

► huge advantage for astronomers in the state — particularly those at smaller institutions, says Cassio Leandro Barbosa, an astronomer at the University of Paraíba Valley in São Paulo state.

Wendy Freedman, chair of the GMT board and director of the Carnegie Observatories, thinks that São Paulo and the GMT are “a good match”. The decision to join will now come down to FAPESP’s review

**“Our reputation would drop off a cliff.”**

of a November 2013 workshop between Brazilian astronomers and the GMT leadership, along with an evaluation of benefits

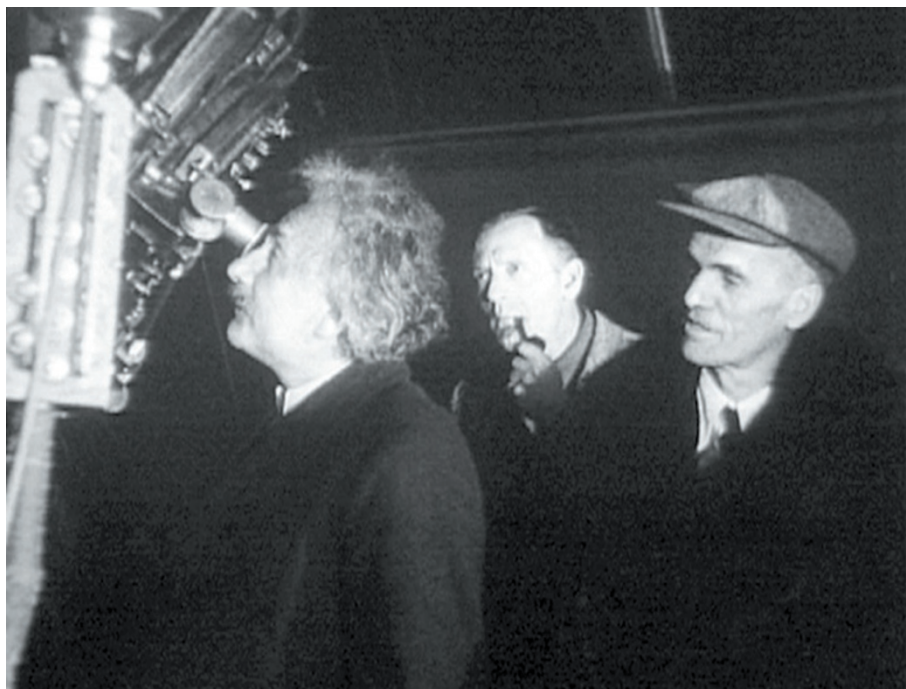
for local industry, says Hernan Chaimovich, special aide to the scientific department at FAPESP. A decision is likely to be made by April, he says.

According to Chaimovich, FAPESP is also in discussions with the Brazilian Ministry of Science and Technology about a federal contribution to the GMT, which would grant telescope access to investigators outside the state of São Paulo. If the ministry does contribute, ESO advocates could have cause for concern, because that might undercut interest in using the E-ELT, a major driver for Brazil to ratify its ESO membership.

For ESO director-general Tim de Zeeuw, one proposal does not necessarily exclude the other. FAPESP’s bid to join the GMT “is independent of the ratification of Brazil to ESO and is very different”, he says. Both megatelescopes are a decade or so away from completion, but being part of the ESO gives Brazilian astronomers access to existing observatories in Chile, such as the Atacama Large Millimeter/submillimeter Array and the Very Large Telescope, he adds. “They are cutting-edge facilities available to the Brazilian community here and now.”

The ratification process formally began in February last year, but has stalled in Congress. De Zeeuw expects Brazil to confirm the agreement in the first half of 2014, but those familiar with the Brazilian system are less willing to make firm predictions in an election year. Beatriz Barbuy, head of the Astronomical Society of Brazil’s ESO committee, is hopeful that the process will wrap up this year. “We will see,” she says. “The next step is to find the budget.”

Further delays could hurt both ESO and Brazil. Under present rules, major construction contracts for the E-ELT cannot be awarded until Brazil’s funds are secure. The country’s growing standing in international science would also take a nose dive, says Barbosa, just as it seeks to join other global organizations, such as CERN, Europe’s particle-physics laboratory near Geneva, Switzerland. “Our reputation would drop off a cliff,” he says. ■



Albert Einstein at Mount Wilson Observatory in 1931, with Edwin Hubble (centre) and Walter Adams.

#### COSMOLOGY

# Einstein’s lost theory uncovered

*Physicist explored the idea of a steady-state Universe in 1931.*

BY DAVIDE CASTELVECCHI

A manuscript that lay unnoticed by scientists for decades has revealed that Albert Einstein once dabbled with an alternative to what we now know as the Big Bang, proposing instead that the Universe expanded steadily and eternally. The recently uncovered work, written in 1931, is reminiscent of a theory championed by British astrophysicist Fred Hoyle nearly 20 years later. Einstein soon abandoned the idea, but the manuscript reveals his continued hesitance to accept that the Universe was created during a single explosive event.

Evidence for the Big Bang first emerged in the 1920s, when US astronomer Edwin Hubble and others discovered that distant galaxies are moving away and that space itself is expanding. This seemed to imply that, in the past, the contents of the observable Universe had been a very dense and hot ‘primordial broth’.

But, from the late 1940s, Hoyle argued that space could be expanding eternally and keeping a roughly constant density. It could do this by continually adding new matter, with elementary particles spontaneously popping up from

space, Hoyle said. Particles would then coalesce to form galaxies and stars, and these would appear at just the right rate to take up the extra room created by the expansion of space. Hoyle’s Universe was always infinite, so its size did not change as it expanded. It was in a ‘steady state’.

The newly uncovered document shows that Einstein had described essentially the same idea much earlier. “For the density to remain constant new particles of matter must be continually formed,” he writes. The manuscript is thought to have been produced during a trip to California in 1931 — in part because it was written on American note paper.

It had been stored in plain sight at the Albert Einstein Archives in Jerusalem — and is freely available to view on its website — but had been mistakenly classified as a first draft of another Einstein paper. Cormac O’Raifeartaigh, a physicist at the Waterford Institute of Technology in Ireland, says that he “almost fell out of his chair” when he realized what the manuscript was about. He and his collaborators have posted their findings, together with an English translation of Einstein’s original German manuscript, on the arXiv preprint server (C. O’Raifeartaigh *et al.* Preprint at <http://arxiv.org/abs/1402.0132>;

2014) and have submitted their paper to the *European Physical Journal*.

"This finding confirms that Hoyle was not a crank," says study co-author Simon Mitton, a science historian at the University of Cambridge, UK, who wrote the 2005 biography *Fred Hoyle: A Life in Science*. The mere fact that Einstein had toyed with a steady-state model could have lent Hoyle more credibility as he engaged the physics community in a debate on the subject. "If only Hoyle had known, he would certainly have used it to punch his opponents," O'Raifeartaigh says.

Although Hoyle's model was eventually ruled out by astronomical observations, it was at least mathematically consistent, tweaking the equations of Einstein's general theory of relativity to provide a possible mechanism for the spontaneous generation of matter. Einstein's unpublished manuscript suggests that, at first, he believed that such a mechanism could arise

$$\begin{aligned} \text{Die Gleichungen (1) liefern} \\ -\frac{3}{4} \alpha^2 + \lambda c^2 = 0 \\ \frac{3}{4} \alpha^2 - \lambda c^2 = 4\pi c^2 \end{aligned}$$

Einstein's correction to his erroneous calculation.

from his original theory without modification. But then he realized that he had made a mistake in his calculations, O'Raifeartaigh and his team suggest. When he corrected it — crossing out a number with a pen of a different colour — he probably decided that the idea would not work and set it aside.

The manuscript was probably "a rough draft commenced with excitement over a neat idea and soon abandoned as the author realized he was fooling himself", says cosmologist James Peebles of Princeton University in New Jersey. There seems to be no record of Einstein ever mentioning these calculations again.

But the fact that Einstein experimented with the steady-state concept demonstrates his continued resistance to the idea of a Big Bang, which he at first found "abominable", even though other theoreticians had shown it to be a natural consequence of his general theory of relativity. (Other leading researchers, such as the eminent Cambridge astronomer Arthur Eddington, were also suspicious of the Big Bang idea, because it suggested a mystical moment of creation.) When astronomers found evidence for cosmic expansion, Einstein had to abandon his bias towards a static Universe, and a steady-state Universe was the next best thing, O'Raifeartaigh and his collaborators say.

Helge Kragh, a science historian at Aarhus University in Denmark, agrees. "What the manuscript shows is that although by then he accepted the expansion of space, [Einstein] was unhappy with a Universe changing in time," he says. ■

## ANIMAL RESEARCH

# Fish-kill method questioned

*Common anaesthetic not the most humane option for zebrafish euthanasia, say studies.*

BY DANIEL CRESSEY

Researchers have called for a common method of killing zebrafish used in laboratories to be abandoned amid growing evidence that it causes unnecessary suffering.

The anaesthetic MS-222, which can be added to tanks to cause overdose, seems to distress the fish, two separate studies have shown. The studies' authors propose that alternative anaesthetics or methods should be used instead.

"These two studies — carried out independently — use different methodologies to reach the same conclusion: zebrafish detect and avoid MS-222 in the water," says Stewart Owen, a senior environmental scientist at AstraZeneca's Brixham Environmental Laboratory in Brixham, UK, and a co-author of one of the studies. "As this is a clear aversive response, as a humane choice, one would no longer use this agent for routine zebrafish anaesthesia."

The use of zebrafish (*Danio rerio*) in research has skyrocketed in recent years as scientists have sought alternatives to more controversial animal models, such as mammals. The fish are cheap and easy to keep, and although no firm data on numbers have been collected, millions are known to be housed in laboratories around the world. Nearly all will eventually be killed.

MS-222 (ethyl 3-aminobenzoate methanesulphate, also known as TMS) is one of the agents most frequently used to kill the creatures.



A researcher checks zebrafish tanks in a cancer lab.

It is listed as an acceptable method of euthanasia by many institutions, and also by societies such as the American Veterinary Medical Association. But the study by Owen and his co-authors, published last year (G. D. Readman *et al.* *PLoS ONE* 8, e73773; 2013), and the second study, published earlier this month by Daniel Weary

and his colleagues at the University of British Columbia in Vancouver, Canada (D. Wong *et al.* *PLoS ONE* 9, e88030; 2014), show that zebrafish seem to find the chemical distressing. The research should fundamentally change the practice, say the authors of both papers.

Owen's study used video tracking to measure whether zebrafish avoided anaesthetics flowing through one side of a tank by moving to the other, untreated side. In the case of MS-222, the team found that zebrafish spent significantly more time in the untreated side than on the side containing the anaesthetic.

Weary's team allowed zebrafish to first spend time in either a light or a dark section of a tank, and then exposed them to MS-222 on their preferred side, the light side. After exposure to the anaesthetic, all but one of 17 fish in the study spent less time on the light side, and nine completely avoided it. This indicates that the fish would rather undergo discomfort — in this case, darkness — than be exposed to MS-222.

"There must be something unpleasant" about MS-222 to produce such a strong signal in the experiment, says Weary, because fish do not avoid many other harmful chemicals to such an extent. "The results are pretty clear," he adds. "We're at a stage where it is a matter of getting policy-makers and researchers to think about this and to rethink the procedures."

There is growing debate over the most humane methods of killing laboratory mammals, with rodent euthanasia coming ▶