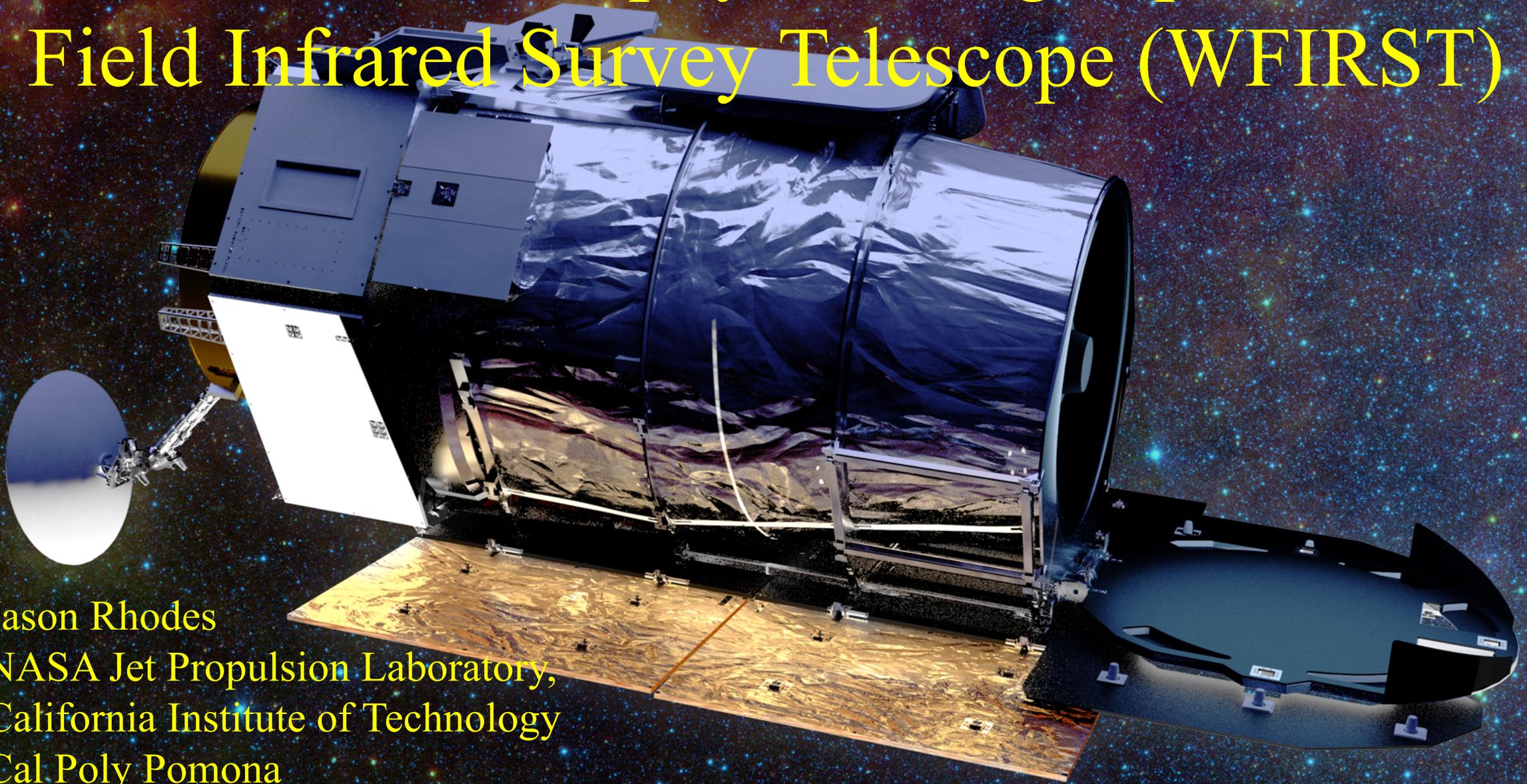


# NASA's Next Astrophysics Flagship: The Wide Field Infrared Survey Telescope (WFIRST)



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Cal Poly Pomona  
October 23, 2018

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**Jet Propulsion Laboratory**  
California Institute of Technology

# ASTROPHYSICS

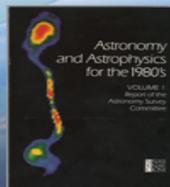
## Decadal Survey Missions

1990



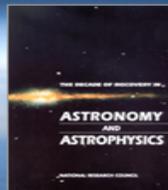
**1972**  
Decadal  
Survey  
*Hubble*

1999



**1982**  
Decadal  
Survey  
*Chandra*

2003



**1991**  
Decadal  
Survey  
*Spitzer*

LRD: 2021



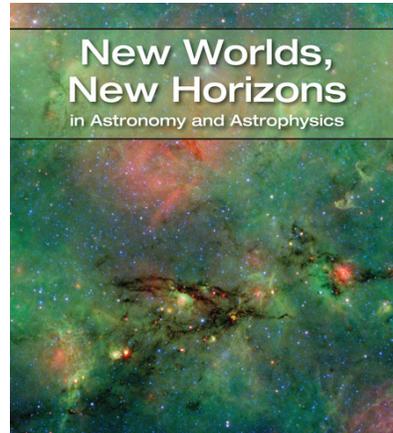
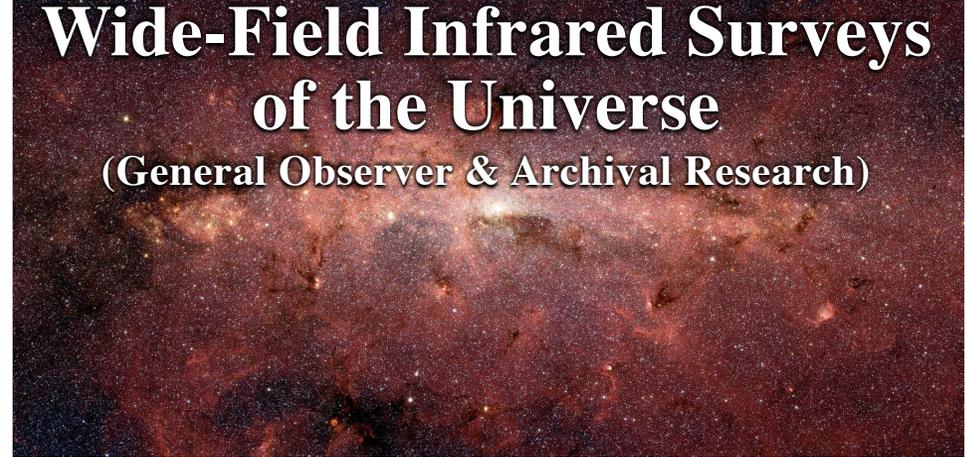
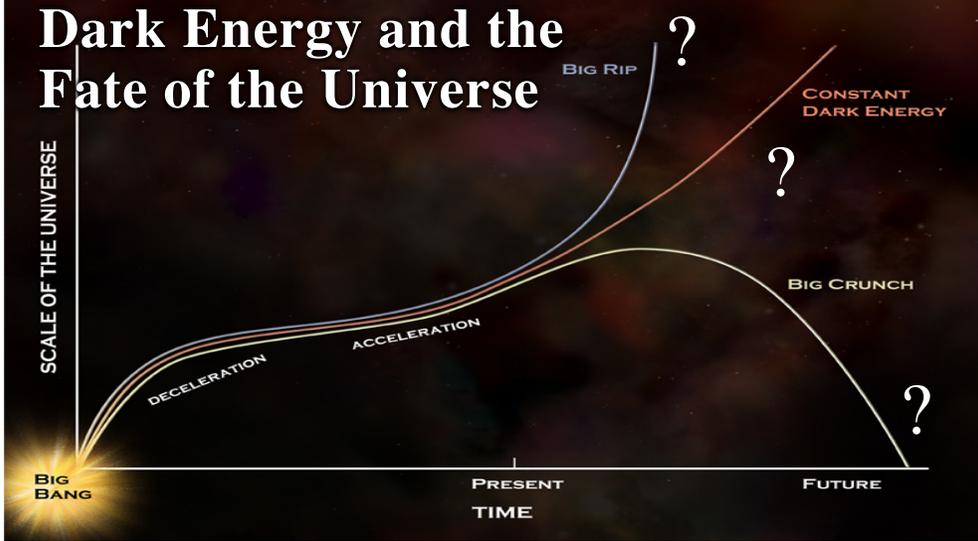
**2001**  
Decadal  
Survey  
*JWST, SOFIA*

LRD: 2020s

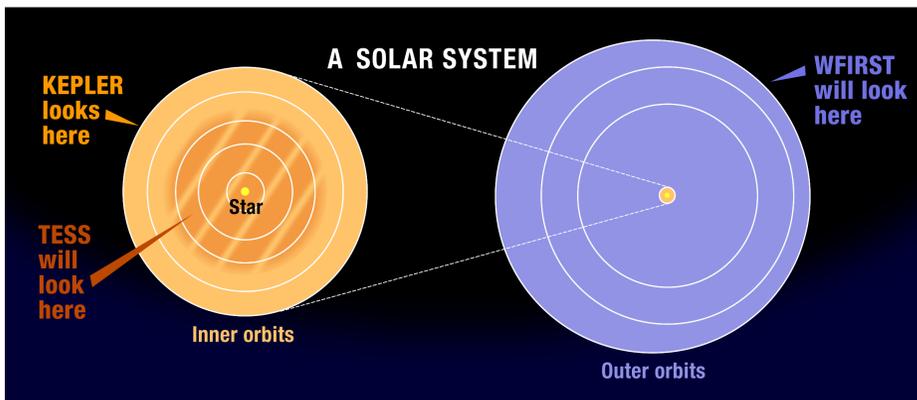


**2010**  
Decadal  
Survey  
*WFIRST*





The full distribution of planets around stars



# A Bigger WFIRST

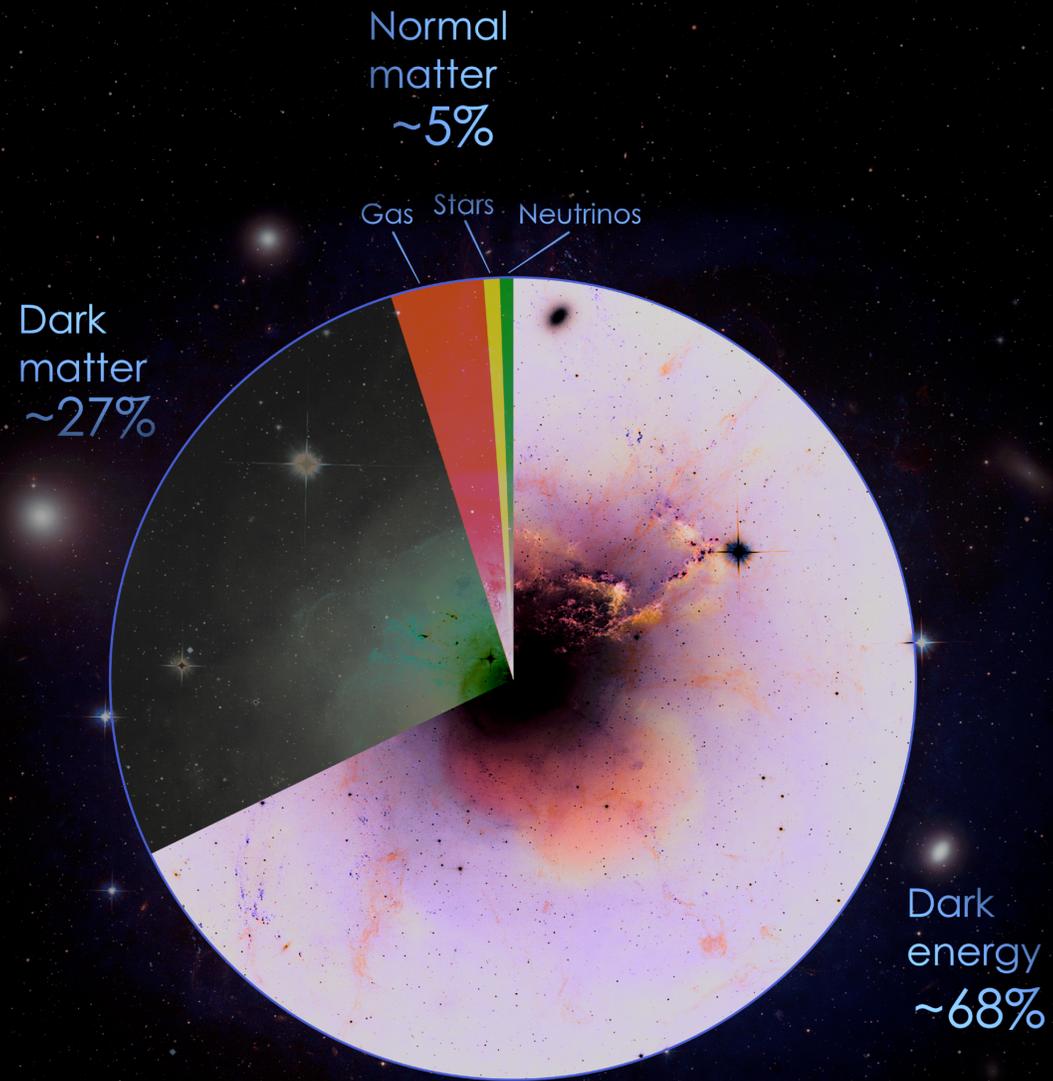
- Uses repurposed 2.4 m telescope from the another government agency
- Three science pillars: dark energy, exoplanets, infrared surveys
- Science done with Wide Field Instrument (WFI), with 18 H4RG detectors



- Coronagraph Instrument (CGI) is a tech demo that will be ~1000x better than previous coronagraphs
- Designed to be Starshade ready
- Designed to be serviceable
- 5 year primary mission at L2
- 10+ year extended mission possible



# The Universe as a Pie Chart

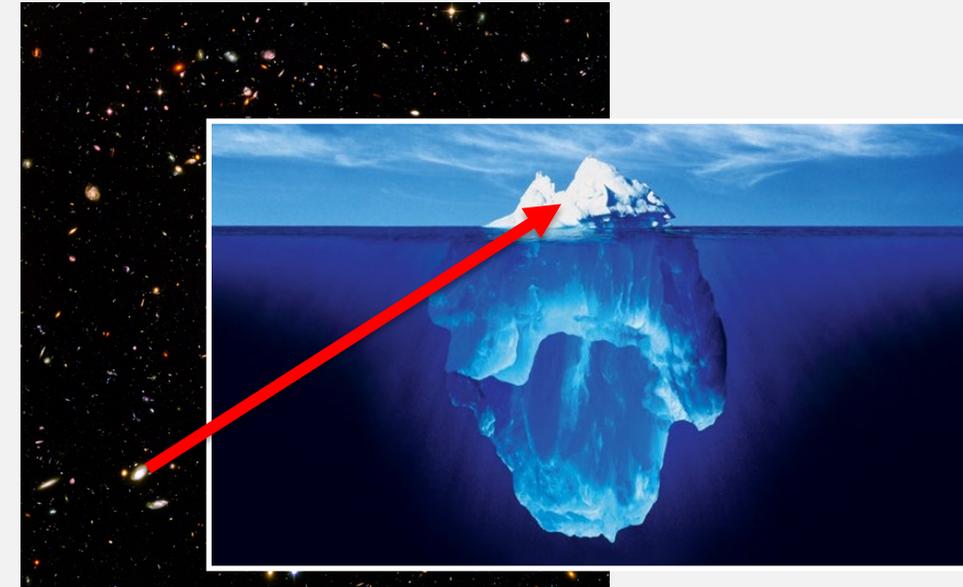
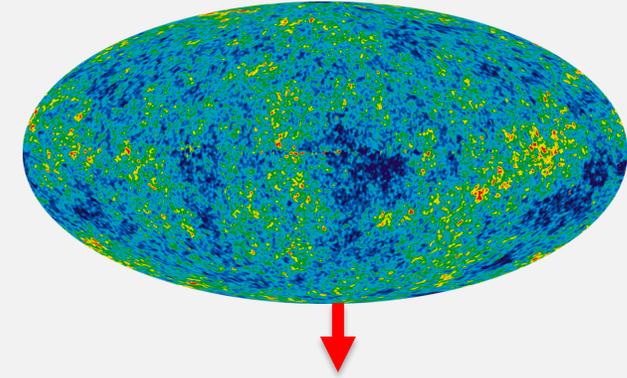


# Consequences of DE



Dark Energy affects the:

- **Expansion history** of the Universe
  - How fast did the Universe expand?
  - Also called the **geometry** of the Universe
- **Growth of structures**
  - How do structures (which are mostly dark matter) evolve and grow over time
  - Attractive gravity competes with repulsive dark energy



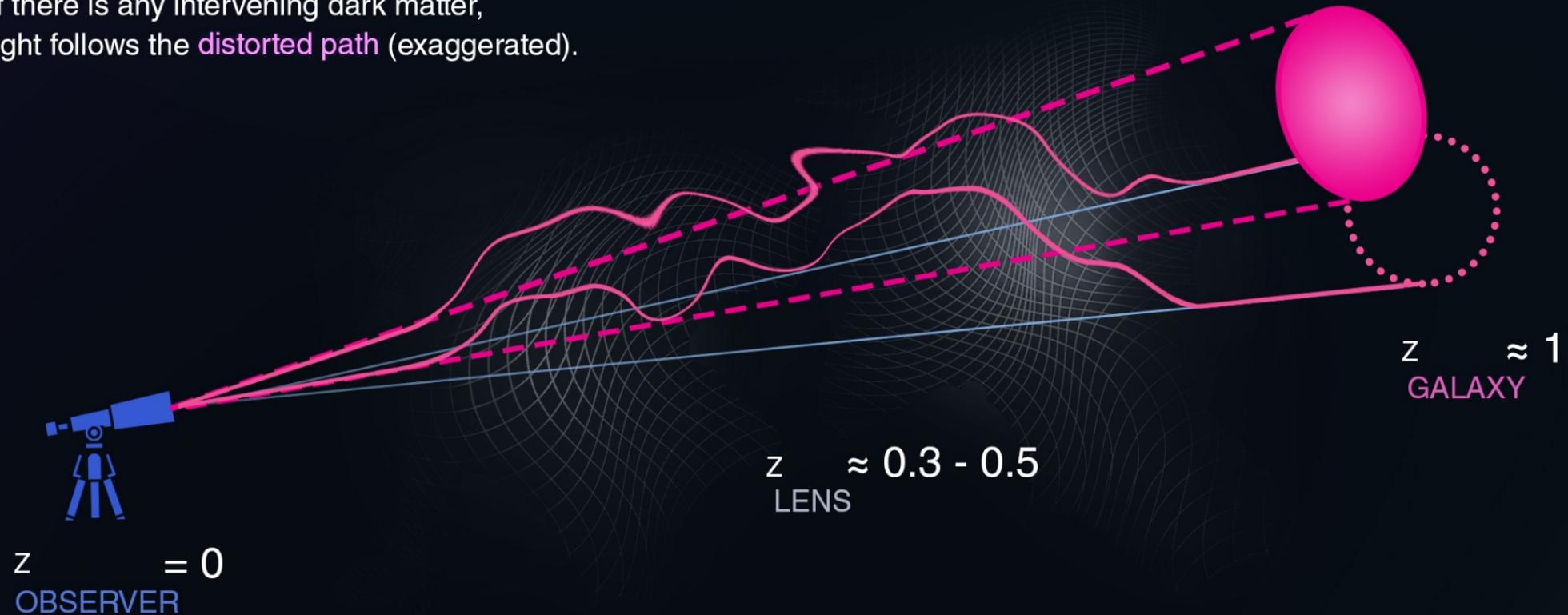
If Einstein's General Relativity is wrong, **modified gravity theories** could explain the accelerating expansion.

This would change the above effects differently, *so we must measure them both!*

# GRAVITATIONAL LENSING



If there is any intervening dark matter, light follows the **distorted path** (exaggerated).



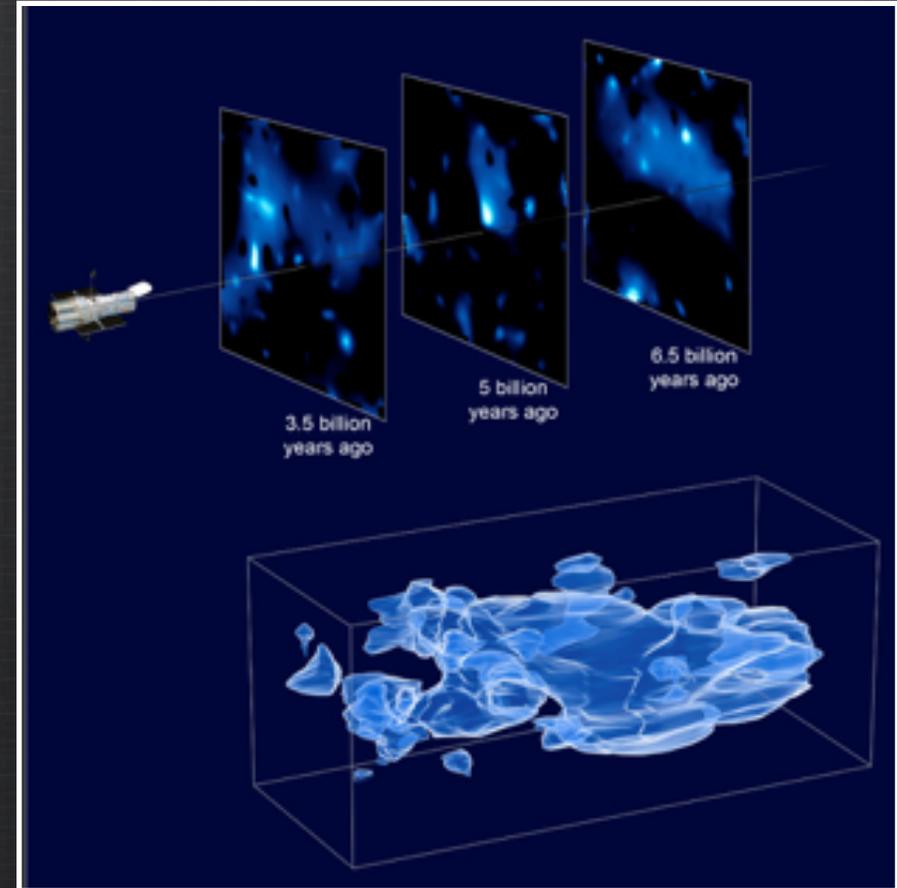
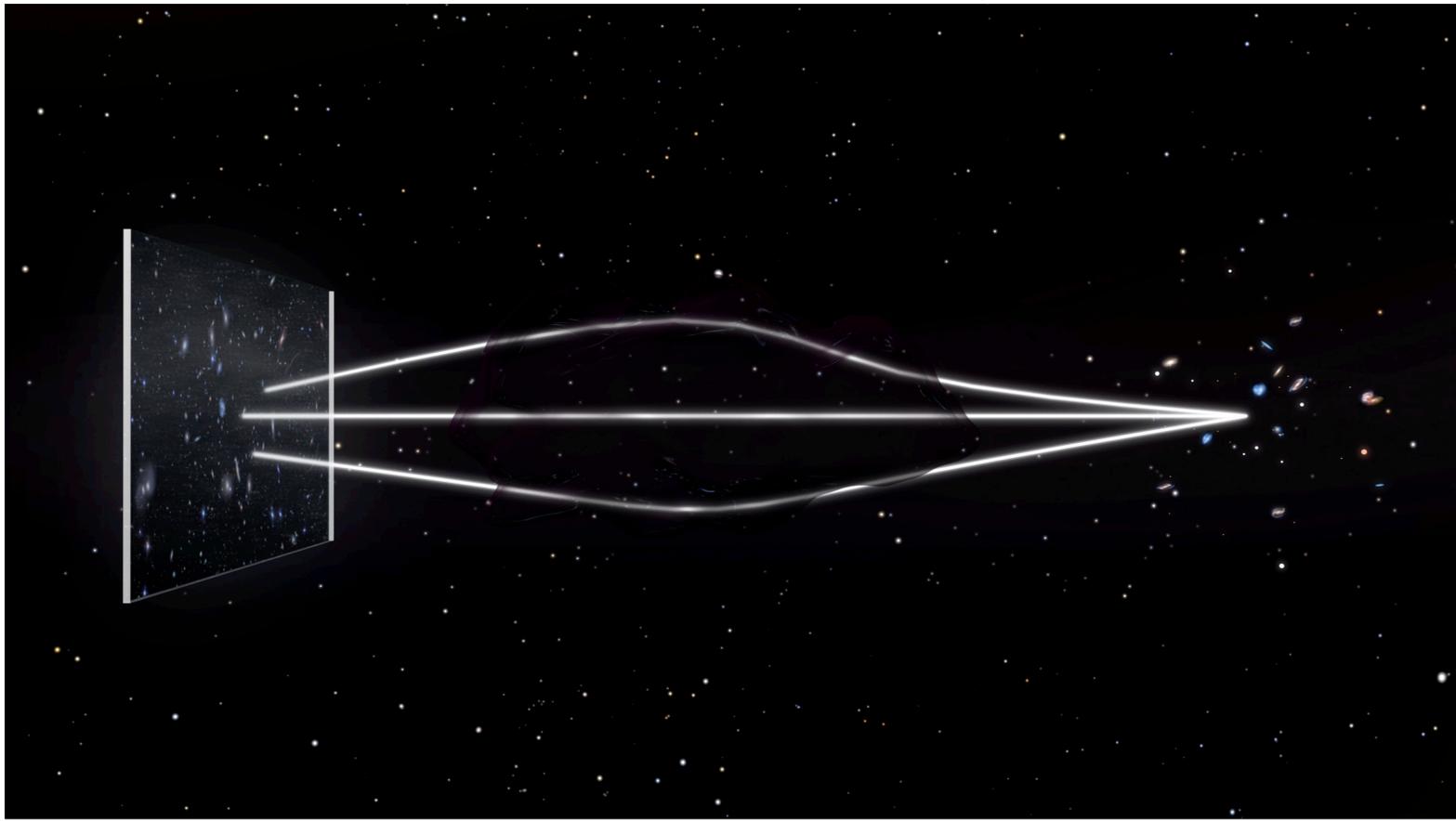
Background images are magnified and sheared by  $\sim 2\%$ , mapping a circle into an ellipse. Like glass lenses, gravitational lenses are most effective when placed roughly half way between the source and the observer.

# A Penny in the Pool



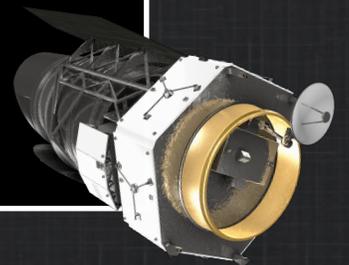
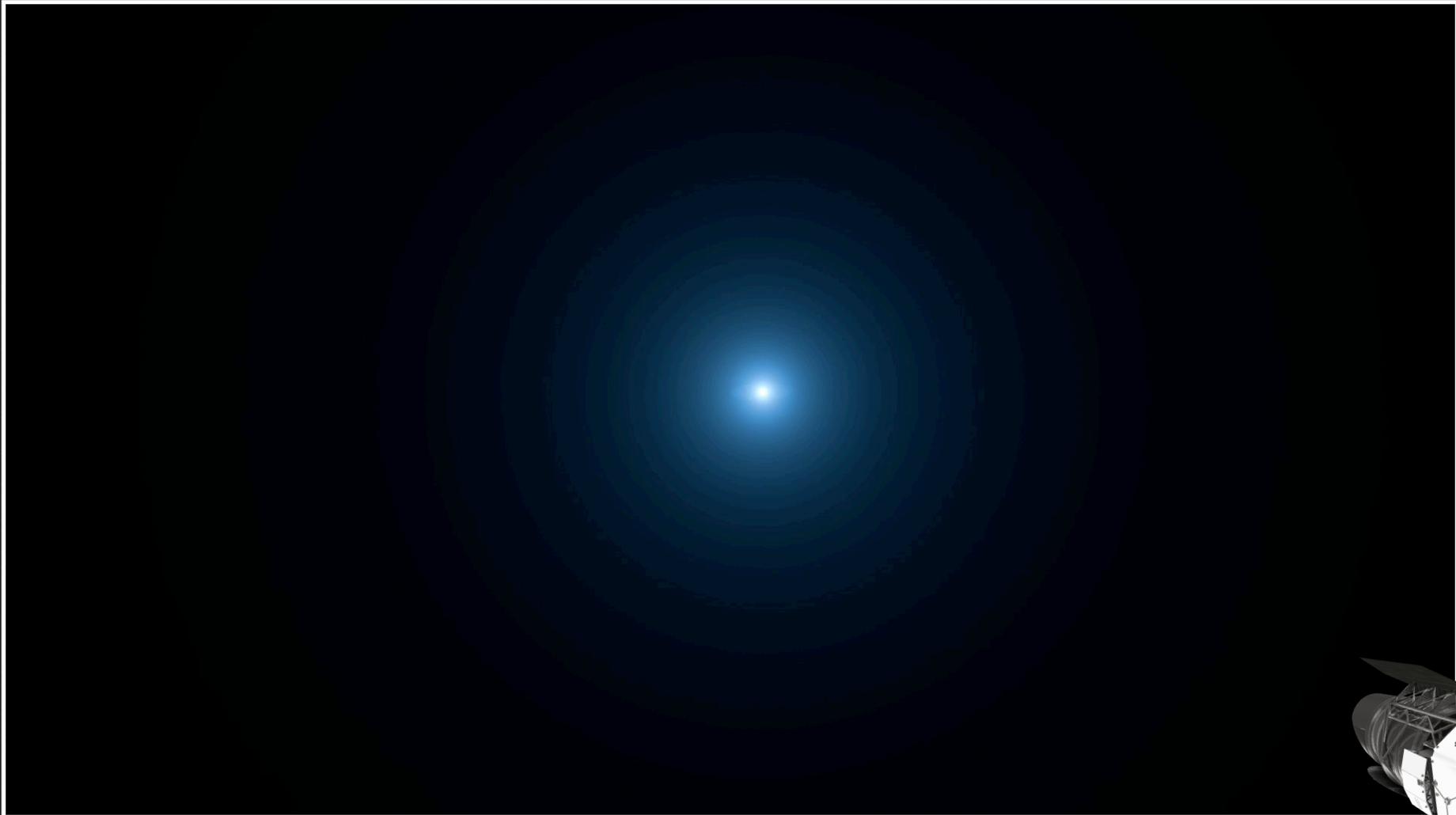
# WFIRST will

measure galaxy shapes to map dark matter and measure the growth of galaxies over the Universe's life



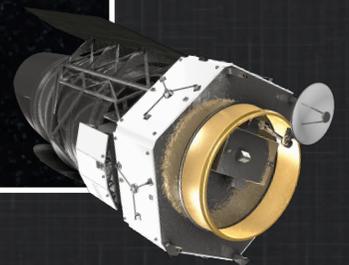
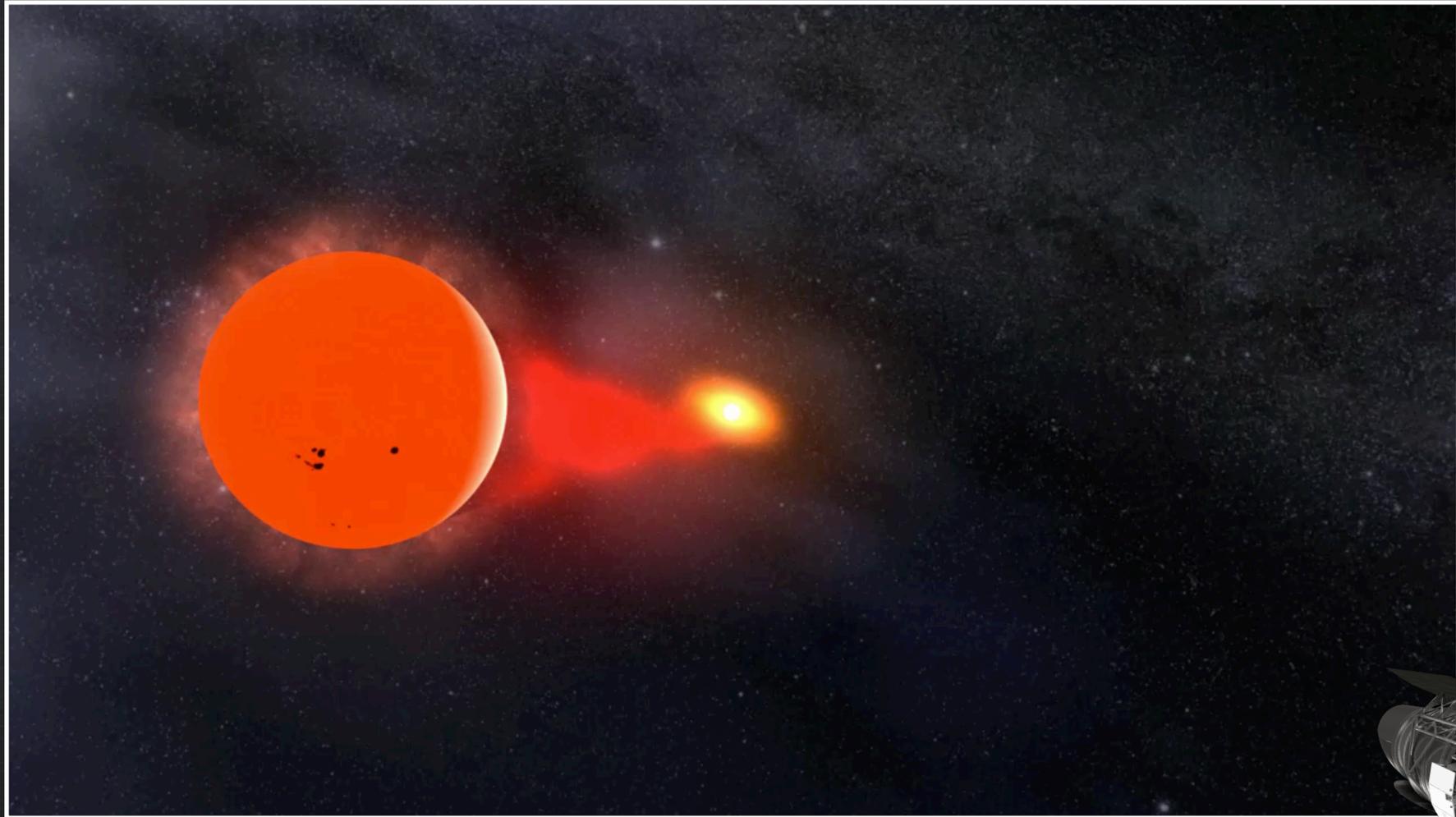
# WFIRST will

map the positions of galaxies to establish a cosmic standard ruler to measure the Universe's expansion history



# WFIRST will

discover exploding stars (supernovae) across cosmic time  
to establish precise distances to galaxies



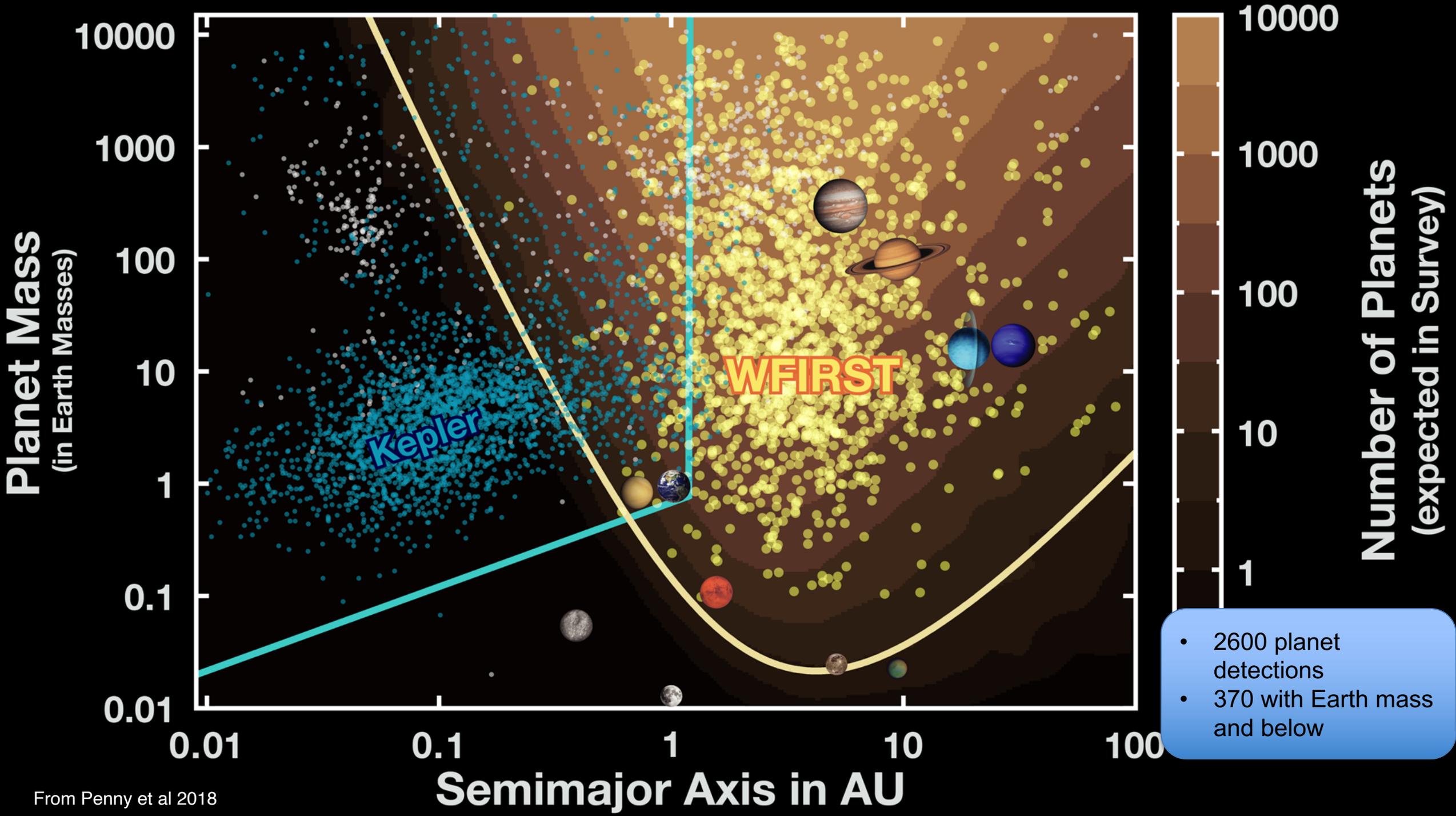


# Exoplanets: Detections by Discovery Year

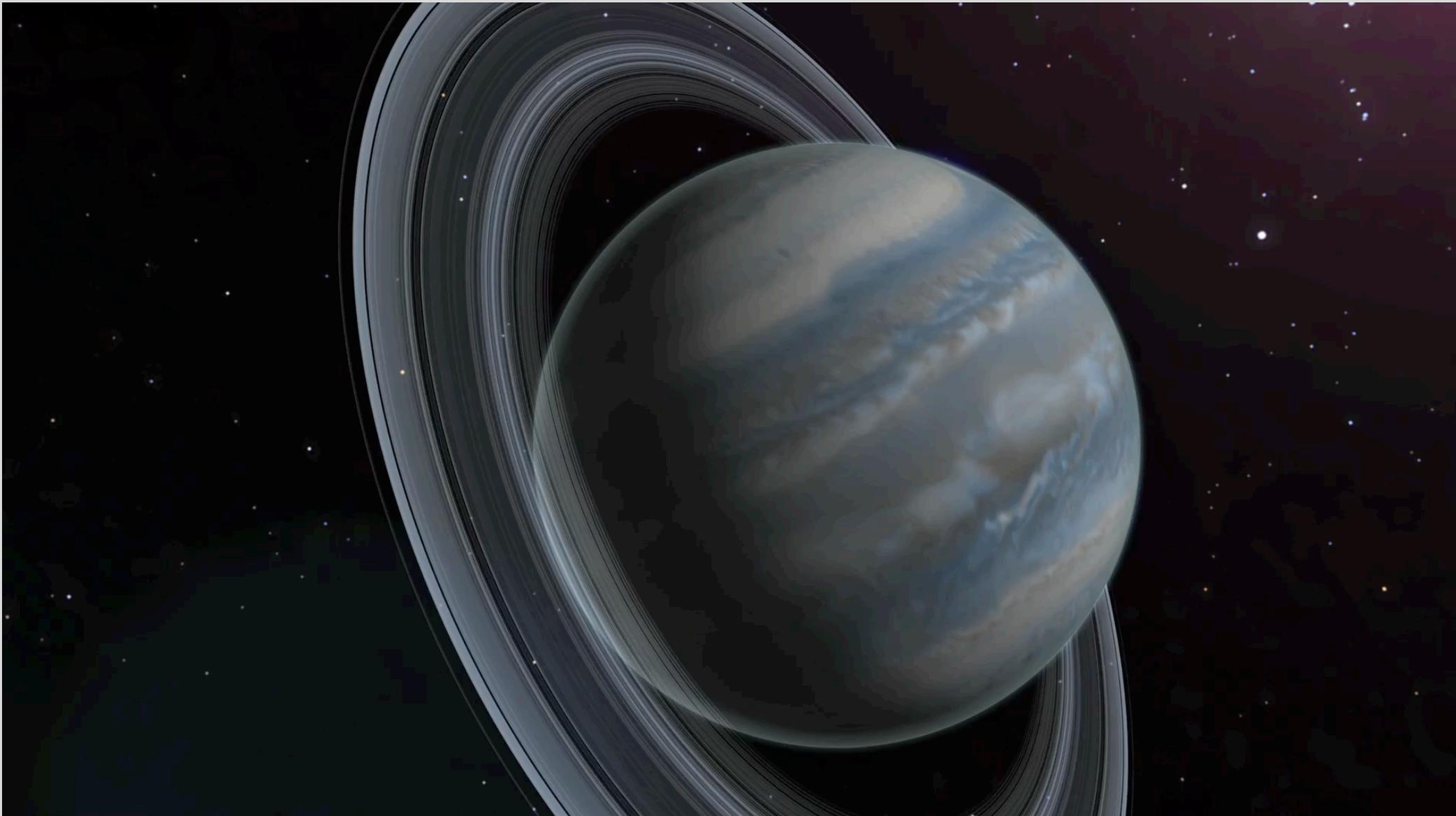
1989-2018

# Microlensing





# Coronagraphy



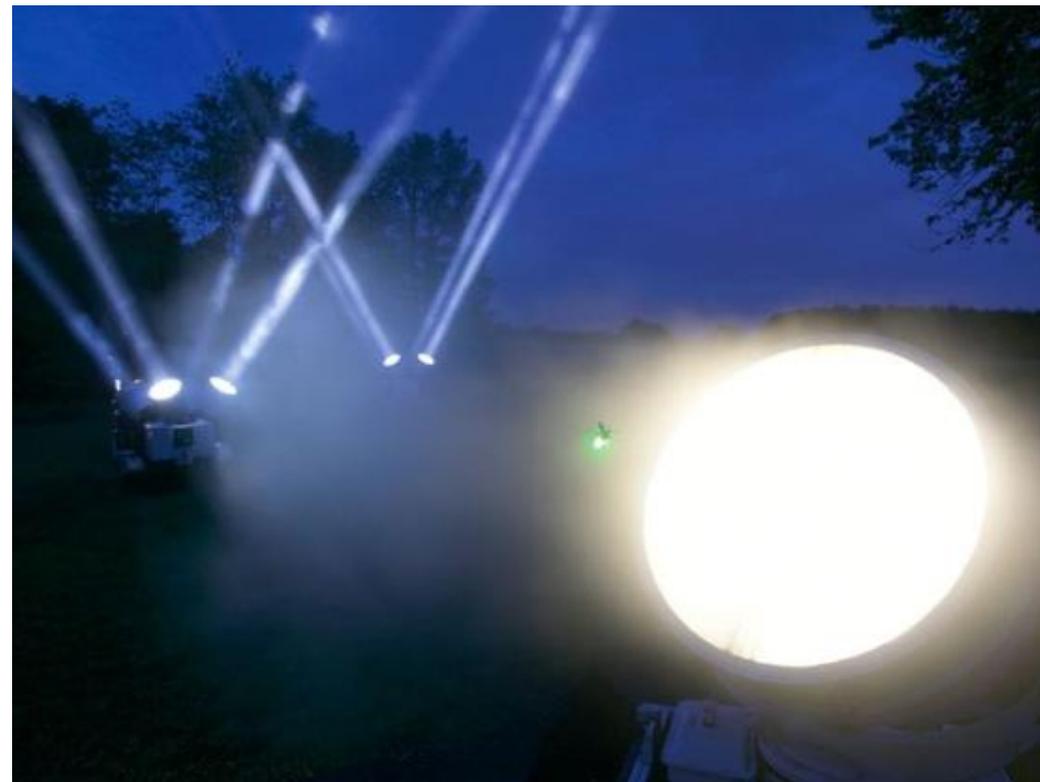


# Coronagraphy is Challenging



# A Firefly and a Spotlight

Seeing an exoplanet around a star is like trying to see a firefly near a spotlight in Los Angeles... when you are in Washington, DC!



Credit: S Gaudi



Seeing an **Earth-like** exoplanet in the **habitable zone** around a **Sun-like** star is like trying to see a firefly near **ONE THOUSAND spotlights** in Los Angeles... when you are in Washington DC!

# Coronagraphy- Powers of 10

Contrast Ratio (planet light to star light)

$10^{-5} - 10^{-6}$  1 part in 100,000 to 1,000,000

What we can get from coronagraphs like GPI now and in the near future

Better than  $10^{-8}$  1 part in 100,000,000

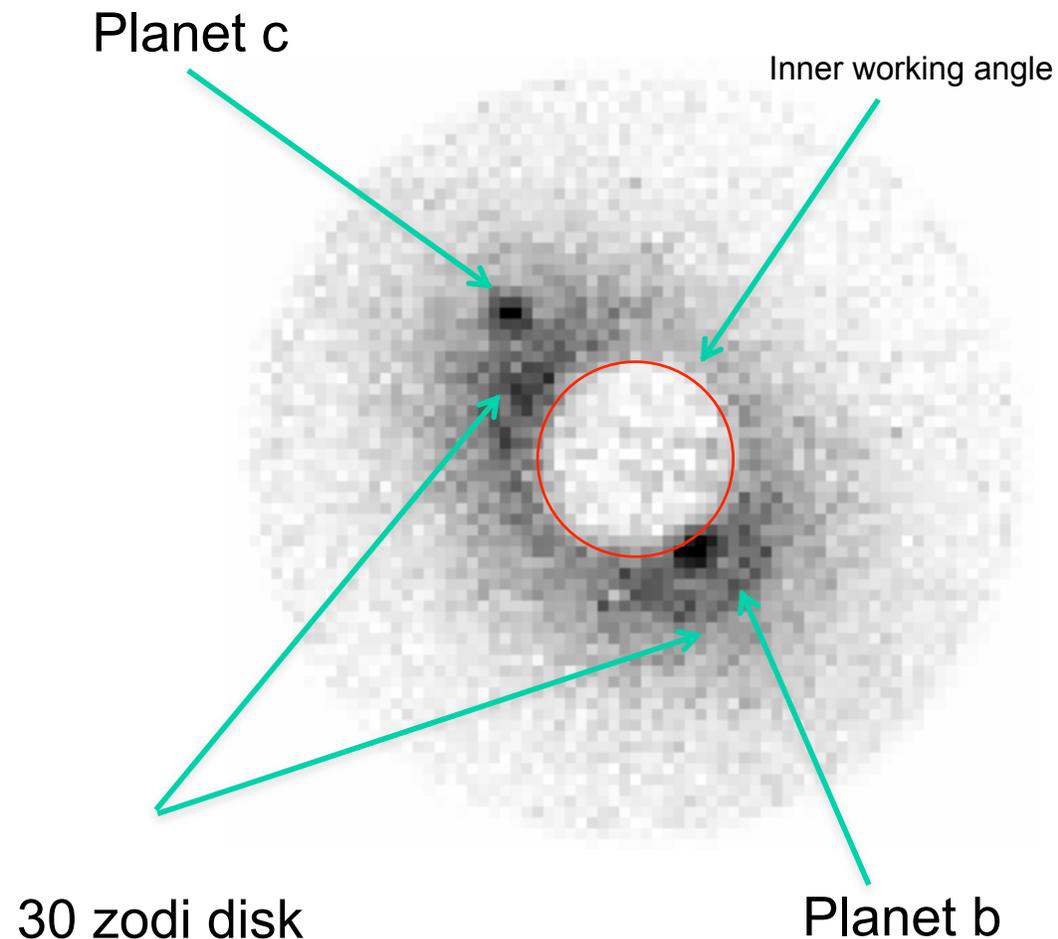
What we have demonstrated in a lab for WFIRST

$10^{-9}$  1 part in 1,000,000,000

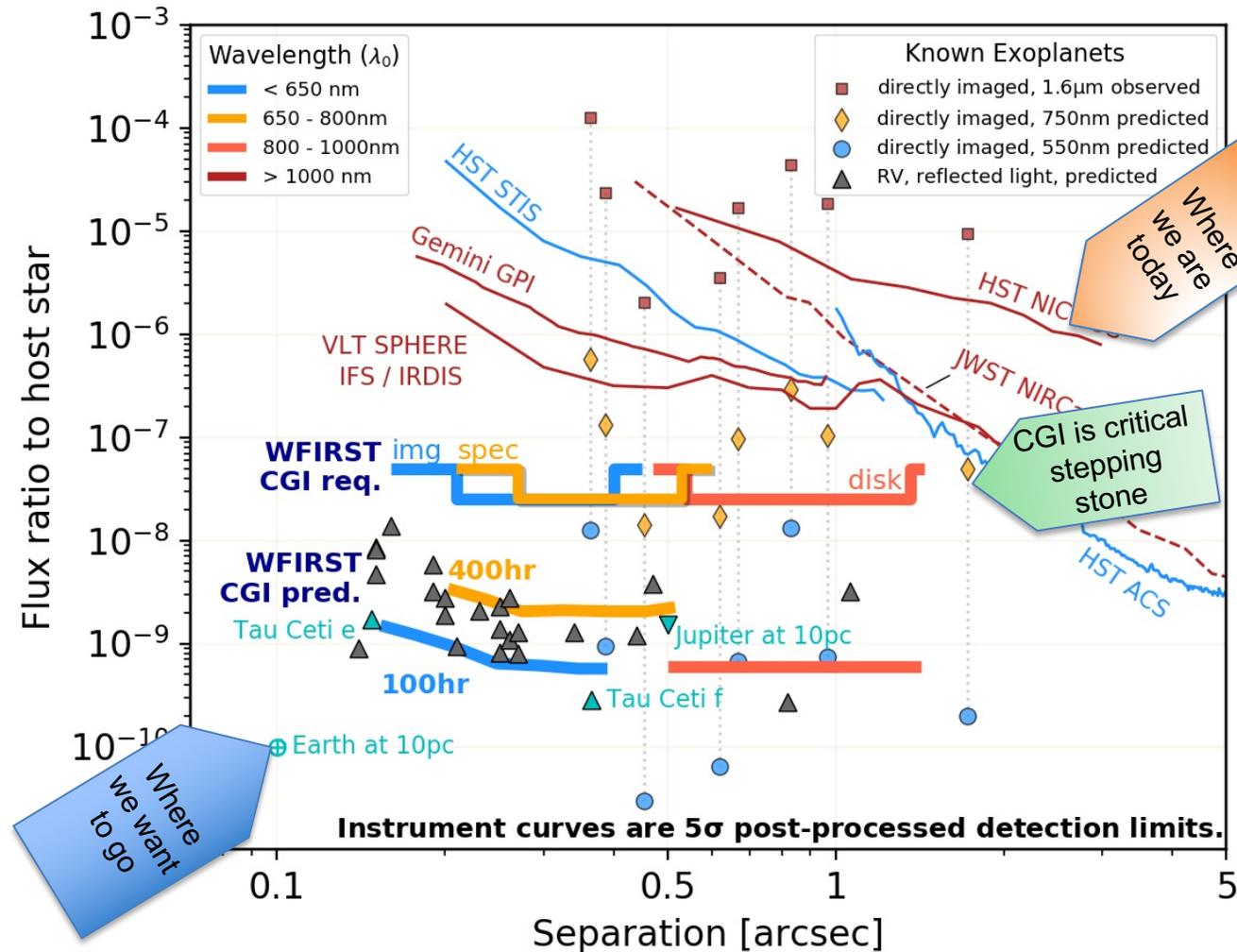
What WFIRST's coronagraph is being designed to achieve

$10^{-10}$  1 part in 10,000,000,000

What we need to see another Earth (with a future mission like HabEx or LUVOIR)



- CGI projected capabilities represent a 1000 fold compared to current capabilities
  - Enabled by active control of optical wavefront errors and pointing
- Dozens of planets within reach of characterization
- exoEarths in Habitable zone further x10-100 improvement in contrast and x2 in spatial resolution
- CGI is a major stepping stone that will obtain optical spectra of mature exoJupiters





# Opportunities with WFIRST

- 2020 Decadal Survey will consider a separate Starshade mission to fly with WFIRST
- 25% General Observer (GO) in 5 year prime mission
- ~100% GO in extended mission
- All prime survey science teams will be competed in ~2021
- All data released immediately- no proprietary period
- CGI available via a Participating Scientists Program
- Baseline mission includes contributions from ESA, France (CNES), Germany (DLR), Japan (JAXA, NAOJ)

# The BIG Questions

- What is the Universe made of ?
- Are we alone?

