TMT Science Forum
Washington D.C, June 23 - 25 2015

Nearby Galaxies in the Near Future with TMT

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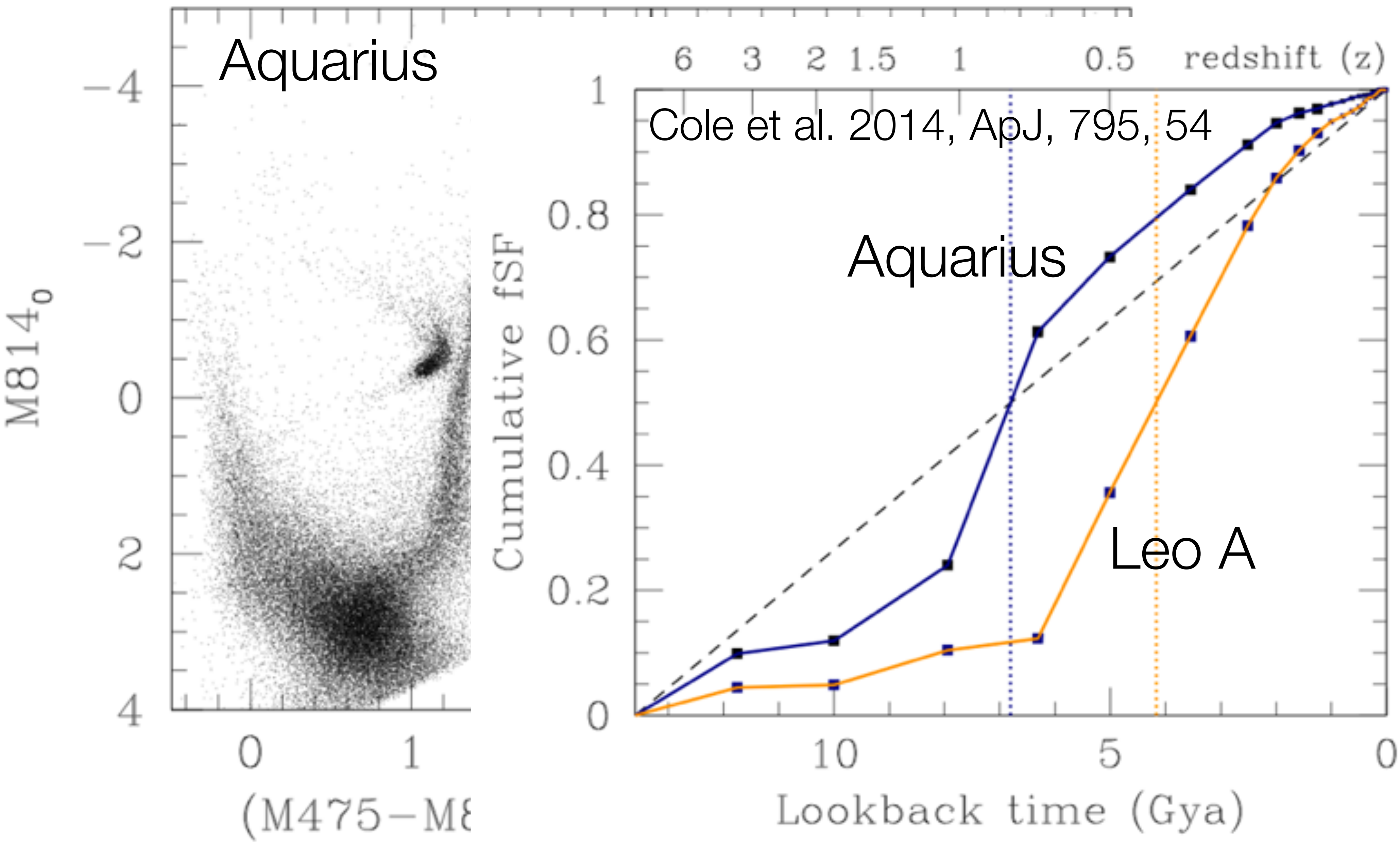
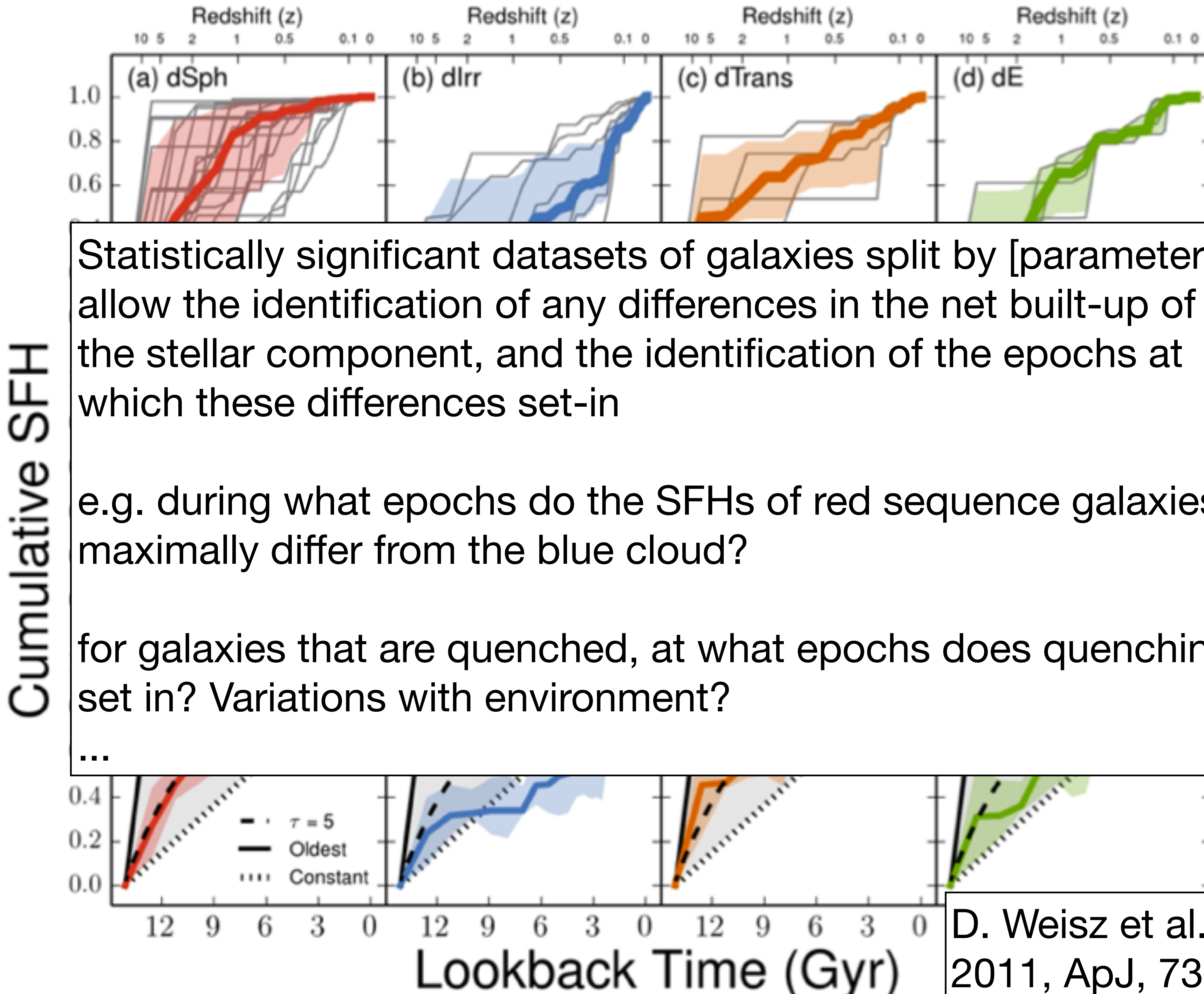
NRC Herzberg, Dominion Astrophysical Observatory

TMT and the Nearby Universe I: Systematically Decomposing Galaxies





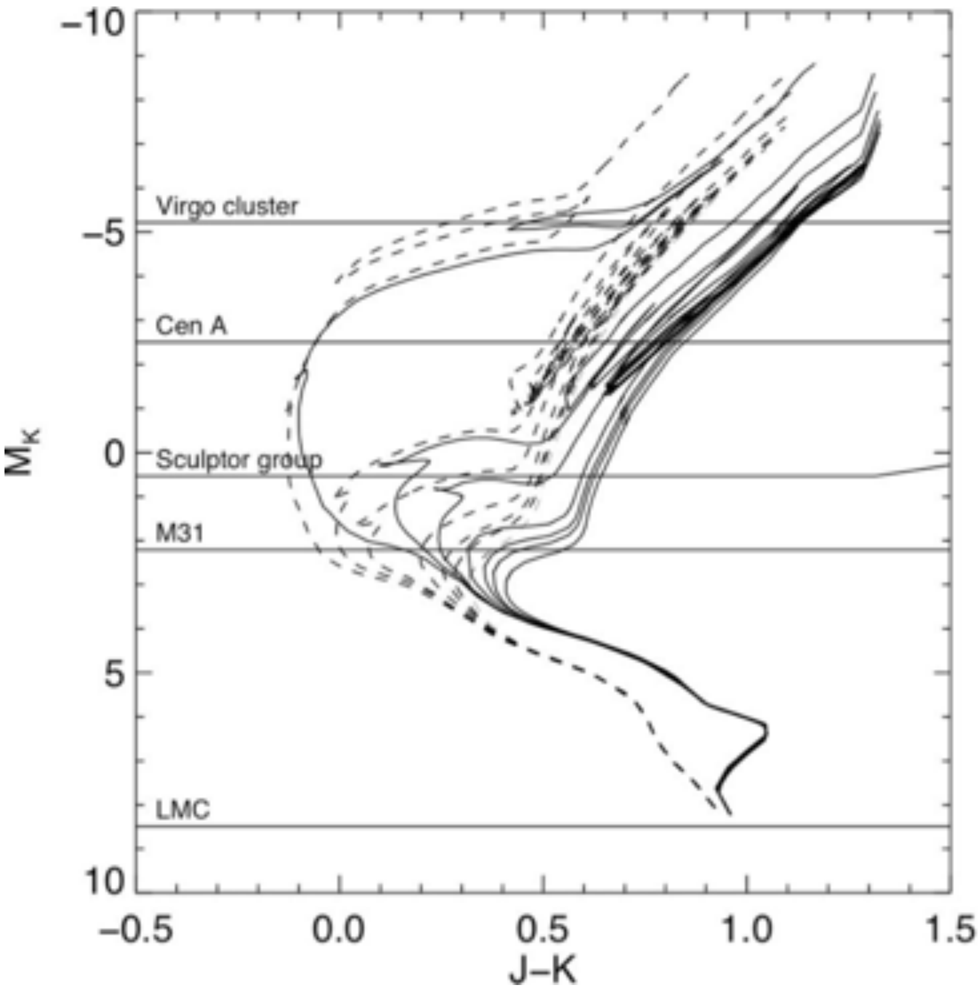
Statistically significant datasets of galaxies split by [parameter] allow the identification of any differences in the net built-up of the stellar component, and the identification of the epochs at which these differences set-in

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?

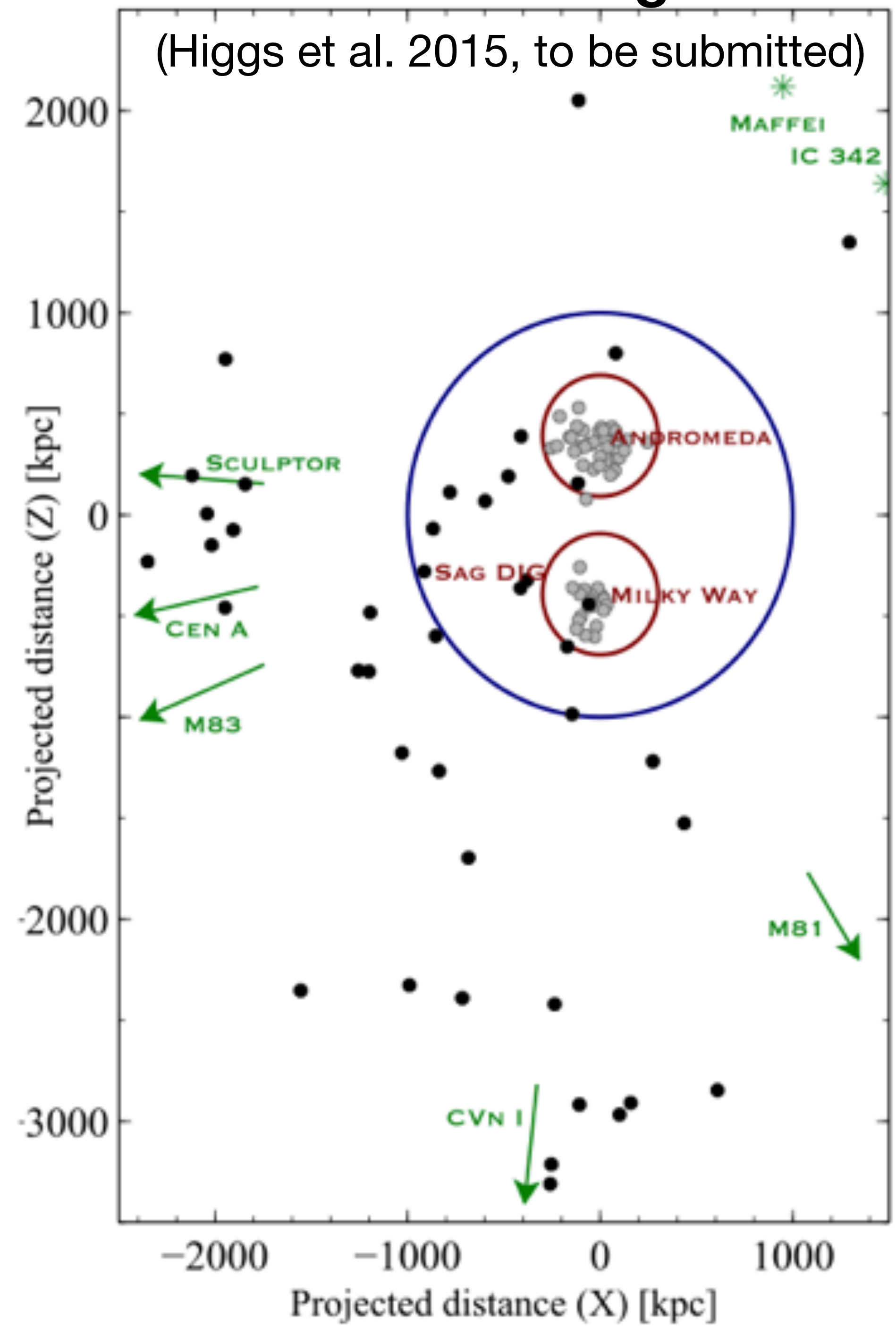
...

D. Weisz et al. 2011, ApJ, 739, 5



The ~100 closest galaxies

(Higgs et al. 2015, to be submitted)



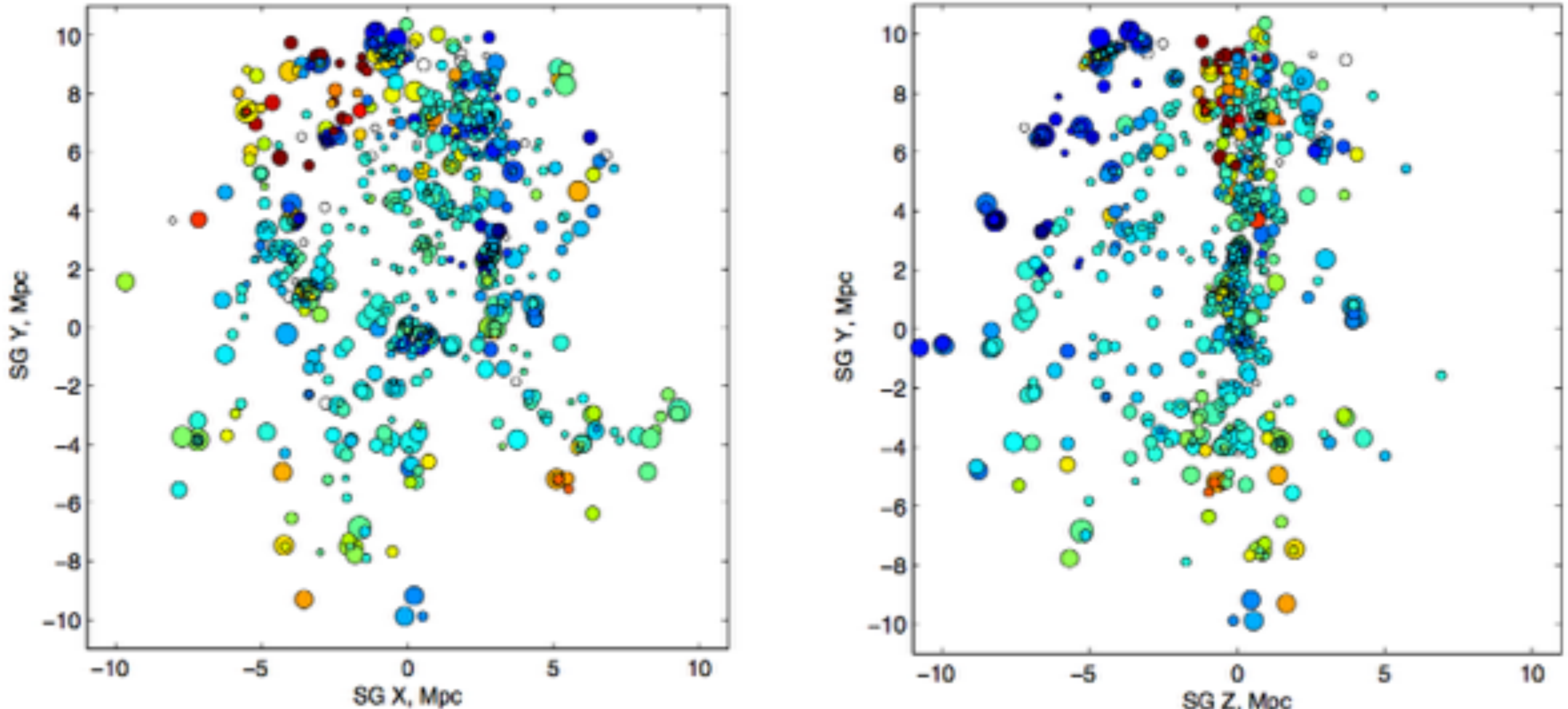
NGC3379, E galaxy @ 11Mpc

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

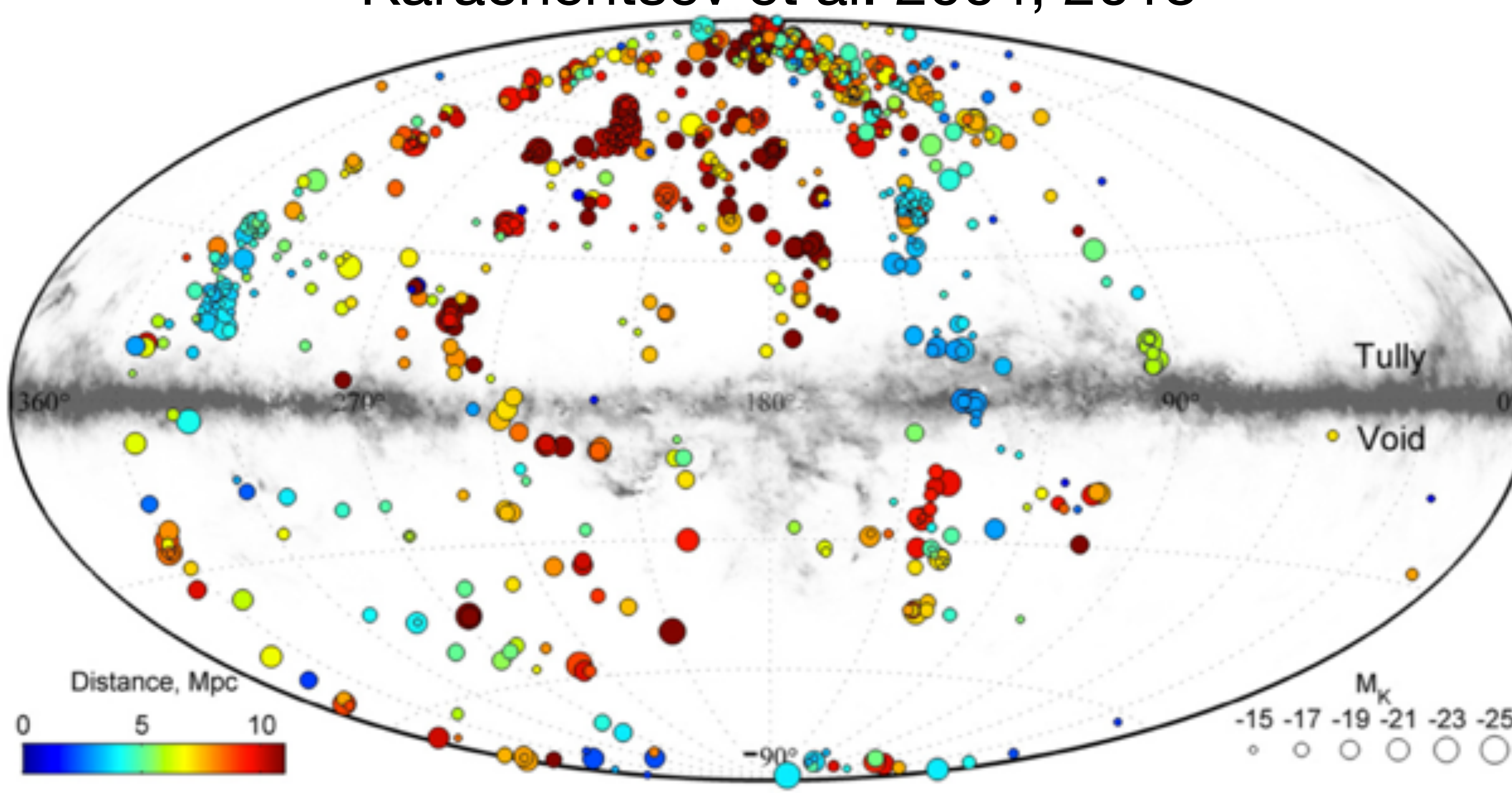
AGB

HB

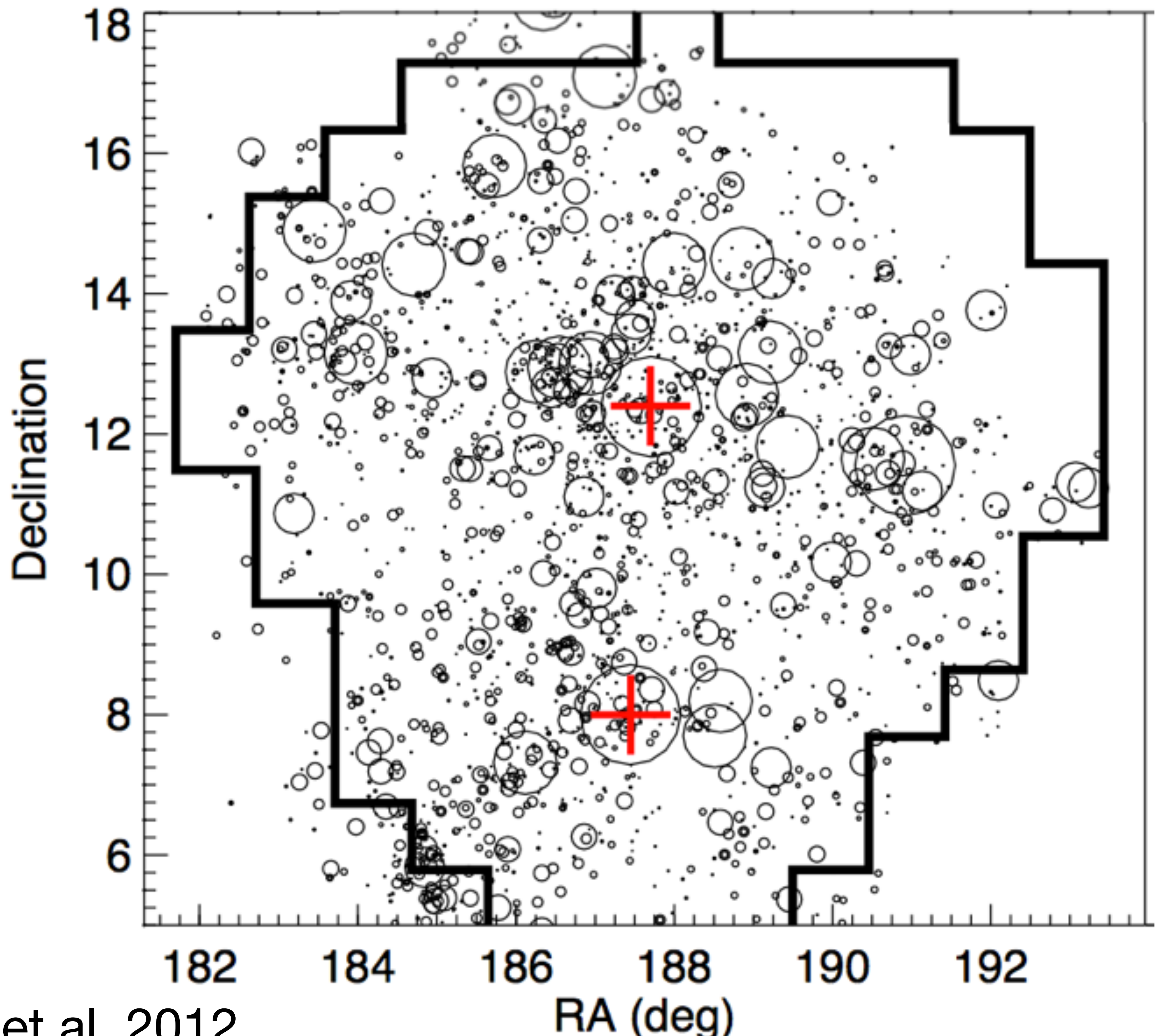
The Local Volume of 879 galaxies (D<11Mpc)



Karachentsev et al. 2004, 2013



The Virgo Cluster (~15Mpc)
The Next Generation Virgo Survey



Ferrarese et al. 2012

Survey Science Synergies

TMT/IRIS FoV is ~16” x 16” (34” x 34”?)

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

- Comprehensive characterisation of structure and environment of Local Volume galaxies essential to aid sample selection, guide field placement and allow consistent interpretation
    - e.g. structural decompositions, color gradients, homogeneous morphological analysis

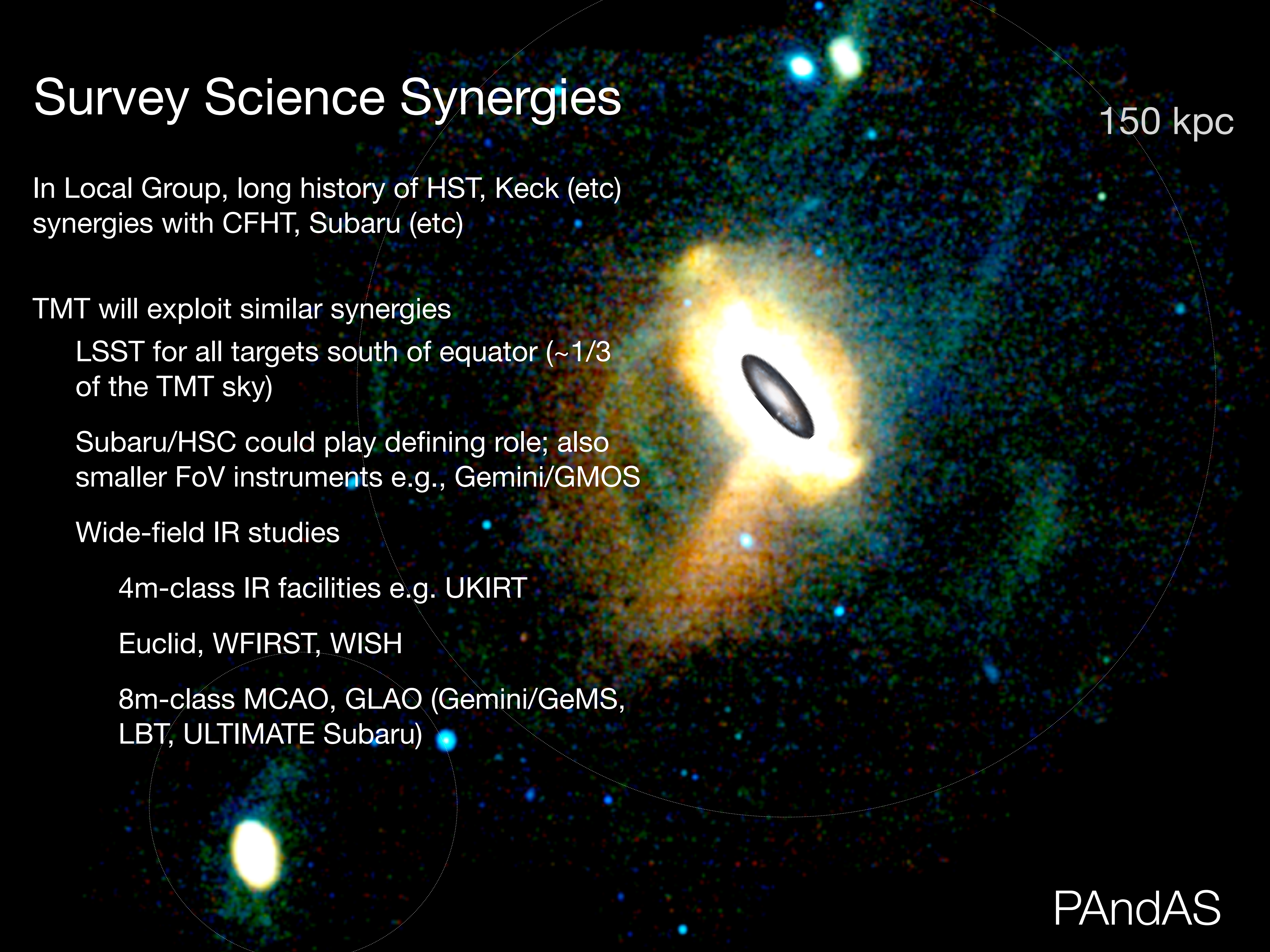
Duc et al., 2015, MNRAS, 446, 120

Survey Science Synergies

In Local Group, long history of HST, Keck (etc) synergies with CFHT, Subaru (etc)

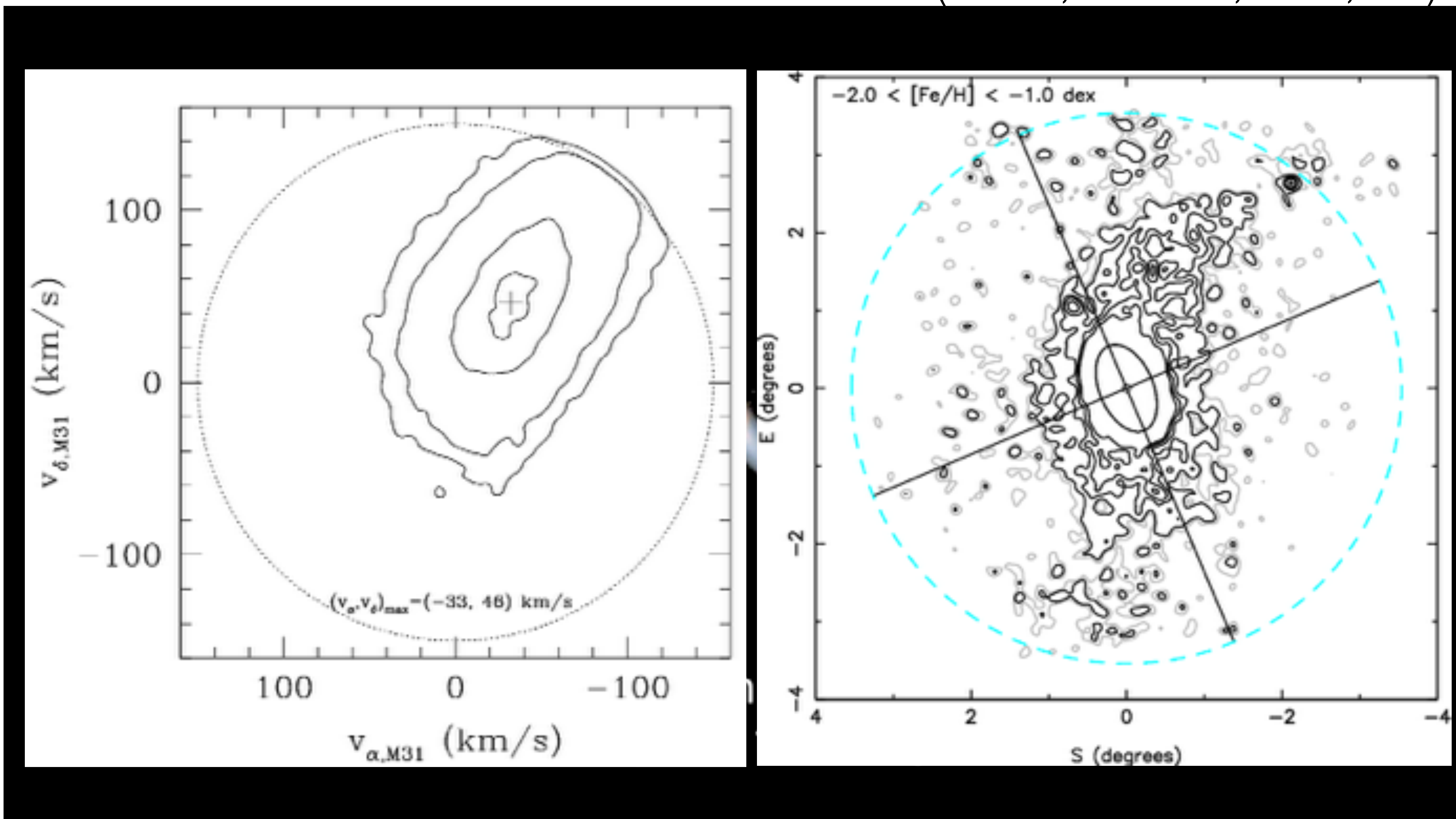
TMT will exploit similar synergies

- LSST for all targets south of equator (~1/3 of the TMT sky)
- Subaru/HSC could play defining role; also smaller FoV instruments e.g., Gemini/GMOS
- Wide-field IR studies
    - 4m-class IR facilities e.g. UKIRT
    - Euclid, WFIRST, WISH
    - 8m-class MCAO, GLAO (Gemini/GeMS, LBT, ULTIMATE Subaru)



Segue: The interaction history of the Local Group

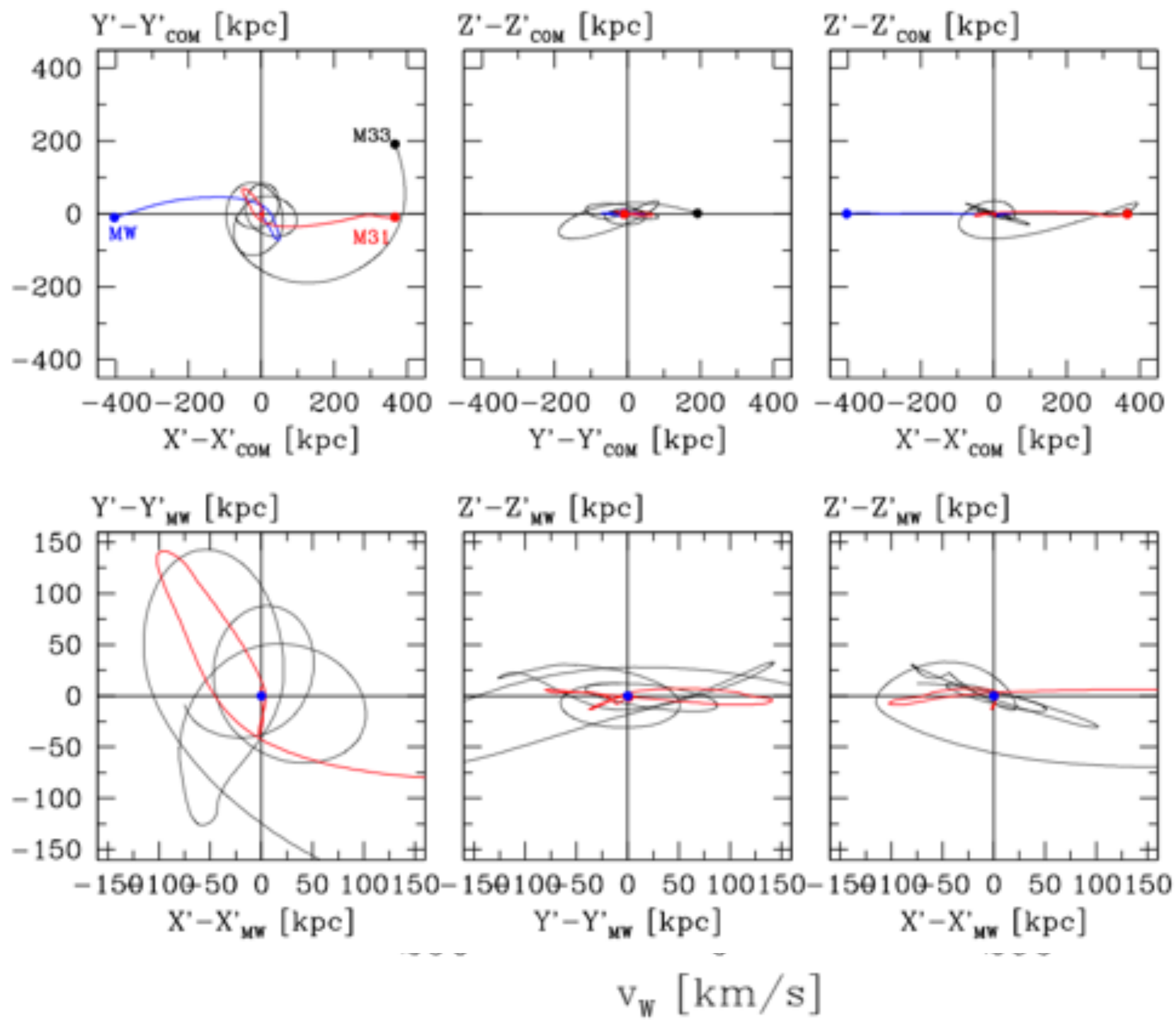
McConnachie et al. (2009, Nature, 464, 44)



Sohn et al, 2012, ApJ, 753, 7
van der Marel 2012, ApJ, 753, 8
van der Marel 2012, ApJ, 753, 9

HST M31 Proper Motion Measurement

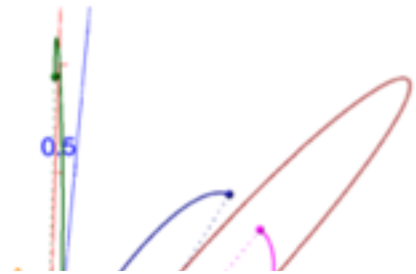
- "[ACS, WFPC3] are capable of measuring relative positions of multiple sources in a field to better than 0.5 mas"
- "The ability to average over large numbers of objects and over the three fields yields a final displacement accuracy of a few thousandths of a pixel, corresponding to only 12 μas/yr"
- Proper motion measurements of three fields in M31 relative to background galaxies
- Consistent with a near-radial MW-M31 orbit



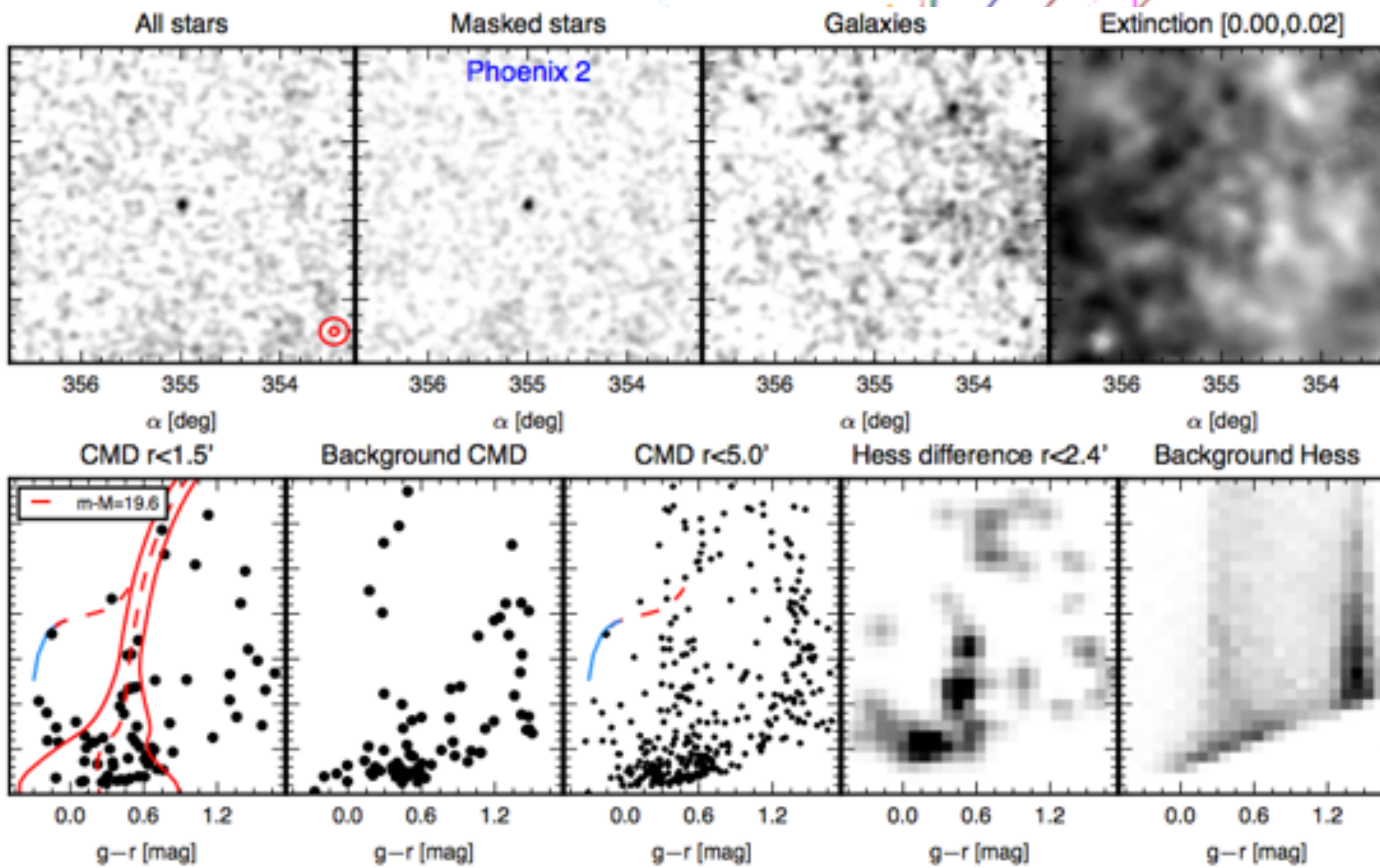
TMT and the Nearby Universe II: Astrometry, dynamics and galaxy masses

TMT relative astrometry accurate to ~10 - 50 microarcsecs per epoch (?)

Useful number:
PM = 200 microarcsecs/yr (Vt/100km/s) (100kpc/D)



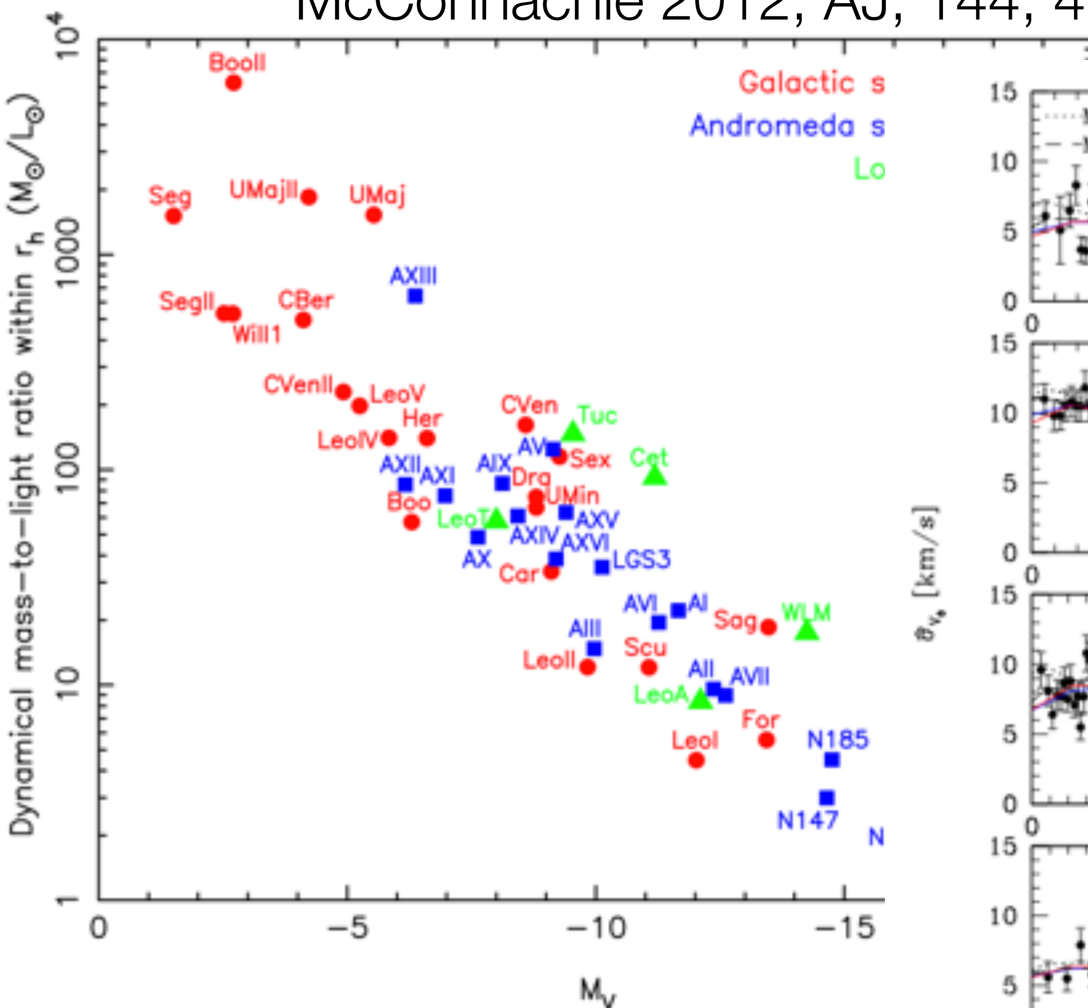
Note: Gaia can't see most of these objects!

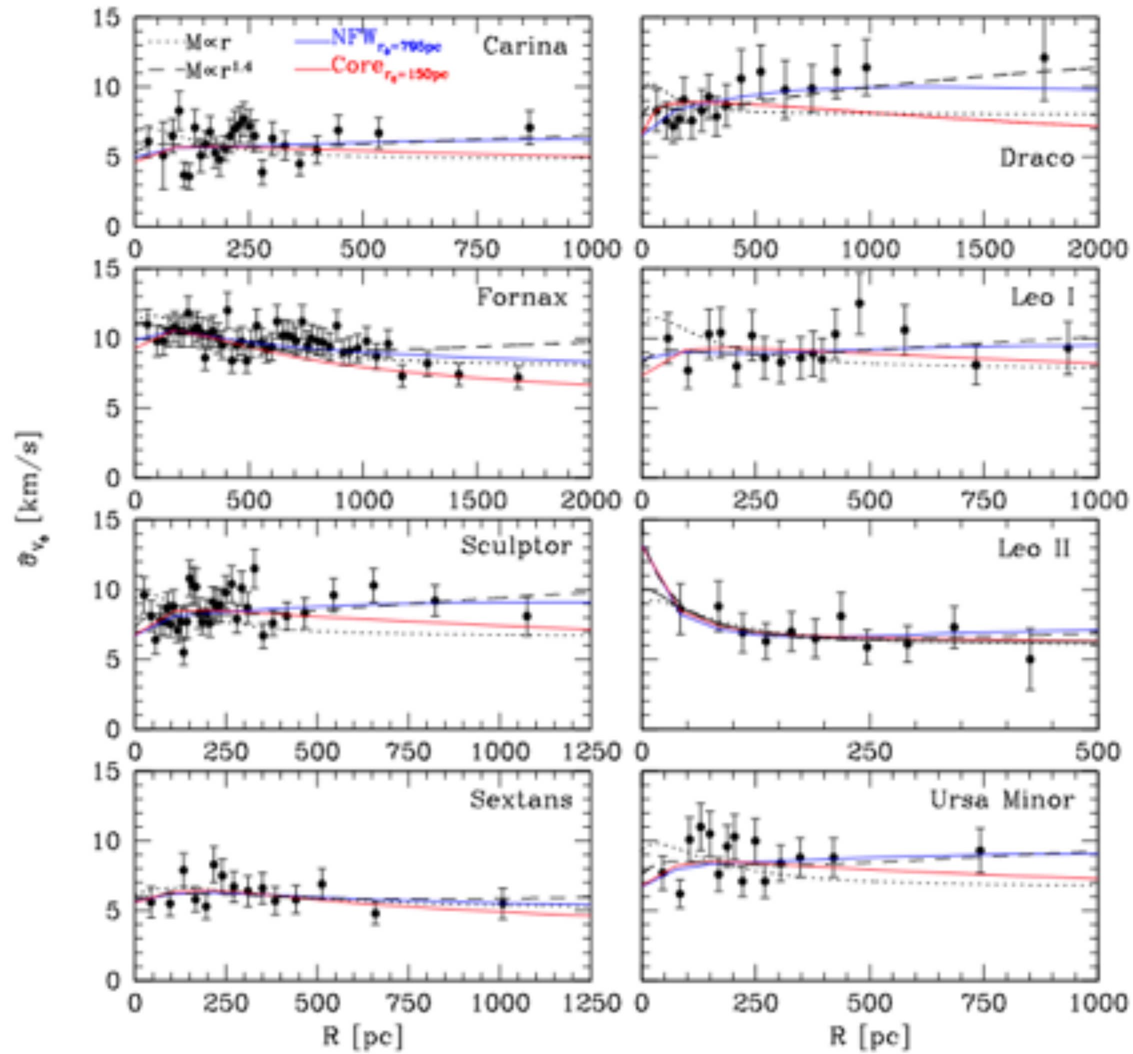


Koposov et al. 2015, ApJ, 805, 130

Internal proper motions of galaxies: Resolving the mass-anisotropy degeneracy

McConnachie 2012, AJ, 144, 4





Walker et al. 2009, ApJ, 704, 1274

Internal proper motions of galaxies: resolving the mass-anisotropy degeneracy

Jeans Eqn
$$\frac{1}{\nu}\frac{d}{dr}(\nu\bar{v_r^2}) + 2\frac{\beta\bar{v_r^2}}{r} = -\frac{GM(r)}{r^2}$$

where $\beta(r) \equiv 1 - \bar{v_\theta^2}/\bar{v_r^2}$

Const. anisotropy
$$\nu\bar{v_r^2} = Gr^{-2\beta}\int_r^\infty s^{2\beta-2}\nu(s)M(s)ds.$$

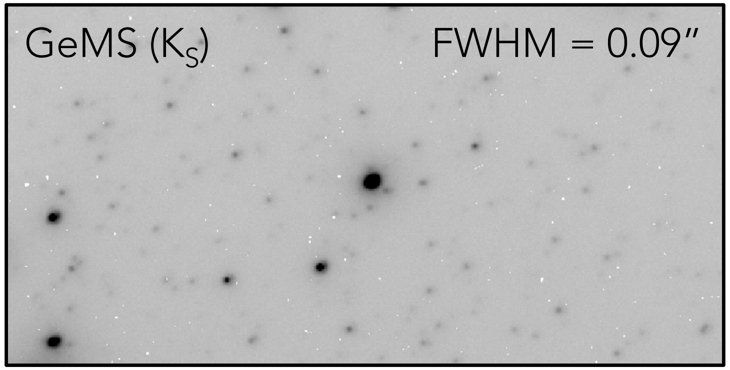
Observables
$$\sigma_p^2(R) = \frac{2}{I(R)}\int_R^\infty \left(1 - \beta\frac{R^2}{r^2}\right)\frac{\nu\bar{v_r^2}r}{\sqrt{r^2 - R^2}}dr$$

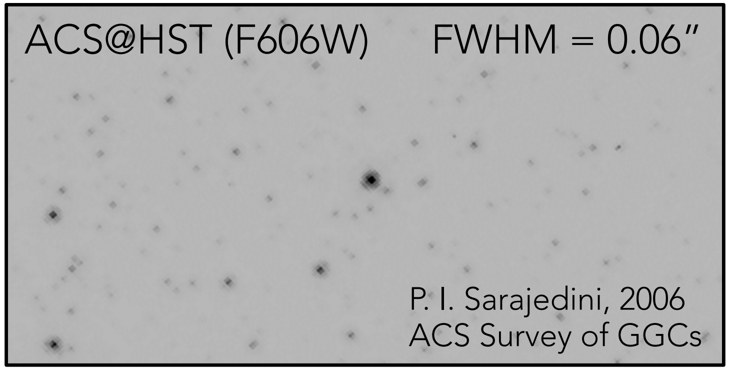
TMT relative astrometry accurate to ~10 - 50 microarcsecs per epoch (?)

Useful number:
PM = 200 microarcsecs/yr (Vt/100km/s) (100kpc/D)

Tangential velocity dispersion of MW satellites ~1 - 10 km/s?
=> PM ~2 - 20 microarcsecs/yr (much easier for closer satellites)

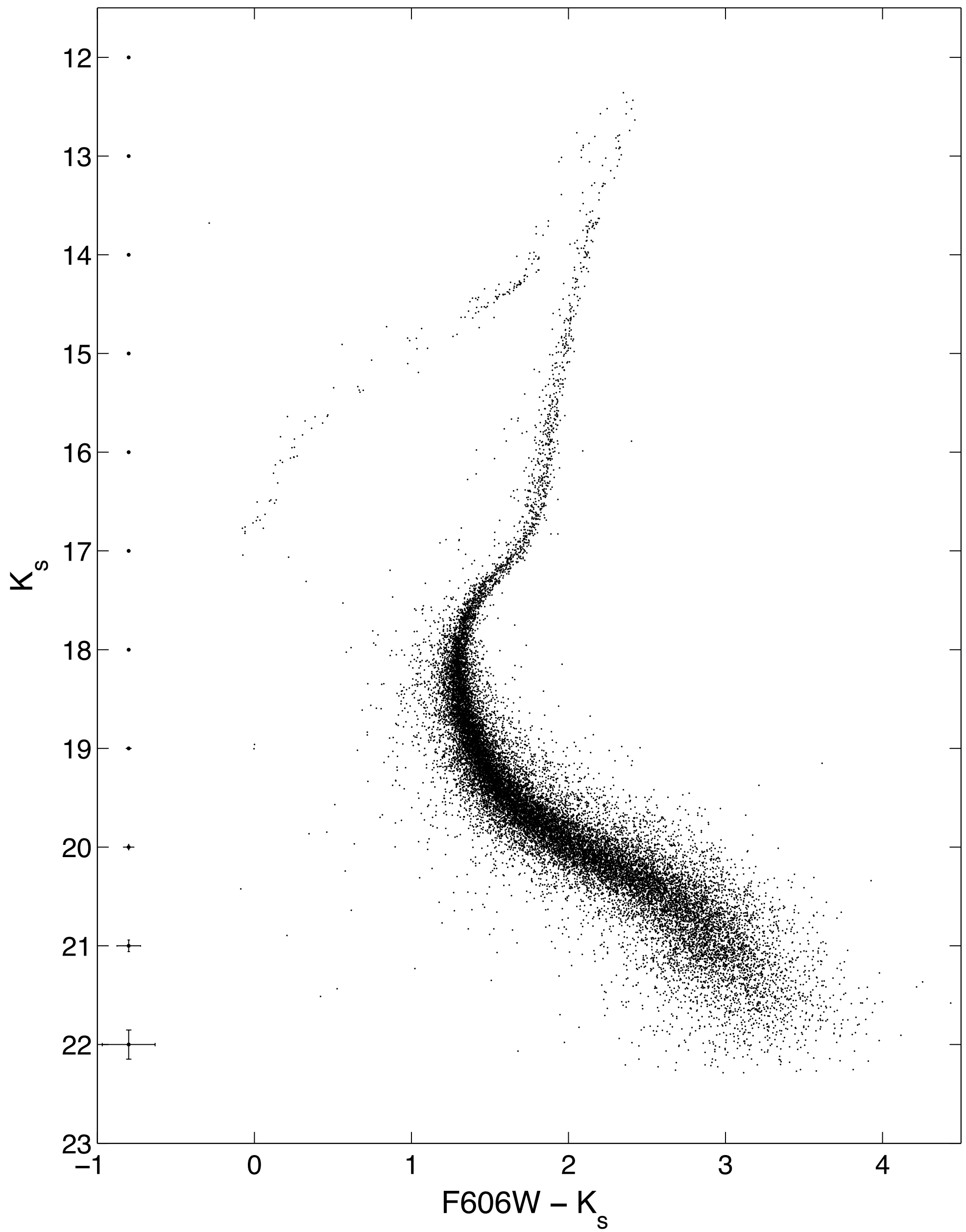
Pathfinder science:
Photometry and Astrometry with MCAO





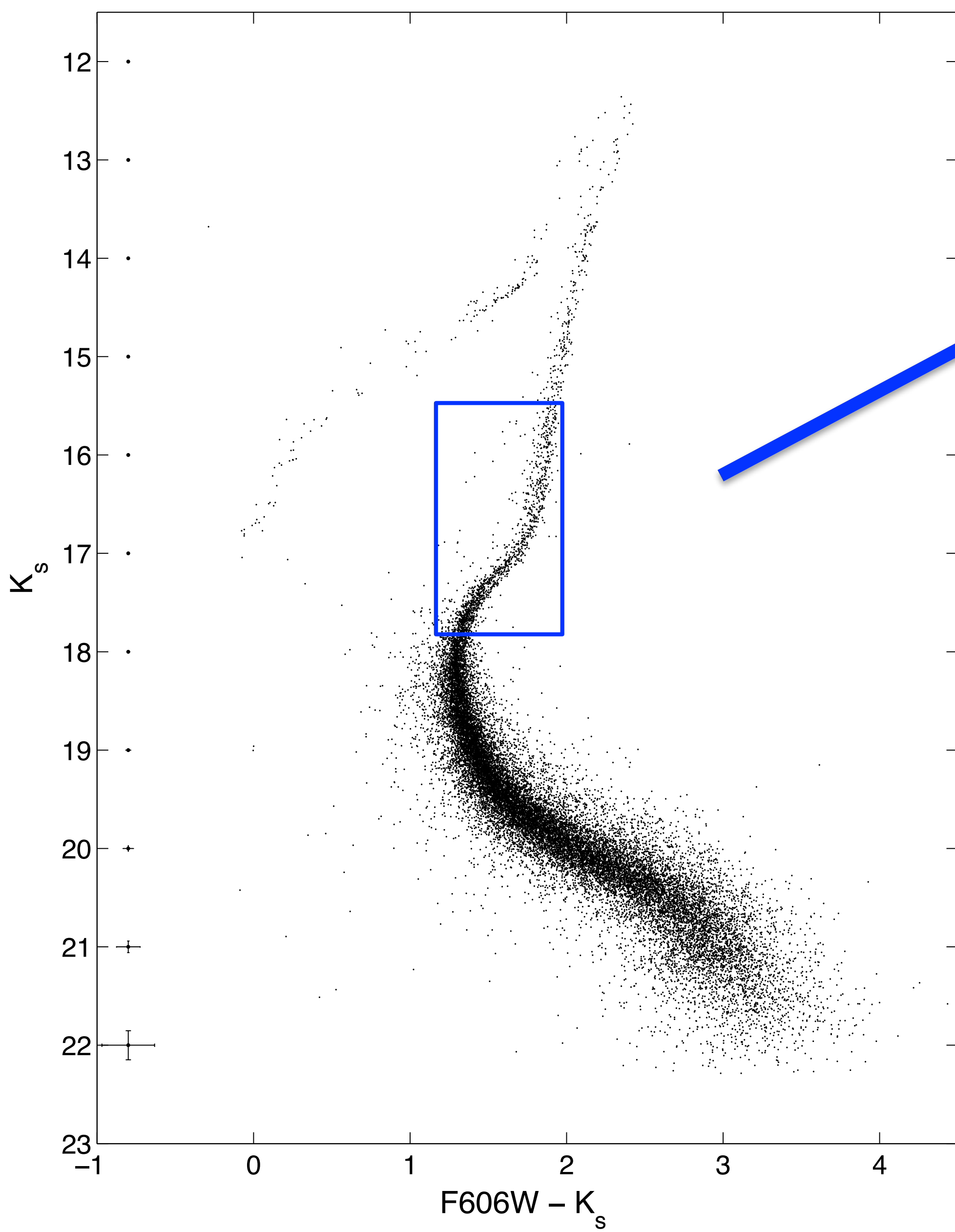
Paolo Turri,
PhD candidate,
U.Victoria

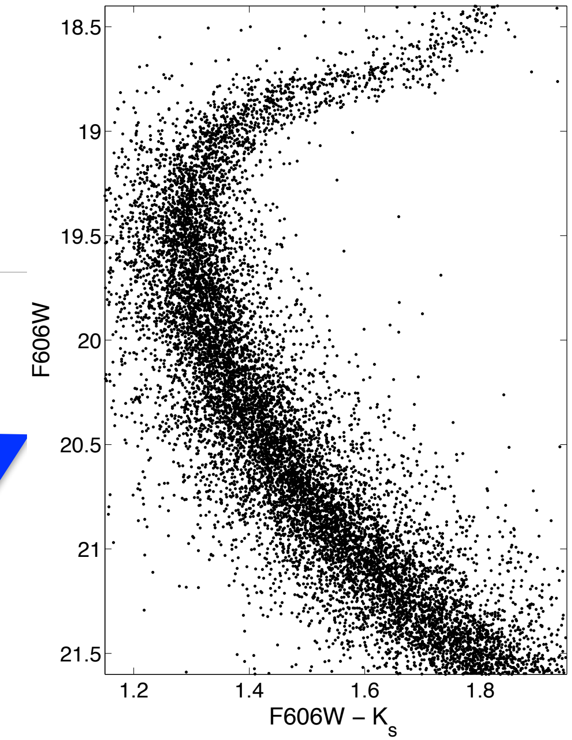
A GeMS/GSAOI view of NGC1851

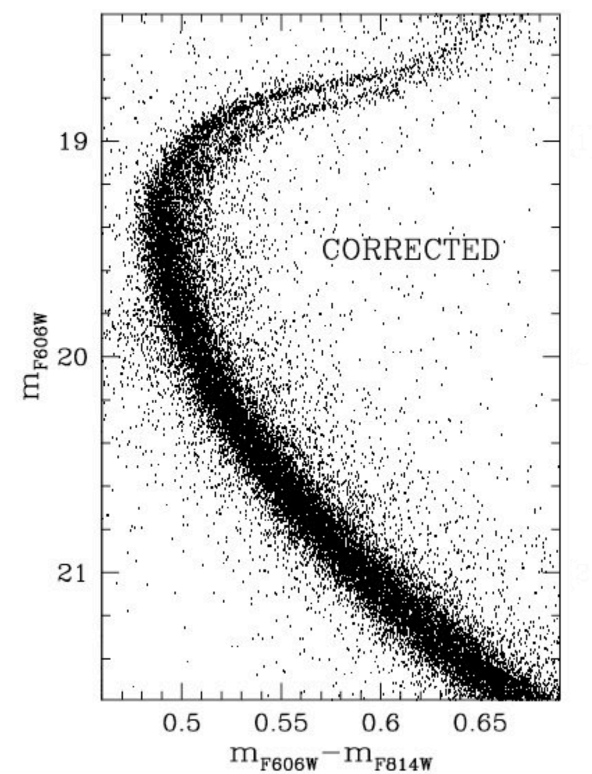


- Deepest NIR CMD obtained from the ground
- Deepest Ks band CMD
- Precise photometry - crucial for TMT since NIR color-temp sensitivity is less

NGC1851's double sub-giant branch

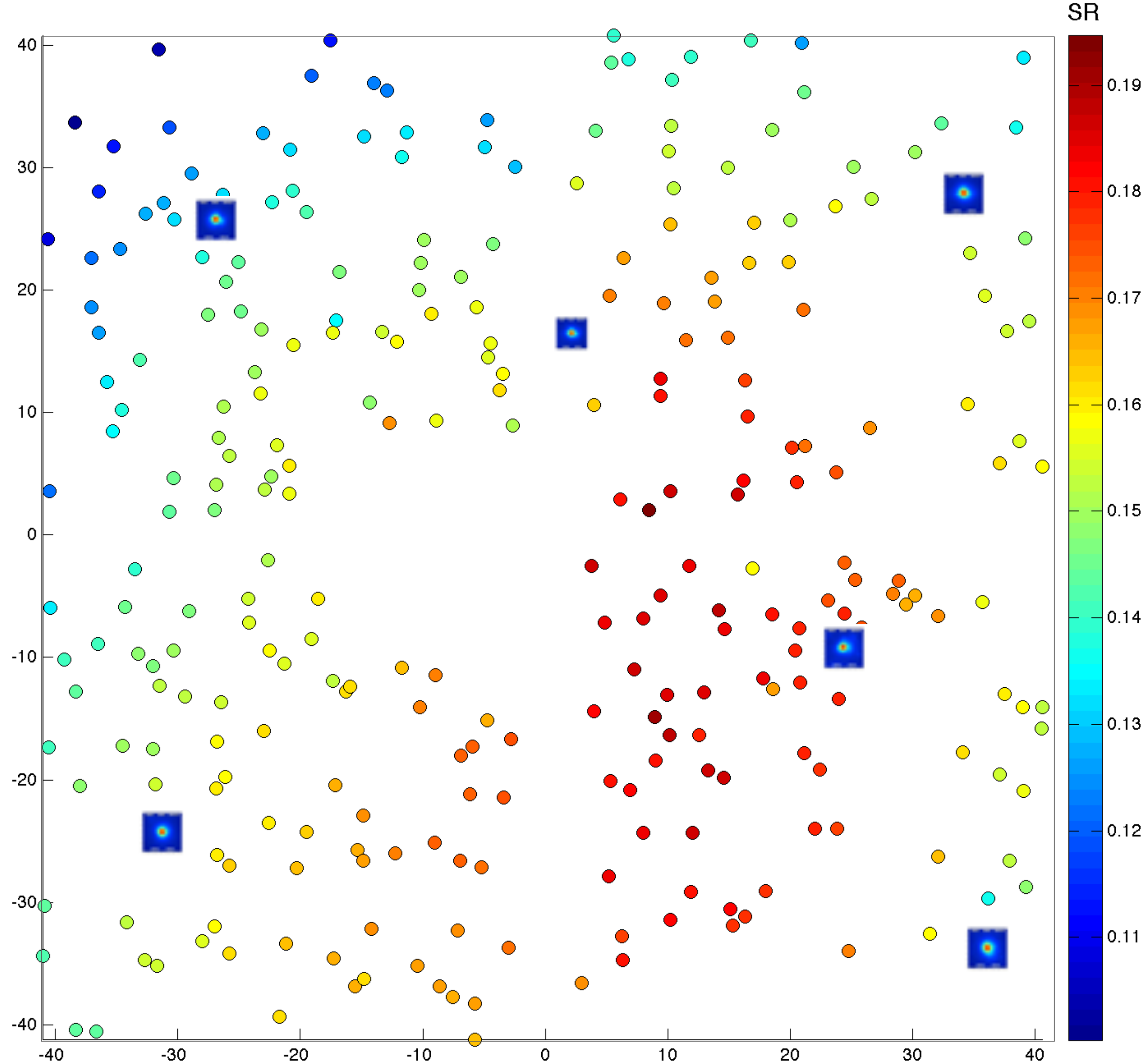




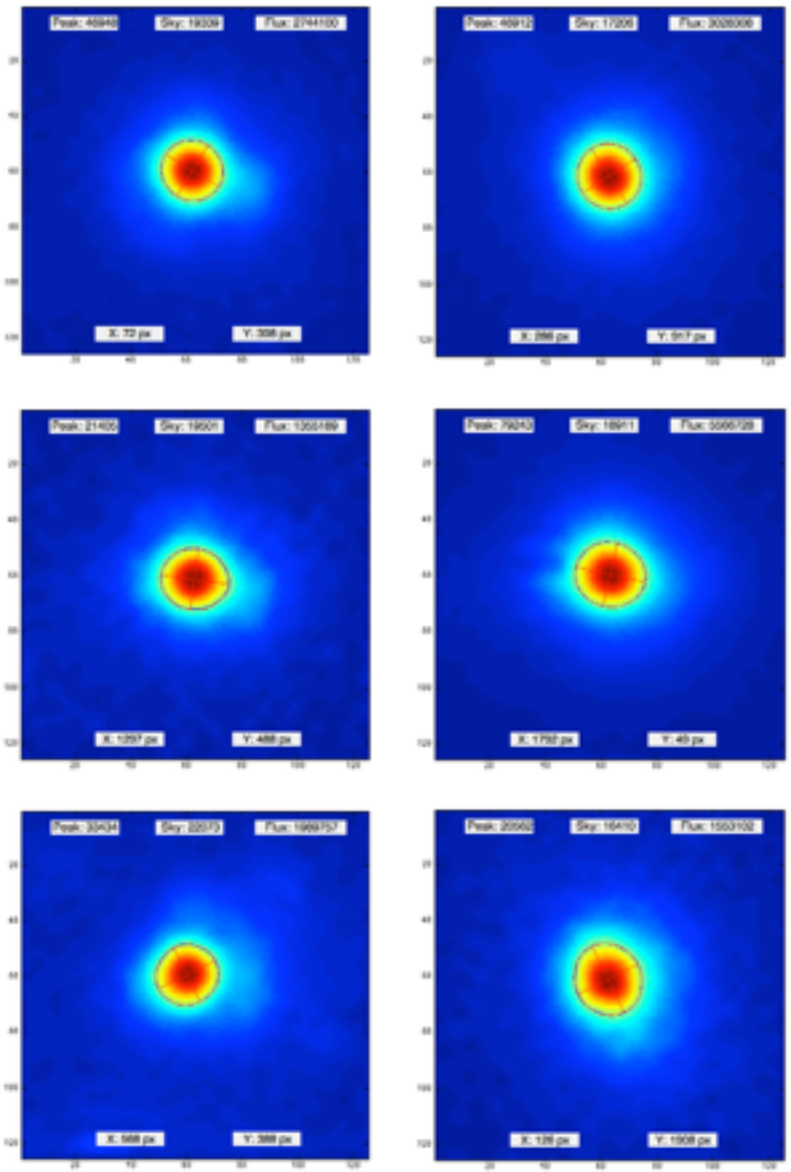


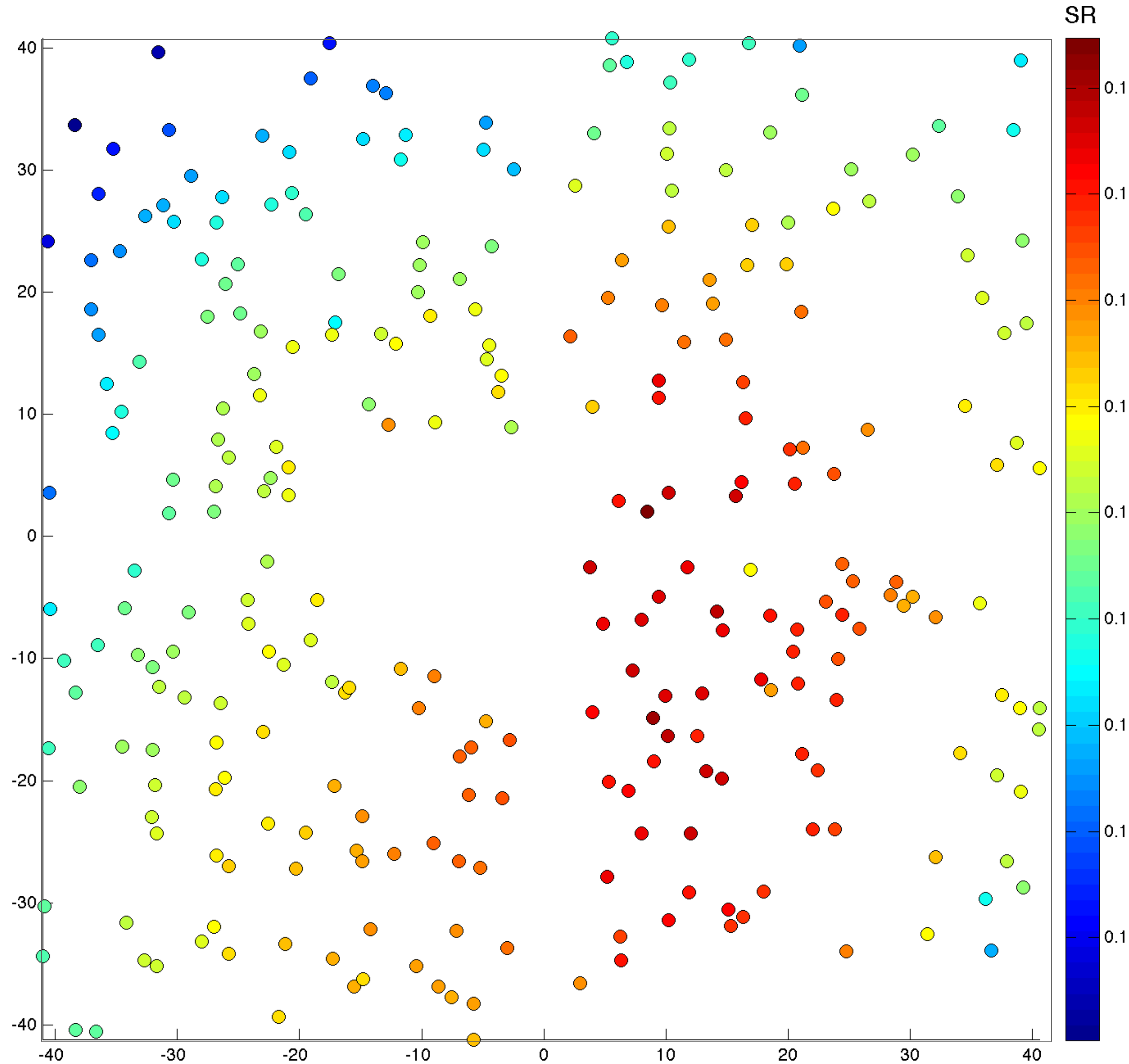
Photometry and astrometry with MCAO: Distribution of PSF stars

- ~30 000 PSFs distributed across field (only bright PSF stars shown)
- Use to map PSF variability and astrometric distortion
- Note: exact positions of stars are known assuming HST field represents “truth”

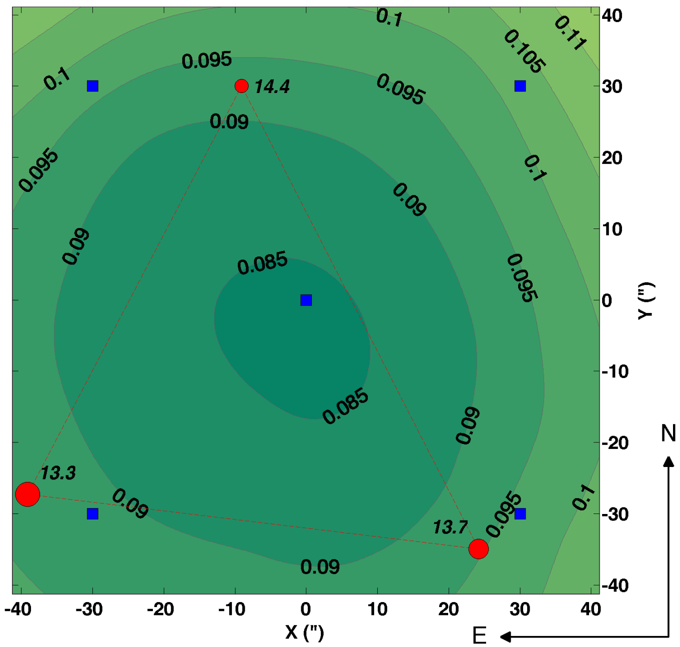


Photometry and astrometry with MCAO: Distribution of PSF stars

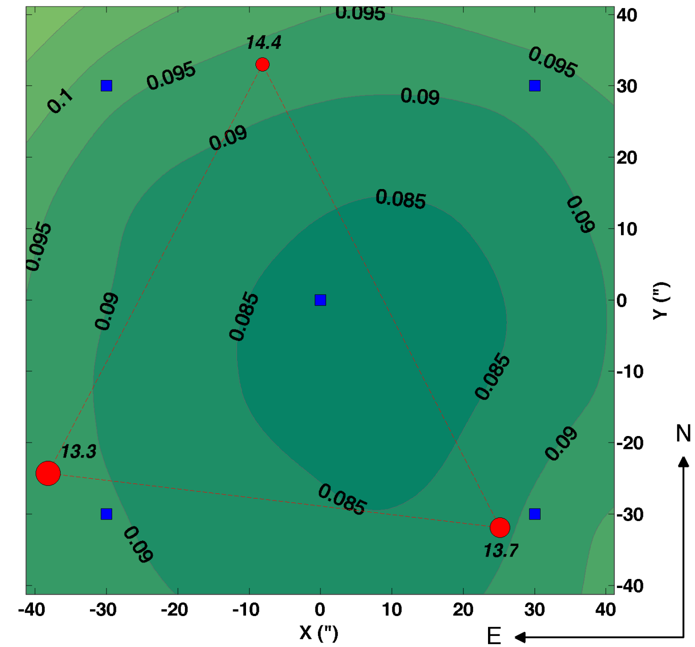


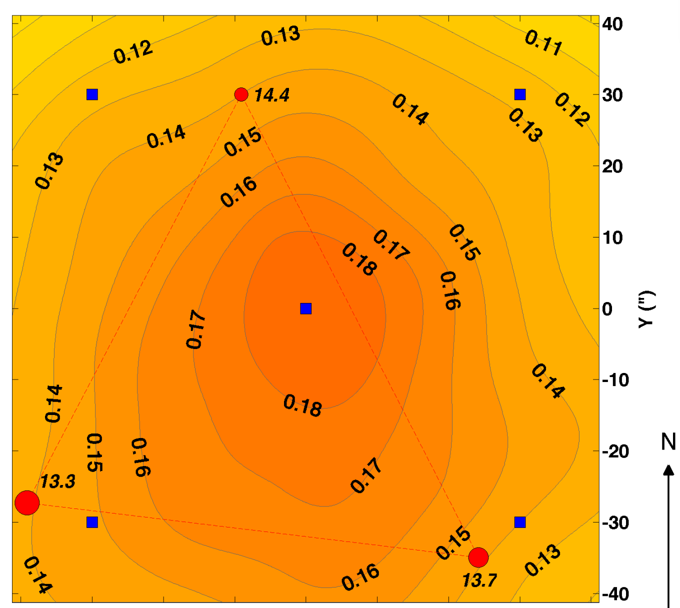


Spatial and temporal stability of the PSF

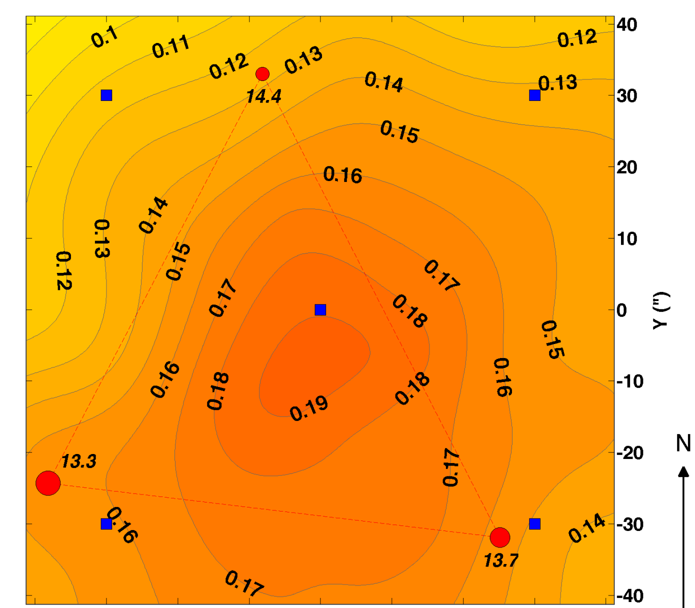


FWHM (")

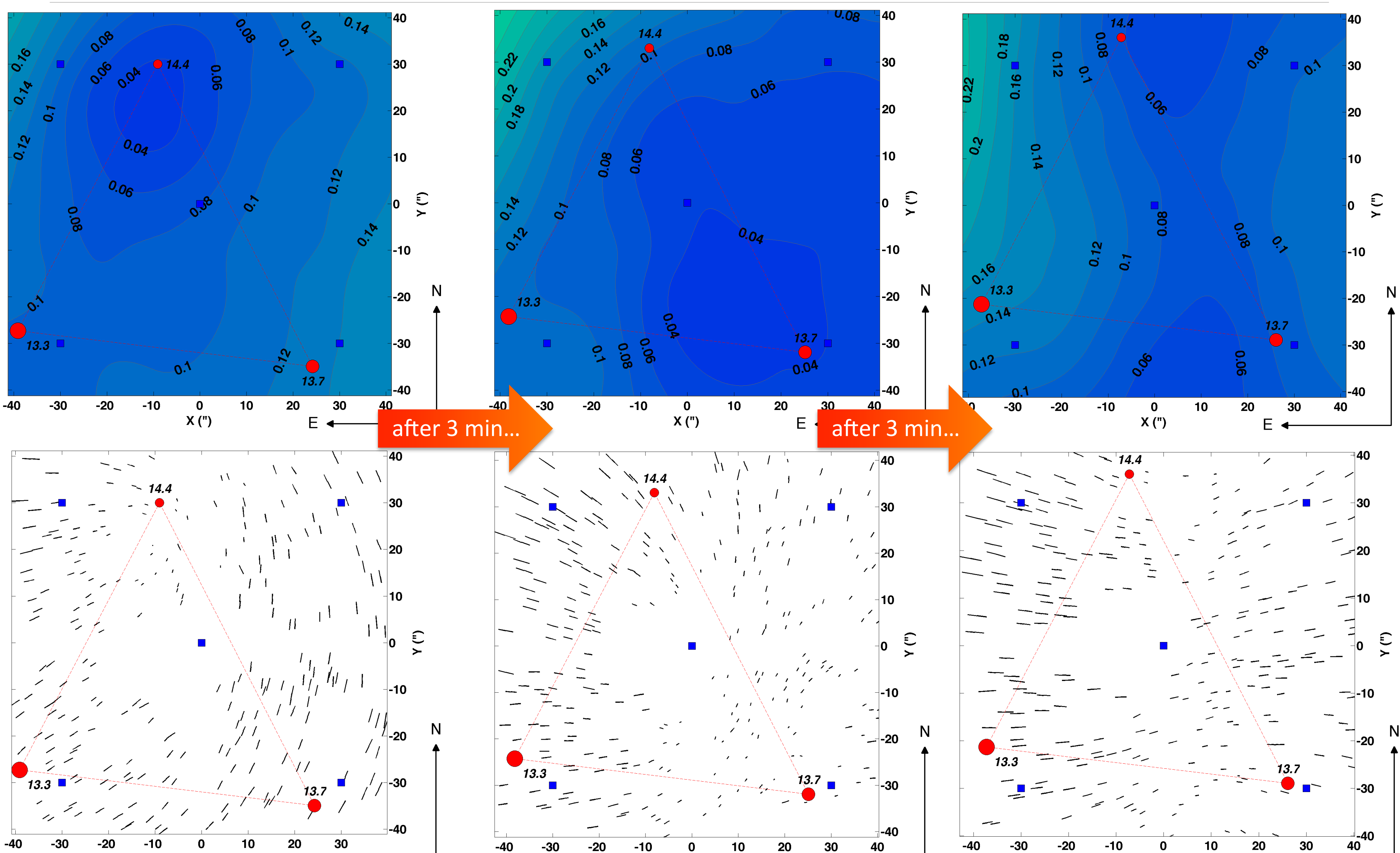




SR

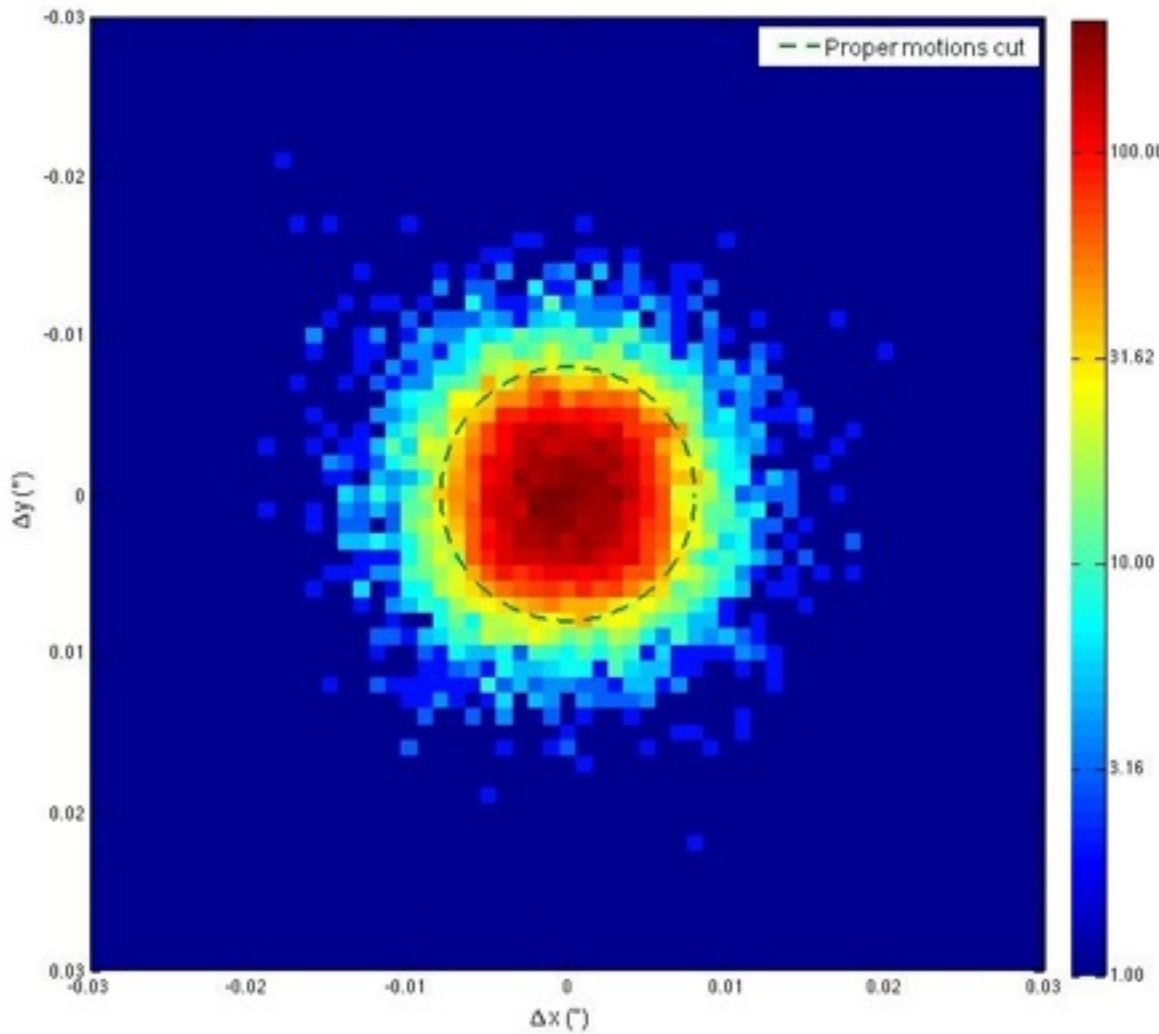


Spatial and temporal stability of the PSF



Astrometric accuracy

- "True" relative position of stars in field known from HST-ACS astrometry
- 16 parameter transformations used to match each GeMS detector/exposure to HST
- CMD already uses proper motion cut
- Relatively simple to calculate the tangential velocity dispersion as measured from residuals in transformation
- Detailed analysis forthcoming



Summary / Fin

- TMT allows for a unique insight into the timescales associated with chemical enrichment and the cycling of baryons in all galaxies out to the distance of the Virgo cluster
  - *spanning all luminosities, morphologies, regions of the color-magnitude diagram and across all environments (from voids to loose groups, groups and galaxy clusters)*
- Key science areas in (at least!):
  - **Astrometry and galaxy masses**
  - **Star formation histories —> building the baryonic components of galaxies**
  - **Chemical abundances (next talk)**
- Science programs demand multi-epoch observations, and/or relatively long observations, and/or large datasets, and/or ancillary datasets
  - **“Key programs” essential**

TMT Cupcakes, CASCA2015, Hamilton, Ontario

- Gemini/GeMS allows for pathfinder science to inform the development of key science areas for TMT; need to capitalise on the MCAO first-light capabilities