Pan-STARRS
ATLAS
and
ngCFHT

John Tonry

Why wide field spectroscopy?

- Multiplex use of expensive aperture!
- Integral field spectroscopy
- Occasional tricks (e.g. differential spectroscopy of occulation)
- But (IMHO) efficiency, aperture, and quality of data usually are more important than number of simultaneous spectra

MOS Figure of Merit

- What exactly should be the figure of merit for a MOS telescope?
  - Large aperture to collect light (m^2)
  - Fast f-ratio to minimize instrument cost
  - Lots and lots of simultaneous spectra! (N)
- How do we get lots of spectra?
  - Instrument with many fibers, slitlets, IFU, etc.
  - Large field of view provides more potential targets (deg^2)
  - High sampling density and flexibility:
    - Ideal is N apertures anywhere in large FOV, immediately configurable
    - Compromise #1: slitless dispersion (big SNR penalty!)
    - Compromise #2: slow configuration, arbitrary location with collision radius
    - Compromise #3: grid of locations, each with patrol area
- Within this context of compromise, the figure of merit that emerges is ($m^2 \times deg^2 \times N$)

Wallpaper vs transients

- Wallpaper is intrinsically boring but high density
  - Targets tend to come from other information: e.g. xray, IR, submm, radio, colors, high resolution from space or AO, motion, time history, etc.
  - Don't discount JWST as a primary source for targets
- Transients are intrinsically interesting but low density
  - PS1 MD: ~1,200 SN/yr to m~23 (~5/deg^2/mo)
  - PS1 MD: ~300/deg^2 variables to m~23 (mostly AGN)
  - If transient surveys are ongoing (e.g. LSST) ngCFHT can probably allocate a fiber or two in every field to transients.

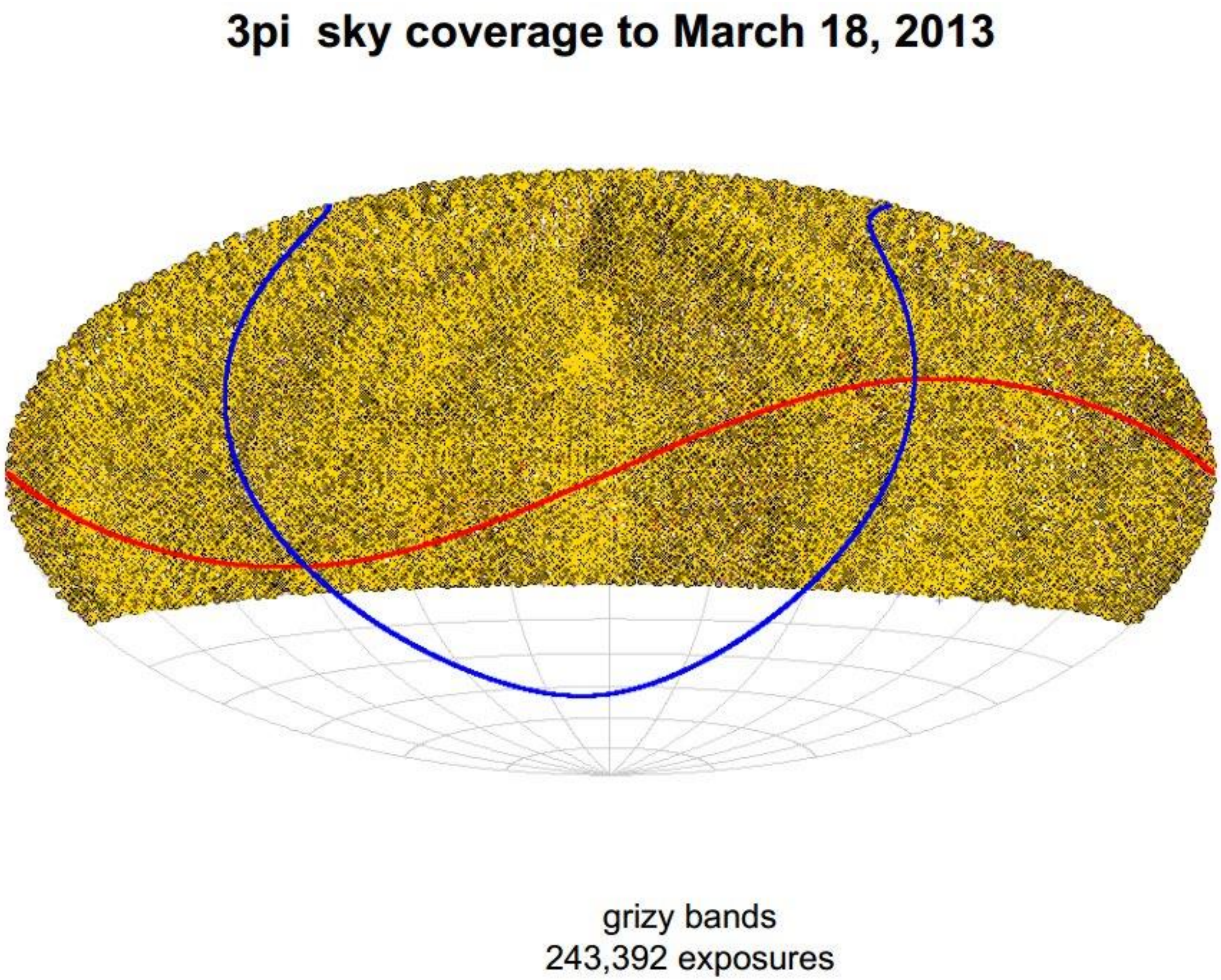
Pan-STARRS1 (PS1SC, 2010-2013)

- Wallpaper over 3π to limiting depths (Nigel Metcalfe)

Band	mPSF	mKron	DR8	Stripe82	UKIDSS
g	23.4	23.0	22.8	24.2	
r	23.4	22.8	22.2	23.6	
i	23.2	22.5	21.6	23.1	
z	22.4	21.7	20.3	21.8	
y	21.3	20.8	-	-	20.2

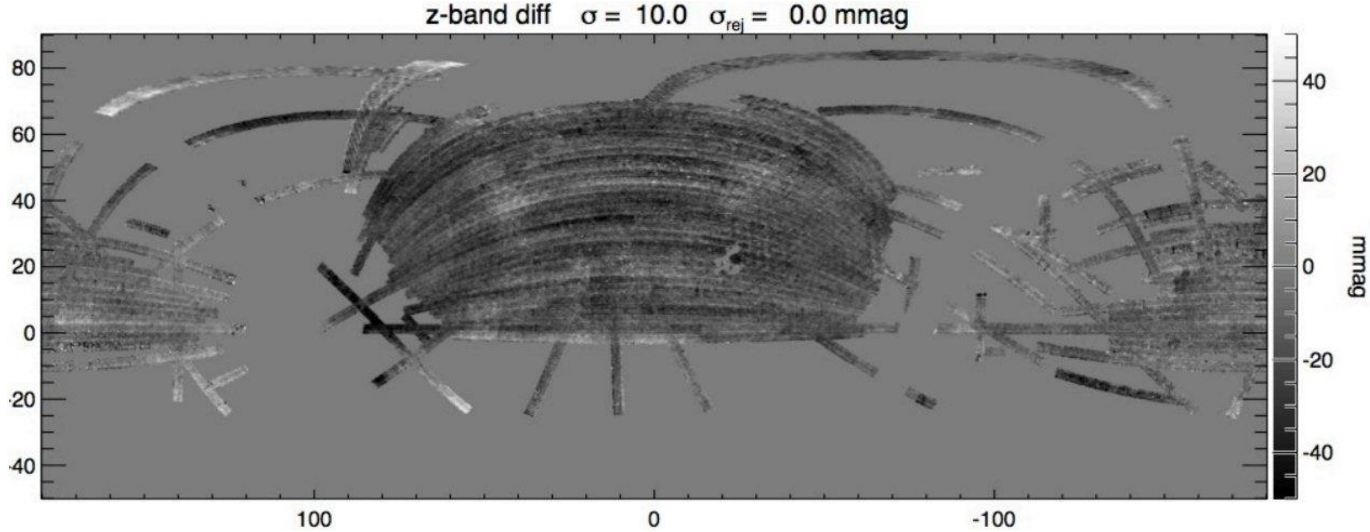
- Photometry better than 0.01 mag, limited by Calspec? Very probable.
  - http://ipp.ifa.hawaii.edu/photladder.20130107.subset
- Astrometry at 10mas tied to ICRS? Possible.
- All products to be made public by STScI by end of 2014.

PS1SC 3pi Coverage

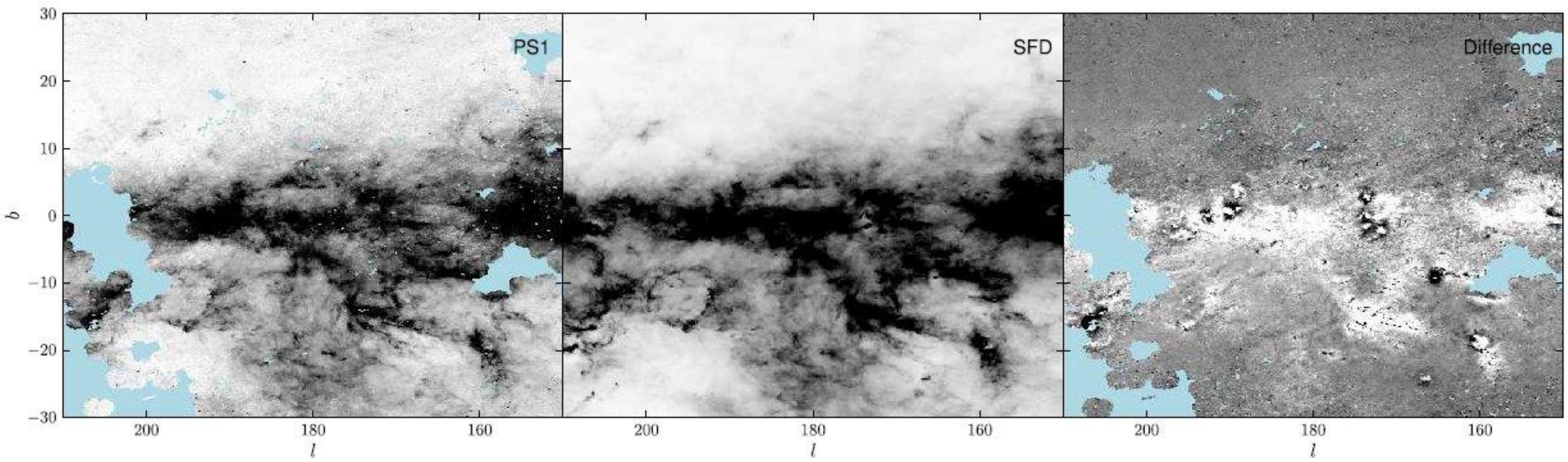


(Ken Chambers, PS1SC meeting 130318)

PS1SC Photometry



Doug Finkbeiner PS1SC meeting 130318



Eddie Schlafly PS1SC meeting 130318

PS1SC Products

- Stars and galaxies
  - $\delta > -30$ and AB<23, grizy with varying depths
  - Photometry <0.01 mag, absolute (IRCS) astrometry <20mas
  - Photo-z's of galaxies with AB<22, dz~0.07(1+z)
- Galactic dust extinction
  - <~0.05 mag, distance resolution dr~2%?
- Cool white dwarf from reduced proper motion
  - ~10/deg^2, lots of WD+RD or WD+BD pairs
- ~10^5 AGN from color and variability
- MW and M31 satellites and streams
- Massive clusters at z<~1

Pan-STARRS (2014-2015)

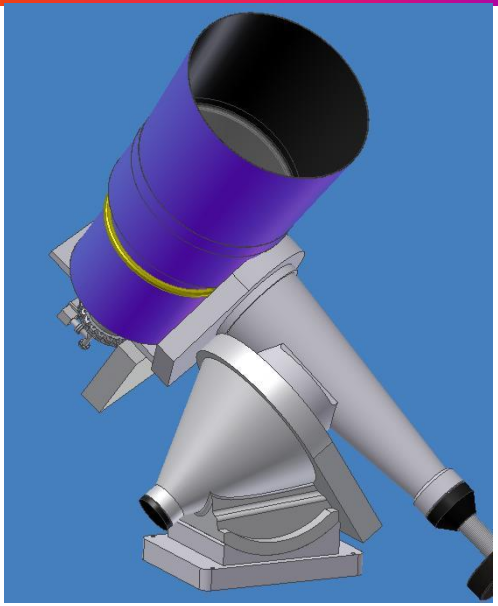
- PS1
  - Primarily NASA NEOO?
  - Perhaps w band primarily near ecliptic?
  - Perhaps improve uniformity of PS1 3pi survey?
- PS2
  - Undergoing commissioning
  - Organizing new operations consortium
  - Operations begin late 2014, early 2015?

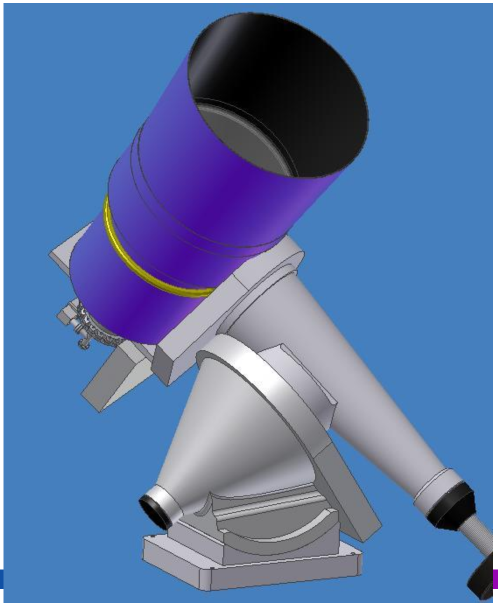
Pan-STARRS (2015-)

- PS1+PS2 (2015-2020)
  - PS1+PS2 has 1/10 the collecting area of LSST, can survey "all sky in 4 nights to i=22.5".
  - Best guess is deeper, better survey than PS1 over ~7,000 deg^2. (E.g. for Euclid photo-z's, lensing, etc)
    - Per-observation limiting magnitude ~22.5 x 100 visits over ~5 years?
    - Final limiting magnitude ~25, griz (2 mag fainter than PS1SC)?
  - Primarily wallpaper? As yet undetermined how much attention will be paid to transients.
  - Mission will be largely dictated by partners footing the bill for operations cost…

ATLAS (2015-2020)

- Project funded by NASA to find dangerous asteroids
  - Two or more small (~40-50cm) telescopes with big field of view (~7-8deg) producing ~3" images.
  - AΩ similar to Pan-STARRS or SkyMapper but images blurrier, so less sensitivity for objects smaller than 3".
  - Broad filters (e.g. g+r, r+i, and g+r+i) intended for sensitivity but retaining some color information.
  - Expect to observe 100,000 deg^2 at m~20, i.e. entire visible sky 4-5 times per night.





ATLAS and ngCFHT

- Transient and variable sources at m<20
  - ~50/nt supernovae at z<0.1
  - ~1-10/yr "interesting" core-collapse SN
  - ~10/deg^2 AGN
- ATLAS transient rate will be comparable to PS, but densities will be much lower and sources will be much brighter.
  - Possibility of having a transient for an arbitrary ngCFHT pointing, but not great.

ATLAS and ngCFHT

- At m<18, sky background is irrelevant and crowding is not serious out of the plane. Special purpose surveys could be undertaken quickly, e.g.
  - Survey 9,000 deg^2 to 0.03 mag at v~18 in ~1 night
- ATLAS should have excellent sensitivity for low surface brightness objects.
  - In 1 year each 3" pixel gets ~1000 observations, sensitivity of μ~22.5 per square arcsec, μ~27 per square arcmin, etc.
  - "LSB" universe can be revealed by subtracting the point sources from another, deeper survey such as Pan-STARRS

Why stop at 10m and 120m^2deg^2?

- Design by Burge and Angel (2002) can increase this by x15 to 1800m^2deg^2
- Overwhelming advantage over any planned spectroscopic facility!
- Intrinsically wide field telescope uses primary, secondary, and focal surface that are all concentric spheres
- Spherical aberration is corrected in patches

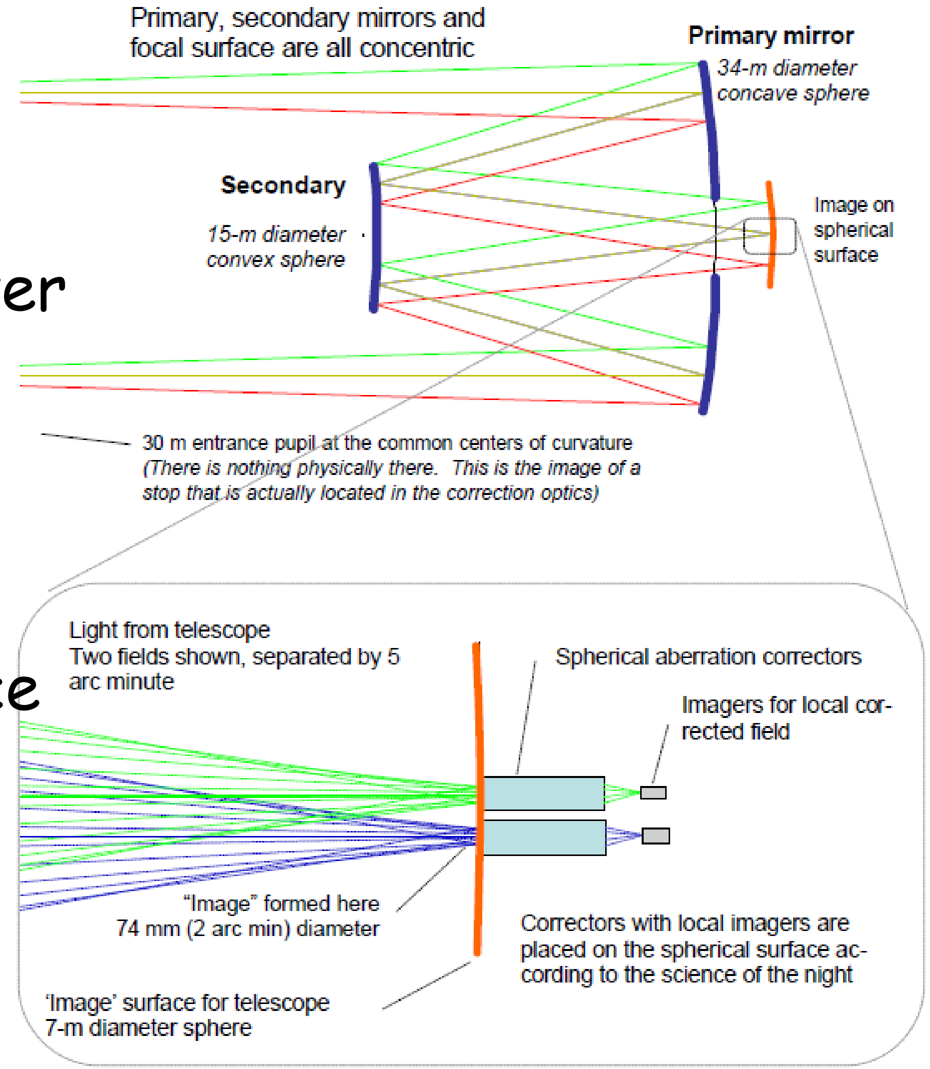
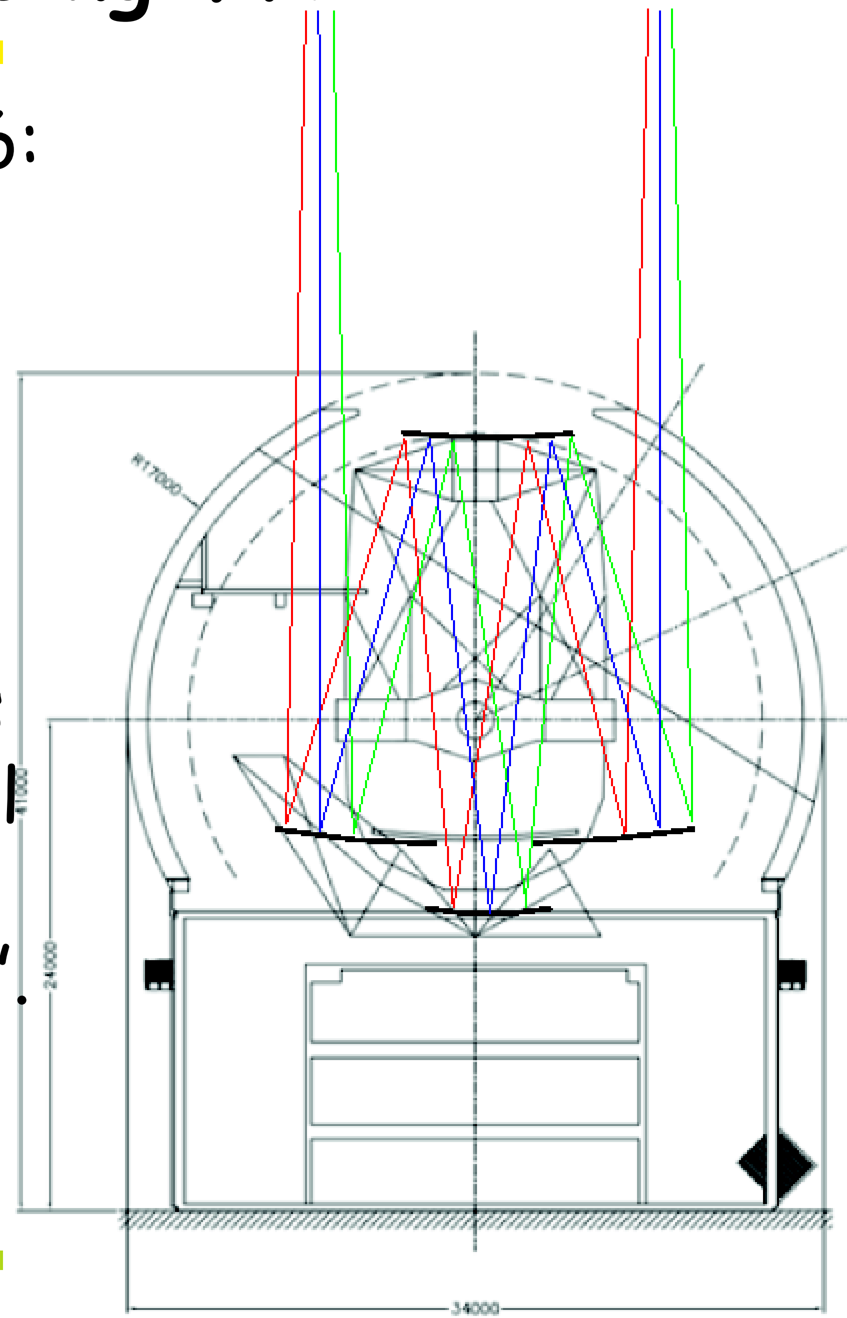


Figure 2. Telescope design for 30-m aperture and 3 degree field of view. The two mirrors create images with 2 arc minute diameter spherical aberration on a 7-m spherical surface. The correctors, shown in the inset, are placed onto the 7-m spherical 'image' surface, and each corrects a field of a few arc seconds.

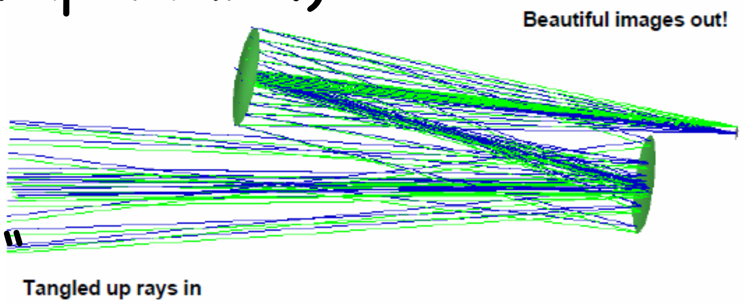
Application to ngCFHT

- Scale Burge design by 0.6:
  - 20m f/2 primary
  - 9m secondary
  - 4m focal surface
  - 3 deg FOV
- Install as many as 1000 corrector/detector units that patrol over the focal surface, each creating superb images over 4x16".



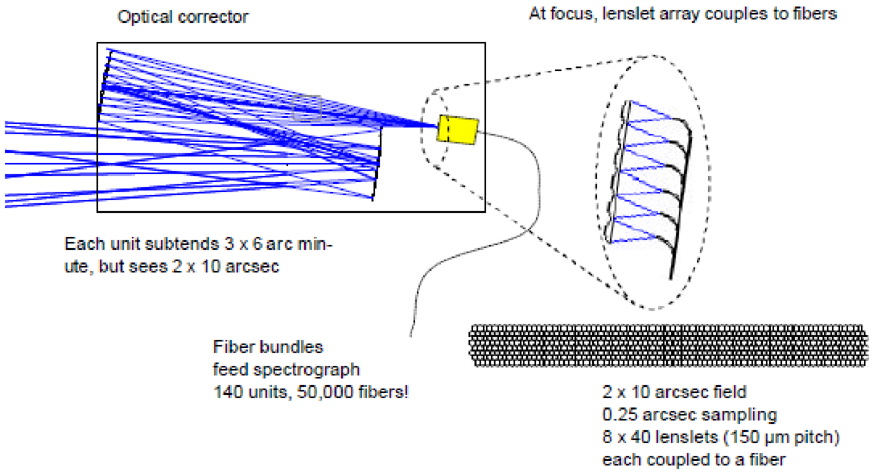
Characteristics

- Aperture
  - 18m entrance pupil 70m above primary mirror
  - f/4.2 overall, 75m FL, (360um/arcsec)
  - Primary mirror segments come from ELT (FL 36m) or TMT (FL 30m) procurement. This brings down the cost and creates a reasonable aperture and size for ngCFHT.
  - Lots of latitude to tweak design, can fit CFHT. (E.g. TMT segments create 15m aperture.)
- 3 deg FOV
- Correctors (~1000)
  - 3.5x7' (8x15cm) with FOV 4x16"
  - uses a pair of inexpensive 70mm aspheric mirrors

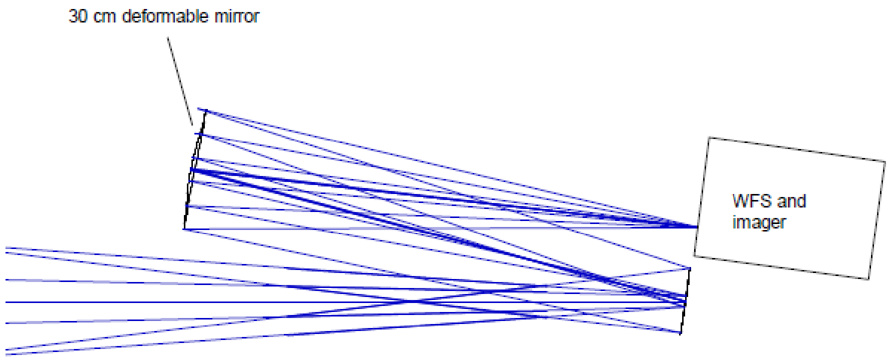


Performance

- 0.2" images over 4x16" FOV suitable for fibers and/or IFU



- One corrector mirror conjugates to ~70m altitude, interesting opportunities for dispersed, "wide field" AO with 18m aperture.



Achievable goal?

- Not science fiction:
  - 18m aperture is **3x** more area than baseline 10m
  - 2′ patrol area (vs 1.7′) and 2′ corrector within 3° is 2100 simultaneous coverage regions (vs baseline 2400)
  - Use a 4x4″ IFU at 0.25″ feeding 256 fibers, slice/select into one for cross-dispersion, otherwise get 500,000 spectra
  - Use 20x20 DM's for GLAO (same correction everywhere) and get 0.4″ images vs 0.7″ and lower sky for point sources by **3x** relative to baseline 10m
  - Increase speed by **x10** or increase sensitivity by **1 mag**.
- Challenges:
  - Cost increases to $270M
  - How to do the secondary mirror? How to make it fit?
  - Will GLAO work?
  - Design and industrial production of correctors. Burge says "refractive solution was hard" and prefers oversized mirrors and large IFU. Need to squeeze down the corrector footprint to the size of spherical aberration. Include ADC.