Preface

A Call to Adventure!

If there is a defining trait of being human, then a need for adventure and a desire to know what lies beyond the horizon's sweeping arc must surely be it. We yearn for adventure, be it within the confines of a favorite book, our hometown, or on some distant exotic island or mountain range.

Adventure! It fills us with passion. It provides us with a reason for action, it builds character, it shakes our assumptions, and it warms us with a sense of achievement. Scottish philosopher and Victorian essayist Thomas Carlyle once defined history as being the distillation of rumor, but surely it could better be described as the collective sum of numerous adventures, the comingled expression of journeys made by mind, body, and soul.

Adventure, it has also been said, brings out the best in us. By gritting our teeth, we have triumphed over adversity, and we assimilate wisdom. Slightly more than 100 years ago now, just within the time span of living memory, such teeth-gritting mettle saw Roald Amundsen and his Norwegian compatriots first set foot on Earth's South Pole (it contemporaneously saw the glorious death of Robert Falcon Scott and his companions). It was the same grit and determination that saw New Zealander Edmund Hillary and Nepalese Sherpa Norgay Tenzing scale the snow-clad summit of Mount Everest, the top of the world, for the very first time in 1953. It was to be only 7 years after that first great ascent before the deepest depths of Earth's oceans, the Mariana Trench, were first plumbed by Don Walsh and Jacques Piccard aboard the bathyscaphe *Trieste*.[1] Above, below, and all around – humans have literally experienced, perhaps only briefly in many circumstances, all of the topology that Earth has to offer.

Historically, high adventure has been confined to Earth and its atmosphere. This all changed, of course, not quite 50 years ago with the initiation of the American Apollo space program, which ultimately saw Neil Armstrong and Buzz Aldrin first walk upon the Moon's surface on July 21, 1969. Human beings, however, have gone no further into space than the Moon. Only robots and spacecraft (proxy human bodies made of aluminum and plastic) have continued the pioneering exploration of the planets and the deep probing of the Solar System. And yet, for all of humanity's technological skills, no spacecraft has to date reached interstellar space.[2] *Voyager 1*, the current long-distance record holder launched in 1977, is now some 18.5 billion kilometers away from the Sun, but this is a minuscule step compared to the 7.4 trillion kilometers outer radius of the Oort Cloud boundary – the zone that gravitationally separates out the Solar System, our current stomping ground, from the rest of the galaxy.

Ever hungry for adventure and raging against the yawning abyss of interstellar space, humanity has long dreamed of traveling to the stars. There may be no reasonable way of achieving such adventure in the present day or even in foreseeable decades, but the journey will assuredly begin one day; we are made of stardust, and to the stars we shall eventually make our way. But where to first? The galaxy is unimaginably large and the potential pathways innumerable. Surely, however, the first steps to the stars will be

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[1] Remarkably, as of this writing, four times more people have walked on the surface of the Moon (12 in total – a.k.a. *The Dusty Dozen*) than have seen the ocean floor of the Mariana Trench in situ (3 in total). And although the Apollo program lasted less than 10 years, the human exploration of the deepest abyssal plain has already occupied more than half a century of adventure. The 1960 descent of the bathyscape *Trieste* was the first dive to carry a human cargo to the abyssal depths of the Challenger Deep, and then, 52 years later – on March 6, 2012 – film director and National Geographic explorer James Cameron, ensconced in the *Deepsea Challenger* submersible, descended the depths to once more cast human eyes over the floor of the Mariana Trench.

[2] I am using here the gravitational boundary, rather than the edge of the heliosphere, where the solar wind pushes up against the interstellar medium. In spite of what you may have otherwise read in press releases, the *Voyager 1* spacecraft is still very much inside of our Solar System.

via our nearest stellar neighbors, and in this case α Centauri offers up a bright and welcoming beacon.

Why α Centauri Beckons

Fortuitously close by galactic standards, α Centauri is not so remote that all hope falters at the thought of one day exploring its new-worldly domain. Not only this, but there is much about α Centauri that will be familiar to future travelers – even to our own eyes if we could be somehow transported there this very instant. Firstly, it would appear to our visual senses that we had not moved at all, for indeed, the very night sky constellations would be the same. Remarkably, as we ultimately explore α Centauri and even the solar neighborhood beyond it, the ancient zodiacal configurations will both follow us and anchor us to the deep past, and they will continue to remind us from where the journey first began. Indeed, the memory of our natal domicile will be written bright upon the sky as the Sun, as seen from α Centauri, will become a new star in the constellation of Cassiopeia.[3]

Certainly, once having arrived at α Centauri, the presence of two progenitrix stars would be odd to our sense of heritage, but these two stars up close are barely different from our familiar Sun. Indeed, they illustrate what the Sun could so easily have been, and they bookend with respect to their physical characteristics what the Sun will become in about a billion years from now.[4]

An instantaneous trip to α Centauri today would not only whisk us through a great cavern of space, it would also transport us something like 10,000 centuries into the Sun's future. Remarkably, therefore, the present-day study of α Cen A and B helps us understand the deep-time and innermost workings of our Sun. Not only this, as we shall see later on in the text, the fate and demise of life in our Solar System will be mirrored at almost the very same epoch three to four billion years hence by any life forms that

[3] Not only will the Sun appear as a new star in Cassiopeia, it will also be the brightest star in that constellation, far outshining Schedar (α Cassiopeia), the erstwhile brightest member as seen from Earth.

[4] It is estimated, as will be seen later, that the α Centauri system formed about six billion years ago.

might have evolved in habitable niches within the α Cen AB system. The possible worlds of α Centauri will certainly be different from those familiar to us in the Solar System, and yet they share a common future. It is an astounding testament to human ingenuity and human intellectual adventure that we can see such connections and describe them with some fair degree of confidence.

For all of its familiarity, however, there is more to the story of α Centauri than its galactic closeness at the present epoch – indeed, it is a rare closeness, and we are fortunate that it is so near at the very time that humanity can realistically envisage the launch of the very first interstellar spacecraft. Look into any modern astronomy textbook, and one of the most remarkable facts that you will discover is that our Milky Way Galaxy contains at least 200 billion stars. The Sun is far from being a lonely wonderer in space. For all its great multitude of companions, however, the Sun's existence is by and large a solitary one. Only rarely do individual stars pass close by each other, and at the present time the nearest star system, the α Centauri system, is about 28 million solar diameters away. Indeed, for stars in general there is a lot of wiggle room before any really close interactions between distinct pairs takes place. The distance between the Sun and α Centauri is still decreasing, but the two will never approach to a margin at which any distinct gravitational interaction will take place. They are indeed the astronomical equivalent of Longfellow's two passing ships in the night. But these passing ships have formed a special bond cemented by human awareness; they sail in consort, and for a brief, lingering, galactic moment they offer humanity the chance of stellar adventure and dramatic change. These passing ships afford future humans, our descendents, the incredible chance of not only finding unity in cause but of becoming cosmic voyagers – new sailors, perhaps even ambassadors, plying the interstellar sea.

Perhaps surprisingly for all of the galactic nearness of α Centauri to the Sun, there is much that we do not know or understand about its component stars; there are indeed deep and fundamental questions (thought adventures) that astronomers have yet to answer. Even at the most fundamental level, it is not presently clear if the α Centauri system is composed of two gravitationally bound stars or three. As we shall see in the main body of the text, it has long been known that the bright naked-eye α Centauri star is actually a binary system composed of two Sunlike analogs: α Cen A and α Cen B. So much is beyond doubt. What is presently unclear, however, is whether Proxima Centauri, the actual closest star to the Sun at the present epoch, forms a gravitationally bound triple system with α Centauri AB – technically, therefore, making Proxima ≡ α Cen C. Remarkably, it is not even clear at the present time whether the standard Newtonian theory of gravity, the great stalwart underpinning of astronomical dynamics, even applies to stellar systems such as α Cen AB and Proxima. This is one of the deeper modern-day mysteries that this book will explore in later pages.

Proxima Hiding in the Shadows

Proxima, again, for all of its adjacency to the Sun, is far from being an obvious star. It cannot in fact be seen by the unaided human eye, and indeed a relatively large-aperture telescope is required to reveal its meager light. It is because of this low intrinsic brightness that Proxima's very existence and nearest stellar neighbor status was only established in the early twentieth century. Remarkably, as will be seen, Proxima as a red dwarf star belongs to the most populous class of stellar objects within our Milky Way Galaxy; for every Sunlike star in the galaxy, there are eight to ten Proxima-like stars. And yet, the unaided human eye can see not one such representative of this vast indigenous population. Adventure, exploration, and discovery not only open our collective eyes to the greater Universe, they also take us beyond our direct human senses, enabling us to *see* those places where likely only the mind will ever go.

As we encounter the centennial of Proxima's discovery, it seems only appropriate to consider how our understanding of the α Centauri system has changed and how astronomical knowledge has evolved during the past 100 years. Indeed, since the discovery of Proxima our appreciation of the stars and planets and the greater cosmos has changed almost beyond recognition. When Proxima was first identified in 1915, Einstein's general theory of relativity, one of the great cornerstones of modern physics, was still a year away from publication. The Bohr model, the first quantum mechanical description for the workings of the atom, was barely 2 years old. Hubble's law and the discovery of the expanding universe were still 15 years in the future. The first public TV broadcast was likewise 15 years distant, and the radio signal bubble centered on Earth was barely 10 light-years across. Indeed, the feeble radio waves representing the very first public broadcast transmitted from the Metropolitan Opera House in New York on January 13, 1910, had only swept past α Centauri the year before Proxima was first identified. Today, over 100 years later, Earth's radio bubble encompasses a volume containing well over a thousand stars.

The α Centauri system became the Sun's closest stellar neighbor about 50,000 years ago. Since that time, it has watched over the rise of human history and the development of civilization as we know it; Proxima in turn, since its discovery, has overseen the incredible advancements in the technologies that define our modern computer-driven and hyperlinked society. The stars of α Centauri will remain our closest stellar companions for another 72,000 years, and we may but dream what continued changes will take place on Earth during this extended period of time. But for all this, as α Centauri drifts ever further away from the Sun, dropping below the threshold of naked-eye visibility in about one million years from the present, its story is far from over – as will be seen in the main text. Indeed, the story of Proxima will be played out within the confines of our evolving galaxy over the next many trillions of years, by which time the Sun and α Centauri A and B will have long cooled off to degenerate black dwarfs. Who knows where humanity might be such colossal timescales hence? What is certain, however, is that we will have changed beyond all present-day recognition and cognition, but then, not just ourselves, the entire observable universe will be very different when Proxima Centauri dies.

Some Notes on Units and Nomenclature

Astronomy texts and astronomers are notoriously bad at mixing their units, a result mostly due to a long history and the sheer scale of the subject. In general, the units to be used in this text will be those of the System International, with distances expressed in meters and masses expressed in kilograms. Other units, however, will be used when planetary and stellar distances are being considered.

It is often said that unit changes are done in order to avoid writing down large numbers, but this of course is just psychological camouflage; the numbers, no matter what the units, measure the same thing. For all this, however, we shall encounter the astronomical unit, the parsec, and the light-year. The first two of these new units follow naturally from the size of Earth's orbit about the Sun (corresponding to 1 astronomical unit, or au) and the distance to a star for which the half-annual parallax is 1 arc sec (corresponding to 1 parsec, or pc). The third distance is derived from the constancy of the speed of light 2.99792×10^8 m/s and the number of seconds in an average Gregorian year, with 1 light-year = 0.3066 pc = 63,239.8 au = 9.4605×10^{15} m. Angles will normally be expressed in degrees or in the subunits of arc minutes (1/60th of a degree) and arc seconds (1/60th of an arc minute). On occasion, the unit of milliarc seconds (mas) will appear, with 1 mas = 1/1,000th of an arc second. On a very few occasions, the angular unit of radians will be introduced, with 2π radians = 360°.

Units for stellar mass, luminosity, and radius will typically be expressed in solar units, with 1 $M_\odot = 1.9891 \times 10^{30}$ kg, 1 $L_\odot$ = 3.85×10 26 W, and 1 $R_\odot = 6.96265 \times 10^8$ m. The Sun unit will be explicitly implied through the use of the symbol $\odot$. Temperatures will be expressed in Kelvin, with the zero Kelvin mark corresponding to the absolute zero point of temperature. The convention, for various historical reasons, is also to write just Kelvin rather than degrees Kelvin. In terms of the more familiar everyday temperature scales, 0 K = –273.15 °C = –459.67 °F.

Several methods will be used to identify individual stars within the text. In some cases, a star has a historical name such as Sirius (derived from the Greek word for "scorching"), which is the brightest star (next to the Sun, of course) observable to the unaided human eye at the present epoch. Sirius is also the brightest star in the constellation of Canis Major (The Great Dog), and its Bayer identification[5] is accordingly α Canis Majoris. Murzim, the second brightest star in Canis Major, is identified as β Canis Majoris and so on through the Greek alphabet for the remaining principle stars in the constellation. Stars can also be identified through their various catalog numbers, and accordingly Sirius in the Henry Draper catalog of stars is identified as HD 48915. In the Hipparchos data catalog, Sirius is identified as HIP 32349. Most of the time, this extended range of celestial monikers – Sirius has at least 58 aliases – is not something for us to worry about, but it is worth being aware of the fact that different names and identification numbers do exist for essentially all cataloged stars.

The identification scheme for stars within a binary system is mostly self-evident, and we have already used it above, but for completeness the two components in a double star system are labeled A and B, with the A label being applied to the more luminous component. Sirius, once again for example, is actually a binary system, and the star that we see with our eyes should technically (at least in the modern era) be called Sirius A. Its small, low-luminosity white dwarf companion, Sirius B, is only observable in a relatively large-aperture telescope, and it was not actually observed until 1862, when Alvin Clark first tested his newly constructed telescope incorporating an 18-in. (0.457 m) objective lens. Sirius A, of course, was observed and known about since before recorded history. It is sometimes convenient to explicitly identify a star as being a binary system, and accordingly Sirius might be described as the system Sirius AB. Likewise, α Centauri can be described as α Centauri AB and more simply still as α Cen AB.

With the discovery by Michel Mayor and Didier Queloz in 1995 of the first exoplanet in orbit around the Sunlike star 51 Pegasi, astronomers needed a new nomenclature scheme to identify nonstellar components. Although there is as yet no officially sanctioned scheme, the most commonly used method identifies the various planets within a specific system with a lowercase letter starting with the letter b and then working systematically through the alphabet. The planet identification label starts with the letter b since technically according to the scheme, the parent

[5] German astronomer Johann Bayer introduced this scheme in his 1603 *Uranometrica* star atlas.

star corresponds to system subcomponent a. Astronomers, however, generally ignore this latter convention and drop the "a" label for the star. (Common usage and historical precedent will always triumph over any set of conventions whether officially sanctioned or not.)

So with this entire preamble in place, the planet discovered by Mayor and Queloz is identified as Pegasi b. Just to make life a little more complicated, planet 51 Pegasi b is sometimes unofficially referred to as Bellerophon after the mythological Greek hero who tamed the winged horse Pegasus. If a second planet were to be found to orbit 51 Peagasi = 51 Pegasi a, it would be identified as 51 Peagasi c.

The planet-labeling sequence is based upon the time of discovery rather than orbital distance from the parent star, and accordingly planet b need not, for example, be the innermost planet within a multiple-planet system. For planets within binary star systems, both the star component and the planet need to be specified. So, for example, if a planet were to be found in orbit about Sirius A = Sirius Aa, it would be identified as Sirius Ab = α Canis Majoris Ab. As we shall see later on, the first planet to be detected in the α Centauri AB system is in orbit around α Cen B = α Cen Ba, and accordingly it is identified as α Cen Bb.

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