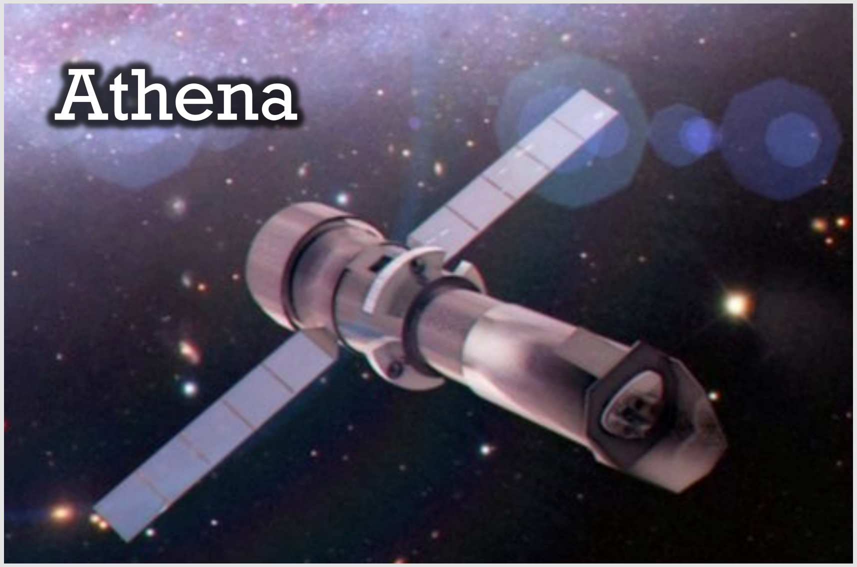
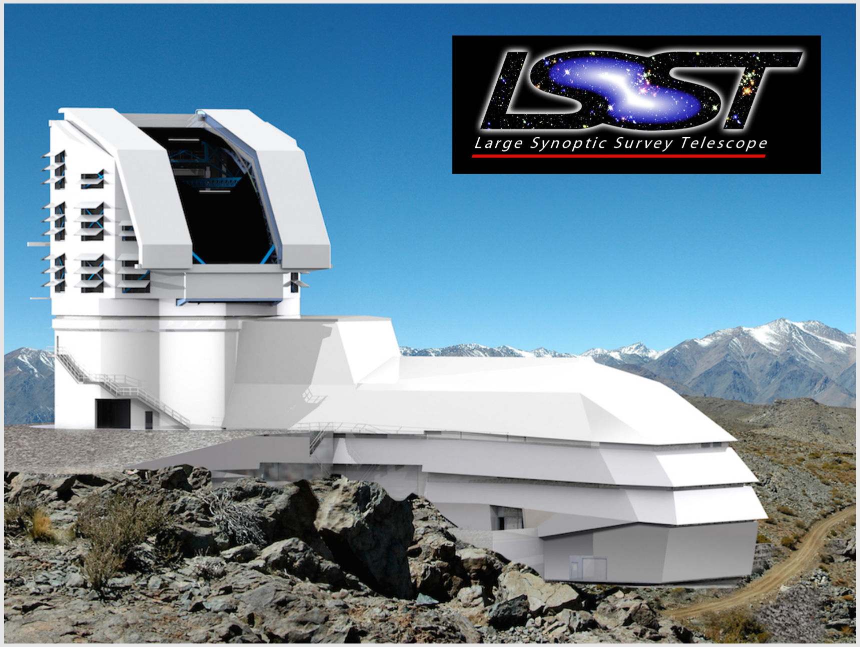
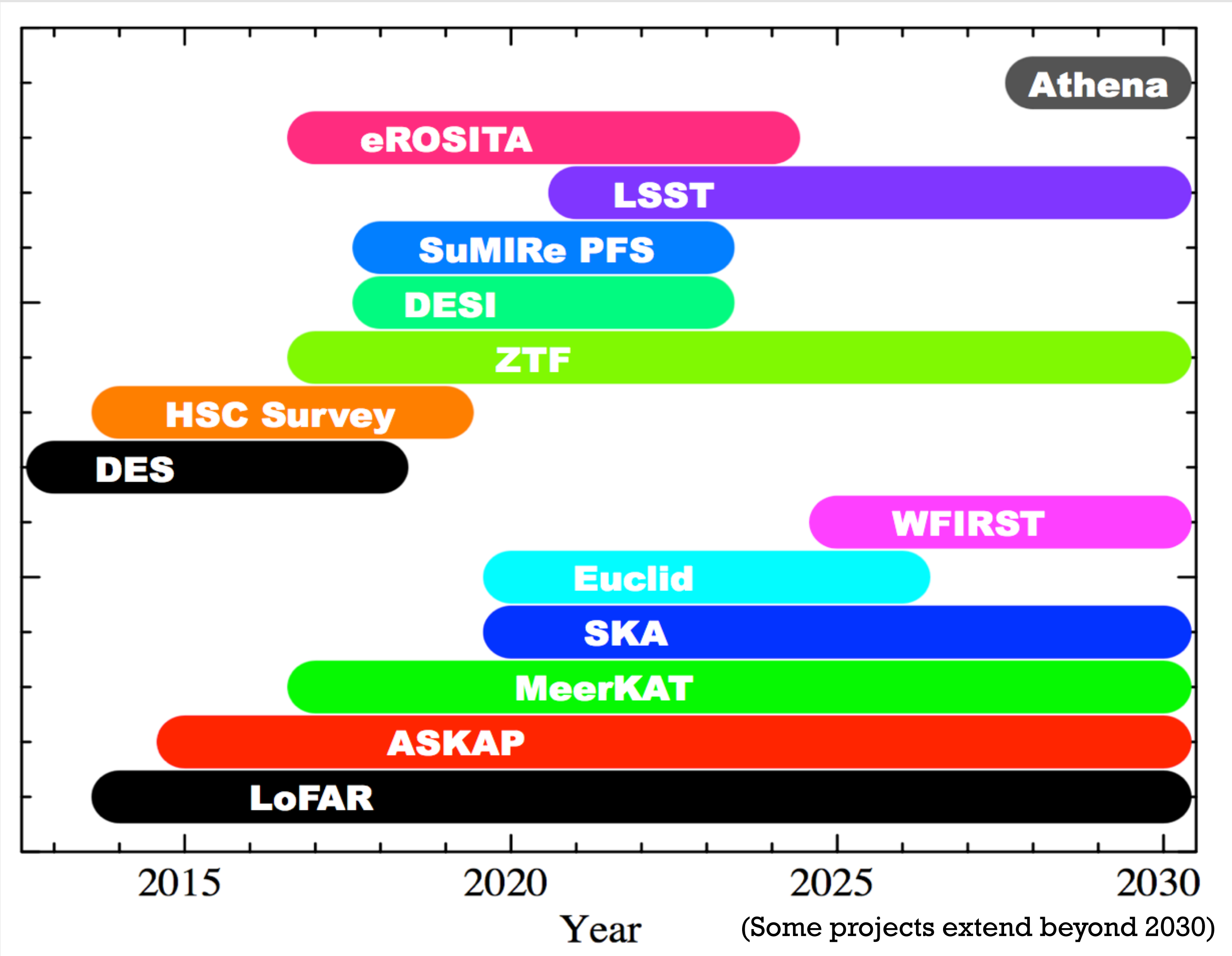
The Landscape of Large Sky Surveys in the Athena Era

Niel Brandt (Penn State)





Some Future Large Survey Projects Out to 2030



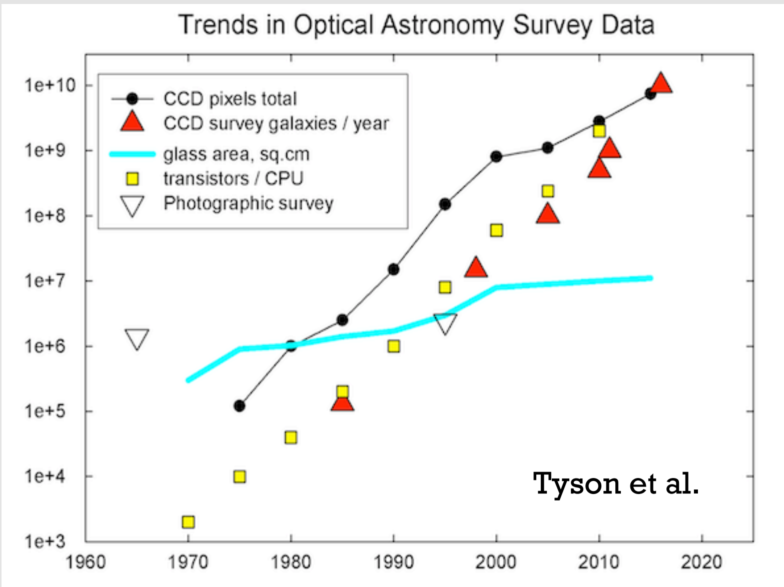
A real challenge to forecast out this far!

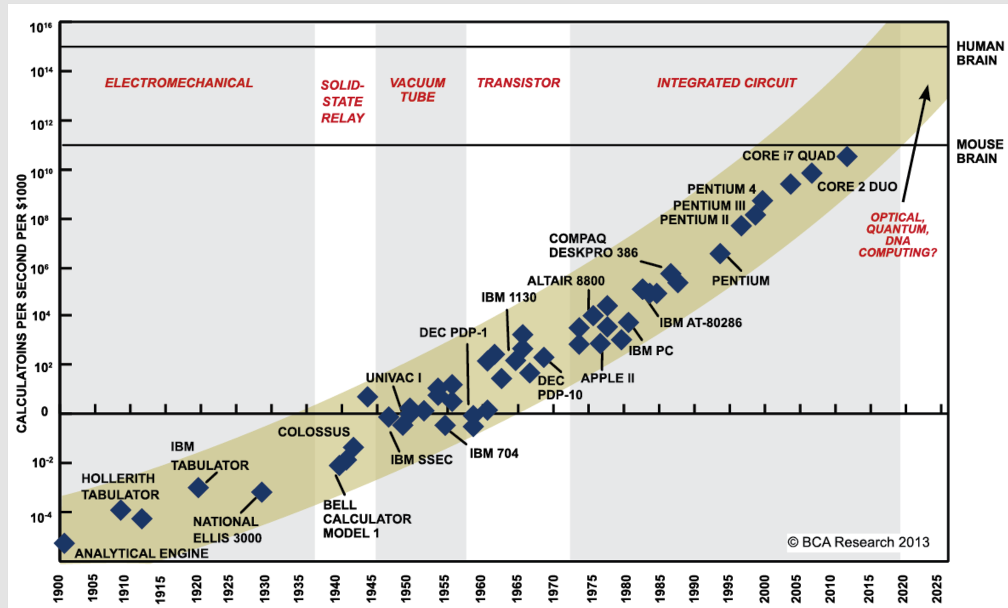
Many exciting future projects will have come and gone by the time of the Athena launch.

LSST should be a substantial fraction of the way through its 10-year survey.

And new projects, yet unknown, will have started!

Tech for a 2028 Athena Launch





Gpix astronomical cameras allowing Ggal surveys.

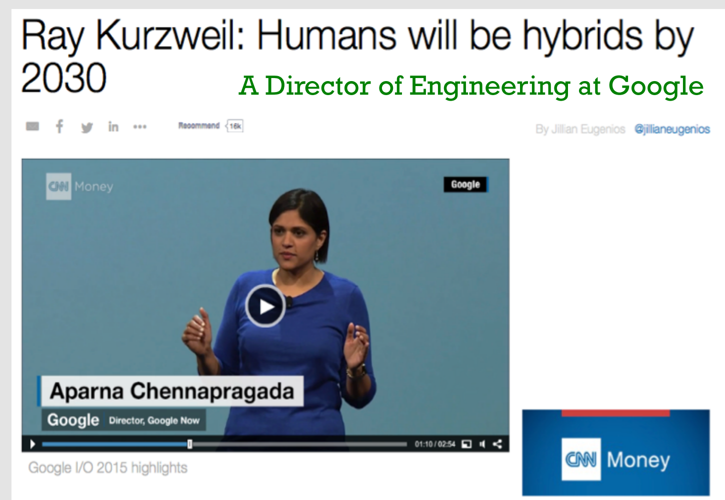
iPhone 14 as powerful as your current desktop.

$10-100 genome sequencing – personalized medicine transformation.

Direct brain-to-cloud connections?

Nanotech-based manufacturing?

AI passes the Turing Test?

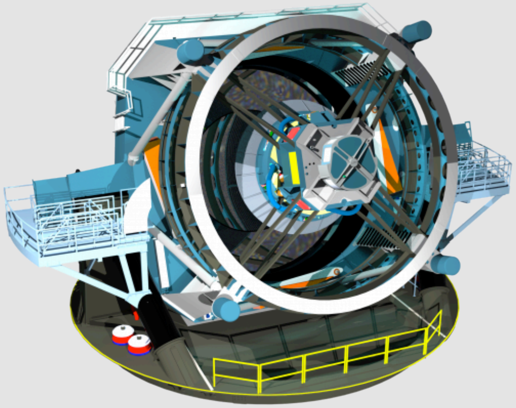


Outline

LSST (and Friends)

Other Large Sky Surveys

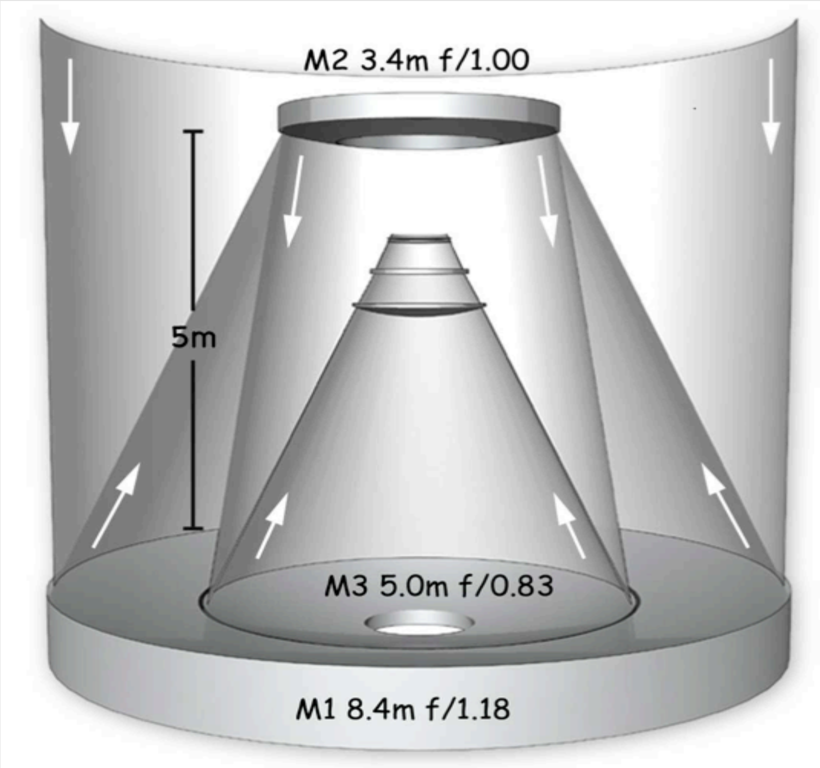
LSST
Large Synoptic Survey Telescope



Quick Overview, Current Status, and Some Athena Connections

LSST: Very Brief Summary

A public optical/NIR survey of ~ half the sky in the *ugrizy* bands to *r* ~ 27.5 based on ~ 820 visits over a 10-year period.



8.4 m, 6.7 m effective - 10 deg^2 - 3.2 Gpix camera

Wide
The observable southern sky. Each exposure covers 50 full Moons.

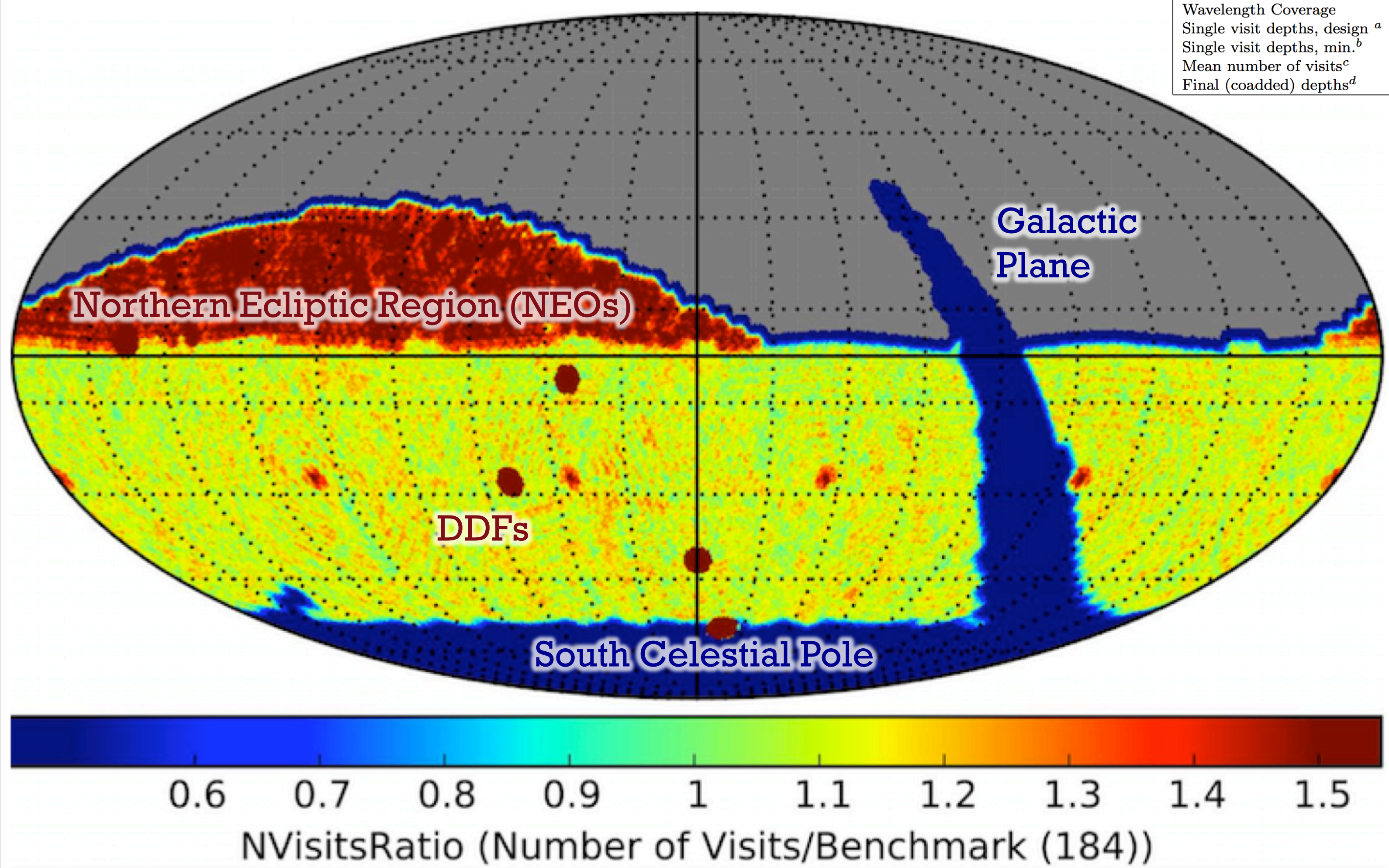
Deep
10-100 times deeper than other very wide-field surveys.

Fast
Rapidly scans the sky with 15 sec exposures, providing a color movie of objects that change or move. Whole observable sky scanned every 3-4 nights.

See arXiv:0805.2366 for more details.

Main Survey - Brief Details

Operations Simulation of *r*-Band Visits



THE LSST BASELINE DESIGN AND SURVEY PARAMETERS

Quantity	Baseline Design Specification
Optical Config.	3-mirror modified Paul-Baker
Mount Config.	Alt-azimuth
Final f-ratio, aperture	f/1.234, 8.4 m
Field of view, étendue	9.6 deg^2, 319 $m^2 deg^2$
Plate Scale	50.9 μm/arcsec (0.2" pix)
Pixel count	3.2 Gigapix
Wavelength Coverage	320 – 1050 nm, *ugrizy*
Single visit depths, design [a]	23.9, 25.0, 24.7, 24.0, 23.3, 22.1
Single visit depths, min.[b]	23.4, 24.6, 24.3, 23.6, 22.9, 21.7
Mean number of visits[c]	56, 80, 184, 184, 160, 160
Final (coadded) depths[d]	26.1, 27.4, 27.5, 26.8, 26.1, 24.9

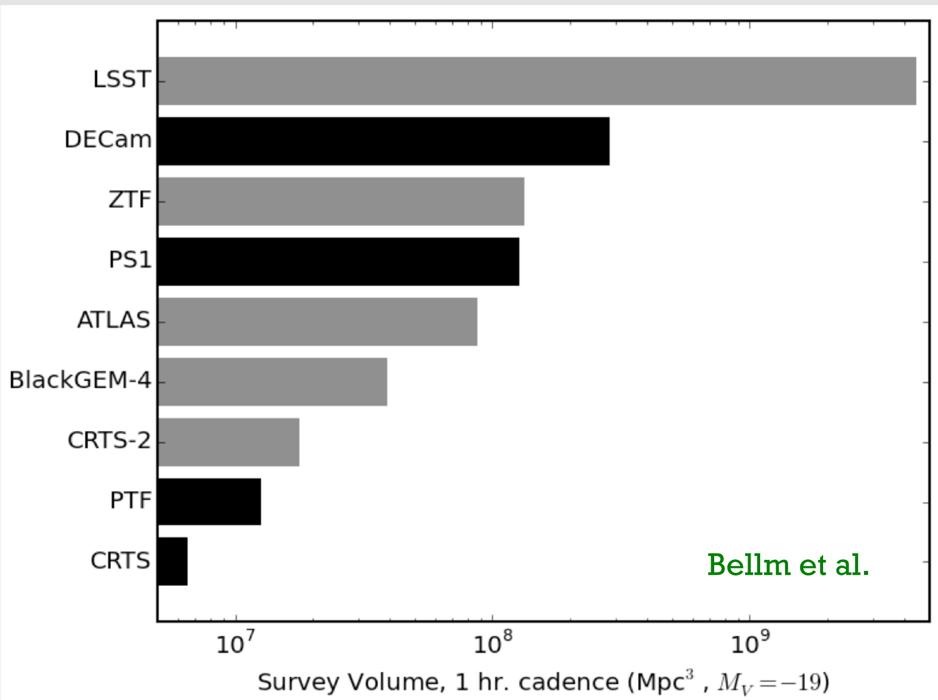
Main survey optimized for homogeneity of depth and number of visits.

Uses 90% of LSST's time.

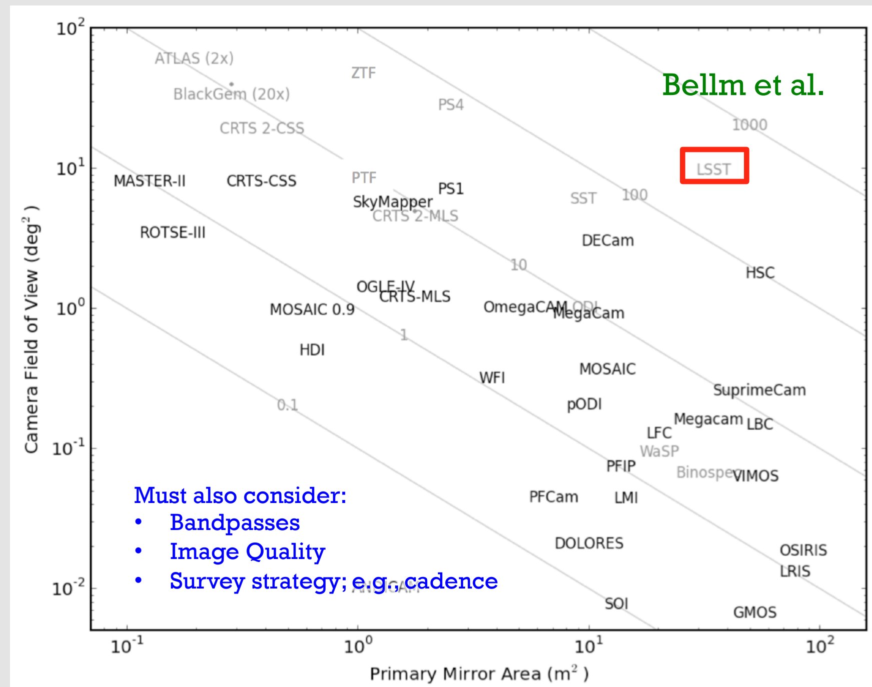
10% for other cadence programs; e.g., Deep Drilling Fields.

Surveying Massive Cosmic Volumes

$10^{9.5}$ Mpc^3 per Hour



Étendue Comparison

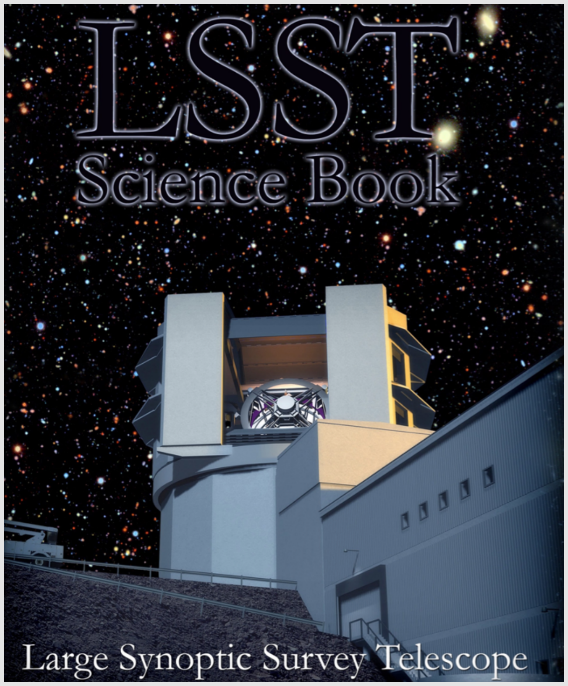


Above an étendue of 200-300 m^2 deg^2 it becomes possible to undertake a single comprehensive multi-band survey of the entire visible sky serving most science opportunities, rather than multiple special surveys in series.

LSST Science Themes

Dark matter, dark energy, cosmology
(e.g., spatial distribution of galaxies, gravitational lensing, supernovae, quasars)

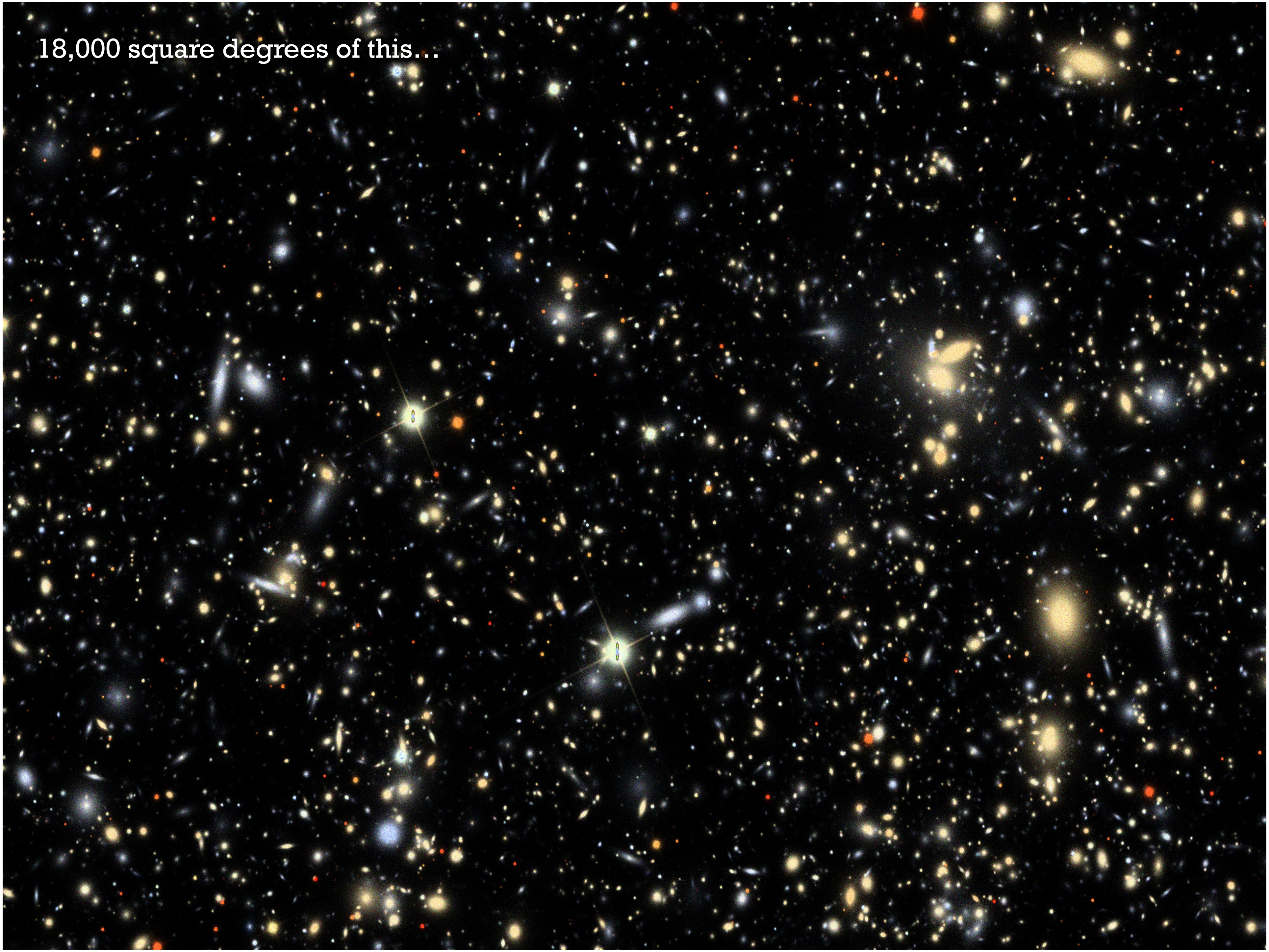
Time-domain astrophysics
(e.g., SMBHs, compact objects, cosmic explosions, variable stars)

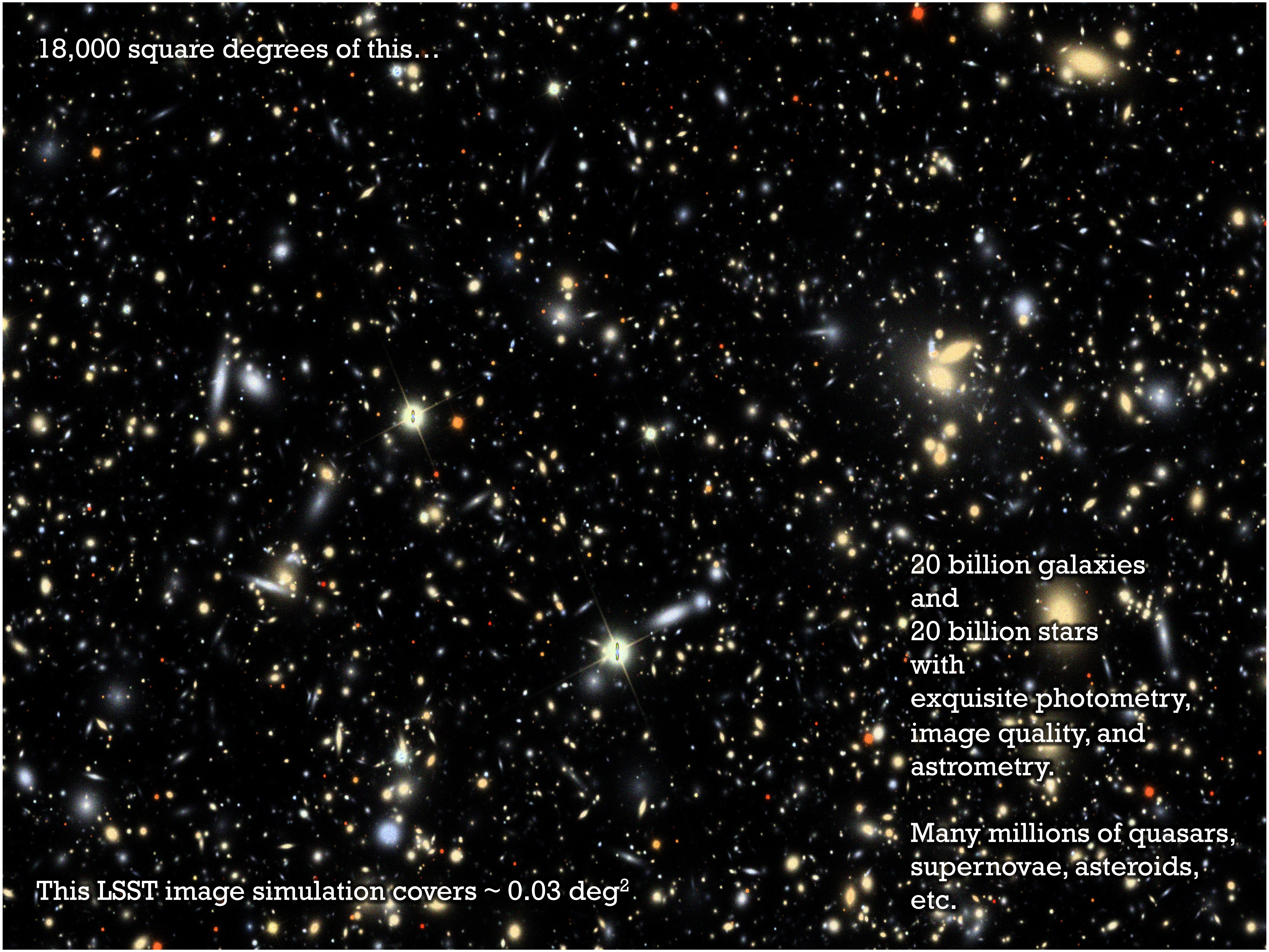


596 pages!

Solar System structure
(e.g., near-Earth asteroids, trans-Neptunian objects)

Milky Way structure
(e.g., stars, star-formation regions, tidal streams)


18,000 square degrees of this…


18,000 square degrees of this…
20 billion galaxies
and
20 billion stars
with
exquisite photometry,
image quality, and
astrometry.
Many millions of quasars,
supernovae, asteroids,
etc.
This LSST image simulation covers ~ 0.03 deg²

Project Status and a Few Updates

Received Federal construction start in 2014 Aug as NSF/DOE project.

Primary/tertiary mirror polishing completed in 2015 Feb. Secondary mirror at Exelis for processing to finished polished state.

Camera construction can begin now that "Critical Decision 3" review passed in 2015 August.

Dome contract initiated.

Site leveled and preparation in progress.

LSST Project actively hiring engineering and science staff.

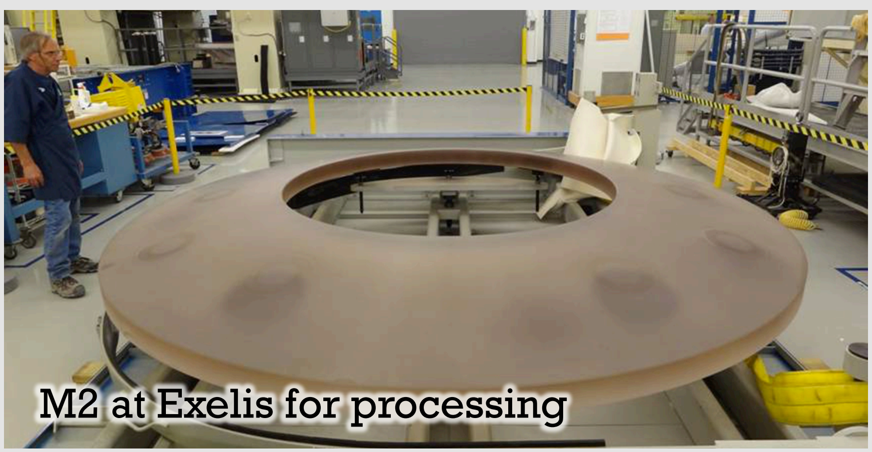
Onset of science operations planned for late 2022 (2019 first light).

Current Project Status

M1M3 after polishing - moved to storage at Tucson International Airport

Members of the CD-3 Review Committee gathered with the members of the LSST Camera Team at the CD-3 Review held at Brookhaven National Laboratory on August 4-6, 2015. Image credit: LSST Project Office

Site bedrock testing in 2015 June



M2 at Exelis for processing

LSST AGN Selection

Multicolor selection in *ugrizy* from $z = 0\text{-}7.5$

- Ultraviolet excess below $z \sim 2.5$
- Lyman-α forest at high redshifts
- Works best when $L_{\rm AGN} > L_{\rm Host}$

Variability

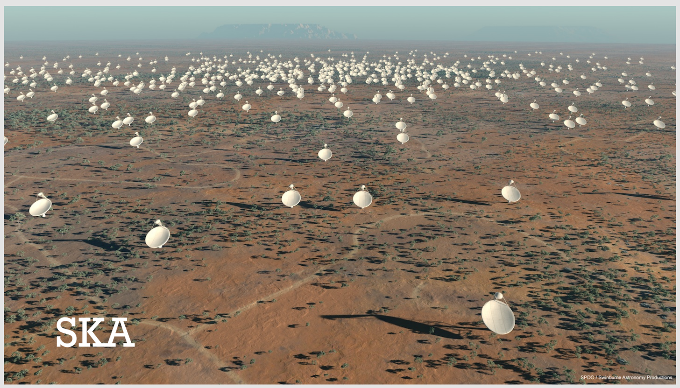
- 55-185 samplings per band over 10 yr
- Highly effective complement to color selection
- Still need effectiveness assessments when $L_{\rm AGN} \sim L_{\rm host}$

Astrometry - Lack of proper motion and differential chromatic refraction

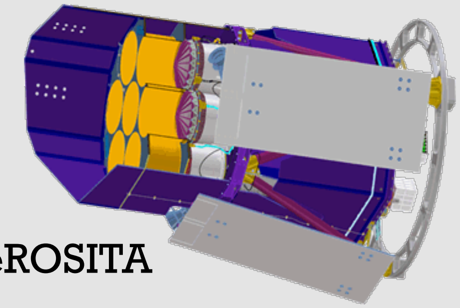
- Will reach ~ 1 mas $\rm yr^{-1}$ at $r \sim 24$
- Minimizes confusion with stars

Multiwavelength AGN Selection

L_R, T_b, morphology

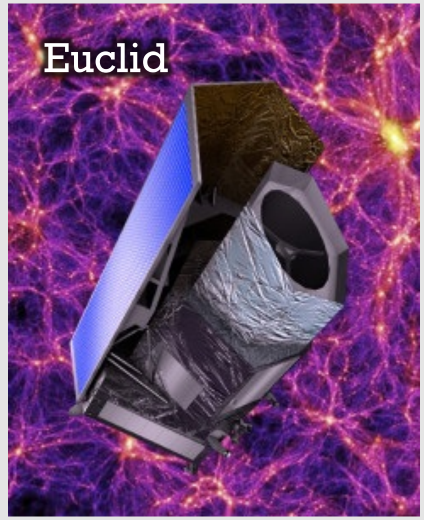


L_X and Γ_X



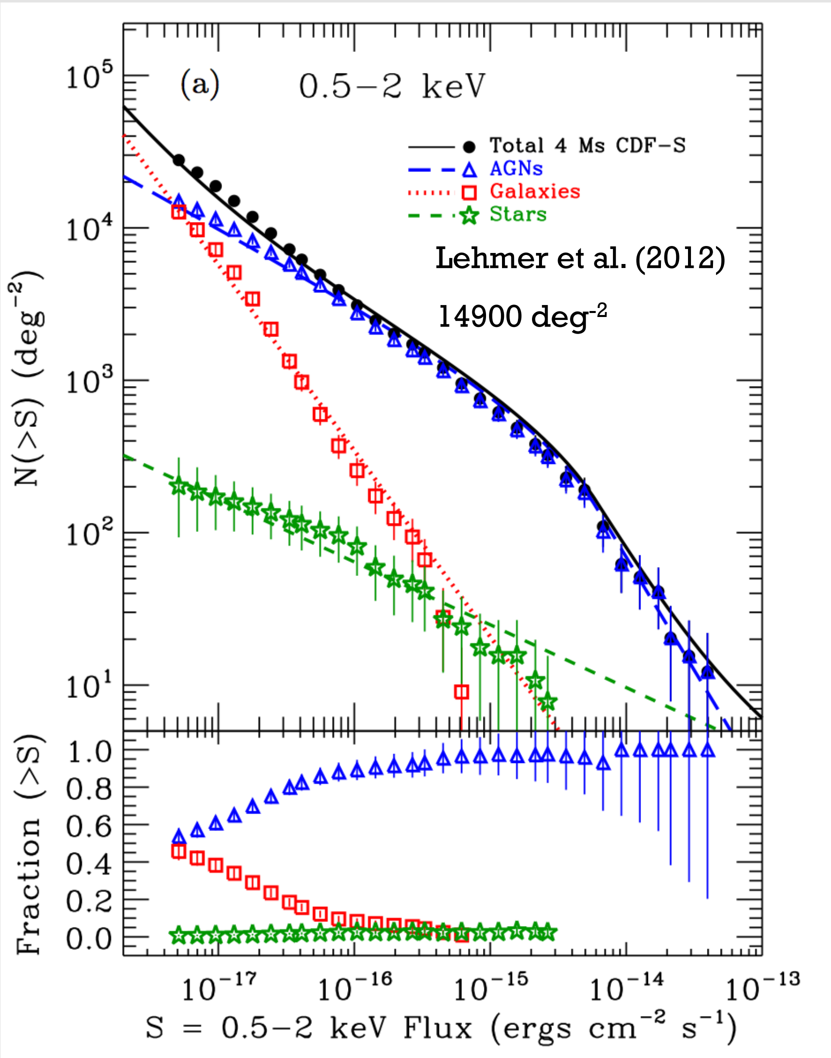
eROSITA

Infrared-optical colors



Plausible AGN Yields

Chandra Deep Field-South Number Counts



Will have detections for 270 million AGNs in 18,000 deg^2 primary LSST survey area.

Obscuration and host-galaxy dilution will hinder AGN selection.

Confidently can select 20 million.

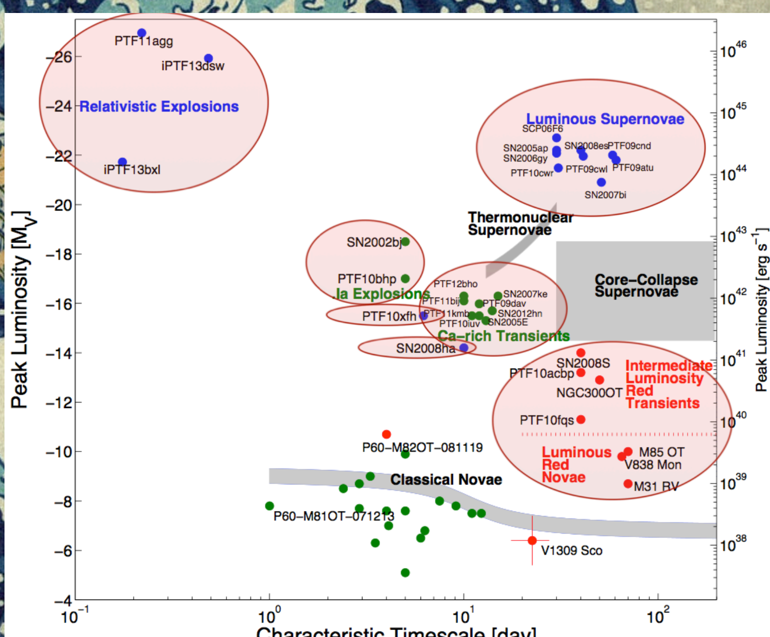
Hope to select 50 million+, especially using multiwavelength data.

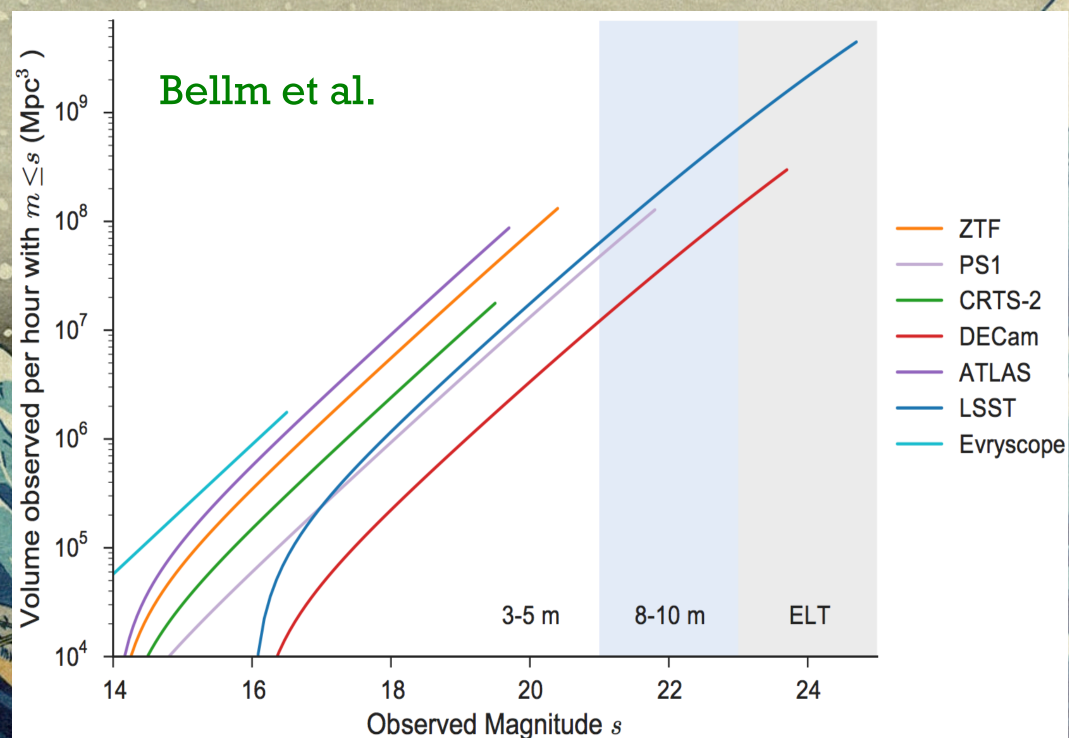
Many excellent AGN targets for Athena within the LSST sample.

The Optical Transients Flood from LSST and Other Facilities

Athena throughput needed for effective X-ray spectroscopy of many transients.

Very important that the agility of the current Athena design is maintained or even improved.





Nightly LSST SMBH Science

Monitoring of ~ 3 million AGNs for massive variability studies.

Discovery of ~ 50 large AGN flares
(e.g., blazars and accretion-disk instabilities).

Discovery of ~ 3 stellar tidal disruption events.

Discovery of ~ 0.1 strong quasar microlensing events.

Binary SMBH inspirals and mergers?

Also ~ 2500 supernovae and ~ 0.2 "orphan" GRB afterglows.

More than enough to saturate Athena!

Outline

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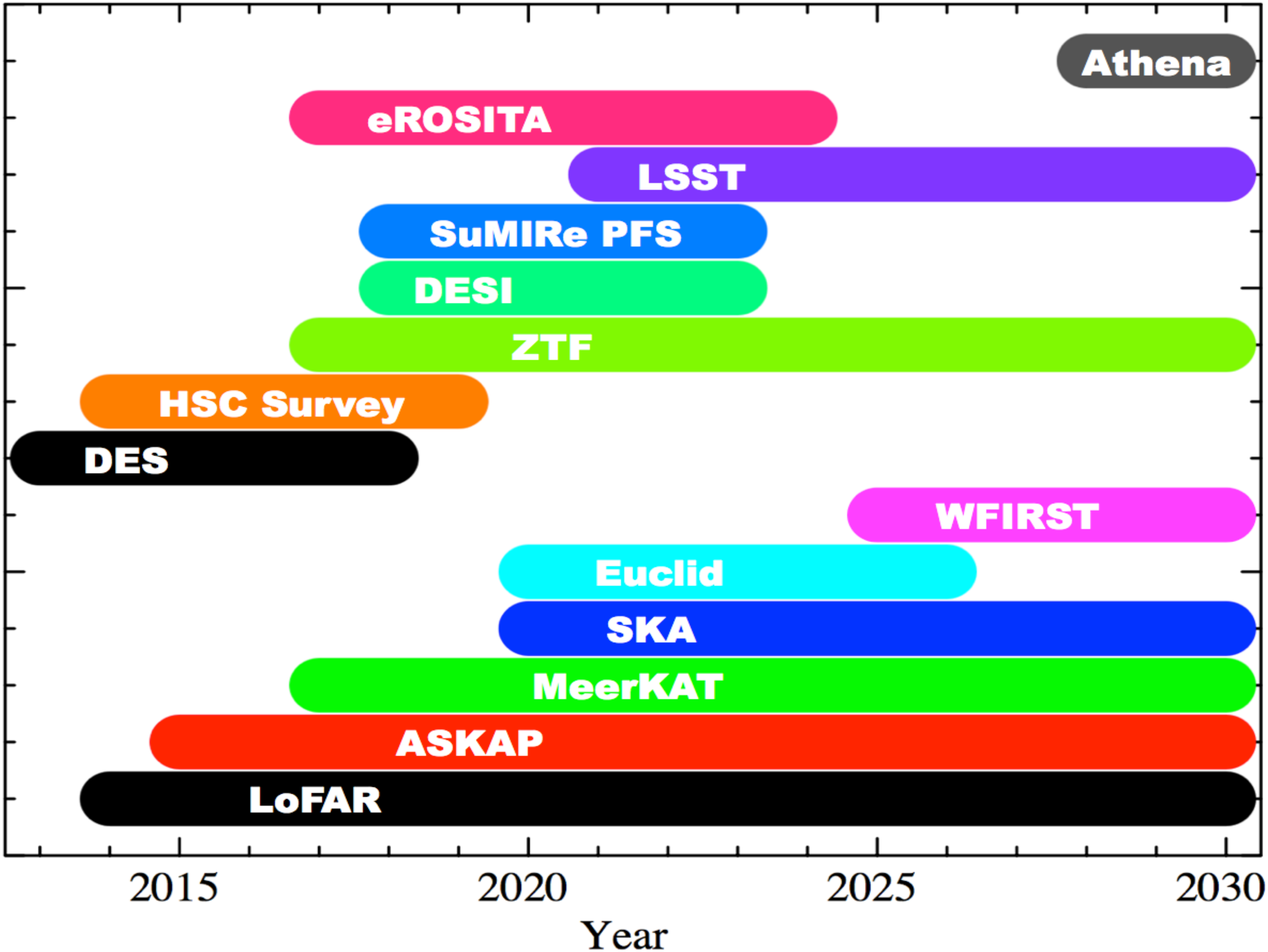
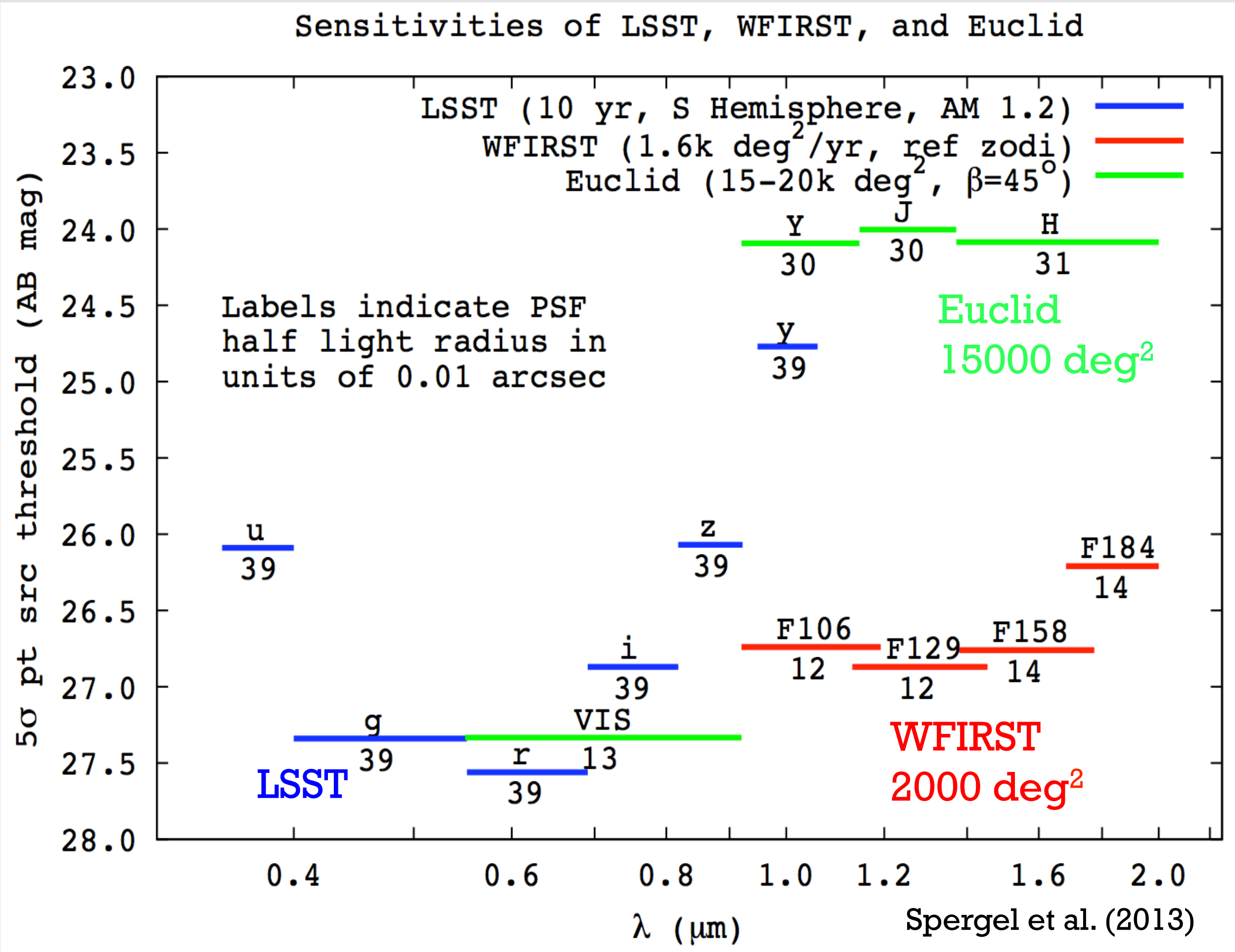
Other Large Sky Surveys



Athena
eROSITA
LSST
SuMIRe PFS
DESI
ZTF
HSC Survey
DES
WFIRST
Euclid
SKA
MeerKAT
ASKAP
LoFAR
2015
2020
2025
2030
Year

High-Redshift Quasars from Euclid, WFIRST, and LSST



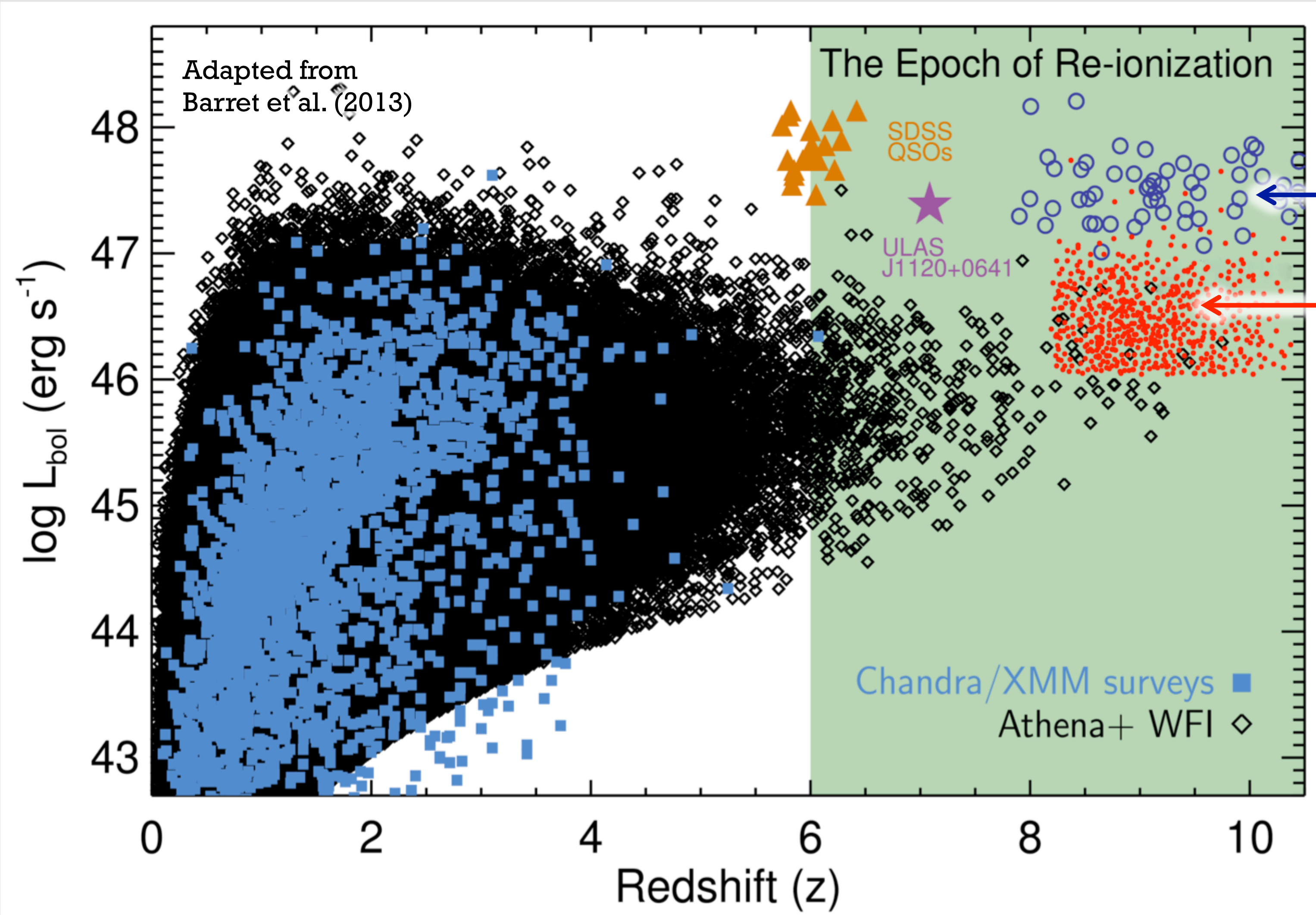
Combination of Euclid, WFIRST, and LSST will be very powerful for finding the first quasars.

Euclid should deliver ~ 30 luminous quasars at $z > 8$.

WFIRST+LSST will push considerably deeper than Euclid over ~ 15% of the area.

Expect ~ 520 quasars at $z > 8$ (~ 2600 at $z > 7$).

Luminosity vs. Redshift for Future High-Redshift AGN Samples



Euclid

WFIRST+LSST at $z > 8$

Lots of great high-*z* targets for Athena spectroscopy!

With good planning, deep WFI exposures on known high-*z* quasars could also serve as "blank-field" survey regions.

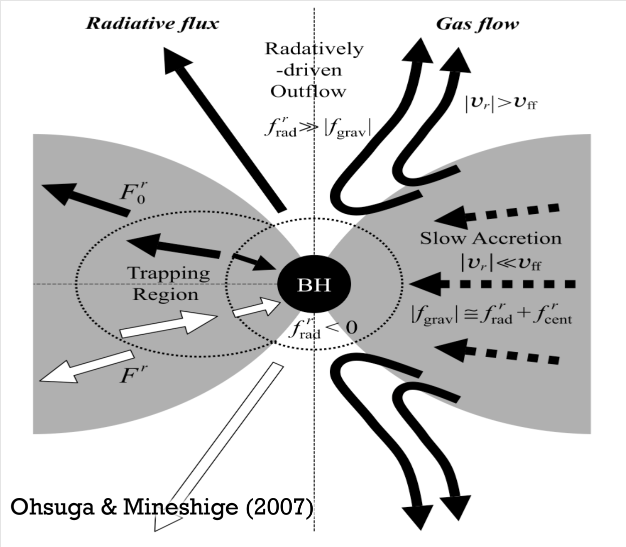
Athena Spectroscopy of the First Quasars from Euclid, WFIRST, and LSST

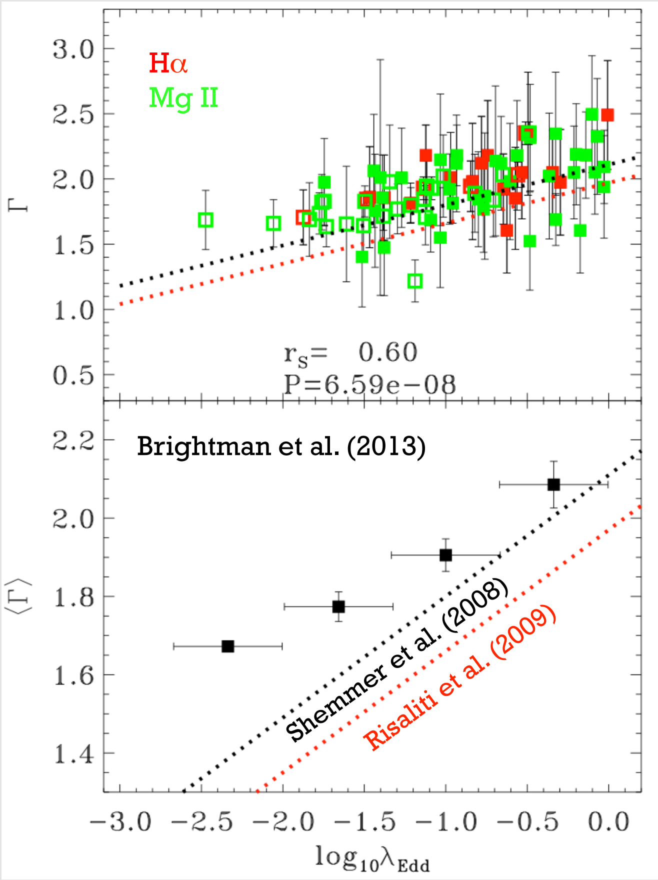
Athena spectroscopy will improve understanding of accretion processes and feedback into the first galaxies.

Theoretically challenging to grow the first SMBH found at z = 4-7.

Would like to determine if their seeds at z = 7-10+ grew by super-Eddington accretion.

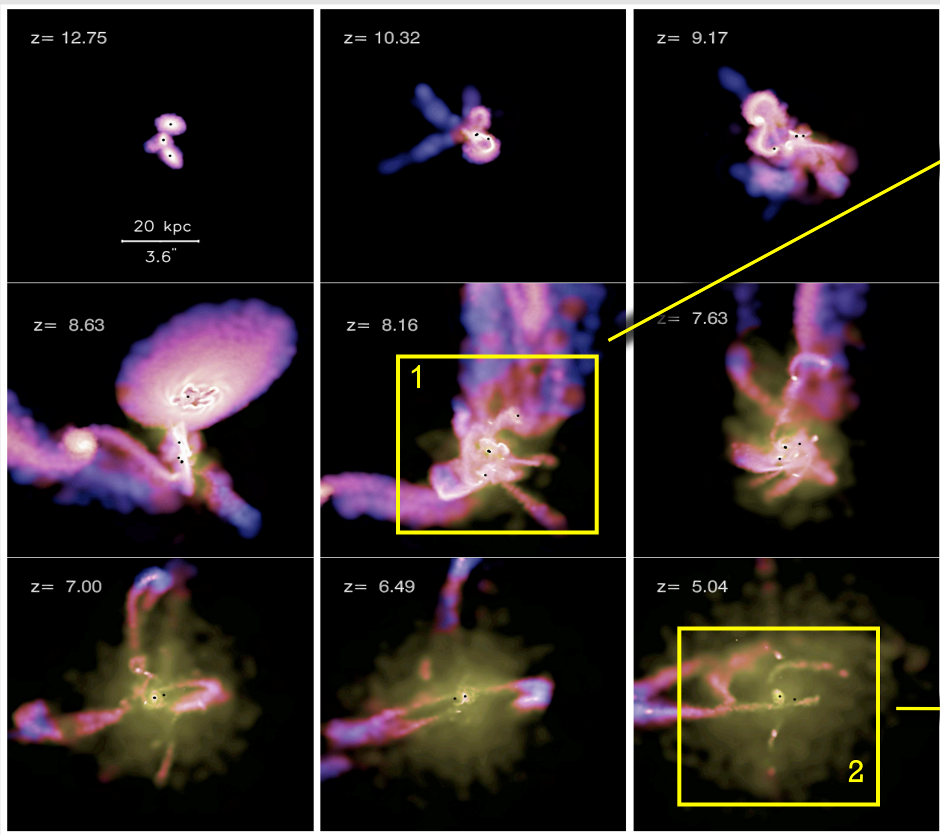
Can use the Γ-λ_{Edd} relation, and perhaps also reflection features and variability.





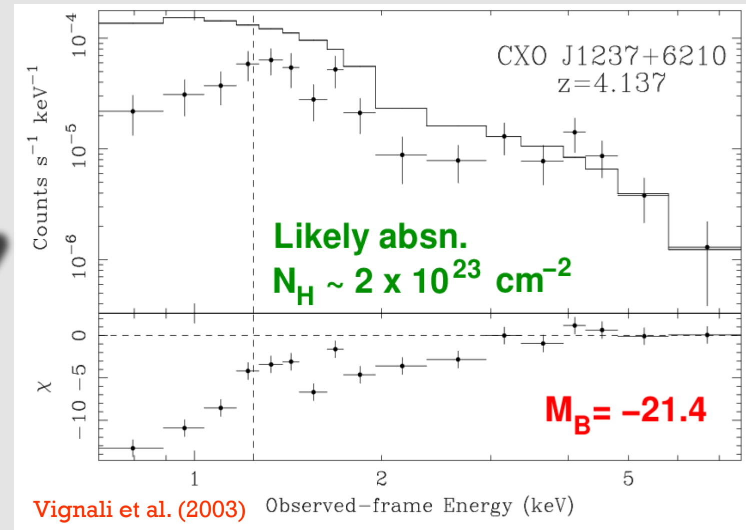
Environments and First-Galaxies Feedback

Gas density and temperature for high-redshift quasar host

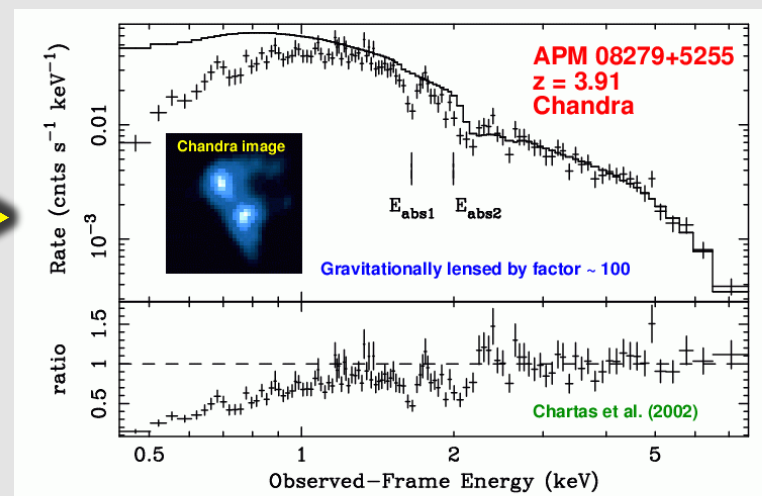


Li et al. (2007)

1. An obscured protoquasar?



2. X-ray BALs showing high-redshift feedback in action?

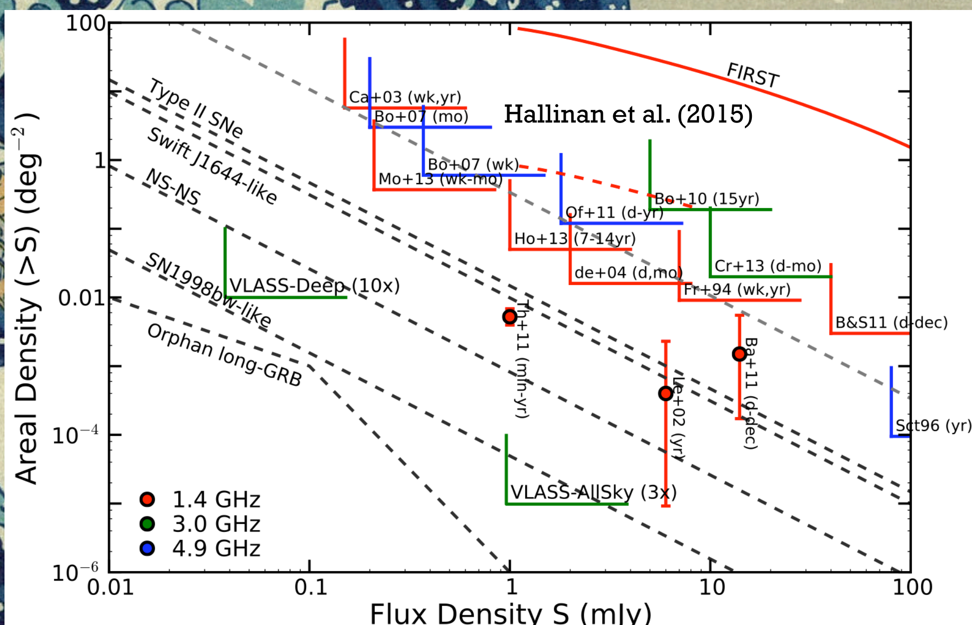


The Radio Transients Flood

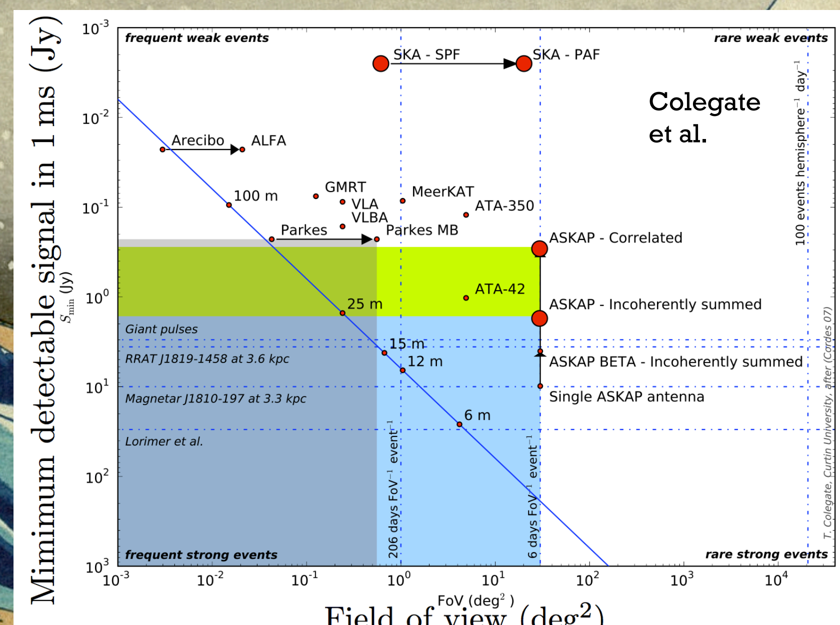
At Athena launch, the flood of radio transients should be comparable to the optical flood.

Flare stars, pulsar giant pulses, RRATs, magnetars, supernovae, orphan GRBs, Lorimer bursts, NS-NS mergers, TDEs, and unknown-unknowns.

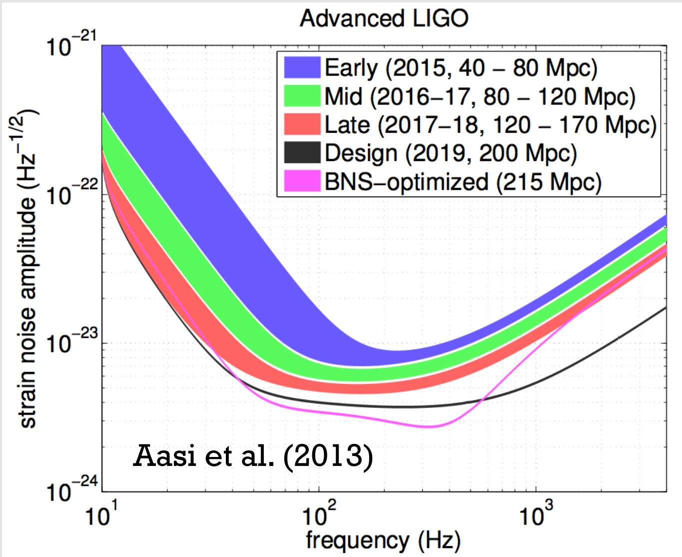
Explosive Extragalactic Radio Transients

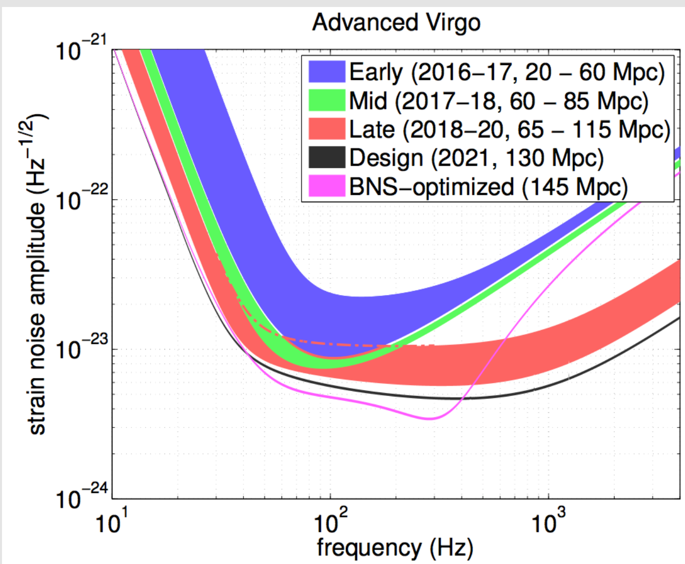


Transients Parameter Space for ASKAP, MeerKAT, SKA

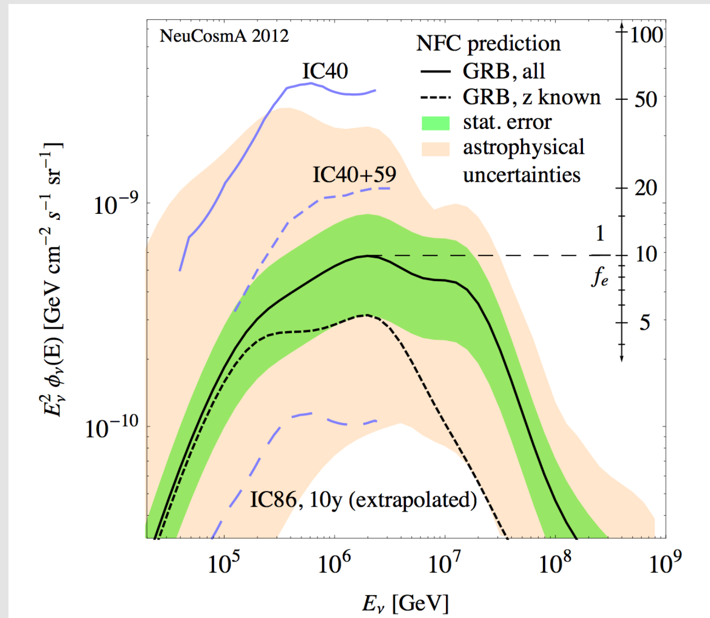


Grav. Wave and Particle Sources



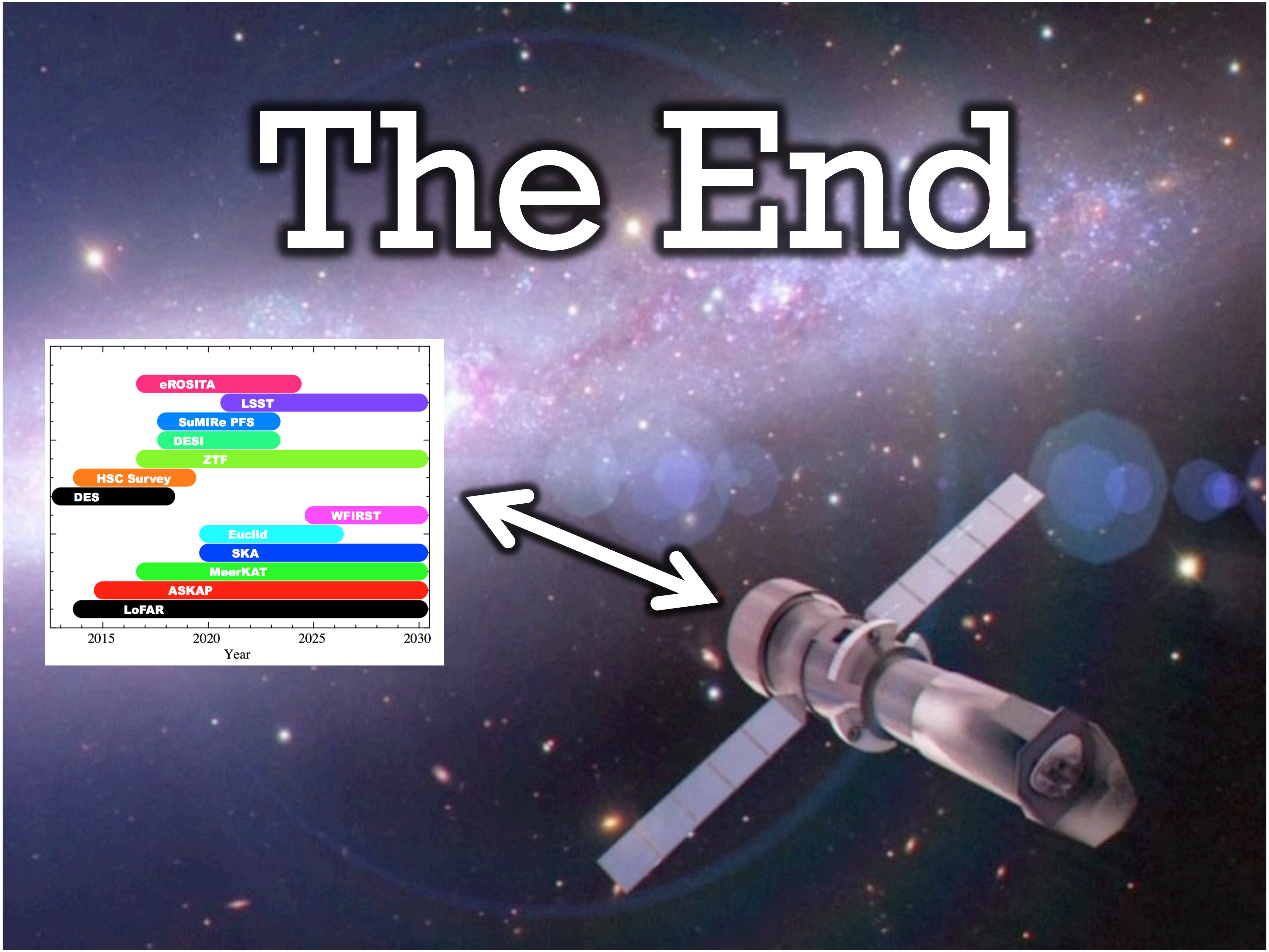


IceCube Upper Limits on Neutrinos from GRBs



Hummer et al. (2012)

The facilities should provide exciting, and perhaps qualitatively new, targets for Athena.


The End
eROSITA
LSST
SuMIRe PFS
DESI
ZTF
HSC Survey
DES
WFIRST
Euclid
SKA
MeerKAT
ASKAP
LoFAR
2015
2020
2025
2030
Year