LUVOIR/HABEX F2F, NOVEMBER 9 2016

# COSMIC ORIGINS APERTURE DRIVERS

# WE ALREADY KNOW THE ANSWER

**III. Astronomical Research with a Large Reflecting Telescope**

The ultimate objective in the instrumentation of an astronomical satellite would be the provision of a large reflecting telescope, equipped with the various measuring devices necessary for different phases of astronomical research. Telescopes on earth have already reached the limit imposed by the irregular fluctuations in atmospheric refraction, giving rise to "bad seeing". It is doubtful whether a telescope larger than 200 inches would offer any appreciable advantage over the 200 inch instrument. Moreover, problems of flexure become very serious in mounting so large an instrument. Both of these limitations disappear in a satellite observatory, and the only limitations on size seem to be the practical ones associated with sending the equipment aloft.

While a large reflecting satellite telescope (possibly 200 to 600 inches in diameter) is some years in the future, it is of interest to explore the possibilities of such an instrument. It would in the first place always have the same resolving power, undisturbed by the terrestrial atmosphere. If the figuring of the mirror could be sufficiently accurate, its resolving power would be enormous, and would make it possible to separate two objects only .01" of arc apart (for a mirror 450 inches in diameter); an object on Mars a mile in radius could be clearly recorded at closest opposition while on the moon an object 50 feet across could be detected with visible radiation. This is at least ten times better than the typical performance of the best terrestrial telescopes. Moreover, in ultra-violet light the theoretical resolving power would of course be considerably greater; ideally an object 10 feet across could be distinguished on the moon

Spitzer, 1946

"It's kind of fun to do the impossible"

–WALT DISNEY

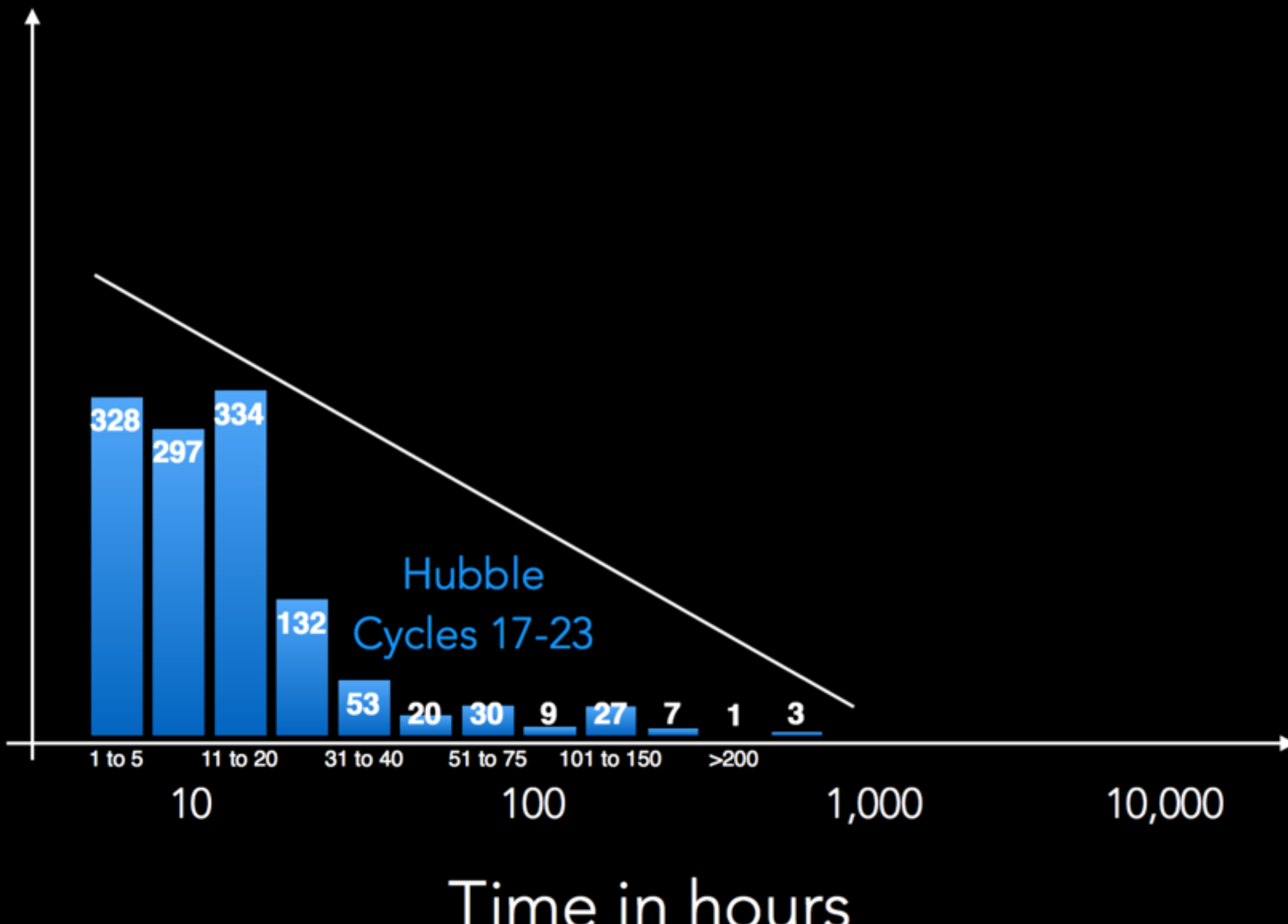
# WHAT DOES IT MEAN TO "DO THE IMPOSSIBLE"?

- Perform a measurement or make a discovery that has never been made
- Hard to predict
- A different *operational* definition:  turn a program that require > 1000 hours into routine ones

# IMPLICATIONS FOR APERTURE

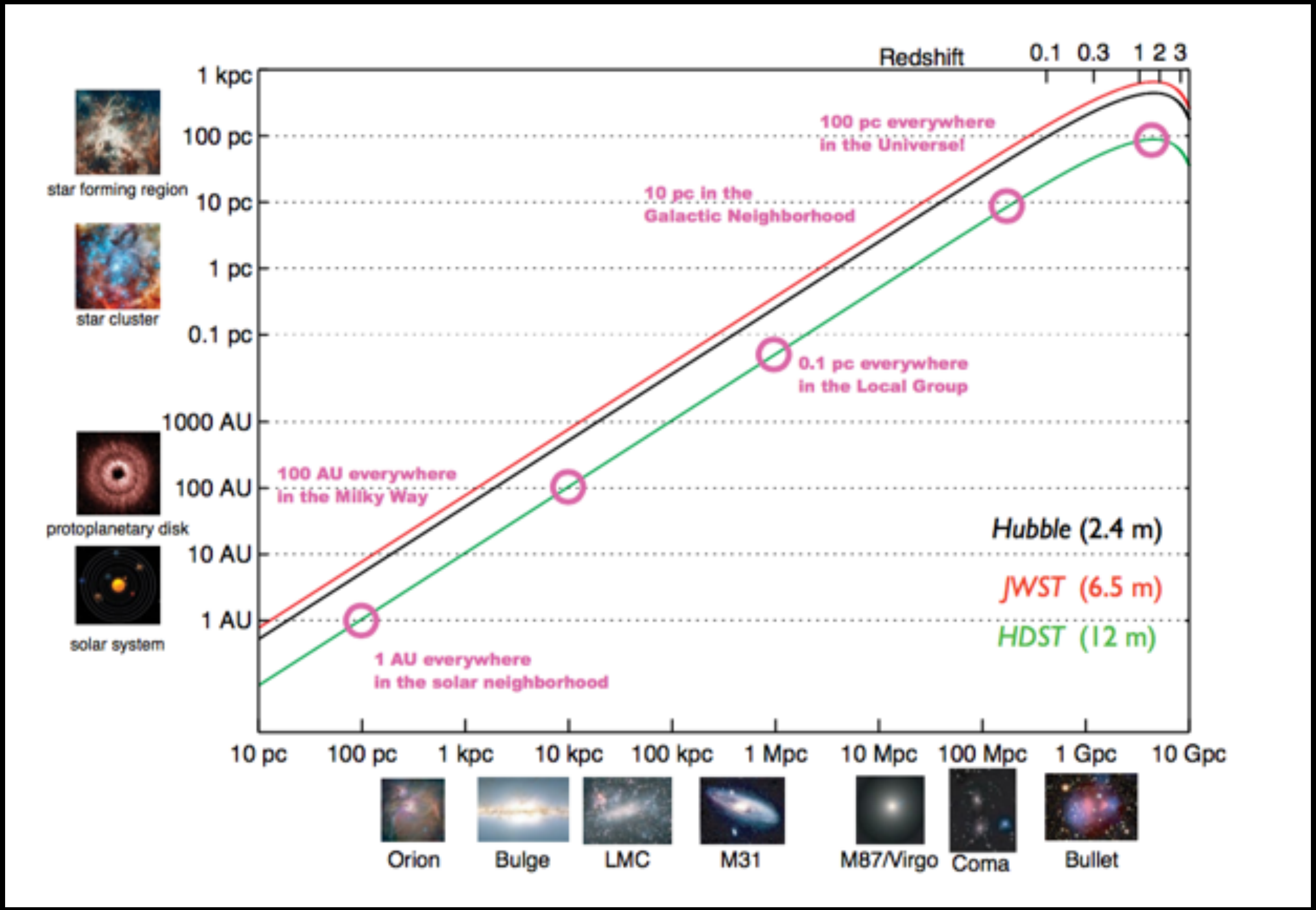
- We should *not* be comparing raw capacity when we compare apertures
- We *should* compare total science programs considered holistically bound by the ultimate limited resource:  mission lifetime

# CASE IN POINT: HST



# OUR GALAXY: YOUNG AND OLD

# NURSERIES ABOUND

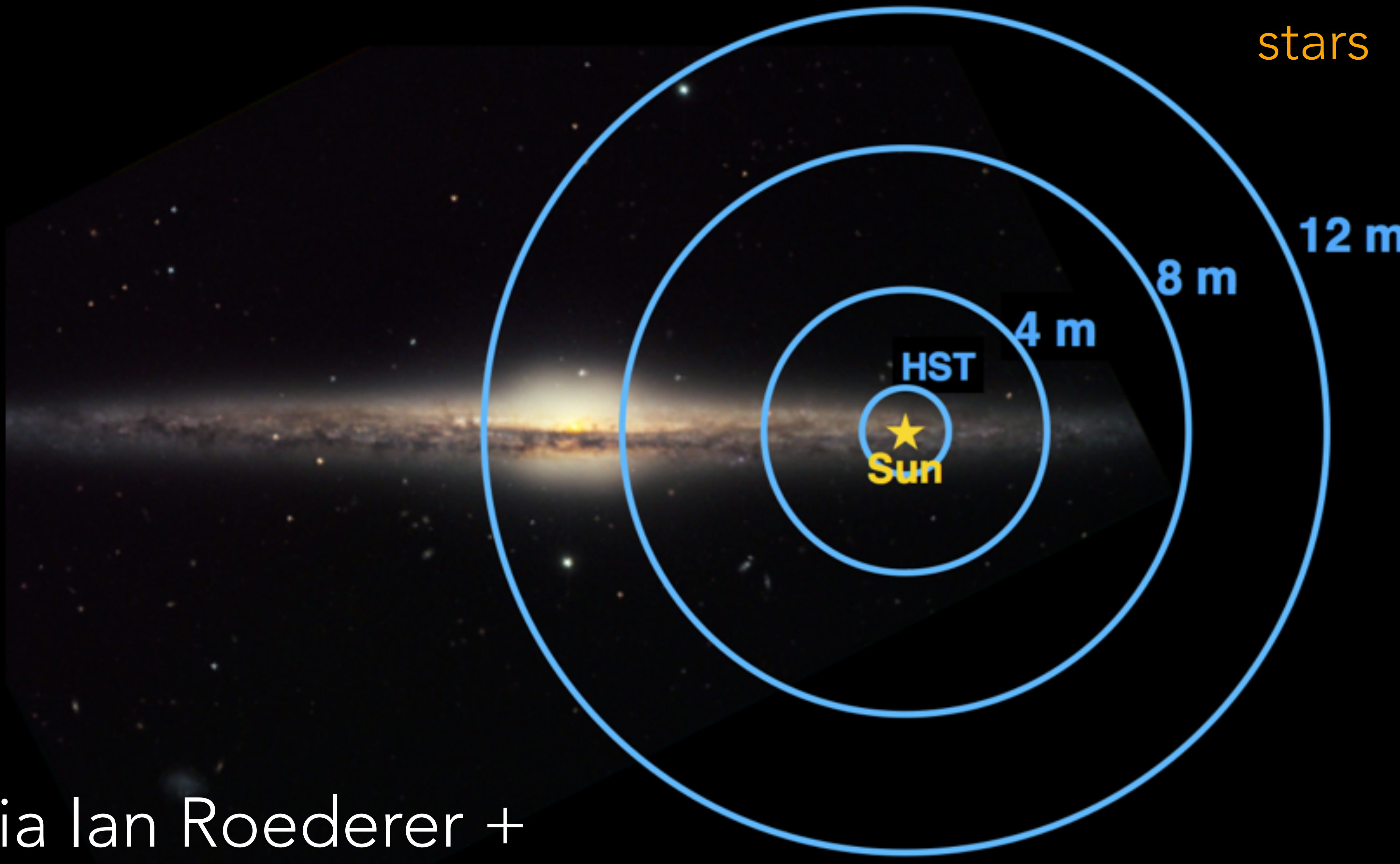



Goal: Measure PPD within the inner 1AU

Needs: Enough aperture to get to Hyades or beyond

# ULTRA-LOW METALLICITY STARS IN THE GALAXY

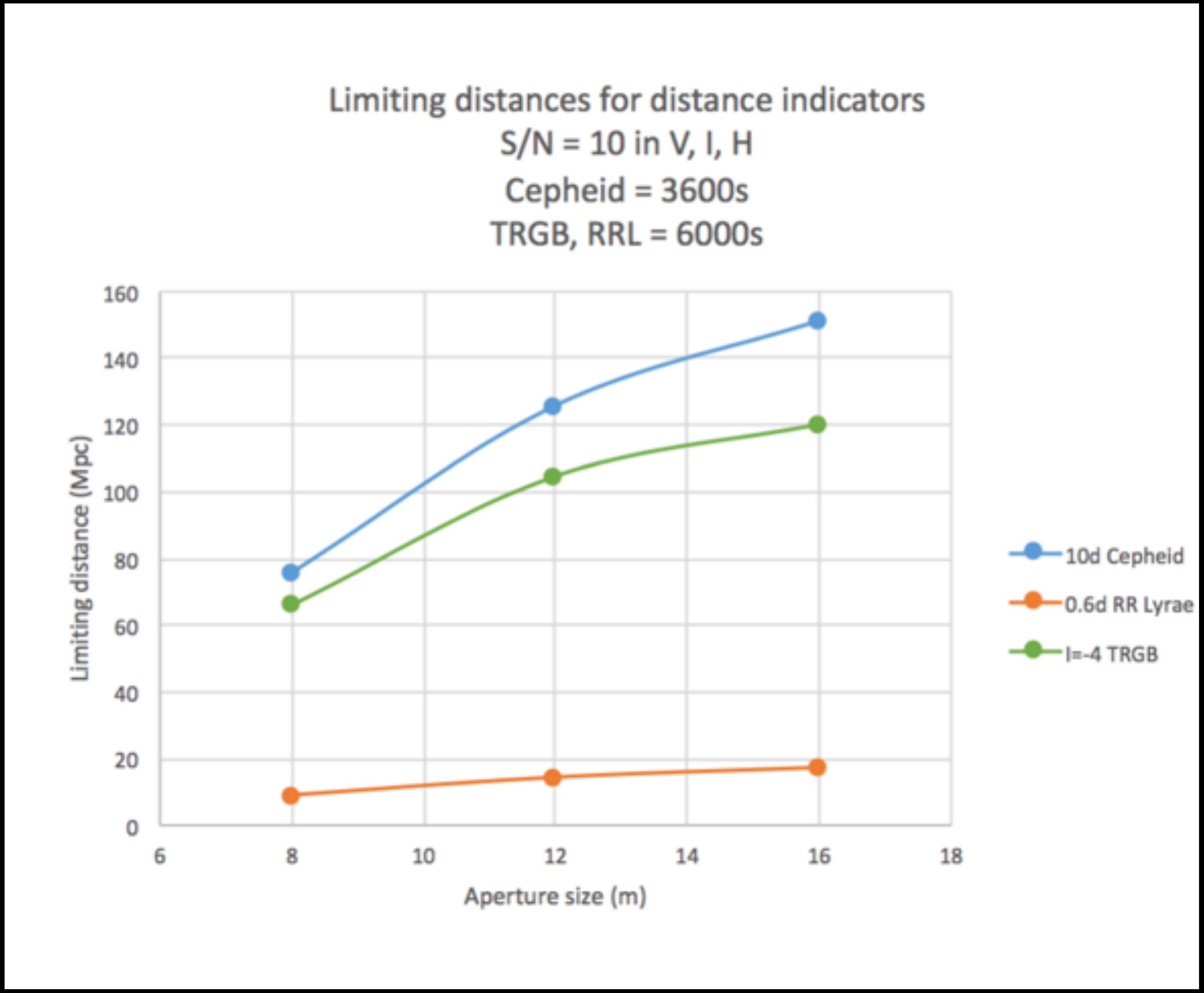
LUVOIR + LUMOS + O/NIRS for red giants and halo stars




via Ian Roederer +

# FROM HERE TO COMA, AND BACK AGAIN.  A LUVOIR TALE

# RE-DEFINE THE DISTANCE LADDER




1% or better on $H_0$

2% or better on $w$

via Vicky Scowcroft

# SUPERNOVAE

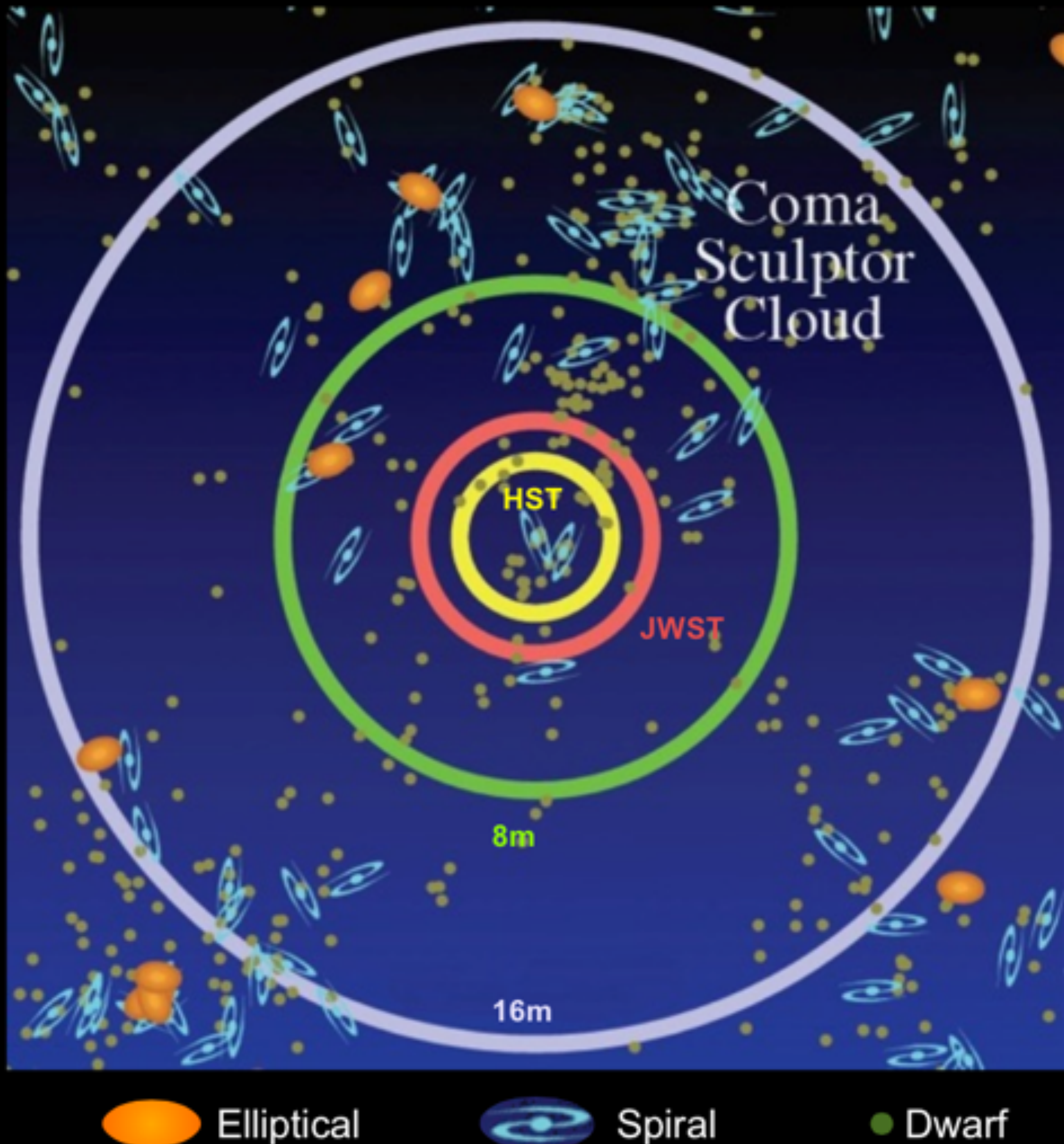
| Program | Measurement | Measurement Requirement | Instrument |
|---|---|---|---|
| **Progenitor Pre-Explosion Survey** | Detection of pre-explosion SN progenitor systems for legacy value. | <60 Mpc complete sample MV<0, mV<34 <60 Mpc novel sample MV<-4, mV<30 | imager |
| **SNIa Post-Impact Companion** | Detection of post-explosion SNIa companion star. | <60 Mpc, MV<-2, mV<32 | imager |
| **Resolving Young SN Remnants** | Detecting spatial evolution in young remnants | | imager |
| **SN Light Echos** | Image and spectra of SN light echoes in local group & beyond. | Requires blue sensitivity. | imager spectrograph |
| **SN Environment via Resolved Stellar Pops** | Constrain CC SN progenitor ages via stellar neighbourhood, post-explosion. | Semi-resolved stellar pops to ~100 Mpc. | imager |
| **Nebular-Phase SNe at Extremely Late Times** | Follow SN LC far into late stage nuclear decays with image/spectra. | Extending from HST's ~28th to ~34th mag like adding >6 years for 2011fe-likes | imager spectrograph |

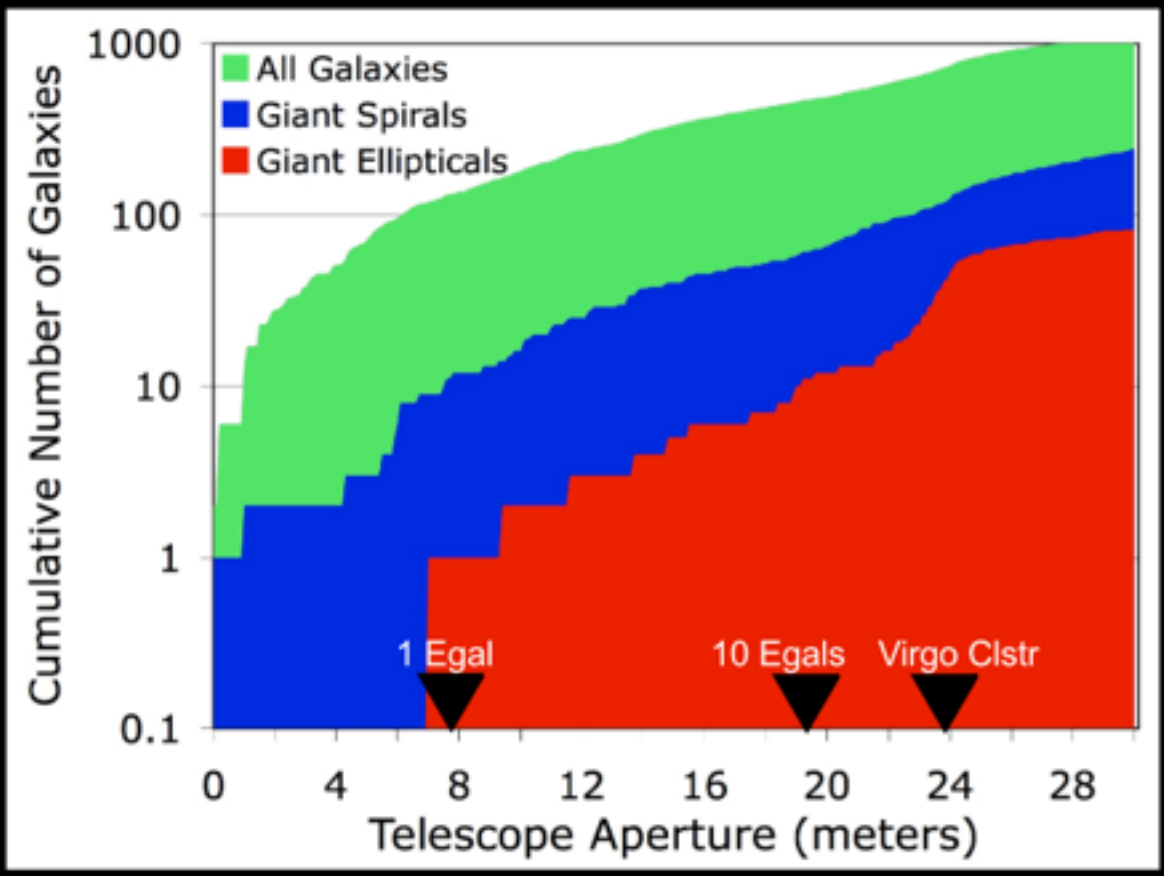
Goal: complete sample out to 60 Mpc

Need: 34th mag. 9+ meters works but survey completeness/time favors 12+

via Melissa Graham

# STELLAR POPULATIONS WRIT LARGE



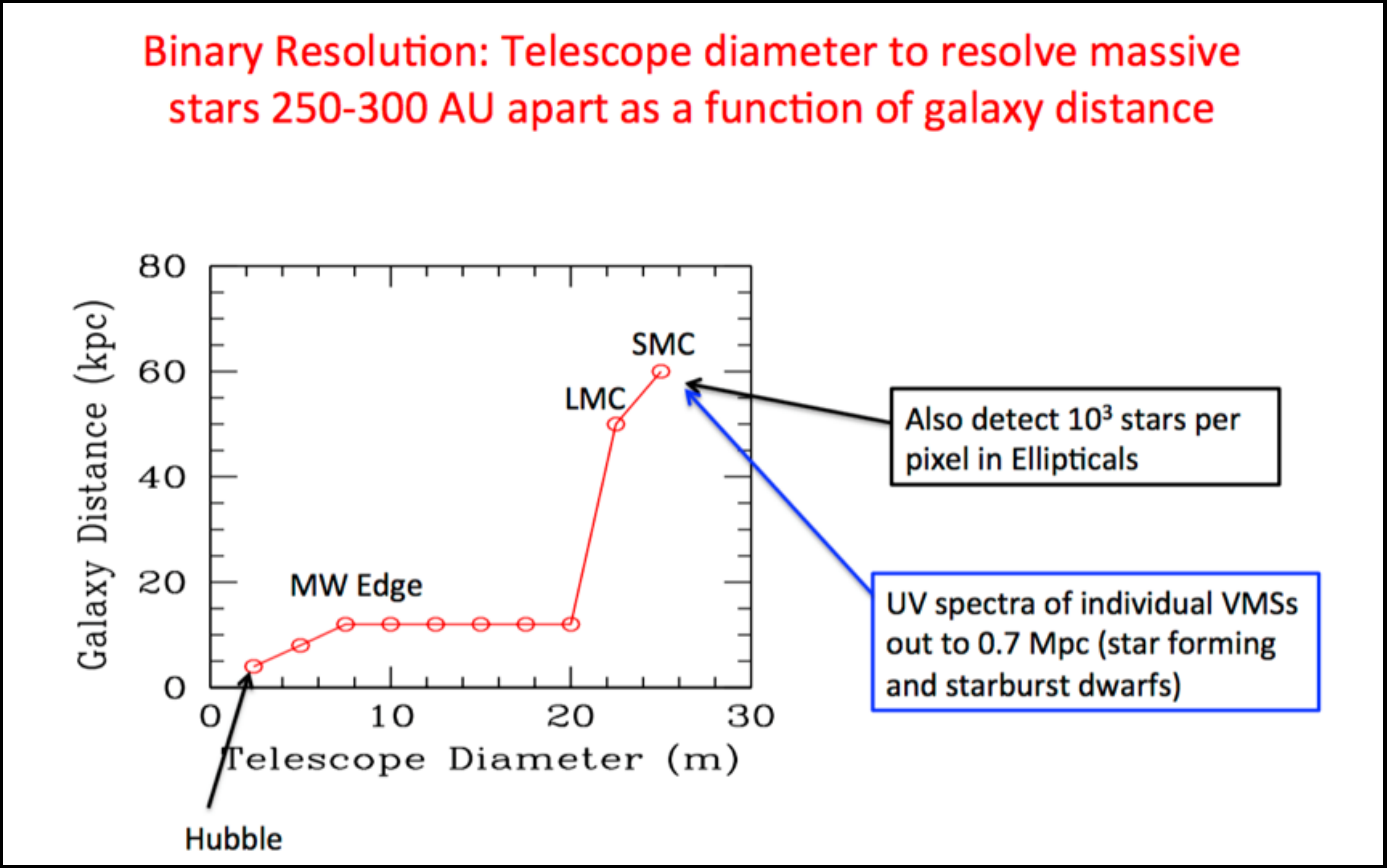




Star formation history sets both chemical evolution and planet formation rates. Visible bands provide best discrimination.

Requires diffraction limited optical imaging and high PSF stability.

Aperture Driver: > 10 m needed to resolve stellar pops down to 1 $M_\odot$ out to the nearest giant ellipticals.

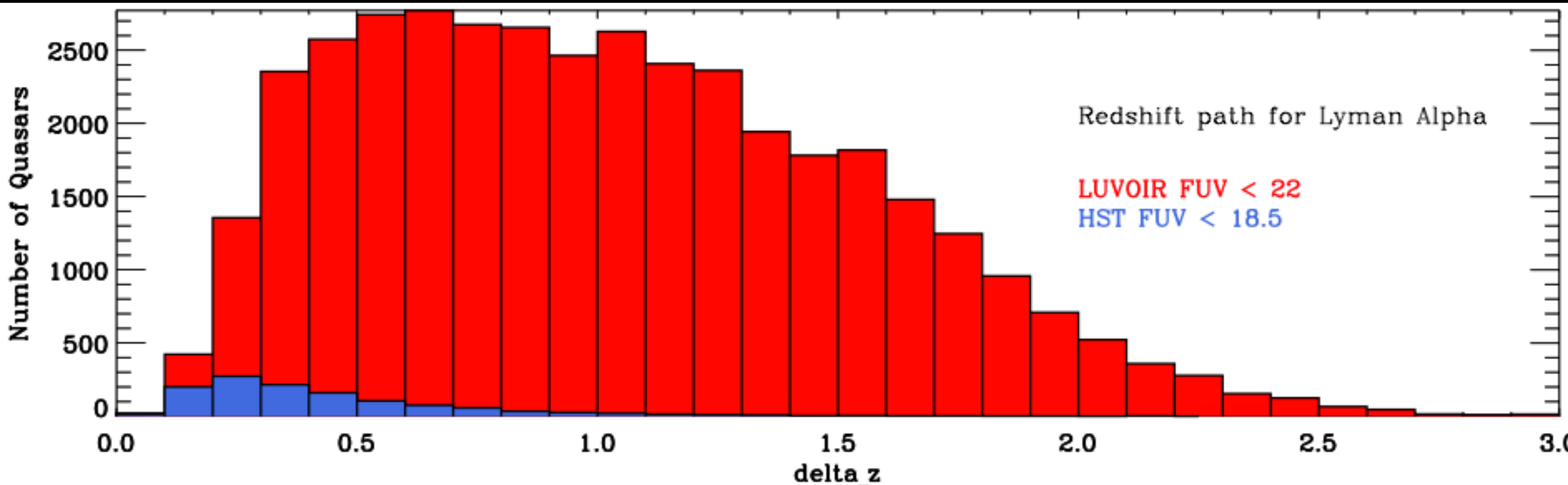
# THE IMF DONE RIGHT



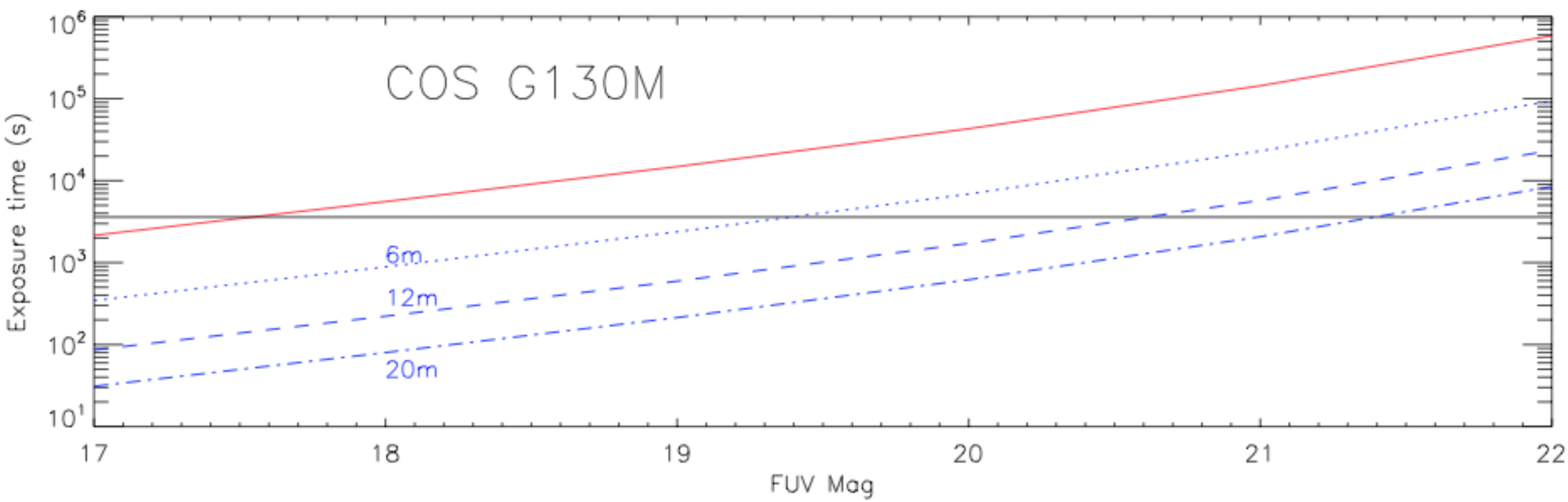

via Daniela Calzetti

# THE UNIVERSE AT ADOLESCENCE

# GAS

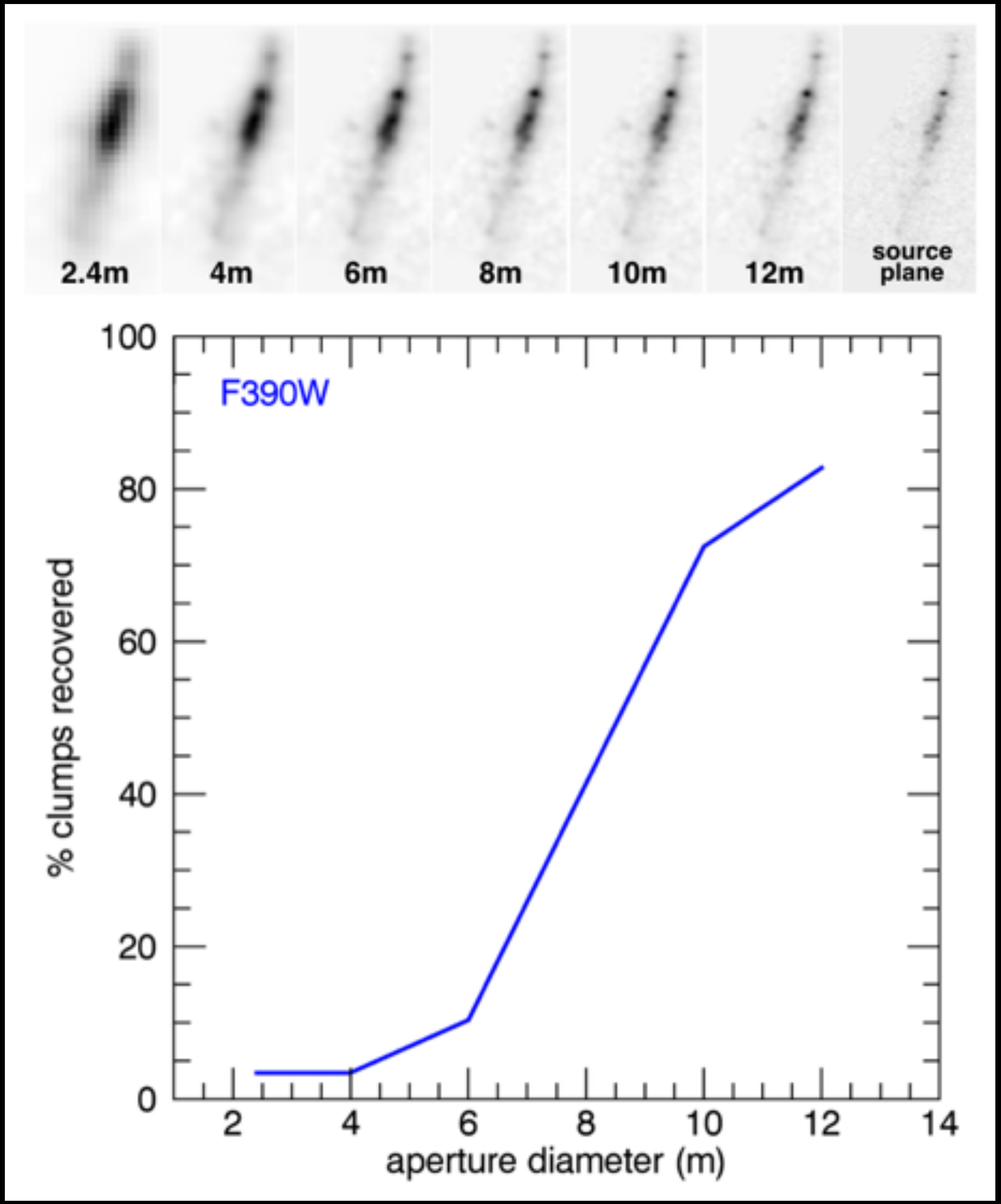


Number of Quasars
2500
2000
1500
1000
500
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
delta_z
Redshift path for Lyman Alpha
LUVOIR FUV < 22
HST FUV < 18.5

COS G130M
Exposure time (s)
$10^6$
$10^5$
$10^4$
$10^3$
$10^2$
$10^1$
6m
12m
20m
17
18
19
20
21
22
FUV Mag

# GAS, AND GALAXIES



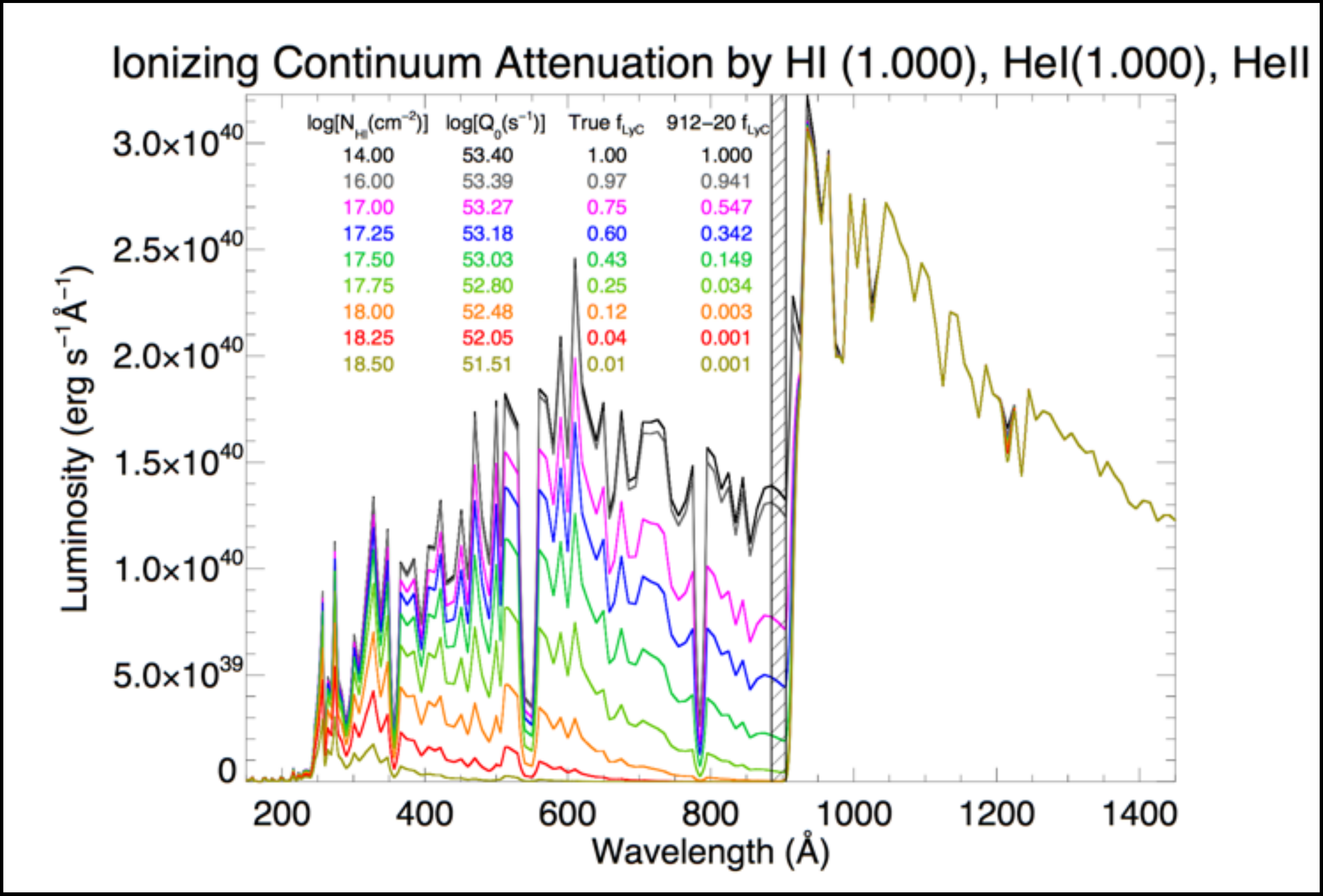

Lensed galaxies with HST

=

normal galaxies with LUVOIR

via Kate Whitaker and Jane Rigby

# GAS, AND GALAXIES, AND LIGHT

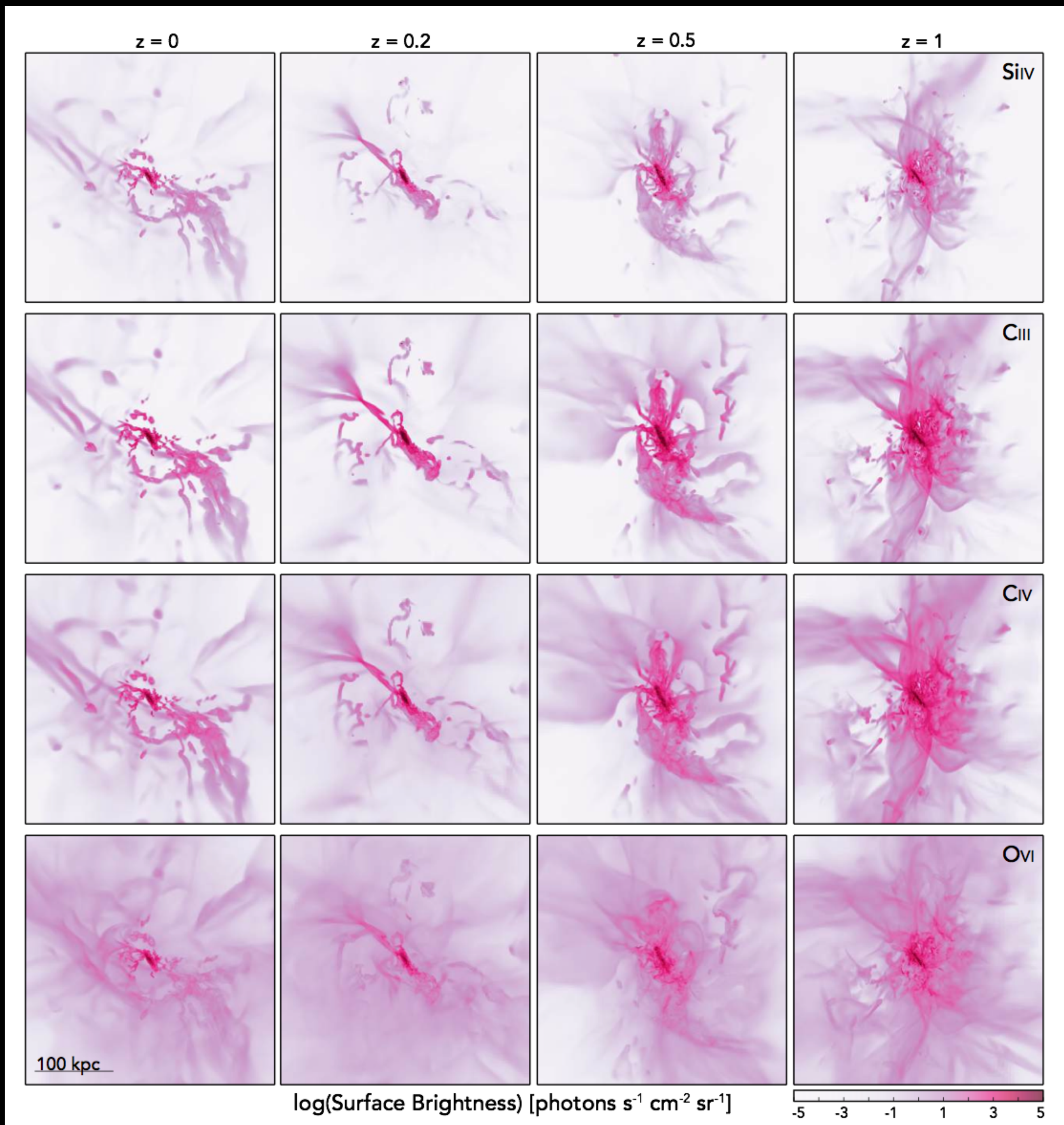



Goal: sensitivity to f_esc = 0.01 for thousands of objects

Needs: LUMOS & 12+ meter (9 meter means reduced survey size/weaker sensitivity/longer program)

via Stephen McCandliss

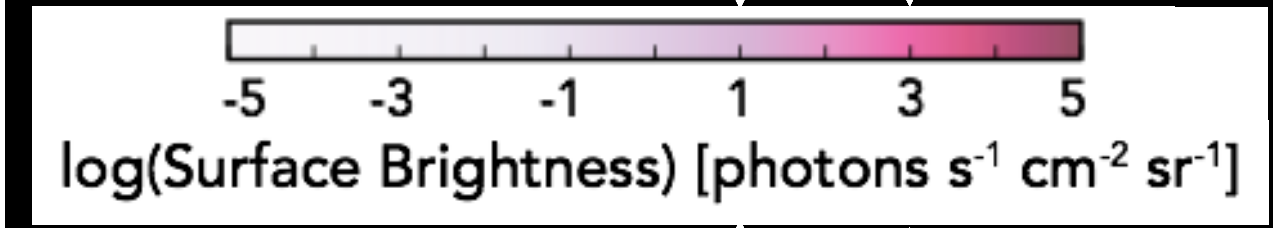
# GAS, AND GALAXIES, AND LIGHT, OH MY




10 meter telescope

15 minutes

40 hours



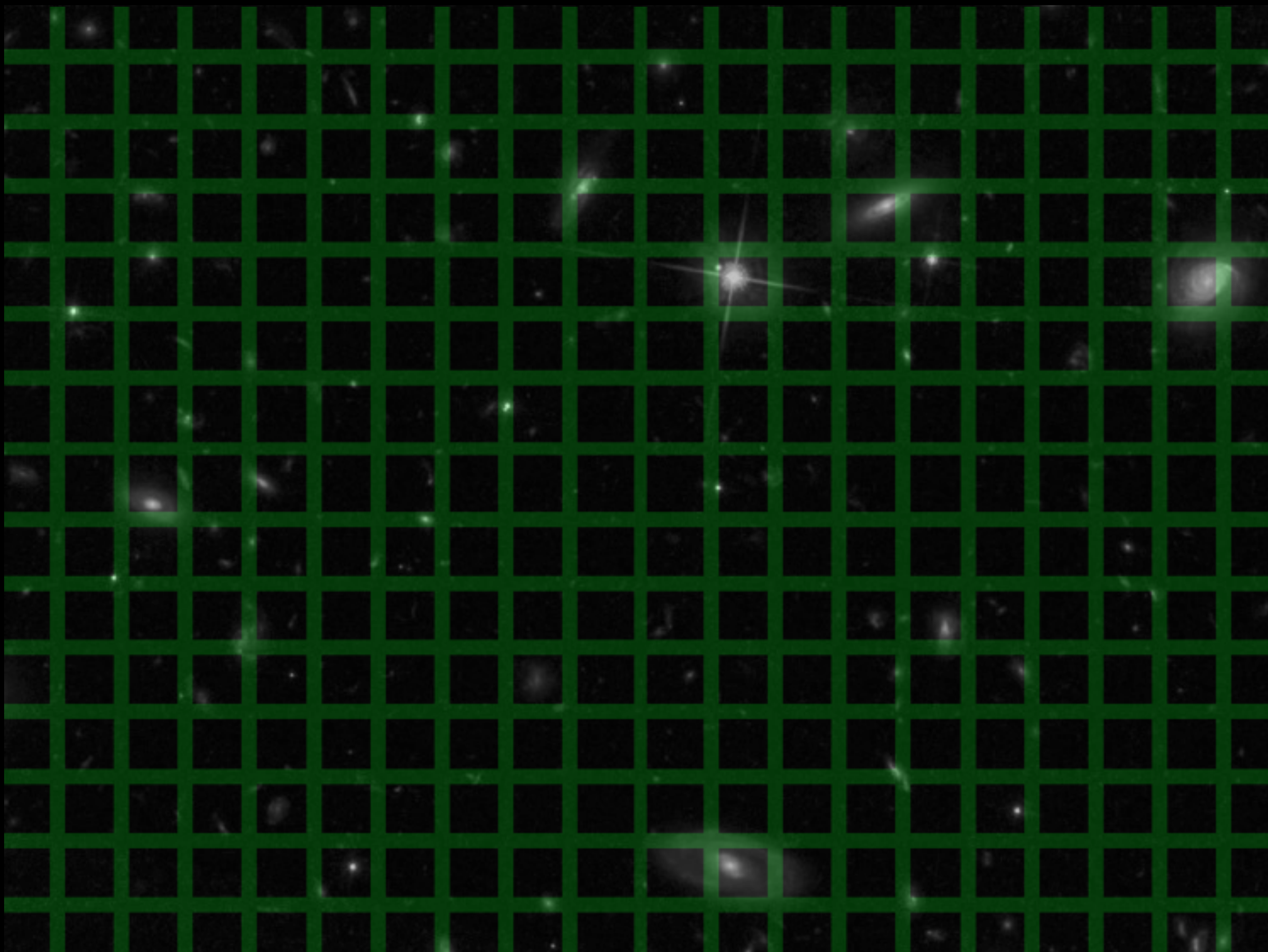

500 hours

3 hours

4 meter telescope

via David Schiminovich

# GAS, AND GALAXIES, AND LIGHT, OH MY....TIMES N



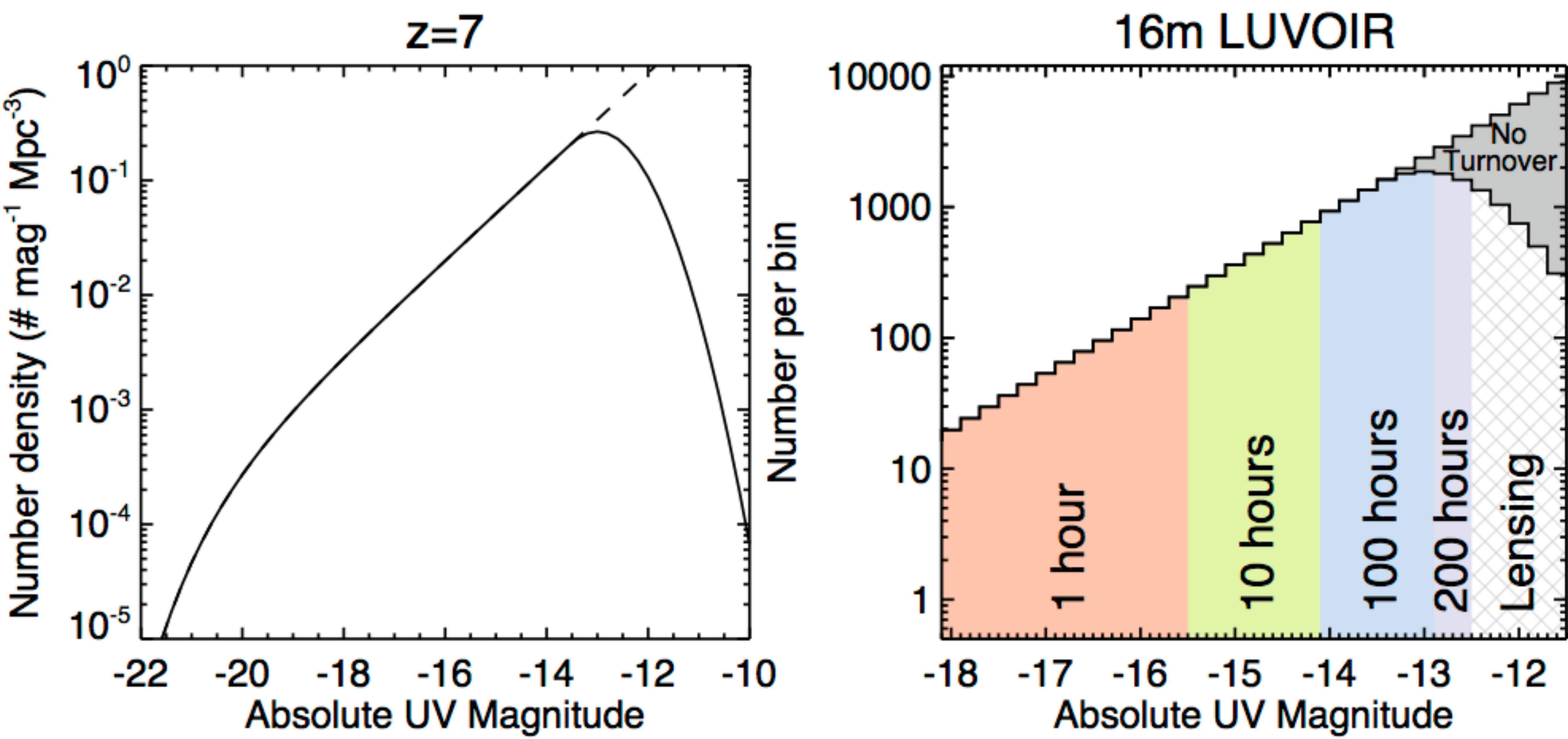
LUMOS:

25th mag galaxy at 5 σ in 1 hour.

There are ~10,000 such galaxies per square degree

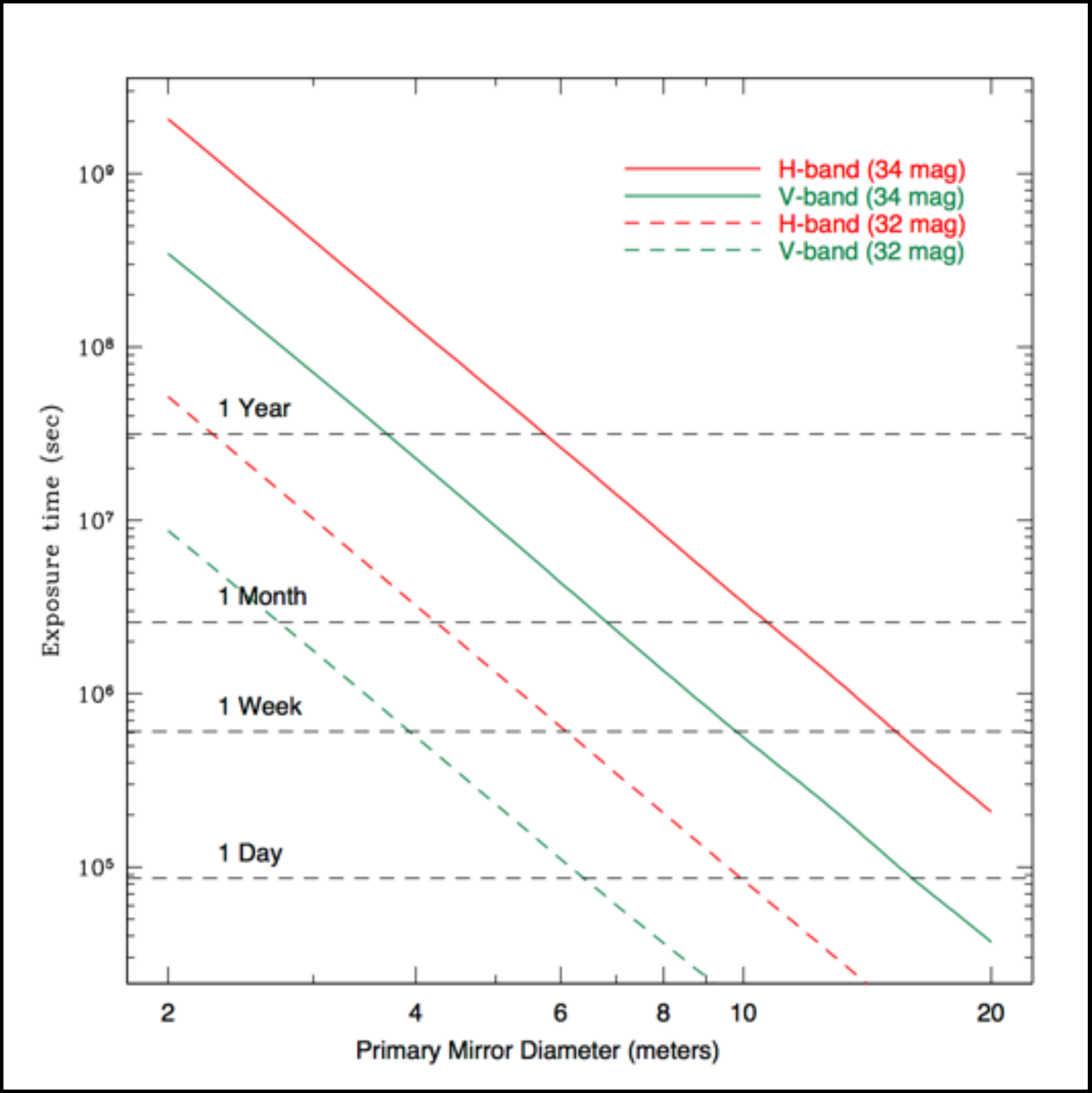
THE UNIVERSE EMERGES FROM THE DARKNESS

# ON THE EDGES OF REIONIZATION IN BOTH MASS AND LIGHT




via Steven Finkelstein

# SCIENCE AT THE OLBER LIMIT




*LUVOIR+HDI: We'll do more in a day than you will all year.*

# BE BOLD

# YOU KNOW YOU WANT TO

## Extra-galactic Parallaxes

- A technique used in radio VLBI astrometry can be used in the optical
- A number of O stars can be monitored, both with proper motion and radial velocity to measure the distance to the galaxy.
  - Proper motion of all the O stars are done at once.

Motion ~ 100km/sec
@ 50 MPc is
0.4 uas/year
~2 uas over 5 years

Direct distance measurement to Virgo

# EMERGENT APERTURE THEMES

- The combination of a need for resolution, sensitivity, and transformative science demands >9 meters
- Much, *much*, more can be explored.  Time to ask.
- *All instruments can do revolutionary COR science*
- Science cases, science cases, science cases!