



Cosmic Exploration **Caltech** with Infrared Telescopes *The Landscape Ahead*

George Helou
California Institute of Technology

Pasadena, May 2015





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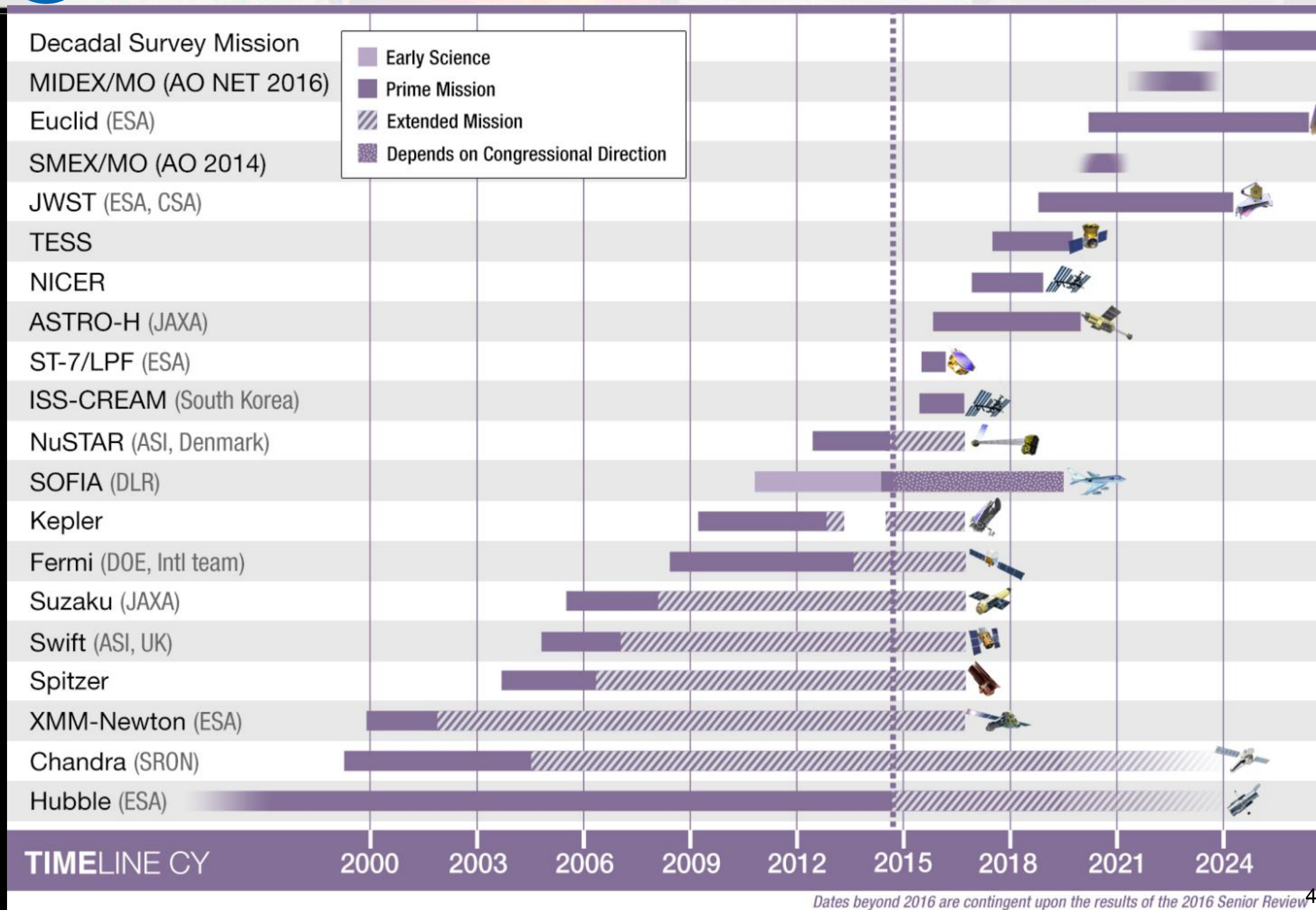
- Facts: Missions & Themes
- Interpretation
- Questions

Pasadena, May 2015

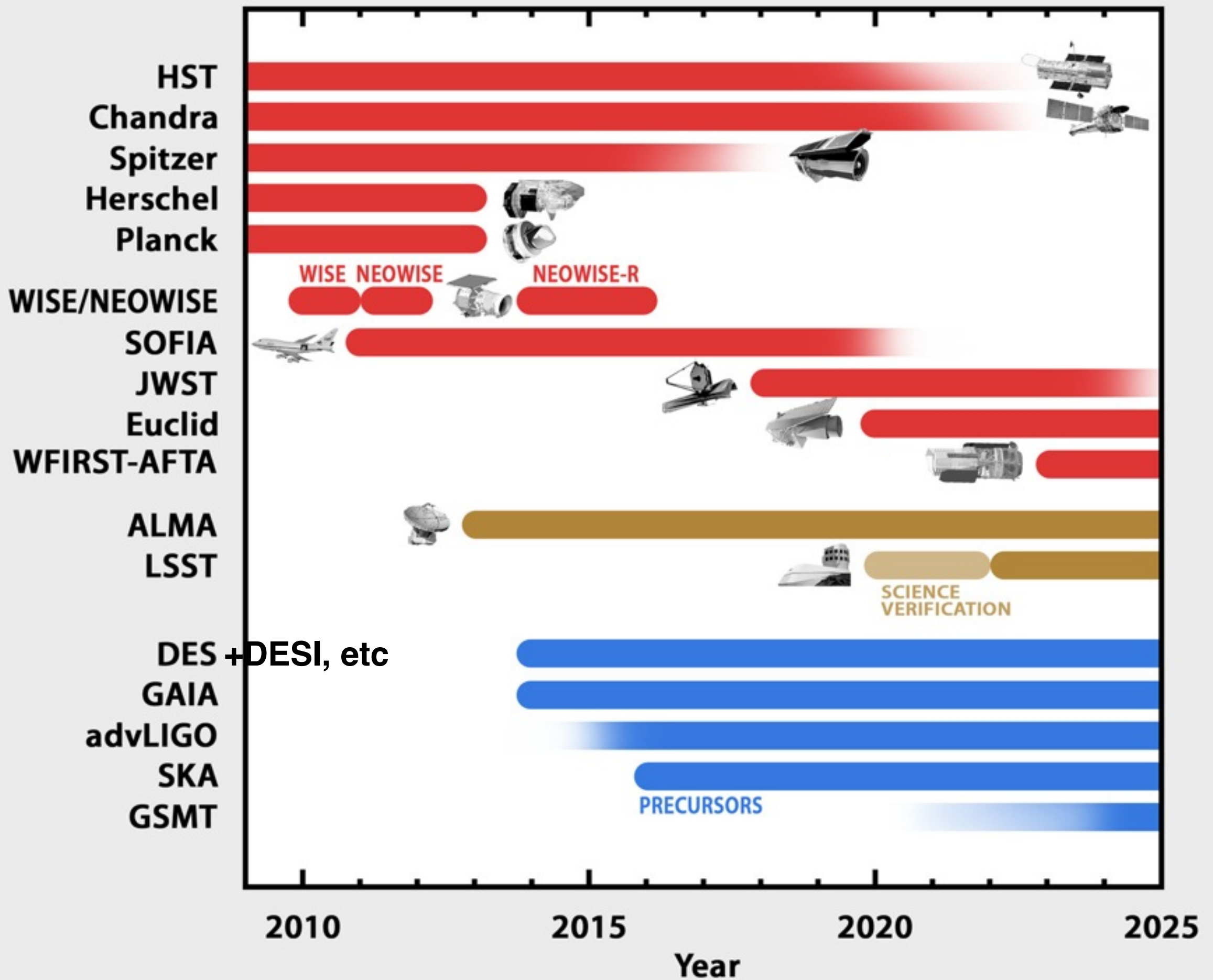
- Facts: Missions & Themes
 - Look ahead to 2020, 2025
- Interpretation
- Questions



Astrophysics Timeline



NASA, ESA, Ground



Cosmic Dawn:

Reionization

First stars, galaxies, BH

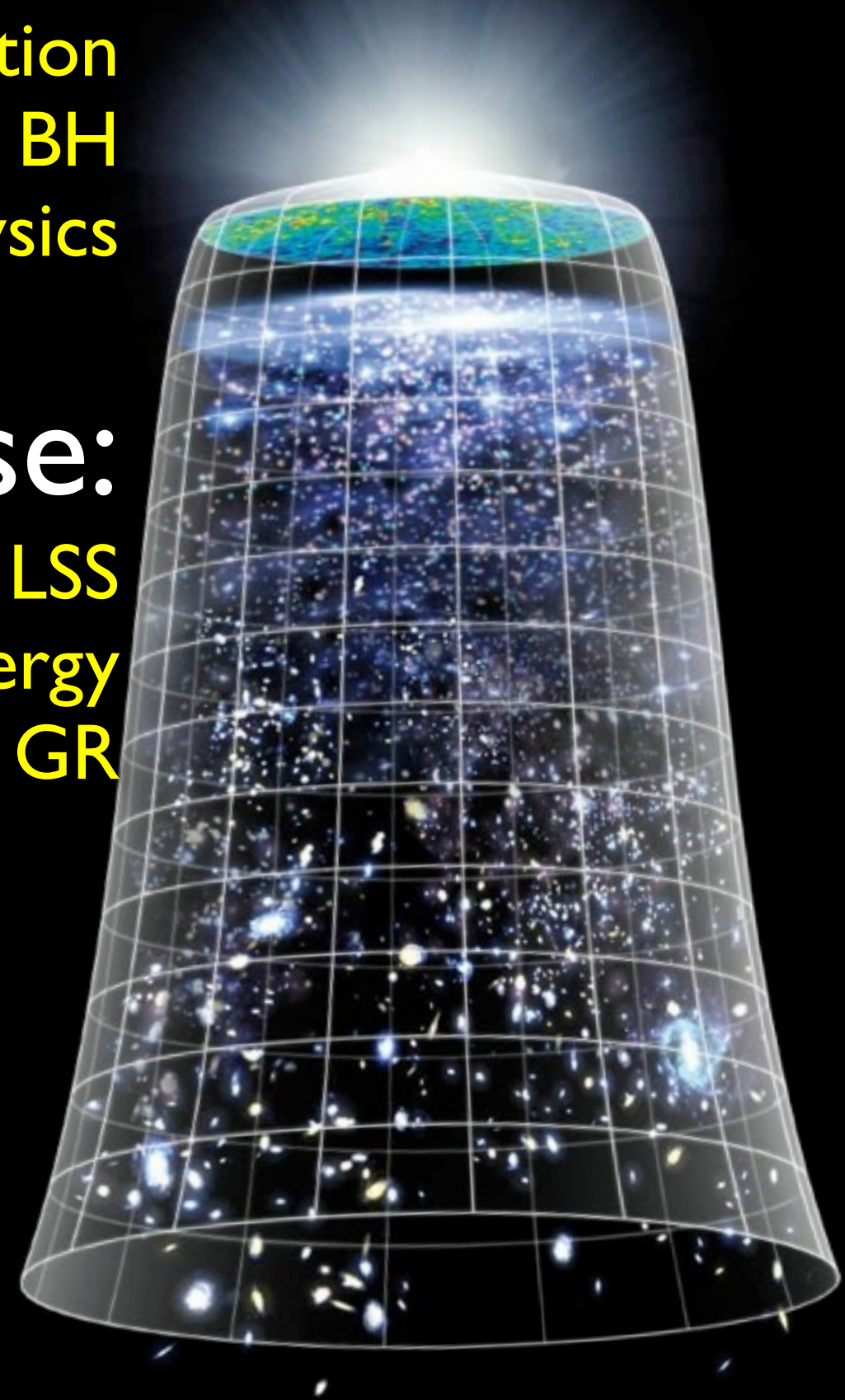
Gastrophysics

Physics of the Universe:

CMB, LSS

Dark Matter & Energy

Gravity Waves , GR



New Worlds:

Seeking habitable worlds
Planetary System Formation

Solar System:

Finding PHA (in time!)
Our System's Dynamical History



Where are we?

decade

« Nel mezzo del cammin di nostra vita
mi ritrovai per una selva oscura,
ché la diritta via era smarrita. »

— Dante Alighieri



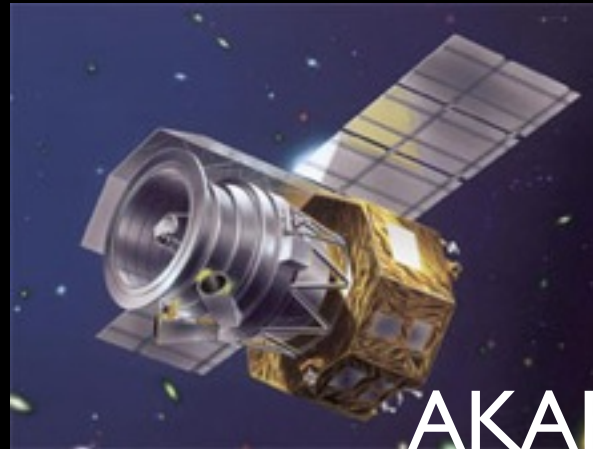
Gustave Foré, *La Selva Oscura*

In the midway of this our mortal life,
I found me in a gloomy wood, astray,
Canto I., lines 1, 2.

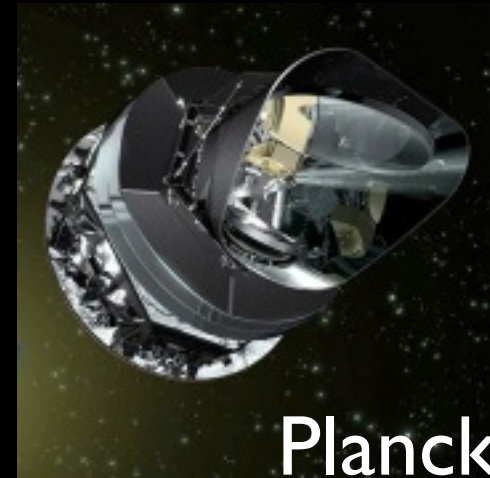
The Infrared Space Telescope Legacy



Herschel



AKARI



Planck



WISE

NEOWISE



IRAS



IRT



MSX



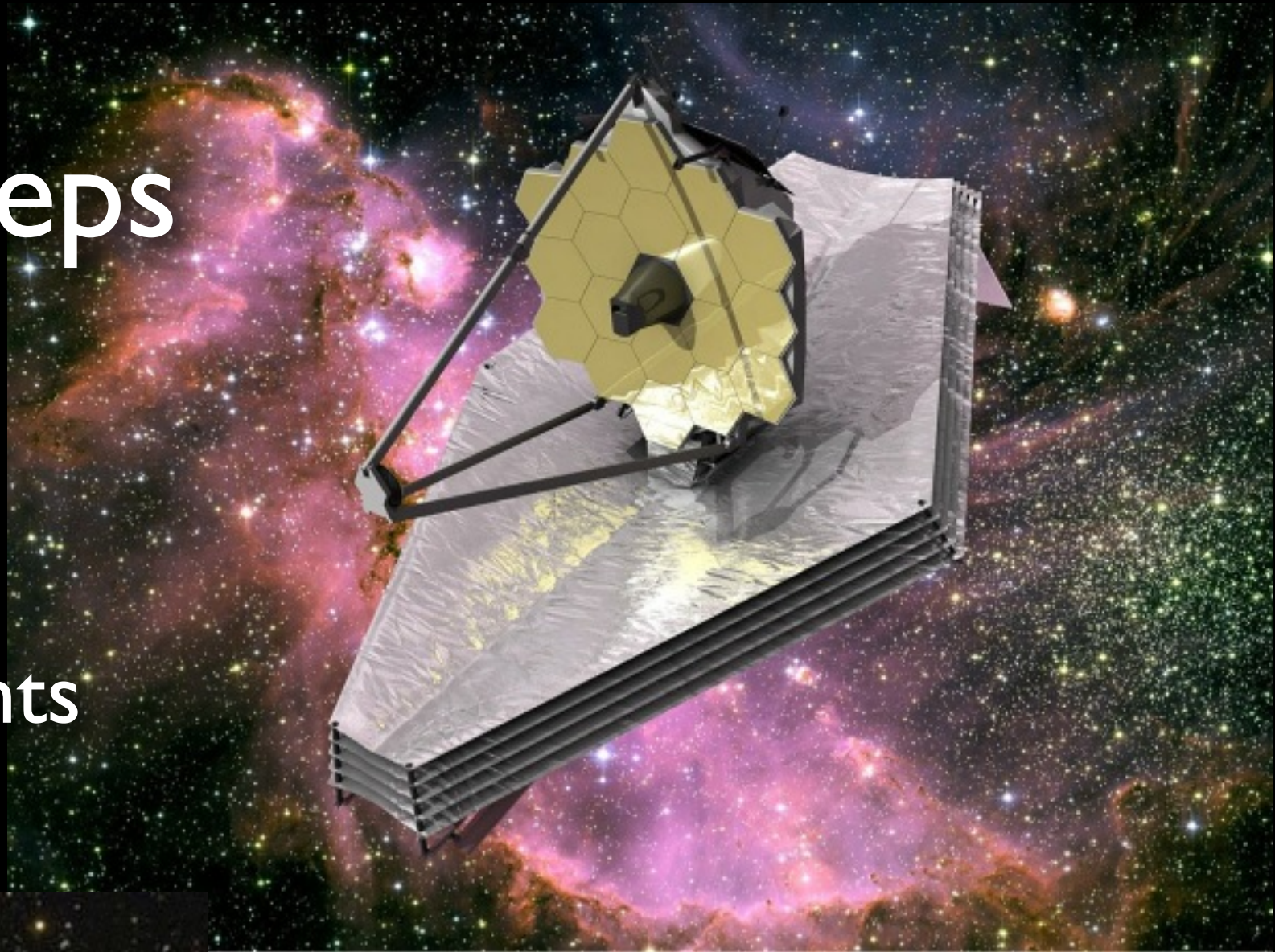
Spitzer



ISO

The Next Steps

- Improved sensitivity, speed of mapping, or specialized instruments



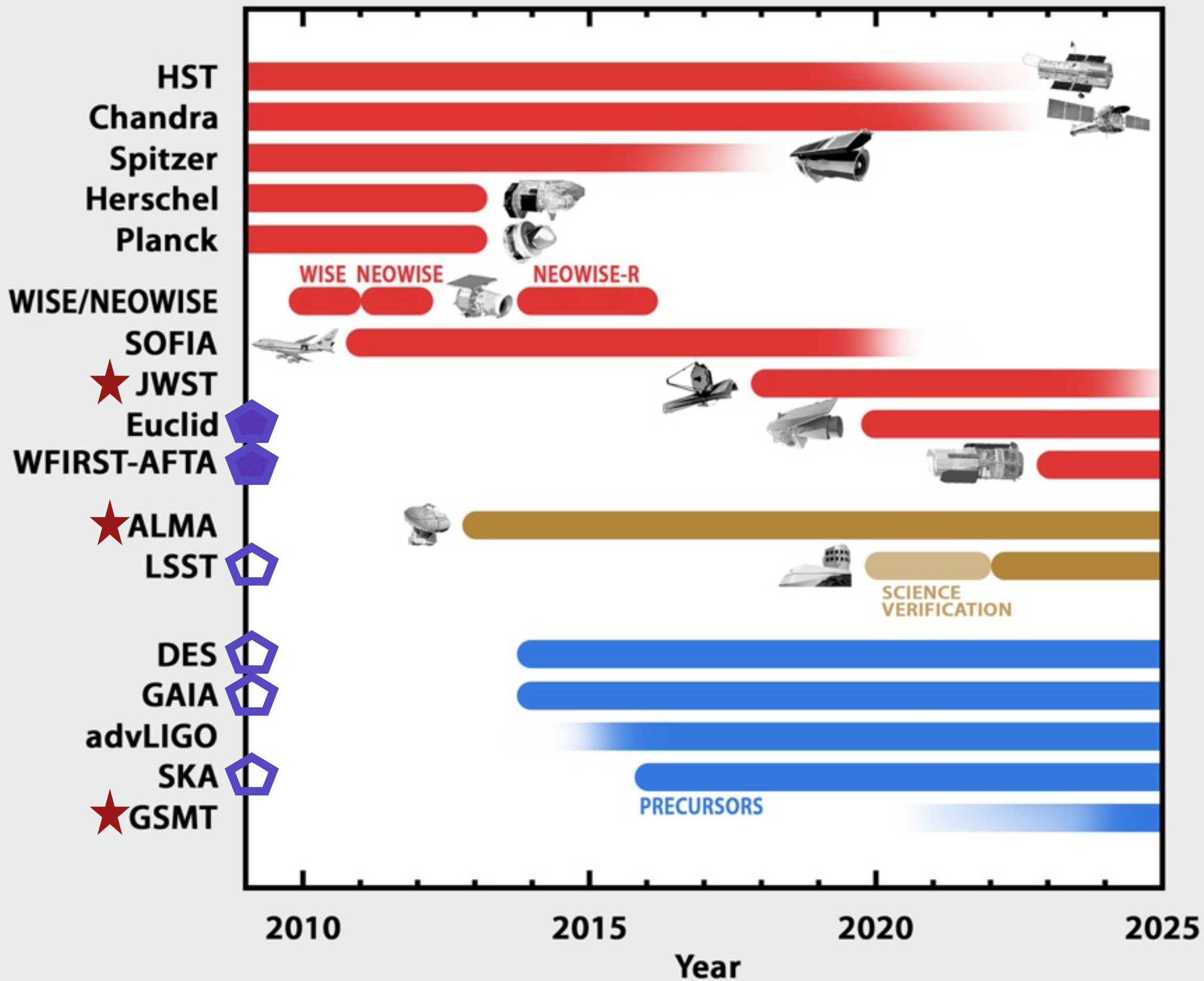
- JWST
- WFIRST
- SPICA'
- ???



Historical Perspective

- Past IR missions have been one of three types
 - ▶ Sky surveys (IRAS, AKARI, WISE, Planck)
 - ▶ Pointed observatories (ISO)
 - ▶ Pointed observatories with strong mapping capability (IRTS, Spitzer, Herschel, MSX)
- Future projects more clearly differentiated in spatial resolution and field of view

NASA, ESA, Ground



Wide-Field Surveys Capabilities

- Mostly in VIS (DES+, GAIA, LSST, Euclid), NIR (Euclid, WFIRST), radio (pre-SKA, SKA)
 - ▶ Euclid (VIS+NIR) $\sim 24\text{-}25.5\text{mag}$, $z\sim[0.6\text{-}2.0]$
 - ▶ WFIRST (NIR) $\sim 26\text{-}27\text{mag}$, $z\sim[1.1\text{-}2.8]$
 - Note: 25mag(AB) is 10^{-18} W m^{-2}

Wide-Field Surveys Science

- Floods of interesting x-gal candidates calling for followup, thousands or more in a given category, with unknown MIR-FIR flux
 - ▶ Redshift range of peak SF, FIR background epoch
 - ▶ At FIR/VIS ~ 1 , these galaxies are CALISTO targets at $f(100\mu\text{m}) \geq 100\mu\text{Jy}$ and in some lines ($>10^{-20} \text{ Wm}^{-2}$)
- Populations of stars in MW/Local Group, revealing outliers and missing links, GAIA: amazing improvement of MW/LG measure

High-Resolution Telescopes

- ALMA will be unbeatable at $>300\mu\text{m}$
 - ▶ Revealing intricate details (down to $0.007''$) of sources at all distances, Solar System to $z>8$
- JWST will dominate at $<30\mu\text{m}$, including deep pencil-beam surveys
 - ▶ Probing the x-gal universe at $z>4$ ($0.07''$ at $2\mu\text{m}$)
- GSMT in 20s, similar capabilities $\sim 0.005''$
- SPIRIT offers $\sim 0.2''$ at $60\mu\text{m}$ (close enough)

What to do?

What to do?

- Do we explore the same landscape as the wide-field surveys, followup those objects?
 - ▶ Most unlikely to find a redundant universe VIS/FIR
 - ▶ The 20s survey suite is incomplete without FIR
- Do we go for high spatial resolution?
Complement ALMA, JWST, GSMT with a FIR interferometer?

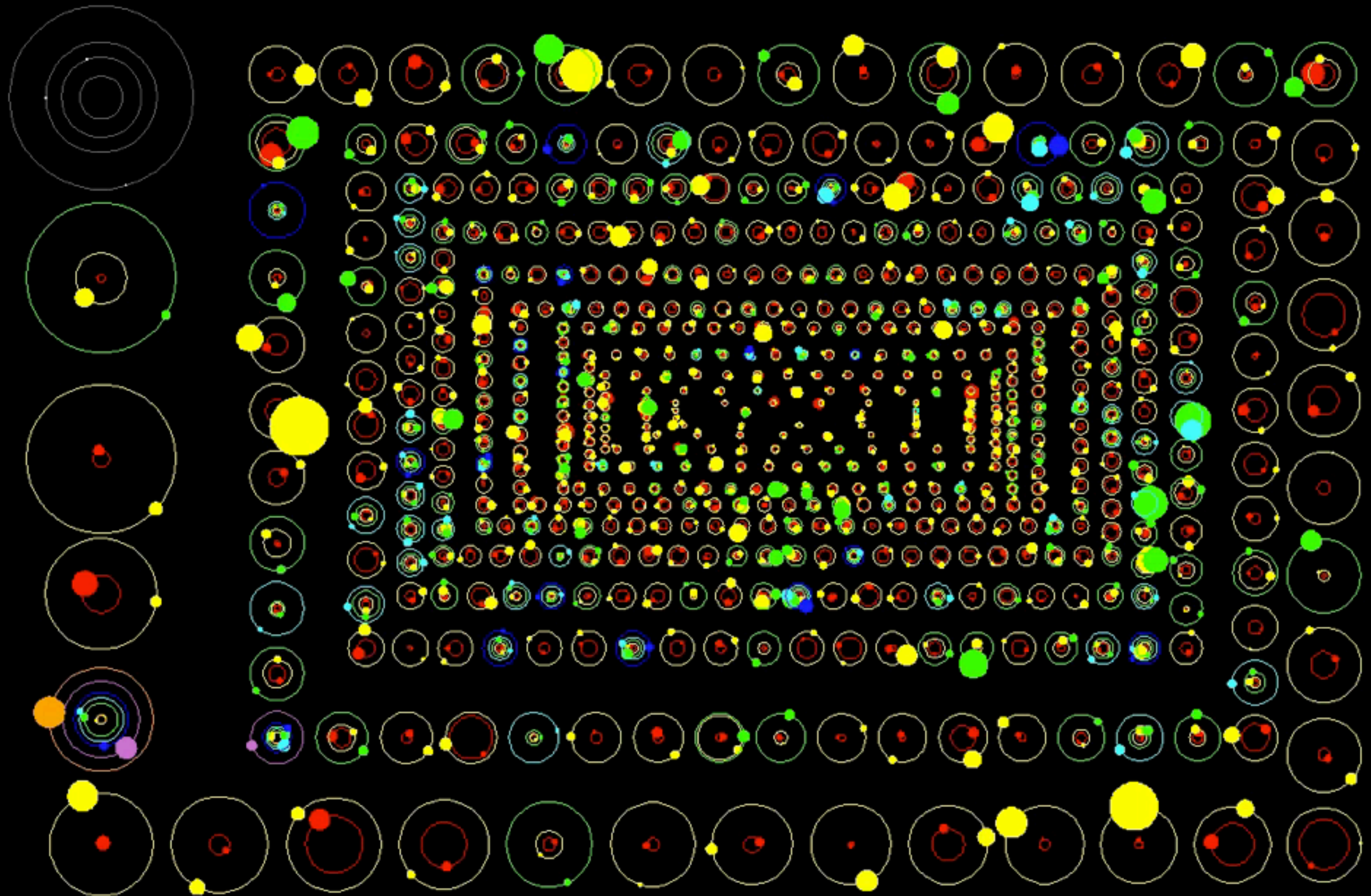
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- Do we explore the same landscape as the wide-field surveys, followup those objects?
 - ▶ Most unlikely to find a redundant universe VIS/FIR
 - ▶ The 20s survey suite is incomplete without FIR
- Do we go for high spatial resolution?
Complement ALMA, JWST, GSMT with a FIR interferometer?
- In any case, let's not ignore topics “not well suited to FIR”, and let's think big picture

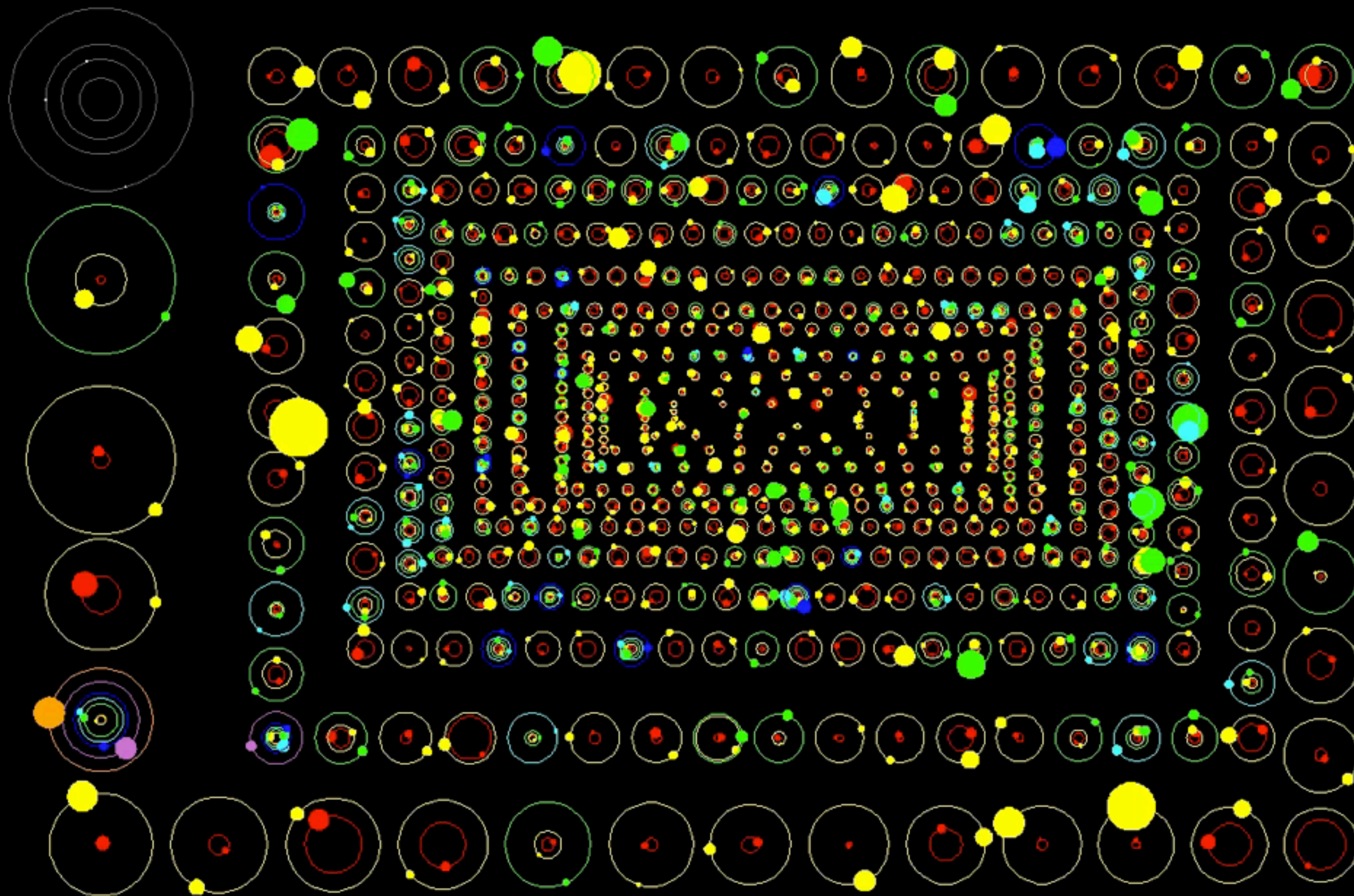
The Kepler Orrery III

$t[\text{BJD}] = 2455215$



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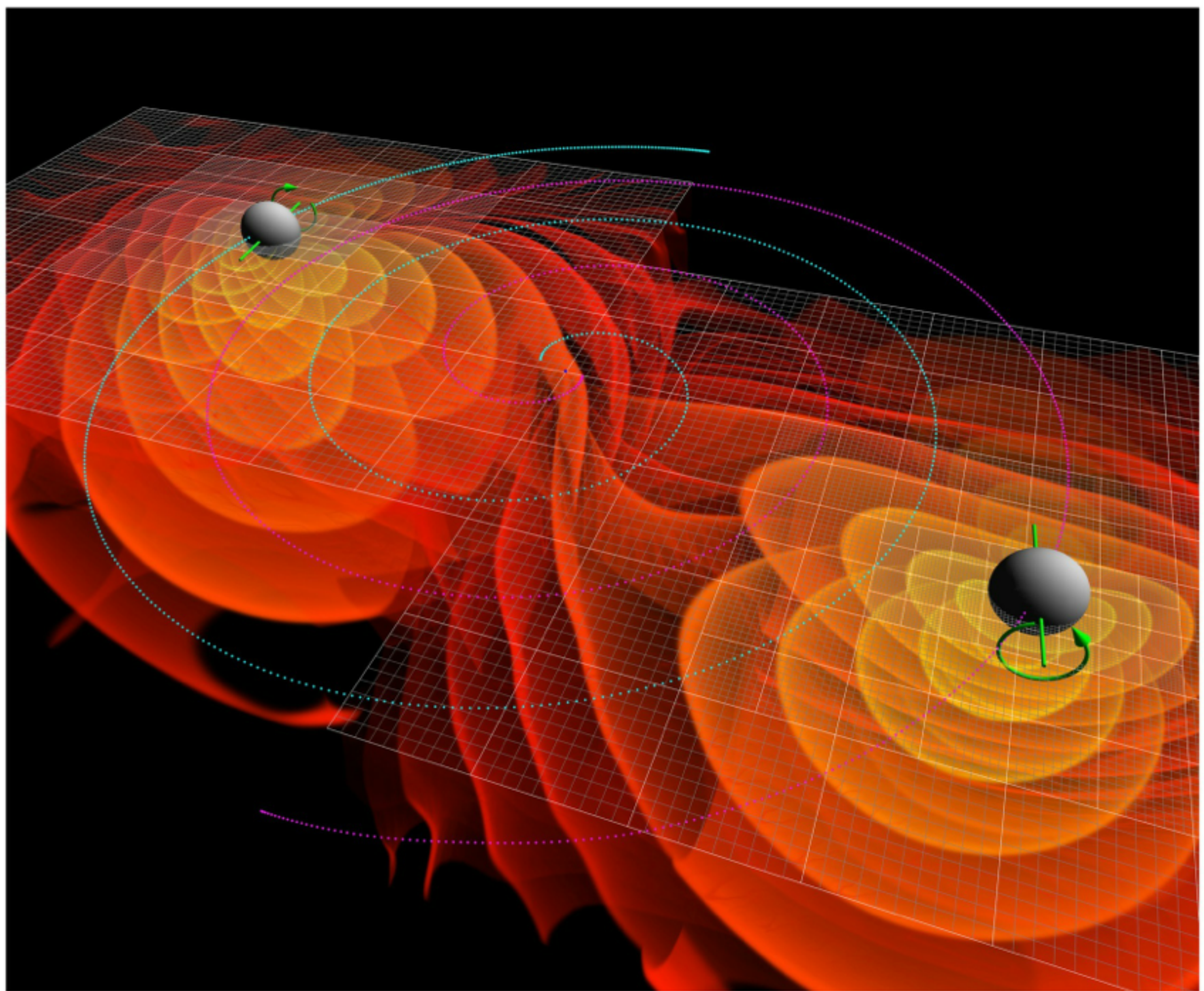


Figure 4.7 This snapshot from a numerical simulation shows the gravitational waves produced by a pair of merging black holes. **Credit: Chris Henze (NASA Ames), from a simulation by J. Centrella, B. Kelly, J. Van Meter, and J. Baker (NASA GSFC)**

Enduring Quests, Daring Visions


	Near-Term	Formative	Visionary
Gravitational Waves		 Gravitational Wave Surveyor	 Gravitational Wave Mapper
Cosmic rays	 JEM-EUSO		
Radio			 Cosmic Dawn Mapper
Microwaves		 CMB Polarization Surveyor	
Infrared	 JWST	 Far IR Surveyor	
	 WFIRST-AFTA	 LUVOIR Surveyor	 ExoEarth Mapper
	 Euclid		
Optical	 TESS		
	 Gaia		
Ultraviolet			
X-rays	 NICER	 Xray Surveyor	 Black Hole Mapper
	 Astro-H		
Gamma rays			

Figure 1.2 Chart of the missions currently planned for launch during the Near-Term Era and of the notional missions of this roadmap for the Formative and Visionary Eras.

The Programmatic Landscape



The Infrared Landscape

The Infrared Landscape

