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Perspective

Cosmic Illuminating Gift: A One-Way Information Box for Extraterrestrial Intelligences

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Abstract

We introduce the concept of a one-way, broadband information package, the *Cosmic Illuminating Gift*, intended to provide distant intelligences with fundamental empirical data about the Universe. Unlike previous messaging to extraterrestrial intelligences (METI) that emphasized greetings or cultural identity, the Gift aims to transmit unbiased, universally interpretable information that recipients could not otherwise obtain due to their distinct spacetime position and epoch. By emphasizing raw observations, rather than human interpretations or cosmological models, the Gift aspires to serve as a neutral and enduring resource. A central assumption of the project is that any potential recipients are likely to possess a level of intelligence and technological sophistication far beyond our own. Accordingly, the content and encoding of the Gift are not designed to "teach" fundamentals, but to deliver compact, logically structured packets that such civilizations could decode even at extremely low signal-to-noise levels. This perspective shifts the challenge from brute-force transmission to ensuring that photons arrive in spectrally quiet windows and that the format is unmistakably artificial and distinguishable from astrophysical backgrounds. We outline strategies for content selection, encoding, and transmission that reflect this assumption. Practical implementation is feasible with current or near-term infrastructure, and future advances will only improve the quality of subsequent Gifts. Ultimately, the endeavor is unique among scientific projects in that it anticipates no feedback or measurable result within the span of our civilization's timeline. Its significance lies instead in the act of contribution itself: offering a durable, universal dataset as a gesture of intellectual solidarity across cosmic distances.

Keywords: cosmology; extraterrestrial intelligence; information transmission; technosignatures; METI

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1. Introduction

The possibility of intelligent life beyond Earth has fascinated thinkers for millennia, long before it became a scientific question. As early as classical Greece, Democritus proposed the existence of innumerable worlds, some with suns and possibly life, anticipating a pluralistic view of the cosmos [1]. In the Persian philosophical tradition, Avicenna (Ibn Sīnā) and Suhrawardi envisioned a cosmos animated by multiple levels of intellect and consciousness, suggesting that intelligence is not a uniquely terrestrial phenomenon [2,3]. Centuries later, Giordano Bruno argued for "countless suns and countless earths" inhabited by rational beings [4], while Christiaan Huygens, in *Cosmotheoros* (1698), offered one of the earliest empirical reflections on life in other worlds [5]. This enduring curiosity about

intelligence in the wider Universe has gradually evolved from metaphysical speculation to scientific exploration.

The search for extraterrestrial intelligence (SETI) has been an enduring scientific and cultural endeavor for more than half a century. Most efforts have concentrated on passive listening, seeking detectable signals from distant civilizations using radio telescopes or, more recently, optical and infrared observatories [6–11]. In contrast, deliberate transmissions from Earth, often grouped under the term Messaging to Extraterrestrial Intelligence (METI), have remained far less frequent and considerably more debated [12]. Famous examples include the 1974 Arecibo message, a short binary broadcast encoded with mathematical and biological information [13], and the Voyager Golden Records, which carried audio-visual representations of human culture aboard spacecraft launched in 1977 [14]. These initiatives were primarily symbolic, intended to spark reflection on humanity's place in the cosmos, rather than to deliver scientific content optimized for long-term universal utility.

The concept presented here, which I call the Cosmic Illuminating Gift, builds on these historical precedents but departs from them in both motivation and scope [6,7,14–17]. Instead of aiming to introduce humanity or establish communication, the goal is to construct a one-way, compact, and self-contained information package containing knowledge of enduring scientific value. The Gift is not envisioned as part of an ongoing dialogue, since any two-way exchange would be constrained by light-travel times of thousands to millions of years, making practical communication implausible. Rather, the Gift is a one-way contribution to the cosmic commons: a broadcast of information that any intelligent recipient could, in principle, decode and use to deepen their understanding of the Universe.

The type of content prioritized in this proposal is therefore distinct from earlier efforts. Instead of cultural artifacts or depictions of terrestrial life, the Gift would encode fundamental cosmological and physical data. These include, primarily, direct cosmological observables (such as maps of the cosmic microwave background (CMB) and catalogs of galaxy redshifts), accompanied by dimensionless constants as primers (such as the proton–electron mass ratio), and reference markers tied to stable astronomical phenomena (such as characteristic pulsar periods and the CMB dipole). Importantly, the emphasis is on raw observational data rather than derived, model-dependent parameters, so that any advanced intelligence may analyze and interpret the information within its own theoretical framework. Such information is of particular value because it cannot easily be reconstructed by an observer at a different location in spacetime. For example, an intelligence located millions of light-years away, or emerging millions of years in the future, would measure a slightly different redshift distribution of galaxies or a different CMB temperature. The Gift, therefore, provides unique insight into the state of the Universe at the time and location of transmission, acting as a kind of scientific time capsule. While in principle, an advanced intelligence might be able to reconstruct much of the physical reality contained within its past light cone, the practical limits of observation, information decay, and processing capacity impose significant constraints. Recent theoretical work suggests that, under certain conditions, even information from within the interior of the causal past could, in principle, be inferred or recovered by a sufficiently advanced observer [18,19]. In this light, the Cosmic Illuminating Gift may not be a transmission of fundamentally unknowable truths, but rather a sharing of data that are uniquely shaped by our position in spacetime, a perspective that may or may not already be accessible to its recipients. Its value, therefore, remains uncertain: for us, receiving such a message from elsewhere would be transformative; for them, it might merely confirm what they already comprehend. Yet perhaps this asymmetry captures the essence of a true gift, something offered not for assurance of need, but out of the hope of shared understanding.

This paper outlines the scientific rationale, design principles, and potential implementation strategies for the Cosmic Illuminating Gift. The discussion will emphasize how the proposed approach complements but diverges from existing METI initiatives, highlight the unique scientific opportunities it presents, and situate the concept within broader debates on interstellar and intergalactic messaging, ethics, and governance [20,21]. The overarching aim is to frame the Gift as not only a symbolic gesture but a meaningful scientific contribution, one that may outlast humanity itself and enrich the knowledge of any future intelligences capable of receiving it.

We should clarify here that his work is intended as a perspective article, aiming to outline a conceptual and scientifically grounded framework rather than a fully optimized technical implementation.

2. Goals of the Project and the Nature of the Information Box

The primary goal of the *Cosmic Illuminating Gift* is to transmit a compact but meaningful information that could be of genuine scientific utility to any intelligent recipient, independent of their biology, culture, or stage of technological development. Unlike previous interstellar messages, which have largely centered on human identity, culture, or symbolic gestures, this project is motivated by a desire to contribute to the universal pool of knowledge. In particular, the Gift is intended to provide information that another intelligence could not otherwise obtain because of its unique spacetime position. It is less a communication attempt and more a *scientific offering*: a one-way broadcast of carefully chosen information that could enrich the understanding of the Universe for a distant or future civilization.

A crucial principle guiding the design of the Gift is neutrality and authenticity of information. We recognize that humanity's current understanding of the cosmos is both incomplete and inevitably framed by the limitations of our observational tools, theoretical frameworks, and even cognitive capacities [22]. Any description of the Universe in terms of its "components" or "interpretations, for example, the present-day model of dark matter and dark energy contributions to the cosmic energy budget, reflects our best current theories but not necessarily the ultimate truth. By the standards of a more advanced intelligence, such frameworks may appear simplistic, provisional, or even misguided. To avoid embedding our own interpretive biases into the message, the Gift must focus on observationally anchored data rather than phenomenological or theoretical constructs.

This principle leads directly to another major aspect of the project: to provide data rather than conclusions. The information included should consist of direct measurements of cosmological and physical quantities, recorded with their uncertainties and anchored to physical standards that are invariant and universally recognizable. Recipients should be empowered to interpret these data within the context of their own scientific paradigms, which may far surpass ours in sophistication. The value of the Gift lies not in asserting how *we* believe the Universe is structured, but in preserving and transmitting a snapshot of empirical knowledge that could complement or challenge the perspective of an intelligence situated at another place and time in the cosmos.

In addition, the Gift acknowledges a profound humility about our current stage of development. Humanity remains a young civilization, only recently capable of peering into the large-scale structure of the Universe and measuring cosmological parameters (within our theoretical frameworks) with reasonable precision [23,24]. Our instruments are limited in sensitivity, our theories remain provisional, and our brains themselves may not be well-suited to comprehending the full scope of fundamental physics. The *Cosmic Illuminating Gift* is therefore not an attempt to instruct, but to offer—to provide data that may be of value to intelligences far older, wiser, or more advanced than we can imagine.

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2.1. Criteria for Information Selection

The selection of content for the Gift is guided by three key criteria:

1. Universality: the information should be meaningful to any scientific intelligence, regardless of their units, languages, or cultural assumptions.
2. Observational Anchoring: the information should be based on empirical measurements, not interpretations or theoretical constructs.
3. Irreproducibility Elsewhere: the information should address aspects of the Universe that another intelligence could not directly measure due to their spacetime position, while remaining internally consistent enough for self-verification by an advanced intelligence.

2.2. Proposed Content Categories

The scientific potential of such a gift for any intelligent civilization could be vast. As a simple illustration, measurements of the redshift drift for millions of galaxies and quasars would allow a precise and accurate reconstruction of the expansion history of the Universe without relying on any cosmological model assumptions. A quantitative illustration of this is presented in the Appendix, where the sensitivity of redshift drift to cosmological parameters is explored in detail (See Appendix B). Here, we do not attempt to explore the full range of possible scientific applications of such a gift; rather, we are simply proposing the concept. Based on these criteria, the following categories of information are recommended, though this list can be trivially expanded.

a. Cosmological Epoch Markers, Astronomical Anchors and Coordinate Systems.

- The current temperature of the cosmic microwave background (CMB).
- Local measurements of the Hubble constant (H_0) at the time of emission [25].
- Pulsar periods and sky positions, serving as long-lived reference points [26,27].
- The direction and magnitude of the local CMB dipole (a large-scale temperature anisotropy caused by motion relative to the cosmic rest frame), indicating our peculiar velocity relative to the CMB rest frame.
- Angular separations of nearby bright stars and galaxies.

b. Observational Datasets with Uncertainties.

- Redshift-distance relations from cepheids and Type Ia supernovae [28].
- Temperature and polarization maps of the Cosmic Microwave background [23].
- Location and redshift of galaxies and quasars from galaxy surveys [24,29].

c. Assumptions made in observations/detections.

- How supernovae and cepheids are calibrated and how their light curves have been analyzed.
- How CMB maps are cleaned and forgrounds are removed.
- How galaxies are selected for large-scale structure surveys.

One should note that such cosmological datasets could be encoded as structured arrays representing sky maps, redshift catalogs, or time series, with explicit dimensional markers and scaling conventions defined in the primer. Moreover, the categories outlined here are not intended to represent an optimized selection under specific technical constraints such as bandwidth or compression, but rather a physically motivated and illustrative framework for structuring cosmological information.

2.3. Avoiding Interpretive Bias

Equally important is the recognition of what should *not* be included in the Gift. We deliberately avoid embedding theoretical constructs that reflect our current interpretations, such as:

- The present-day breakdown of the Universe into dark energy, dark matter, and baryonic matter fractions.
- Any specific hypothesis for the nature of dark energy or dark matter.
- Anthropocentric or Earth-specific narratives.

An advanced intelligence could interpret the raw data within its own frameworks, potentially yielding conclusions far more accurate than our own.

The goals of the *Cosmic Illuminating Gift* are therefore threefold: (1) to provide a one-way dataset of lasting scientific value, (2) to focus strictly on observationally grounded information rather than theoretical interpretations, and (3) to transmit data that could not otherwise be reconstructed by an intelligence situated elsewhere in spacetime.

A further consideration concerns the verifiability of the Gift's content. Although the data are, by design, irreproducible from another spacetime vantage point, it is reasonable to expect that a sufficiently advanced intelligence could assess their internal consistency and empirical coherence. We assume that such recipients would be capable of identifying correlations among independent observables, such as redshift–distance relations, spectral energy distributions, and pulsar timing references, to evaluate whether the dataset represents a physically self-consistent view of the Universe. In this sense, verification does not rely on external replication but on the logical integrity and cross-consistency of the transmitted data. The structure of the Gift should therefore facilitate such validation by an intelligent observer, rather than seek to convince through interpretation or narrative.

3. Encoding and Format of the Information Package

In designing the *Cosmic Illuminating Gift*, we begin from the premise that any potential recipients are at least as intelligent as ourselves, and most likely considerably more advanced. The encoding should therefore not attempt to be overly didactic or simplistic. Instead, it should aim for logical elegance, compactness, and internal consistency. The message must be designed in a way that a capable intelligence can reconstruct its principles with minimal ambiguity, while ensuring that its artificial nature is unmistakable.

3.1. Rationale: Intelligence and Decodability

A key design principle is the assumption of recipient intelligence. History provides ample evidence that logically structured but encrypted communications can be broken by human effort, even under extreme secrecy. For instance, Allied cryptanalysts were able to decipher the German *Enigma* cipher during World War II [30], not because the message was intended to be simple, but because it was logical, systematic, and ultimately decipherable with enough intelligence and persistence. By analogy, an extraterrestrial civilization with advanced analytic capabilities should be able to decode a rigorously structured signal, even if its format is initially unfamiliar. Even though the decodability cannot be necessarily guaranteed, particularly given the unknown cognitive frameworks of potential recipients, the use of mathematically structured, non-random patterns and physical invariants provides a reasonable basis for assuming that sufficiently advanced intelligences could infer the underlying logic of the message.

This assumption allows us to prioritize compactness and efficiency. Instead of filling the message with redundancy intended for a novice audience, we can structure it in a logically consistent way, transmitting further with less energy cost. A streamlined design

increases the likelihood of detection across interstellar or intergalactic distances while respecting the presumed intelligence of the recipients.

3.2. Primer and Universal Constants

Although recipients may be highly intelligent, a minimal "primer" remains essential to establish conventions. This should not attempt to teach elementary arithmetic but should instead:

- Explicitly introduce binary as the base representation, beginning with short integer sequences.
- Demonstrate mapping rules from integers to arrays, matrices, and symbolic strings.
- Define conventions for operations, delimiters, and block structures.

Once these rules are set, the remainder of the packet can be expressed efficiently, avoiding unnecessary repetition. The primer should be as short as possible while ensuring internal consistency.

In addition to establishing conventions, the content of the Gift should be grounded in universal constants or ratios that are unlikely to be parochial. Dimensionless physical ratios are particularly valuable, such as:

- The ratios of atomic energy levels.
- The proton-to-electron mass ratio ($m_p/m_e \approx 1836$).
- The neutron–proton mass difference ratio.

Mathematical constants should also be highlighted, since they arise repeatedly across natural law and geometry:

- π, arising in geometry, wave mechanics, and probability distributions.
- e, the base of natural logarithms, embedded in growth, decay, and entropy formulations.

It is also essential to provide temporal benchmarks to establish a universal timescale. Possible standards include:

- The measured half-life of elementary particles (within the framework of particle physics), such as the free neutron ($\tau_n \approx 880$ s), a fundamental weak-interaction process that is invariant throughout the Universe [31].
- The hyperfine transition (a quantum energy level splitting in hydrogen) of neutral hydrogen (21 cm line), which naturally defines both a wavelength and its corresponding frequency (1.42 GHz), thereby setting a reference clock cycle [32–34].
- More generally, decay times of long-lived isotopes or oscillation frequencies of atomic processes, which can anchor time across vast distances and civilizations.

Embedding such constants/ratios provides a bridge between mathematics, physics, and temporal reference frames. Together, the primer and universal constants ensure that the Gift resonates with any scientific intelligence, allowing recipients to cross-calibrate both the spatial and temporal scales of the Universe.

3.3. Distinctiveness from Natural Signals

One of the most critical requirements is that the message must be unmistakably artificial. The cosmos is rich in structured signals, from pulsars and quasars to fast radio bursts (FRBs) and stochastic backgrounds. To avoid confusion, the message should display properties that cannot plausibly be attributed to natural processes:

- Use modulation patterns based on prime numbers or sequences of irrational constants. Such structures are extremely unlikely to arise in natural astrophysical processes.
- Include framing markers that are statistically distinct from noise, such as long consecutive primes or binary representations of π extended to high precision.

- Apply nested repetition schemes or self-referential codes that exhibit a level of meta-organization absent in natural emissions.

Even at low signal-to-noise (SNR) ratios, such features would reveal the intentional, artificial nature of the transmission. The signal must "stand out" as a deliberate artifact, not a product of cosmic background processes.

The encoding and format of the *Cosmic Illuminating Gift* should balance four principles: compactness, logical rigor, universality, and artificial distinctiveness. By embedding physical (including temporal) and mathematical constants in multiple representations, employing streamlined error correction, and ensuring that the signal is unmistakably artificial, the Gift would maximize its interpretability and reach. Crucially, the assumption of recipient intelligence allows the message to be elegant rather than verbose, efficient rather than redundant. In this way, the Gift respects both the unknown sophistication of its audience and the limitations of interstellar or even intergalactic transmission.

4. Target Selection and Transmission Strategy

A central operational assumption of this project is that any technologically advanced recipients will be capable of detecting and interpreting extremely weak, but well-structured signals, provided photons carrying the message actually arrive at their detectors. Under this premise, even very distant targets such as the Andromeda galaxy become realistic choices: the problem becomes one of delivering an identifiable, distinguishable signal to the target's locale. This assumption alters the optimization space: rather than maximizing brute-force redundancy to overcome limited recipient capabilities, we optimize for spectral quietness, pointing precision, and energy concentration so that the few photons that arrive are maximally informative and unmistakably artificial.

4.1. Target Selection: Principles and Tradeoffs

a. *Nearby stellar systems.* Nearby stars (tens of light-years) remain attractive because the required transmitter EIRP (Effective Isotropic Radiated Power) and integration times are modest, and potential recipients could receive the message on astronomically short timescales. When targeting nearby exoplanet hosts in the habitable zone, narrow high-gain beams are efficient and minimize wasted power. However, the likelihood of advanced intelligent life existing in such close proximity is extremely low, so the very local universe cannot realistically serve as the primary focus of this project.

b. *Galactic-scale targeting.* Pointing toward regions of high stellar density (e.g., the galactic plane or selected directions with many known exoplanet hosts) trades greater exposure for a larger range and hence higher transmitter requirements. If the goal is to maximize the number of potential recipients within the Milky Way, a mixture of narrow targeted beams and a small number of broader sweeps is sensible.

c. *Extragalactic targeting (e.g., Andromeda).* Under the stated assumption about recipient sensitivity, extragalactic targets are feasible in principle. The main engineering challenge is delivering a detectable photon flux after enormous geometric dilution. However, if the transmitter can concentrate energy into an extremely narrow beam and select a spectral band that is exceptionally quiet at the receiver's sky position and redshift, then detection becomes possible for sufficiently capable receivers [35]. Thus Andromeda and other nearby galaxies should remain in the candidate list, especially for transmissions conceived as long-term scientific archives rather than near-term outreach.

d. *Hybrid strategy.* In practice, a hybrid program can be feasible: prioritize several nearby, high-value targets (confirmed habitable-zone planets), allocate a set of directed

beams at dense Galactic regions, and reserve occasional high-energy, tightly focused transmissions aimed at selected extragalactic targets as a long-term archival gambit.

4.2. Spectral Window Selection: Quietness per Target

The optimal frequency band depends critically on the target type and its intervening propagation medium. The design goal is to select a spectral window that is as quiet as possible for that line of sight:

- Local (nearby stars): choose bands with low Galactic radio noise (diffuse radio emission from the Milky Way produced by charged particles and magnetic fields) and minimal local spectral lines (discrete frequencies of light emitted or absorbed by atoms and molecules); the traditional "water hole" around the hydrogen hyperfine frequency remains attractive because of its relative quietness and universal physical meaning [6].
- Galactic plane/center lines of sight: avoid strong diffuse synchrotron or thermal emission windows; move to higher microwave bands if necessary to escape Galactic foregrounds and scattering.
- Extragalactic lines of sight: account for cosmological effects (red/blueshift and intergalactic dispersion). For a given extragalactic target with redshift z, select emitted frequency f_{emit} so that the observed frequency at the target $f_{\text{obs}} = f_{\text{emit}}/(1+z)$ lies in a quiet local window there. In the initial stages of this project, this is not expected to pose a major challenge, since most nearby galaxies have very low redshifts, requiring only modest fine-tuning.

Because the recipient is assumed to be able to detect weak signals, the central optimization reduces to *minimizing the astrophysical background at the receiver for the chosen line of sight*. In practice, this implies a per-target spectral survey (or reliance on existing sky maps) to pick the cleanest narrow windows in which to place the payload.

4.3. Bandwidth, Modulation, and Information Efficiency

a. *Bandwidth tradeoffs.* Narrowband carriers are exceedingly easy to detect against broad natural backgrounds and allow low-SNR detection with long integration [36]. Wideband transmissions can carry more information per photon but are more easily confounded with natural broadband emission and suffer more from dispersion and scattering. Given the advanced-recipient assumption, an efficient compromise is to use:
   - A narrow, low-bandwidth pilot/carrier (beacon) that signals artificiality and provides synchronization information, and
   - A higher-bandwidth, efficiently coded payload channel (or channels) placed in the cleanest contiguous spectral window available at the target.

b. *Modulation and structure.* We can use logically simple, highly non-random modulation patterns that are both compact and unambiguously artificial (prime sequences, nested self-describing frames, binary expansions of irrational constants) [37]. Advanced recipients can infer structure from short pilot sequences; these allow the payload to use compact, high-efficiency modulation schemes combined with strong forward-error correction.

A detailed quantitative treatment of bandwidth optimization, compression strategies, and detectability is beyond the scope of the present perspective paper and is left for future work.

4.4. Power, Antennas, and Beam Strategy

a. *Antenna and EIRP considerations.* For a given target distance R, desired flux density at the receiver, and frequency, the required transmitter EIRP scales with R^2 and the inverse square of wavelength/beam solid angle [15]. Therefore:

- For nearby stellar targets, existing large single dishes or moderate phased arrays can provide adequate EIRP and reasonable beamwidths.
- For extragalactic targets, extreme aperture sizes (very large phased arrays) or space-based transmitters with sustained high power are required to produce sufficiently narrow beams (see Appendix A).

b. *Pointing precision and ephemerides.* Narrow beams demand accurate target ephemerides and compensation for proper motion, parallax, and target reflex motion. For nearby exoplanets, the transmitter must track the target star's motion and, if possible, phase transmissions to known orbital epochs to maximize interception probability.

4.5. Repetition Strategy: One-Time vs. Repeated Transmission

a. *One-time archival transmissions.* A single, high-effort transmission aligns with the concept of a one-time cosmic gift: minimal recurring resource use, symbolic clarity, and archival intent. This is defensible if recipients are assumed to be able to detect weak signals when they arrive and are waiting for such a signal!

b. *Periodic repetition.* Periodic or sparse repetition (e.g., yearly or scheduled bursts) increases the detection probability and protects against transient interference or missed alignment. A mixed approach of occasional strong archival shots plus a lower cadence repetition schedule balances cost and robustness.

In principle, no fundamental limit prevents the extraction of structured signals. Even transmissions that appear faint to us could be readily detectable by more advanced civilizations. Design should focus on stability, clarity, and quiet spectral windows, enabling the *Cosmic Illuminating Gift* to reach stars and galaxies like Andromeda.

5. Practical Implementation: Platform Options, Costs, and Schedule

Designing and transmitting the *Cosmic Illuminating Gift* is a formidable undertaking, but not beyond the scope of foreseeable human capabilities. Several pathways exist for realizing such a project, differing in terms of technical readiness, resource requirements, and long-term feasibility.

5.1. Platform Options

Ground-based radio facilities provide the most immediate and cost-effective option. Existing large single dishes such as FAST (Five-hundred-meter Aperture Spherical Radio Telescope) [38] or phased array facilities like the Square Kilometre Array (SKA) [39] can, in principle, allocate limited observing time for directed transmissions. These instruments already achieve the high gain and beam narrowness required for interstellar distances, though not yet for extragalactic archival attempts. Modest upgrades to power-handling and control systems could adapt them for one-way message delivery.

Space-based transmitters represent a more ambitious but powerful approach. Placing high-gain arrays in space eliminates atmospheric absorption, expands accessible frequency windows, and allows for continuous pointing without terrestrial constraints. Solar-powered platforms in Earth orbit, or eventually in deep-space locations (e.g., Sun-Earth or Earth–Moon Lagrange points), could steadily accumulate energy and release it in directed bursts toward selected targets. While far more expensive, this approach maximizes long-term reliability and reduces terrestrial interference.

Hybrid strategies are also possible, beginning with ground-based test transmissions to nearby stars, followed by the development of a dedicated space-based facility for archival transmissions to extragalactic destinations such as Andromeda. (An alternative or complementary approach could involve physical carriers, such as spacecraft-based archives containing the encoded dataset. Although such probes would travel far more slowly than

electromagnetic signals, the long timescales inherent to the concept render this difference less critical. This approach may offer practical advantages in terms of persistence and detectability over cosmic timescales.)

5.2. Costs and Feasibility

Relative to other "big science" projects, a one-way transmission is financially tractable. The marginal cost of dedicating a few hours of time on an existing giant radio telescope once in a while is minimal compared to building entirely new facilities. A full-scale, purpose-built phased array optimized for messaging would be more expensive, but plausibly within the $1–10 billion range—comparable to flagship space missions or particle physics experiments [15]. Space-based options may exceed this scale, but could be developed in synergy with broader infrastructure for astronomy and communications. Importantly, the transmission power requirements are significantly reduced by our assumption of highly capable recipients, making the project more achievable than beacon strategies designed to "shout" across the galaxy.

5.3. Schedule Considerations

A practical roadmap could proceed in phases. Phase I (0–5 years) would involve preparatory studies: encoding design, spectral window optimization, and ground-based test transmissions at low power to nearby stars. Phase II (5–15 years) could implement dedicated campaigns with existing large telescopes, targeting both local exoplanet systems and selected Galactic regions. Phase III (15–30 years) could see the construction of a dedicated high-gain array or a space-based platform capable of delivering transmissions to extragalactic targets, culminating in the archival message beamed toward Andromeda. Such a phased schedule allows incremental development, early testing of key ideas, and progressive scaling to ambitious goals. While large-scale implementation may not be immediately feasible within current sociopolitical and economic frameworks, the concept is inherently scalable. Early-stage efforts, such as low-power transmissions or pilot encoding experiments, could serve as proof-of-concept, allowing gradual development over time.

5.4. Evolution of the Gift

An essential aspect of this endeavor is its capacity for continuous improvement. As human technology advances, both the way we observe the universe and the way we transmit information will improve correspondingly. More sensitive detectors, larger telescopes, and more efficient transmission systems will allow us to craft subsequent versions of the Cosmic Illuminating Gift with greater compactness, clarity, and reach. Thus, the project should not be seen as a single static act, but rather as an evolving process: each generation can refine the message, expand the dataset, and extend its range. Future versions of the Gift may include higher resolution cosmological data or even an entirely new form of data representation enabled by unforeseen breakthroughs in physics and computation [40]. This evolutionary perspective ensures that humanity's cosmic offering only becomes more powerful and enduring over time.

5.5. A Unique Non-Result Experiment

Perhaps the most striking feature of the Cosmic Illuminating Gift is that, unlike almost all other scientific experiments, it is designed to yield no result. Traditional experiments are motivated by feedback, measurements, data, or confirmation that guide further inquiry. By contrast, this project produces no such expectation. Its photons may traverse thousands or millions of years before ever reaching another intelligence, and any response, if it exists, will lie far outside the timescale of human civilization. In this sense, the project is profoundly different: it is not an experiment in the conventional sense, but a deliberate act of one-way

generosity. This lack of feedback is not a weakness but a defining feature, distinguishing the effort as a contribution to cosmic knowledge rather than a transaction. It reminds us that science can also serve as a gift, a form of art, offered without anticipation of return. We should clarify, however, that by 'no result,' we mean no result for the current and near-future generations of humanity. There may, of course, be a result for other civilizations to whom this message is addressed, and who knows, perhaps our distant descendants will one day receive a response.

In sum, practical implementation of the *Cosmic Illuminating Gift* is feasible within existing or near-term human technological capabilities. Costs are on par with other major scientific enterprises, especially when leveraging current ground-based assets. By pursuing a phased schedule, allowing for continuous refinement as technology progresses, and embracing the one-way, non-result nature of the project, humanity can realize this unique undertaking in the coming decades, transforming a philosophical idea into a concrete act of cosmic generosity.

6. Ethics, Governance, and Caution

Any proposal to deliberately transmit information into space falls within the broader debate about *Messaging to Extraterrestrial Intelligence* (METI). Critics of METI have argued that sending powerful signals without global consensus could expose humanity to unknown risks [21]. Others counter that such fears may be exaggerated, given that Earth has already been radiating detectable signals for nearly a century and that advanced civilizations would not likely be surprised by our existence [41]. In this context, the *Cosmic Illuminating Gift* occupies a distinctive position: it is not a greeting, not an invitation to respond, but an archival transmission of universal data, a one-way scientific offering. Nevertheless, its ethical and governance implications demand careful consideration.

6.1. Decision-Making and Representation

A central ethical question is: who has the authority to send such a message, and on whose behalf? No single nation, institution, or research group can credibly claim to represent humanity as a whole. Thus, governance structures must be international from the outset, ideally coordinated through existing bodies such as the United Nations Office for Outer Space Affairs, in consultation with the SETI/METI scientific community. Broad public consultation is also essential, not only to ensure transparency but to legitimize the project as a collective human undertaking rather than a unilateral act.

6.2. Risk and Benefit

The risks of transmitting the Gift differ in character from typical METI projects. Because the Gift is explicitly framed as a dataset rather than a social greeting, its potential to be perceived as a provocation is reduced. Still, concerns about drawing attention to our presence cannot be dismissed entirely. The counterpoint is that the scientific and philosophical benefits are profound: the act itself forces humanity to reflect on what knowledge is most fundamental, what can be expressed in a universal way, and how our scientific culture can contribute to a cosmic commons. Even if the Gift is never received, the intellectual exercise has intrinsic value. Moreover, sending an extragalactic signal, such as toward Andromeda, approximately 2.5 million light-years away, would eliminate such provocation risks altogether.

6.3. Transparency and Coordination

To maintain legitimacy, the entire process, from content selection to encoding design to target choice, should be conducted transparently, with international input and oversight. Norms already developed in the SETI/METI community, such as public disclosure and

peer review of transmission plans, provide a starting framework [42]. Transparency helps prevent the perception that humanity is acting in secret or with hidden motives.

6.4. Clarifying Intentions

Finally, it is crucial to communicate, both to ourselves and to any hypothetical recipients, the intention behind the Gift. Unlike past messages that introduced our culture, biology, or location, this project deliberately avoids parochial narratives. Its purpose is not to establish communication but to provide universally relevant data. By framing the Gift as a scientific offering rather than a greeting, we minimize the risk of misinterpretation as a threat or summons.

The ethics of the *Cosmic Illuminating Gift* require as much attention as its technical implementation. Governance must be international, decisions transparent, and intentions explicit. By adopting a framework of openness, caution, and humility, the project can advance not as a unilateral risk but as a collective act of human generosity, rooted in the idea that knowledge itself can be our most enduring and least threatening contribution to the universe.

7. Conclusions

The *Cosmic Illuminating Gift* represents a conceptual step toward rethinking humankind's relationship with the broader universe. Rather than aiming to communicate greetings, solicit responses, or convey cultural identity, the Gift is conceived as a one-way, compact transmission of universal information that transcends human interpretation. It is, in essence, a dataset designed to be self-consistent, logically encoded, and accessible to any scientific intelligence capable of detecting it. The emphasis on unbiased data from our unique position in space-time, rather than our contingent cosmological models or anthropocentric narratives, underscores the humility with which this project approaches the unknown. The integrity of the Gift lies in its internal coherence: it should be verifiable through cross-consistency rather than external observation. We acknowledge the limitations of our species' understanding and physiology, and we aim instead to provide a foundation of information that others may interpret within their own frameworks.

This reframing also challenges conventional views of active messaging to extraterrestrial intelligences (METI). Unlike typical scientific experiments that anticipate observable results, the Gift is unique in that it is not expected to yield direct outcomes or feedback within any human timescale. Its significance lies in the act itself: the recognition that our civilization, at its present stage, has the capacity to create a legacy artifact, an enduring beacon of knowledge, however modest, that might reach others across cosmic distances. This shift in perspective makes the endeavor less about immediate return and more about long-term contribution to a universal commons of knowledge.

The technical considerations outlined in this work, from encoding strategies and frequency selection to platform feasibility and governance, highlight that such a transmission is not merely speculative. With existing or near-term infrastructure, humanity could implement the project in phases, continually improving the fidelity and scope of the Gift as technology advances. Moreover, the emphasis on ethical responsibility, transparency, and international coordination ensures that the initiative aligns with broader scientific and societal norms, mitigating risks while maximizing potential benefits.

Beyond its scientific intent, the Cosmic Illuminating Gift can also embody a profoundly symbolic gesture. Among the data it transmits, we might include an image of the recipient's own galaxy as seen from Earth, an ancient snapshot of their cosmic home millions of years in the past. While such an image may hold limited scientific novelty for them, it carries deep emotional and philosophical meaning: a reflection of their origins seen through another

civilization's eyes. Just as the Pale Blue Dot photograph of Earth transformed humanity's self-awareness by showing our world as a tiny speck suspended in vastness [43], the distant view of one's own galaxy could evoke a similar sense of humility, continuity, and wonder. In this sense, the Gift becomes not only an archive of knowledge but also a quiet acknowledgment of shared cosmic existence.

In conclusion, the *Cosmic Illuminating Gift* should not be seen as a definitive statement, but as an evolving process: an acknowledgment that, even as a young civilization, humanity can offer something meaningful to the universe. By transmitting data grounded in universal constants, mathematics, and empirical observations from our unique space-time coordination, we are not asserting authority but extending a gesture of intellectual solidarity to any intelligence capable of receiving it. Whether or not the Gift is ever found or decoded, its preparation and transmission embody a profound statement about our values, aspirations, and place within the cosmos.

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Appendix A. Antenna and EIRP Considerations

For a given target distance R, desired flux density at the receiver S, and operating wavelength λ, the required transmitter effective isotropic radiated power (EIRP) follows the inverse-square law:

$$\text{EIRP} = 4\pi R^2 S,$$

where R is the distance to the target and S is the required flux density at the receiver (W m^{-2} Hz^{-1}). The achievable EIRP depends on the transmitter power P_t and antenna gain G:

$$\text{EIRP} = P_t\, G, \quad \text{with} \quad G \approx \frac{4\pi A}{\lambda^2},$$

where P_t is transmitted power, A is effective antenna aperture, and λ is the wavelength.

Example: FAST

Consider FAST, with effective aperture $A \approx 3 \times 10^4\,\text{m}^2$, transmitting at $f = 1.4\,\text{GHz}$ ($\lambda \approx 0.21\,\text{m}$). The antenna gain is

$$G \approx \frac{4\pi A}{\lambda^2} \approx \frac{4\pi(3\times 10^4)}{(0.21)^2} \approx 8.5 \times 10^6.$$

With transmitter power $P_t = 1\,\text{MW}$, the EIRP is

$$\text{EIRP} = P_t G \approx 8.5 \times 10^{12}\,\text{W}.$$

The received flux density at distance R is

$$S = \frac{\text{EIRP}}{4\pi R^2}.$$

a. Nearby star (10 ly).

For $R \approx 9.5 \times 10^{16}$ m,

$$S \approx 7.5 \times 10^{-23}\,\mathrm{W\,m^{-2}},$$

within reach of modern radio astronomy.

b. Andromeda Galaxy (2.5 Mly).

For $R \approx 2.4 \times 10^{22}$ m,

$$S \approx 1.2 \times 10^{-33}\,\mathrm{W\,m^{-2}},$$

far below human detection limits, but potentially recoverable by a far more advanced civilization.

Appendix B. Redshift Drift and Observational Prospects

In connection with the discussion in Section 2.2, we present here a brief quantitative illustration of how redshift drift measurements encode information about cosmic expansion and gravitational dynamics. Redshift drift is the secular change of the cosmological redshift of distant sources produced by the time evolution of the cosmic scale factor [44–47]. It provides a direct, model-independent probe of the expansion history of the Universe by comparing spectra of the same source measured at different observer times.

The observed cosmological redshift is related to the scale factor $a(t)$ by

$$1 + z(t) \;=\; \frac{a(t_0)}{a(t_e)}, \tag{A1}$$

where t_0 is the observer (current) cosmic time and t_e the emission time. Differentiating with respect to the observer time t_0 (and using the standard light-propagation relation $dt_e/dt_0 = 1/(1+z)$) yields the redshift drift rate $\dot{z} \equiv dz/dt_0$:

$$\dot{z} \;=\; H_0(1+z) \;-\; H(z) \tag{A2}$$

where $H_0 \equiv H(t_0)$ is the Hubble constant today and $H(z) \equiv H(t_e)$ is the Hubble parameter at redshift z.

The accumulated change in redshift over an observer time interval Δt_0 is, to first order,

$$\Delta z \;\approx\; \dot{z}\,\Delta t_0 \tag{A3}$$

so longer the Δt_0, there will be a larger change in the redshift of the objects. One should note that the $\dot{z}$ is function of redshift and the expansion rate of the universe.

For a simple numerical estimates below, we adopt a fiducial flat ΛCDM cosmology with $H_0 = 70\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$, and consider a galaxy at redshift $z = 1$. In a flat ΛCDM cosmology,

$$H(z) \;=\; H_0\sqrt{\Omega_m(1+z)^3 + \Omega_\Lambda}\,, \tag{A4}$$

with the usual density parameters Ω_m and Ω_Λ. The Hubble parameter at $z = 1$ evaluates to

$$H(z=1) \approx\; 123.25\ \mathrm{km\,s^{-1}\,Mpc^{-1}}.$$

Hence the redshift drift rate is

$$\dot{z} \;=\; 70 \times (1+1) - 123.2477 \;\approx\; 16.7523\ \mathrm{km\,s^{-1}\,Mpc^{-1}}.$$

Converting units ($1\ \mathrm{km\,s^{-1}\,Mpc^{-1}} \;\approx\; 3.24078 \times 10^{-20}\ \mathrm{s^{-1}}$) gives $\dot{z} \;\approx\; 5.42905 \times 10^{-19}\ \mathrm{s^{-1}}$.

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Table A1 lists the accumulated redshift change $\Delta z = \dot{z}\,\Delta t_0$ for a set of observer time intervals Δt_0. Times are given in years; the conversion used is 1 yr $= 3.15576 \times 10^7$ s.

Table A1. Accumulated redshift change Δz for a galaxy at $z = 1$ in the fiducial cosmology.

Observer Time Interval Δt_0	**Δz**
10 years	1.7133×10^{-10}
100 years	1.7133×10^{-9}
1000 years	1.7133×10^{-8}
100,000 years	1.7133×10^{-6}
2.5 million years	4.2832×10^{-5}

The corresponding redshift changes are extremely small on human timescales. For example, over 10–30 years the accumulated drift is of order $\Delta z \sim 10^{-10}$–10^{-9}, which is far below the current practical limits of spectrographic redshift measurements for galaxies or quasars, where typical uncertainties are at the level of $\Delta z \sim 10^{-6}$–10^{-7} due to faintness of the sources and broadening of spectral lines [47]. Over millions of years, however, the cumulative redshift drift grows to $\Delta z \sim 10^{-5}$, which would be trivially detectable in principle. One can, in principle, perform quantitative forecast analyses to constrain cosmological quantities and key parameters using such a Gift. A detailed exploration of this is beyond the scope of the present perspective paper and is left for future work.

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