Seeing through Superman's Eyes: Some Conjectures on X-Ray Vision

Jim Schaal

Writer's comment: *This essay was written for Kurt Roggli's introductory course in the philosophy of mind. The assignment, following our class discussions on the nature of sensation and perception, was to answer the question: How did Superman's X-ray vision work? My response is unabashedly materialist, eschewing magical "explanations" and attempting instead to account for the caped crusader's unusual talent in purely physical terms informed by analogies to human visual anatomy, X-ray astronomy, and quantum mechanics. My own academic interests focus on our observations and theories of the physical world, on the constraints these impose upon our philosophic views about reality and knowledge, and on the influences our ontological and epistemological preconceptions exert in turn upon our physics. This essay calls upon physics and biology only for qualitative explanations and results, and evades the really perplexing philosophic puzzles surrounding the interface between sensory organs and consciousness, "body" and "mind." Still, it was an amusing excursion, and I hope you enjoy reading it as much as I enjoyed writing it.*

Before you read on, I should like to thank Kurt Roggli for making a sometimes dry subject truly engaging, Charles Nesbit for teaching me about clarity and grace in essay writing, and Ken Parker for providing useful information on mirror systems for X-ray astronomy.

-Jim Schaal

Instructor's comment: *Seeing your own hand is one of the mundane occurrences of daily life, and yet visual perception is a most mysterious and marvelous achievement. How is it actually accomplished? How is it even possible? In considering issues in the philosophy of mind, philosophers often employ imagination in order to think about conceptual possibilities. I asked students to imagine how Superman's X-ray vision might work. It was my hope that this playful task would allow the student to remain undaunted when entertaining and outlining some of the conditions of visual perception.*

Jim Schaal's amusing paper focuses on some of the more technical aspects of X-ray emission and reception while ignoring other interesting features of visual perceiving (e.g., psychological features), but this is perhaps a virtue given the depth and complexity of the issues involved.

-Kurt W. Roggli, Associate In, Philosophy Department

Superman deserved his name: he was faster than a speeding bullet, more powerful than a locomotive, and able to leap tall buildings in a single bound. On her deathbed, according to unsubstantiated rumor, Lois Lane admitted that he also had certain other preternatural abilities. But the most fantastic of Superman's many talents was his X-ray vision. The caped crusader could, reliable sources alleged, see through walls and other opaque materials and thus spy out dastardly criminals and other hazards to the general populace. No one knew for certain how he could do this—not even his close associate, the noted scientist Bruce Banner.

There have been no recorded opportunities for a medical examination of Superman's visual apparatus. Once the superhero offered himself to the authorities for research in the interest of national security but reneged when he discovered that the tests would include X-ray mappings of his skull. So all we have to go on is conjecture. At most, we can make some intelligent inferences about the physical and anatomical requirements for X-ray vision; we can no more account for the nature of Superman's vision in mental terms than we can account for our own. We cannot easily imagine either the immediate sensations Superman experienced when looking through walls or the manner in which these sensations translated into conscious perceptions of "walls," but we can guess about the mechanics of his vision.

The earliest conjecture, and the one still prevalent in the popular lore, is that Superman's vision must work something like the X-ray transmission photography commonly used in hospitals and laboratories. In this technique, high-energy photons with wavelengths of about 10 Å (1 angstrom = 10^{-10} meter) are produced by an X-ray emitter tube (Röntgen tube) and directed at the object under examination. These photons are absorbed by dense materials and transmitted by less dense materials; the transmitted photons expose a photographic emulsion placed opposite the tube to yield a negative image of the object's internal structure. On this naive conjecture, Superman's eyes would function as the photographic plate. But what would be the analogue of the Röntgen tube? Plainly, Superman did not have an accomplice wheeling an X-ray source about, placing it behind every object he wished to observe. Nor could he rely on ambient X-ray illumination, since the photon flux from solar flares and other astronomical sources is very weak in the X-ray region of the spectrum and since virtually all of this flux is absorbed by the earth's atmosphere.

Let us assume that Superman had specially adapted retinas sensitive to photons in the X-ray region. These retinas would have to be very sensitive in order to provide satisfactory vision; our own eyes can detect light intensities corresponding to as few as a half-dozen visible photons, yet we still stub our toes on furniture during nocturnal visits to the bathroom. Indeed, insensitive X-ray retinas would pose more serious hazards, for to function at all they would require bright X-ray illumination. Such intense X-rays cause genetic damage to human cells and probably also to Superhuman cells. The potential for genetic damage is probably the reason for Superman's documented aversion to kryptonite, a strong X-ray emitter which would appear to him more blinding than a dozen suns.

If we assume Superman did have X-ray retinas, we must still account for the means by which the incoming X-rays are focused. Because X-rays have very high frequencies (between about 10 to 1000 times higher than visible light), they cannot be focused by conventional refractive lenses; because they consist of uncharged photons, they cannot be focused with electric or magnetic fields. They can only be focused with mirror systems of two types.

Normal-incidence X-ray mirrors consist of many layers of transparent film of quarter-wavelength thickness and alternating indices of refraction, which in Superman's case might consist of something resembling our own corneal tissue. His eyes might then resemble rich-field Newtonian reflector telescopes (See Figure 1). Although they might have small blind spots directly behind the pupil, his eyes could be compact and easily rotated by ocular muscles like our own. But if our own best technology is indicative, they would function only for "soft" X-rays of wavelengths greater than 10 Å, which are absorbed by most solids and rapidly attenuated by air. Worse, even if they worked for "hard" X-rays, his eyes would be limited to a narrow band of wavelengths by necessity of their reliance on quarter-wave phase reflection. As a result, Superman would be severely "colorblind," unable to see any wavelengths outside that narrow band.

If, instead, Superman's eyes were constructed of grazing-incidence (Wolter) mirrors, they could function over a wide range of wavelengths, including hard X-rays. They would need only simple reflecting surfaces of parabolic and hyperbolic cross-section, whose shape might be distorted by small muscles to allow changes in focus. But Wolter mirrors must be constructed as long, narrow cylinders, so that they would be difficult to aim and would occupy much of Superman's cranium (See Figure 2). Superman would have to forego rolling his eyes and stealing sidelong glances at Ms. Lane. Yet this anatomical limitation of grazing-incidence optics is surely less serious than the "colorblindness" imposed by normal-incidence optics, especially when we consider below the means by which Superman could discriminate objects by their "color," or the wavelength of radiation they emit. For this reason, it seems most likely that Superman's eyes utilized grazing-incidence optics.

We have already noted that there is not enough background X-ray radiation under terrestrial conditions to light Superman's way. Even if there were, this radiation would only provide information about the relative density of objects, which (as any medical radiologist will attest) can be highly ambiguous, even when one knows what to look for. Therefore, Superman must have some means of producing X-ray radiation which unambiguously characterizes the materials he observes. The photons emitted by excited atoms provide just such a characterization.

An atom has a cloud of electrons surrounding its nucleus. These electrons occupy somewhat fuzzy orbits, each of which has an associated electric potential energy. Ordinarily, when the atom is in its "ground state," the electrons occupy the orbits of lowest energy. But when the atom absorbs energy from a collision with some other particle, some electrons are "bumped up" to higher energy orbits, and the atom is said to be in an "excited state." These excited states are unstable, so that the atom eventually returns to its ground state; when it does so, the excess energy is released in the form of a photon whose wavelength is inversely proportional to the energy difference between states. When these photons are observed with an X-ray spectroscope, every chemical element proves to have a different set of wavelengths (or emission line spectrum), which results from its unique set of electronic energy orbits. Thus one can, in principle, determine precisely the composition of an unknown material by exciting its atoms and observing its emission line spectrum.

Excited atoms emit photons in the X-ray region only when they have been excited to very high energy states. The most common process leading to such emissions is the so-called *bremsstrahlung* (or "braking radiation") process, in which fast electrons transfer some of their kinetic energy to an atom by interacting with the electric field surrounding its nucleus. This process yields a smoothly varying intensity spectrum which does not characterize specific elements, but it also yields a line spectrum which does. Thus Superman could "see" what objects are made of by firing fast electrons at them and observing their emission spectra with his X-ray retinas. He would have to have learned (perhaps by childhood training with known elements) to recognize the characteristic spectra, just as the experienced music listener learns to recognize the distinctive sound spectrum of an oboe and picks it out from all the other woodwinds in the orchestra.

Superman still must have some means of "illuminating" objects with fast electrons. He might have some biological analogue of an electron gun like those used in television tubes. In order to produce electrons with sufficient kinetic energy to excite atoms by the *bremsstrahlung* process, he would have to accelerate them through a voltage potential difference of tens of thousands of volts. Furthermore, since most of the electrons would be wasted, producing X-ray photons which never reach his eyes, he would have to be able to sustain very high currents. Electric eels are capable of generating sufficient voltages, but only as static potentials; no known Earth creature can generate such high currents by biological means. Superman's ability to power a high-current electron gun remains a puzzle whose solution promises mindboggling applications; the puzzle may someday be solved if sufficient grant funds are forthcoming.

Some aspects of Superman's X-ray vision seem destined to remain shrouded in mystery. For example, no plausible conjecture explains why Clark Kent wore glasses, except possibly as a disguise. It is likely that his alter ego habitually removed the glasses not only to appear more Supermanly, but also to reduce interference from metal parts in the spectacle frame. Another mystery which has intrigued many of his adolescent admirers: could Superman see through Lois Lane's clothing? Yes, most likely—and through her skin, and through her guts, and through everything several yards behind her. If he derived any satisfaction from this ability (if, in other words, he attained an excited state) the caped crusader masked it with the utmost decorum. A final and more subtle mystery: could Superman recognize his ladyfriend's photograph? The answer here is unclear, since there is no guarantee that a photographic reproduction using visible light will also be an accurate facsimile in the X-ray region.

We may never know in full how Superman's X-ray vision really worked, unless Christopher Reeve tells all in another numbered sequel. But some scientific conjectures, based upon hours of exhausting and only partly specious research, suggest how it might have worked. Superman must have had, at the very least, an eye consisting of an X-ray sensitive retina and some grazing-incidence mirror optics. He must also have had an electron gun to produce characteristic emission spectra in the objects of his attention.

If the X-ray eye was constructed to resemble an ordinary human eye, he could only have had one X-ray eye, since that eye would not have worked in the visible region and all reports indicate that he had no more than the usual pair of eyes. If so, he could not have had stereoptic vision, which must have made supersonic flight very difficult. Alternatively, he might have had concealed X-ray eyes; he must also have had a concealed electron gun, since such devices are notoriously difficult to disguise as noses. Whatever the exact details of Superman's visual apparatus, we know that it worked and worked well: no matter how devious the conspiracy, no matter how cunning the ambush set for him by his foes, Superman saw through them all.

SUPERMAN'S X-RAY EYE

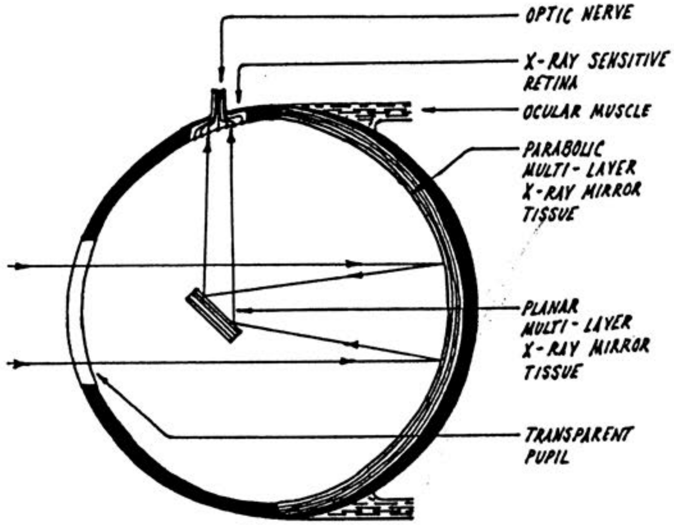

FIGURE 1. SCHEMATIC DIAGRAM OF X-RAY EYE USING NORMAL-INCIDENCE OPTICS

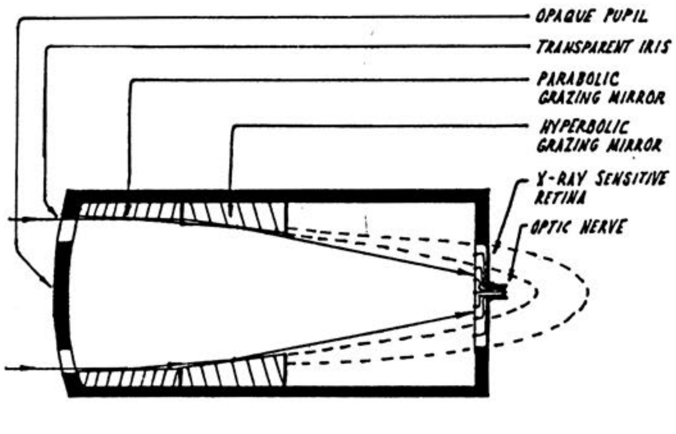

FIGURE 2. SCHEMATIC DIAGRAM OF X-RAY EYE USING GRAZING-INCIDENCE OPTICS