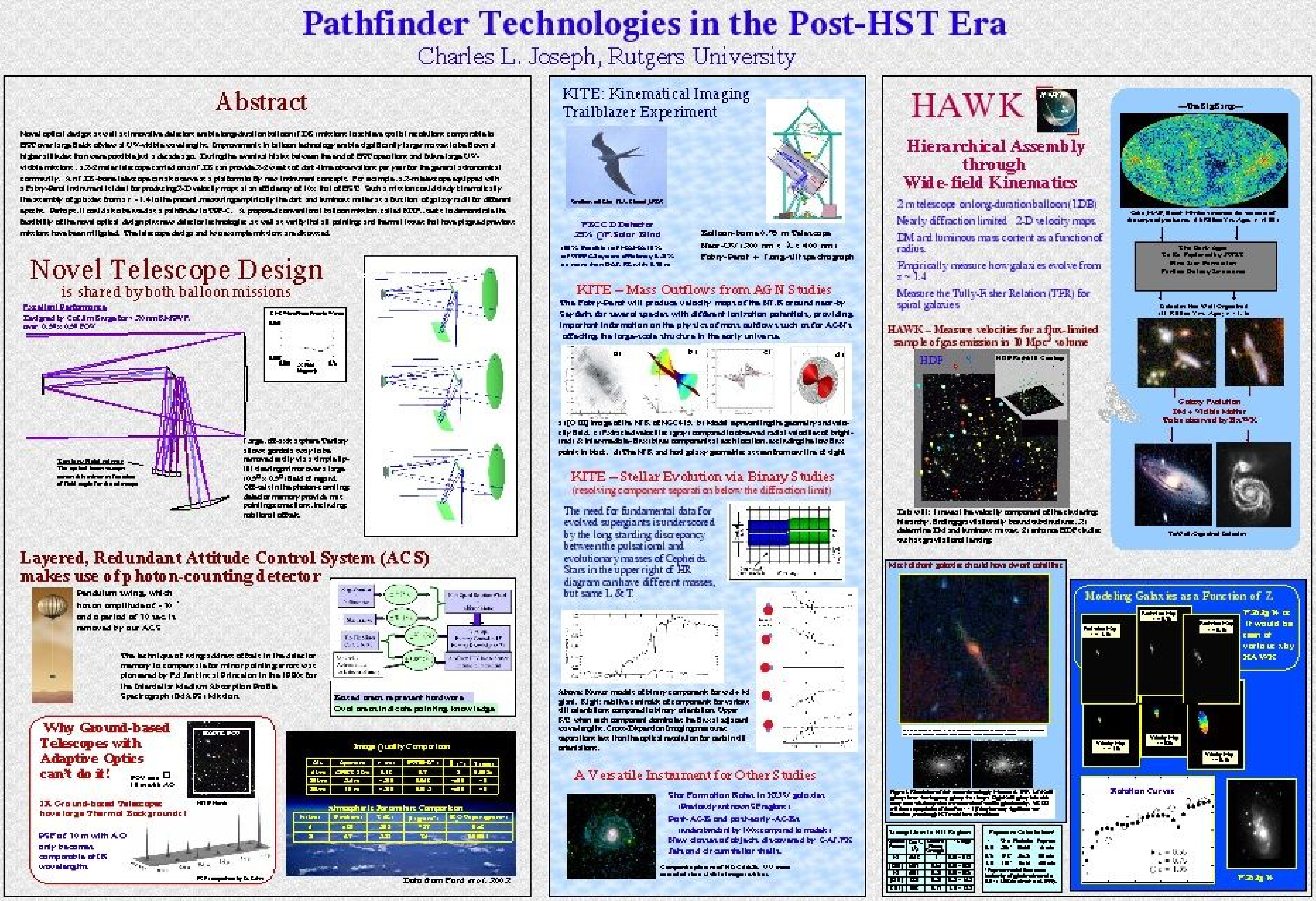
Proposed Balloon Missions, Charles L Joseph, PI

-- The Poster ---

(Various parts of the poster are expanded in the following slides.)



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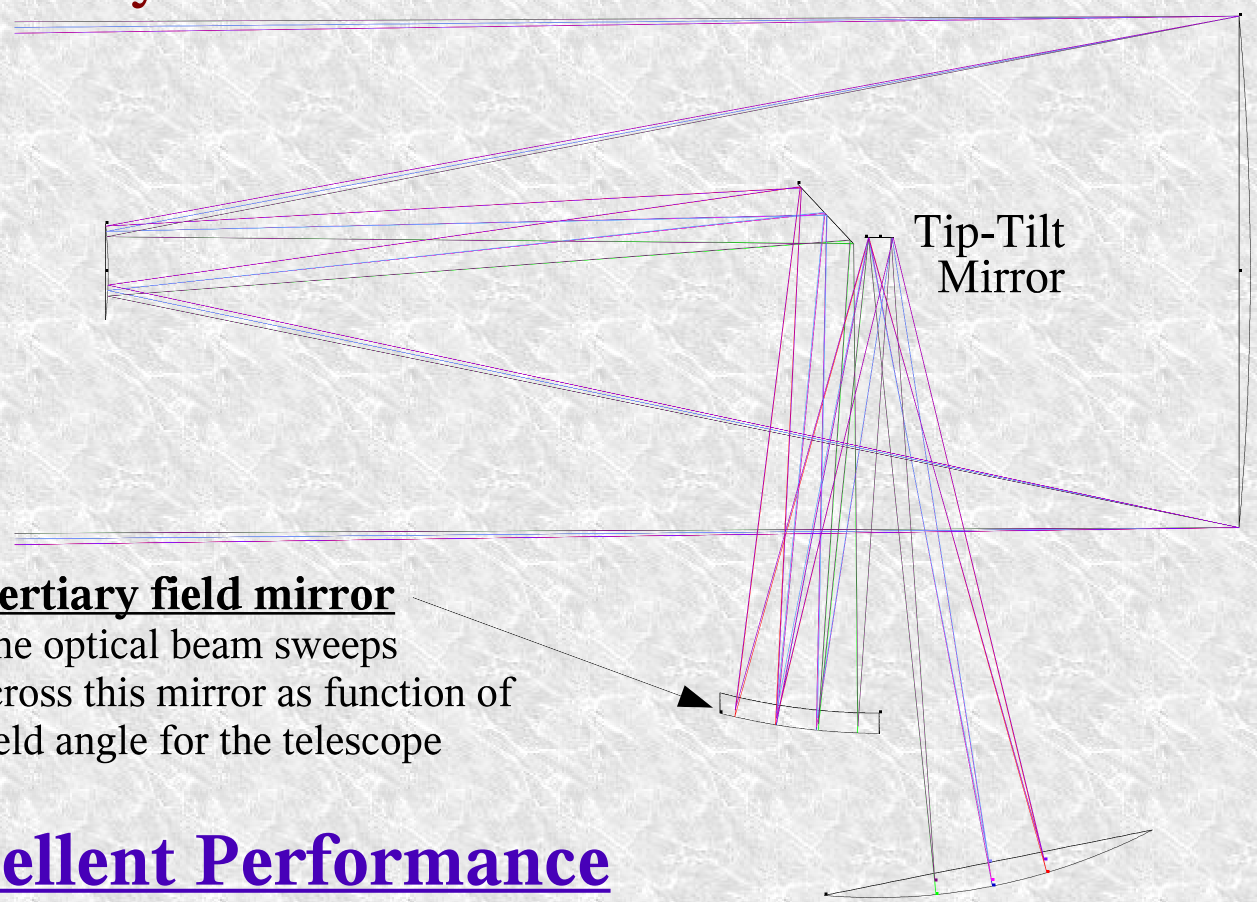
Pathfinder Technologies in the Post-HST Era -- Charles L. Joseph, Rutgers University

Abstract: Novel optical designs as well as innovative detectors enable long-duration balloon (LDB) missions to achieve spatial resolutions comparable to HST over large fields of view at UV-visible wavelengths. Improvements in balloon technology enable significantly larger masses to be flown at higher altitudes than were possible just a decade ago. During the eventual hiatus between the end of HST operations and future large UV-visible space missions, a 2-3 meter telescope carried on an LDB can provide 2-3 weeks of dark-time observations per year for the general astronomical community. An LDB-borne telescope can also serve as a platform to fly new instrument concepts. For example, a 3-m telescope equipped with an Integral Field Spectrograph and a Fabry-Perot instrument is ideal for producing 2-D velocity maps at an efficiency of 10x that of HST. Such a mission could study kinematically the assembly of galaxies from a z ~ 1.4 to the present, measuring empirically the dark and luminous matter as a function of galaxy radii for different epochs. Perhaps, it could also be used as a pathfinder to TPF-C. A proposed conventional balloon mission, called KITE, seeks to demonstrate the feasibility of the novel optical design plus new detector technologies, as well as verify that all pointing and thermal issues that have plagued previous missions have been mitigated. The telescope design and two example missions are discussed.

Novel Telescope Design
is shared by both balloon missions

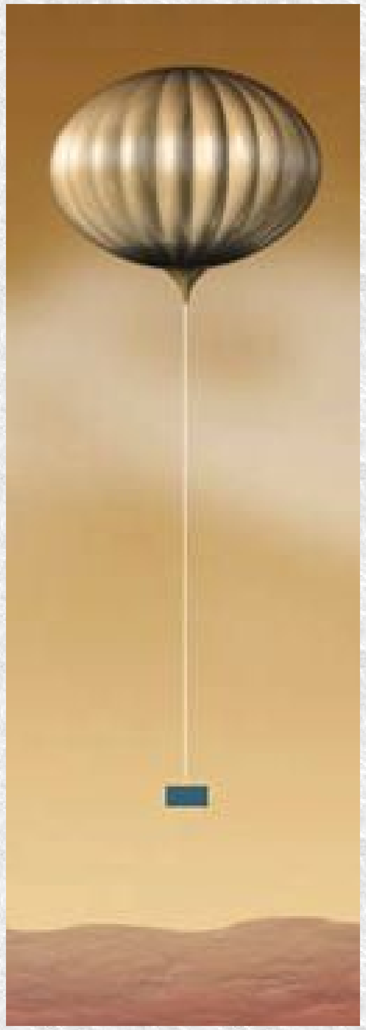


Tertiary field mirror
The optical beam sweeps across this mirror as function of field angle for the telescope

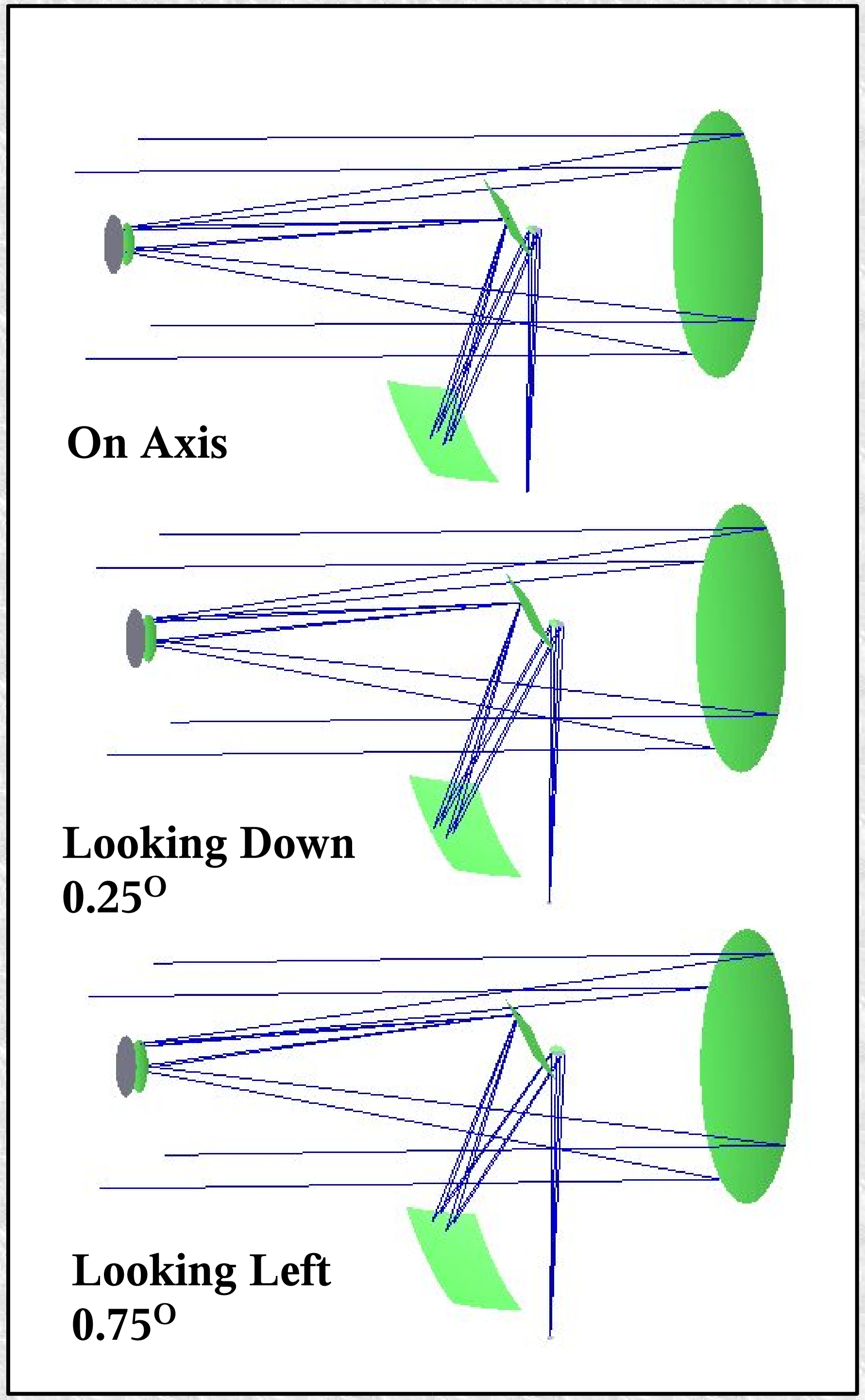
Excellent Performance

Designed by CoI Jim Burge for < 20 nm RMSWE over 1.5° x 0.5° FOV

Large, off-axis asphere Tertiary allows gondola sway to be removed easily via a simple tip-tilt steering mirror over a large (1.5^{O} x 0.5^{O}) field of regard. Off-sets in the photon-counting detector memory provide mas pointing corrections, including rotational offsets.



Pendulum swing, which has an amplitude of ~10’ and a period of 10 sec. is removed by our ACS



Advantages of being at Balloon Flotation Altitudes

Atmospheric Parameters vs. Altitude

h (km)	P (mbars)	T (^{O}K)	ρ (gm m^{-3})	H_2O Vapor(gm m^{-3})
4	680	253	937	0.68
28**	14.0	220	17.7	0.0003
35	4.7	222	7.4	0.0001

**Altitude for previous Missions (1965-1985)

Data from Ford *et al.* 2000

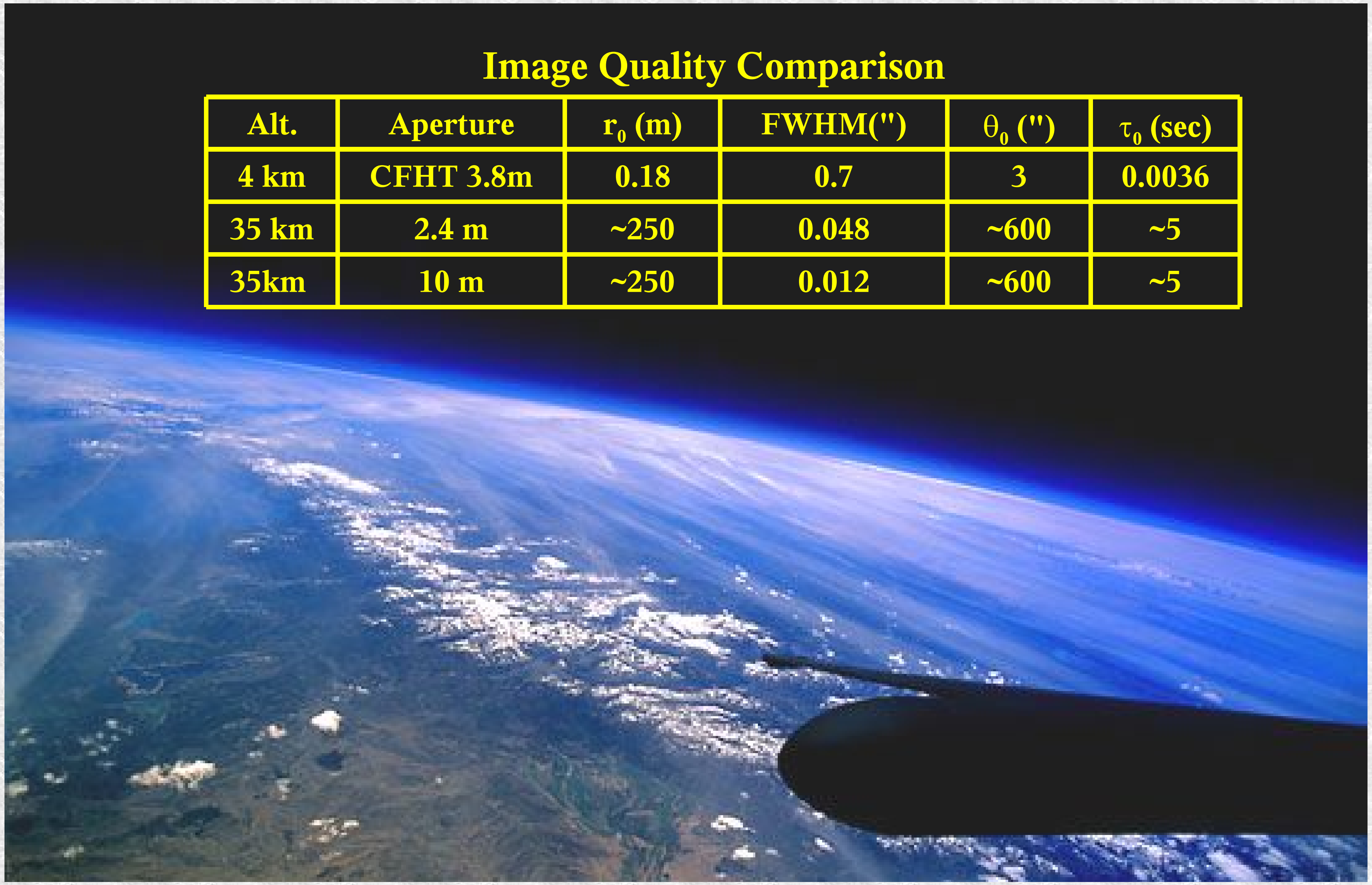


Image Quality Comparison

Alt.	Aperture	r_0 (m)	FWHM(")	θ_0 (")	τ_0 (sec)
4 km	CFHT 3.8m	0.18	0.7	3	0.0036
35 km	2.4 m	~250	0.048	~600	~5
35km	10 m	~250	0.012	~600	~5

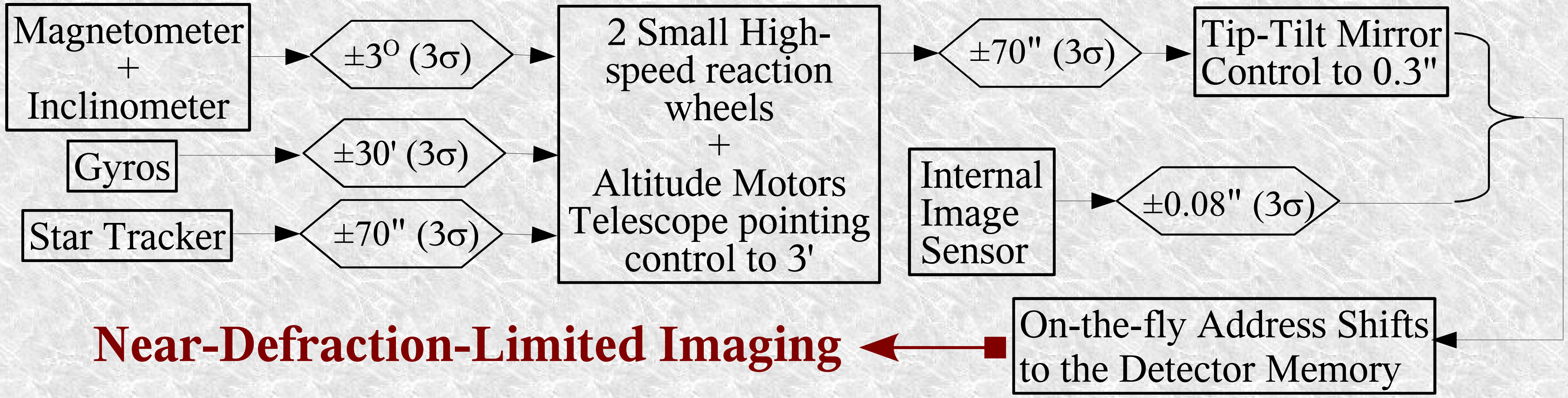
Balloon technology enables heavier payloads to fly at higher altitudes, allowing payloads named after predatory birds to soar!

New Flights:	35-37 km
Prev. Flights: (1965-1985)	23-28 km
U2 Spy Planes:	21 km

Picture out the window at 75,000 ft (left)

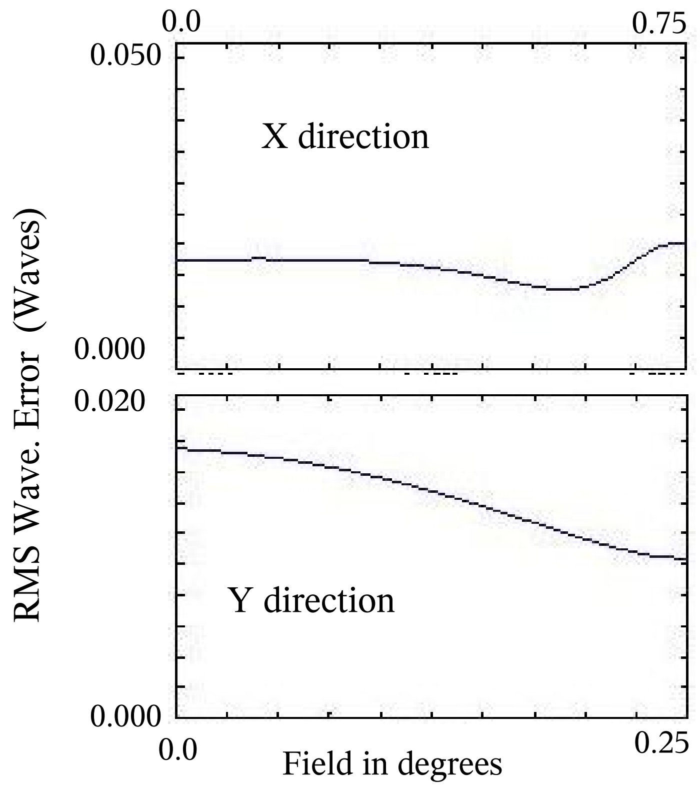
Note: time constants, τ_0, and coherence lengths, r_0 and θ_0, inferred from tables!

Layered, Redundant Attitude Control System (ACS) makes use of photon-counting detector



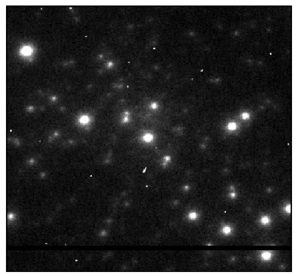
The technique of using address offsets in the detector memory to compensate for minor pointing errors was pioneered by Ed Jenkins at Princeton in the 1980s for the Interstellar Medium Absorption Profile Spectrograph (IMAPS) Mission.

Excellent wavefront quality (RMSWE < 20 nm) Over 1.5° x 0.5° Field of Regard

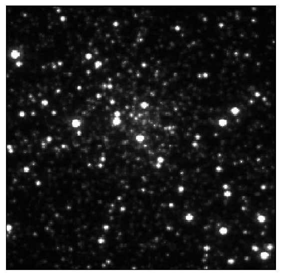


Why Ground-basedTelescopes with Adaptive Optics can't do it!

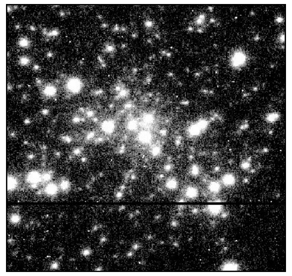
Telscope with AO fail for U, B,V, & Bluer



852 nm AO Image CFHT



HST Image



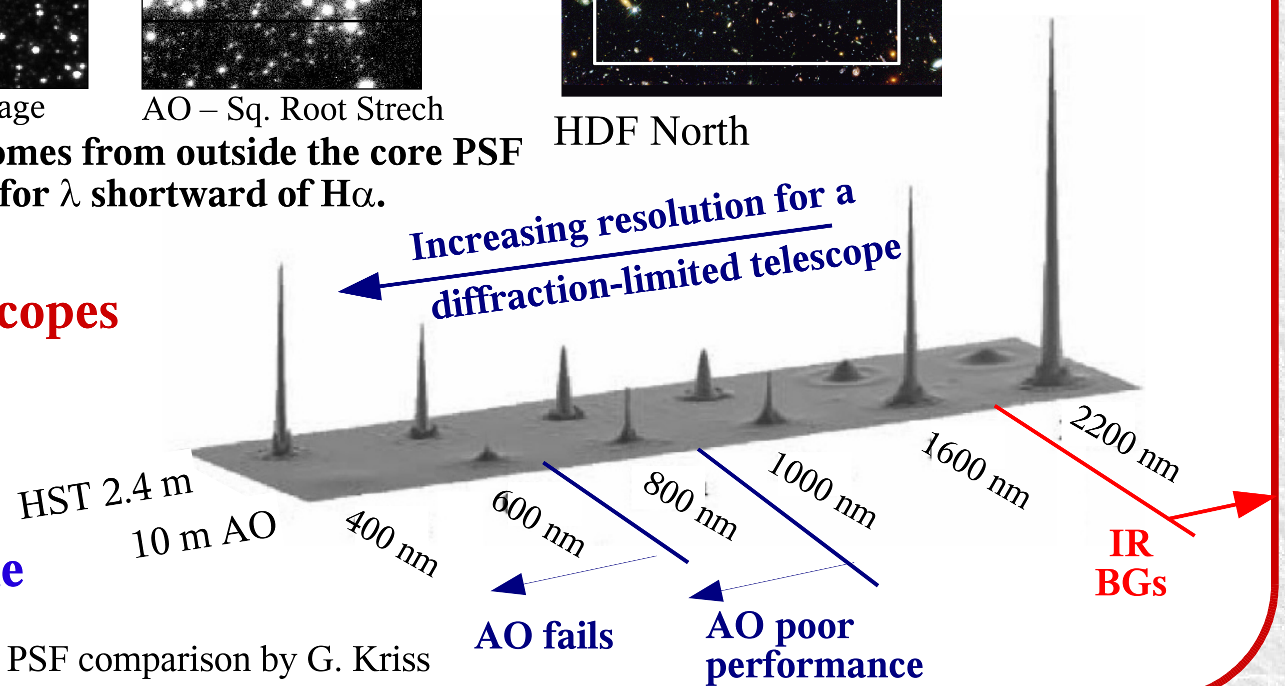
AO – Sq. Root Strech

HDF North

More than 90% contamination comes from outside the core PSF for λ < 852 nm. AO system fails for λ shortward of Hα. Gebhardt *et al.* 2000.

IR Ground-based Telescopes have very large Thermal Backgrounds!

PSF of 10 m with AO only become comparable at IR wavelengths



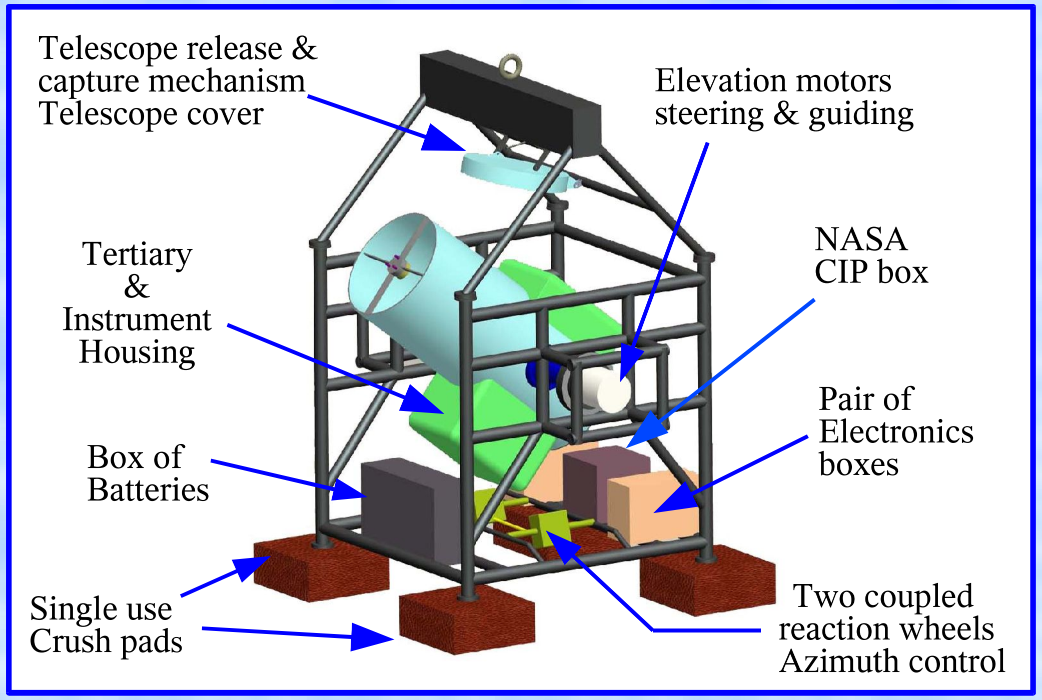
PSF comparison by G. Kriss

Swallow-tail Kite
D.A. Rintoul, USGS

KITE: Kinematical Imaging Trailblazer Experiment

A pathfinder mission to prove technologies.

Balloon-borne 0.75 m Telescope
Near-UV (200 nm < λ < 400 nm)
Instruments:
- **Integral Field Spectrograph**
- **Camera / Fabry-Perot**
- **Long-slit spectrograph**



Prime Science Objective:

O VI and Ly-α studies of Circumgalactic Ly-α Gas (“Ly-α Blobs” or LABs)

The Image Sensor Provides Enhanced Capabilities

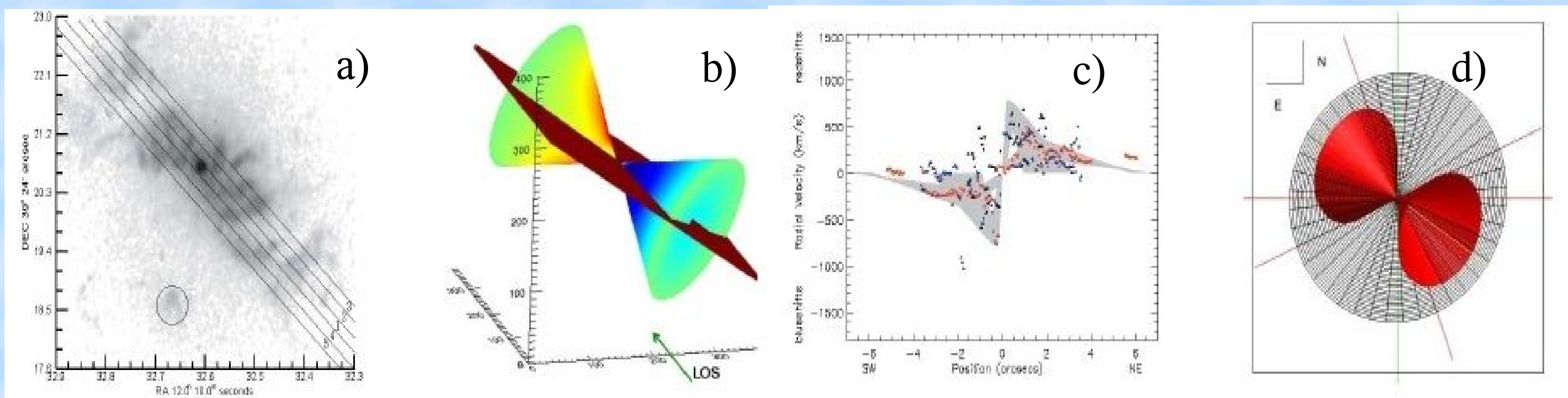
Photon-counter => address offsets to accumulating memory in real time. Critical for subarcsecond corrections & image rotation.

EBCCD Detector
25% QE Solar Blind

(50% Possible) c/f MAMA 10%
c/f WFPC2 system efficiency 0.25%
6x more than GALEX with 0.75 m

KITE – Mass Outflows from AGN Studies

The Fabry-Perot will produce velocity maps of the NLR around near-by Seyferts for several species with different ionization potentials, providing important information on the physics of mass outflows such as for AGNs affecting the large-scale structure in the early universe.



a) [O III] image of the NLR of NGC415. b) Model representing the geometry and velocity field. c) Extracted velocities (gray) compared to observed radial velocities of bright- (red) & inter-mediate-flux (blue) components at each location, excluding the low flux points in black. d) The NLR and host galaxy geometries as seen from our line of sight.

Swallow-tail Kite D.A. Rintoul, USGS

KITE: Kinematical Imaging Trailblazer Experiment

A pathfinder mission to prove technologies.

A Versatile Instrument for Other Studies

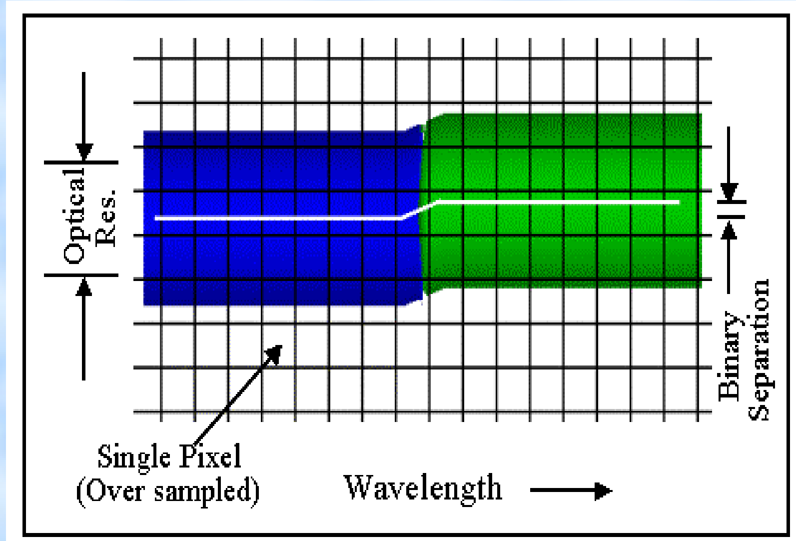
- **Star Formation Rates in XUV galaxies**
  (Previously unknown SF regions)
- **Post-AGB and post-early-AGBs**
  (underabundant by 100x compared to models)
- **New classes of objects discovered by GALEX**
- **Jets and circumstellar shells.**

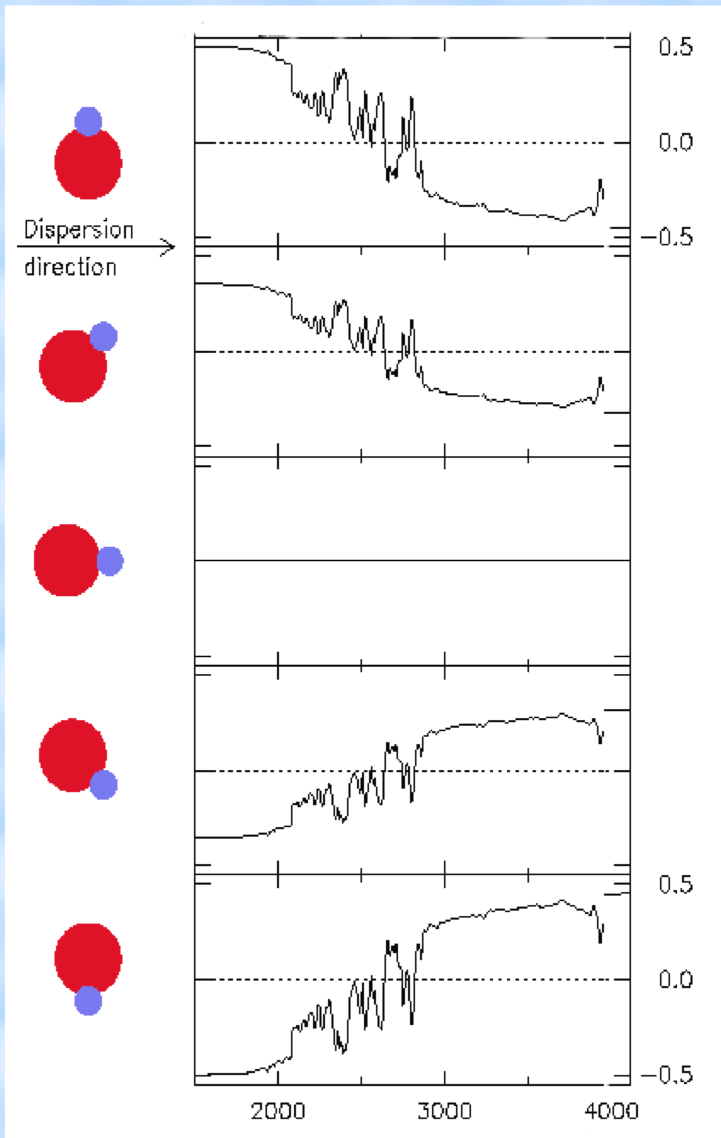
Composite picture of NGC 4625.
UV more extended than visible
image (white).

KITE – Stellar Evolution via Binary Studies

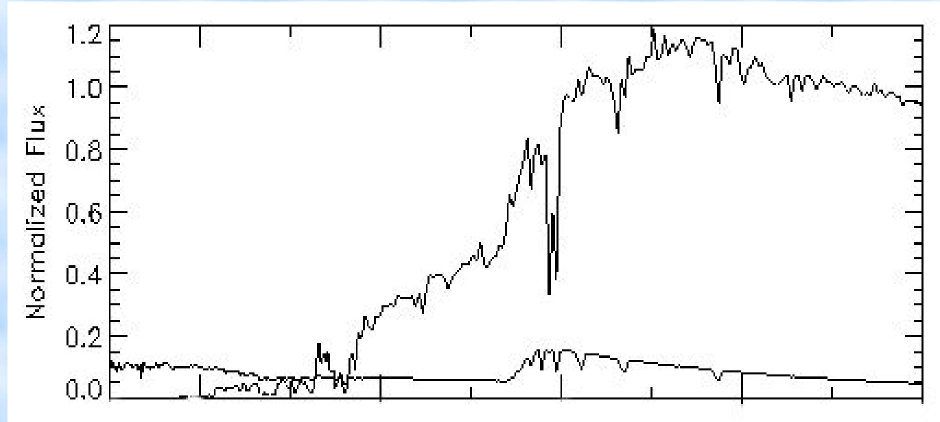
(resolving component separation below the diffraction limit)

The need for fundamental data for evolved supergiants is underscored by the long standing discrepancy between the pulsational and evolutionary masses of Cepheids. Stars in the upper right of HR diagram can have different masses, but same L & T.





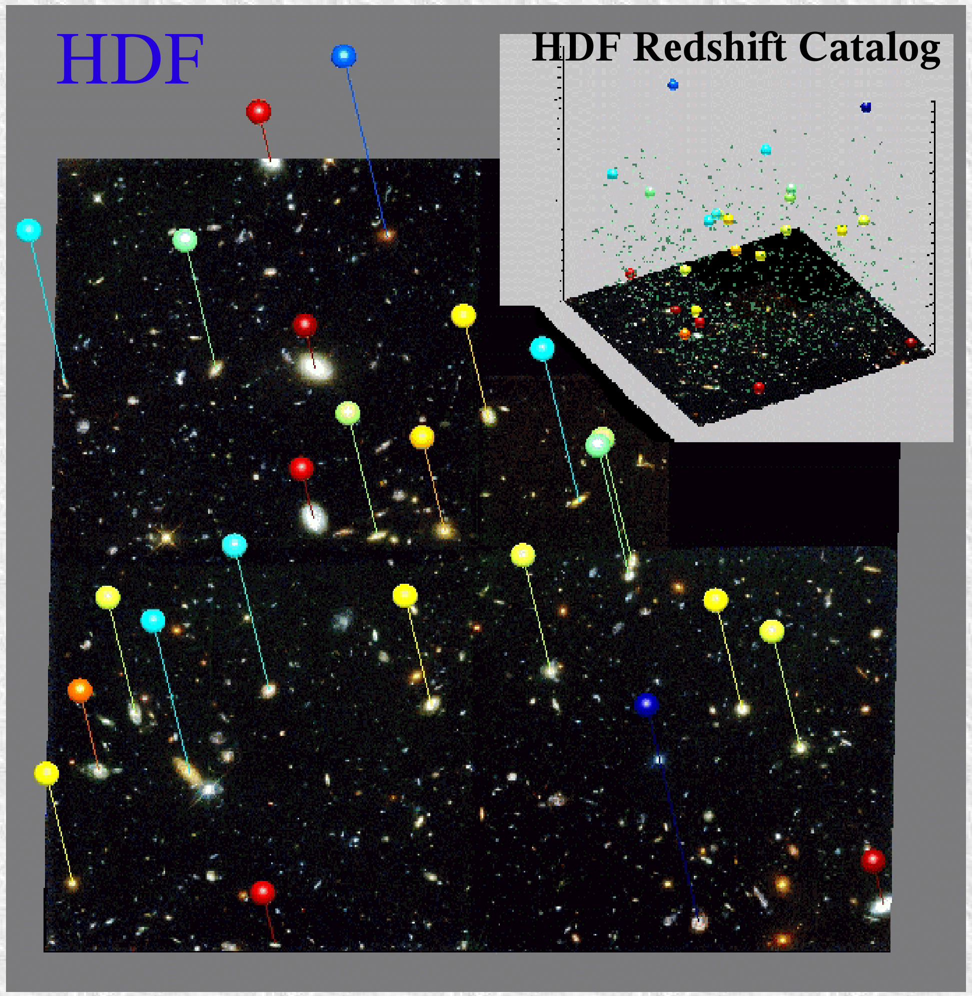
Upper Right: when each component dominates the flux at adjacent wave-lengths, Cross-Dispersion Imaging measures separations less than the optical resolution for certain slit orientations. Left relative centroids of components for various slit orientations compared to binary orientation. Below: Kurucz models of binary components for wd + M giant.



HAWK

Hierarchical Assembly through Wide-field Kinematics

HAWK – Measure velocities for a flux-limited sample of gas emission in 10 Mpc^3 volume



100x more componets picked up than HST!

A Community Facility in the post-HST era?

3-4 m telescope on long-duration balloon (LDB) provides 2-3 weeks per year observing time

Nearly diffraction limited 2-D velocity maps and Imaging.

DM and luminous mass content as a function of radius.

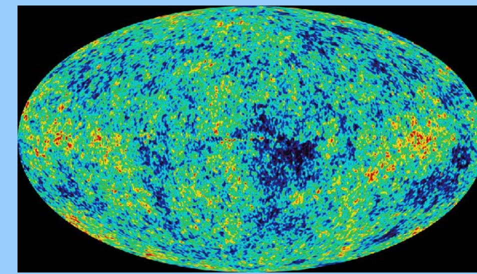
Empirically measure how galaxies evolve from z ~ 1.4

Measure the Tully-Fisher Relation (TFR) for spiral galaxies

Ideal instrument to study a wide range of issues on AGN & nebulea

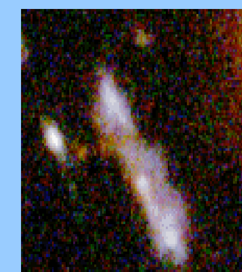
The HAWK data will: 1) reveal the velocity component of the clustering hierarchy, finding gravitationally bound substructures. 2) determine DM and luminous masses as a function of galaxy radii and redshift. 3) enhance HDF studies such as gravitational lensing.

---The Big Bang ---



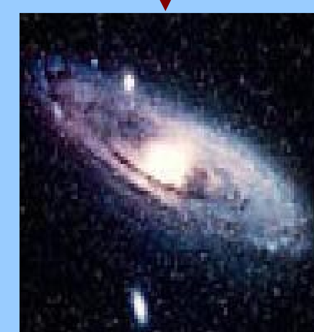
Cobe, MAP, Planck Missions measure the structure of the very early universe. (15 Billion Yrs. Ago. z > 100)

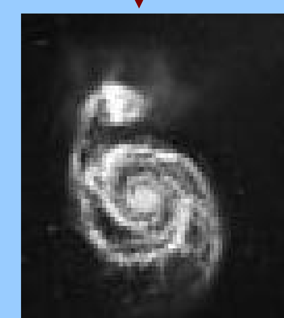
The Dark Ages
To Be Explored by JWST
First Star Formation
Earliest Galaxy Structures



Galaxies Not Well Organized (11 Billion Yrs. Ago; z ~ 1.5)

Galaxy Evolution
DM + Visible Matter
To be observed by HAWK

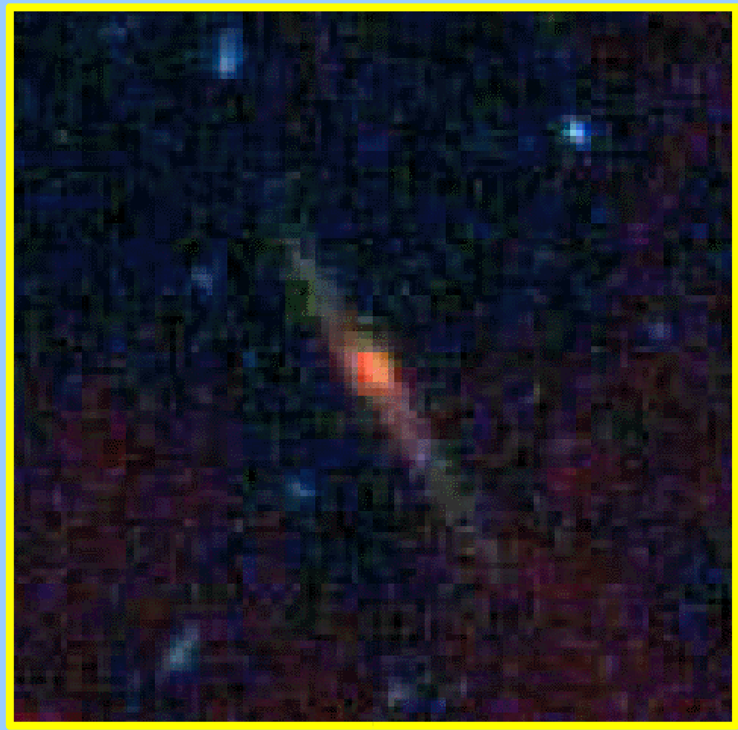




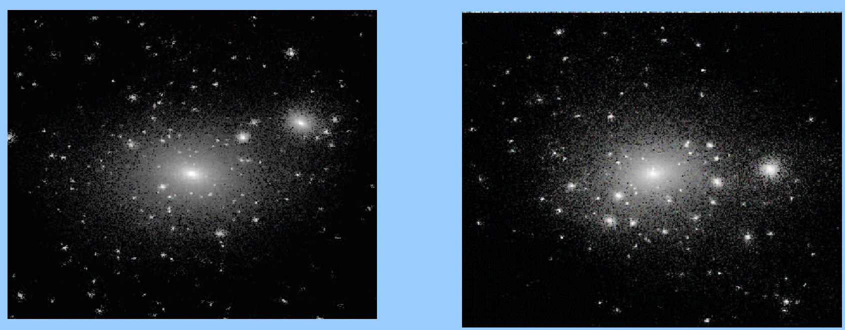
To Well-Organized Galaxies

Pathfinder Technologies in the Post-HST Era -- Charles L. Joseph, Rutgers University

Most large galaxies should have more dwarf satellites

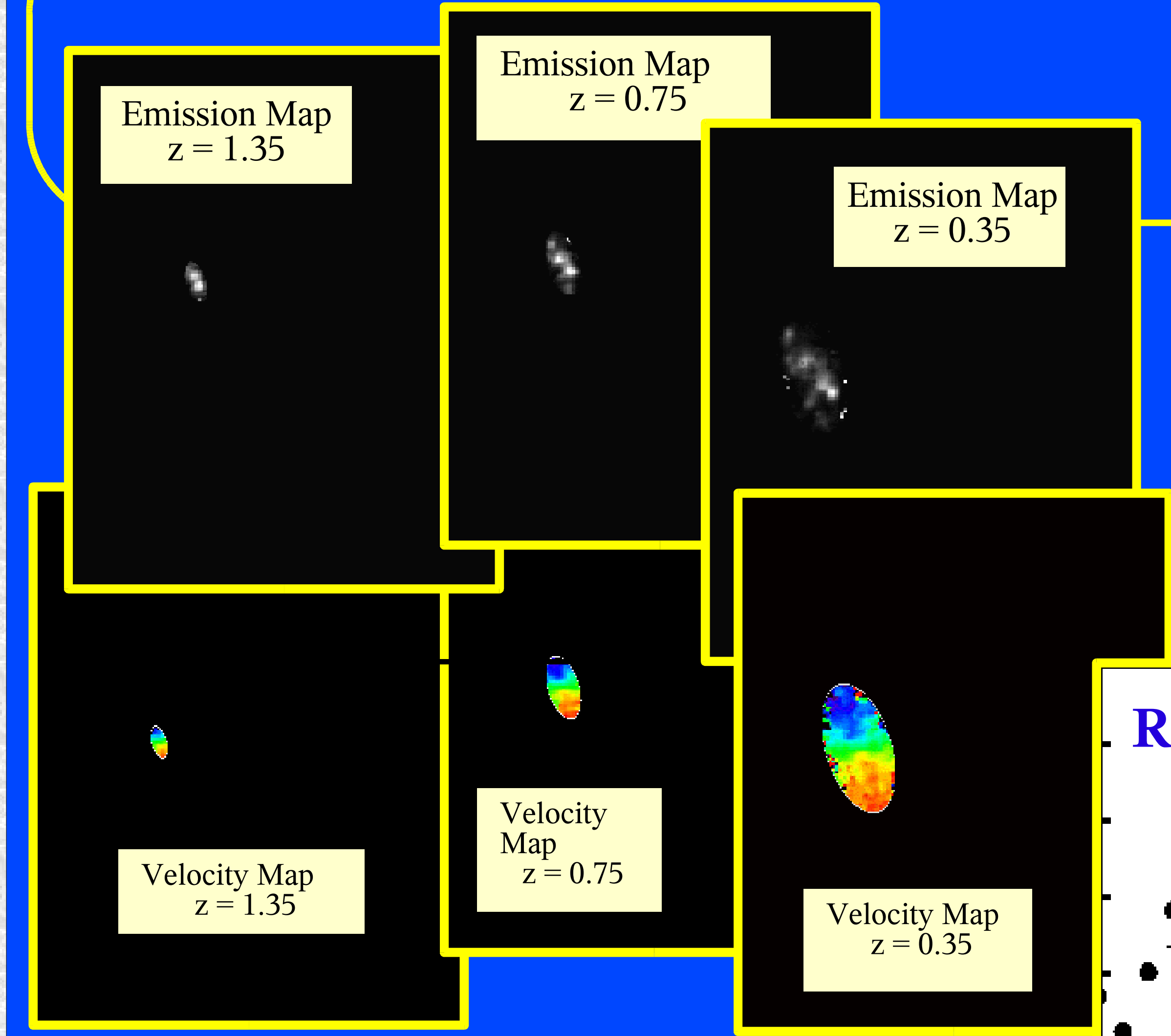


GSS-104-4024 (z=0.81). HST/NICMOS+WFPC2 A rare high-redshift galaxy showing the satellite dwarfs predicted by models. (Data taken by N. Vogt.)



Simulations of dark matter clustering by Moore et al. 1999. Left: galaxy cluster showing many galaxy-size clumps. Right: galaxy halo with many more sub-clumps than are seen as dwarf satellite galaxies today. HAWK will detect a population of dwarfs at z ~ 1, if they have any significant star formation, even though HST would have missed them.

Modeling Galaxies as a Function of z



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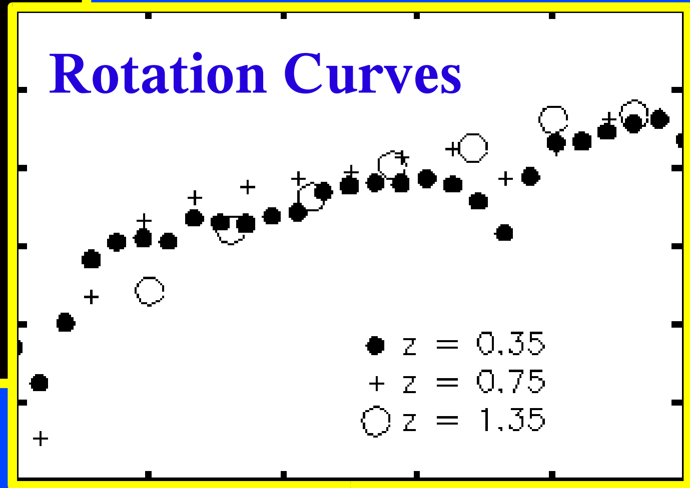

Internal rotational velocities can be measured for 0 < z < ~ 1.4

Exposure Calculations*

z	Size	Pixelation	Exposure
0.35	2.65”	50x50	45 min
0.75	1.93”	25x25	180 min
1.35	1.30”	16x16	630 min

*Exposures scaled from mean luminosity of galaxies observed at 0.8<z<1.0 (Glazebrook et al. 1999).

Strong Lines in H II Regions

Spectral Feature	Rest λ (Å)	Relative Photon Strength	z Range
H I	6563	1	0.00 – 0.37
[O III]	5007	0.56	0.00 – 0.80
H I	4861	0.24	0.00 – 0.85
[O II]	3727	0.21	0.21 – 1.42
C III]	1908	0.17	1.36 – 3.72