The Crystal Ball: What Discoveries are in Store?

Neil Gehrels Memorial Symposium

John Mather
NASA's Goddard Space Flight Center
May 22, 2018

The Crystal Ball

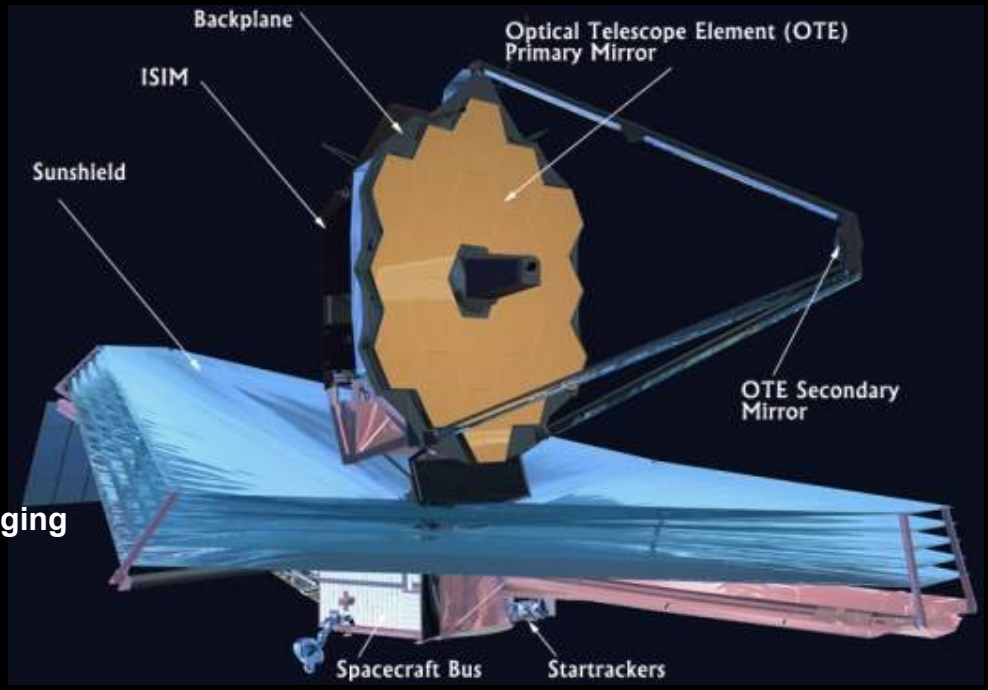
The Crystal Ball has been waiting for your visit! Do you have a question that you have been waiting to ask? Click on the Crystal Ball and your personal fortune-teller browser window will appear and ask for your question. Follow the instructions carefully and you will soon receive the answers to all your questions.

(http://predictions.astrology.com/cb/) but 404 - File or directory not found

How much would you pay for all the secrets of the Universe?

- Worldwide budget to build great space observatories: ~ 700 M$? (~$1/ person/yr for North America, Europe, & Japan)
- Cost for each: $2 - $8 B
- ➔ one every 3 – 12 years for all topics
- But HST to JWST is ~ 28 yrs

James Webb Space Telescope (JWST)



Organization

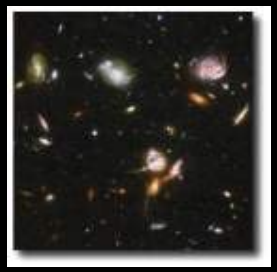
- Mission Lead: Goddard Space Flight Center
- International collaboration with ESA & CSA
- Prime Contractor: Northrop Grumman Aerospace Systems
- Instruments:
  - Near Infrared Camera (NIRCam) – Univ. of Arizona
  - Near Infrared Spectrograph (NIRSpec) – ESA
  - Mid-Infrared Instrument (MIRI) – JPL/ESA
  - Fine Guidance Sensor (FGS) and Near IR Imaging Slitless Spectrograph (NIRISS) – CSA
- Operations: Space Telescope Science Institute

Description

- Deployable infrared telescope with 6.5 meter diameter segmented adjustable primary mirror
- Cryogenic temperature telescope and instruments for infrared performance
- Launch on an ESA-supplied Ariane 5 rocket to Sun-Earth L2
- 5-year science mission (10-year goal)

www.JWST.nasa.gov

JWST Science Themes



End of the dark ages: First light and reionization

The assembly of galaxies

Birth of stars and proto-planetary systems

Planetary systems and the origin of life

JWST Early Release Science (HEA gets ~ 3 of 13)

- A JWST Study of the Starburst-AGN Connection in Merging LIRGs (PI: Lee Armus)
- Q-3D: Imaging Spectroscopy of Quasar Hosts with JWST Analyzed with a Powerful New PSF Decomposition and Spectral Analysis Package (PI: Dominika Wylezalek)
- Nuclear Dynamics of a Nearby Seyfert with NIRSpec Integral Field Spectroscopy (PI: Misty Bentz)

JWST GTO HEA observations

- IFU Spectroscopy of the Host Galaxies of Strongly Lensed Quasars, Massimo Stiavelli
- Formation Histories and Stellar Masses of Very High-z Quasars, George Rieke
- NIRSpec-IFU Observations of Two QSOs at z=6, Pierre Ferruit
- NIRSpec and MIRI spectroscopy of QSOs - part #3, Pierre Ferruit
- NIRSpec IFS of BR1202, Pierre Ferruit
- Cosmic Re-ionization, Metal Enrichment, and Host Galaxies from Quasar Spectroscopy, Chris Willott
- Exploring the End of Cosmic Reionization, Simon Lilly
- NIRSpec and MIRI IFS of SMGs & QSOs, Luis Colina Robledo
- Are There AGN Embedded in All Ultraluminous Infrared Galaxies (ULIRGs)?, George Rieke

Possible Discoveries in 2020's

- Galaxy observations match simulations??
- New population of faint high-z objects found, implications for BH formation, galaxy formation, particle physics
- Hot IGM mapped, and is not where it was supposed to be
- DM annihilation signal found in Fermi γ maps
- High z supernovae found, differ from known types
- Dark Matter in a lab – particles, axions, or nothing
- More Higgs particles found at LHC
- Supernova in Milky Way found – long overdue!
- Einstein's Λ constant fits most dark energy data, drat!
- CIB – CXB spatial correlation explained by ?

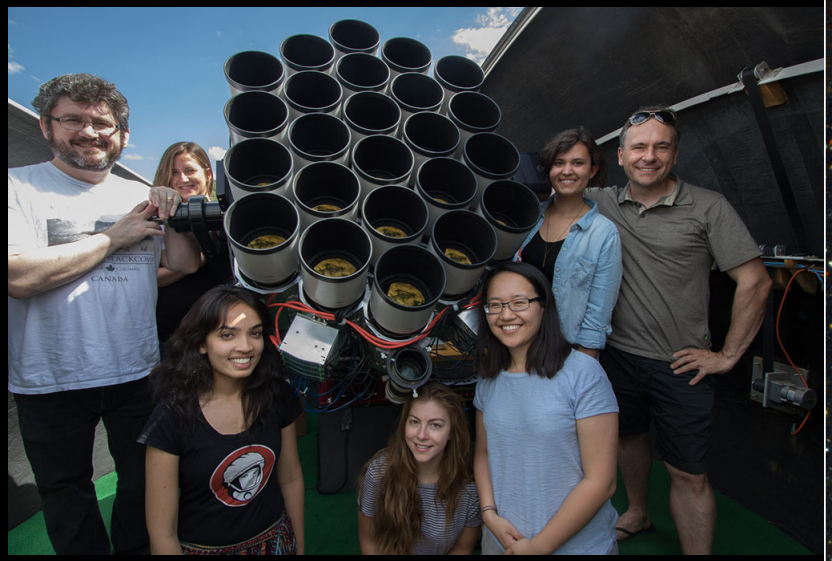
Possible Discoveries in 2020s

- BUT: Continuing tension between SN, BAO, CMB, weak lensing, clustering measurements of H_0 and Dark Energy
- FRB's localized and explained, very surprising story
- CMB B-mode polarization detected (on ground) from primordial gravitational waves, supports equipartition with other modes; demand for a space mission
- Magnetic reconnection events observed by MMS and explained by theory and simulations (magnetic lightning bolts); implications for HE astrophysics
- HE cosmic ray acceleration mechanism misunderstood, again
- Neutron star- black hole mergers observed – LIGO + Fermi + every available telescope
- Microlensing finds population of stellar mass black holes

Possible Discoveries in 2020s

- Dip in 78 MHz redshifted 21 cm from CMB implies strange processes at high z>10, maybe dark matter cools baryons, maybe early galaxy formation, TBC
- Simulated supernova in 3D matches real one
- NANOGrav sees low frequency gravitational waves
- Event Horizon Telescope maps a black hole close up
- Einstein is still not wrong
- Theory of Everything emerges
- Black hole evaporation verified in lab model
- X-ray and radio emission from exoplanets
- X-ray and radio flares found on exoplanet host stars
- High energy neutrino sources (IceCube) identified

Dragonfly discovers Galaxy of 99.99% Dark Matter, will find many more



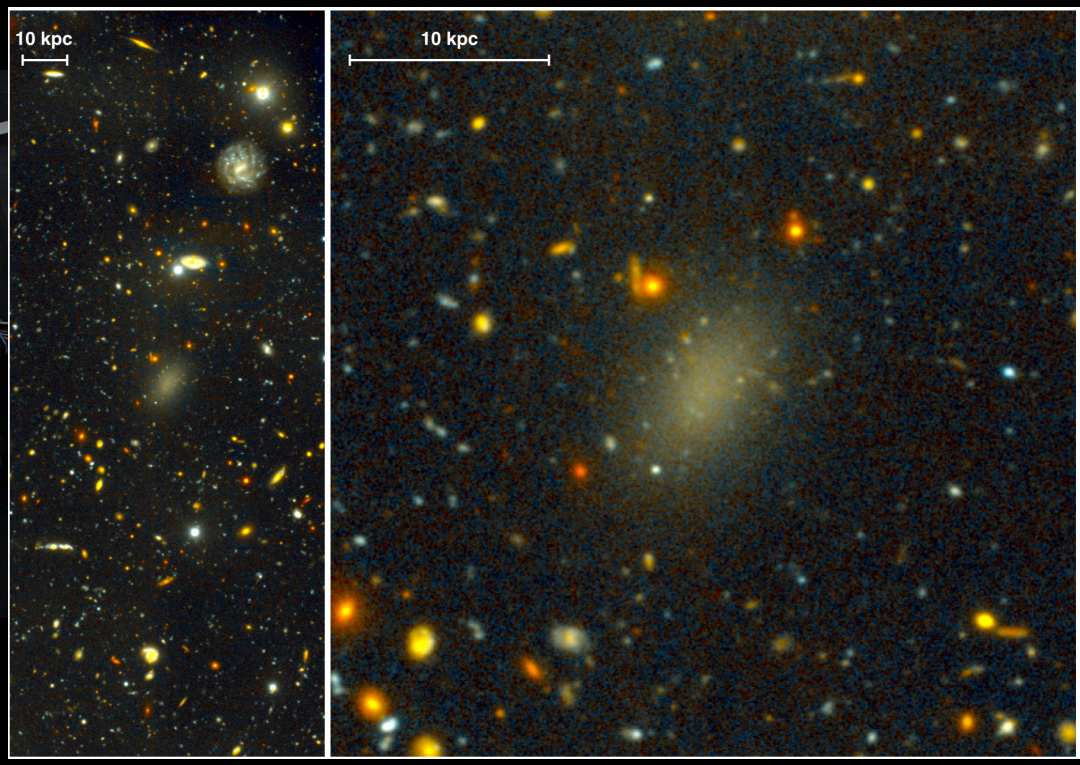
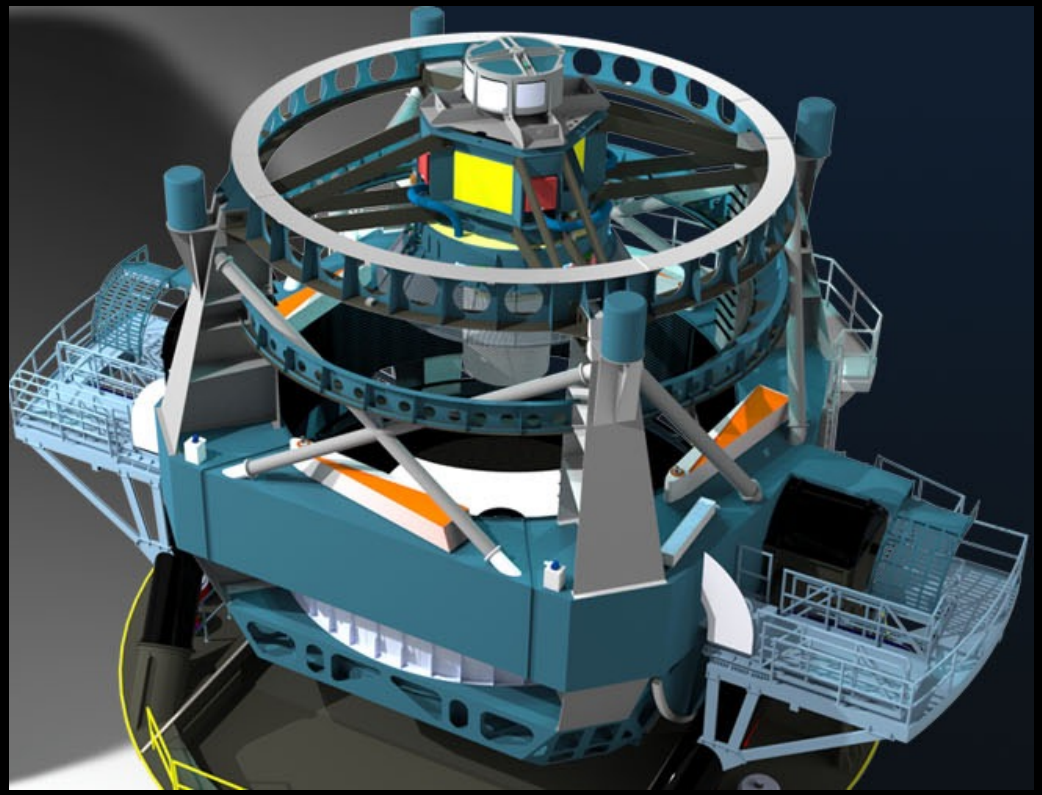


Image credit: Pieter van Dokkum, Roberto Abraham, Gemini Observatory/ AURA.

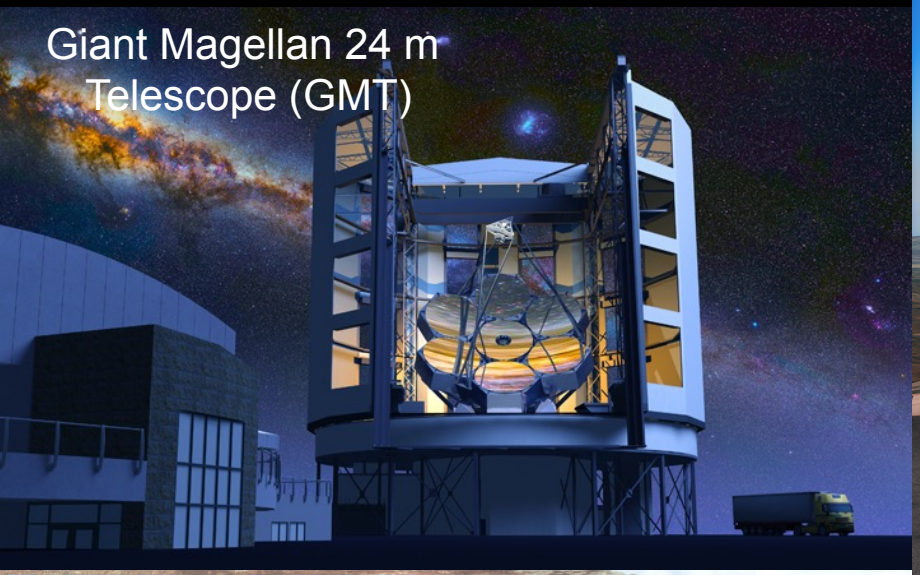
Large Synoptic Survey Telescope
LSST.org

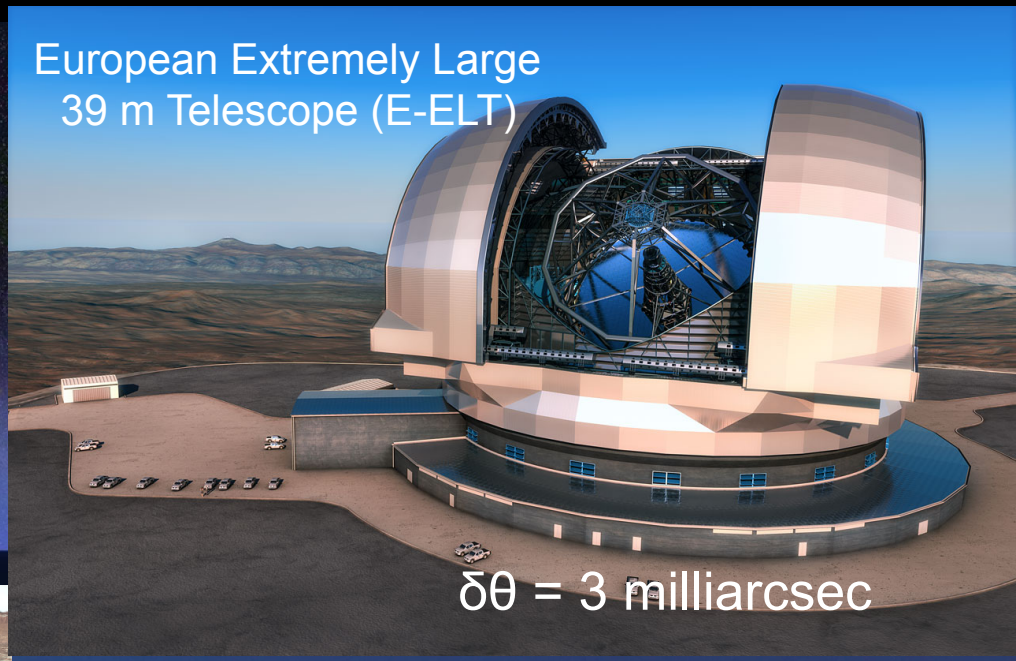


This telescope will produce the deepest, widest, image of the Universe:

- **27-ft (8.4-m) mirror, the width of a singles tennis court**
- **3200 megapixel camera**
- **Each image the size of 40 full moons**
- **37 billion stars and galaxies**
- **10 year survey of the sky**
- **10 million alerts, 1000 pairs of exposures, 15 Terabytes of data .. every night!**

24 meters (1000 inches) and up!

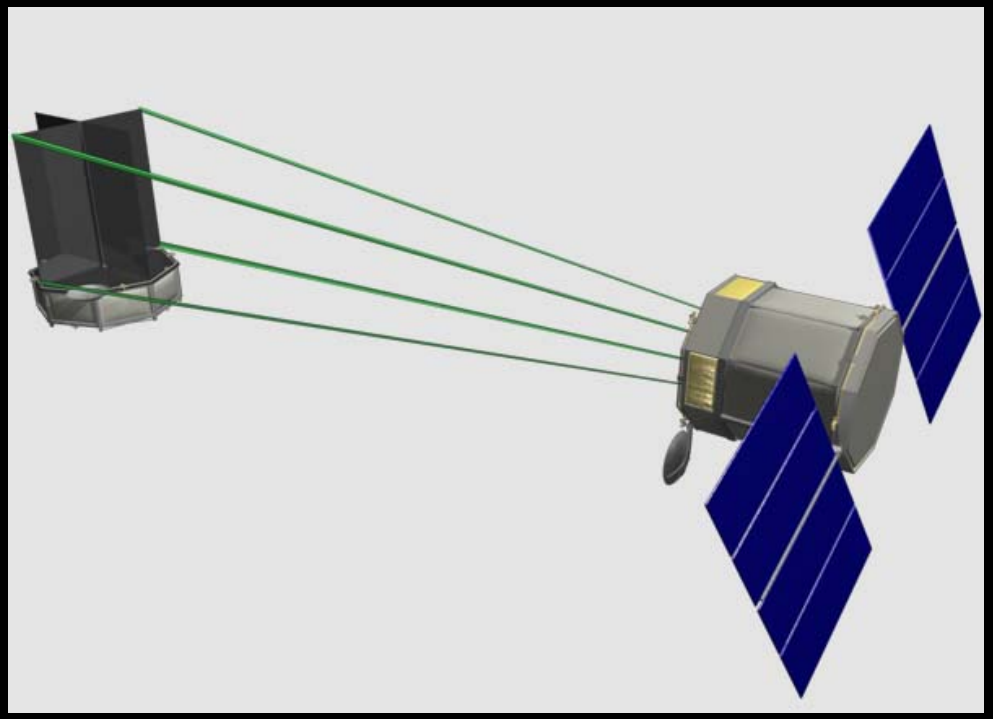




Formation Flying Fresnel Telescope

X-ray/Gamma-ray Imaging

- **Diffractive Fresnel optics**
- **Milli-arcsecond resolution → 1 - 100 km spacecraft separation**
- **Micro-arcsecond angular resolution → 10^4 - 10^6 km spacecraft separation**
- **x-ray/gamma-ray band (5 - 1000 keV)**
- **Formation flying of lens-craft and detector-craft**



And now for something completely different*: Starshade with E-ELT, GMT, TMT

John Mather & Eliad Peretz, GSFC

- D^4 advantage: 1 hr with 30 m = 1 yr with 3 m
- All the instrumentation you can imagine
- Extreme AO for visible bands, 0.003” res
- High elliptical orbit to match velocity of observatory; return every 3 sidereal days
- Thrust to match acceleration of telescope
- Refueling for long life
- Can move to deep space any time
- Weekly images of planetary systems

Monty Python, 1971

Thank you Neil!