A STAR'S COMPANIONS

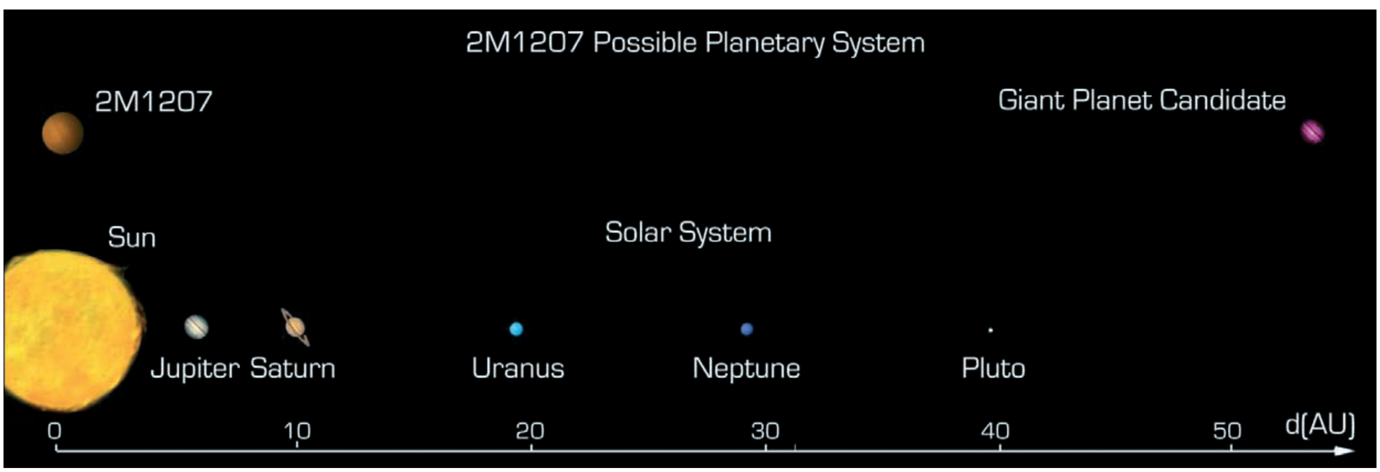
Extrasolar Planets

• Fr. Giuseppe KOCH s.j. •

Do you remember *The Little Prince* by Antoine de Saint-Exupéry? Let's imagine a trip like his to *Proxima Centauri*, the star closest to our sun. Looking back into the night sky in the direction from which we came, the Sun would appear to be just another tiny star. No one would ever expect that it could have planets around it, and that on one of those planets you would find intelligent life, and that it is home to us.

Likewise, we don't know if *Proxima* has a similar array of planets. The distances are too large. Until just a few years ago this seemed to present an insurmountable problem to the study planets outside our solar system (*extrasolar planets* or *exoplanets*). But astronomers are very inventive, and won't give up. With the development of various means of research, and the continual advance in precision of our instruments, the exoplanet hunters have finally realized their dream. In thirteen years, from the first discoveries in 1995 through the end of 2008, some 333 extrasolar planets have been found around some 260 different stars.

On October 6, 1995, in Florence not far from the Arcetri hillside home of Galileo (he of the "Medici Planets"), the astronomers Michel Mayor and Didier Queloz of the Observatory of Geneva announced to the Ninth Cambridge Workshop that they had discovered the presence of the planet *51Peg b*, the first known planet orbiting a star outside our Solar System. It orbits around a star very similar to the Sun, *51 Pegasi* (51 Peg), lying 48 light years away. The discovery was made thanks to an advanced technology spectrograph attached to the 1.93 meter telescope at the Observatory of *Haute Provence*.



Above *This figure, provided by the European Southern Observatory (ESO), compares our solar system with the system inferred to orbit about the Brown Dwarf star 2M1207. The sizes of the objects are drawn to the same scale, but the distances have been strongly compressed. From the infrared colors and the spectral data available, they conclude that this star is orbited by a 5 jupiter-mass planet, about 55 AU from 2M1207 (55 times more distant than the Earth is from the Sun). However, unlike a planet at such a large distance from our Sun, the surface temperature of this object appears to be about 10 times hotter than Jupiter, about 1000 °C. The explanation is that this very young planet is still contracting and releasing energy from its interior. (Jupiter itself, though much smaller and much older, is still releasing gravitational energy from its interior in this way, though not nearly as much.)*

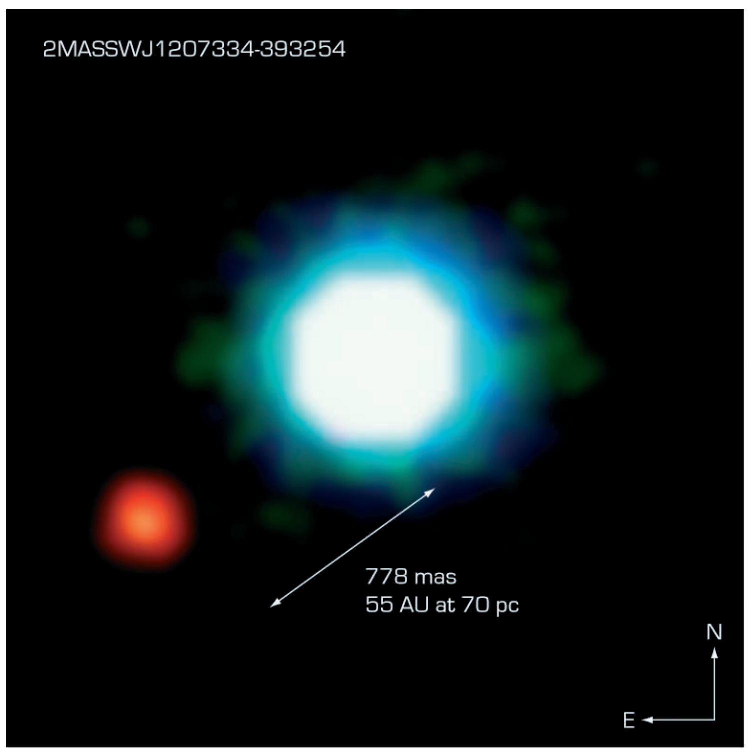
Following the announcement in Florence, other groups of researchers turned their instruments towards 51 Peg and soon confirmed this discovery. The first of these, after only a few days, were a pair of American astronomers, Geoffrey Marcy and Paul Butler, who observed at the Lick Observatory of the University of California at Santa Cruz, and who, like their Swiss colleagues, had been working for years to find extrasolar planets. These two teams and their colleagues have dominated the scene of exoplanets; in the decade since the announcement of *51Peg b* they have been responsible for the great majority of discoveries. The official IAU list of exoplanets as of February 2005 counted 127; only 16 were found between 1995 and 1999, and for the first ten years these discoveries occurred at a rate of roughly one per month. But 150 more have been found in the last three years. In the third week of June, 2008, researchers announced the discovery of nine new exoplanets, of which five were so-called "super-Earths," planets that may be terrestrial in nature with masses only a few times larger than Earth's. Seeing how the rate of discovery is accelerating, it won't be long before we find a true "twin" of our planet.

What can we say about 51 Peg and its companion 51 Peg b?

51 Peg is a 5.5th magnitude star, of a spectral type quite similar to the Sun, and therefore its color is yellow-white and it has roughly the same mass and luminosity as the Sun. It is located 48 light years from us (our Sun is eight light-minutes away from us, about 150 million kilometers). It is located in the sky near the western edge of the Great Square, which makes up the wing of the constellation Pegasus. According to Greek legend, Pegasus was the winged horse that was formed from the blood of Medusa when she was beheaded by Perseus. The constellation is easy to find in the northern sky, attached to a large square of stars situated on the opposite side of Polaris (the North Star) from the Ursa Major, the Big Dipper. It dominates the eastern sky in autumn.

51 Peg is a typical G-type star; but its companion, the planet 51 Peg b, was full of surprises for the astronomers. Its estimated mass is about half the mass of Jupiter (this is at minimum; because of the way the planet was discovered, a larger mass cannot be ruled out but it is probably half the mass of Jupiter). That makes it about 150 times more massive than the Earth. And it lies in a circular orbit around 51 Peg. But the period of that orbit is only 4.23 Earth days! That means it must be only about seven million kilometers from its mother star – eight times closer to it than Mercury is to our Sun. It was completely unexpected that a "giant" planet, comparable to Jupiter, would be found at a radius only 5% of the Sun-Earth distance, about a hundred times closer than Jupiter is to the Sun. The nearness of 51 Peg b to its mother star implies that it must have a surface temperature of around 1500 degrees. There is no possibility of life on a planet like that. We now call 51 Peg b and planets like it, "Hot Jupiters" or, more generally, Extrasolar Giant Planets (EGPs).

According to all the models for planetary system formation current at the time it was discovered, nobody had ever thought that one could find such a massive planet so close to its "sun." Ever since 51 Peg b came on the scene, theorists have been frantically busy revising their theories on the origin and evolution of stars and their planetary systems.



Right *This composite image of the brown dwarf object 2M1207 (center) and the fainter object seen near it, at an angular distance of 778 milliarcsec, was released by the European Southern Observatory (ESO) in 2006. It may represent the first image of an exoplanet, at least in infrared wavelengths. The photo is based on three near-infrared exposures (in the H, K and L′ wavebands) with the NACO adaptive-optics facility at the 8.2-m VLT Yepun telescope at the ESO Paranal Observatory.*

What do we know about the formation of stars and their planetary disks?

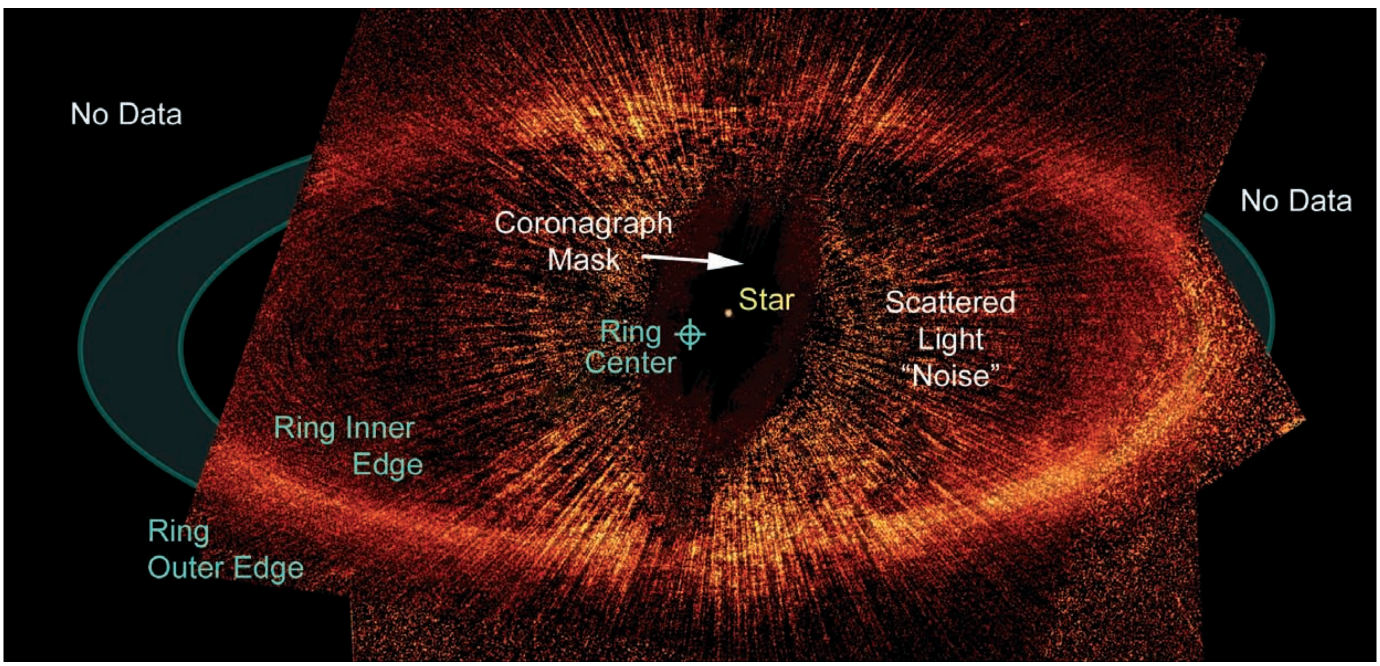
In the standard model of the formation and evolution of the universe according to the Big Bang paradigm, the formation of stars came in a sequence of phases as a part of the contraction due to gravity of extensive clouds of gas, present as atoms and molecules. In the case of "first generation" stars, this means exclusively hydrogen and helium. For stars of the second and successive generations, the clouds forming the star also contained micrograins of dust, formed of several million atoms, heavier elements left over as the residue of the previous generation of stars.

Once the protostar is formed, the cloud in the next phase is present as a somewhat flattened disk of rotating material: the so-called *protostellar nebula* (*solar nebula* refers to our planetary system).

It is generally accepted that such a circumstellar disk plays a fundamental role in the formation of stars and that planets are formed from within it. Before the discovery of 51 Peg b, the theories of such disks were based only on the unique data point of our own solar system.

The material at the center of the disk begins to condense into a star while a small part of the nebula gives rise to the planets, in the coldest and most distant parts of the system. In our solar system, the rocky planets – Mercury, Venus, Earth, and Mars – and the asteroid belt are situated relatively close to the central star; the gas giants are much further away from the Sun. Jupiter and Saturn are, respectively, five and ten times as far from the Sun as the Earth-Sun distance (an *astronomical unit*, or AU). In the case of our planetary system, analyzing the chemical composition of the Sun and the planets and comparing from one to the next the percentage of trace elements heavier than hydrogen and helium, you can ascertain that each "metallic" element is present with the same relative abundance. This is one clear indication that the star and the planets came out of the same nebula, the same "quarry" of original material.

Models of formation and evolution originally proposed for the solar



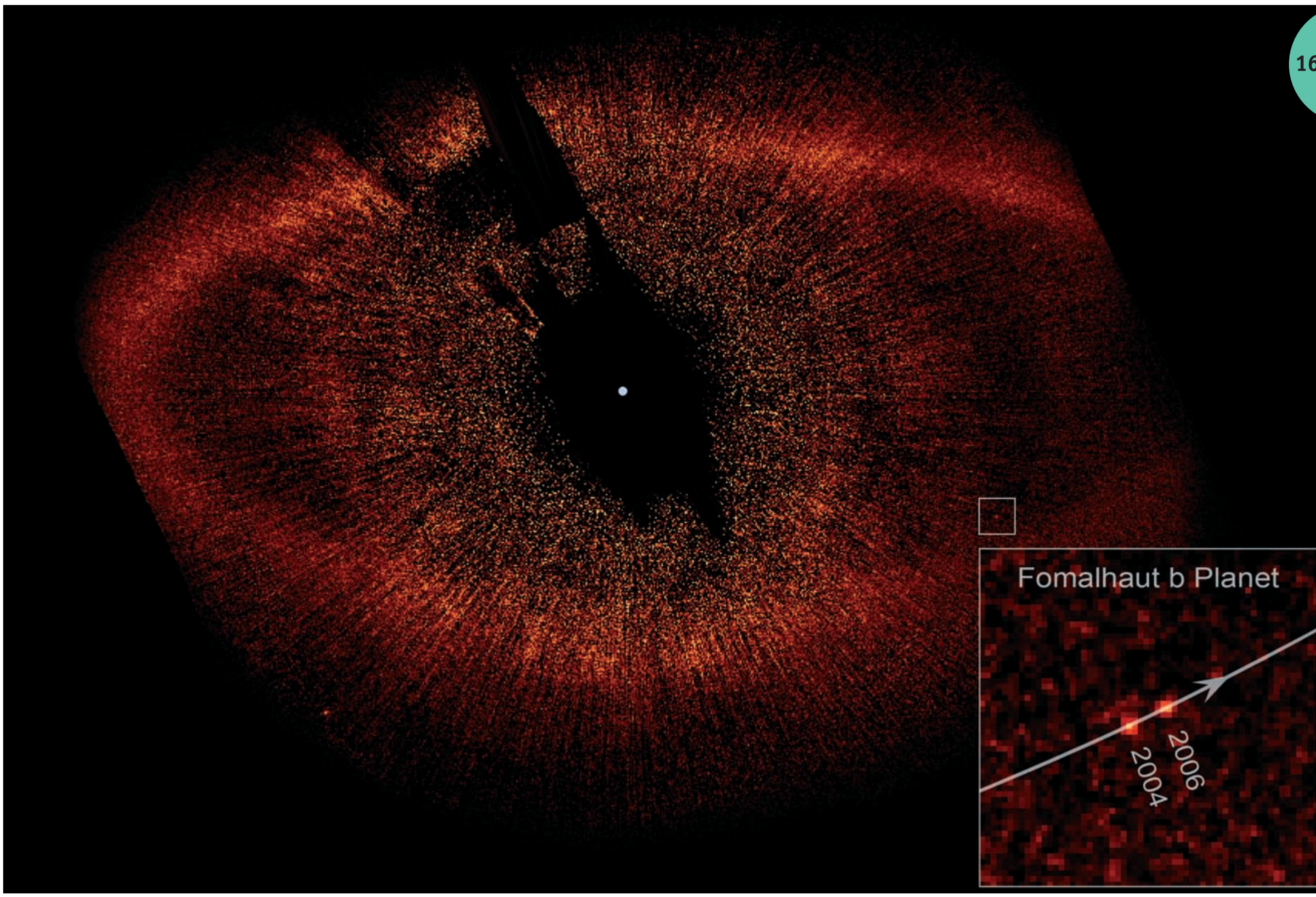
Above *The top view, taken by NASA's Hubble Space Telescope, shows a dust ring around the nearby, bright young star Fomalhaut. The center of the ring is about 15 AU away from the star. The dot near the ring's center marks the star's location. Astronomers predicted that a planet, at that time still unseen, moving in an elliptical orbit was reshaping the ring, orbiting some 50 to 70 astronomical units from the star.*
Credit: *NASA, ESA, P. Kalas and J. Graham (University of California, Berkeley), and M. Clampin (NASA's Goddard Space Flight Center).*

system ought to be able to provide an explanation for the observed properties of the new solar systems discovered around stars other than the Sun. The study of the formation and evolution of these systems range from computer simulations, to the observations of several tens of protoplanetary disks, which can be observed in our telescopes in various phases of their evolution. It is just as if you were to take examples of various children of various ages from different parts of the world and attempt to construct from them the growth of a human being from birth, through adolescence, and into adulthood. From this we learn that full development of the planets takes place over a period of tens to hundreds of millions of years.

New Systems of Planets

The discovery of the first exoplanet was rapidly followed by an overwhelming series of successive discoveries. It was not just an increase in the number of individual planets, but the rise of many different lines of research that followed, one after another.

In 1999 the first *system* of extrasolar planets was found to orbit about



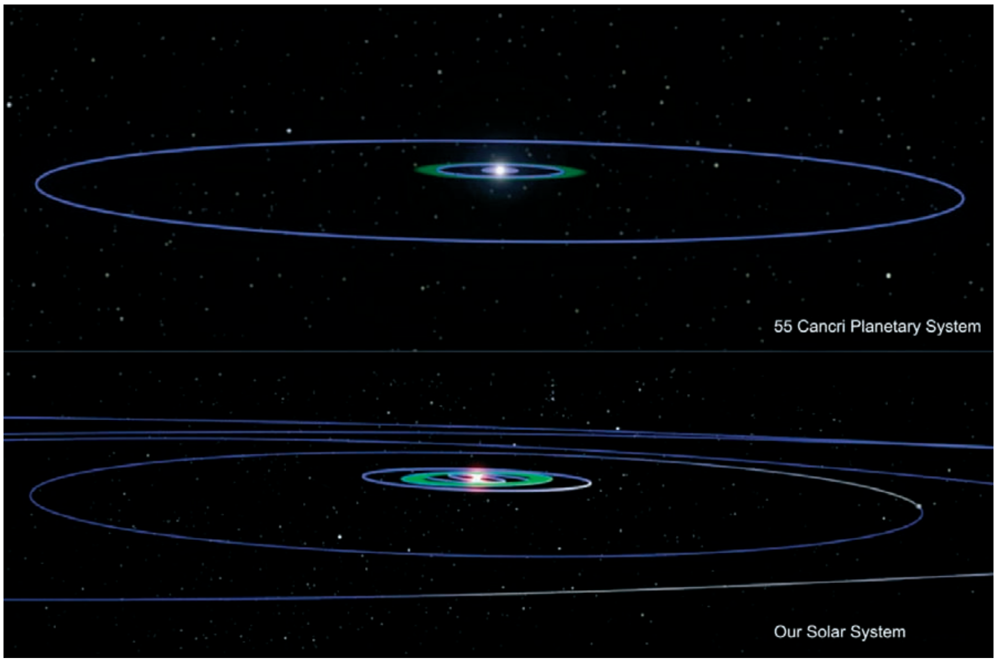
Above *This Hubble Space Telescope image shows the newly discovered planet, Fomalhaut b, (see the small white box at lower right) orbiting its parent star, Fomalhaut. The inset at bottom right is a composite image showing the planet's position during Hubble observations taken in 2004 and 2006. The white dot in the center of the image marks the star's location; the region here is black because a coronagraph was used to block out the star's bright glare so that the dim planet could be seen. Fomalhaut b is 1 billion times fainter than its star. The red dot at lower left is a background star. This planet is the one predicted by the offset ring seen on the opposite page.* Credit: *NASA, ESA, P. Kalas, J. Graham, E. Chiang, E. Kite (University of California, Berkeley), M. Clampin (NASA Goddard Space Flight Center), M. Fitzgerald (Lawrence Livermore National Laboratory), and K. Stapelfeldt and J. Krist (NASA Jet Propulsion Laboratory).*

the star Upsilon Andromeda (υ And): the first instance of several planets orbiting together around the same star. After the first companion of υ And was found in 1996, another two were discovered. With the case of υ And a new chapter in planetary science was opened: our planetary system was not alone. There was now at least one other "sun" accompanied by a family of planets, to be sure with somewhat elliptical orbits; this behavior means that the planets would be notably different in temperature during the path covered over an orbit, which is quite unlike the situation of the Sun's planets. Of the three planets of υ And, the intermediate one completes an orbit in 242 days, at a distance from the star comparable to that of Venus from the Sun. The orbit of the outermost planet is at a distance similar to that ranging from the Earth to the region of the asteroids, between Mars and Jupiter.

In 2002 a second extrasolar planetary system was discovered, when the second and third planets were found around the star 55 of the constellation Cancer (55 Cnc). This star is also a G type, with a mass and temperature close to that of the Sun. Up to now this continues to be the system with the largest number of planets – five of them. The fourth was announced in August 2004, with a period of only 2.8 days but, most interestingly, with a minimum mass comparable to that of Neptune, only 14 terrestrial masses. The period of these five planets (their "years") ranges from 2.8 days, to 14, 44, and 260 days, and finally to the maximum of 14.3 years. The planet with the longest period, 55 Cnc d, marked a new stage in exoplanet research because it was the first gas giant planet of the Jupiter type to be found at a distance from its star similar to that of Jupiter to the Sun.

On June 16, 2008, an ESO press release announced the discovering of three "super-Earths" around the star HD 40307; the smallest has a mass of only 4.2 terrestrial masses. Commenting on the news, the fruit of five years of labor, Michel Mayor – the previously mentioned discoverer of 51 Peg b – said, "It is clear that these planets are only the tip of the iceberg. The analysis of all the stars studied with our HARPS spectrograph at the 3.6 m telescope at the La Silla Observatory shows that about a third of the solar-type stars are accompanied by super-Earths or Neptune-type planets. It is very likely, then, that there are planets like the Earth that are as yet beyond the sensitivity of our instruments."

While up to a few years ago we were able to think that ours was the only planetary system, as of the end of 2008 the *Encyclopedia of Extrasolar Planets* listed 35 multiple systems comprising of 77 planets (about 25% of the known exoplanets). Besides the Cnc 55 system, there is another system of four planets, and four systems with three. And so we have at our disposal a rich laboratory for the study of the formation and evolution of planetary systems. We know now that these systems, with their hot giants very close to the mother star and with planets in or-



Above *A comparison of two planetary systems: 55 Cancri (top) and our own. Blue lines show the orbits of planets, including the dwarf planet Pluto in our solar system. The 55 Cancri system is currently the closest known analogue to our solar system. Both have similar stars, in mass and age. Both have planetary systems with giant planets in their outer regions. The giant located far away from 55 Cancri is four times the mass of our Jupiter, and completes one orbit every 14 years at a distance of five times that between Earth and the Sun. Both systems also contain inner planets that are less massive than their outer planets. But the planets known so far to orbit 55 Cancri are all larger than Earth, and orbit closer to their star than Earth is to the sun.*
Image credit: *NASA/JPL-Caltech.*

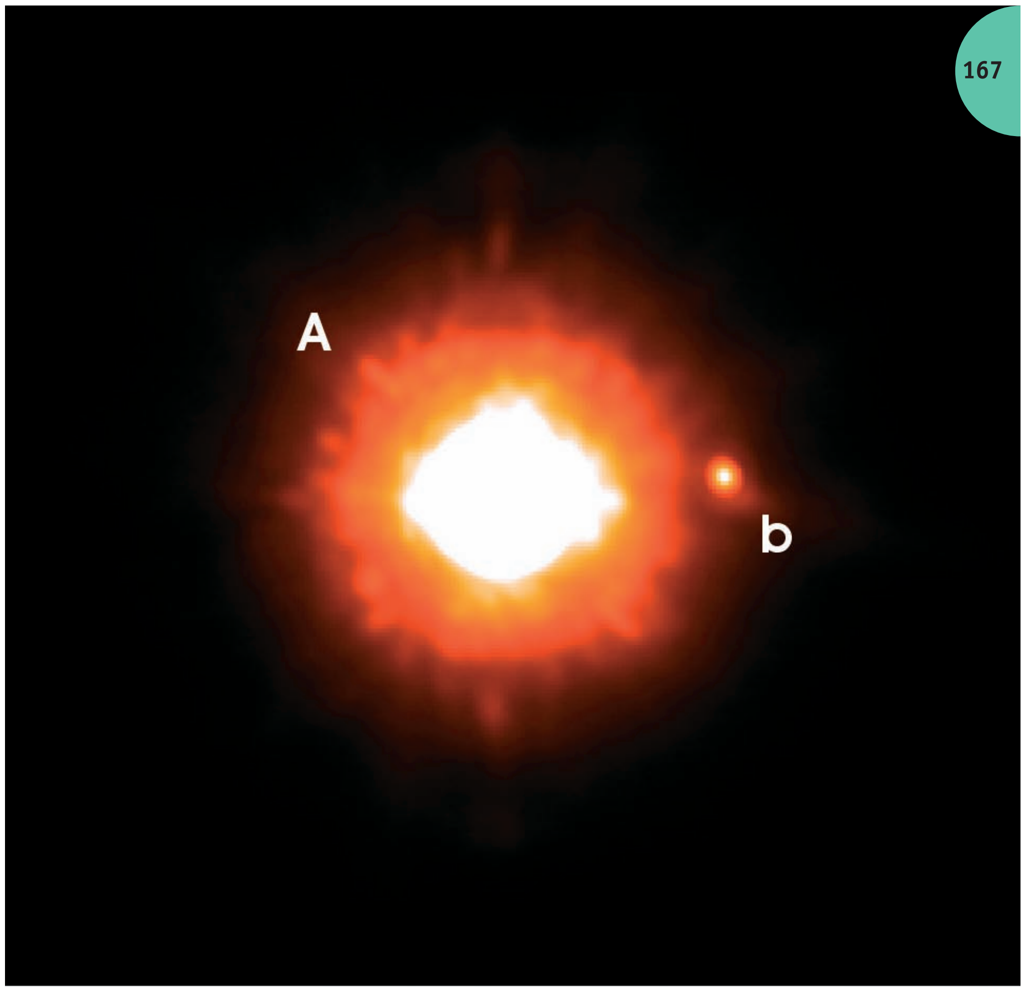
bits that are very elliptical and very inclined, can have a structure completely different from that of the Solar System. Current theories are being put to the test and now need to respond to new questions: how are the masses of the various planets distributed? Can they move from the inner to the outer parts of their system, or vice-versa? And are the planes of their orbits generally coplanar, as is the case in our Solar System? How did the Hot Jupiters get so close to their mother stars? Did they form at a greater distance away and then migrate there? The newly observed data give us new directions for elaborating new theories. A system like ours, with more or less circular orbits, may be the exception rather than the rule.

It is reasonable to think that any number of the gas giant planets would have their "moons" just like Jupiter and Saturn. And we emphasize that, just like the satellites around Jupiter and Saturn (for example, Titan, that object of the extraordinary Cassini-Huygens mission to Saturn, and Europa, the satellite of Jupiter) are the focus of current research looking to discover environments in our planetary system that could be compatible with the presence of life forms.

How do we define a planet now?

This question may appear naïve, and its answer obvious. A few years ago you could simply say, "A planet is one of the nine large bodies that do not shine by their own light and which orbit around the Sun." Today the situation has changed, and the question has sparked a considerable controversy. The introduction onto the scene of extrasolar planets has reopened the discussion as to what qualities should be the characteristics that allow a celestial body to be given the title of "planet."

In the General Assembly of the IAU at Prague in August, 2006 the majority of the assembled astronomers decided that Pluto, with a mass much smaller and an orbit far more elliptical and inclined than that of the other Solar planets, should be demoted from the classical list of planets in our Solar System and inserted into the new category of "dwarf planet": a celestial object in orbit about the Sun at a distance greater than Neptune with a mass that, while sufficient to pull it into a roughly spherical shape, is still not massive enough to clear out other bodies from the vicinity of its orbit and gravitationally dominate its region of space. This last characteristic is considered necessary for any a body to retain member-

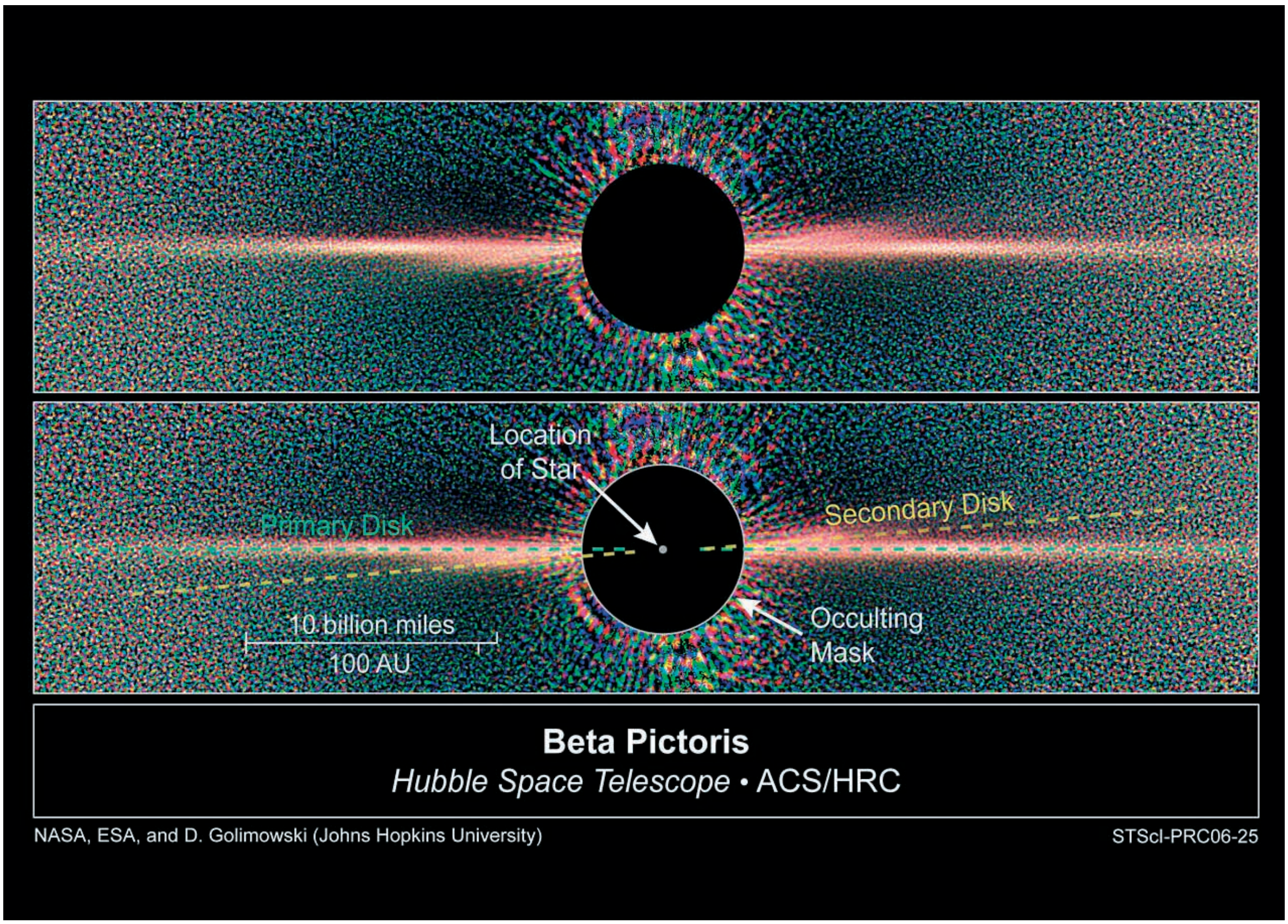


Above *This infrared image from the Very Large Telescope (VLT) at European Southern Observatory (ESO) in Chile shows a feeble point of light to the right of the star GQ Lupi; this is its cold planet. It is 250 times fainter than the star itself and orbits at a distance of roughly 100 astronomical units from its star.*

discoveries. (In June 2008, the executive committee of the IAU determined that any dwarf planet beyond Neptune, like Pluto, will be called a "plutoid" in its honor.)

For an exoplanet, the definition given by the appropriate IAU Working Group requires that it be a body which has a mass less than that which would allow the thermonuclear fusion of deuterium (such a mass is normally calculated as 13 Jupiter masses) in orbit about a star or a stellar remnant.

This definition of an extrasolar planet puts into play four particular extrasolar bodies which constitute a separate category with respect to the others. They are objects with a few terrestrial masses, three of them found to orbit around the pulsar PSR 1257+12. They were actually the first of the extrasolar planets to be discovered; the Polish astronomer Alexander Wolszczan detected their presence with the



Above *This Hubble Space Telescope view of Beta Pictoris shows a primary dust disk and a much fainter secondary dust disk, circumstantial evidence for the existence of a planet in a similarly inclined orbit. Astronomers used the Advanced Camera's coronagraph to block out the light from the bright star (the black circle in the center of the image).*
Credit: *NASA, ESA, D. Golimowski (Johns Hopkins University), D. Ardila (IPAC), J. Krist (JPL), M. Clampin (GSFC), H. Ford (JHU), and G. Illingworth (UCO/Lick) and the ACS Science Team.*

ship in the classical category of solar planets. It is understood that this definition, though somewhat arbitrary, is still necessary because researchers need to have at their disposal a common terminology that permits them to categorize these objects and avoid confusion in the communication of their

Arecibo radio telescope in 1991. Pulsars are rapidly rotating, super-dense neutron stars, the product of supernova explosions and emitters of regular pulses of intense radiation. (The presence of a planet modifies the frequency of their signal in a periodic way.) It is still not clear how such formidable explosions, which destroy the mother star, could still leave behind nearby planets.

Just beyond the 13 Jupiter mass limit is the category of "brown dwarfs." These are the smallest stars, intermediate between solar type stars and giant planets. They are intermediate objects, because the temperature in their center is not sufficient to ignite the thermonuclear reaction that burns hydrogen into helium, but only a brief reaction requiring deuterium. Thus they are lower mass stars which, in their evolution, remain too cold to be seats of stable and prolonged nuclear reaction. The greater part of the new exoplanets have masses near this deuterium burning limit, and it is sometimes rather difficult to distinguish them from brown dwarfs because the Doppler method of radial velocities (which has found more than 90% of the exoplanets up to now) cannot determine, by itself, the true mass of the planet, but only a lower limit for that mass. This method, from the displacement in the parent star's spectral lines due to the Doppler effect, deduces the presence of a planet from the variations of the speed of the star in its movement towards or away from Earth.

Other methods for discovering planets are coming to our assistance, however, enriching the catalog of extrasolar planets and resolving the problem of minimum masses. Among these techniques are observing the slight dimming of a star's light when a planet crosses in front of the planet (*transits*) in our line of sight (some 50 planets have been discovered with this *transit method*); very precise astrometry using space telescopes that can measure the wobble of a star; and *gravitational microlensing* which occurs when the gravitational field of a star acts like a lens, magnifying the light of a distant background star and its planets.

All of these methods have detected the presence of candidate extrasolar planets only in an indirect way. But in September, 2004, a team from ESA presented the first direct image of a planet, 2M1207b, which was subsequently confirmed by the Hubble Space Telescope. In November, 2008, that same instrument obtained the first extraordinary image in visible light of the planet Fomalhaut b, orbiting its mother star every 872 years. Its sun is a young (200 million year old) star a mere 25 light years from us, the brightest star in the constellation Piscis Austrinus (The Southern Fish). As of this writing, the catalogue of extrasolar planets lists eleven that have been imaged directly.

How do we make sense of our "collection" of planets?

Because of the enormous distances we can't talk of actually exploring these places; that's for the far distant future. But we can begin to draw some interesting inferences from the data at hand already. It's the normal way that science proceeds: after you collect your experimental data, you classify it into various groups and come up with various hypotheses or theories that are consistent with the data. We are beginning to pass into that phase in the study of extrasolar planets, making the first tentative passes at an analysis of their characteristics.

Our collection of 333 extrasolar planets is hardly complete; in the next ten years we're likely to find hundreds or thousands more examples. Those are the kinds of numbers needed to make sense out of all the different varieties of extrasolar planets. And as more lower-mass planets appear, we should be ready for more surprises

Astronomers are not interested just in finding new planets; they want to bring to light and find statistical relationships among their various properties, to indicate the next promising direction for future research. They are looking for correlations between the masses of the planets, their sizes, the periods of their revolutions and other characteristics of their orbits. For planets observed to transit their mother stars, so that an estimate of the planet's dimensions can be made, you can add to the mix the density, which is an indication of its internal composition. By observing planet transits you can also analyze their atmospheres spectroscopically; for the all systems, you can measure the spectra of the mother stars and look for a correlation between the "metal" content of the stars and the probability that a star has planets. All of these ingredients are needed before one can come up with a hypothesis to make sense of this collection of data.

As we increase the number of known planetary systems, we have completely revised the study of the evolution of protoplanetary disks and the dynamics of the probable "migration" of planets during the formation of such systems. The study of extrasolar systems has significantly deepened our understanding of our solar system. It has given rise to the debate among scientists as to which characteristics of our solar system are commonplace enough, and which are quite rare.

Future Developments

Many programs involving the largest Earth-based telescopes are now aiming to obtain direct images of giant extrasolar planets. Meanwhile, projects are underway to monitor hundreds of thousands of stars for possible transits. The COROT (France/ESA) satellite, in orbit since December, 2006, plans on monitoring the light curves of 12,000 stars in each series of observations, and it has already discovered some exoplanets. Starting in April, 2009, the Kepler space mission will be dedicated to a four year mission to search for Earth-like "twins" by looking for transiting planets, similar to our own, orbiting about 100,000 stars in our galaxy in the constellations Lyra and Cygnus. If medium and small-sized planets are common, Kepler could find hundreds of them, of which a few dozen may be "twins" in habitable zones around their stars.

In 2013, if all goes according to plan, the next generation James Webb Space Telescope will be launched, fruit of a collaboration between ESA and NASA, with a 6.5 meter mirror. JWST will orbit at 1.5 million kilometers from the Earth (much more than the 500 km altitude of Hubble). While looking at other galaxies in the primitive (distant) universe, JWST will actually study planetary systems in formation. It should be able to directly image planets and give us information about the chemical composition of their atmospheres.

Proceeding from that will come the search for *biological markers,* such as oxygen, ozone, water vapor and methane, and even indications of photosynthesis in their spectra, which could signal the possible presence, now or in the past, of biological agents that on Earth would be indications of life on their surfaces. The resulting information will contribute to the planning of missions planned for the coming years such as TPF (Terrestrial Planet Finder) and Darwin from NASA and ESA. The preliminary studies for these missions propose a battery of five or six telescopes, each a meter and a half in diameter. They will "fly in formation" in an orbit a million and a half kilometers from the Earth, four times more distant than the Moon, to look for terrestrial-type planets using *interferometry* where the light from each telescope is compared against the next in order to reduce the effect of the brightness of the mother star by a factor of ten million and thus make any planets easier to see.

The Significance of the Discovery of Extrasolar Planets

The advent of extrasolar planets has opened a new page in astronomy and it has already given a formidable impulse into both theoretical and experimental research. Beyond the scientific results, it is clear that these discoveries have also relaunched the question of the presence of other habitable worlds. The search for Earth's twins and the possibility of life on them remains a priority with both a scientific and an emotional resonance.

Fundamentally, the study of astronomy is not merely using a telescope or a computer. While one needs exceptional patience to record the observational data – ever more refined, thanks to the ever advancing technology – and to come up with ever more comprehensive and complete hypotheses, astronomy goes deeper; it nurtures our desire to comprehend how our brief and fragile existence can be connected with that of the planets, stars, and galaxies. Like a six year old child unable to tell a star from a planet, we can let our imaginations go and ask ourselves the question if there is, in some other world, someone we can play with.

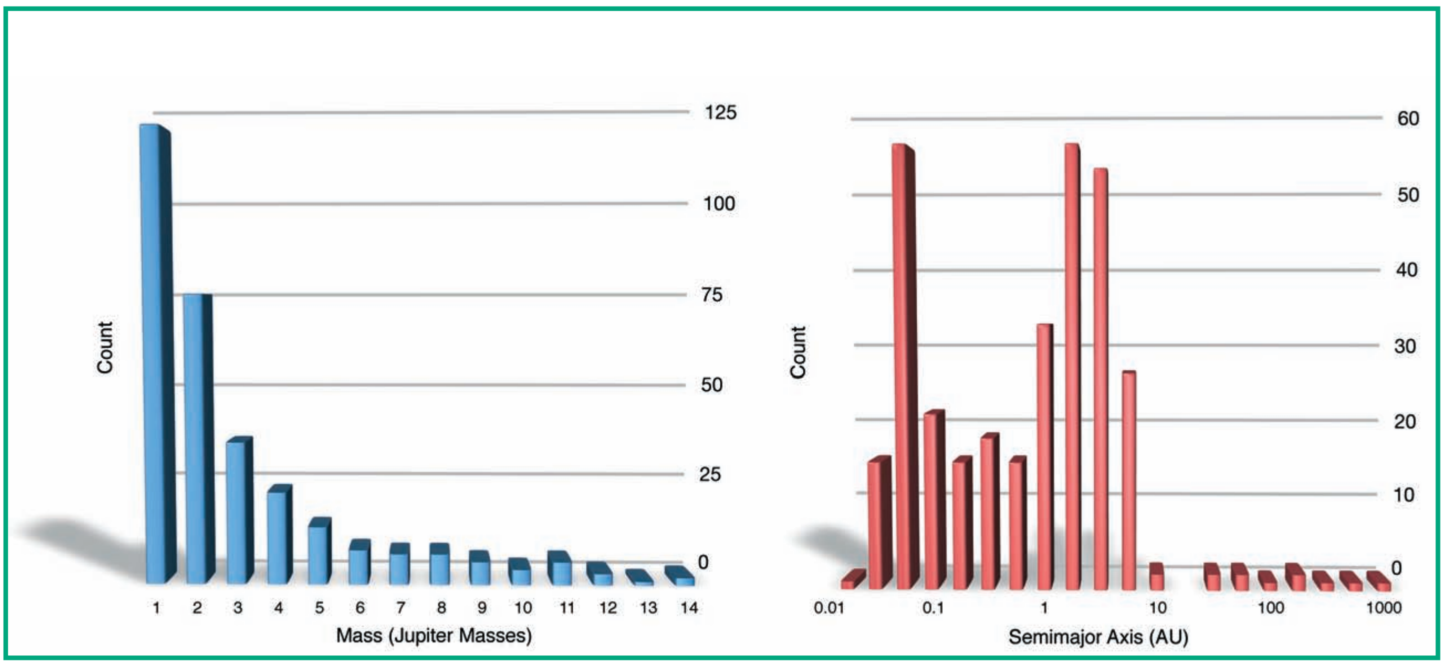
For millennia, humanity has posed this question. Epicurus in his letter to Herodotus wrote, "there are an infinite number of worlds, some like ours, other diverse... nothing hinders such an infinity... and we shouldn't think that such worlds necessarily all have the same form. No one can prove that… in such a kind of world it could not be possible that there are present the seeds from which can arise animals and plants and all the rest of the things that we see."

But now, after centuries of anticipation and often fantastic speculation, we have turned the page; we have sure, reproducible evidence that many planets actually exist in the known universe. Still, we need to distinguish the possibility of the existence of an embryonic form of life on the planets, from the positive affirmation that certain exoplanets have, and continue to have over time, the necessary conditions for primitive forms to evolve to the point of consciousness and intelligent life.

At this point, it is worth looking at the theological implications connected with the eventual discovery of intelligent life in a plurality of worlds in our universe. In 1277 the bishop of Paris, Stephan Tempier, condemned the proposition of traditional Aristoteleanism according to which the Prime Cause could not have made other worlds (arguing that to hold such a belief diminished God's omnipotence). But when Thomas Aquinas supported the existence of only one world, he deemed that such uniqueness was necessary to affirm the uniqueness of the Creator (S.Th I, q 47, ad 3). Still, the medieval concept of "many worlds" does not really correspond to our present discussion of many extrasolar planets; rather it is somewhat more related to recent cosmological speculations about "multi-universes."

In more recent times, we can recall the openness of Fr. Angelo Secchi SJ (a pioneer of astrophysics) concerning the possibility of extraterrestrial life; likewise that of the Barnabite priest, Fr. Francesco Denza, first director of the re-formed Specola Vaticana. And we note the manifest confidence of Pierre Teilhard de Chardin, SJ, who wrote in 1953 *Une suite au problème des origines humaines: La multiplicité des mondes habités* ("An aspect of the problem of the origin of humanity: the multiplicity of habitable worlds")

Among the astronomers at the Specola, there have been diverse opinions on the possibility of eventually encountering ET. But I have the impression that these are determined not so much by the evidence of the research data itself, as by the general sense of



Above *The range of masses (left) and average orbital distances (right) of the 333 exoplanets discovered as of the end of 2008. (One AU is the average distance from the Earth to the Sun.) Most discovery techniques have an easier time finding planets with larger masses and planets closer to their stars, but more recent discoveries and newer methods have begun to reveal planets in a wide range of sizes and positions. (Data from the online* Extrasolar Planets Encyclopedia*)* how the universe and life works, with the basic "Copernican" sense that there are no special privileges for planet Earth.

I believe that certainly patient and methodical observations are to be preferred to the speculations of science fiction writers. While it seems reasonable to suppose that there is a strong possibility the universe will come up with new forms of life every time conditions allow for it, one's imagination may run more freely than one's science. One must remember that the possibility of entering into contact with an evolved alien form of life is terribly limited. If, twenty years from now, thanks to future space telescopes, we are able to observe planets with the appropriate characteristics and if, for example, in their atmospheres there is a strong concentration of oxygen or some other indication of biological activity that would support the probable presence of life, we would still remain quite frustrated. From the point of view of philosophy, such a discovery would be extremely important, but we would still not in fact be able to tell what sort of life we were dealing with. Still, it is to be expected that a scientist will focus on what can be obtained with the available means today. While the goal is admittedly distant, the field of investigation is fascinating and rich with promise.

We can say that the discovery and the initial characterization of extrasolar planets would let us broaden our understanding of the cosmos, moving from the realm of stars – which we have long studied – to the more intimate scale of "worlds," which are instinctively more attractive to us… the kinds of places where human beings can have adventures. Certainly, the planets discovered up to now are not likely to be hospitable for life forms, but we are gradually approaching the discovery of bodies with ever smaller masses; there's no reason to think that we won't eventually come across one similar to our Earth.

The great undertakings of science – and such is the study of extrasolar planets, which has involved such a large number of international research groups, both theoretical and experimental – has more than just practical benefits, such as improving our technology. It engages the human mind and heart with its untiring search for truth and beauty. It is encouraging to see how many people of science have dedicated their energies to a project whose scale is such that only their successors will be able to see its fruit. In June, 2007, the Specola dedicated its eleventh Summer School to introducing more than two dozen young students to this fascinating interdisciplinary topic.

The founder of the Society of Jesus, Ignatius of Loyola, in his brief autobiographical note written (in the third person) at the request of his first companions, left us this description of his early and decisive time of conversion: "His greatest consolation came from the contemplation of the heavens and the stars, which he would gaze at long and often, because from them there was born in him the strongest impulse to serve Our Saviour." What he experienced was not just a delicate sensibility and an esthetic sense, but an interior movement that allowed him to discern the loving action of God unfolding in creation and gave him the desire to participate in it. Such contemplation nourishes the vitality of faith.

This is well expressed in Sacred Scripture: "He dismisses the light, and it departs. He calls it, and it obeys Him, trembling. Before Him the stars at their posts shine and rejoice. When He calls them, they answer, "Here we are!" shining with joy for their Maker. (Baruch 3,33-35).

And again: "When I see your heavens, the work of your fingers, the Moon and stars that you set in place -— What are humans that you are mindful of them, mere mortals that you care for them?" (Psalm 8, 4-5).

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