LECTURE XXIII: Parallactics; Nebulosity; Spectroscopy—The New Astronomy

The work of William Herschel was not unknown in the relatively tiny world of serious astronomy but it had surprisingly little immediate effect on the overall enterprise. Despite his many marvelous and continuing discoveries: the wonderment over the sheer distances and increasing cosmic vastness, the strangeness of the nebulae, Herschel's amazing and ever expanding star catalogues and his ongoing observations (aside from the discovery of Uranus) garnered more amusement than serious interest. If few paid much attention to his work while he was actually engaged in it, that may have had much to do with the fact that, without the benefit of his tremendously advanced homemade instruments, others could not penetrate anywhere near his depth of telescopic vision to verify his observations. The interest of most astronomers was concentrated on the solar system, an enterprise they considered much more likely to reveal useful knowledge. The sidereal world, though intriguing, was much too speculative. The Universe, it was felt, could never be known, and what good were complicated catalogues of bodies that could hardly be seen, and could never be investigated beyond establishing (or only disputing) their relative positions and barely perceived luminosities?

Thus Laplace's concentration on the Solar System in his treatises on the development and functioning of the cosmos. William Herschel's son, John (who became nearly as famous in the 18th century as Einstein in the 20th), in carrying on his father's astronomical work, would devote to sidereal astronomy only 38 out of over 400 pages of his first book, the rest is confined to his studies of our system of planets, satellites, asteroids, comets, and our sun. Even later, an influential French philosopher of the early 19th century, considering stellar astronomy in his *Cours de philosophie positive* [1830's], well after the elder Herschel's passing, wrote this of the stars:

> We conceive the possibility of determining their forms, their distances, their magnitudes, and their movements, but we can never by any means investigate their chemical composition or mineralogical structure, still less the nature of the organic beings that live on their surface, etc. In short, to put the matter in scientific terms [the only terms meaningful to **Auguste Comte**], the positive knowledge we can have of the stars is limited solely to their geometrical and mechanical phenomena, and can never be extended by physical, chemical, physiological, and social research, such as can be expended on entities accessible to all our diverse means of observation.

Later still, in *Traité philosophique d'astronomie populaire* [1844], Comte still thought

> It is then in vain that for half a century it has been endeavored to distinguish two astronomies, the one solar, the other sidereal. In the eyes of those for whom science consists of real laws and not of incoherent facts, the second exists only in the name, and the first alone constitutes the true astronomy; and I am not afraid to assert that it will always be so.

[*From* Comte *as quoted in* Crowe; MODERN THEORIES OF THE UNIVERSE: *From Herschel to Hubble*; ch.4, 'From William Herschel to 1860'; Dover, NY, 1994; pp.147-8]

Parallactics:

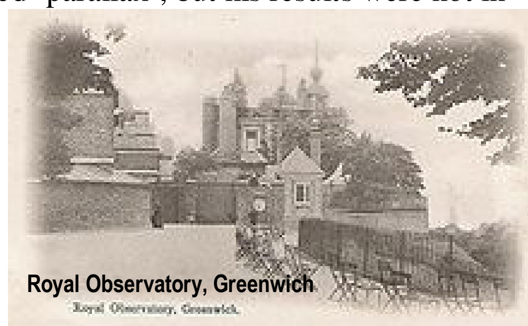
We will hear more of Comte, but first we need to push astronomy forward. Not everyone in astronomy shared Comte's view about the unimportance or limitations of stellar investigation. H.W.M. Olbers [1758-1840] published his *On the Transparency of Space*, for instance, which contains in part his attempt to end the still ongoing debate over whether the world is finite or infinite. Known ever since as 'Olber's Paradox', it presents a mathematically based argument suggesting that darkness at night—given the transparency of space and the fact that an infinite number of stars do not completely fill the sky—would resolve the argument in favor of a finite Universe, unless space is *not* transparent, and scattered clouds of non-luminous matter exist blocking the path of much of the starlight. (On the other hand, a possibility not entertained by Olbers, maybe it's that, even in infinite space, an infinite number of stars do not exist simultaneously, but do so over eternity—continuously forming, growing, contracting, exploding, the old ones ending their existence; relinquishing the unending night for the young to run their course. And then, too, there might be regions of space, vast beyond all comprehension, deficient in star-forming material. Furthermore, the light from stars that formed sufficiently distant from us has not reached us, and might not reach our 'location' until the sun and all the stars we now see about us have burnt themselves out and we are long non-existent—plus, light from stars that were born hundreds of billions of years before our system existed, and which no longer exist themselves, would have arrived and passed on before humans were around to perceive it; before the solar system or even the Milky Way galaxy was formed. In short, though over eternity they are infinite, at any given slice of time the stars are finite in number, though certainly uncountable and mostly unobservable.) Now, even with the latest astrophysical paradigm of cosmic evolution, with an origin in the big bang and gravity-bound, inward curving space, such that cosmologists try to convince eachother that the Universe is 'infinitely finite' (or something like that), Olber's Paradox continues to be seriously debated and we may be bring it up again in a later discussion.

Both stellar and solar astronomy progressed by improving instruments. Our next honorable mention: Germany and

Josef Fraunhofer [1787-1826]

one of the most gifted optical instrument makers of all time. A method discovered by Pierre Guinand for making large, flint-glass lenses became the basis of an optical institute in Munich with Fraunhofer as director. Astronomy for the next half century was dominated by the Munich made telescopes, and the race continued to establish a stellar parallax, as there was still no other means of establishing the distances of stars from our location or from eachother, and thus no way to measure the observable universe.

Robert Hooke thought he had managed the breakthrough in 1669, and Flamsteed shortly thereafter [1690?], and Olaus Roemer in Denmark. But James Bradley showed their results were erroneous. In the following century Wm. Herschel had hoped to achieve the goal by utilizing double stars but never claimed success. Astronomers in Italy, using inferior instruments to Herschel's constructions and the new Fraunhofers, claimed [1808] to have found parallax for Aldeberan, Sirius, Procyon, and Vega. John Brinkley, in Ireland, using an instrument, according to England's Astronomer Royal, John Pond, "superior to any of similar construction on the Continent" [*quote from* "The Historical Search for Stellar Parallax", *article,* J.D. Fernie, *Journal of the Royal Astronomical Society of Canada*, #69 (1975), p.226], also claimed 'parallax', but his results were not in agreement with the Italians. Pond, with the even better Greenwich instrument could not establish any parallax at all in these stars and concluded (1822), "in proportion as instruments have been imperfect in their construction, they have misled observers into the belief of the existence of sensible parallax." [*Ibid.*]



Royal Observatory, Greenwich

In 1829 Friedrich Wilhelm Bessel [1784-1846], as Director of the Königsburg Observatory, acquired a new Fraunhofer telescope called a heliometer (special lens for accurately measuring the diameter of the Sun and planets). Friedrich Georg Wilhelm Struve [1793-1864] (does it seem all German astronomers have either the name Friedrich and/or Wilhelm?), in 1837, using the Fraunhofer at the Pulkova observatory, thought he had determined a parallax for Vega, but by his tentativeness in reporting he missed out on being known as the first to do so. Anyway, he had to revise his measurements in 1839. Bessel read of Struve's result and began observing 61 Cygni. In 1838 he announced a parallactic shift of just over 3″ that was widely accepted as reliable. Knowing the radius of the Earth's orbit (93 million miles to the Sun) and now the angle of parallax, by using triangulation the distance to the star could be computed [*Demonstrate this on available chalk- or dry-erase board or easel, etc.*], which Bessel announced, is "657,700 mean distances of the Earth from the Sun…." So "light employs 10.3 years to traverse this distance". [*from* "The Parallax of 61 Cygni" *by* F.W. Bessel *as found in* Harlow Shapley and Helen Howarth (eds.), A SOURCE BOOK OF ASTRONOMY; McGraw-Hill, NY, 1929; p.219]

Now we have distances requiring abandonment of the Earth-associated measuring scale of miles or kilometers. Astronomers who already were using 'astronomical units' (the mean radius of Earth's orbit—ie., the distance to the Sun) found even that too short for sidereal work and began utilizing either '*parsecs*' (the distance of an object that produces a parallax of one second of arc [= 1.92×10^{13} or 1,920,000,000,000,000 miles]) or *light-years* (the distance travelled by light through empty space in the course of one year [at 186,000 miles per second = 5.88×10^{12} or 588,000,000,000,000 miles]). Thus one parsec = 3.26 light-years. Since parsecs take in more territory (the longer of the two units), even though they are less understandable to the mathematically challenged layman than light-years, and also since they seem to eliminate the dimension of time, the parsec is generally the choice of today's astronomers and cosmologists in measuring and comparing distances and areas. Since the obscure trigonometric origin of the parsec, making it abstract, tends to diminish the sheer awesomeness of cosmic proportions, we will stick to the easily understood and thus more dramatic light-year.

Nebulosity:

Before we had this new measuring stick, estimates of the size of the Universe were wildly divergent (anywhere from a few thousand to extreme and unsupported guesses at millions of light years—and there were still those who held it was infinitely expansive so we would never find the limit), and the argument over 'island universes' seemed irresolvable. Mysterious luminous cloudiness of certain celestial objects, 'nebulae', had been known since the development of the telescope. The similar appearance of these to what began to be resolved, by Galileo, into the billions of stars of the Milky Way, led many to believe the smaller nebulous patches, increasing in number with improvements in the telescope and mostly seen outside of the plane formed by our galaxy, might be the same: other galaxies of stars.

William Herschel, by the startling advance in magnification achieved by his home-made instruments, had greatly increased their number. Some astronomers saw Herschel's success in resolving so very many (but by no means all) of these nebulae into separate stars, as evidence that these were, indeed, other galaxies beyond our local system—'island universes' enormously remote. Others were convinced that everything that could (or would) be seen was part of the same singular cosmic system and that all the nebulae were star-clusters somehow involved with the Milky Way. If the nebulae could be completely resolved into stars as with those in the Milky Way, went their argument, then they too must be part of it—or at least not radically separated from it. Wilhelm Struve, in fact, one of the greatest of that era's astronomers, was convinced that telescopic power had not even reached the extremities of the Milky Way, proposing that

> …if we consider all the fixed stars which surround the sun, as forming a great system, that of the Milky Way, we are in complete ignorance as to its extent, and that we have not the least idea as to the external form of that immense system.
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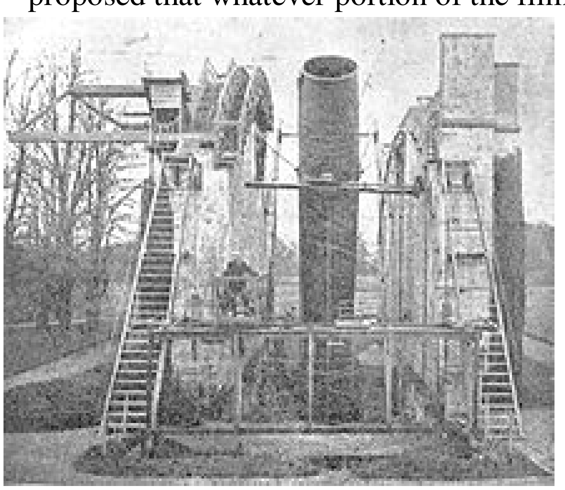
> [*as quoted in* Crowe, MODERN THEORIES OF THE UNIVERSE ; Dover Press, 1994; p.159, *from* F.G.W. Struve, *ÉTUDES d'ASTROMOMIE STELLAIRE*; St. Petersburg, 1847; p.87]

But what of unresolved or only partially resolved nebulae stars? Herschel had not established —nor did he even suggest—that all nebulae were star-systems. He had only proposed that whatever portion of the filmy luminescence did not resolve into stars might somehow be associated with the stellar process: that it might be at least part of the raw material of stars. Many of his colleagues in this age just prior to astrophysics, agreed with the evolutionary idea that Herschel's 'shining fluid' might be the very cause of star-shine.



With William Herschel's death, William Parsons, 3rd Earl of Rosse [1800-1867] became the exponent of monstrous telescopes. Lord Rosse started out pretty big, erecting in 1840 a 36-inch aperture reflector. By 1845 he had constructed a reflector of 72-inch aperture with a 54-foot focal length, 'the **Leviathan of Parsontown**'. The complicated assembly was supported by a 60-foot high brick wall and would remain the largest telescope ever built until the early 20th century.

It was with the 'Leviathan' telescope that he discovered the spiral nebulae, which later (1852) would be considered by Stephen Alexander at the College of New Jersey (now Princeton University) to be the general shape of the Milky Way. How Alexander determined that is somewhat a mystery since, other than Lord Rosse's discovery of a few spirals (many of which later proved not to be spirals at all), there seems to have been no recorded observations in support of our galaxy having such a form. Yet Alexander, in a paper that was contained in a section entitled "The Milky Way—A Spiral" found in an American publication, *The Astronomical Journal*, said he supposed "that the Milky Way and the stars within it together constitute a spiral with several (it may be *four*) branches, and a central (probably spheroidal) cluster…." [*quoted in* Crowe, MODERN THEORIES OF THE UNIVERSE, p.174; *from Alexander's paper*, "On the Origin of the Forms and the Present Condition of Some of the Clusters of Stars and several of the Nebulae" *in Astronomical Journal*, 2 (1852), p.101].

Sir John, the younger Herschel, took his growing family to South Africa where he erected a 20-foot reflector to survey the southern stars. In his six years there, during which he added three more children to the three he had taken with him (he would add six more when he returned to England—as if to make up for having been an only child himself) and catalogued over a thousand more nebulae, most of which could not be seen from north of the equator. He also found that all nebulae, relative to the Milky Way, seemed to be arranged increasingly toward the poles above and below the galactic disc while practically avoiding the plane—which was troubling. One would have expected them to be spread more evenly throughout the sky. This arrangement was so pronounced that it begged of a solution—not yet forthcoming. At first he considered the nebulae to be composed of: "a self-luminous or phosphorescent substance, gradually subsiding into stars and sidereal systems" [*from his* TREATISE ON ASTRONOMY (1833)]. Later, however, he admitted his father's 'shining fluid' was purely hypothetical and seemed to expect all nebulae would be eventually resolved into stars [RESULTS OF ASTRONOMICAL OBSERVATIONS . . . AT THE CAPE OF GOOD HOPE; Smith, Elder, and Co., London, 1847; p.139; *quote and above information as found in* Crowe, MODERN THEORIES OF THE UNIVERSE, pp.161-165].

Sir John Friedrich Wilhelm Herschel (drawing by his daughter)

It was time for America to get into the astronomical race with a new Fraunhofer telescope delivered from Munich to Harvard College. It was received by William Cranch Bond [1789-1859], the leading American observer. Soon thereafter he wrote to the college president describing what he had accomplished with it in very short order:

Dear Sir [*President Everett of Harvard*]—

You will rejoice with me that the great nebula in Orion has yielded to the power of our incomparable telescope.

This morning the atmosphere being in a favorable condition, at a bout 3 o'clock the telescope was set upon the Trapezium in the great nebula of Orion.—Under a power of 200, the 5th star was immediately conspicuous; but our attention was directly absorbed with the splendid revelations made in its immediate neighborhood. This part of the nebula was resolved into bright points of light. The number of stars was too great to attempt counting them; many were however readily located and mapped. The double character of the brightest star of the Trapezium was readily recognized with a power of 600.—This is "Struve's 6th star;" and certain of the stars composing the nebula were seen as double stars under this power.

It should be borne in mind that this nebula and that of Andromeda have been the last strong-hold of the nebular theory; that is, the idea first thrown out by the elder Herschel, of masses of nebulous matter in process of condensation into systems. The nebula in Orion yielded not to the unrivaled skill of both the Herschels, armed with their excellent Reflectors.

It even defied the power of Lord Rosse's three-foot mirrors, giving "not the slightest trace of resolvability," or separation into a number of *single* sparking points.

And even when, for the first time, Lord Rosse's grand Reflector of six-feet speculum was directed to the object, "not the veriest trace of a star was to be seen." Subsequently his Lordship communicated the result of his farther examination of Orion as follows:—

"I think I may safely say, that there can be little if any doubt as the resolvability of the nebula.—We could plainly see that all about the Trapezium is a mass of stars; the rest of the nebula also abounding in stars, and exhibiting the characteristics of resolvability strongly marked."

This has hitherto been considered as the greatest effort of the largest reflecting telescope in the world;—and this our own telescope has accomplished.

I feel deeply sensible of the odiousness of comparisons;—but innumerable applications have been made to me for evidence of the excellence of the instrument, and I can see no other way I which the public are to be made acquainted with its merits.

With sincere respect and esteem, I remain, Sir, your obedient servant,

W.C. Bond

[*Published in* *American Journal of Science and Arts*, Series 2, #4 (1847), p.427; *quoted in* Crowe, MODERN THEORIES OF THE UNIVERSE, pp.171-2]

More and more astronomers were converted to the very large cosmos idea with at least some of the nebulae as separate galaxies vastly removed. As there is little in science that garners unanimity among its practitioners, there were important dissenters such as William Whewell [1794-1866], one of the most learned persons of his day, and Herbert Spencer [1820-1903], prominent philosopher (a proponent of biological evolution but dismissive of the possibility of extra-terrestrial life), and even the great astronomer, Wilhelm Struve at Pulkova. William Herschel having found movement in some nebulae, their reservations were well argued: Why was it that motion was detected if these nebulae were greatly separated from us?—If stars were not distinguishable by the mightiest telescopes in parts of our Milky Way, how was it they were resolved in other galaxies at inconceivably greater distances?—and, Does not the strange accumulation of nebulae toward the poles of the Milky Way system, while they are relatively absent on the plane, imply a relationship? It must be all one system—but some questions simply go unanswered when attention is drawn to more important problems as sciences develop.

A New Astronomy:

Only 30 years after Comte wrote "the positive knowledge we can have of the stars is limited solely to their geometrical and mechanical phenomena, and can never be extended by physical [and] chemical…research" he was refuted in practice via the development of *spectroscopy* and its application to astronomy to create the brand new science of astrophysics.

The rainbow is the natural expression of the light spectrum. It was known in antiquity that a prism or clear crystal would form a rainbow, but it was not understood that it did so by separating the various wavelengths by refraction or slowing, since the nature of the ray was not understood or questioned and the speed was assumed to be instantaneous. It is known to have been considered by a few, who found it interesting to speculate on such impractical matters, that the glass or crystal substance somehow shaded the ray of light, darkening it slightly, increasingly in the direction of the red and blue edges of the display. It remained for Newton to do the prismatic experiments and to discover that white light contains the whole spectrum and that it can be divided into its colors by refraction as well as restored to whiteness by the reverse process. Due to his atomistic presuppositions behind the mechanics of what has been called his 'billiard-ball' model of the world, he worked out a corpuscular theory of light. While the wave theory, as best proposed at that time by Huygens, seems to have been more widely accepted, neither hypothesis managed to explain the phenomenon of light sufficiently to defeat the opposing view. The atomic theory taking hold in chemistry since Dalton and Boyle seemed to support Newton's contention that light consisted of particles, but the trend in general science, likely due to the inexplicit 'action at a distance' conundrum and the new theories of electricity and magnetism, was toward a belief in the continuity of nature that was difficult to reconcile with the idea of discrete, indivisible atoms. But the door had been opened to experimentation, in the course of which it was discovered that the light given off from elements on Earth, when heated to the point of luminescence, also contained elements of the spectrum, and that the spectrum extended on both ends beyond our perception. William Herschel, as early as 1800, discovered the infrared range by simply placing a thermometer in the various ranges of light to see if heat might be involved in differentiating the various colors. The very next year J.W. Ritter discovered the ultraviolet range by noting that certain chemical reactions could be instigated by this unseen part of 'light'. John Herschel, in 1827 [the year of Beethoven's death], found that he could identify metallic salts when they were burned in a flame by observing characteristic signals in their spectra, an embryonic suggestion of the future science of spectral analysis, which received an enormous boost when combined with the relatively new and rapidly advancing invention of photography.

HANDOUT: "Highlights in the Development of Spectroscopy as Related to Astronomy"
from M.J. Crowe, MODERN THEORIES OF THE UNIVERSE; Dover, NY, 1994; pp.178-189 (*from Lec.22*)

WHAT IS SPECTROSCOPY? As shown in the hand out (mentioned above), it was gradually discovered by Josef Fraunhofer in the 1820s that the spectrum, displayed through a prism as arranged in the spectroscope, produced a natural array of lines and colors revealing the identification of the elements emitting the light, like a signature. This provided great insight into the constitution of matter for physicists and chemists and was almost immediately applied to astronomy. Fraunhofer himself discovered differences between the spectra of several first magnitude stars and the Sun. Among the first to expand the use of this discovery and thus to conceive the new science of astrophysics was **Gustav Robert Kirchhoff** [1824-1887] and first to explore the more distant nebula and fainter stars was **William Huggins** [1824-1910]. In 1859, what was (as we shall soon see) truly a banner year in the course of Western culture, Kirchhoff and **Robert Wilhelm Bunsen** [1811-1899] (of Bunsen burner fame) essentially founded the sub-science of spectrum analysis, inspiring Kirchhoff to analyze the light of the Sun and publish his findings concerning its chemical constitution. Huggins, upon reading of Kirchhoff's work on the Sun, was himself inspired to utilize this method to discover (in defiance of Comte) the chemistry of stars, even analyzing nebulae.

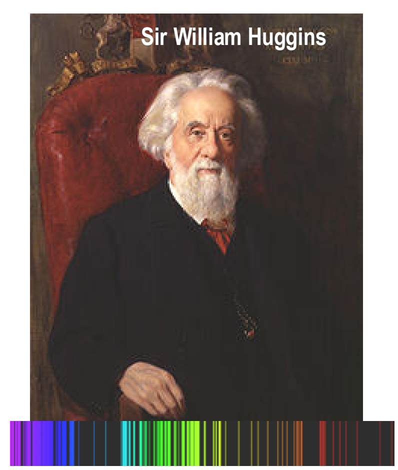
Huggins found the routine of astronomical work boring, he tells us,

> …and in a vague way sought about in my mind for the possibility of research upon the heavens in a new direction or by new methods. It was just at this time … that the news reached me of Kirchhoff's great discovery of the true nature of the chemical constitution of the sun from his interpretation of the Fraunhofer lines.
>
> This news was to me like a coming upon a spring of water in a dry and thirsty land. Here at last presented itself the very order of work for which in an indefinite way I was looking—namely, to extend his novel methods of research upon the sun to the other heavenly bodies.

["The New Astronomy: A personal Retropect";
from *The Nineteenth Century Review*, #41 (1897), p.911;
as quoted in Crowe, MODERN THEORIES OF THE UNIVERSE; Dover, 1994; p.184]

Adding to what Huggins considered the less than exciting, almost non-activity of real time observing, by converting the telescope into an extension of the camera astronomy would soon take a huge leap forward. Objects so distant as to be practically motionless and so faint as to tax the eye and tease the observer into false assumptions could now be subjected to long exposure, gathering the glimmering light into crisp and bright images on a photographic plate and thus revealing details of objects and their spectra that could never have been seen by the method of direct observation.

Huggins went further than chemical analysis. As he became familiar with the various spectral patterns, and probably because of his experimenting with new methods to attain spectra from weak and very distant objects, he noticed a shift in Fraunhofer lines associated with certain stars toward either the red or blue end of the visible spectrum. In what must have been a boost for the wave theory of light over the corpuscular theory, he attributed this shift to the same mechanics as are involved in the Doppler Effect in acoustics, whereby approaching sirens, for example, rise in pitch and retreating sounds are lowered. In other words, the shortening or lengthening of wave lengths due to the light source moving toward or away from us, respectively, caused a spectral shift, by which he could detect the velocity of luminous celestial objects, though only for those moving relatively rapidly toward us or away from us, naturally, since Doppler effects do not result from virtually imperceptible sideways movements by objects at great distances from the observer or receiver.



This new discovery called renewed attention to a major problem—actually two problems that had been lurking in the background of the mechanistic cosmic concept. The more general problem was whether the world is made up of discreet particles or is a continuum. The discreet version, naturally, inclined toward the corpuscular theory of light, while the continuum version allowed the wave theory. For most of the 19th century the wave theory was preferred, but both had seemingly unsolvable difficulties.

The corpuscular theory had it that nearly infinitesimal particles of light—perhaps the smallest of indivisible atomic entities—swarmed in every direction from the source, traveling in straight lines to be absorbed by various material objects or to bounce off of them into our eyes and be registered upon the retina. The air around us is thin enough to seem invisible, allowing most light-particles to pass through unobstructed (you may call these corpuscles 'photons,' but that word, and the full concept of light quanta, had not yet been invented). But clearly the passage of light, especially over cosmic distances, required nearly empty space, granted by the atomic theory associated with Newton's billiard-ball reality, given that matter is generally sparse between astronomical objects. The explanation of refraction through a lens or a prism, then, seemed to require differing corpuscles for each color of the spectrum, each type of which must travel at its own changing velocity through the various transparent or translucent media in order to be bent in their progress at different angles, thus separating into the rainbow. But then there ought to be sharper lines between colors. And how was it that they passed through solid objects at all, like panes of glass or crystals, or through water?—i.e., how shall transparency be explained? These problems seemed insurmountable and gave way to the wave theory.

Not so fast! The corpuscular theory explained why light could pass through a tiny slit without the wave being broken, and their straight-line motion explained why shadows did have a crisp outline, whereas waves would tend to bend around the edges of objects, thus roughing or clouding the edges of their shadows and reducing the shadow size. Furthermore, waves need some sort of gas-like or liquid-like medium (just as sound waves need an atmosphere). In other words, it is not that a particle of light reaches your eye from a distant object, but rather that a disturbance (some sort of motion) at the object stirs the medium between it and you and the disturbance is carried, something like ocean waves, by the reaction of the medium to your eye where it is registered as illumination—a totally mechanical explanation. Such a disturbance, defined as 'light emission', could not travel through empty space, so the wave theory needed to be aligned with the Descartes-influenced, continuum nature of the world, which necessitated the concept of the ether. A disturbance, caused presumably by interior heat or a reaction to motion from without, which causes a distant star to pulsate in the vibration range that produces light, sets up waves of similar frequencies (corresponding to the visible spectrum) in the universal ether; waves that propagate outward until they are interfered with by opaque objects and cancelled, or they are reflected to an observer's eyes causing the reaction at the retina called sight, or they encounter a photographic plate where they cause a chemical reaction allowing them to be stored as an imprint. The wave front, made up of many different wave-lengths corresponding to the various colors, is slightly redirected when passing through transparent objects and particularly refracted through a lens or prism. The different wave-lengths, corresponding to the various 'colors', are 'bent' by differing degrees, thus separating the colors into the spectrum, and explaining why they can be bent again, in reverse, through a second prism and re-combined into white light.

While wave theory may have seemed the more satisfactory in several ways (particularly with Huggin's new discovery of the Doppler shift), the existence of sharp-edged shadows begged explanation. And this ether idea: shouldn't we be able to detect it? Wouldn't it cause noticeable resistance to the movement of planets and moons, comets—the Earth? Mathematical evaluation of the light-wave idea indicates that, in order to transmit these tiny waves at light-speed, the ether would have to be infinitely rigid, whereas to allow unfettered motion of celestial bodies required the opposite character: infinite pliability. The thinking at the time, which favored waves of light, seemed to expect that the dual nature of the ether would eventually lend itself to our understanding.

It did not. Those hopes were not to be realized, and this wave/particle conundrum could not be resolved under what Thomas S. Kuhn has referred to as the mechanistic 'paradigm'. Materialists have failed to explain it, and it was largely this problem of the nature of light that led theoretical physics of the late 19th century to attempt abandonment of Newtonian physics altogether, to the concept of 'field theory' (Faraday, Maxwell, and Hertz), to Einstein's photo-electric paper [1905] and to his theory of relativity.

The world has not really taken much notice of the change, continuing to improve technologically as Newtonian-mechanistic science seems to work just fine in practice. Theoretically, however, physics was in shambles. And in over a hundred years since the quantum theory (so ironically called 'quantum *mechanics*') of Planck, Schrödinger, Heisenberg, Dirac, Bohr, *et al* in the early 20th century—and despite the optimistic predictions of some of today's top thinkers like Roger Penrose and Stephen Hawking (who have been saying for decades that we are only a decade or so away from the 'Grand Unified Theory'), it has become only a worse morass.

In our present examination of cosmology, however, we have not yet reached this crisis of mechanics. Though serious problems were proving resistant, 19th century scientists remained faithful to the mighty Newton, optimistic that all would be resolved in his favor. To them we shall return in our next gathering to see if Auguste Comte can provide a 'positivist' science of society and, later, how biology and the world will react to the evolutionary thought of Herbert Spencer, Alfred Russell Wallace, and the man whose name would soon become practically synonymous with evolution, Charles Darwin.

HANDOUT: Reading for next lecture—ch.16 "Sociology: Comte and His Successors" *from* THE COUNTER-REVOLUTION OF SCIENCE *by* F.A. Hayek; Liberty Fund, Indianapolis, 1979 (republished from Free Press, Glencoe IL, 1952); pp.321-363