Aalto University
School of Electrical
Engineering

Future missions

Space instrumentation, 29.10.2020

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This week's topics

1. **Trends / aims / interests**

   What's currently going on with space telescopes

2. **Near-future missions & plans**

   What's going to happen next

3. **Far-future possibilities**

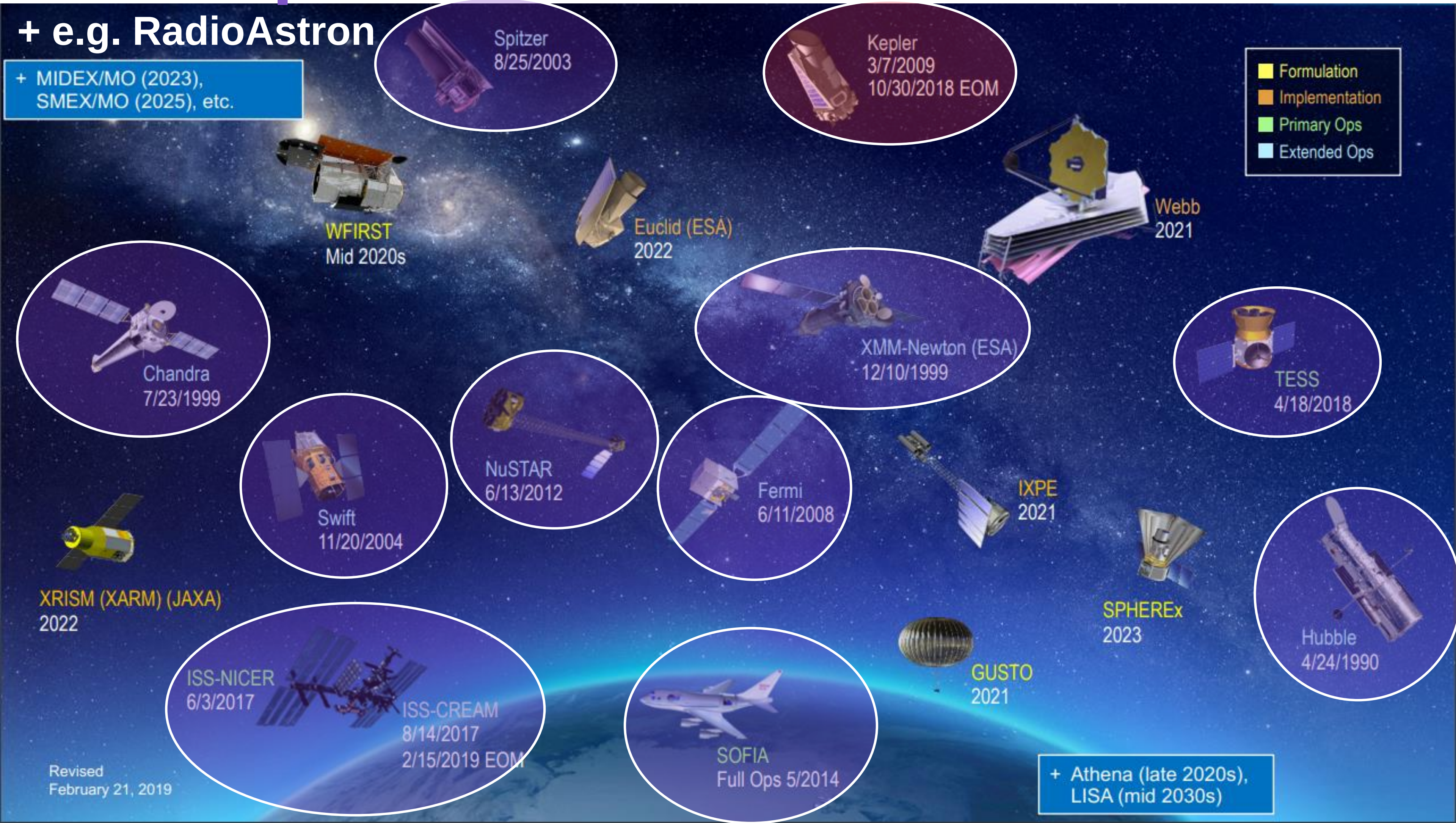
   Thinking outside the box

4. **Group work**

   A closer look at a few interesting space observatories

Some space observatories now and soon

+ e.g. RadioAstron



What are we trying to see/do?

Hot topics:

- Dark energy & cosmology
- Exoplanets & extraterrestrial life
- Gravitational astronomy

Continuous improvement

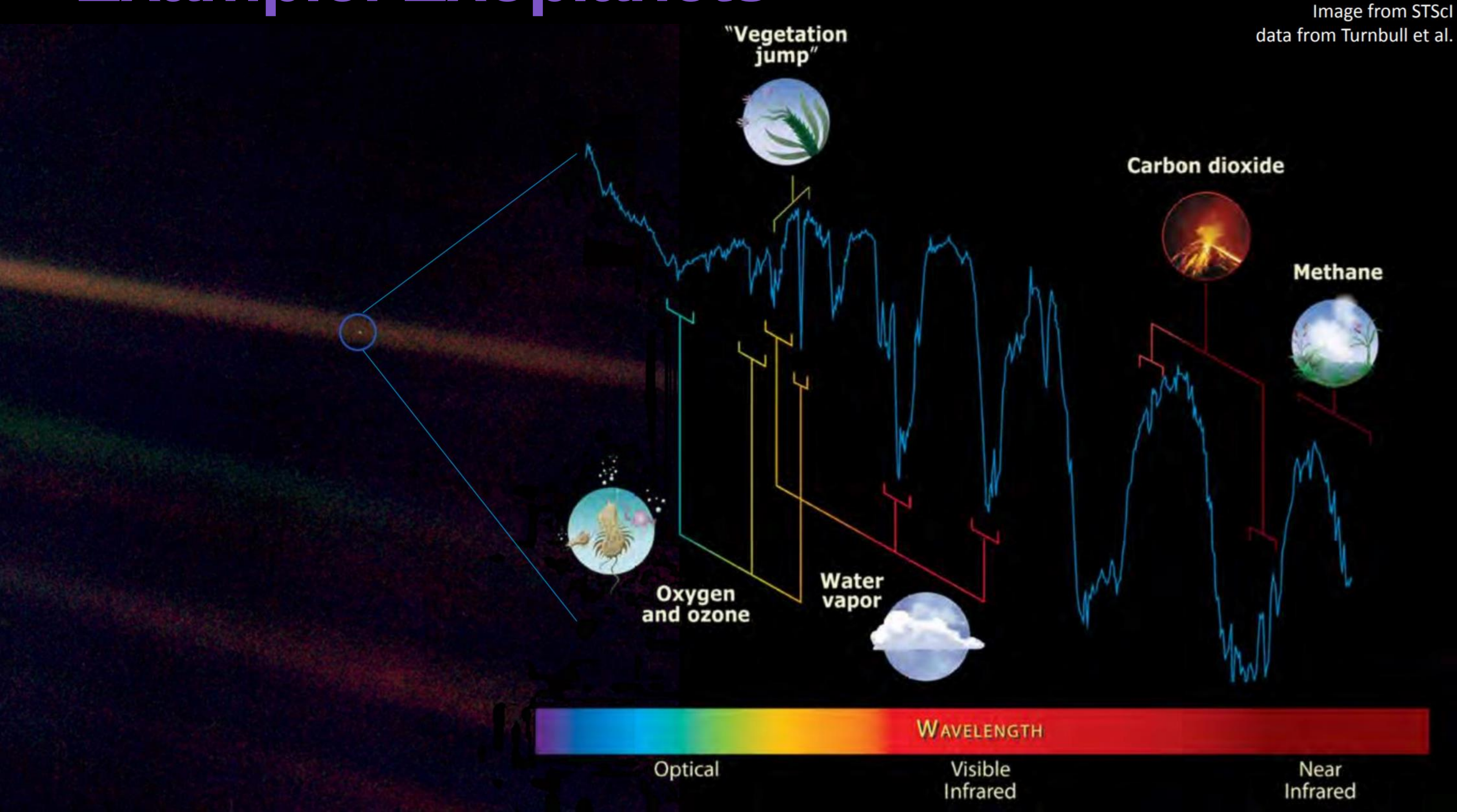
- Sensitivity
- Resolution
- Coverage (time and sky-area)
- But: survey vs. observatory (Cf. Merja's lecture)

New venues

- Gravitational waves
- Properties of exoplanets
  - *E.g. biomarkers in the atmosphere*
  - *Cf: 14.9.2020: "Possible Marker of Life Spotted on Venus"* https://www.almaobservatory.org/en/press-releases/possible-marker-of-life-spotted-on-venus/

Example: Exoplanets

https://sites.nationalacademies.org/cs/groups/ssbsite/documents/webpage/ssb_176470.pdf

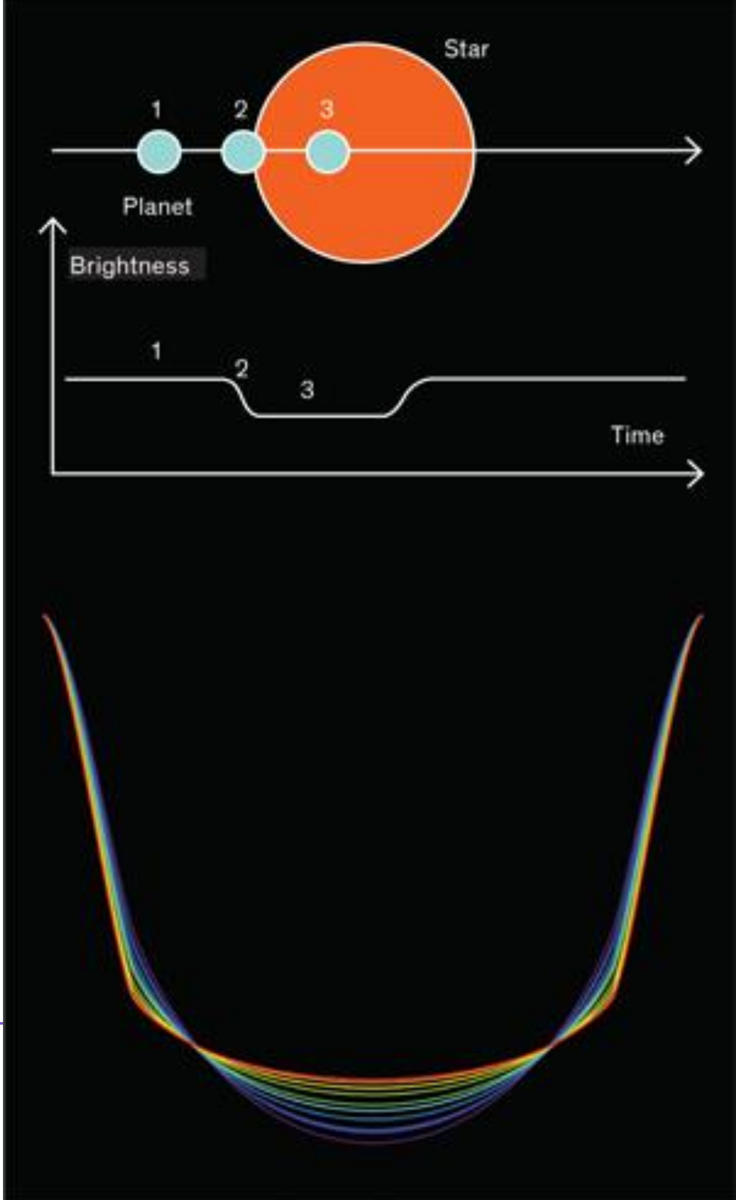


Example: Exoplanets

Transits

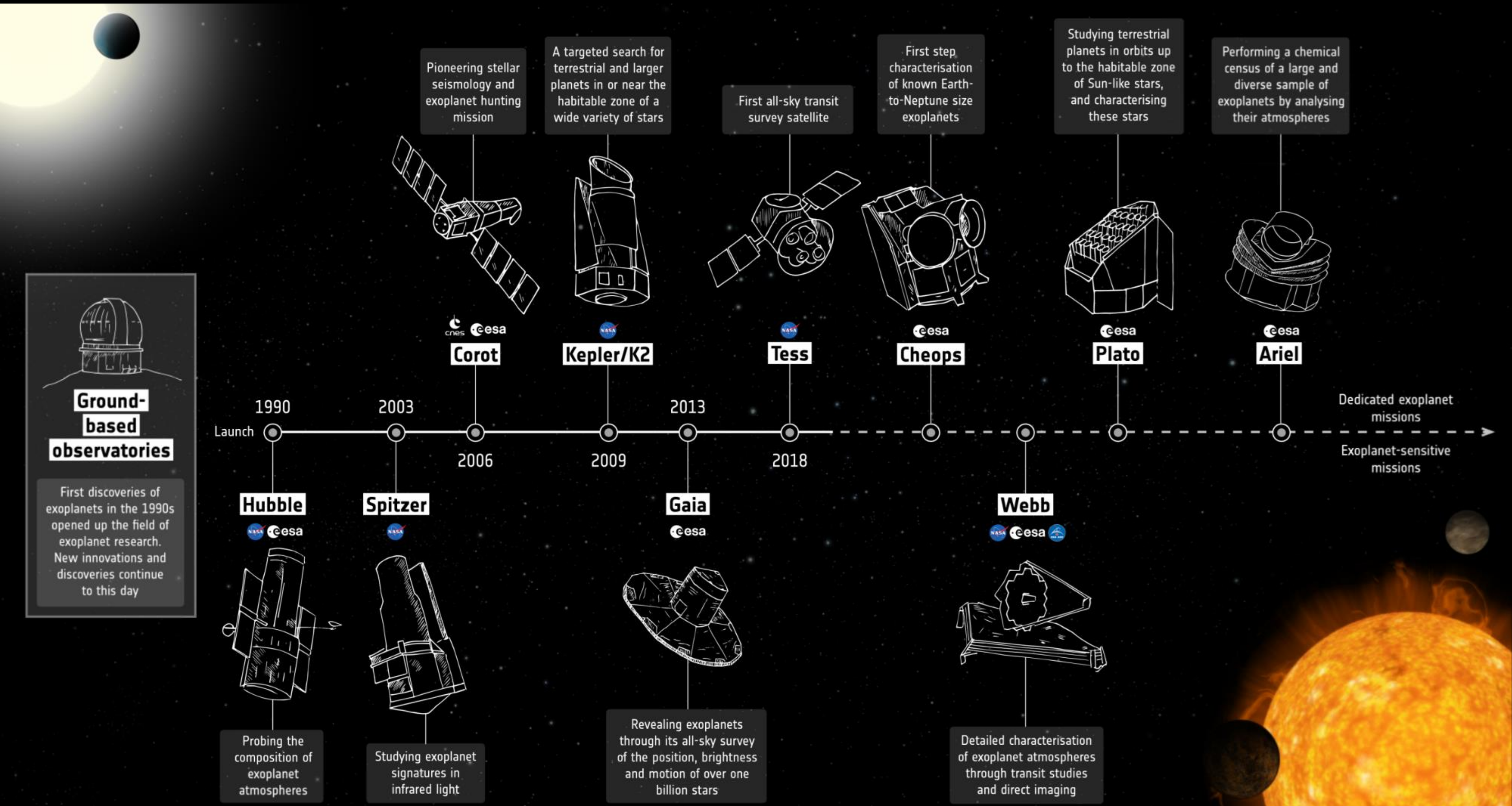
- One detection method
- Dip in the total brightness
- If the planet has atmosphere, it absorbs different amounts of the star's light at different wavelenghts

→ *differences in the observed light tell us about physical properties and composition.*



For details, see e.g. http://spectrum.ieee.org/aerospace/satellites/how-space-telescopes-will-find-earth-20

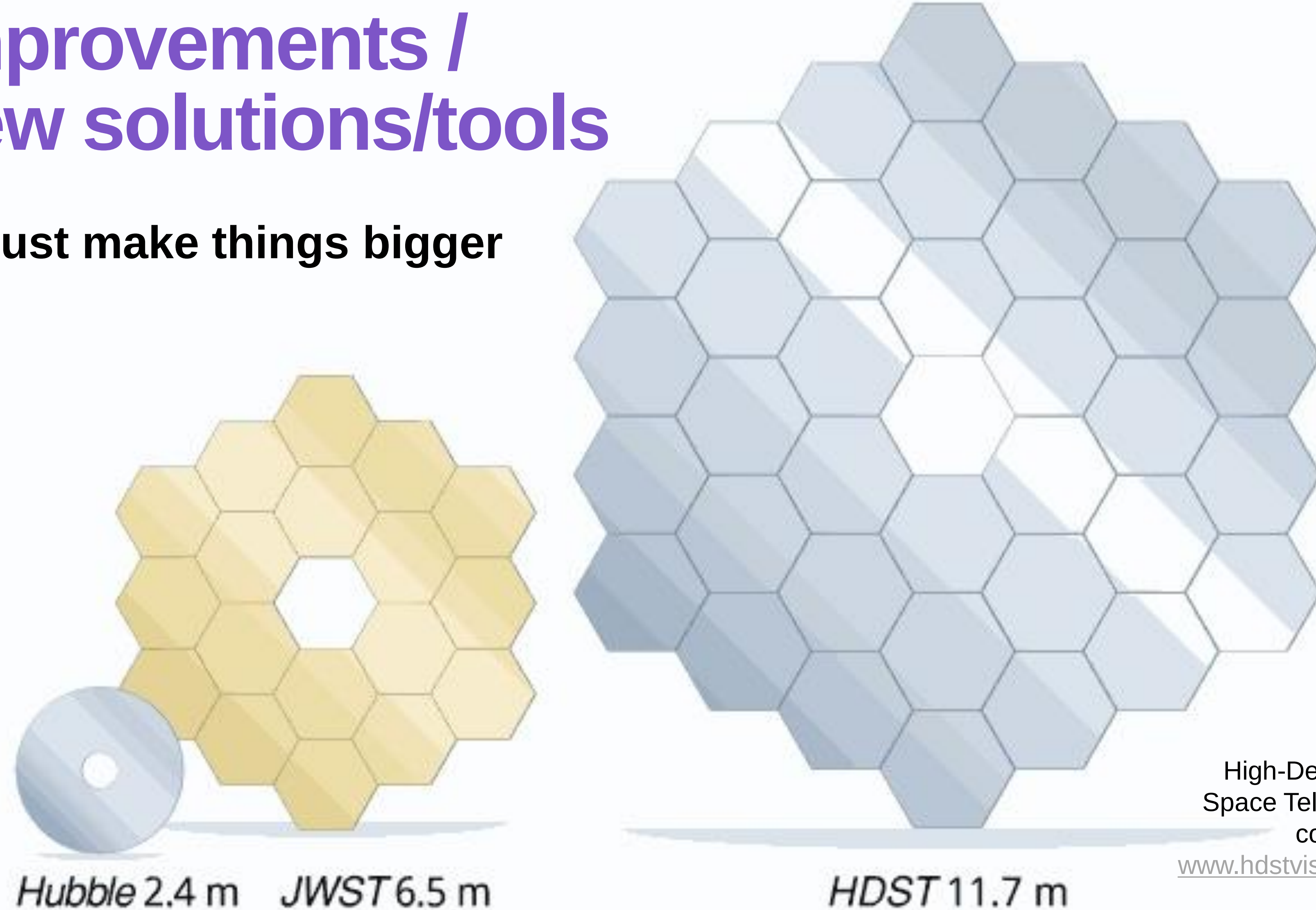
Example: Exoplanets



https://www.esa.int/spaceinimages/Images/2018/08/Exoplanet_mission_timeline

Improvements / new solutions/tools

- **Just make things bigger**

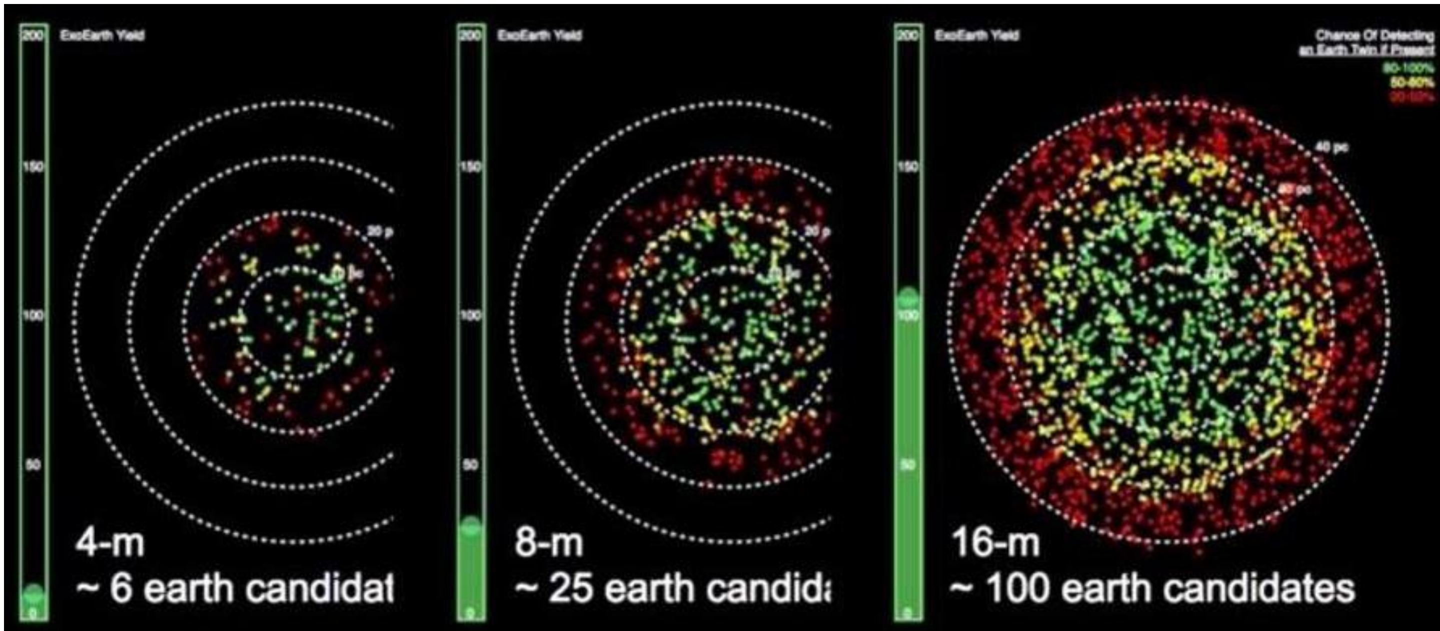


High-Definition Space Telescope concept: www.hdstvision.org

Improvements / new solutions/tools

- **Just make things bigger**

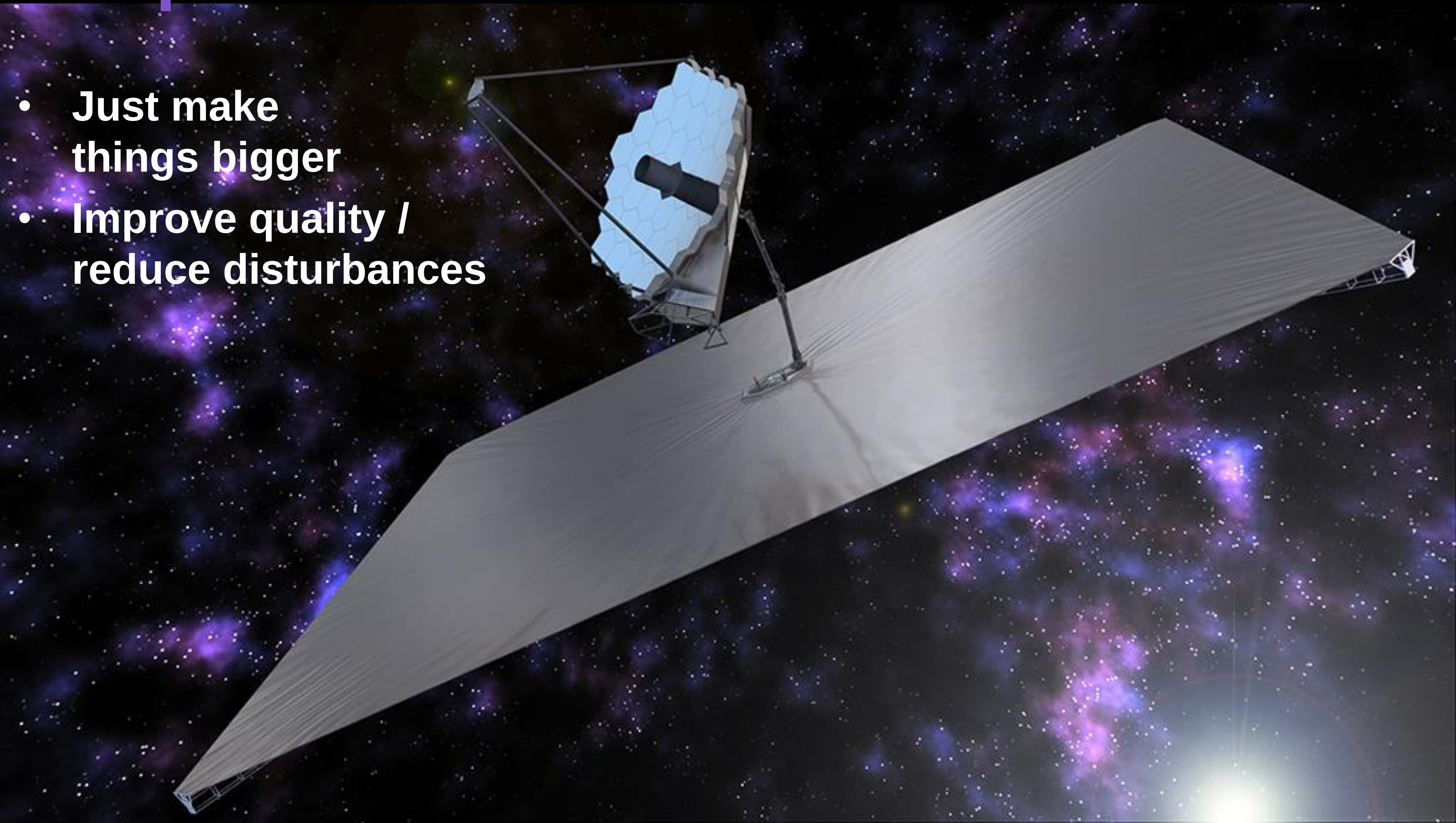
ExoEarth candidates as function of aperture



https://sites.nationalacademies.org/cs/groups/ssbsite/documents/webpage/ssb_176470.pdf

Improvements / new solutions/tools

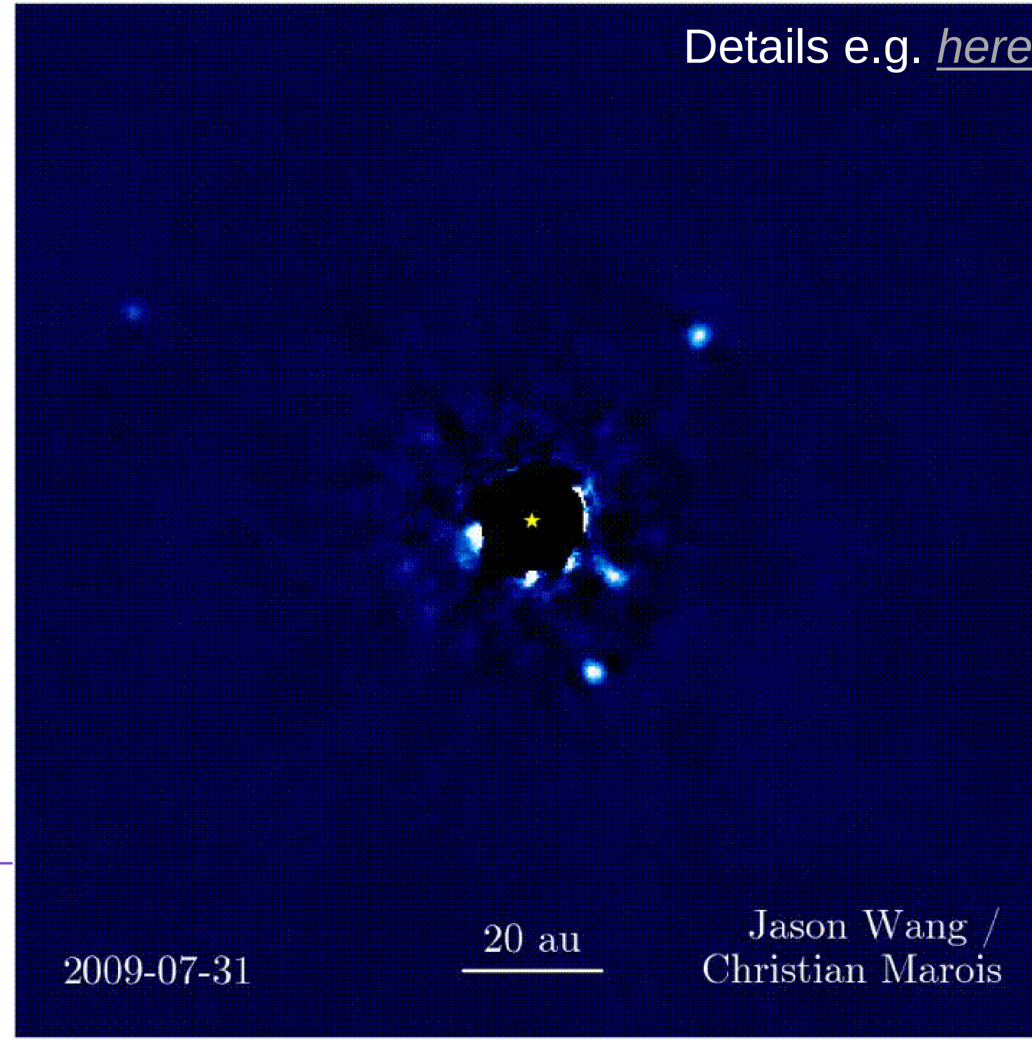
- Just make things bigger
- Improve quality / reduce disturbances



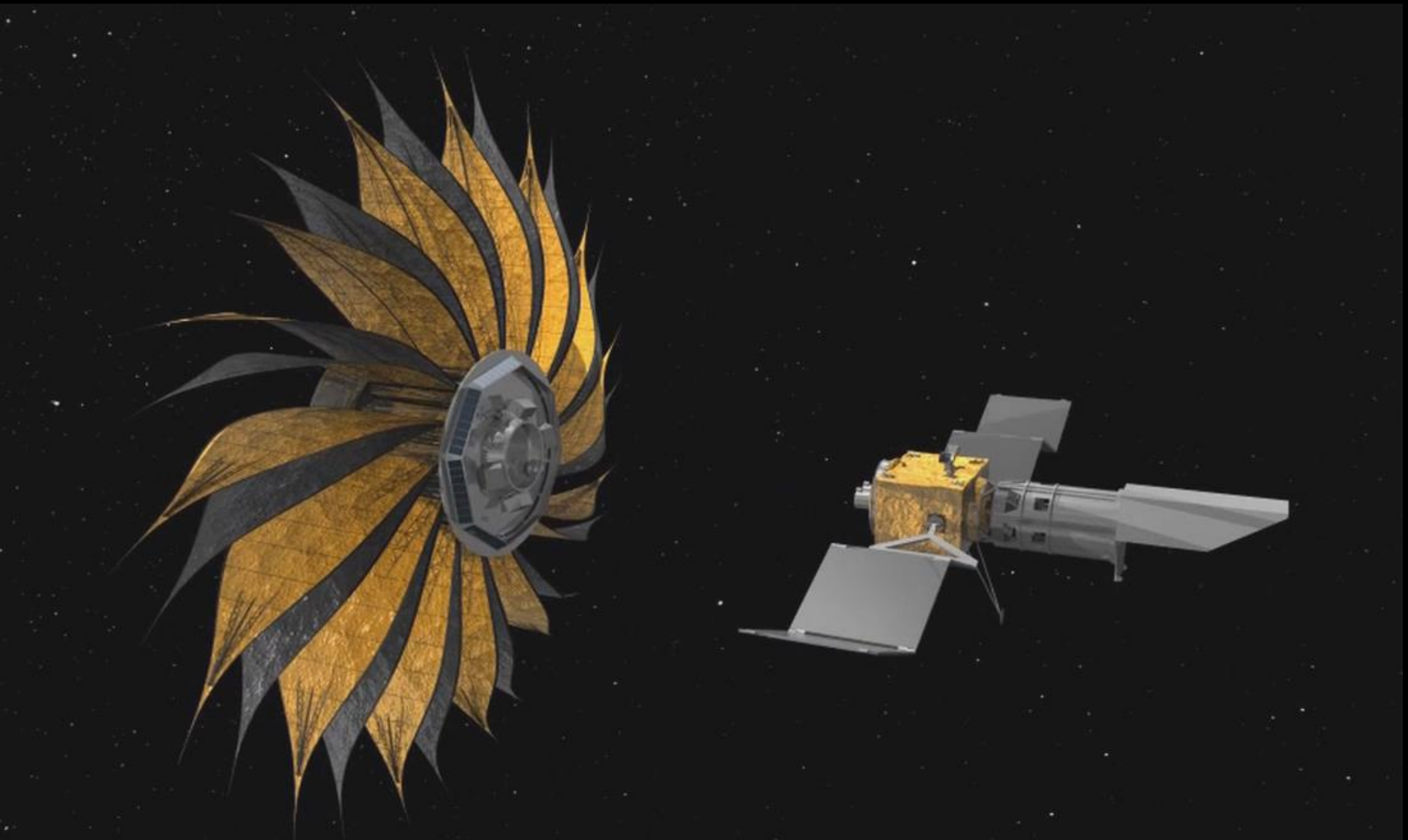
Improvements / new solutions/tools

- **Just make things bigger**
- **Improve quality, reduce disturbances**
- **Focus better on the interesting stuff**
  - E.g. Earth-Sun contrast ratio around 1:10^{10}
  - How?
  - Coronagraphs & starshades

Coronagraph: youtube/czD5YcR1G4M
Starshade: youtube/ALGIoexo-ac



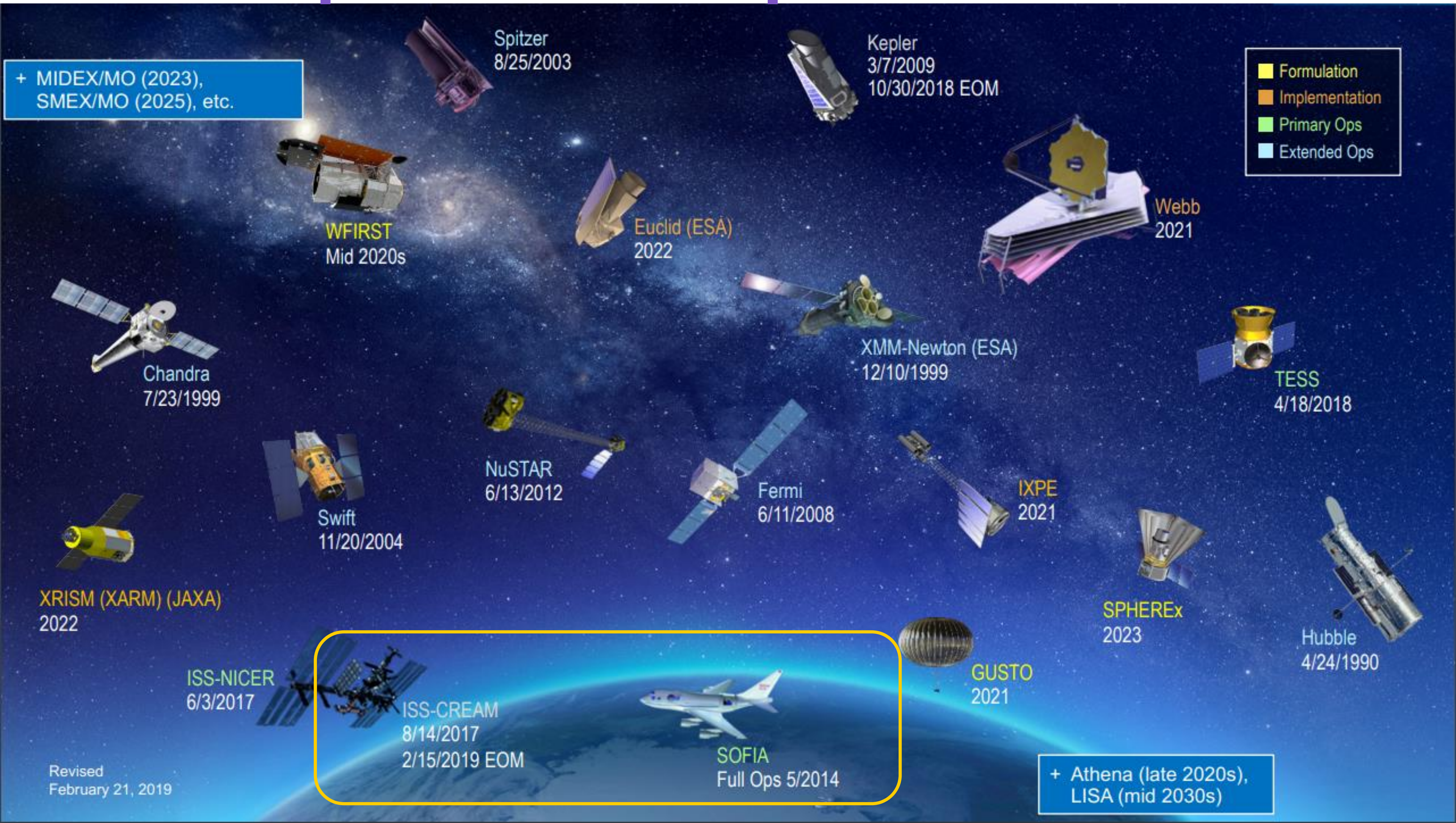
https://exoplanets.nasa.gov/resources/1015/



http://photojournal.jpl.nasa.gov/catalog/PIA2091

"A 10-m prototype of the starshade's inner disk is demonstrated at NASA's Jet Propulsion Laboratory." (Source)

Also "space" telescopes



SOFIA (Stratospheric Observatory For Infrared Astronomy)

26.10.2020: SOFIA detects water on sunlit surface of the Moon;
https://www.nasa.gov/press-release/nasa-s-sofia-discovers-water-on-sunlit-surface-of-moon
https://www.nature.com/articles/s41550-020-01222-x

Courtesy of Mission Operations Specialist Dr Anna Parikka

- **2.7-metre telescope**
- **12-15 km altitude**
  - Above 99% of atm. & H_2O vapor
- **8 hour observations thrice a week**
- **Main benefit: not in space**
  - Maintainable and highly adaptable

Not just ESA & NASA

- Hard X-ray Modulation Telescope (HXMT) ***(June 2017)***
  - China ('s first space telescope)
  - Scan for new transient sources, monitor known variable sources, observe X-ray binaries
- Spektr-RG (SRG) ***(~~1995~~, ~~'96~~, ~~'97~~, ~~'98~~, ~~'99~~, ~~2000~~, ~~'02~~, ~~'03~~, ~~never~~, ~~'08~~, ~~'18~~, July 2019)***
  - "Spectrum + Röntgen + Gamma"
  - Russia + ESA, MPI, …
  - Galaxy clusters, active galactic nuclei, evolution of supermassive black holes, dark energy, expansion of the universe

Near-future

What's next in space telescopes

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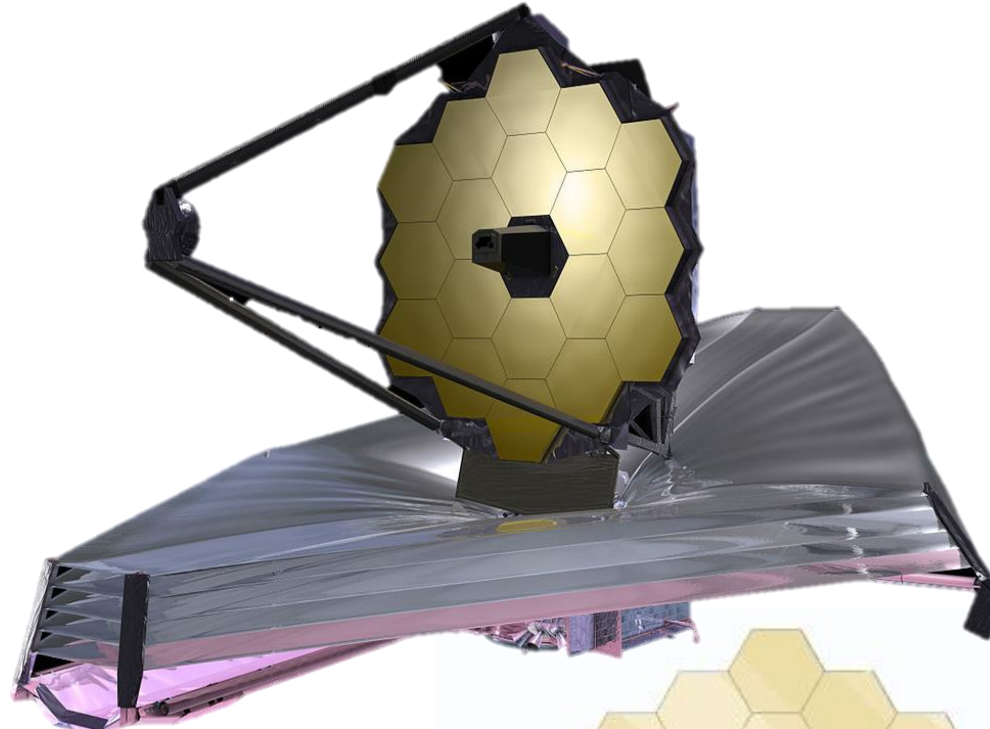
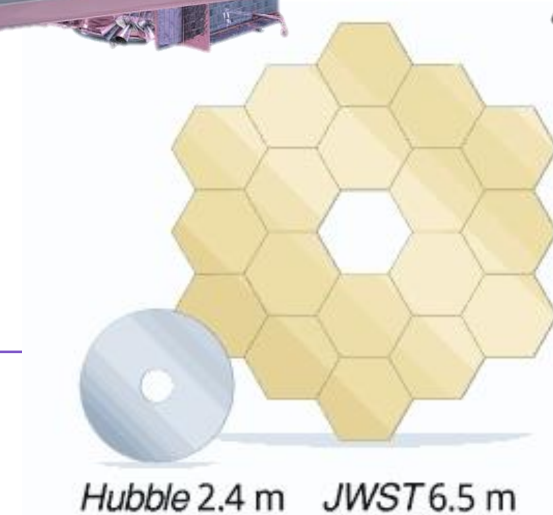
JWST

- https://www.jwst.nasa.gov/
- **James Webb Space Telescope**
- **“Hubble 2.0”**
- **Set time frame**
  - Only enough fuel for 10 years.
- **Budget problems:**
  - Initially: 1-3.5 B$,
    launch 2007-2011
  - Now: >10 B$, launch Oct 31 2021?
    (LUVOIR: 20 B$; NASA cap 2-5 B$ 2018)



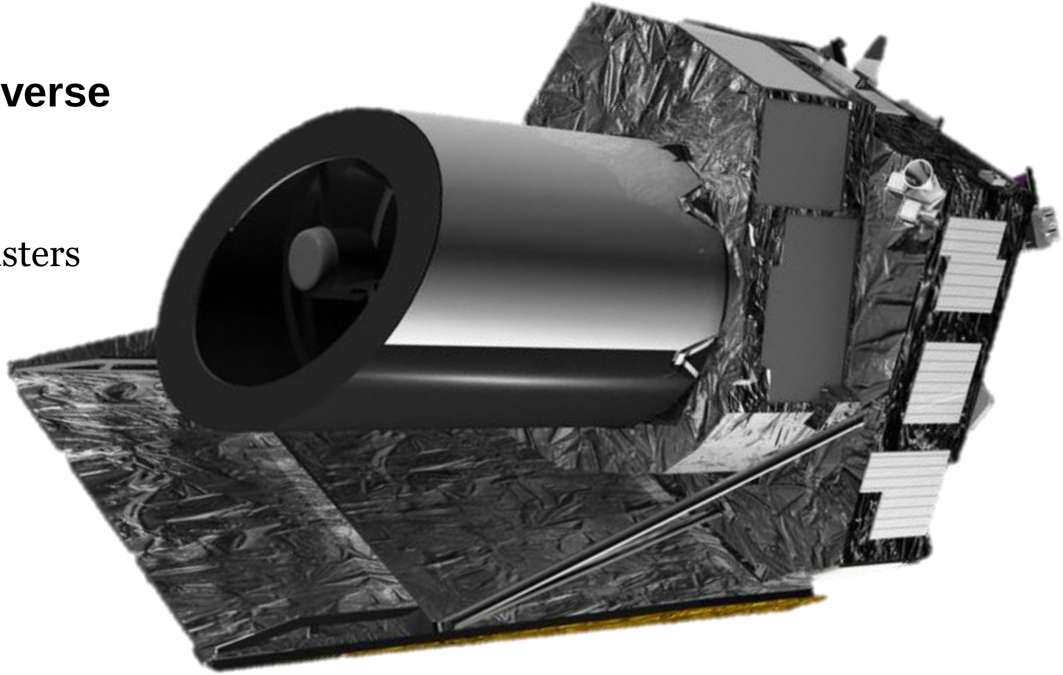


https://www.youtube.com/watch?v=vpVz3UrSsE4

Euclid

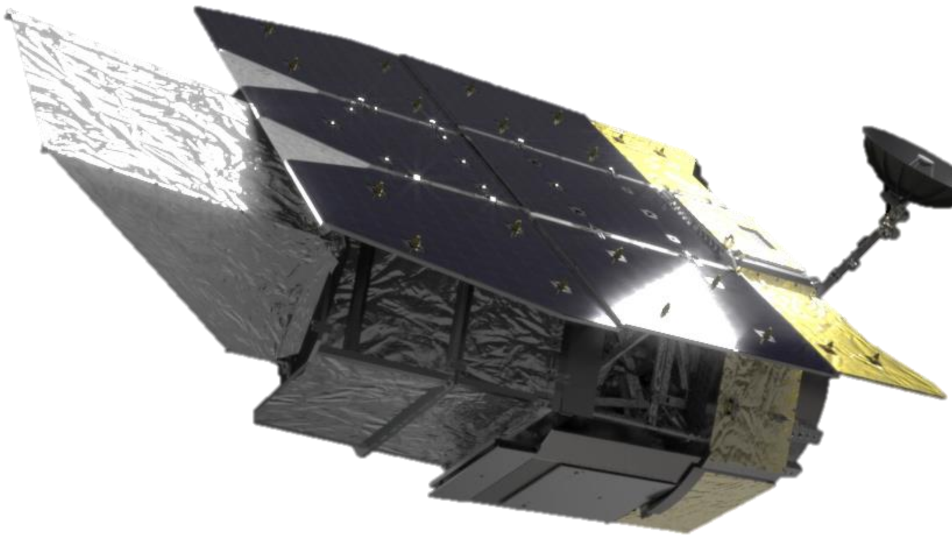
- https://sci.esa.int/web/euclid
  https://www.euclid-ec.org/

- **Cosmology: Expansion of the universe – contribution of DM & DE**
  - What is dark matter?
  - Acoustic oscillations – from galaxy clusters
  - Weak gravitational lensing
- **Surveys: deep + wide**
- **H2/2022**
- **Visible and NIR**
- **L2 point, 6 years**



Roman Space Telescope (né WFIRST)

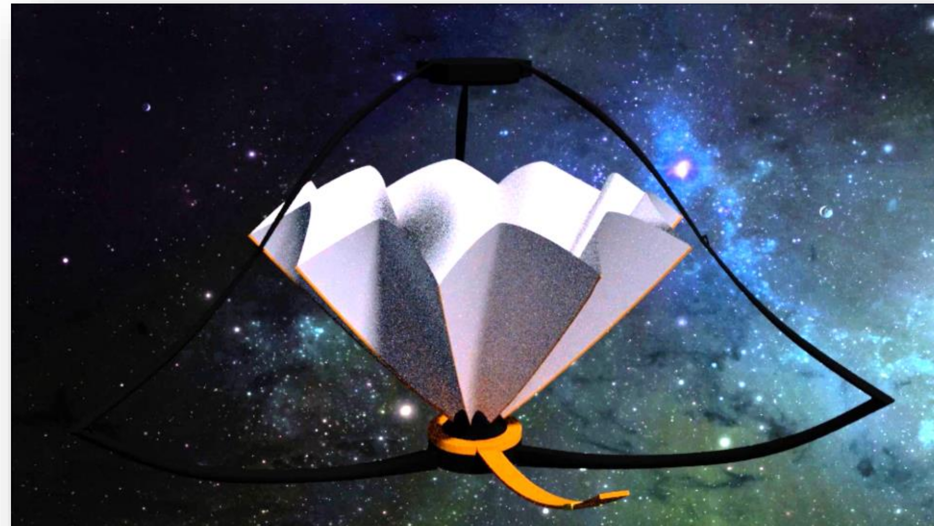
- https://roman.gsfc.nasa.gov/
- **Nancy Grace Roman Space Telescope**
- **Wide Field Infrared Survey Telescope (hence WFIRST)**
  - 100 times the field of view compared to Hubble in a single observation
- **2025**
- **Limited lifespan: fuel for ~5-6 years**
- **Coronagraph. Possibly starshade**
- **Survey**
  - Doesn't see small exoplanets
- **Dark matter, Dark Energy, exoplanets**



Thinking outside the box

Aperture

- Foldable mirror
- 16-metre
- NASA Innovative Advanced Concepts (NIAC)
- Surface-correction after deployment by magnetic read-head



Aperture

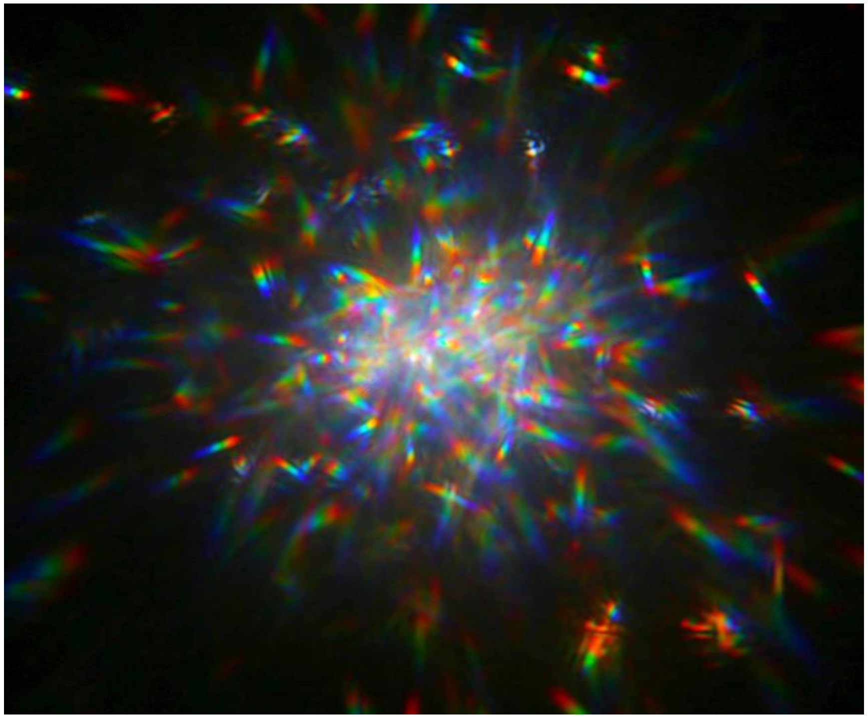
https://www.youtube.com/watch?v=4j-Elbjvh78

Imaging using Solar Gravitational Lens

The **solar gravitational lens** (SGL) [...] offers **brightness amplification** of up to a factor of ~1e11 (at 1 um) and **extreme angular resolution** (~1e-10 arcsec). As such, it allows for extraordinary observational capabilities for direct **high-resolution imaging and spectroscopy of Earth-like exoplanets**. [...] a mission to the strong interference region of the SGL (beyond 547.6 AU) carrying **a meter-class telescope with a solar coronagraph** would directly image a habitable Earth-like exoplanet within our stellar neighborhood. For an exo-Earth at 30 pc, the telescope could measure the brightness of the Einstein ring formed by the exoplanet's light around the Sun. [...] in 6 months of integration time one can reconstruct the exoplanet image with **~25 km-scale surface resolution**, enough to see surface features and signs of habitability.

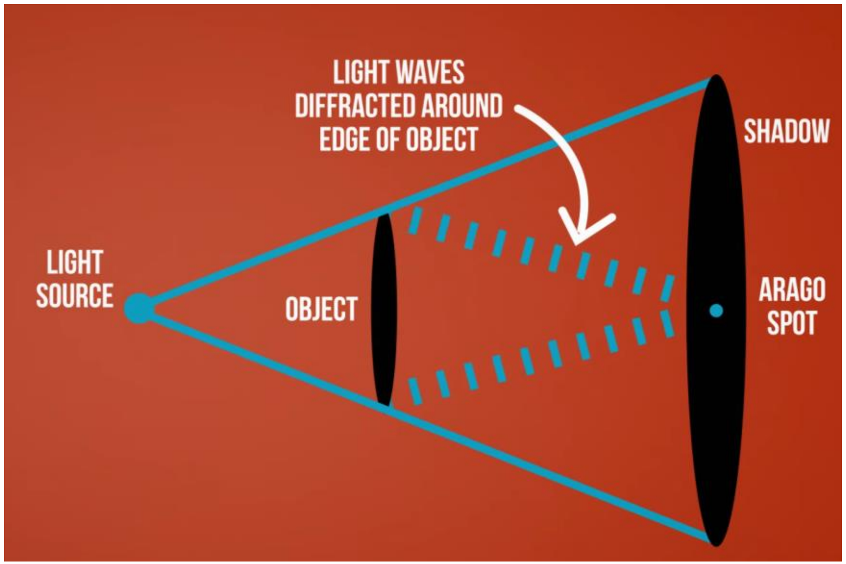
https://www.nasa.gov/directorates/spacetech/niac/2020_Phase_I_Phase_II/Direct_Multipixel_Imaging_and_Spectroscopy_of_an_Exoplanet/

“Orbiting rainbows”



NIAC: “In the proposed Orbiting Rainbows system, the **small cloud of glitter-like grains** would be trapped and **manipulated with multiple laser beams**. The trapping happens because of pressure from the laser light [...] shapes the cloud and pushes the small grains to align in the same direction. In a space telescope, the tenuous cloud would be formed by **millions of grains, each possibly as small as fractions of a millimeter in diameter**. [...] Because a cloud of glitter specks is not a smooth surface, the image produced from those specks in a telescope will be noisier -- with more speckled distortion -- than what a regular mirror would generate. That's why researchers are **developing algorithms** to take multiple images and **computationally remove the speckle effect** from the glitter.”

Aragoscope



- **Still purely a concept, but a real possibility (NIAC programme)**
- **Light waves diffracts around a disk**
  - → Interference
  - → Arago spot behind a perfectly circular disc
  - Same resolution than with a same-size lense
- **Space telescope and an opaque disk (e.g. 500m diameter)**
  - 1000 x Hubble resolution (but not sensitivity!)

https://www.nasa.gov/content/the-aragoscope-ultra-high-resolution-optics-at-low-cost

Three future missions and concepts

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Group work

Missions, concepts, ideas

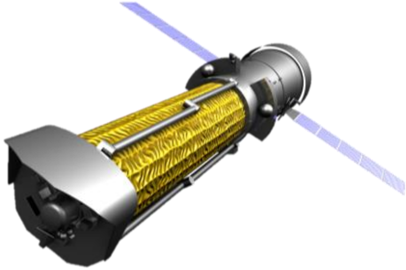
- **What?**
- **Why?**
- **When, where?**
- **How?**
- **What's new?**

LISA

"will be the first space-based gravitational wave observatory"

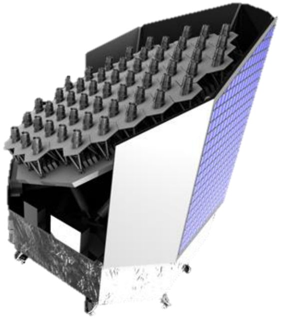
ATHENA

"The next-generation X-ray telescope will address key questions in astrophysics"



PLATO

"to find and study a large number of extrasolar planetary systems, with emphasis on the properties of terrestrial planets in the habitable zone around solar-like stars"



Group work instructions

Part 1: Preparation [10 min]

1. Soon you'll be put in mission-specific breakout rooms. Your group will specialize in one mission well enough to present it to the other groups.
2. Each member starts by specializing in one small part of the mission. Parts are taken in alphabetical order by member's Zoom names.
   1. *Antti:* ***Purpose / science questions***
   2. *Bettina:* ***Schedule / time frame***
   3. *Christina:* ***Orbit / path***
   4. *Dave:* ***Instrumentation / technology***
   5. *Esko:* ***Unique or novel tech. or science***
3. To find answers:
   1. *MyCourses page > Mission plans*
   2. *Internet (ESA, NASA, caution wih Wikipedia)*

Part 2: Collecting [10 min]

1. Go to **flinga.fi** and use access code **FM3MXEE**
2. On the Flinga whiteboard each group/mission has their own area, and each topic has a section waiting.
   1. *Begin by adding your name under your mission title.*
   2. *Then go on filling your topic. Maybe use a text editor on your computer and copy-paste a longer answer to Flinga.*
   3. *You can also add pictures or draw.*
   4. *Make sure your part is OK before looking at others.*

Part 3: Coordination [10 min]

1. Together, in your Zoom room, start looking at your mission as a whole.
   1. *Go through each point; the person(s) responsible for them explain them to others. Ask questions if needed.*
   2. *Is all clear? Is everything answered? Is this a clear overview of the mission?*
   3. *Fill in possible gaps, or edit/move the text and other elements if need be, so that the "presentation" is clear and logical.*

Part 4: Presentation [15 min]

1. Get back to the main Zoom session (breakout rooms will close).
2. One group at time, present your mission to others.
   1. *Use the Zoom voice for telling what your mission is about. Go through at least all the parts mentioned above.*
   2. *Note that everyone will have the Flinga board open and can follow the text and illustrations there while hearing you on Zoom.*
3. When other groups present their missions, pay attention and ask clarifications if needed.

Group work instructions

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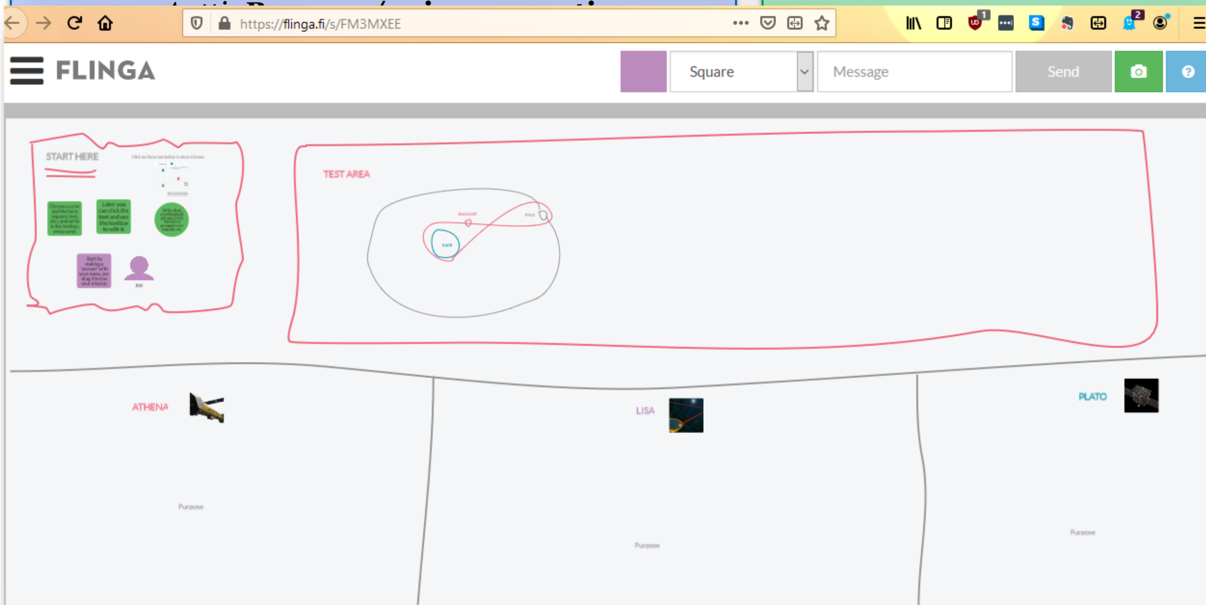

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Summary

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