Cocktail party at the beginning of the universe FREE

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letters

Imaging technologies need trained practitioners

I was dismayed by the statement attributed to Angela Gronenborn in David Kramer's piece (Physics Today, February 2008, page 27) that nuclear magnetic resonance (NMR) "technology is less mature than x-ray crystallography, which has evolved to the point where it is considered 'black box,' meaning experimenters don't need to be conversant in the technology to use it." I agree that it has become substantially easier to collect x-ray diffraction images, analyze them, use that information to solve the phase problem, view electron density, and build a crystal structure. However, I strongly disagree that the devices, algorithms, or field is so complicated as to be hidden or mysterious—a so-called black box—to the user or that a user doesn't need to be conversant with the technology to use it.

Do we really want scientists in any field to use software, instrumentation, and technologies that they don't understand? Are we training undergraduates, graduate students, and postdoctoral research fellows adequately, or at a minimal level to produce a noncritical set of data? At a time when scientific research and technology are changing so rapidly, and are more accessible, don't we wish to encourage researchers to understand as much as they can? That is the correct paradigm.

I appreciate the fact that it's easier to include crystallography as a central investigative tool in all major fields of scientific research. However, that also means that it's easier to collect data incorrectly due to overlaps, overexposure, poor sample quality, or incompleteness, or to process it rapidly and incorrectly as with poor indexing, wrong unit cell, wrong space group, or twinning, and still arrive at some sort of electron density and resultant structure. Anyone using crystallography needs to be critical at each step. Several recent retractions of protein structures published in high-profile journals attest to the increased lack of critical analysis. We should not confuse ease with transparency and ignorance with rigor for any technology. A major fault with our present educational hegemony is that the fundamentals of crystallography are no longer adequately presented in science courses. Crystallography, like NMR, is an incredibly powerful tool and continues to develop and thrive on the challenge of investigating larger, more dynamic, and more complex biological and chemical systems. It is liberated and expansive because of its maturity.

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Gronenborn replies: My comment comparing nuclear magnetic resonance and x-ray crystallography as structural techniques was intended to highlight the younger nature of NMR versus crystallography. Crystallographers and NMR spectroscopists worth their salt would never advocate blind use of technologies without a thorough understanding of their basic principles, strengths, and limitations. Problems arising from loose interpretation and misuse of technology without critical analysis of the origin, quality, and reproducibility of generated data are, unfortunately, too common. But not every scientist is a methods developer or is, as David Kramer puts it in his report, well "conversant in the technology." Success in the complex structural-biology tasks that lie ahead can be ensured only through rigorous education and training of students to critically and carefully use all methodologies available.

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Cocktail party at the beginning of the universe

I've just finished reading the feature article by Daniel Eisenstein and Charles Bennett about cosmic sound waves (Physics Today, April 2008, page 44). As an acoustical engineer, I am especially drawn to the 1 part in 10^5 smoothness of the cosmic microwave background (CMB) fluctuations and the attendant "sound wave" analogy. I'm wondering whether your readers appreciate the elegance of this analogy.

Although 1/100 000 may at first seem tiny, acousticians deal in such ratios daily. Consider that an atmospheric pressure fluctuation of 1 bar, expressed in decibels, is approximately 194 dB, while a typical sound level measured in a crowded room of moderate size full of loudly talking people might easily approach 80 dB, a pressure ratio well below 10^{-5}. Thus lively conversation superimposed on atmospheric pressure looks exactly like the *Wilkinson Microwave Anisotropy Probe*'s CMB anisotropy. So a proper analogy for the CMB fluctuations might be the cocktail party at the beginning of the universe. Acoustically, one part in 10^5 smoothness is not a terribly small variation but rather should be regarded as quite normal. We should expect to be able, in a sense, to extract portions of the intelligible conversation from among the din. CMB analysts are working with what would be analogous to a snapshot of an instant in that cocktail party conversation rather than having to wrestle, as acousticians must, with a fully dynamic situation. In Eisenstein and Bennett's figure 2, the three peaks in the power spectral density function at 0.6°, 0.4°, and 0.2° reveal hints of that conversation. It is interesting to consider where this line of thought might lead.

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Domingo de Soto, early dynamics theorist

The public recognition that innovative scientists receive is nowadays regarded as a fundamental incentive to scientific research. Before Galileo, when scientists were mostly members of the religious orders that controlled medieval universities, acknowledging prior work was not considered so important. For that and other reasons the authors of many significant scientific contributions receded into an obscurity from which only modern scholarship has rescued them. Edith Sylla's interesting article about Thomas Bradwardine's influence on the development of dynamics (PHYSICS TODAY, April 2008, page 51) prompts me to draw attention to what may have been a key original contribution. Spanish Dominican friar Domingo de Soto (1494–1560) clearly stated that a freely falling body undergoes uniform acceleration (*motus uniformiter difformis*): "For when a heavy object falls through a homogeneous medium from a height, it moves with greater velocity at the end than at the beginning. . . . And what is more, the [motion] . . . increases uniformly difformly."[1]

There is no evidence, and it is unlikely, that de Soto's assertion was based on experiment; it was an intuition that must have been suggested by experience, of course, but without any attempt to control that experience so as to extract from it the desired information. In fact, the immediate context of his assertion is not a discussion of the physics of falling bodies but a classification of types of motion; that heavy bodies fall with uniform acceleration is mentioned to illustrate the notion of uniform acceleration, and perhaps only secondarily as a natural-world example of that abstract concept. Be that as it may, the example remained in the literature for scholars of that time to consider (eight editions of de Soto's *Quaestiones super octo libros physicorum Aristotelis* were published between 1551 and 1613), and it is likely to have been known to Galileo, who mentions de Soto in his *Tractatus de Elementis* and who attended classes by some of de Soto's intellectual descendants[2] at the Roman College (now the Pontifical Gregorian University) in Rome.

Furthermore, it was accompanied by an explicit indication that because of the uniformly accelerated nature of its motion, the distance traveled by a freely falling body can be calculated using the mean velocity theorem that had been stated and proved in the 14th century by the Oxford Calculators: for in seeking an appropriate global measure of the velocity of a uniformly accelerating object such as a falling heavy body, de Soto notes that "if the moving object A keeps increasing its velocity from 0 to 8, it covers just as much space as [another object] B moving with a uniform velocity of 4 in the same period of time."[1] He was thus the first to apply mathematics successfully to this physical problem—without experimental verification, but in a way that, because it was mathematically precise *and* physical, constituted an exceptionally clear invitation to experimental verification for such inquisitive minds as were prepared to recognize it.

If de Soto's writings did influence Galileo, as seems quite probable, they may have influenced his thinking on dynamics as well as on kinematics. According to Juan José Pérez Camacho and Ignacio Sols Lucía, de Soto's concept of the *resistentia interna* of a body foreshadows Galileo's *resistenza interna* in being intrinsic to the body itself rather than to its medium, and proportional to the weight of the body.[3] What is less tenable is Pérez Camacho and Sols Lucía's thesis that de Soto considered the velocity v of a moving body to be proportional to the motive force f and inversely proportional to its *resistentia interna* r—which would be correct in the case of a body accelerated from rest by a constant force, with time as the constant of proportionality and inertial mass as *resistentia interna.* On the contrary, it seems clear that de Soto's understanding of the relationship among these quantities corresponded not to the formula $v \propto f/r$ but rather to the formula $v \propto \log(f/r)$, first proposed by Bradwardine.[4] The road from Aristotle to Galileo was long and tortuous, and those who advanced in one dimension often remained stationary or receded in others; de Soto's contribution, though modest, may have been vital.

References

1. D. de Soto, cited in translation in W. A. Wallace, *Isis* **59**, 384 (1968), p. 400.
2. W. A. Wallace, *Domingo de Soto and the Early Galileo: Essays on Intellectual History*, Ashgate, Aldershot, UK, and Burlington, VT (2004).