Next-generation telescopes could search for intelligent civilizations directly

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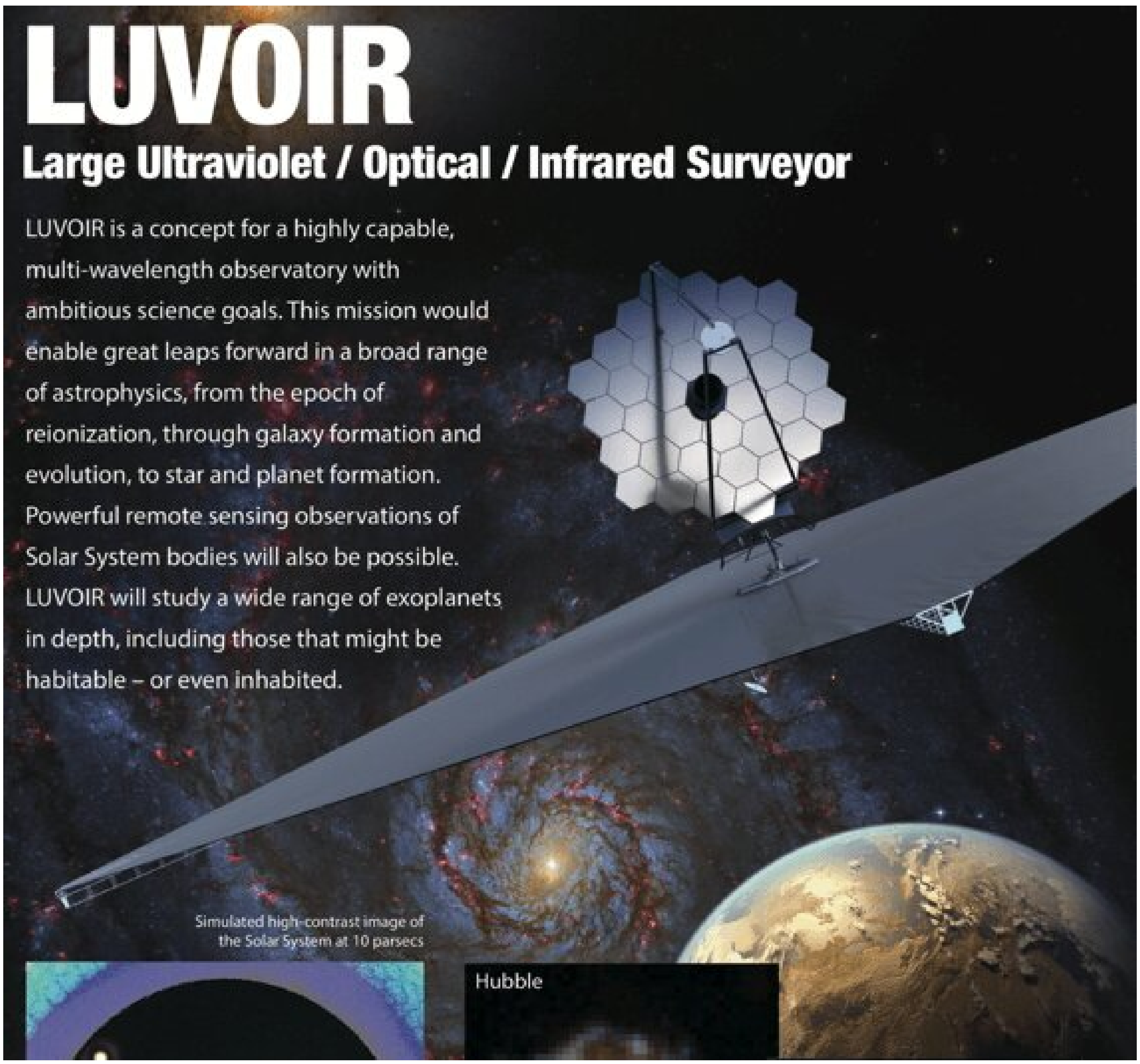


A mission concept poster for NASA's LUVOIR telescope. LUVOIR will see in optical, ultraviolet, and infrared, making it a powerful and versatile telescope.

Credit: NASA/GSFC

We're still in the early days of searching for life elsewhere. The Perseverance rover is on its way to a paleo-delta on Mars to look for fossilized signs of ancient bacterial life. SETI's been watching the sky with radio dishes, listening for signals from distant worlds. Our telescopes are beginning to scan the atmospheres of distant exoplanets for biosignatures.

Soon, we'll take another step forward in the search when new, powerful telescopes begin to search not just for life but for other civilizations.

The search for biosignatures is gaining momentum. If we can find atmospheric indications of life at another planet or moon—things like methane and nitrous oxide and a host of other chemical compounds—then we can wonder if living things produced them. But the search for technosignatures raises the level of the game. Only a technological civilization can produce technosignatures.

Technosignatures are simply the effects of technology on an environment. Light from massive cities, particular atmospheric chemicals, and even satellites orbiting a planet are all technosignatures. The granddaddy of all technosignatures is probably the Dyson sphere. A Dyson sphere is a hypothetical megastructure surrounding a star and capturing its solar energy output. The idea is that as a civilization grows, its energy requirements will balloon, and the only way to gather the energy the civilization requires is to surround its star with an energy-gathering sphere.

In 2021, the National Academies of Sciences released their Decadal Survey on Astronomy and Astrophysics 2020, called Astro2020. They release one every 10 years, and each survey outlines the critical challenges in astrophysics and astronomy for the next decade. Astro2020 contains several recommendations that can advance the search for technosignatures. A NASA working group has released a white paper digging into the technosignature part of Astro2020.

The paper is titled "Opportunities for Technosignature Science in the Astro2020 Report." It comes from Nexus for Exoplanet System Science (NExSS). NExSS is a multidisciplinary group that includes Earth scientists, planetary scientists, heliophysicists, and astrophysicists. They bring a collaborative and synthesized approach to the search for biosignatures and technosignatures.

"Technosignatures refer to any observable manifestations of extraterrestrial technology, and the search for technosignatures is part of the continuum of the astrobiological search for biosignatures," the paper says. "The search for technosignatures is directly relevant to the 'World and Suns in Context' theme and 'Pathways to Habitable Worlds' program in the Astro2020 report."

The white paper aims to "… demonstrate the relevance of technosignature science to a wide range of missions…" The NExSS group is urging the larger science community to include the search for technosignatures in the design and implementation of projects like LUVOIR, ELTs, infrared and X-ray observatories, and other similar facilities.

LUVOIR (Large Ultraviolet Optical Infrared Surveyor) is a NASA telescope concept in two proposed sizes. LUVOIR-A is a 15-meter mirror design, and LUVOIR-B is an eight-meter design. Thanks to its multi-wavelength capabilities, it's a powerful and versatile design with many applications. It would be situated at L2 but would be serviceable like the Hubble was.

ASTRO2020 focuses on the biosignature aspect of LUVOIR in the search for habitable planets, but it mentions technosignatures a couple of times. The authors of this new white paper point out that LUVOIR would be an effective tool in the search for technosignatures. "Industrial pollution represents a class of atmospheric constituents on Earth that could conceivably be technosignatures if observed in the spectra of an exoplanet," they write. "One example is nitrogen dioxide (NO_2), which has large sources on Earth from combustion that are greater than non-anthropogenic sources."

NO_2 makes a good case study in detection scenarios. Elevated NO_2 levels in a planet's atmosphere can indicate industrial activity. But there are natural sources, too, and any detection would have to be studied carefully in case of false positives. This is the same problem biosignature detections face: They need to be unambiguous. But whether a signal is a false positive or not, it first has to be detected.

The white paper authors believe LUVOIR can detect NO_2, and to strengthen their case, they cite previous studies showing that LUVOIR could successfully detect NO_2 in the atmospheres of exoplanets. "A study by Kopparapu et al. (2021) showed that the absorption features of NO_2 … could be detectable with the Large Ultraviolet Optical Infrared Surveyor. Kopparapu et al. (2021) found that a 15 m LUVOIR-like telescope could detect Earth-like levels of NO_2 for a planet around a sun-like star at 10 PC (~33 light-years) with ~400 hours of observation."

The white paper also addresses how LUVOIR could detect more purposeful technosignatures like laser signals and optical beacons. "Optical beacons could provide a cost-effective means of directed communication between exoplanetary systems, which could be encoded and transmitted through rapid nanosecond pulses," the paper states. LUVOIR could help with these, too, by placing "… constraints on the prevalence of optical beacons and other pulsed laser signals."

The authors couple the detection of optical beacons with the detection and characterization of habitable rocky planets and say that LUVOIR is a powerful tool for these detections. "Space missions such as the IR/O/UV telescope could provide detectability constraints on the prevalence of optical beacons in exoplanetary systems," they write. "… relatively low-powered optical beacons could be detectable with the IR/O/UV telescope for most or all targets where the characterization of rocky planets within the HZ is also possible."

Extremely Large Telescopes (ELTs) can also play a role in the search for technosignatures. An ELT is a telescope with a primary mirror larger than about eight meters. Eight meters is a design limitation because telescope mirrors larger than that are heavy and deform themselves. ELTs get around that physical limitation with segmented mirrors. The European Extremely Large Telescope (E-ELT) is the most well-known example of an ELT and should see first light in 2027, but the white paper explicitly mentions two other ELTs.

One is the Giant Magellan Telescope (GMT), and the other is the Thirty Meter Telescope (TMT.) Together, the ELTs seeing first light through the next decade will be powerful engines for advancing scientific objectives. The white paper expands on ELTs' role in the hunt for technosignatures.

"The GMT and TMT are ongoing projects that have been developing for many years," the paper says. "These ground-based facilities could be capable of characterizing the atmospheres of terrestrial planets discovered by missions like TESS and CHEOPS at optical and near-infrared wavelengths."

Red dwarfs are the most prevalent type of star, but their light is dimmer, which makes them more challenging targets. The GMT and the TMT should be able to study the atmospheres of exoplanets around red dwarfs. "Possible spectral technosignatures such as atmospheric pollution and optical beacons … could likewise be constrained with observations of exoplanetary systems by ELTs."

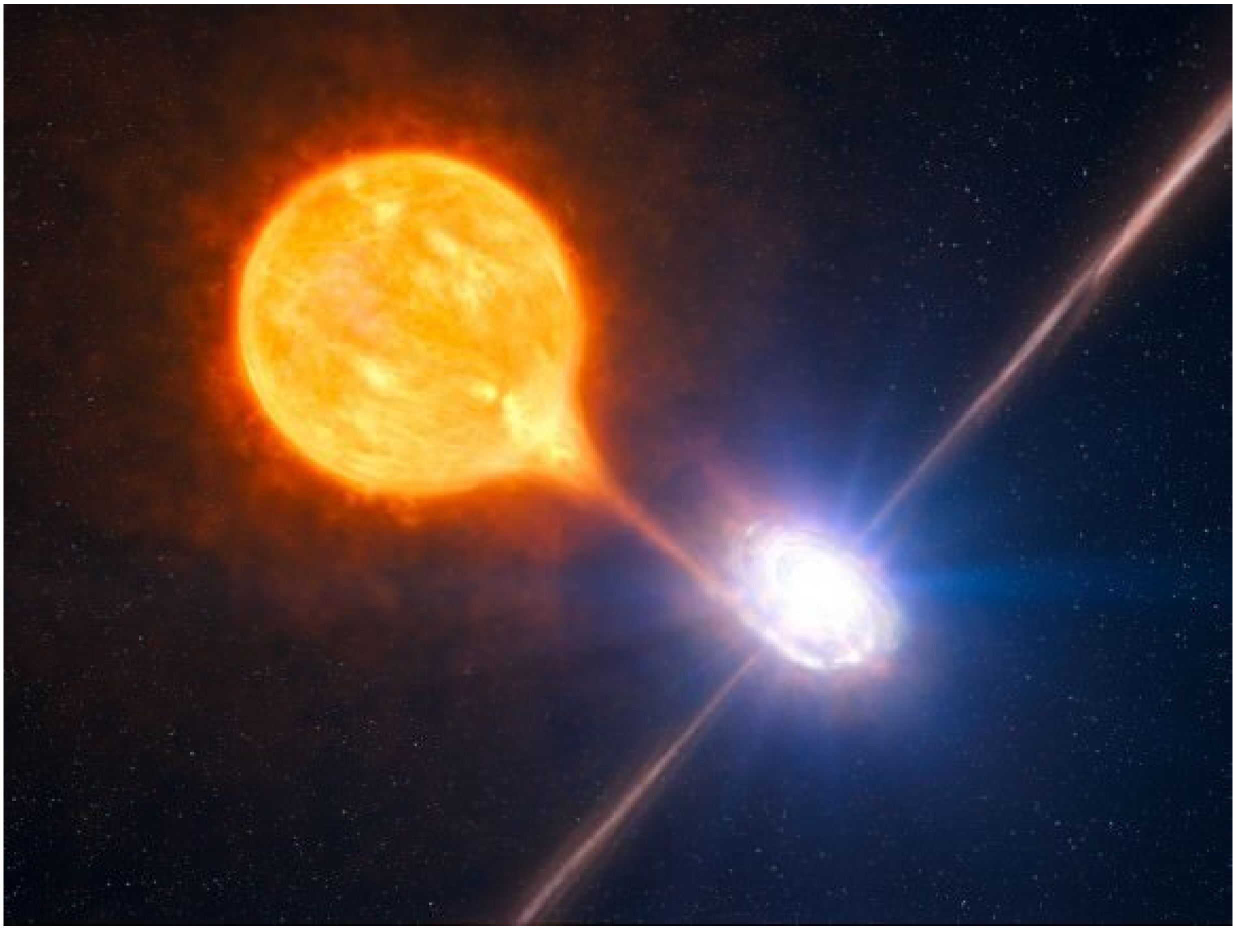
The white paper also talks about far-InfraRed (FIR) probes. There are gaps in our observing capabilities, and FIR probes are one of those gaps. They have to be space-based facilities to be effective, and they could play a crucial role in the search for technosignatures. "… the aforementioned wavelength range is exciting for the so-called artifact SETI, of which the best-known example is Dyson spheres, the energy-harvesting megastructures conceived by Olaf Stapledon and formalized by their eponym Freeman Dyson."

In 1960 Dyson published his paper "Search for Artificial Stellar Sources of Infra-Red Radiation." As the title makes clear, IR radiation is key to detecting this type of megastructure. A Dyson sphere would harvest an enormous amount of energy, an almost inconceivable amount, and the process would undoubtedly produce some waste heat. An FIR probe may not detect the waste heat because of the wavelengths involved, but it could rule out other FIR sources and streamline the search. "However, a Dyson sphere would typically not have much far-infrared emission, unlike dust. Thus, far IR capabilities offer a way to significantly reduce the problem of confounders such as protoplanetary disks."

Infrared probes can also detect specific chemicals in exoplanet atmospheres that are strong indications of industrial activity. Chlorofluorocarbons are one class of chemicals. "… none of the abiotic or biological (but non-technological) pathways operating today can give rise to chlorofluorocarbons (CFCs)," the white paper states. The authors say that IR spectroscopy could detect CFCs, which can persist in an atmosphere for tens of thousands of years. The James Webb Space Telescope can detect CFCs in some cases, but it has a lot of other jobs.

Deeper into the white paper, things get a little murky. X-ray probes could detect technosignatures, but the authors say the topic warrants further investigation. They say X-rays are "… not a promising 'messenger' for artificial signals from ETIs since the latter are conventionally associated with radio (and optical) wavelengths." But X-rays are still intriguing because of the novel ways an advanced civilization could use them to create signals.

"If a km-sized rock were to be hurled onto the surface of a neutron star, it may result in an intense X-ray pulse of $\sim 10^{29}$ W that might be detectable throughout the Milky Way." That might sound far-fetched, but who knows? They also say that an advanced civilization could use their technology to modulate existing X-ray sources like X-ray binaries to send signals.



An artist’s illustration of an x-ray binary. As the black hole draws material from the donor star, the material is heated and emits powerful x-rays visible at great distances. Could an advanced civilization use x-ray binaries to send signals? Image Credit: NASA

The white paper also covers radio astronomy, the cosmic microwave background, and pulsar timing. According to the authors, each of these can be part of our search for technosignatures.

This white paper is a scientific plea. The ASTRO2020 report relegates the search for technosignatures to the report's appendices, and the white paper authors hope to raise its prominence.

"Technosignature observations can often be conducted commensally with other observations, and many technosignature searches can be conducted without changing the recommended mission architecture," the authors write in the white paper's conclusion.

They point out that including the search for technosignatures wouldn't incur any additional expense and that the possibility of finding technosignatures is too important to ignore.

"This white paper recommends that all of the missions and facilities discussed above should consider including the search for technosignatures as part of the explicitly stated science case."

More information: Jacob Haqq-Misra et al, Opportunities for Technosignature Science in the Astro2020 Report. arXiv:2203.08968v1 [astro-ph.IM], arxiv.org/abs/2203.08968

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