

major increase. If faculty take advantage of collaborative efforts, modest college research need not be expensive. We agree that there are tradeoffs, but money is less a problem than time for most of us.

We certainly agree with Walstad on the importance of providing high-quality educational experiences for students not intending to major in physics. However, the topic of the June issue of *PHYSICS TODAY* was the education of professional physicists, and that is the reason for our emphasis. Our experience has been that many physicists and administrators are skeptical about the possibilities for doing successful research in colleges. This deters physicists who enjoy both research and teaching (and can pursue both with distinction) from applying for faculty positions in colleges. By providing concrete evidence for the existence of successful college research programs, we hoped to modify this prejudice.

Walstad implies that our case is substantially based on the existence of a correlation between the PhD productivity of colleges and their success in research as measured either by publications or by grant-getting. We made no such claim (though we think that there may be a correlation) because there does not appear to be valid quantitative evidence on which to base it. (We dispute Walstad's claim that data from our reference 6 may be used to show the absence of a correlation. The number of institutions is small, they were preselected for inclusion, and the data for PhD productivity and research success are for different periods.) Our argument that research activities are useful educational experiences for undergraduates does not depend on whether they choose the PhD path or not. However, we personally know many students who chose graduate study after a successful college research experience.

We would like to correct two errors in our article: We regret the omission of an award to Connecticut College from the list of Research Corporation grants. The grant is for studies of photon emission from collisional excitation of N_2O , NO_2 and SF_6 . An error also appeared in the profile of Robert Warner of Oberlin College, whose research has received continuous outside support from the NSF since 1965 (not 1985).

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I was pleased that *PHYSICS TODAY* invited college teachers Jerry Gollub and Neal Abraham to write an article on the important role of college research in both fundamental physics and the education of scientists. Other readers who found the article interesting should be aware of the Council on Undergraduate Research, to which both authors belong, and of whose Physics Council I am president. It is an organization of college faculty who have joined together to encourage research efforts in the undergraduate environment. The directory *Research in Physics and Astronomy at Private Undergraduate Institutions*, referred to in their article, is available from Brian Andreen, Editor, 6840 East Broadway Boulevard, Tucson AZ 85710, for \$25 prepaid or \$30 charged. It provides useful information about the major private-college physics departments for use by graduate departments, employers, funding agencies, other colleges or high schools.

The CUR also publishes a thrice-yearly newsletter to share ideas about college research efforts, including funding information and case studies. Subscriptions (\$22/year) may be ordered from Michael P. Doyle, Newsletter Editor, Council on Undergraduate Research, Department of Chemistry, Trinity University, San Antonio TX 78284.

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7/86

Calibrating with bubbles

If the large-scale distribution of galaxies resembles the disposition of soap films in "the suds in the kitchen sink," as is compellingly indicated by Valerie de Lapparent, Margaret Geller and John Huchra's recent redshift survey (*PHYSICS TODAY*, May, page 17), we may eventually be afforded new handles on the old cosmological problems of the distance scale, expansion rate and global curvature of the universe.

Attempts to infer the cosmological distances of remote objects from their brightnesses or redshifts have remained uncertain owing to the possibility that the distribution of luminosities of objects or the rate of global expansion may have varied with the age of the universe. (What we see at great distances are necessarily in the remote past.) However, if we make the usual cosmological assumption that the Earth does not occupy a privileged position, then the sharply bounded cells or "bubbles" within which lumi-

nous galaxies are virtually absent should not on the average be elongated in directions that are systematically oriented with respect to their direction from the Earth. By fitting ellipsoids (or, in two-dimensional slices, ellipses) to the boundaries of apparently empty cells in surveys of the sort reported by de Lapparent, Geller and Huchra, we should eventually be able to use any systematic elongations or compressions along radial directions from the Earth to determine what correction of the distance scale, if any, is needed at each redshift to render the principal axes of the ellipsoids equal or, at least, uncorrelated with radial direction from the Earth.

Any residual dependence on distance of the average size of the cells would then furnish evidence concerning secular trends in the sizes of these cells over cosmological time.

Finally, for all cells within a given range of redshifts, the extent to which the average number of cells sharing a boundary with each individual cell deviates below or above 12 (the close packing number for Euclidean space) would indicate the extent to which the global curvature of the universe at the corresponding temporal epoch was positive or negative, respectively.

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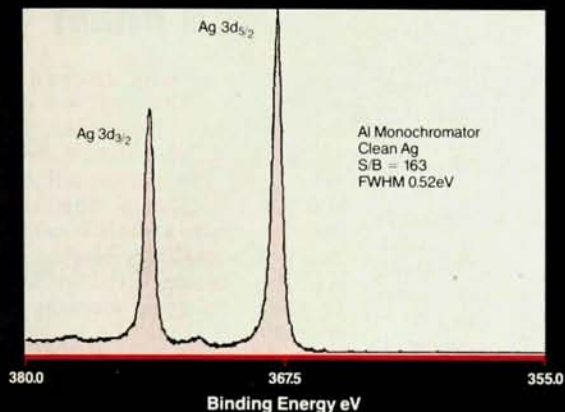
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That ol' dark matter

The news story on the "bubbly universe" (May, page 17) needs some additional clarification. Three primary theories are discussed in trying to account for this structure: primordial explosions, cold dark matter and hot dark matter (also called the "pancake theory"). Unfortunately, the interviews included in the theoretical section of the story quoted only proponents of the first two models. This may be related to the fact that Yakov Zel'dovich's group in the USSR is primarily associated with the third model, which is an appropriate one if any of the three(?) neutrinos has a small but finite mass.

Such models are often studied by numerical simulation. It is unknown whether such large voids as the bubbly universe appears to contain can form in the primordial explosion model by propagating explosions. The cold dark matter model does not produce large voids naturally. It is possible to reinterpret the model so as to cause some voids to appear; they of course must appear extremely commonly, as they seem to in the observational data. Note

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letters

that one is now treading on very
subjective ground, as it is possible to
search a multitude of interpretations of
a numerical model until one is found
that fits the data.

It is not true that none of these
models anticipated the existence of
such large voids. In fact, they are a
natural outcome of the hot dark matter
model, and have been extensively stud-
ied as such.¹ The news story misses the
point that not only are such voids a
generic prediction of models of this
type, but that their size is precisely
what is expected for reasonable values
of the Hubble constant and the density
of matter in the universe in such
models. The study quotes objections to
the hot dark matter model by propo-
nents of the cold dark matter idea,
primarily the excessively large auto-
correlation length. That objection has
been questioned in a variety of ways. It
is based on equating the autocorrela-
tion lengths of particles interacting
purely gravitationally in a model in
which hydrodynamic processes are
known to be quite important. More
generally, it is based on a reinterpret-
ation of the model, in which galaxies
form only in the collapsed pancakes;
this increases the correlation strength.
If one relaxes the assumption that mass
traces light, one must be prepared to do
so in a complicated way. It is easy to
write a biasing prescription that re-
duces the amplitude again by judicious-
ly choosing galaxy masses.

It is also not correct that the first
structures form too late in hot dark
matter models. The first nonlinearities
appear at a redshift of 4 relative to
the moment I describe above,² which is
about the same as that of the first
known quasistellar objects, the most
ancient known nonlinearities.

I do not wish to appear to be an
advocate of hot dark matter. In fact I
think the question is open. All the
models have positive and negative fea-
tures when compared with the data and
with "reasonable" theoretical interpre-
tations. The exclusion of this model
from serious discussion in your story
seems to be based largely on the socio-
logical phenomenon that it is not popu-
lar in North America. The numerical
simulations can be more and more
reliably interpreted when we concen-
trate on large-scale features, which we
can be more confident are based purely
on gravity. It is an objective fact that
the hot dark matter model is the only
one that predicted the existence of such
voids. [See also the article on page 28.]

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5/86

Memories of Wheatley

Some time ago we received the sad
news: John Wheatley was dead [see
PHYSICS TODAY, September, page 73].
First the telegram from a former stu-
dent, later the phone call from Los
Alamos, and then the confusion
between space and time came to my
mind. I saw John, Martha and the
children near the fire, Martha waiting
for the bus in a cold winter, a long trip
through Patagonia on a lonely dirt
road, John planning one week's work
for the lab—but let me put some order
in this story.

Many people will be able to talk
about the relevant scientific contribu-
tions made by Wheatley, and most of
them will be better able than I to
explain how his scientific and technical
contributions have been crucial to the
modern understanding of condensed
matter. However, very few are in a
position to talk about the Patagonian
adventure in which Wheatley took the
leading part.

In August 1955 a young Argentinian
theoretical physicist, Jose Antonio Bal-
seiro, supported by the Argentine
Atomic Energy Commission, started a
new teaching and research institute in
Argentina with a small group of colla-
borators and students. They came to
Bariloche, a small town 1100 miles
from Buenos Aires at 41° latitude in a
beautiful national park. Two flights
and three trains per week and an
almost useless dirt road were the only
connections with the civilized world.
Why a research and teaching institu-
tion was started in such isolation be-
longs to Argentinian history and is not
the subject of this letter. What is
important to point out is that Balseiro
had a strong and clear commitment to
build a research center based on experi-
mental physics. Such a decision, which
might seem trivial to people in indus-
trialized countries, is by no means a
simple task in ours. Balseiro asked for
the support of Argentinian and inter-
national funding agencies. The first
result of their positive response was a
continuous flow of visiting professors
teaching courses and advising on re-
search projects.

In 1958, Jim Daniels came from
Vancouver offering his collaboration in