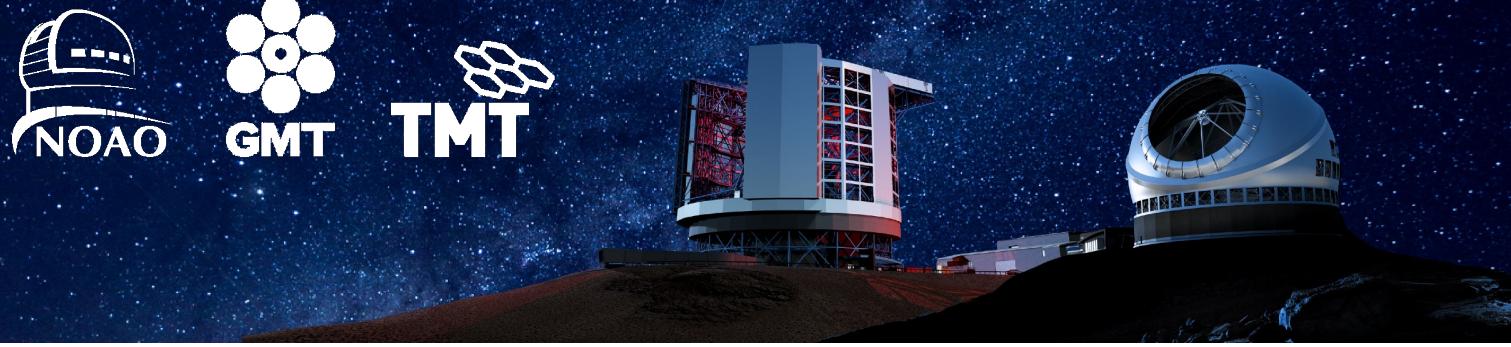


# The US Extremely Large Telescope Program



## Origins and Fundamental Physics of Supermassive Black Holes

Jenny E Greene

GC Team: Tuan Do, Andrea Ghez, Jessica Lu, Matthew Hosek, Andrew Bellini, Sukanya Chakrabarti, Mark Morris, Shoko Sakai

IMBH team: Tuan Do, Andrea Bellini, Jonelle Walsh, Kayhan Gultekin, Karl Gebhardt, Aaron Barth, Matthew Hosek, Dongwon Kim, Mattia Libralato, Jessica Lu, Matthew Malkan



# US-ELT: Transforming Black Hole Science

Is GR the right description of black holes?

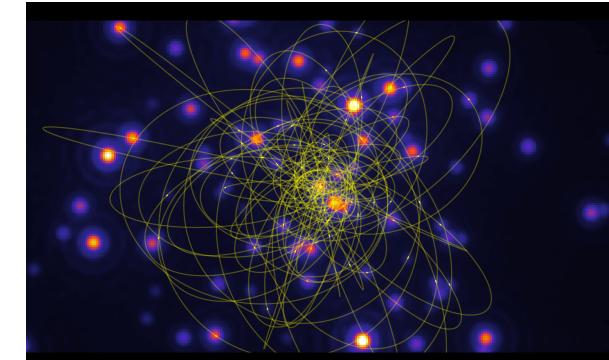
Proper motions and radial velocities of stars at the Galactic Center

How did supermassive black holes (SMBH) form?

Search for intermediate-mass black holes

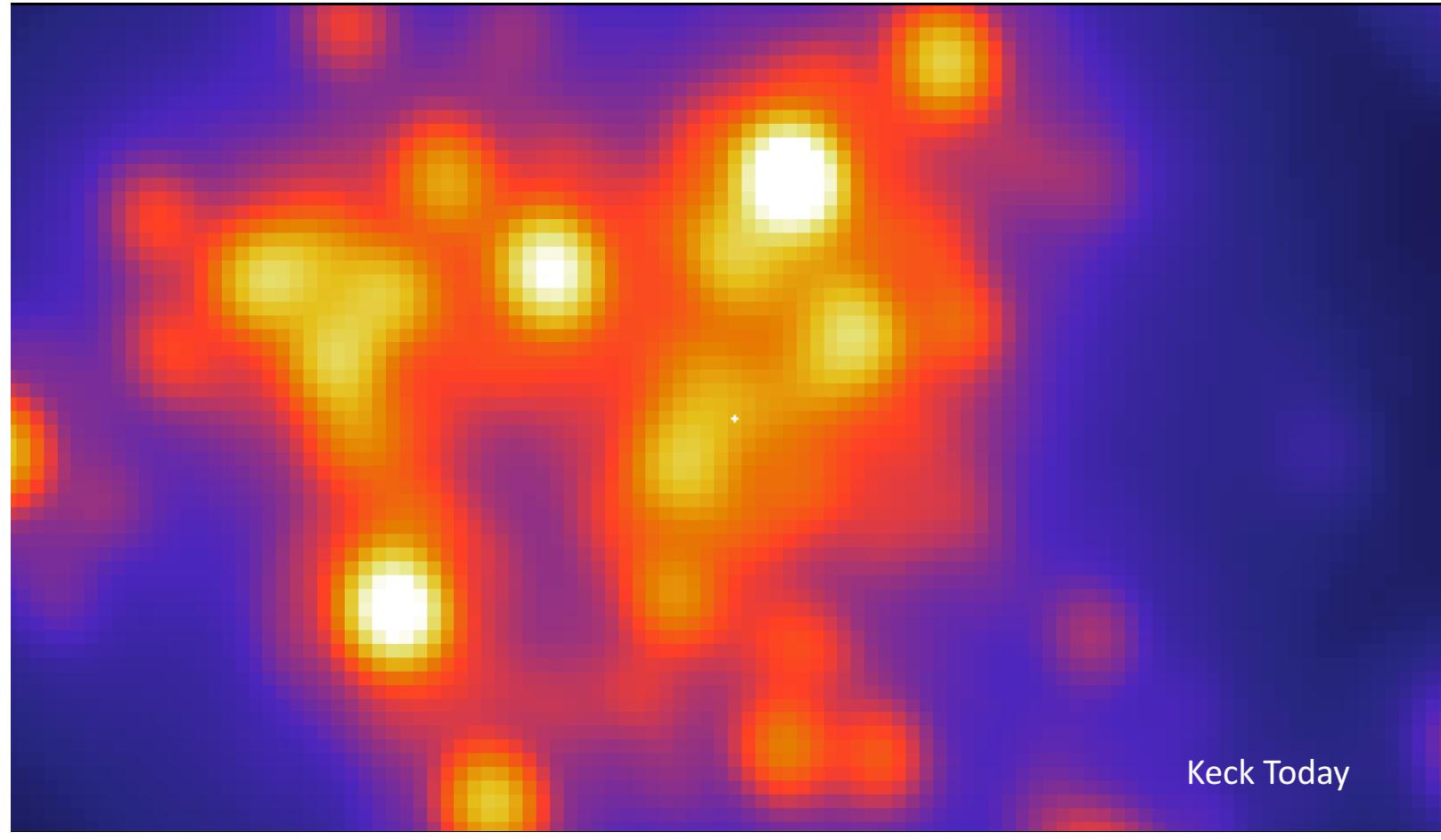
How did SMBHs evolve through cosmic time?

Search for SMBHs out to  $z \sim 2$  (won't cover now)





# Zooming Into Stellar Nuclei



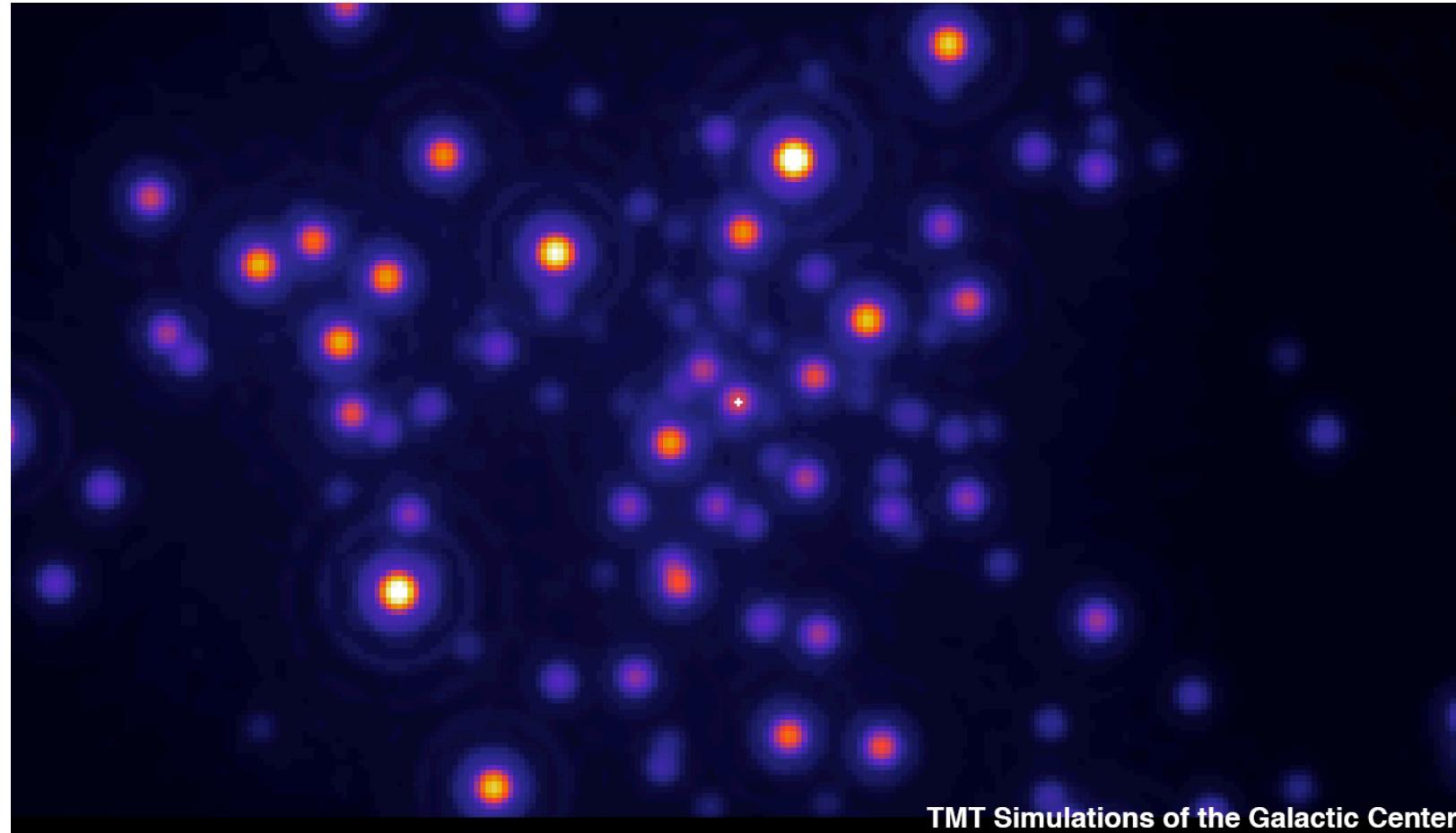
**Both angular resolution  
and depth are key**

From 17 to 120 stars to  
be monitored at the GC

Reach the sphere of  
Influence of 1000 Msun  
BHs in the MW and 10,000  
Msun BHs to >5Mpc



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# Galactic Center Experiment

## Simulations:

Number of stars: 121 (TMT) vs 17 (present-day)

Assumes: 5x better astrometry  
10x better radial velocities

Cadence: 3 RV and 3 PM  
measurements/yr for three years

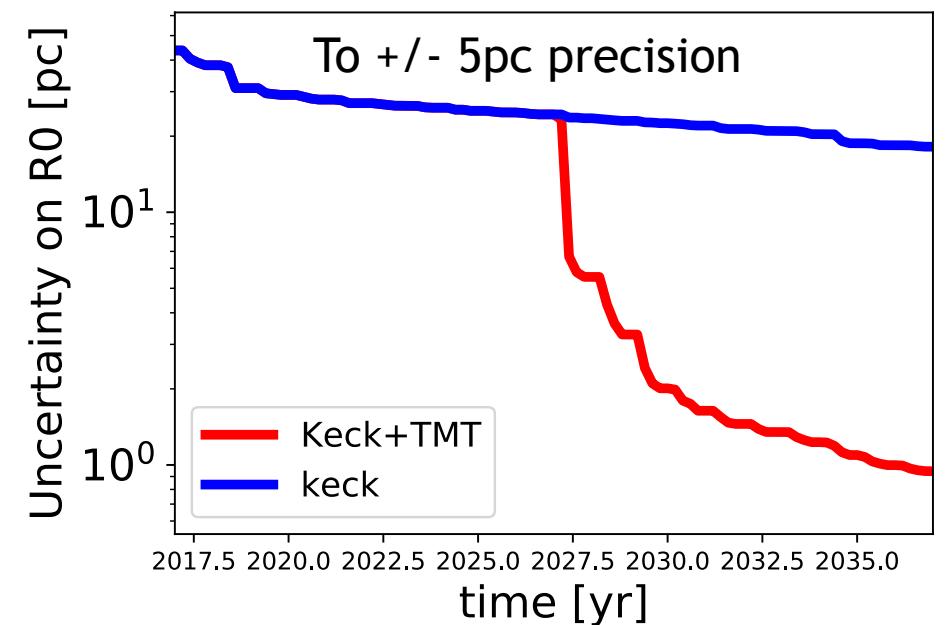
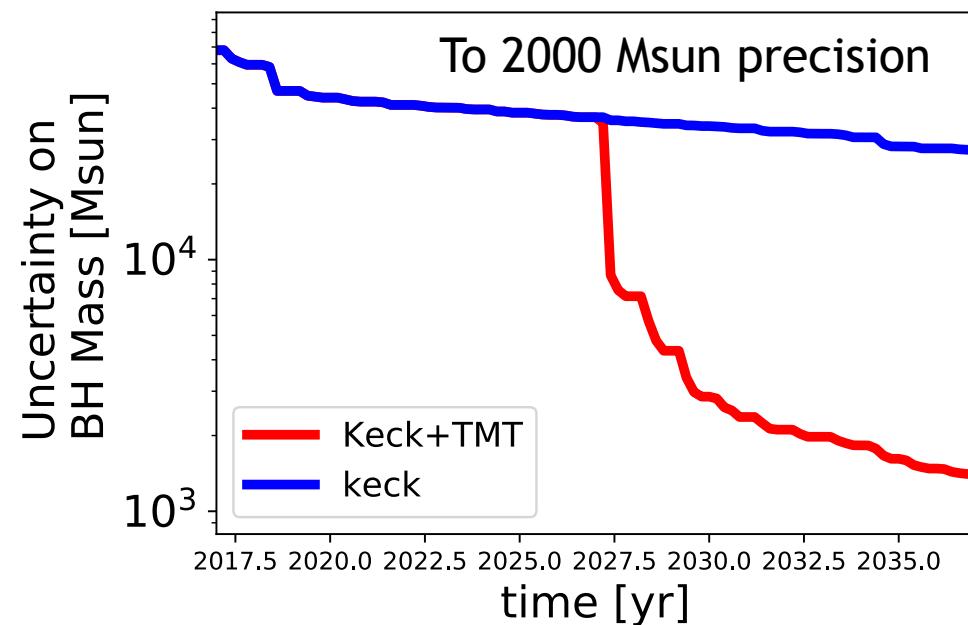
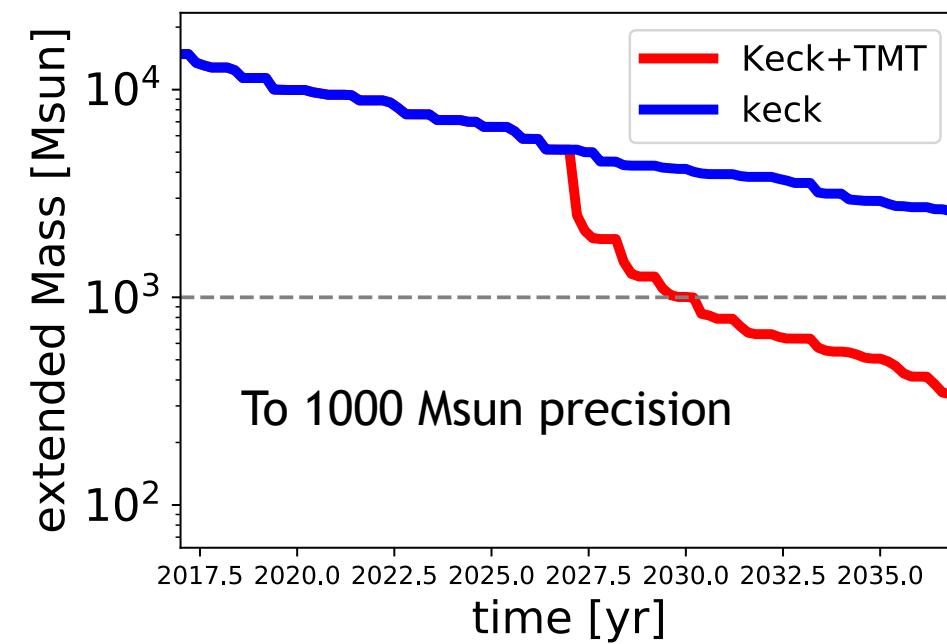
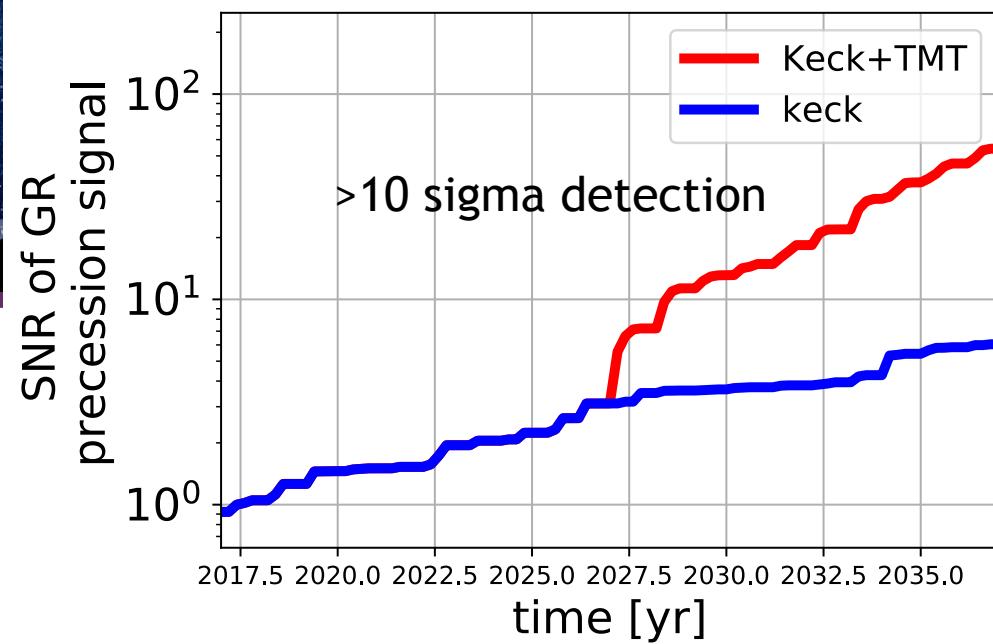
Total time: 360 hrs (IRIS)

## Instrumentation:

TMT/IRIS for astrometry+moderate resolution spectroscopy

GMTNIRS for high-resolution spectroscopy for shortest-period stars

**Two-telescope system:** provides complementary instrumentation, longer baseline modeling, insurance against weather





# How do SMBHs Form?

??

Stellar Mass  
Black Holes

<100 Msun

$10^2$

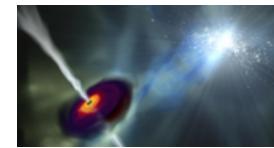


gravitational  
runaway?



PopIII SNe?

Direct collapse?



$10^3$

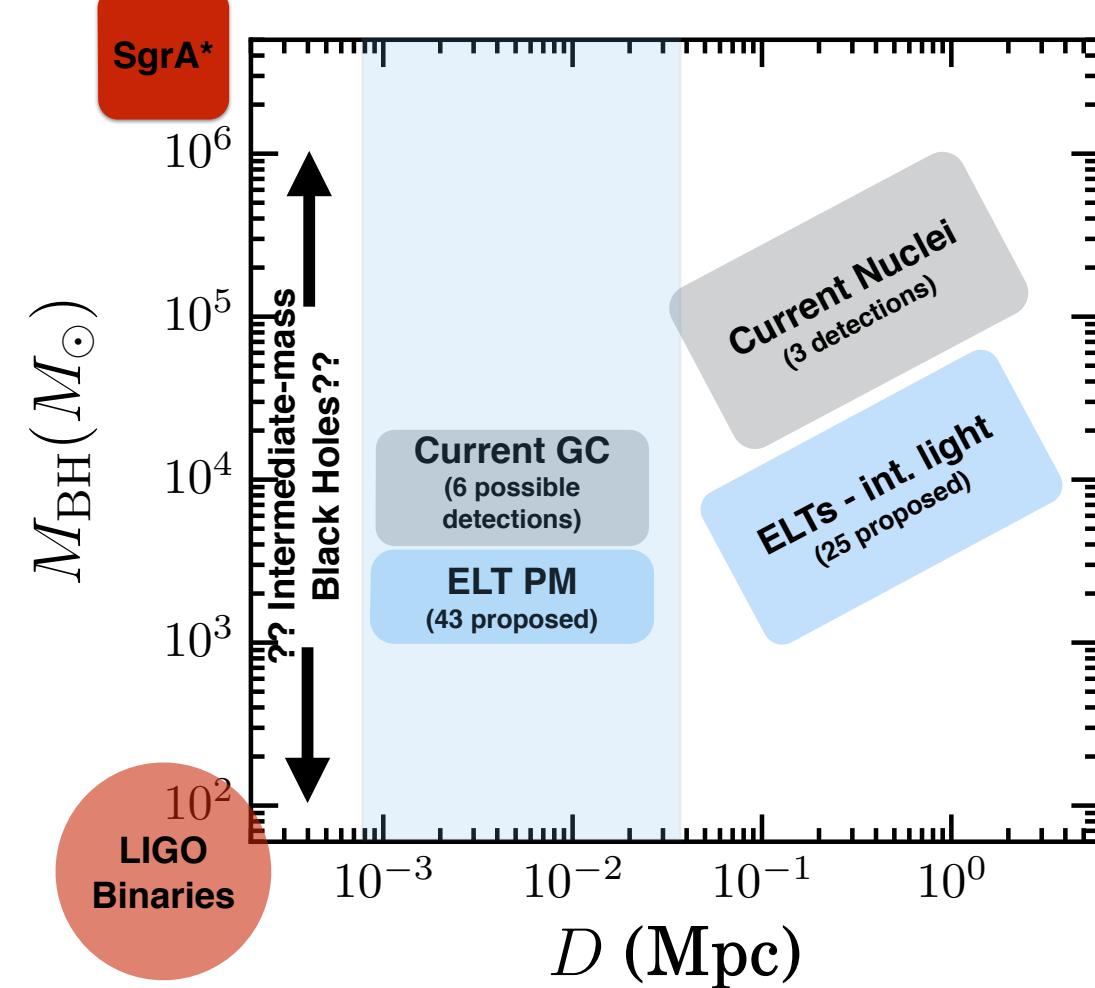
$10^4$

> $10^5$  Msun

Supermassive  
Black Holes

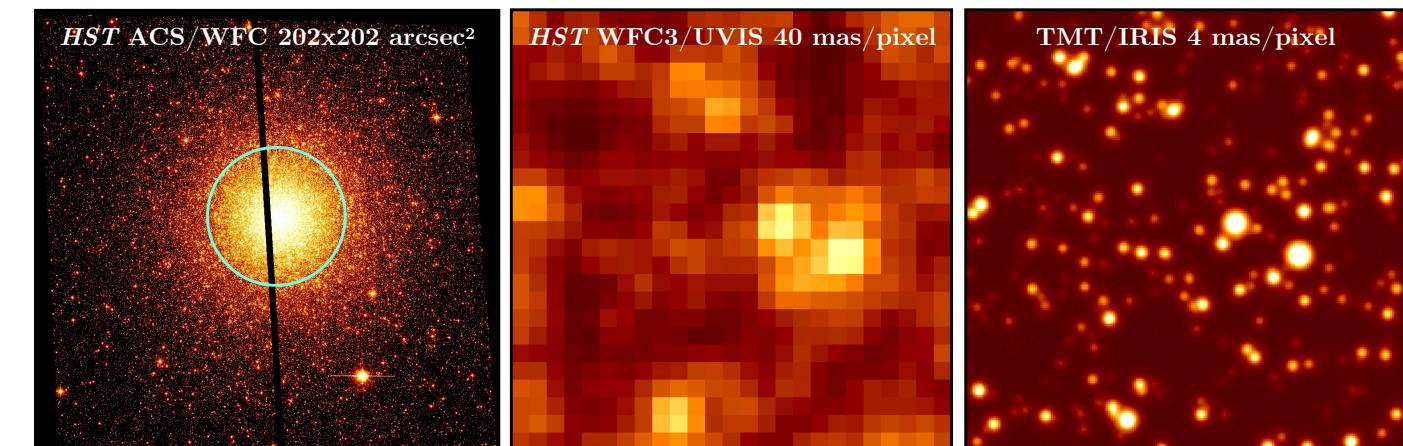


# Search for Intermediate-mass Black Holes



## Two Experiments:

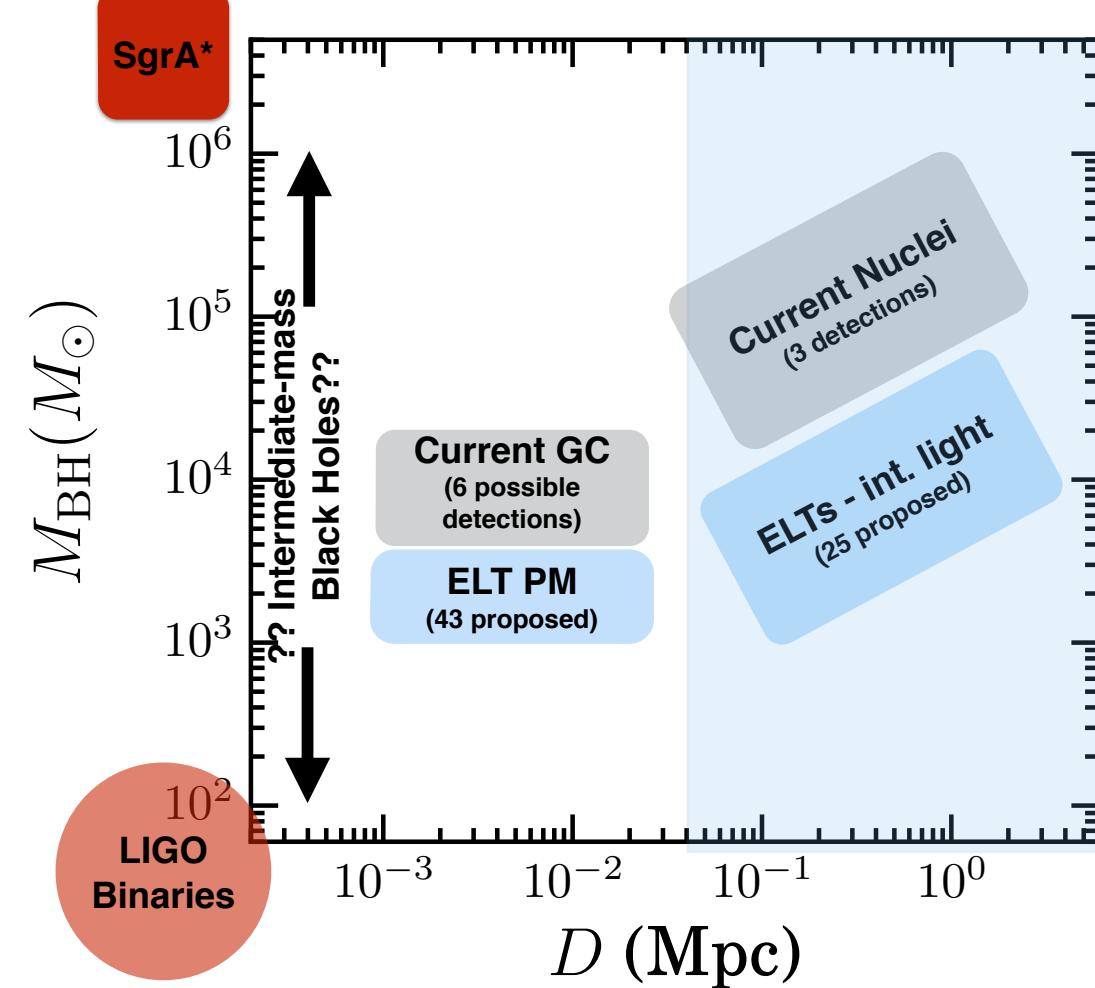
Proper motion measurements of 43 MW GCs  
2e3 Msun limits with 3 epochs  
100 total hrs\*



\*depending on geometric distortion



# Search for Intermediate-mass Black Holes



## Two Experiments:

Integrated-light observations of 25 stellar nuclei in galaxies  $< 5 \text{ Mpc}$

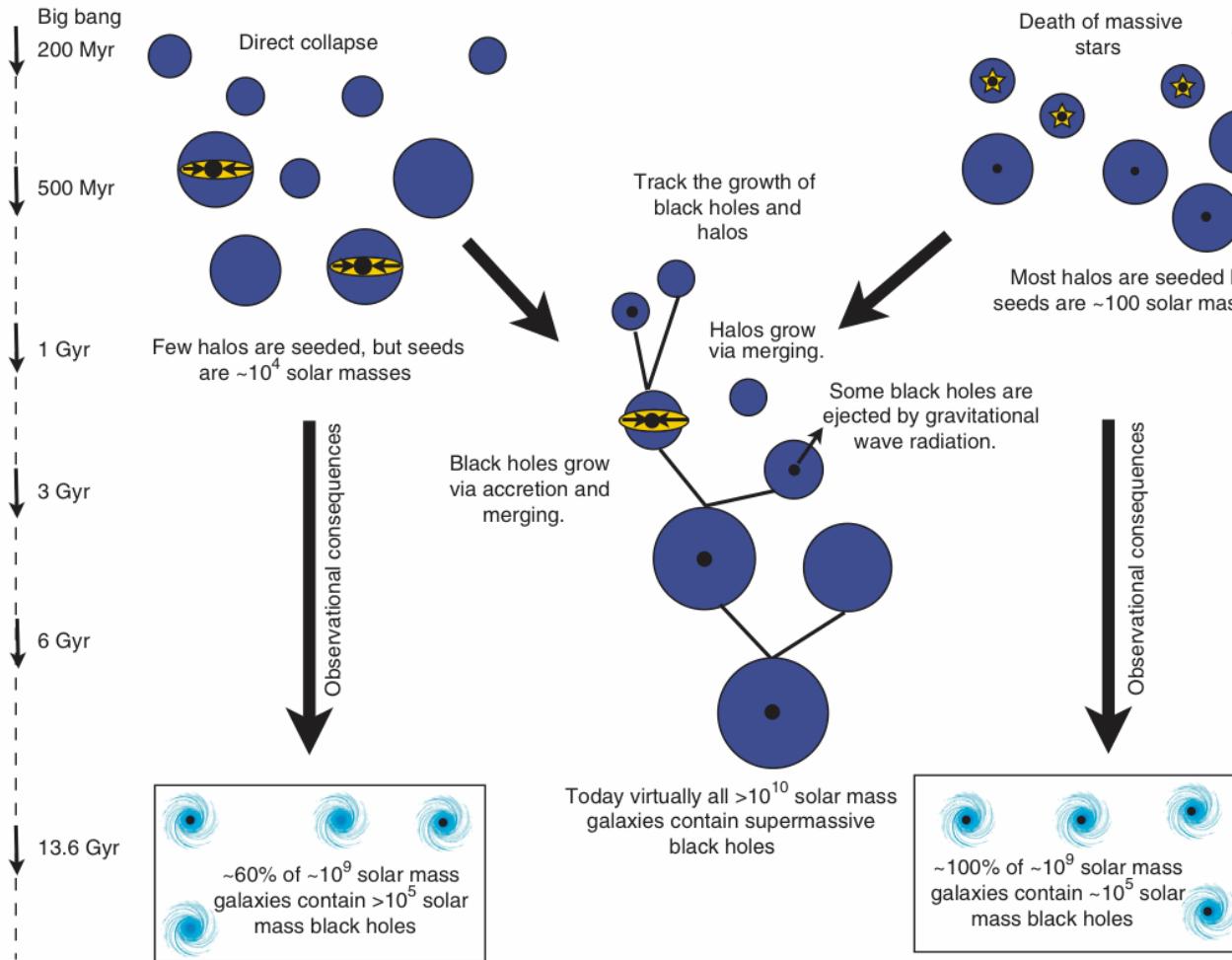
TMT/IRIS+GMTIFS  $< 5 \text{ Mpc}$ :

$10^4 M_{\odot}$  limits, 120 hrs

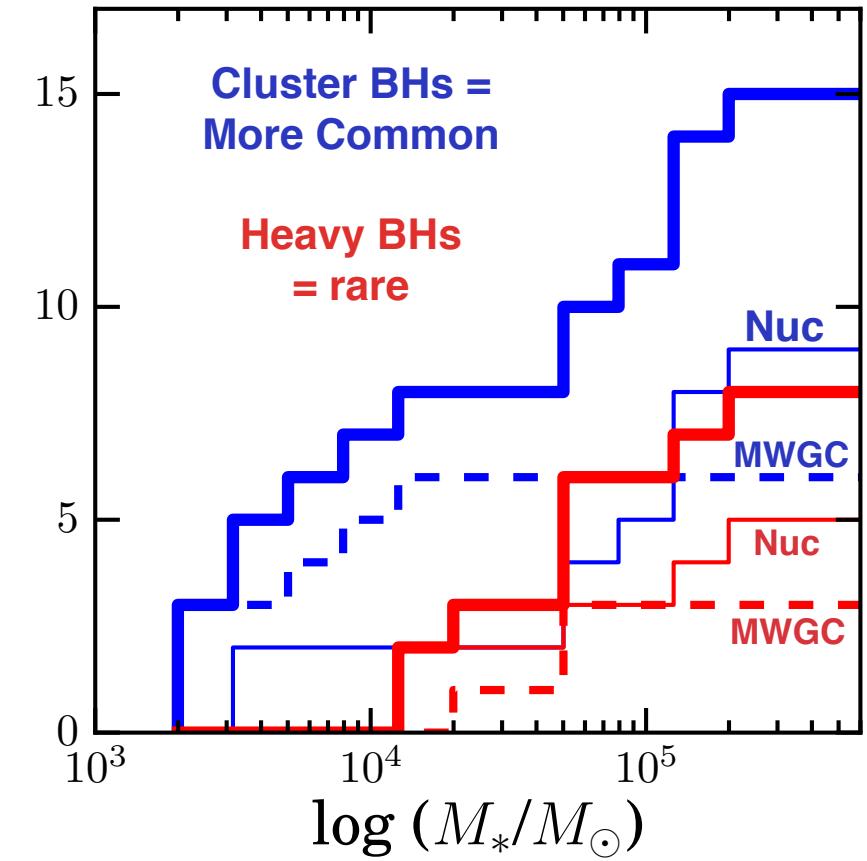
Two-telescope system: Access to all available targets (and detection rate may be low)



# Solve the Seed Problem



TOTAL NUMBER





# US-ELT: Transforming Black Hole Science

Is GR the right description of black holes?

Proper motions and radial velocities of stars at the Galactic Center

Extended mass distributions and GR tests: 360 hrs

How did supermassive black holes (SMBH) form?

Search for intermediate-mass black holes

Mass function and environments, first-ever detections of IMBHs: 200-300hrs

The combination of angular resolution  
and sensitivity will transform BH science

