Explaining the Universe:
Why Arts Education and Science Education Need Each Other

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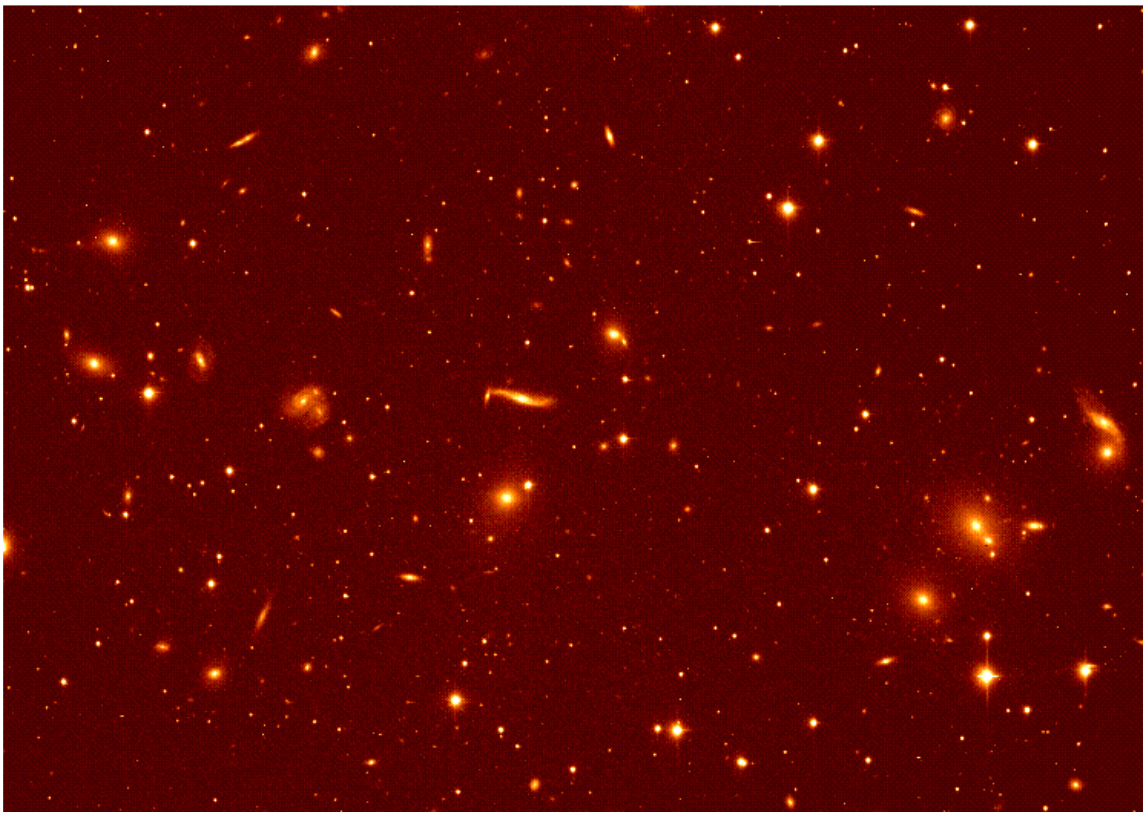

Figure 1: Hercules Cluster of Galaxies; Image provided by Gregory Bothun, University of Oregon

This is an awe-inspiring portrait. The more you know about it, the more wondrous it becomes. Every smudge of light in this picture is an entire galaxy of stars. Each galaxy in this photograph contains billions of stars. So this picture, which shows hundreds of galaxies, is of an immense space, containing trillions of suns.[1]

This is a photograph from a large telescope of the Hercules Cluster of Galaxies, so named

because it shows a region of space beyond the constellation Hercules. Hercules itself is composed of stars in our own galaxy, the Milky Way. The galaxies we see here are far beyond any of the stars we can see with our naked eyes, indeed far beyond any of the stars in the Milky Way galaxy.

The distances to the galaxies in this picture are so great that we don't use units like miles or kilometers to express them. Instead, the measure is the "light-year": the distance traveled by light over one year, moving at a speed of 186,000 miles per second. Even at that colossal speed, it took the light from these galaxies 700 million years to reach us. So these galaxies are 700 million light-years away.

This distance also means that the photograph, even though it was taken only a few years ago, was already a very ancient picture of the galaxy cluster. These galaxies look as they did 700 million years ago, long before humankind took its current shape. Yet this huge amount of time is only a fraction of the age of most stars, so the Hercules Cluster of Galaxies probably looks about the same today as it did when this light left the cluster.

At the great distances of these galaxies from us and from each other, and at the great speeds with which they are each moving, the behavior of space and time familiar to us from our everyday experiences no longer applies. Instead, space and time on this scale have begun to warp, to merge into Einsteinian space-time. Einsteinian space-time tells us, among other things, that this particular arrangement of these galaxies in space and time cannot be thought of as a simple universal image. This photograph is valid from our own place in time and in space, but as seen from other locations in the universe, or even from within the Hercules Cluster itself, these galaxies would never have had this particular arrangement. Infinitely many valid descriptions of the cluster are possible, all different but all related precisely to each other by the equations of Einstein's relativity theory.

Simultaneity is one of the most profound casualties of the new Einsteinian view of the universe. Simultaneous events are strictly a local phenomenon, not a universal one. There can be no single snapshot of this cluster of galaxies which is uniquely "correct," because there is no such thing as a "moment in time" for the universe as a whole. We can continue to think of our own time and our own planet as having moments, but we must learn that thinking about the whole universe requires different, less familiar organizing principles and metaphors.

There might have been, once, a universal moment of time. From the speeds of these galaxies, and of other clusters of galaxies we have studied around the universe, all moving away from each other, we suspect there may have been a singular moment when all this motion began--the "big bang," when all space and time were at a single starting point. We can even estimate when that moment was, although today's guess, about 15 billion years ago, is under debate and will continue to be refined as we continue to study the universe. The possibility also exists that such a unique moment in time will come again, at the end of a cycle of the universe as we know it.

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If it were well taught, this picture from science and its implications should be exciting to learn about. That we dare to believe we are beginning to understand the structure of time and space, the birth and fate of the universe, is an amazing demonstration of faith in human achievement.

I am a science educator, and I'm sure you can tell that I find this story deeply fascinating and profound. My problem is that most children do not know this story, and even if they are (rarely) taught about it, they do not find it fascinating or profound. Like most science educators I have thought long and hard about what is wrong with science education in this country. I have concluded that the solution is not just more good science teachers and good science curriculum, but also more and better arts education. That is because what it takes to be astonished and moved by this photograph is not simply learning the names and numbers that go with the image, but understanding how those facts are part of the larger story of our history, cultural accomplishments, and aspirations.

There are three ingredients in most learning environments. First, we need to know *what* we are going to learn. The current movement towards creating national standards for education is addressing that ingredient vigorously, if not without some important debate. Second, we need to know *how* we are going to learn. Cognitive and pedagogical studies have made significant advances, and we now have a much better understanding of the mechanics of learning, from the microscopic scale of neurons in the brain to the social factors of classroom organization and the potentials of new technological tools.

But the third ingredient is often missing from science education. That ingredient is a desire to learn. If it isn't clear, both intellectually and emotionally, *why* children and their teachers are supposed to learn something, be it art or science, then learning is likely to be shallow and short-lived. A burning desire to learn and to understand can overcome all manner of difficulties. Emotion, passion, awe, and wonder can make learning happen, even if the standards, the curriculum, and the classroom equipment are less than ideal.

Who addresses the need for a burning desire to learn? Words and sentiments like passion, awe, and wonder seem to come more comfortably to artists and poets than they do to scientists and science educators, who (with a few notable exceptions) have never been very good about expressing their underlying emotions.

Instead, science educators have tried to come up with practical, pedestrian reasons for learning science. We've said that there are jobs you can get if you know this stuff. Unfortunately, we also know that the job market for Ph.D.s in the sciences goes through cycles, and happens to be at a low ebb at the moment. One of the most visible scientists of 1997 was Alan Hale, the co-discoverer of Comet Hale-Bopp, who found himself talking as much about his unemployed status as he did about the comet. It can certainly be

argued that knowledge and skills in the sciences have broad applications, and that a PhD. in mathematical analysis can command a high salary on Wall Street this month. But this doesn't seem to me the most direct way to the hearts of elementary school children and teachers.

We have also defended science education in terms of teaching general problem-solving skills. I believe in this argument. Looking around at my colleagues, however, I would have a hard time proving that scientists are happier, have more stable marriages, vote more intelligently, or are more effective participants in their broader communities than are people with similarly deep professional commitments to the arts or the humanities.

* * *

I believe the arts can create a desire to learn, even to learn science. When I try to teach astronomy to adults, including the meaning of the picture of the Hercules Cluster of Galaxies, I use a substantial and moving explanation of what this picture *means* which was prepared by a poet, not a scientist. Here is the opening section of a long poem, "Margrave," written in 1932 by Robinson Jeffers:[2]

> On the small marble-paved platform
> On the turret on the head of the tower,
> Watching the night deepen.
> I feel the rock-edge of the continent
> Reel eastward with me below the broad stars.
>
> . . .
>
> The earth was the world and man was its measure, but our minds have looked
> Through the little mock-dome of heaven the telescope-slotted observatory eyeball,
> there space and multitude came in
> And the earth is a particle of dust by a sand-grain sun, lost in a nameless cove of
> the shores of a continent.
> Galaxy on galaxy, innumerable swirls of innumerable stars, endured as it were
> forever and humanity
> Came into being, its two or three million years are a moment, in a moment it will
> certainly cease out from being
> And galaxy on galaxy endure after that as it were forever...

This is only the beginning of the poem. The information the poem provides about the new astronomy of the twentieth century, and the view the poem expresses about the meaning of that astronomy, grow and evolve during the work. I'll quote from the end of the poem at the conclusion of this essay.

Jeffers was not out to explain science. "Margrave" is about the human condition, and the

title character is, in fact, a murderer on death row. But Jeffers finds science a useful tool in expressing attitudes towards our place, morally, culturally, and physically, in the cosmos. In doing so he expresses some of the emotional impact of twentieth century astronomy.

Poetry, music, painting, sculpture, the theater--these offer another set of explanations of the universe, complementary to the explanations of science. The arts regularly use science as metaphor, model, or foil. I think that looking at the intersections of the arts and the sciences, such as the work of Robinson Jeffers, can help us put science in perspective and create the emotional need to understand what science has to teach us. And, by the way, I believe that the sciences are needed to put the arts in perspective. Vladimir Nabokov has noted that "There is no science without fancy, and no art without facts."[3]

Science can help us know what is there; poetry and the arts can help us know what is important.

In astronomy, having two views of the same object enhances our understanding enormously. We first measured the distance to the stars using this literal technique, called parallax. The same basic idea has been part of literature and the arts for centuries. "Perspectivism" illuminates the meanings of a gold doubloon in *Moby Dick*, and the meanings of a human act in *Rashomon*. Art isn't replacing science, nor science art, but each can help us understand the powers and limitations of the other.

Suppose I am trying to explain the intense satisfaction that can follow the invention of a new theorem, say in geometry. One current technique is to help children invent their own theories, compare their ideas with nature, and discover the joy of invention by doing it themselves. It doesn't happen every day, but it can with skilled teachers and curriculum. But another, complementary way to realize this delight is by gazing at Jose Ribera's image of Archimedes at a moment of triumph (Figure 2). The smile tells a convincing story. How can we not want to feel the emotion Archimedes won through his study of geometry?

Isaac Newton's cosmology combined with a tradition of clockworks and automata to create a new metaphor: the clockwork universe. For two centuries poets and artists joined scientists and philosophers in trying to explain what this idea meant in terms of the human condition. John Donne's dismay ("'Tis all in pieces; all coherence gone"[4]) was followed generations later by Francis Thompson's celebration ("All things linked are...that thou canst not stir a flower, without troubling of a star"[5]). Now the clockwork universe image itself has been cast aside, and we are seeking the meanings of an Einsteinian cosmology from the scientists and the artists.

Our own generation of scientists has produced a new realization of the levels of complexity in the world, with "chaos theory" and a new understanding of an older theory, thermodynamics, showing us yet another way to view what happens around us. How shall I teach this? My tool kit has been wonderfully enriched by Tom Stoppard's play

Arcadia (Figure 3). It looks like, and is, a romantic tale of two eras. It is also a deeply moving evocation of genius, mathematics, and chaos theory. Stoppard's *Hapgood* may provide a similar aid to teaching quantum physics, but I didn't cry at the end, as I did each of the three times I saw *Arcadia*.

There is much science in the work of the painter Remedios Varo, an exile from Franco's Spain who went to Mexico and produced a remarkable series of surrealist paintings.[6] Her "Phenomenon of Weightlessness" (Figure 4) was used as the cover of a textbook on relativity, *The Riddle of Gravitation,*[7] by a great philosopher/scientist Peter Bergmann. One of my favorites among her paintings is "Revelation or the Clockmaker" (Figure 5). For me, the image speaks of the wonder of one model, the clockwork universe, being replaced by another. It makes me want to understand the charm of the old vision, and to learn what is in the new vision which has so enthralled the clockmaker.

Scientists themselves have emotional struggles coming to grips with the meaning of what they are learning. Yet it is rare that a scientist, like Robert Jastrow, finds himself writing a book like *God and the Astronomers*[8] to try to explain inner feelings. The poets usually do it better. By the end of Jeffers' poem, the narrator has reached his own accommodation: not a happily secure enlightenment, but at least an informed acceptance of the new view of the universe and our situation in it.

The images at the end of "Margrave" are literally accurate. The stars in the galaxies *are* "shining their substance away." Einstein's $E = mc^2$ describes, in mathematical language, precisely the same phenomenon. I'm not arguing that Jeffers' poem should replace astronomy textbooks. I do believe that by stimulating the compelling need to understand, which the poet expresses so clearly, arts education can help revitalize science education, and reaffirm the essential joy of learning.

> On the little stone-girdled platform
> Over the earth and the ocean
> I seem to have stood a long time and watched the stars pass.
> They also shall perish I believe.
> Here to-day, gone to-morrow, desperate wee galaxies
> Scattering themselves and shining their substance away
> Like a passionate thought. It is very well ordered.

Notes:

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originally presented by Alan J. Friedman and Carol C. Donley in *Einstein as Myth and Muse* (Cambridge: Cambridge University Press, 1985).

1. The Hercules Cluster's official name is Abell 2151. A few of the spots of light in this picture are not galaxies, but are relatively nearby individual stars in our own galaxy, which happen to lie along our light of sight to the distant cluster. These nearby stars can be recognized because their images are perfectly round with a faint cross-shape of light superimposed. This cross-shape effect is created inside the telescope when starlight is diffracted by support vanes.

2. From *The Selected Poetry of Robinson Jeffers* (New York: Random House, 1938, 1963).

3. "An Interview with Nabokov," *Wisconsin Studies in Contemporary Literature* VIII:140-141; Spring 1967.

4. John Donne, "An Anatomy of the World: The First Anniversary" (1611), line 213.

5. Francis Thompson, "The Mistress of Vision," in *Complete Poetical Works of Francis Thompson* (New York: Modern Library, n.d. [1903?]), p. 184.

6. Reproductions of Varo's work may be found in an excellent critical biography: Janet A. Kaplan, *Unexpected Journeys/The Art and Life of Remedios Varo* (New York: Abbeville Press, 1988).

7. Peter Bergmann, *The Riddle of Gravitation* (New York: Charles Scribner's Sons, 1968).

8. Robert Jastrow, *God and the Astronomers* (New York: Norton, 1978).