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Cosmic Exploration with Infrared Telescopes
The Landscape Ahead

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Pasadena, May 2015

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- Facts: Missions & Themes
- Interpretation
- Questions

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  - Look ahead to 2020, 2025
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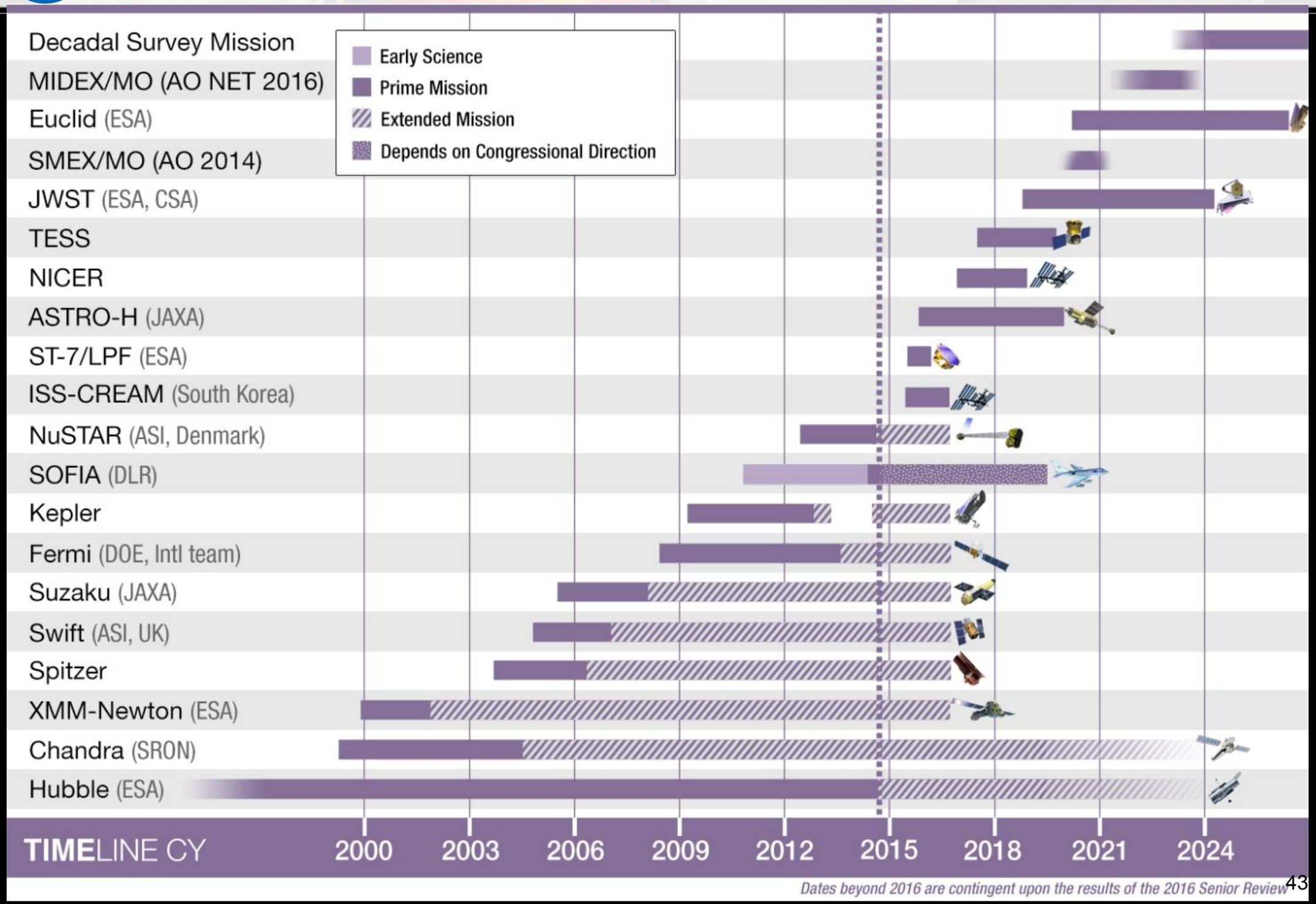
NASA Missions

Astrophysics Timeline



NASA, ESA, Ground

Science Themes

Cosmic Dawn:

Reionization

First stars, galaxies, BH

Gastrophysics

Physics of the Universe:

CMB, LSS

Dark Matter & Energy

Gravity Waves , GR

Science Themes

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

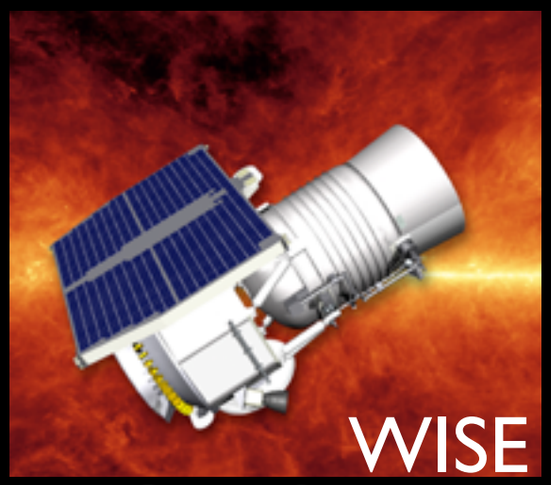
Gustave Foré, *La Selva Oscura*

The Infrared Space Telescope Legacy

AKARI

Planck

Herschel



NEOWISE

IRAS

MSX

Spitzer

ISO

The Next Steps

- Improved sensitivity, speed of mapping, or specialized instruments

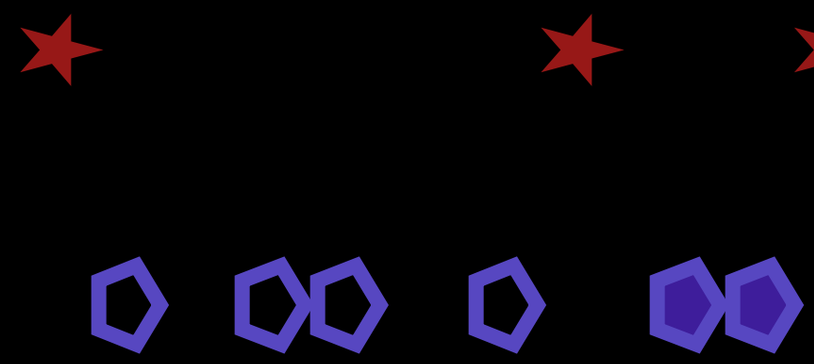
- JWST
- WFIRST
- SPICA’
- ???

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) ~24-25.5mag, z~[0.6-2.0]
  - WFIRST (NIR) ~26-27mag, z~[1.1-2.8]
    - 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(100μm)≥100μJy and in some lines (>10^{-20} 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 >300μm
  - Revealing intricate details (down to 0.007”) of sources at all distances, Solar System to z>8
- JWST will dominate at <30μm, including deep pencil-beam surveys
  - Probing the x-gal universe at z>4 (0.07” at 2μm)
- GSMT in 20s, similar capabilities ~0.005”
- SPIRIT offers ~0.2” at 60μm (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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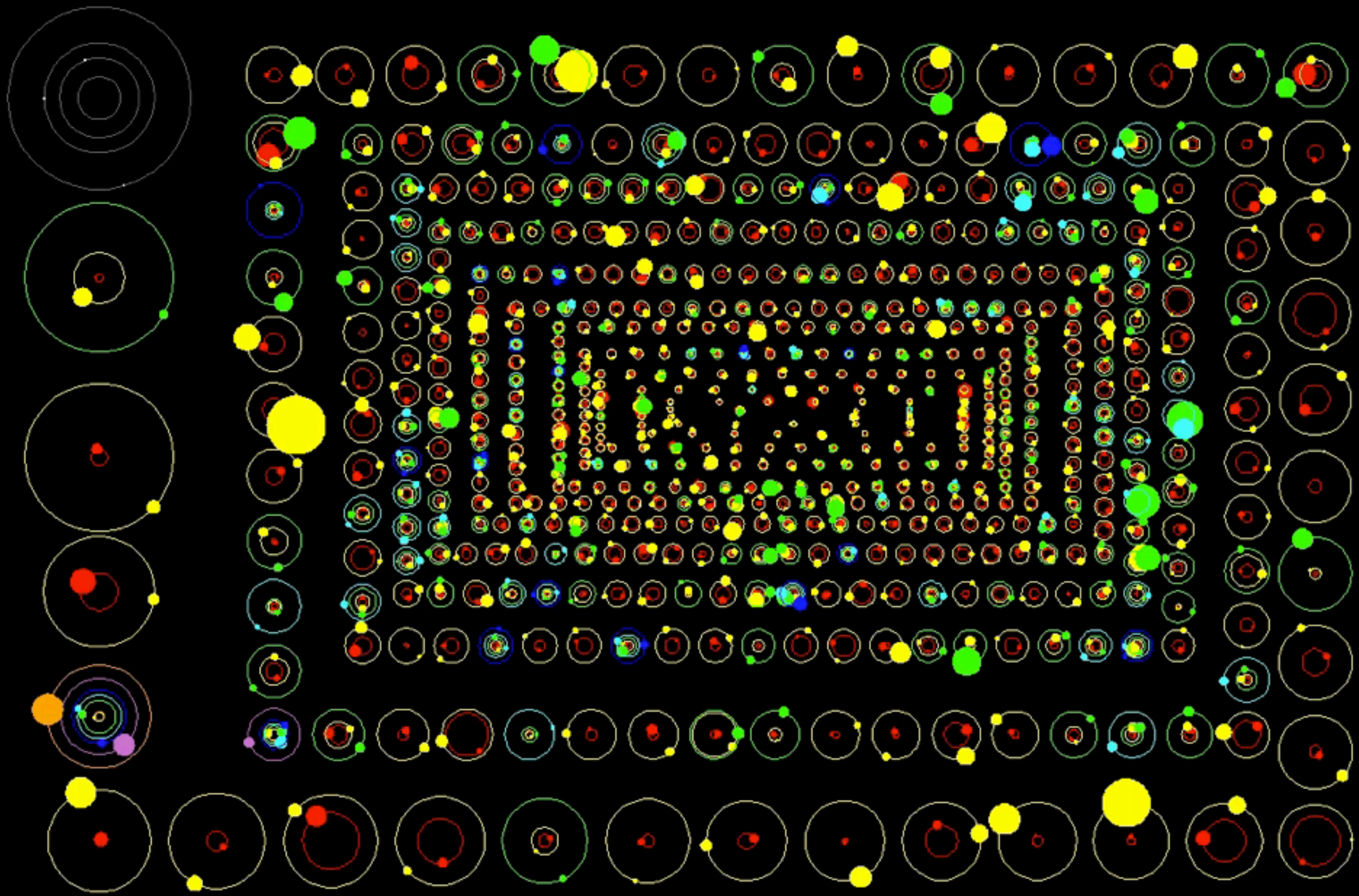
- Do we explore the same landscape as the wide-field surveys, followup those objects?
  - Most unlikely to find a redundant universe VIS/FIR
  - The 20s survey suite is incomplete without FIR
- Do we go for high spatial resolution? Complement ALMA, JWST, GSMT with a FIR interferometer?
- In any case, let's not ignore topics "not well suited to FIR", and let's think big picture

The Kepler Orrery III

t[BJD] = 2455215



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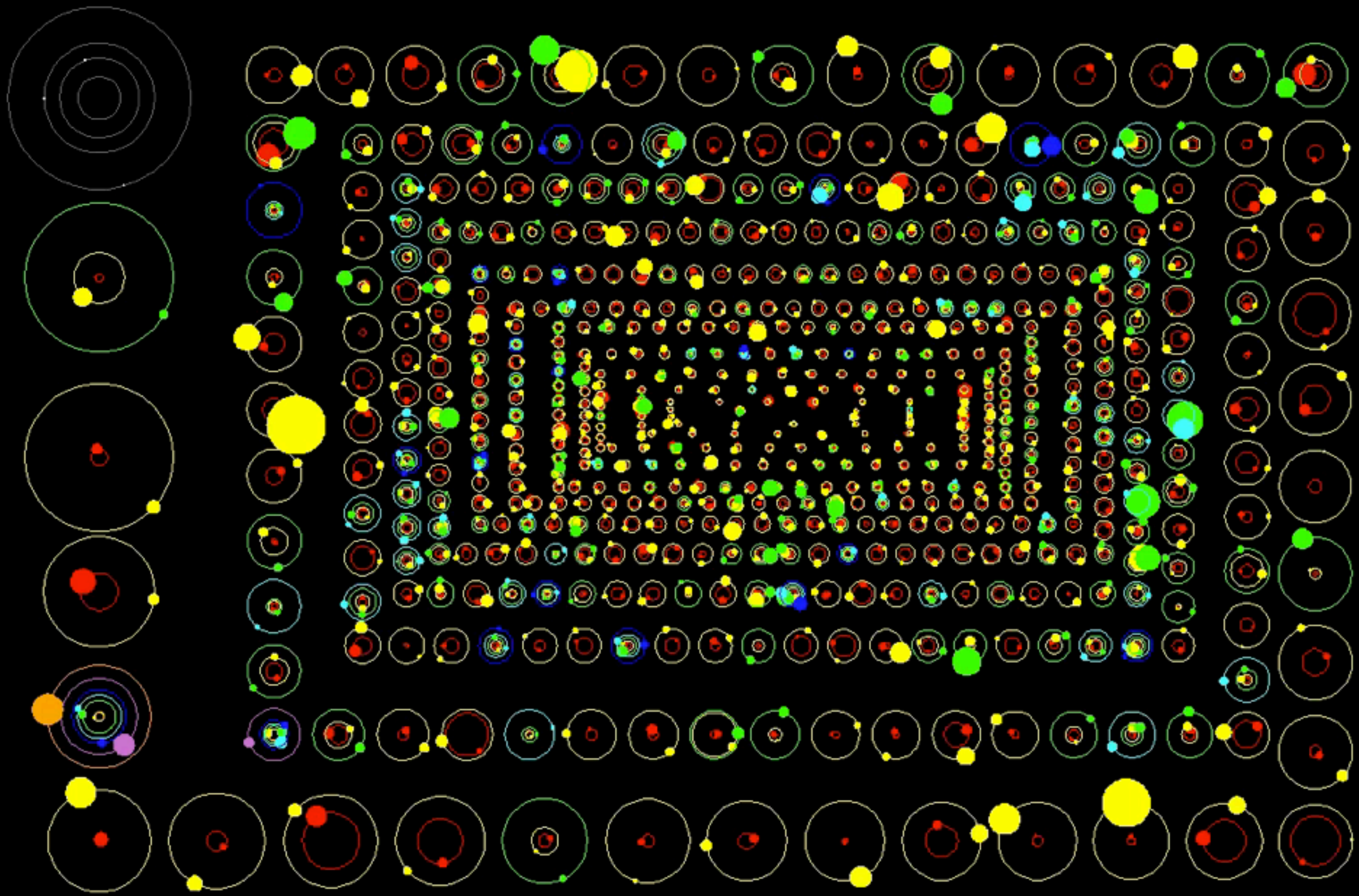


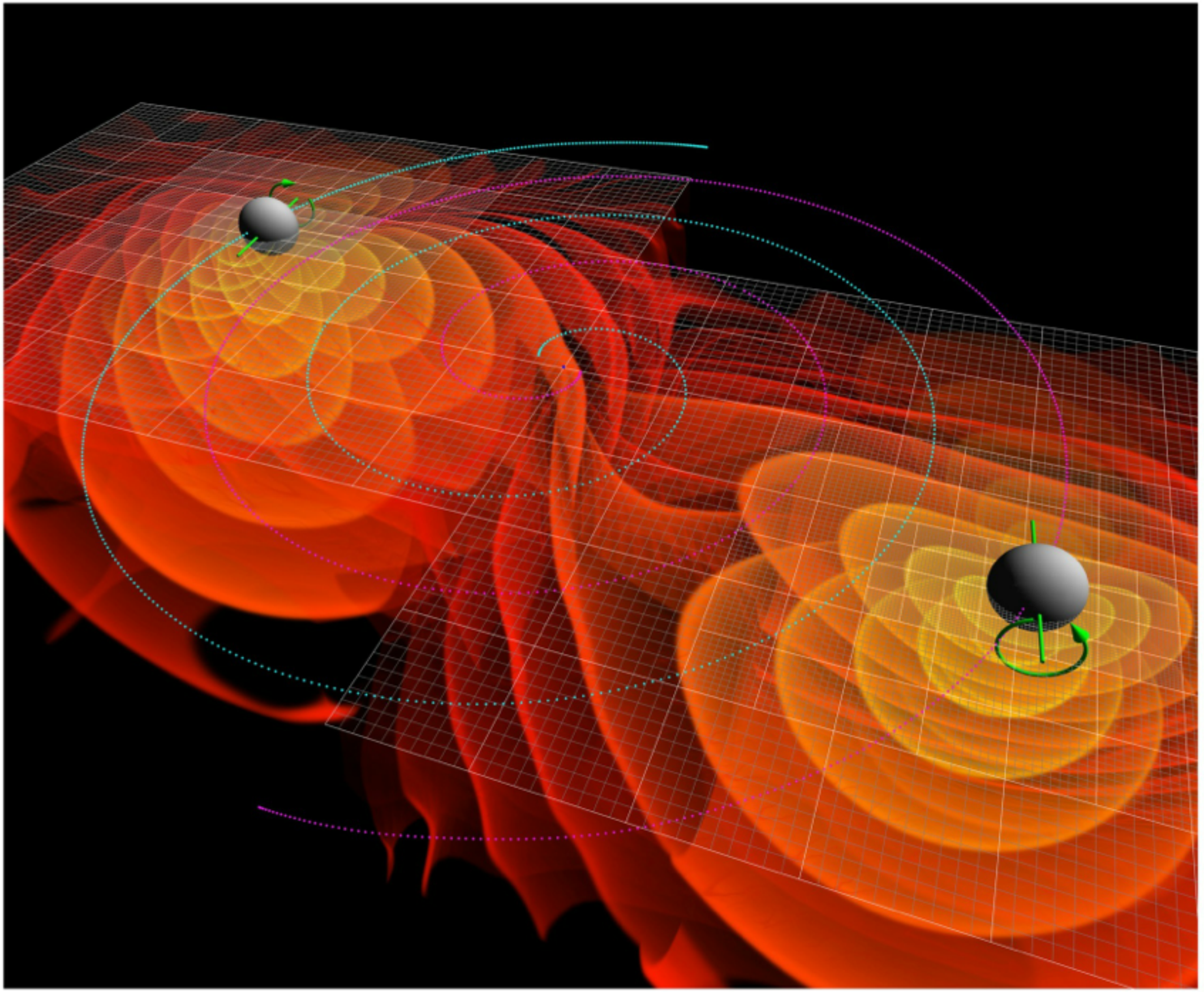


Figure 4.7 *This snapshot from a numerical simulation shows the gravitational waves produced by a pair of merging black holes.* ***Credit: Chris Henze (NASA Ames), from a simulation by J. Centrella, B. Kelly, J. Van Meter, and J. Baker (NASA GSFC)***

Enduring Quests, Daring Visions

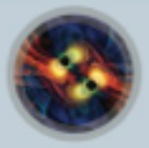
	Near-Term	Formative	Visionary
Gravitational Waves		 Gravitational Wave Surveyor	 Gravitational Wave Mapper
Cosmic rays	 JEM-EUSO		
Radio			 Cosmic Dawn Mapper
Microwaves		 CMB Polarization Surveyor	
Infrared	 JWST	 Far IR Surveyor	
	 WFIRST-AFTA  Euclid	 LUVOIR Surveyor	 ExoEarth Mapper
Optical	 TESS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

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The Infrared Landscape

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