

# Comet 3I/Atlas and Our Links with the Wider Cosmos

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## Abstract

Comet 3I/Atlas shows all the signs of being a comet escaping from a distant planetary system, probably from above the disc of the galaxy, and traversing through the inner solar system. The emitted dust coma and tail could carry genetic material that may possibly soft-land through the terrestrial atmosphere and thus potentially contribute to the evolution of life on Earth and thence in the wider planetary system.

## Keywords

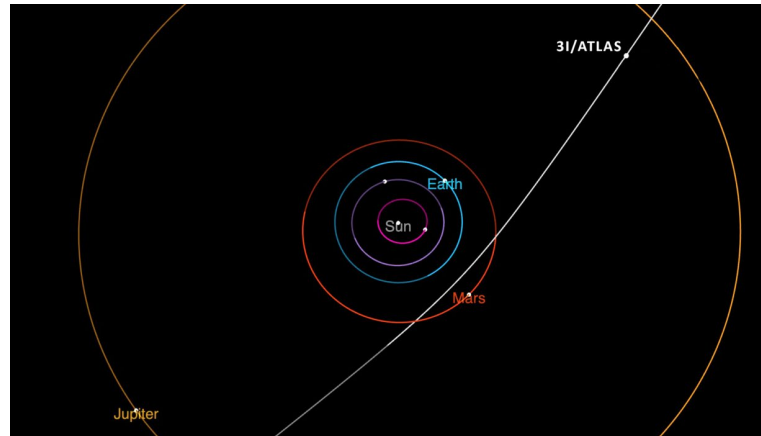
Comets, Hyperbolic Comets, Panspermia, Evolution

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## 1. Introduction

The NASA-supported telescopes in Chile, first reported observations of a new comet 3I/ATLAS on July 1, 2025 and this discovery has since been amply confirmed [1]. The comet was in a hyperbolic orbit (Figure 1 and Figure 2), implying that it reached our solar system from an exoplanetary system around a distant star and is now heading back at a speed of 57 km/s [1] into interstellar space. With its developing dust coma and dust tail photographed by the Hubble telescope in August 2025 it will eventually travel out into interstellar space, subject to perturbing forces from planets and the asteroid belt. A fraction of the dust debris it leaves behind—perhaps including biological material—collides with interplanetary dust so may be captured into our planetary system, where the Poynting-Robertson radiative effect will cause it to spiral inwards to the Sun. This comet estimated to measure about 20 km across, streaking in from the depths of interstellar space and shedding dust particles that the Earth's atmosphere might pick up, is a reminder

of our inexorable connection to the vast external Universe.



**Figure 1.** Orbit of Comet 3I/ATLAS (Courtesy NASA).



**Figure 2.** Hubble Telescope image of Comet 3I/ATLAS showing a coma and a developing tail—August 2025 (Courtesy NASA).

Comet 3I/ATLAS is, however, not the first interstellar comet that has so far been observed. Over the past decade astronomers have discovered a few similar comets traversing through our solar system in hyperbolic orbits. One such comet was named *Ouamumua* and another *2I/Borisov*, both of which were discovered in the past decade [2].

## 2. Comets and Their Origin

Interstellar hyperbolic comets still remain relatively rare compared with the much wider class of short-period comets that are gravitationally bound to our planetary system, and which are occasionally perturbed into orbits that take them to the inner regions of the planetary region. The current view is that a few hundred billion such comets surround our solar system forming what is called the “Oort cloud

of comets” at a distance of 2000 to 100,000 times the Earth’s mean distance from the sun (1 AU). About a billion of these comets are considered to be larger than 20 km in diameter, and within such objects radioactivity from Al-26 and Fe-60 could have melted the interior in the first few Myr of the history of our planetary system.

Comets and icy planetesimals in the Oort Cloud are considered to be the first solid bodies that condensed in the parent cloud from which the planets were formed. Each of the larger comets amongst these possesses radioactively heated interiors where microbial life can flourish, and provide the seeds of life in the cosmos [3]. Occasionally comets from this Oort Cloud (beyond the orbits of Neptune and Jupiter) can plunge into the inner regions of the planetary system. Some of these comets end up as the class of short-period comets—Halley’s comet being one of hundreds of such period comets. Comets collide directly with the Earth only very rarely, but cometary material (including bacterial dust in our view) expelled from the tails of comets enters our planet on a regular basis. By sampling stratospheric material at a height of 41 km we have estimated an in-fall rate to Earth amounting to hundreds of tonnes of biological material per day [3].

### 3. Exoplanetary Systems and Comets

Detections of exoplanets—planets orbiting distant stars outside our own solar system—have proceeded apace since the launch of NASA’s Kepler satellite in 2009 [4]. To date Kepler has detected a total of nearly 6000 exoplanetary systems. It would be reasonable to posit that a fraction of these systems may have a genesis and history similar to our solar system so that associated cometary clouds would be the rule rather than the exception. Consequently, a finite rate of escape of comets from such systems would be expected, so that comets like Boris, Ouamumua and the recent comet Atlas may all be considered escapees from such alien planetary systems.

We can argue that our own planetary system gathered its initial complement of dust mainly via comets visiting our early protoplanetary nebula [5] [6]. Dust grains of that nebula would sputter surfaces of visitors like Comet Atlas, which pass through at high speeds ~20 - 30 km/s. The sputtered material would be in part accreted into the primitive solar nebula and thence into comets and planets, the Earth, Mars etc. On the assumption that cometary dust grains are carriers of biological material the early Earth would thereby have gained blended genetic material from the variety of comets that would have been around in that early epoch [6]. Since the start of life on Earth, we would have received a trickle of material carried by comets in hyperbolic orbits like Atlas, but much more material from the periodic comets whose emitted dust cannot escape the Sun’s gravity.

In the 20<sup>th</sup> century, it was thought that the Oort Cloud of comets in the solar system were the source of both escapee and periodic comets which feed cometary debris into the planetary area. Over the last decade, theoretical modelling has shown that the major planets cause greater dynamical activity in the nearby inner

Cloud (Edgeworth-Kuiper belt plus a scattered cometary cloud) and thus in creating escapees. Gravitational sling-shots can thus pass on a comet from one planet's influence to another. Jupiter, Saturn and Neptune may boost the speed of such comets closer to the solar system's escape speeds, but they still would mostly remain in the inner Cloud. Sling-shot interactions with the major planets can further boost speeds well above escape speed, thus causing the release of large numbers of comets into interstellar space.

In this scenario, escapee comets will carry both their initial interior content of deep-frozen microbes as well as the dust debris that impacted them during their excursion into the inner planetary region. That debris would necessarily include asteroid fragments and, more significantly, the ejecta from asteroid/comet impacts on Mars and Earth. (It is worth noting in this context that the Chixculub impact ~60 Myr ago was big enough to blast off soil and rock fragments into planetary space). Bearing in mind such processes it would be reasonable to conclude that our class of escapee comets would carry "modern" genetic material as well as that of their frozen-interiors to mingle with interstellar comets from other systems, gradually mixing biotic material on a galactic scale.

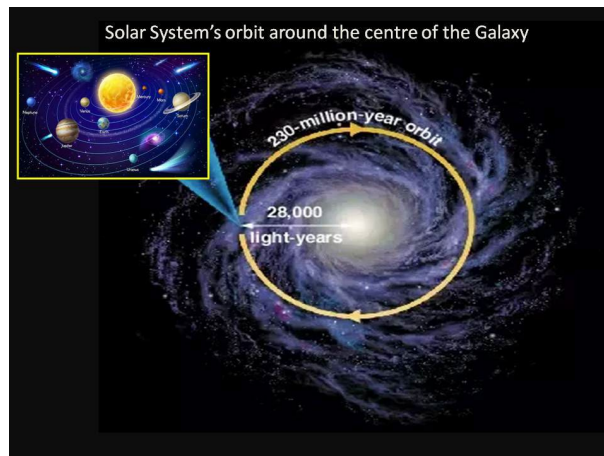
#### 4. Site of Origin of Comet 3I/Atlas

In a recent paper Hopkins *et al.* [7] have made a case for the origin of Comet 3I/Atlas being from a planetary system that is located significantly above the mid-plane of the Galaxy. Studying its chemistry and dynamics could thus add to our understanding of how the processes of planetesimal formation and evolution take place across the disk of the Milky Way. Hopkins *et al.* [7] present a preliminary assessment of Comet Atlas 3I in the context of what they describe as the "Ōtautahi-Oxford model" together with models of protoplanetary disk chemistry and Galactic dynamics. The claim is their model shows that both the velocity and radiant of Comet 3I Atlas are within their predicted range for an interstellar comet. Its velocity is furthermore inferred to predict a cometary age of over 7.6 Gyr and also a high mass fraction of water, which they argue may become observable in due course. They also conclude that it is very unlikely that Comet Atlas 3I shares an origin with either of the previous two interstellar comet detections – Comets Boris and Uamua.

Comets originating in the plane of our galaxy have ages comparable to the Solar System's 4.5 billion-year lifespan, whereas comets originating above the galactic plane could be much older. Hopkins *et al.* [7] have argued that the newly detected comet formed in the Milky Way's "thick disc", a region of ancient stars that account for an estimated 10 per cent of the total stellar mass of the Galaxy. In such a case the biological endowment carried by this comet could be ancient, novel and certainly distinct from the cometary material that is normally transported to Earth and inner planets from the Oort Cloud. The latter would of course be derived from home-grown cometary bodies on a continuing and regular basis.

## 5. Horizontal Gene Transfer on a Galactic Scale

In 2004 two of the present authors [8] proposed that although genetic information carried by comets in our own solar system are the main contributors to the origin and evolution of life on our planet, there would also be the products of local evolution on a planet that could be transferred across galactic distances.



**Figure 3.** Schematic path of the solar system around the centre of the Galaxy. The Sun's revolution around the centre of the Galaxy every 240 million years brings it within reach of molecular clouds on the average once every 35 - 40 million years.

The present-day solar system with its extended halo of ~100 billion comets moves around the centre of the galaxy with a period of ~240 My (**Figure 3**). Every 40 million years, on the average, this comet cloud becomes perturbed due to the close passage to an interstellar molecular cloud (e.g. the Orion Nebula). The resulting gravitational interaction then leads to hundreds of comets from the Oort Cloud being injected into the inner regions of our planetary system, some to eventually collide with the Earth. Such collisions can not only cause extinctions of species (as one impact did some 65 million years ago, killing the dinosaurs), but they could also result in the expulsion of surface material from the Earth back into interstellar space. A fraction of the Earth-debris so expelled would inevitably survive shock-heating and could be laden with viable microbial ecologies of all types as well as genes and viruses of evolved life from our solar system that would be widely distributed on a galactic scale. As a consequence, life-bearing material could reach newly-forming planetary systems in the passing molecular cloud within a few hundred million years of the ejection event.

According to such a picture any new planetary system then comes to be infected with terrestrial microbes - terrestrial genes that can contribute, *via* horizontal gene transfer, to an ongoing process of local biological evolution. If every life-bearing planet thus transfers genes (bacteria, viruses, somatic cells and in rare instances deep frozen seeds) in this way to more than one other planetary system, life throughout the galaxy will become thoroughly mixed and so would essentially

constitute a single connected galactic biosphere. Whilst comets could supply a source of primitive life (bacteria, viruses and genes) to interstellar clouds and thence to new planetary systems and embryonic exoplanets, the genetic products of evolved life (local evolution) could also be disseminated on a galaxy-wide scale.

A mechanism can thus be identified for the genes of evolved Earth-life to be transferred to alien habitable exoplanets. A fraction of the Earth-debris so expelled survives shock-heating and could be laden with viable microbial ecologies as well as genes of evolved life. Such life-bearing material from the Earth could reach newly-forming planetary systems in the passing molecular cloud within a million years of the ejection event. A habitable exoplanet could then become infected with microorganisms from Earth as well as genes from terrestrially established life that can contribute to the process of local biological evolution in some distant location.

## 6. Spectroscopic Evidence for Cometary Biology

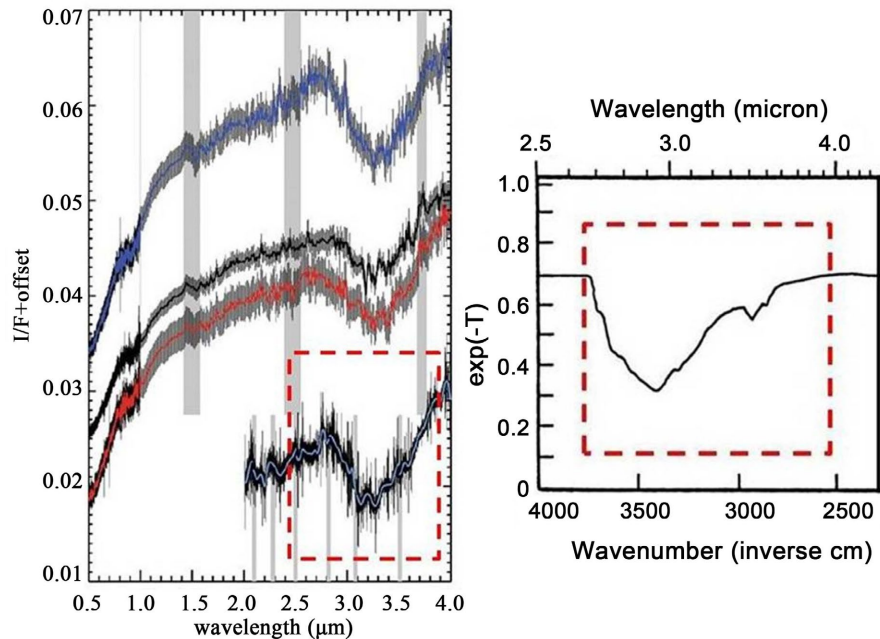
By the mid-1980's, a large body of spectroscopic evidence had accumulated to justify the claim that the chemical make-up of cosmic dust as well as cometary dust as was uncannily identifiable with that of terrestrial bacteria [5] [6] [9]-[11]. This body of data started with explorations of Halley's comet in 1986 [12] but continued with more detailed studies that included the space exploration of a range of other comets.

More recently the European Space Agency's Rosetta Mission to comet 67P/C-G that was launched in 2004 has provided the most detailed observations that satisfy all the consistency checks for biology and the theory of cometary panspermia [13]. **Figure 4** shows the close similarity between the surface properties of the comet 67P/C-G and the spectrum of a desiccated bacterial sample. All such correspondences with biological spectra, however, have tended to be dismissed by a majority of "main stream" astronomers who wish to maintain against all odds that life is a planetary phenomenon with *de novo* origination having occurred against insuperable odds on the primordial Earth, and possibly independently on exoplanets that have been recently found to have biochemical signatures.

The most recent attempt to degrade the importance of correspondences such as shown in **Figure 4** is in the interpretation of the recent detection of DMS (dimethyl sulphide) on the comet 67P/C-G [14] [15]. Previously the detection by Madhusudhan *et al.* [16] of this molecule in an exoplanet was considered a biomarker, because on the Earth this molecule appears to be only produced through biology. When it was found that a spectral signature of dimethyl sulfide DMS was present in the spectra of comet 67P/C-G the tables appear to have turned radically. Because comets were written off by the astronomical establishment as "dead" or "lifeless" the whole story of such molecules being biomarkers has also come to be revised [15].

If due account is taken of all the relevant available evidence, the new results on the presence of DMS in the comet further support the existence of cometary life. Nor does the finding by the Rosetta team in any way challenge the DMS molecule's

usefulness as a biosignature more generally in the wider universe. It merely confirms it, and more generally reaffirms that life is unequivocally a cosmic phenomenon as had been maintained by Fred Hoyle, Chandra Wickramasinghe and their many collaborators from the early 1980's to the present day.



**Figure 4.** The surface reflectivity spectra of comet 67P/C-G (left panel) compared with the transmittance curve measured in the laboratory for *E. coli* (right panel) (ref.13).

## 7. Transfer of Microbiota from Comets to Other Planets

A further implication of the theory of cometary panspermia is that microbial life must be transferred beyond Earth to other planetary bodies in the solar system. Mars, Venus, and the Jovian moon Europa are a sample of the places that are by no means written off in regard to the possibility of microbial life. On the contrary they are most likely to be sites in the solar system to which cometary biology would have been transferred, but whether life could have taken root and evolved in these planets still remains unresolved.

On the scheme we have discussed every new planetary system that forms and evolves in the galaxy must inevitably come to be infected with terrestrial microbes carrying terrestrial genes that can contribute, via horizontal gene transfer, to an ongoing process of local biological evolution. Once life has got started and evolved on an alien planet or planets of the new system the same process can be repeated (via comet collisions) transferring genetic material carrying local evolutionary 'experience' to other molecular clouds and other nascent planetary systems. If every life-bearing planet can transfer genes in this way to more than one other planetary system (say 1.1 on the average) with a characteristic time of 40 My then the number of seeded planets after 9 billion years (lifetime of the Galaxy) is  $(1.1)^{9000/40} \sim 2 \times 10^9$ . Such a vast number of "infected" planets illustrates that Darwinian evolu-

tion, involving horizontal gene transfers, must operate not only on the Earth or even within the confines of the solar system but on a truly galactic scale. Life throughout the galaxy on this picture would constitute one single connected biosphere.

A great deal of attention has been focussed nowadays on the planet Mars with attempts to find evidence of contemporary life, fossil life and potential life habitats on that planet. The Jovian moon Europa, the Venusian atmosphere, the outer planets and comets are also on the astrobiologist's agenda but possibly further down the time-line. The unambiguous discovery of life on any one of these solar system objects would be a major scientific breakthrough and would offer the first direct proof of the concept of an interconnected cosmic biosphere.

If comets, as we have argued in a long series of books and papers from 1980's [5] [6] [11], are indeed the carriers of bacteria, viruses and of all biological genetic material, we are now witnessing in the appearance of the new comet 3I-Atlas just another example of our solar system's potential to acquire a new compliment of comet dust that could include bacteria and genes from distant planetary systems. Whether or not such genes will eventually enter the Earth to contribute to the future evolution of terrestrial life is a question that remains unresolved at the present time.

## 8. Concluding Remarks

In conclusion, we note that although the presence of extraterrestrial microbiota on a cosmic scale is still being vigorously resisted, their undisputed presence in one cosmic location (e.g. Earth) must make it logically difficult to accept that a variety of processes (e.g. well-attested impact events) can lead to their dispersal into the wider galactic medium. Likewise, if the recent DMS discovery on an exoplanet is accepted as evidence of biology [15] [16], a similar argument for interstellar dispersal can be made, thus further supporting the case for the galaxy being legitimately regarded as a single connected biosphere (<https://ui.adsabs.harvard.edu/abs/2025AJ....170..257S/abstract>). Finally, the discovery of stratospheric microbes and the microbes on the surfaces of orbiting spacecraft all point in the same direction. A multiplicity of supportive arguments therefore exists to support the arguments for the validity of biology-based interpretation of the correspondences of infrared spectra of microorganisms and astronomical systems, as we showed in **Figure 4**.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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