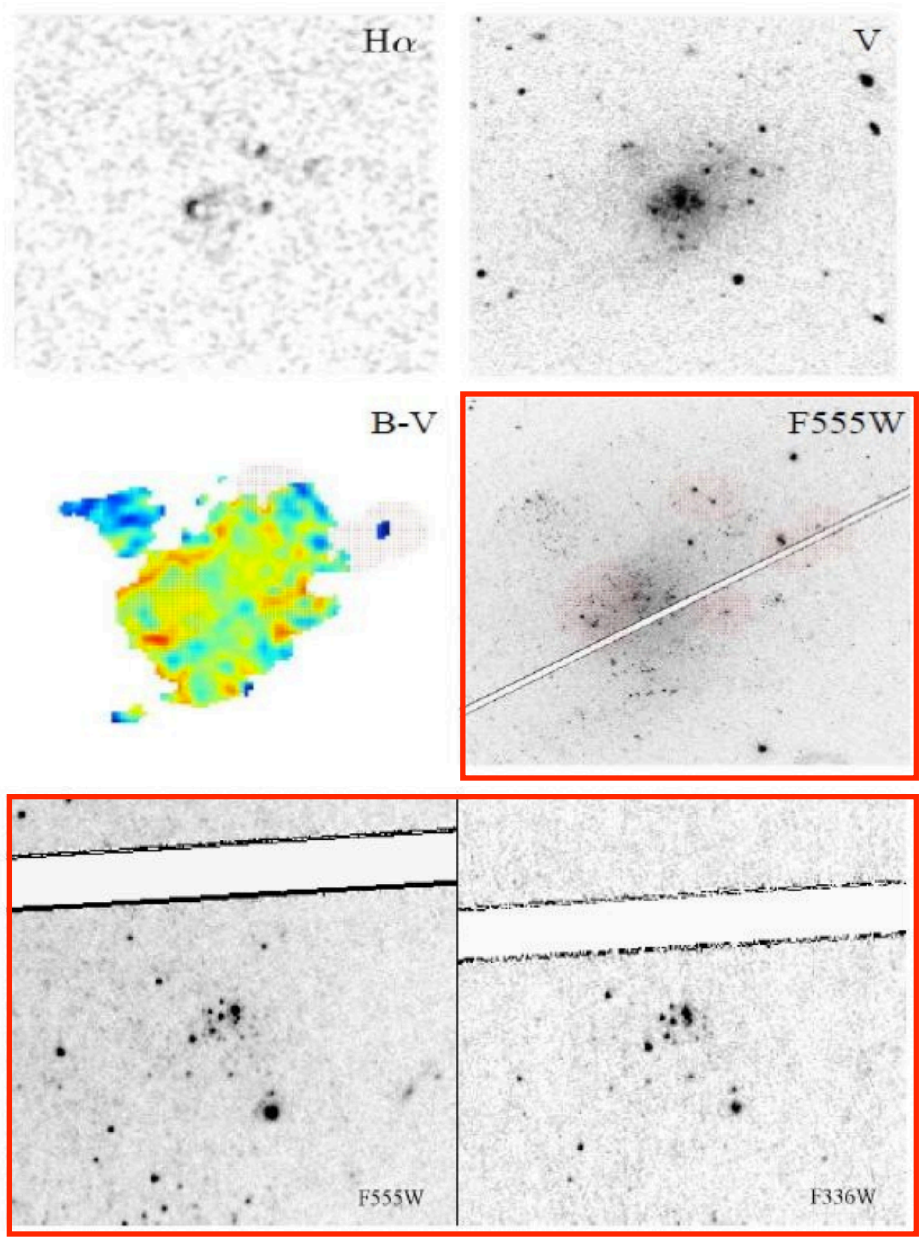
Moderate resolution spectrum of early A supergiant in M33; Urbaneja et al 2007

From the Local Volume to the low-redshift Universe



From the Local Volume to the low-redshift Universe

- Individual star clusters, HII regions, visible out to much larger distances than stars
  - GCs as tracers of the dynamics of galaxies
  - star formation in the not-quite-local Universe; blue compact dwarfs, SF as a function environment
  - spatial resolution essential, AO-assisted IFUs



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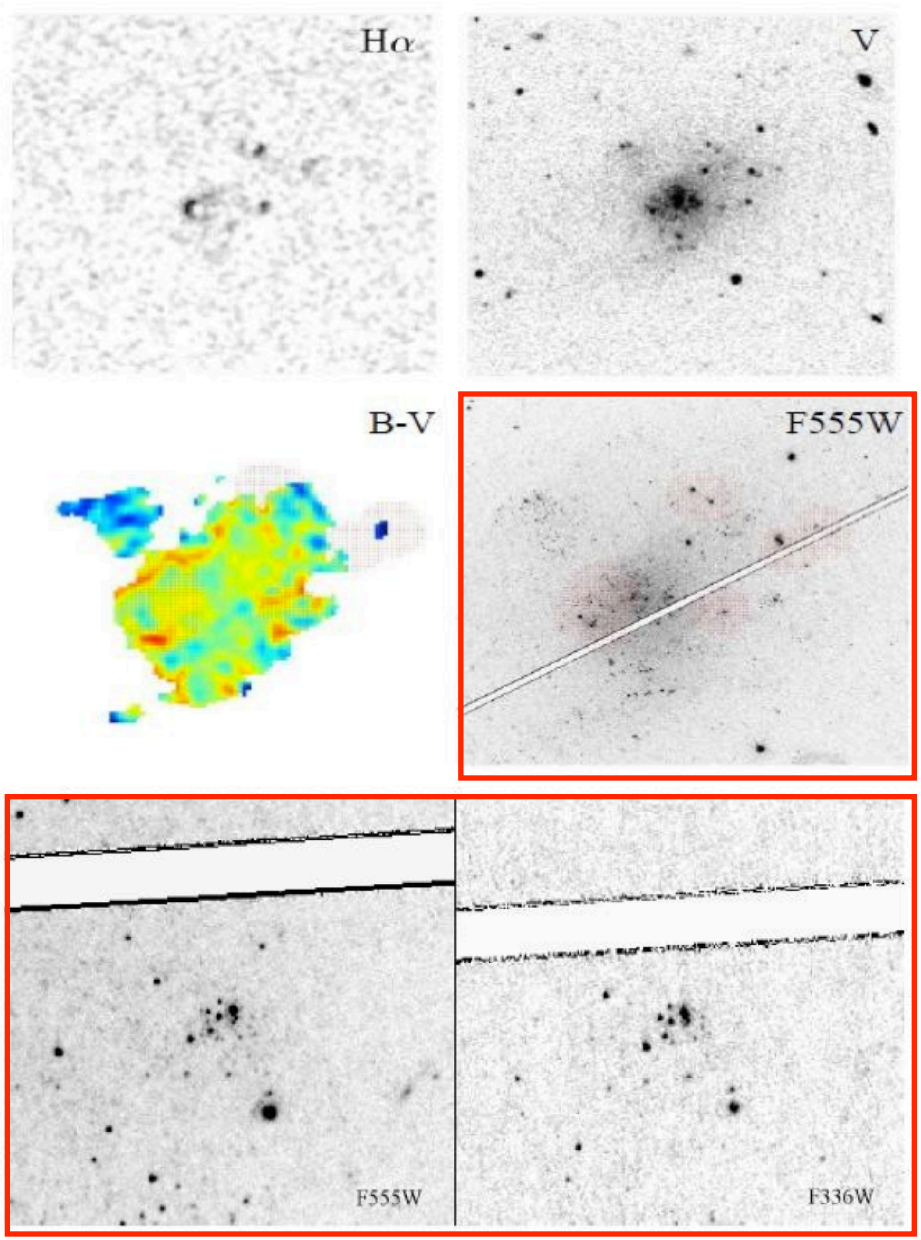
- Study of local star formation, merger history, secular effects *for a population of galaxies*



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  - c.f. TMT/IRIS FoV: 16” x 16”
  - c.f. optical - NIR optimisation of the TMT
- How well do we “do” resolved stellar pops in the NIR?
  - Theoretical: color-temperature transformations, evolved stellar pops, line lists (APOGEE transforming the field)
  - Practical: photometry, astrometry with wide-field AO

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  - 8’ x 3’ squared FoV, 576” (total slit length, 200 objects); R=1000 - 8000+, 0.31 - 1.1microns
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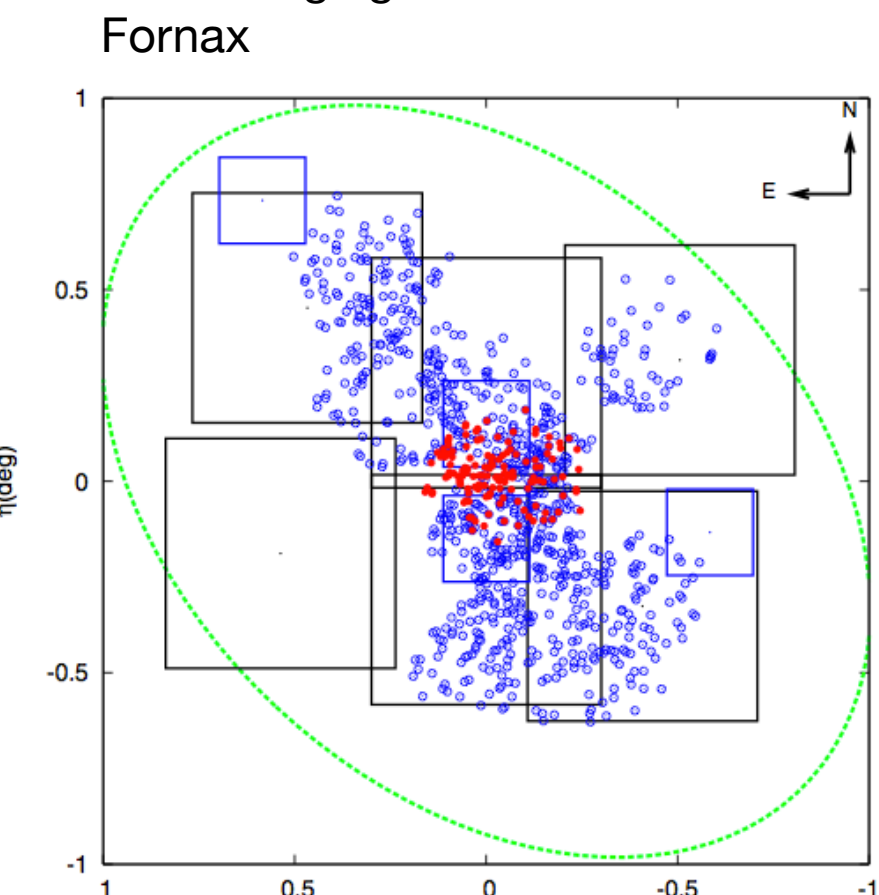
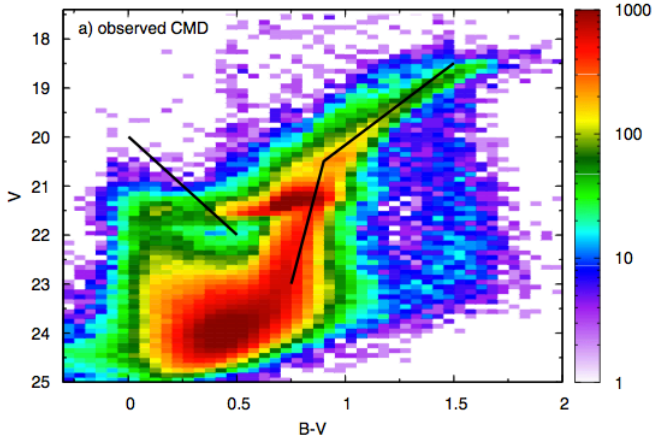
- IRMS (Infrared Multi-Slit Spectrometer)
  - 2’x1’ spectrographic field, AO assisted (0.2arcsecs?), 0.9 - 2.5microns, 46 slits, R~3200+, + wide field imaging (not critically sampled)
  - MOS spectroscopy for [Fe/H] of individual stars *[Q: do Kirby+ techniques work at 3200?]...*

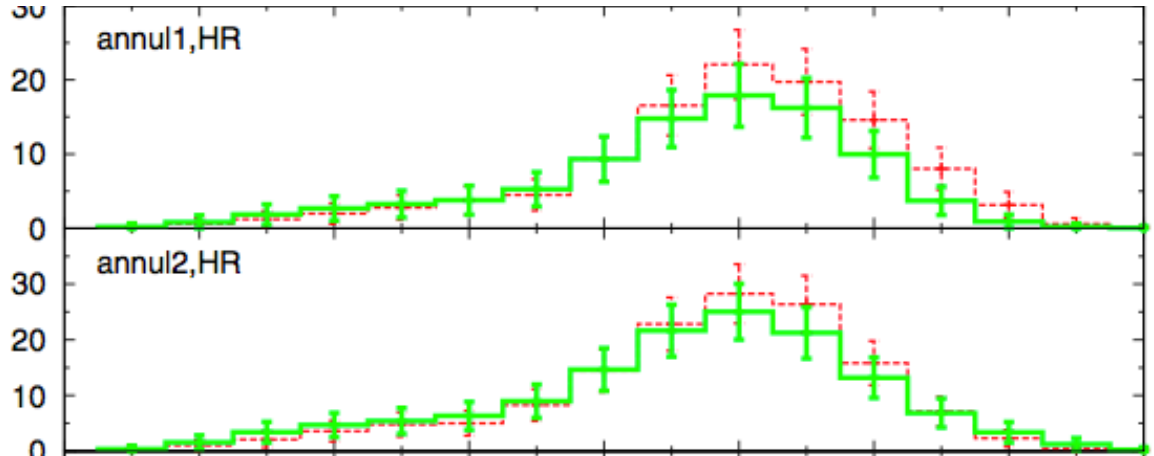
Instrument complements and usage

- Use multiple instruments for single science programs?
  - e.g. Diffraction limited imaging + AO-assisted MOS; metallicity information to break degeneracies?
  - cf recent papers by de Boer et al. (2012, A&A, 544, 73)

CTIO imaging +VLT/FLAMES + Keck/DEIMOS
Fornax







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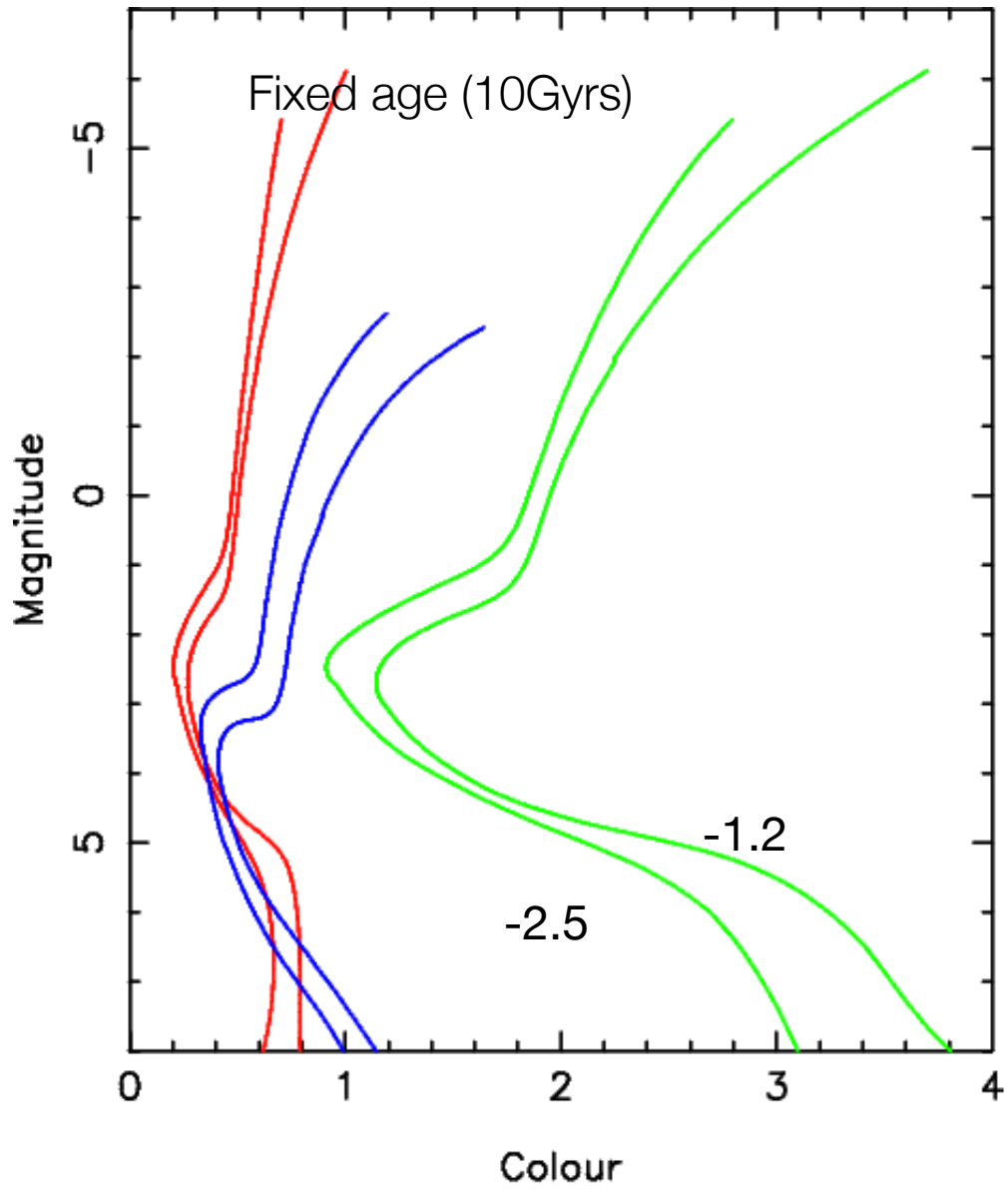
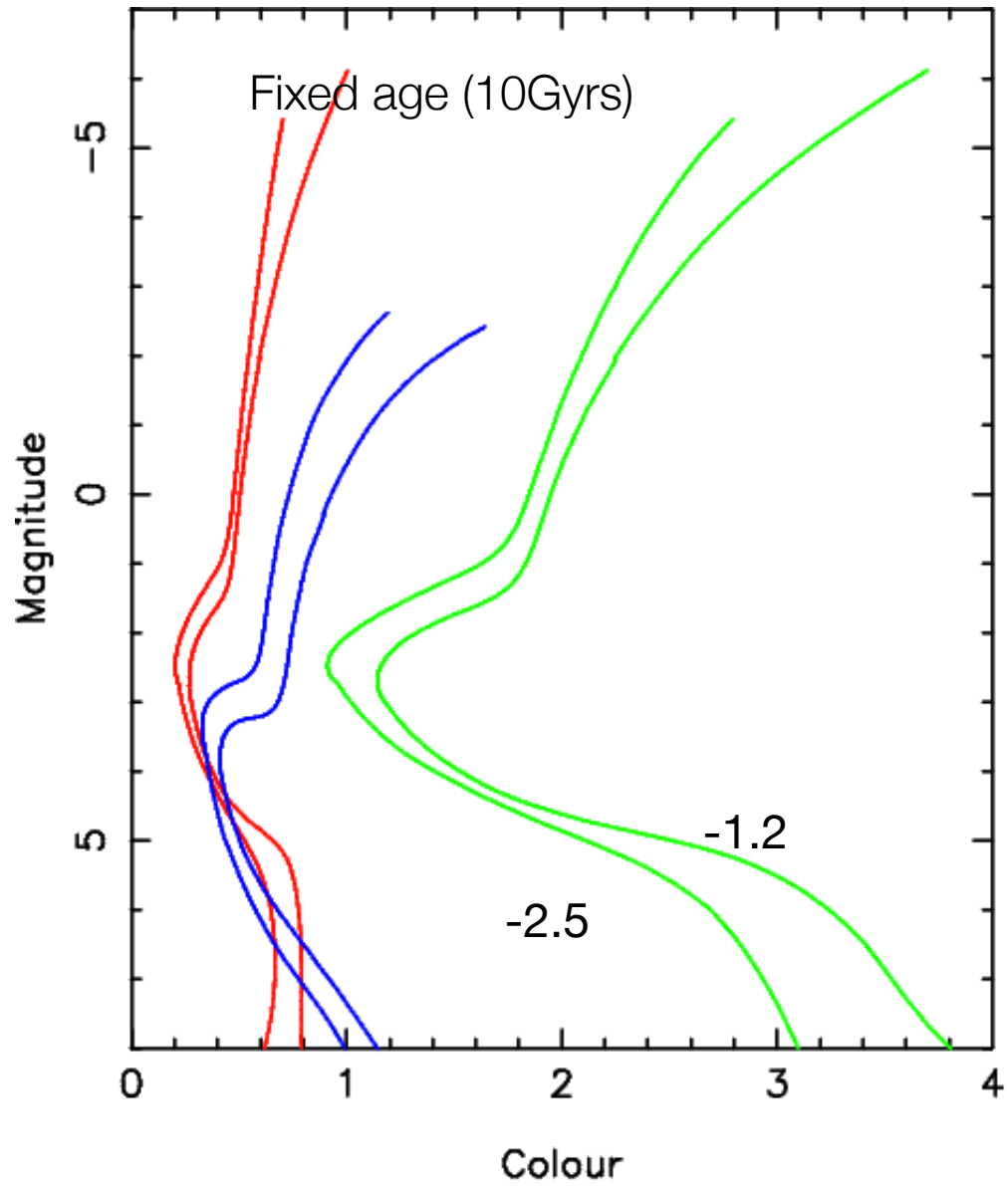
  - e.g. Resolved imaging + seeing-limited optical spectroscopy (“integrated light”) or IFS NIR spectroscopy ?? (very intriguing simultaneous imaging +spectroscopy in IRIS)

Near IR considerations



Near IR considerations

- Optical is information rich for stars (peak of SED, large number of transitions at blue wavelengths)
- Optical + NIR bands give excellent temperature sensitivity



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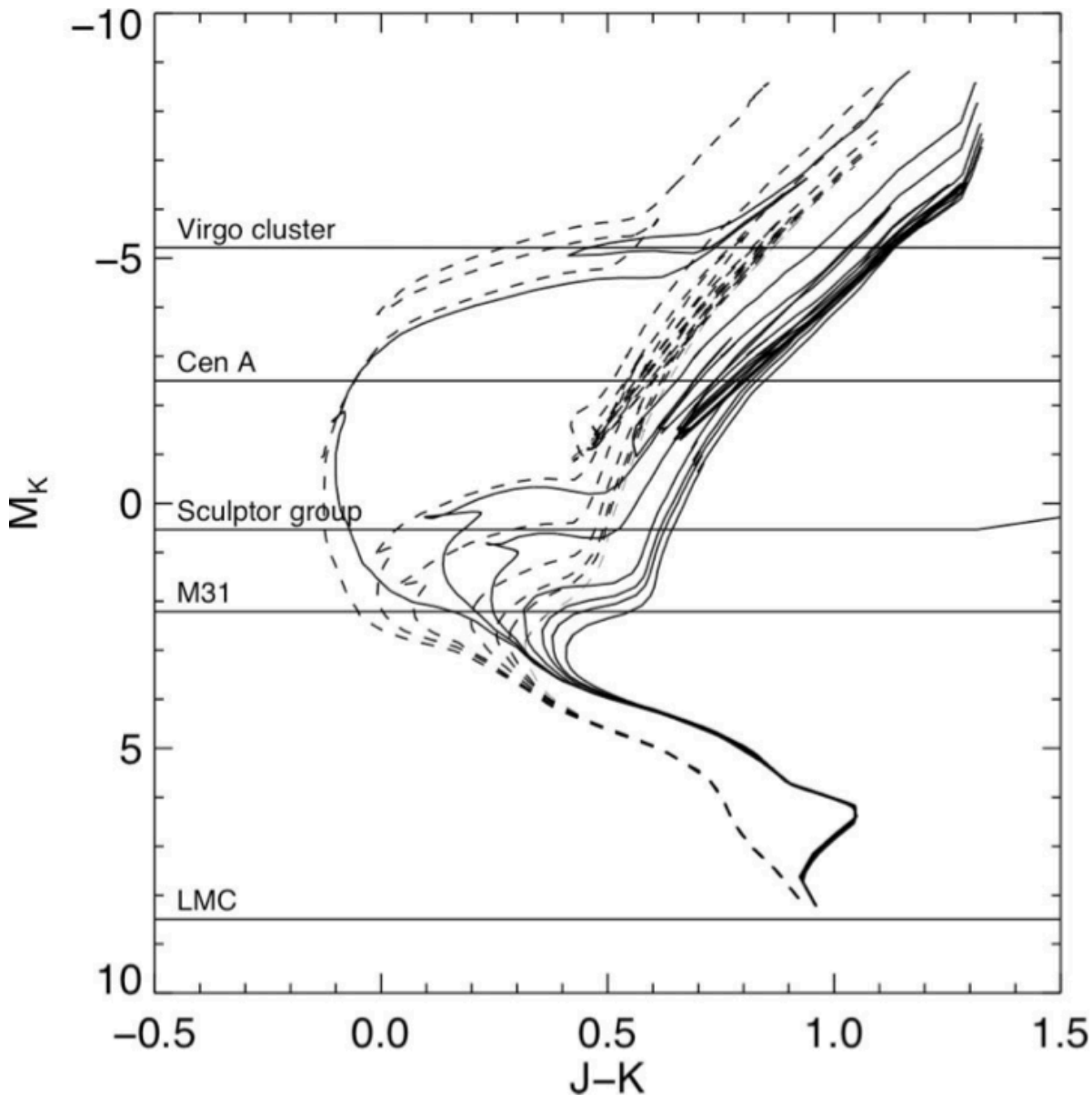
  - **Empirical: can we calibrate AGB stars? (difficult since few single stellar pops with AGB stars e.g. Galactic globular clusters)**



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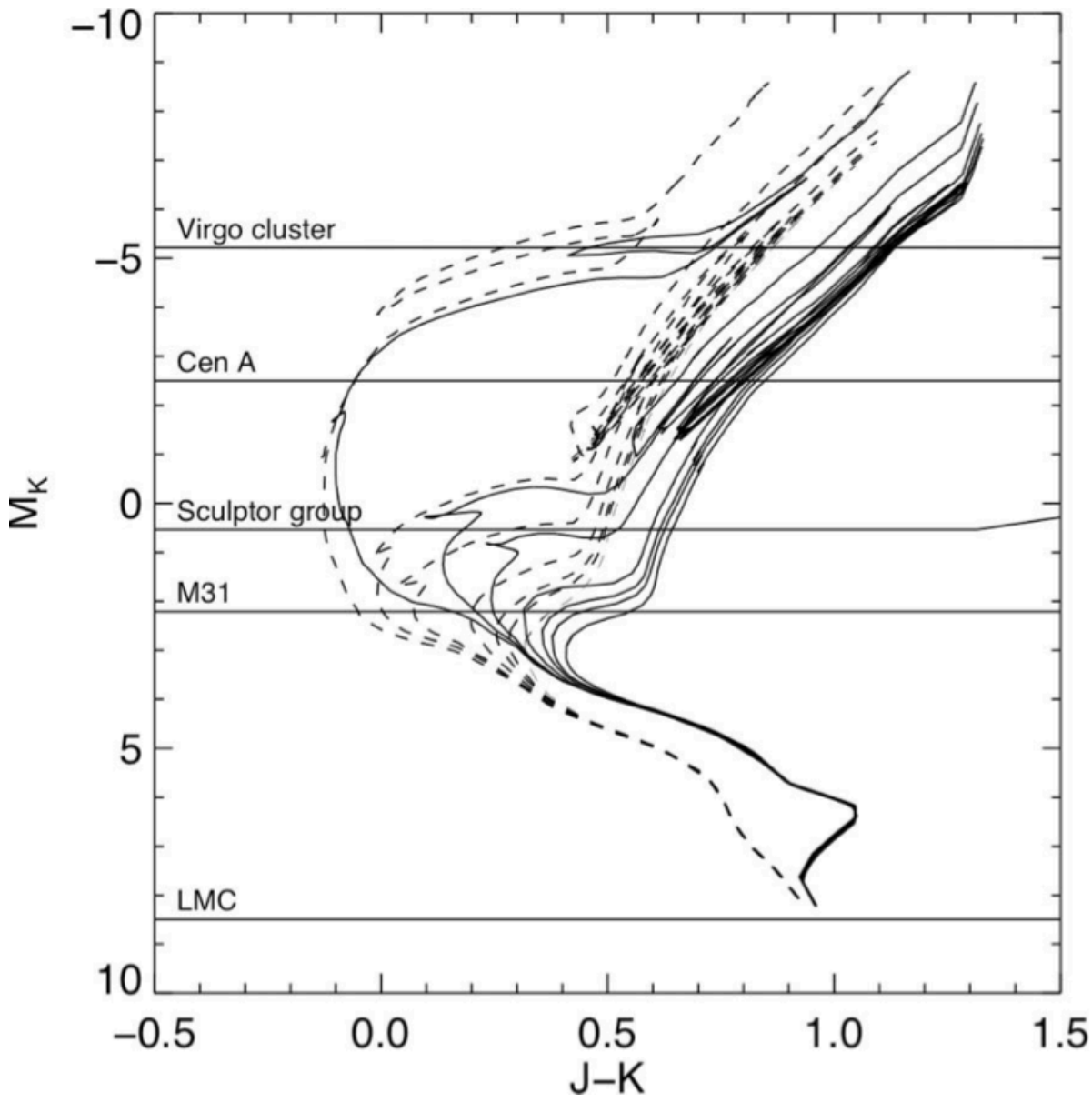
- How well tested are stellar population models in the near IR? (color-temp relations as well as stellar evolution)



NIR stellar pops with MCAO

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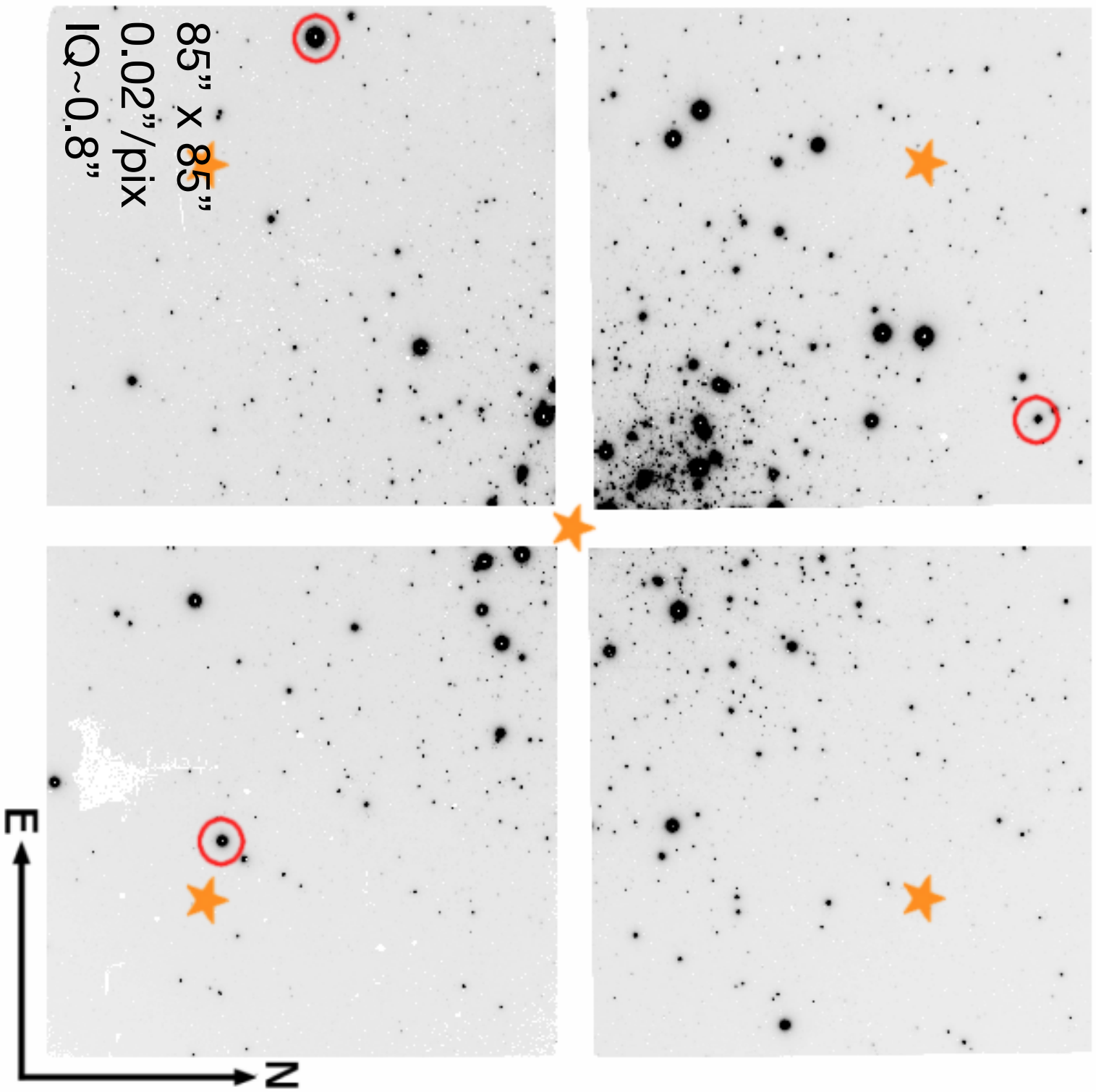
- 1/2 dozen different Galactic GCs
  - J, Ks filters
  - 960s per filter, split into dithered 6 x 160s exposures (although more for NGC1851)
  - Right: J,Ks color composite of NGC1851 (also NGC6681, NGC6723, NGC5904, NGC6652, NGC2808)
  - **All targets have exquisite HST/ACS data**

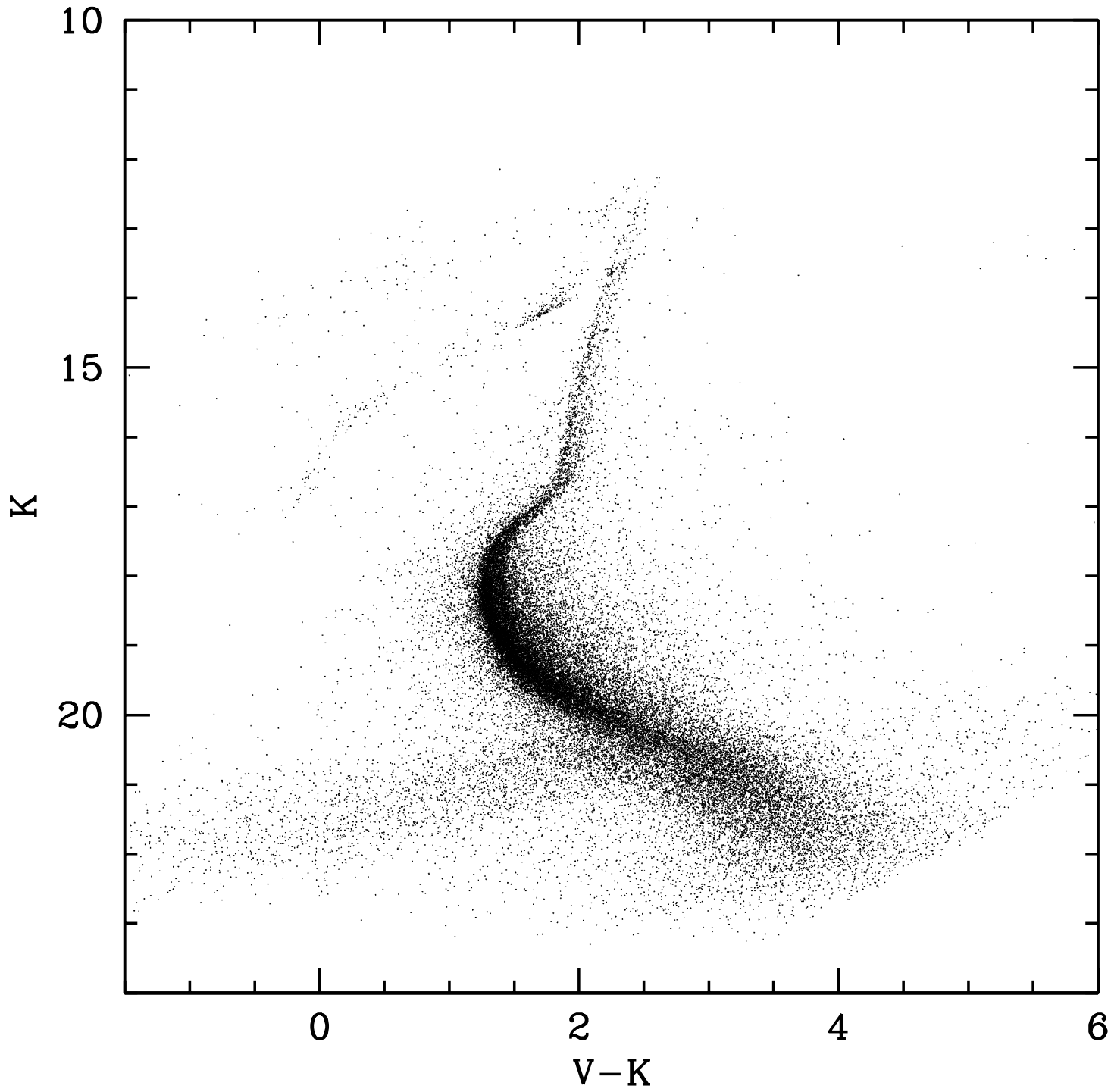
Single 160s sub-exposure on NGC1851(D~12 kpc)



NGC1851

K vs V-K
(uncalibrated)

V from Sarajedini
HST/ACS GC
survey



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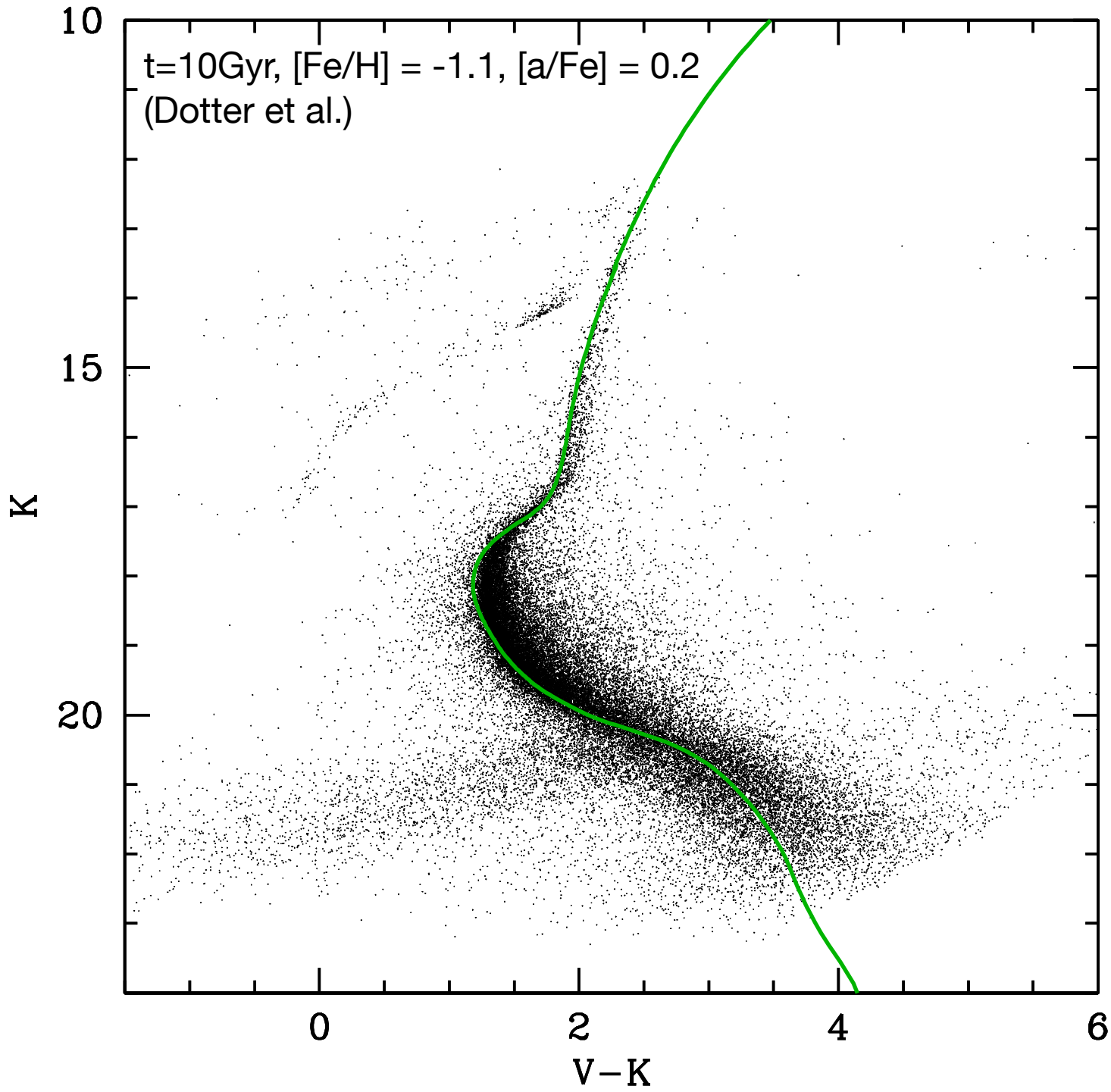

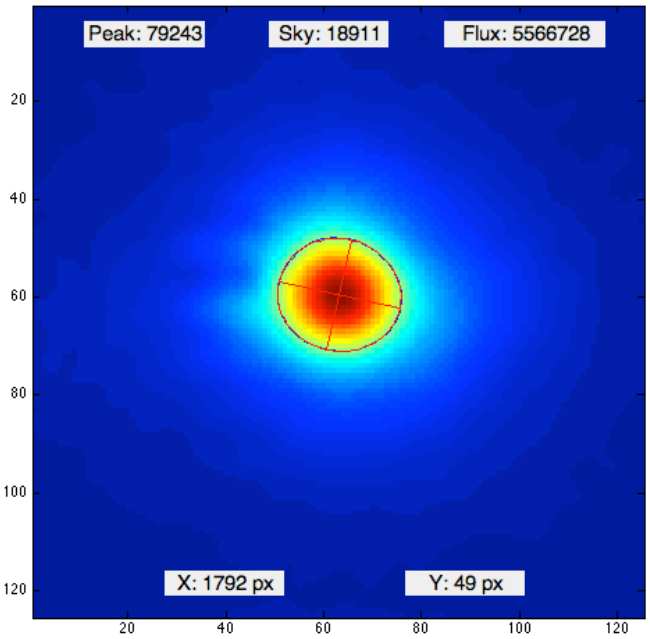
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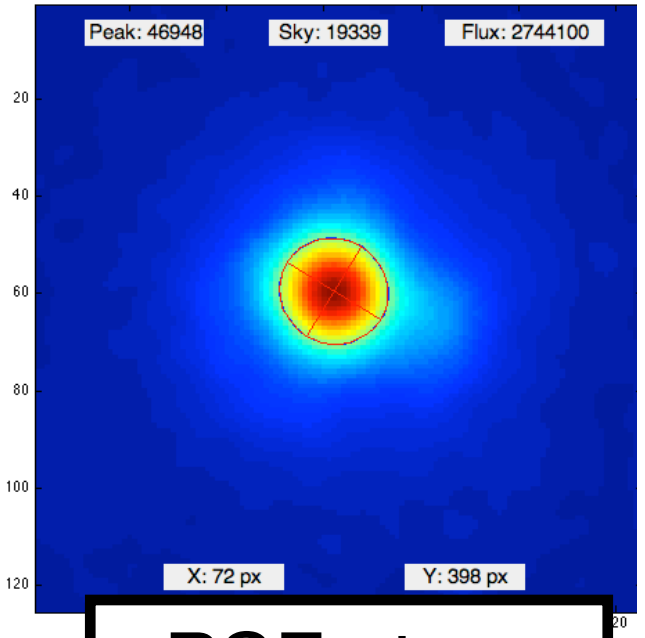
Y: 49 px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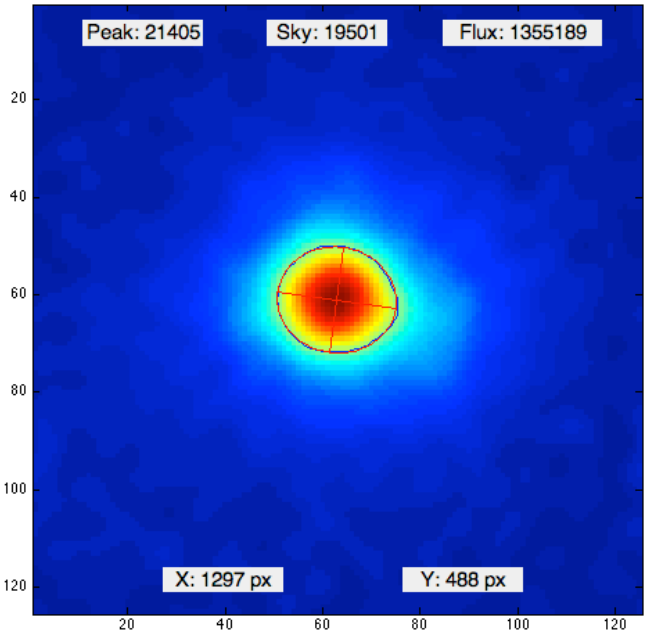
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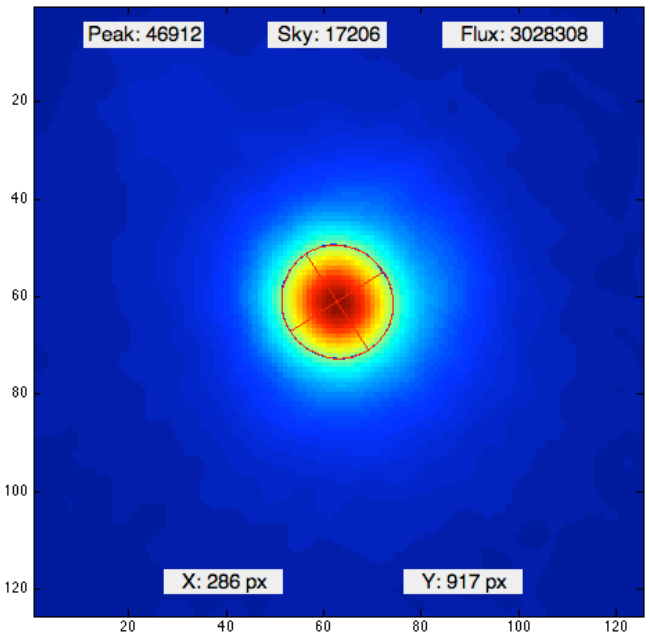
PSF stars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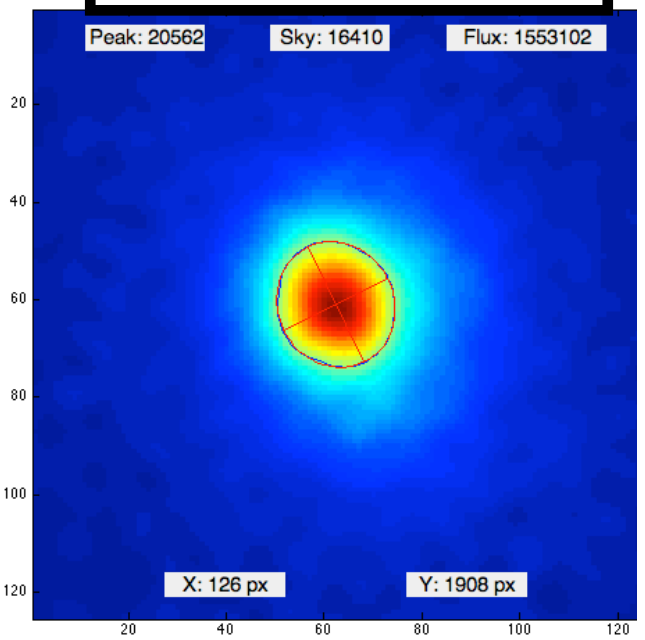
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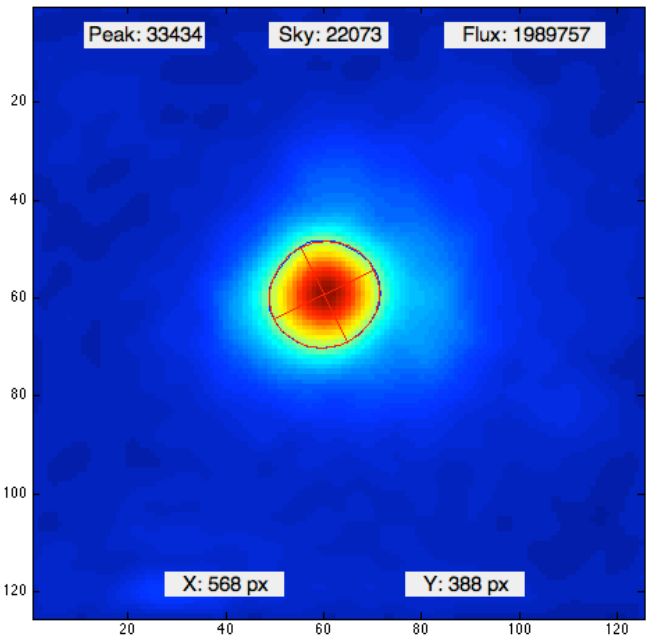
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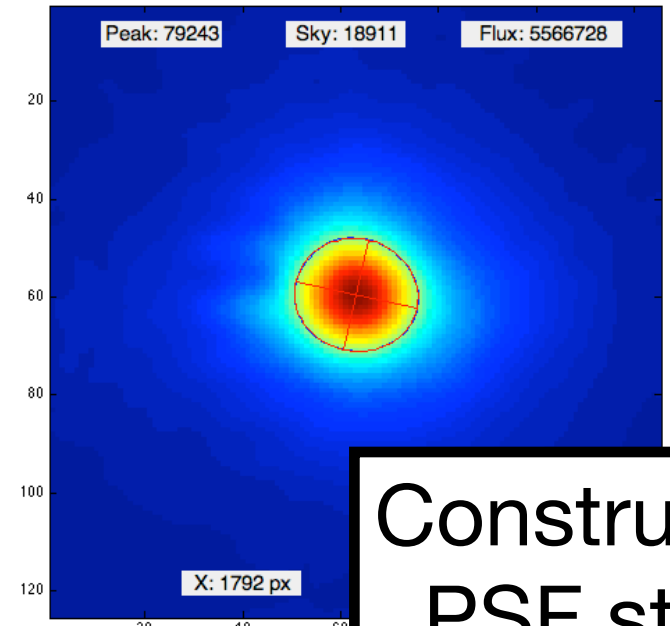
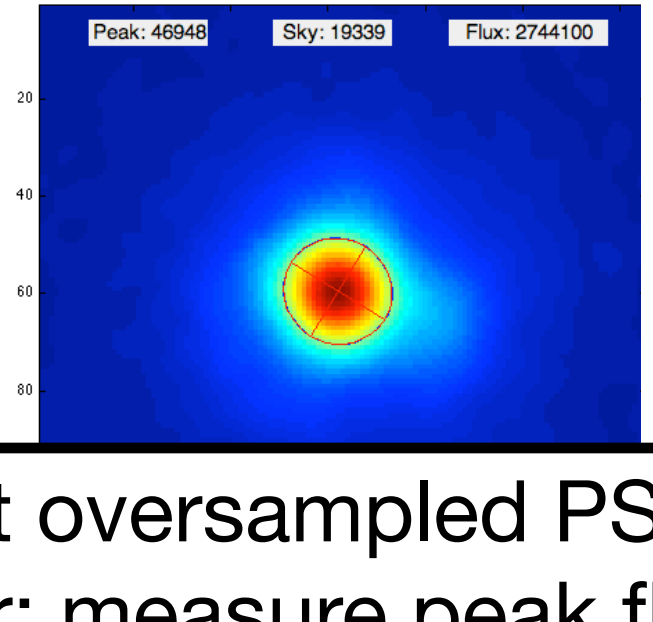
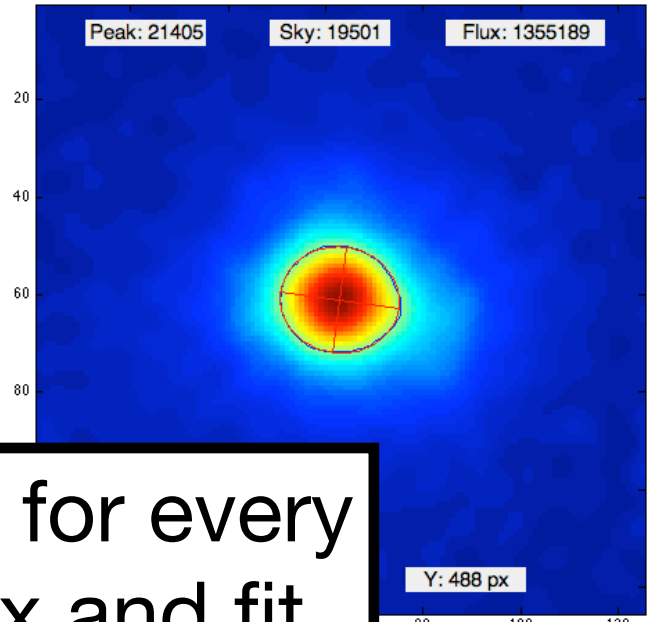
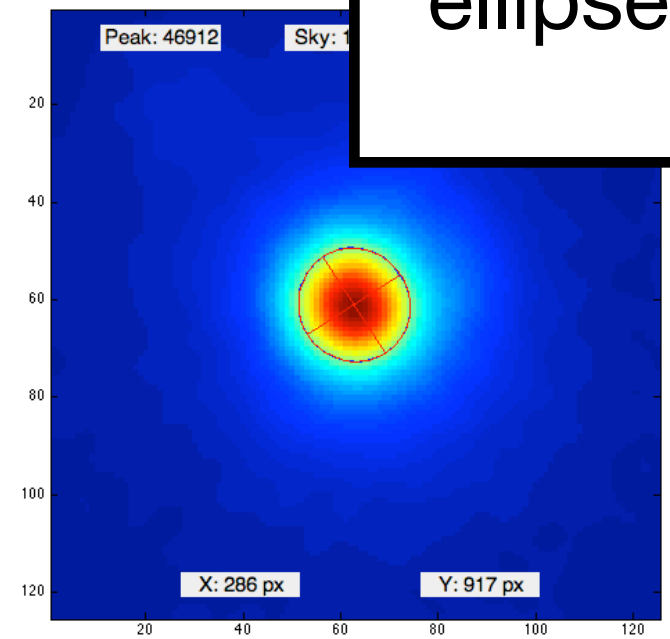
X: 568 px
Y: 388 px

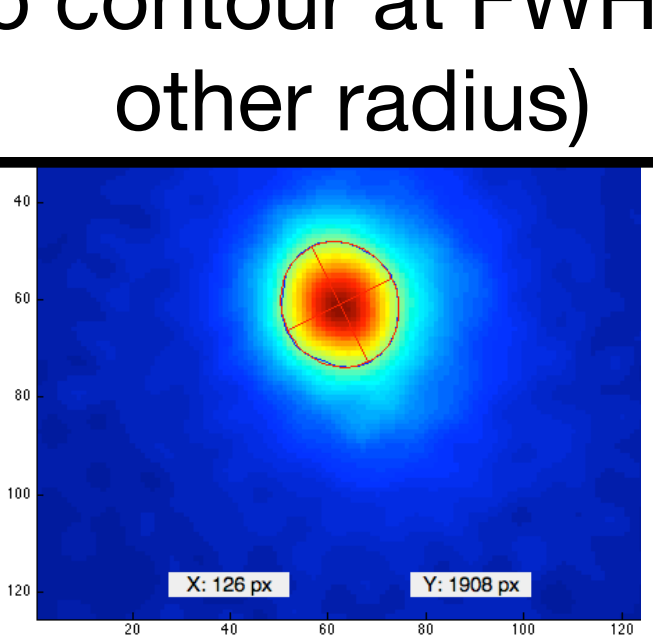


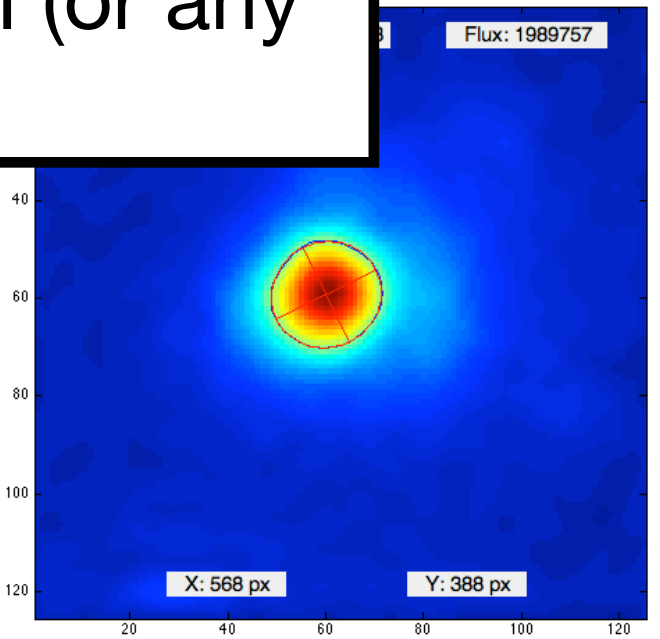




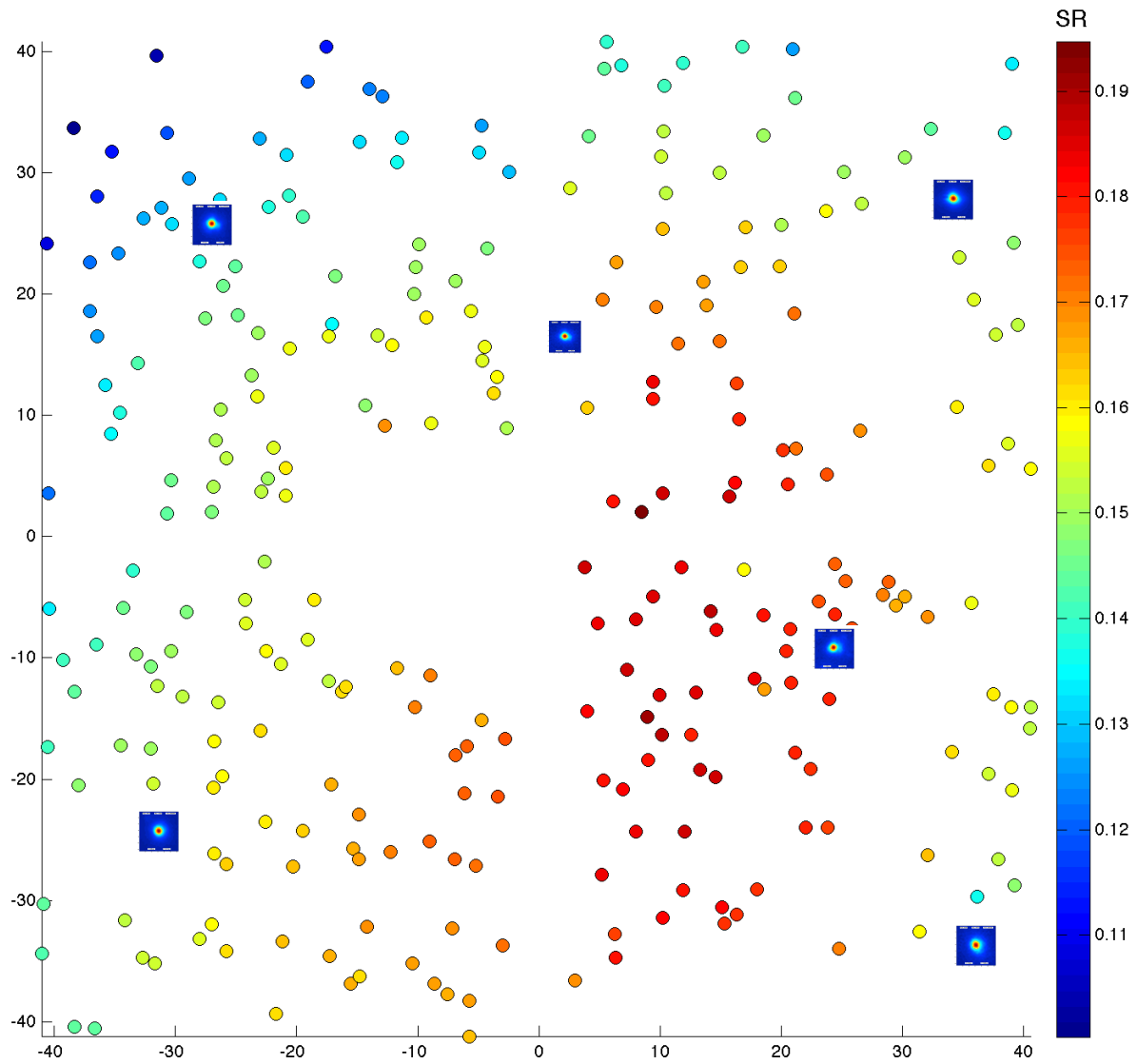
Construct oversampled PSF for every PSF star; measure peak flux and fit ellipse to contour at FWHM (or any other radius)







Distribution of PSF stars



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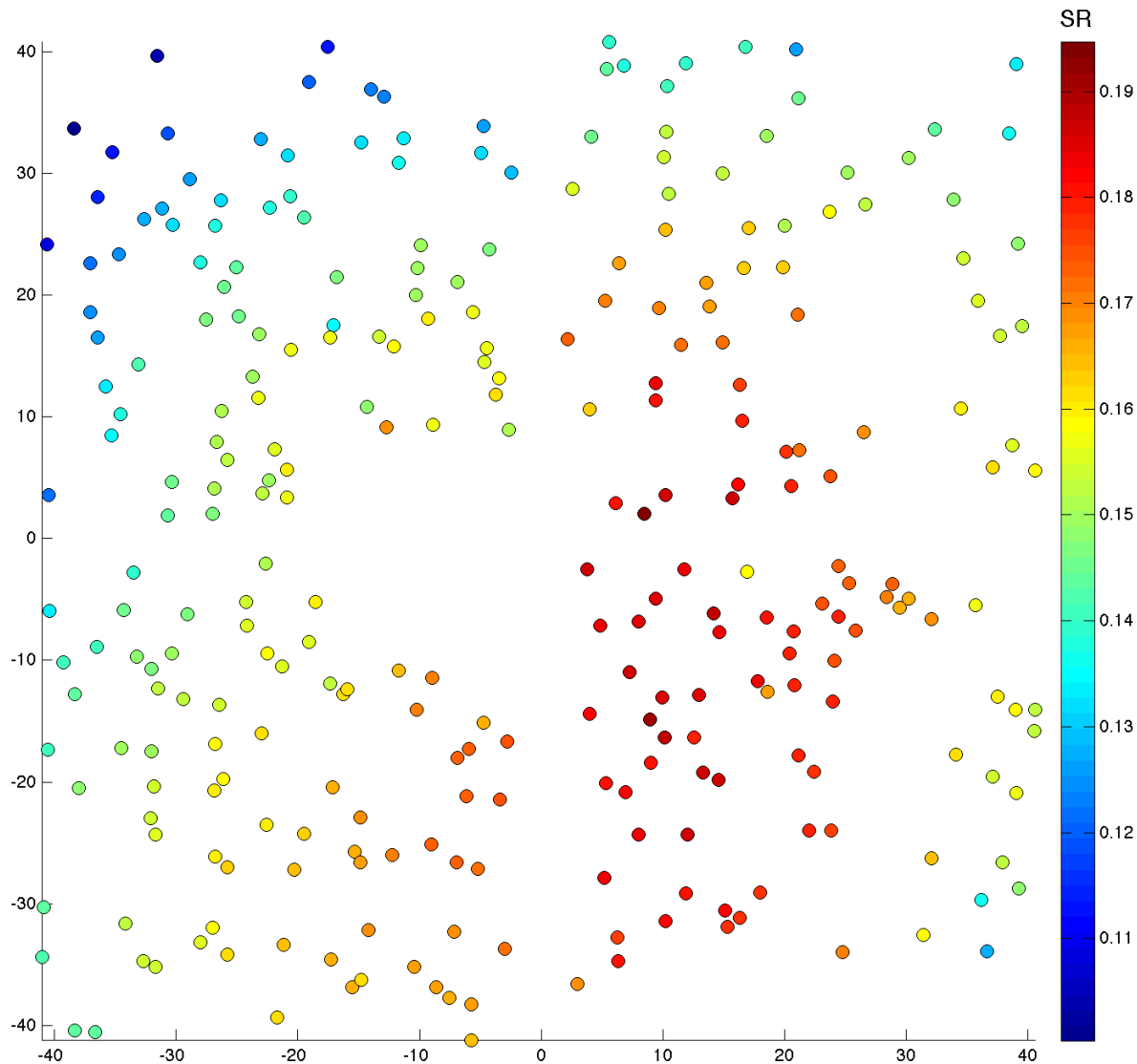
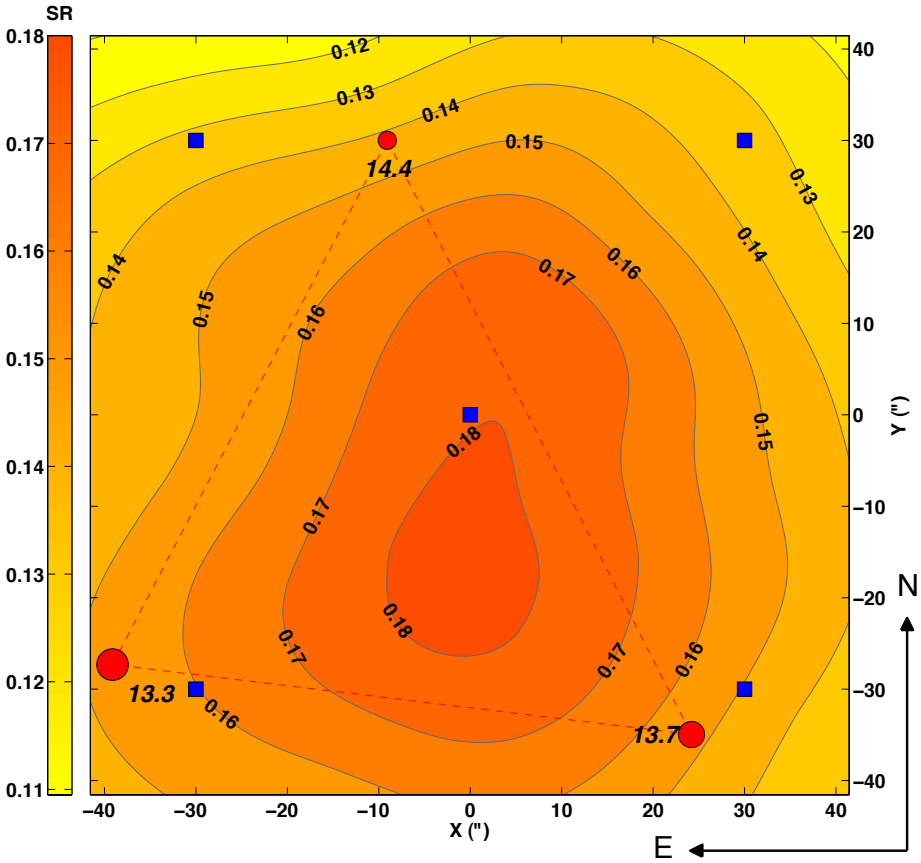
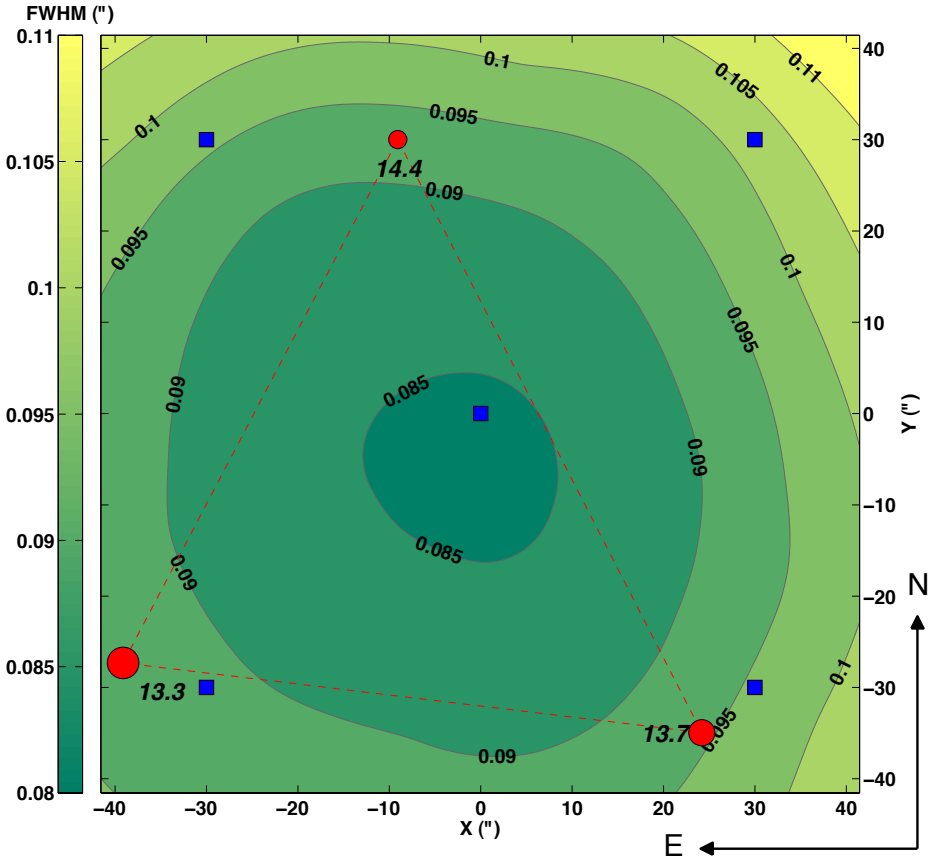




Strehl

0.18 (peak)

Minimum within NGS asterism



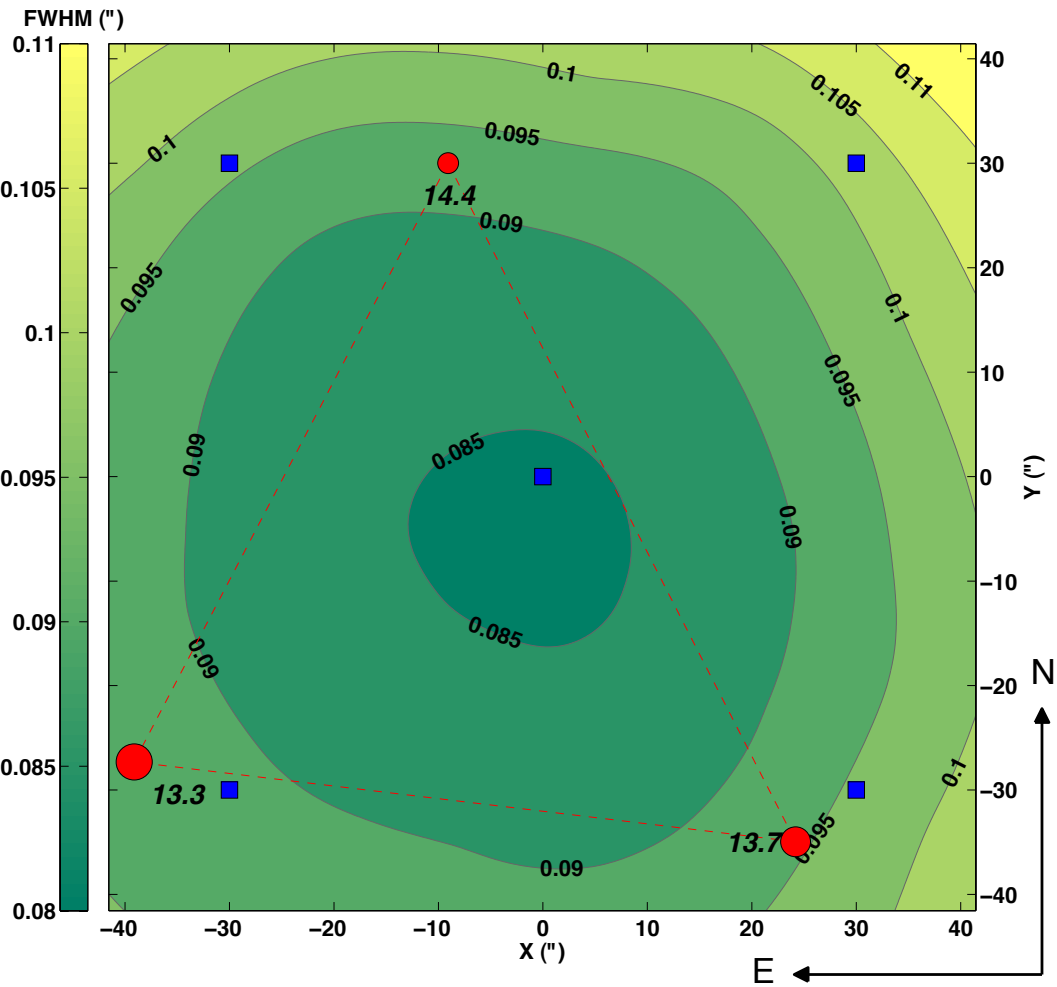
FWHM

~0.09”

Minimum within NGS asterism

Variation in time

dt = 0 minutes



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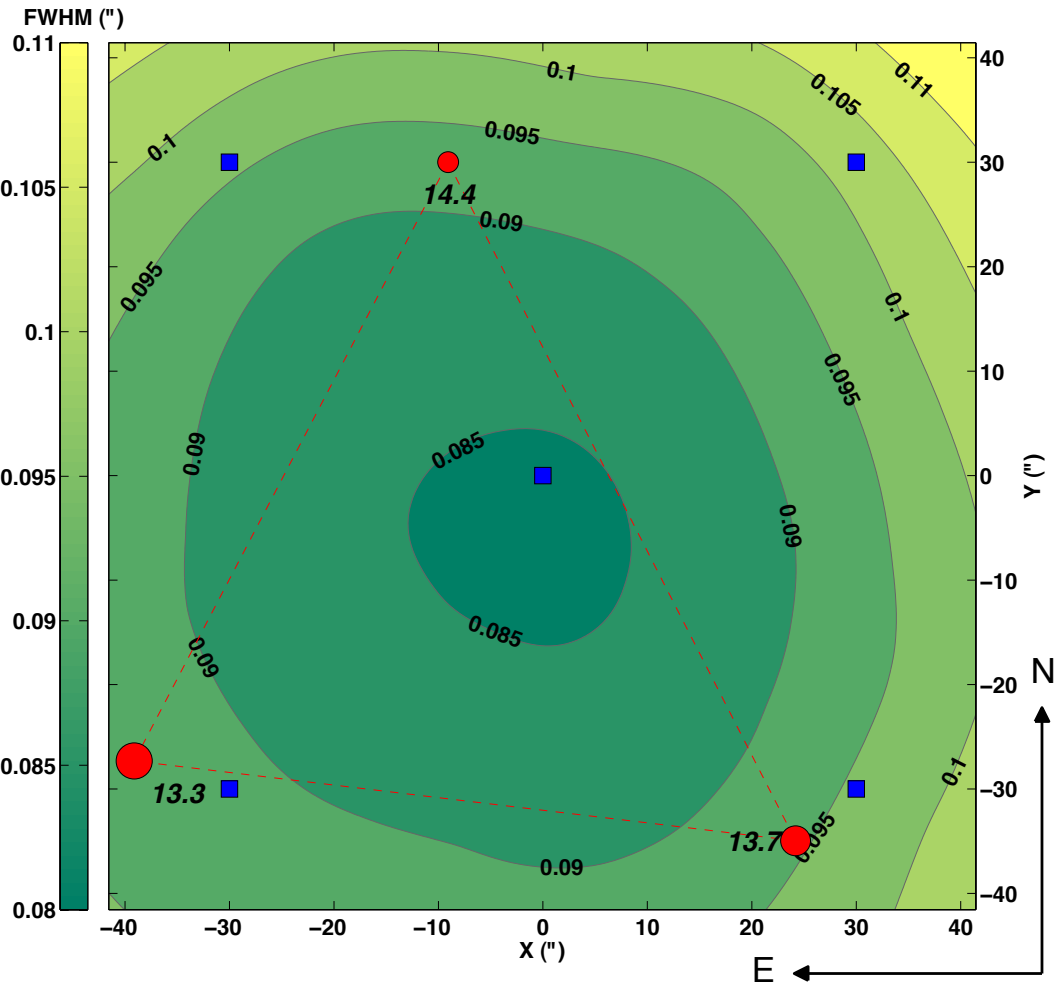
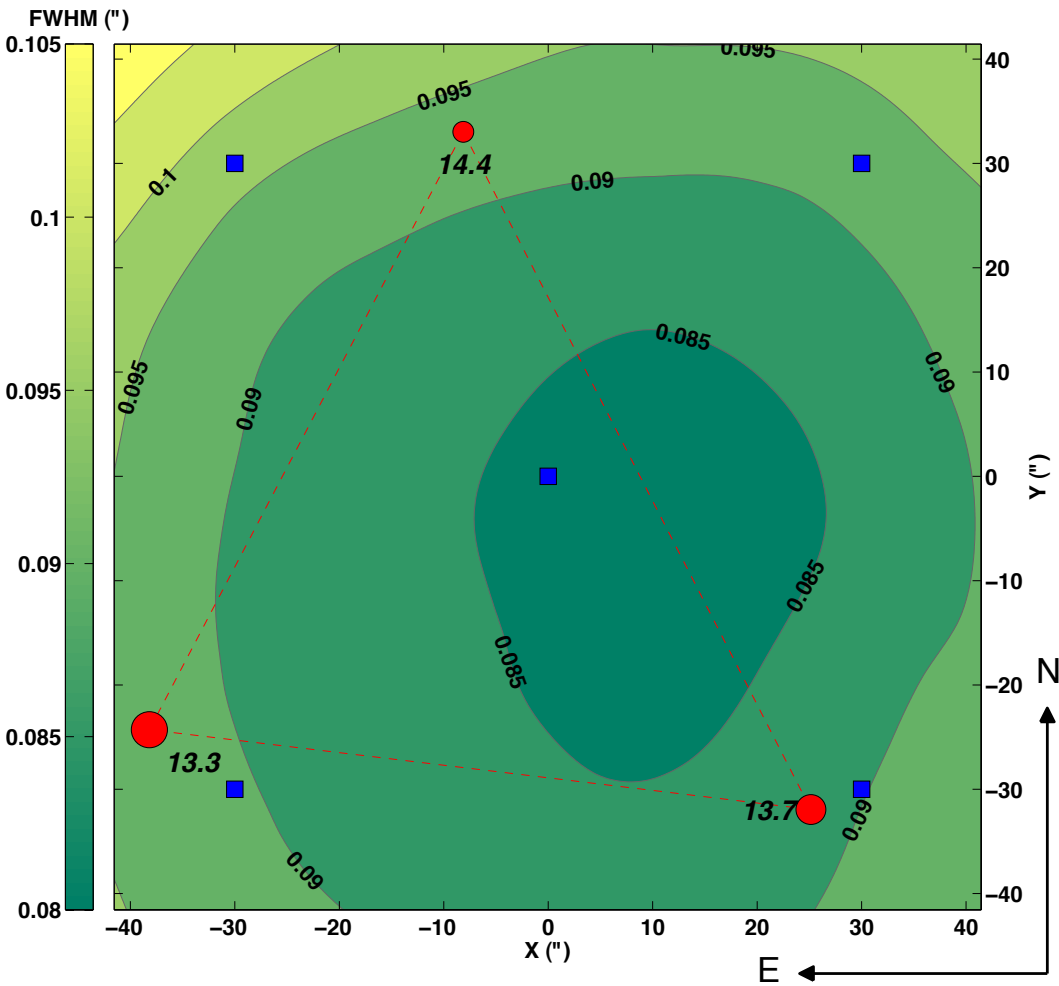
dt = 0 minutes



dt = 9 minutes



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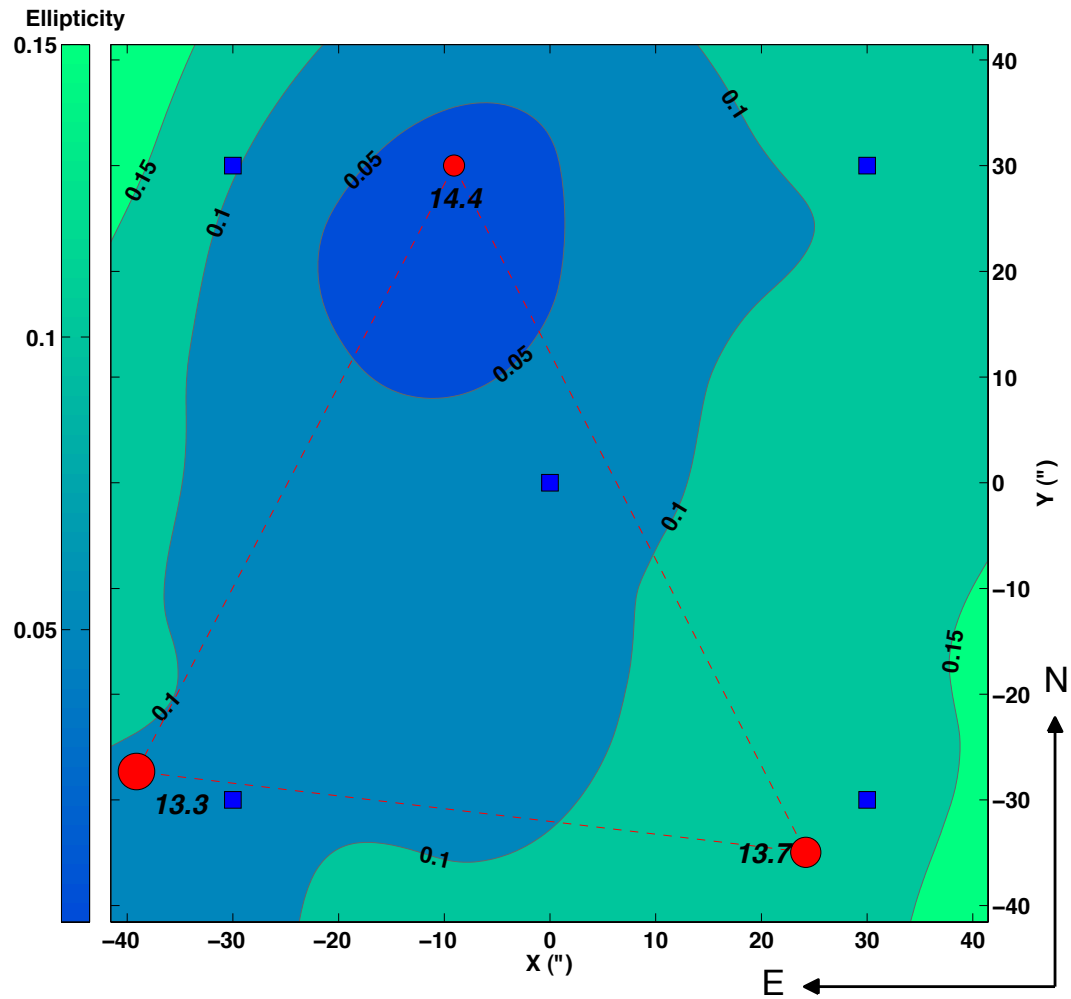
dt = 0 minutes



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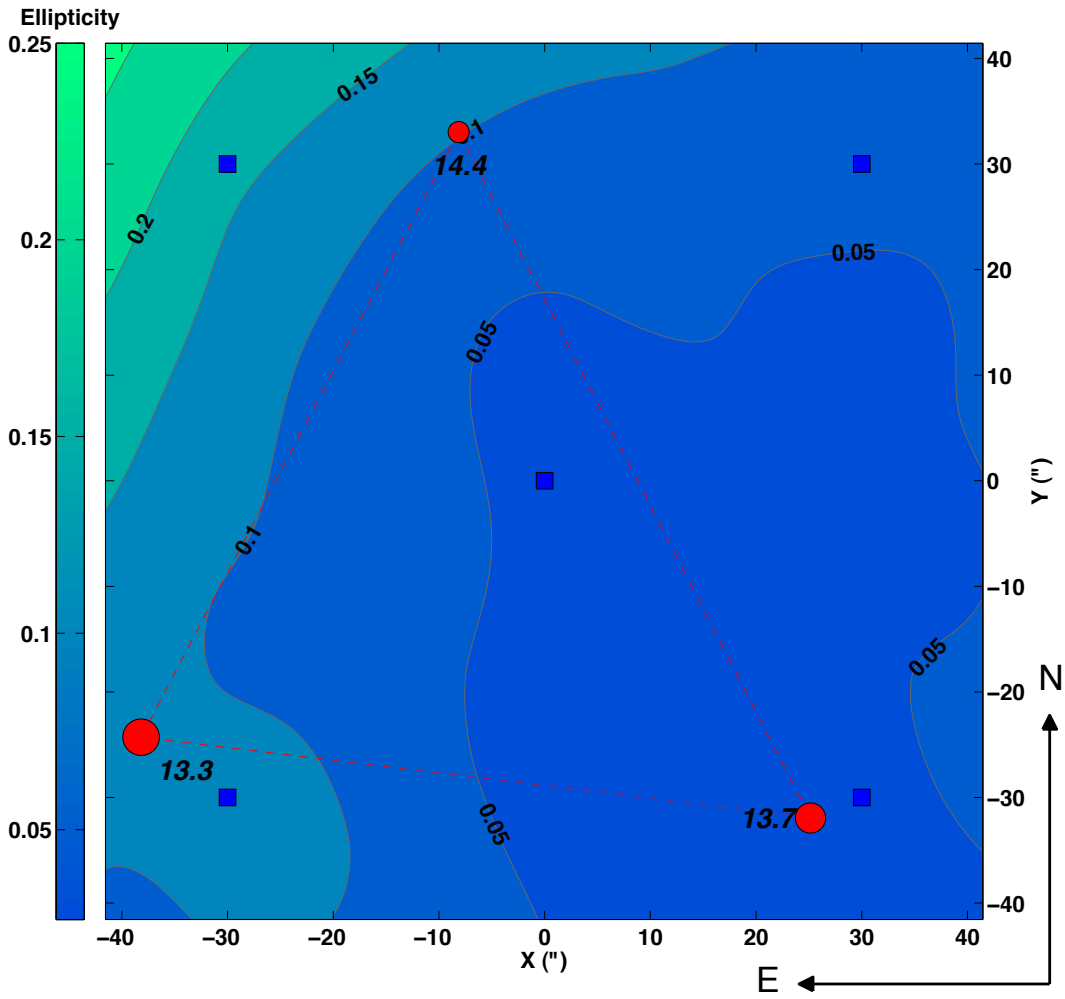

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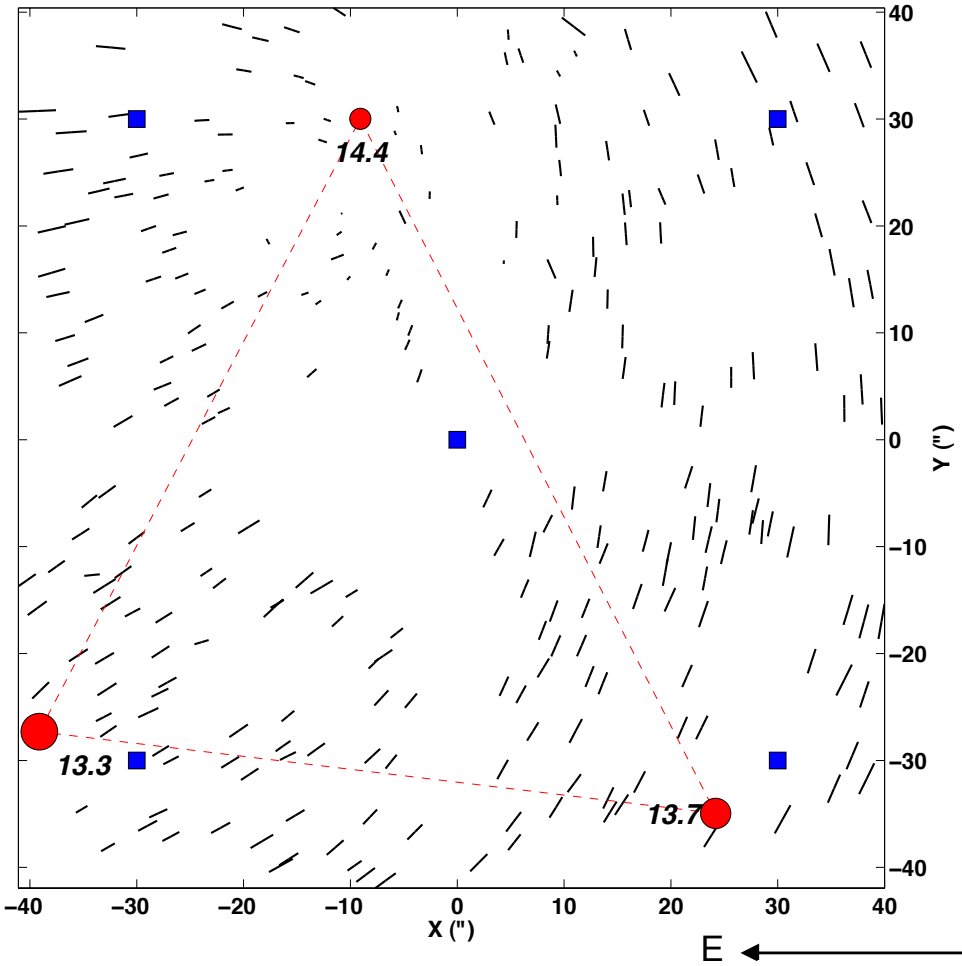

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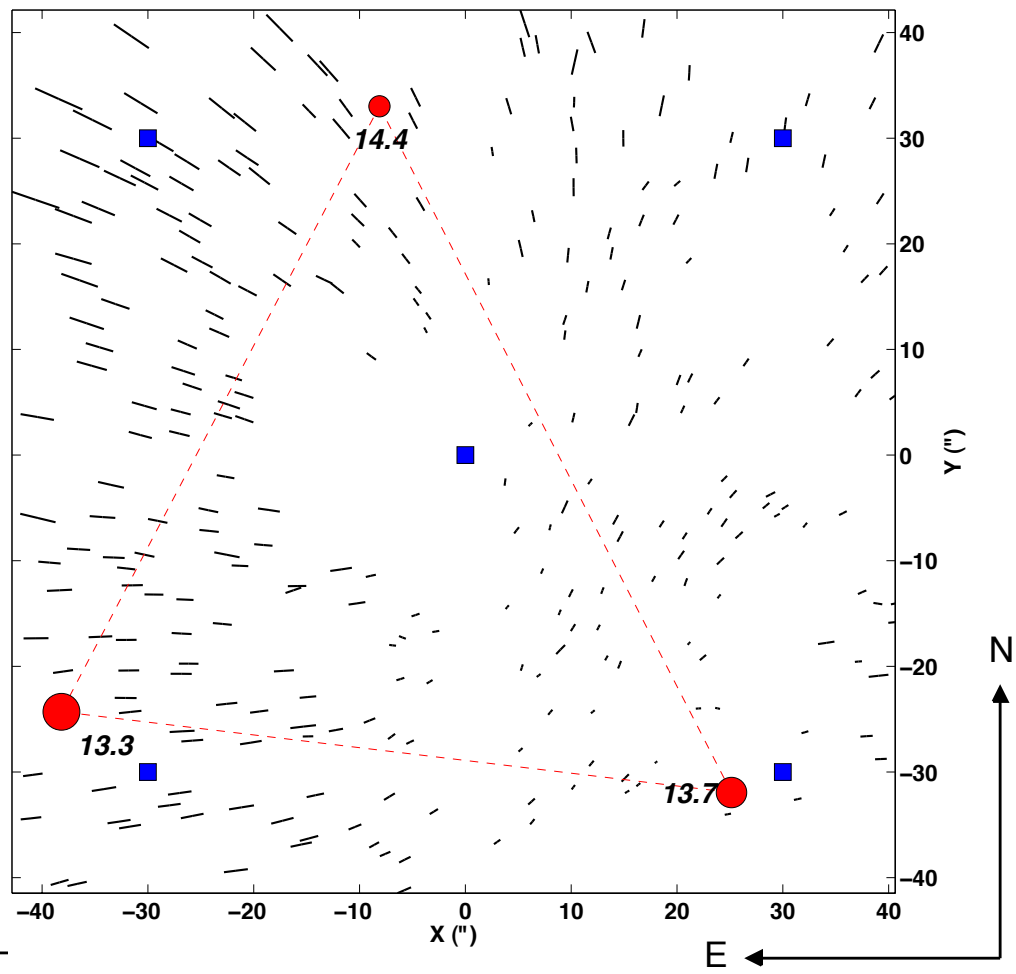

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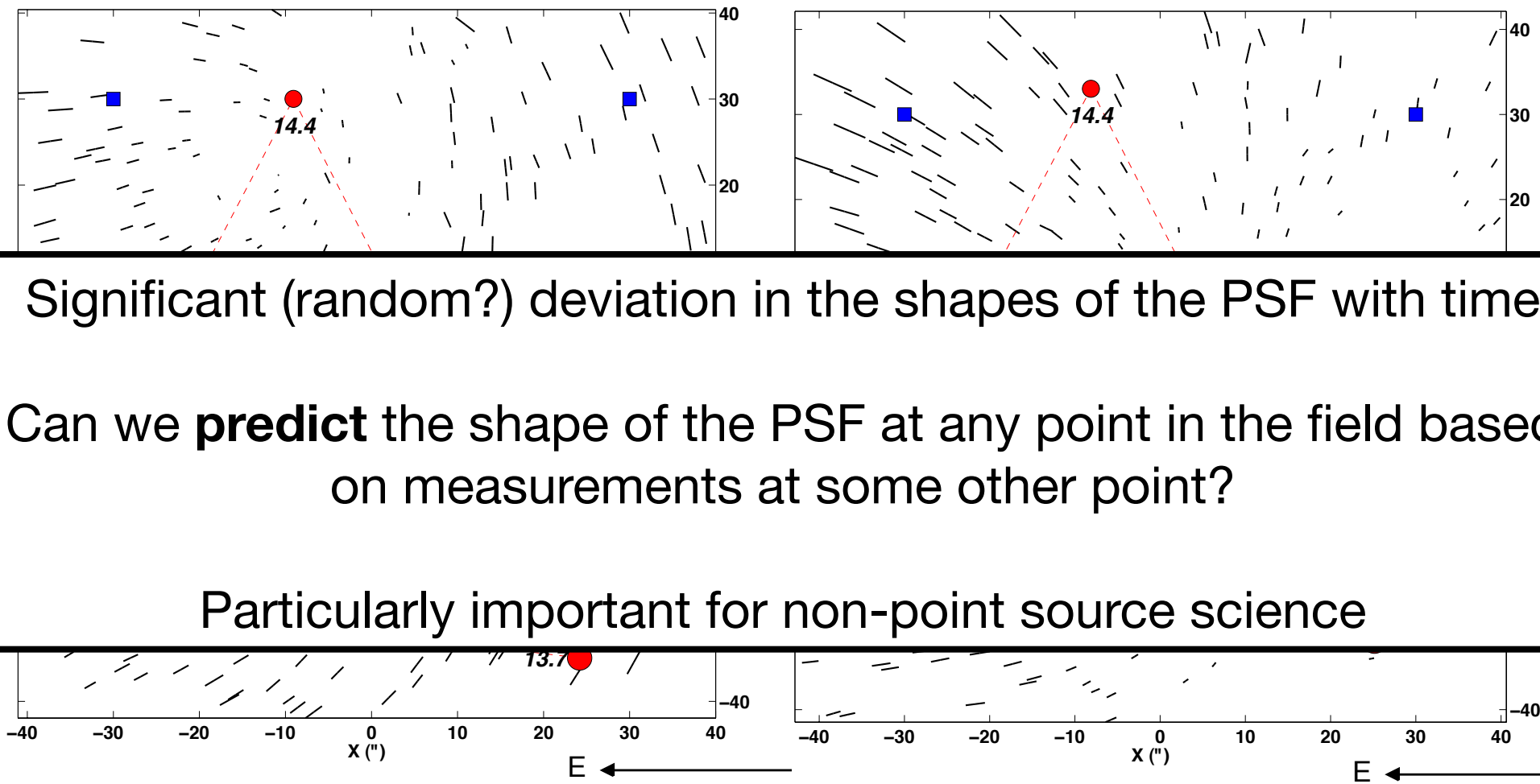

Significant (random?) deviation in the shapes of the PSF with time

Can we **predict** the shape of the PSF at any point in the field based on measurements at some other point?

Particularly important for non-point source science

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- Astrometry:
  - Form of astrometric distortion and its stability (ultimately, predictability) (using relative positions from HST/ACS as “truth”)
  - ultimately limits astrometric accuracy e.g., for proper motions of nearby galaxies; internal dynamics of dwarf galaxies

III Facility Context

- TMT will be the Jewel in the Crown of the OIR astronomical network of the 2020+
- How do we use TMT in this context?

Wide fields and TMT

NGC3379, E galaxy @ 11Mpc

Name	r (arcsec)	Σ_K (mag arcsec^{-2})	K_{lim}	Time (secs)	
R_e	30	17.0	25.7	282	**AGB**
$3R_e$	90	19.3	28.5	47200	**HB**
R_{tot}	190	22.5	31.6	∞	
K (1 hour)	—	—	27.9	3600	

Wide fields and TMT

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For deep imaging, IRIS FoV is ~16 x 16 arcsecs (34” x 34”?)

- cf. modal size of (early-type) galaxies in Virgo (Sersic r~5-40”; Ferrarese et al. 2012)
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- How do we decide where to put fields? **Essential** for interpretation
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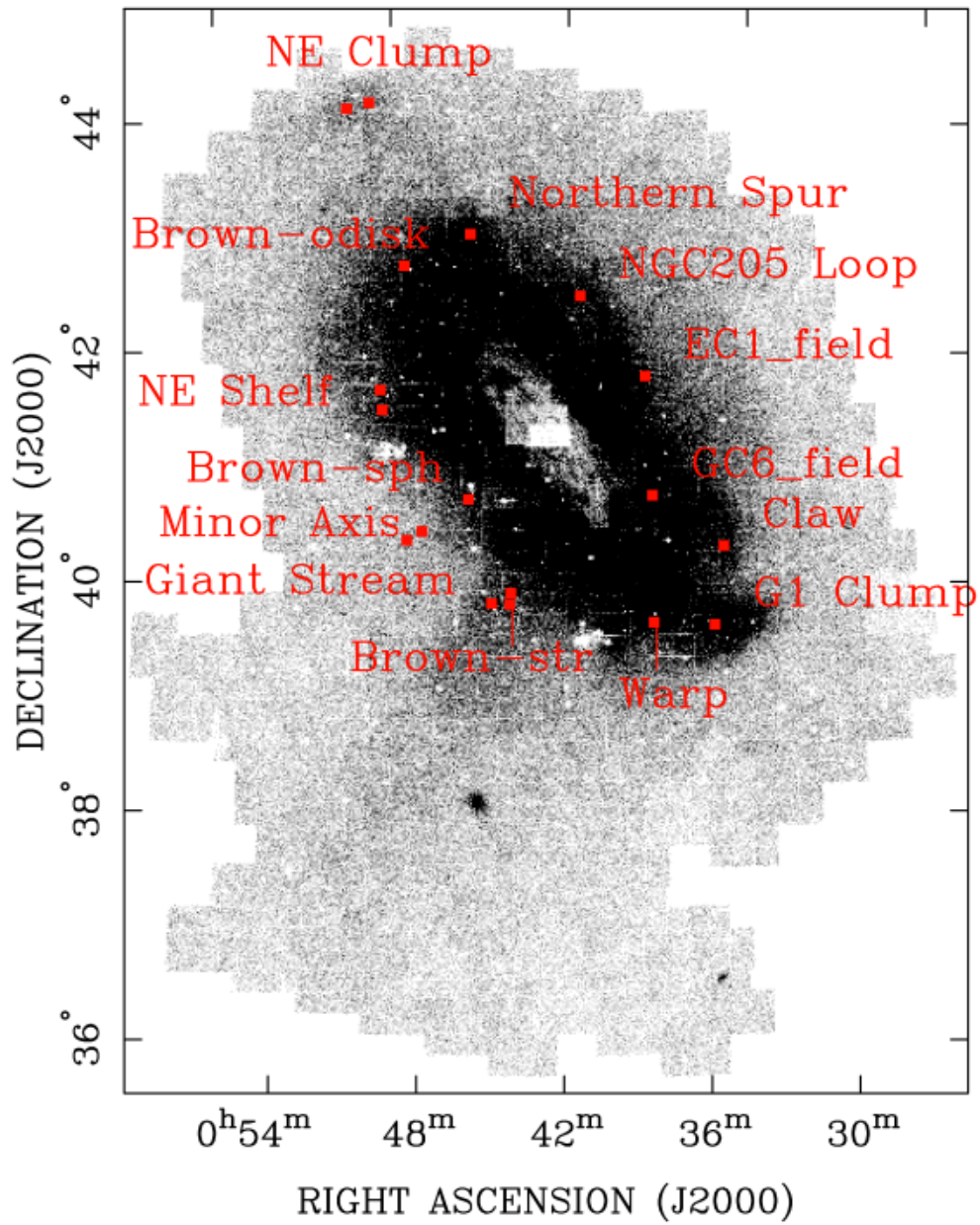

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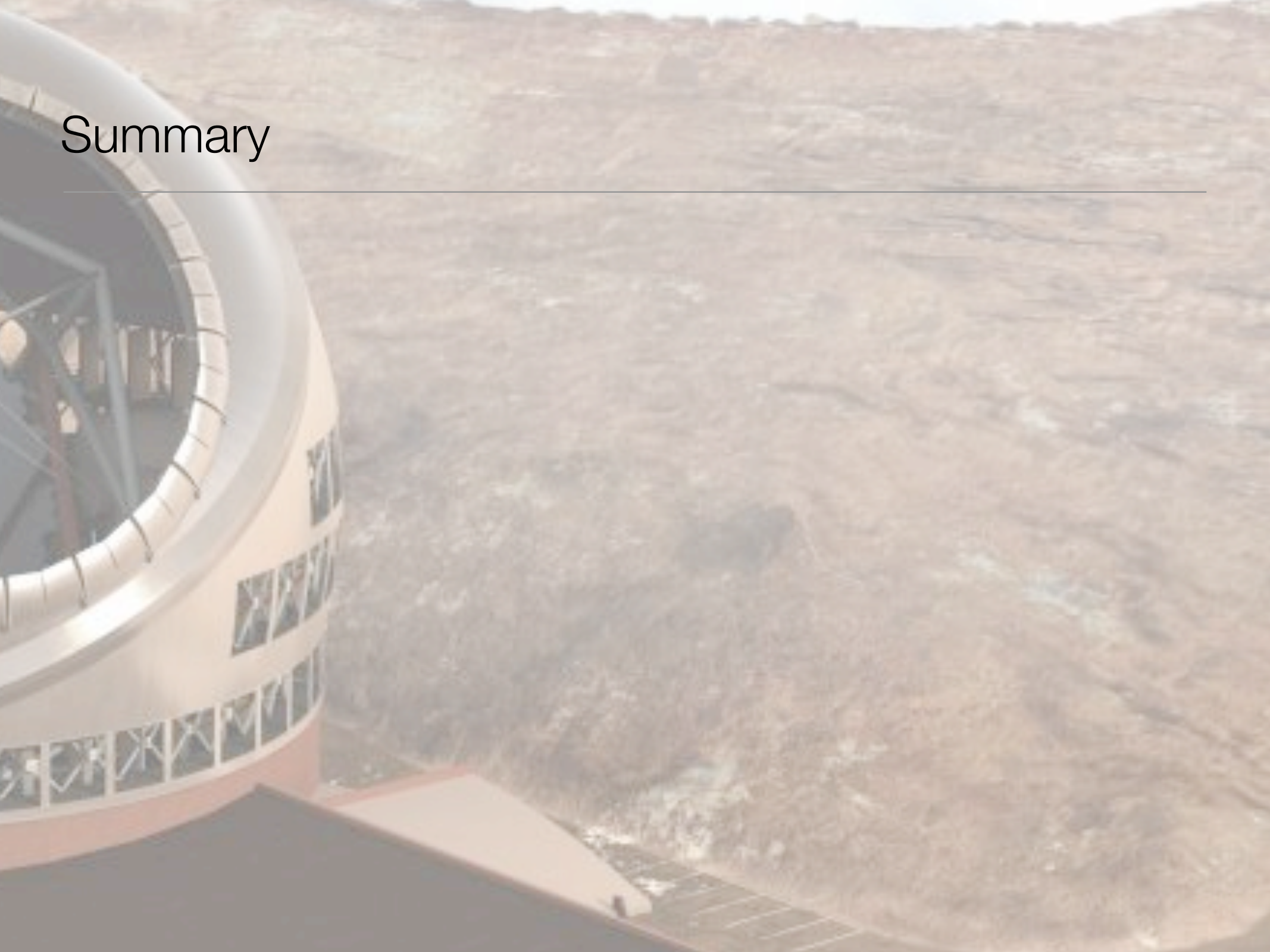
- Wide-field IR studies of local volume galaxies clearly useful to compliment narrower field of TMT
  - 4m-class IR facilities e.g. UKIRT
  - Space missions: Euclid, WFIRST, WISH
  - 8m-class MCAO, GLAO (Gemini/GeMS, LBT, rumors of Subaru GLAO...)

Summary



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Programs

- How best to use TMT *first-light instrumentation* suite for maximum science return?
- Observations are still very expensive; potential for development of key programs to best address most pressing science questions?
- Synergies with other facilities obvious and necessary