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Associate Editor Dens Milne
News Editor Michael Banks
Production Editor Louise Unwin

Managing Editor Susan Curtis
Marketing and Circulation Gemma Bailey
Advertisement Sales Chris Thomas
Advertisement Production Mark Trimnell
Diagram Artist Alison Tovey
Art Director Andrew Giaquinto

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Physics World
Temple Circus, Temple Way, Bristol BS1 6HG, UK
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E-mail: pwld@iop.org
Web: physicsworld.com

Special report: Brazil

With Brazil hosting the 2014 FIFA World Cup – and staging the Olympic Games in Rio de Janeiro two years later – the eyes of the world are focused on a country that is now a leading player on the global stage. While there have been criticisms of the huge sums of money spent on these sporting events, the government has also invested heavily in science, with spending on research more than quadrupling since the turn of the century. This *Physics World* special report examines some of the challenges and opportunities for Brazilian physics, and includes an exclusive interview with the country's science minister Marco Antonio Raupp, who is himself a physicist by training (p9).

We hope you enjoy the report and please do e-mail your comments to pwld@iop.org.

Matin Durrani, Editor, *Physics World*

On the cover
Making an impact on the global stage (*Shutterstock*)

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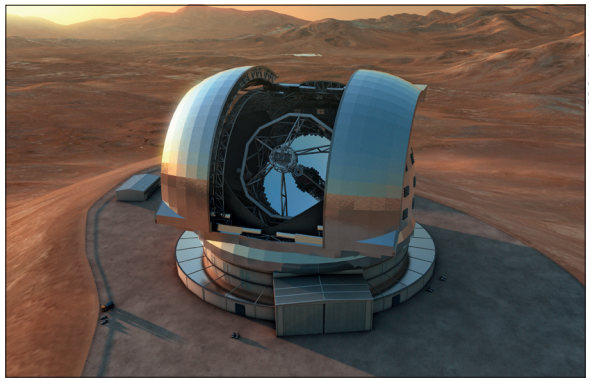
Brazil set to join astronomy elite

Brazil is poised to become the first non-European member of the European Southern Observatory (ESO), with an agreement between the country and ESO set to be fully ratified later this year by the Brazilian government. If Brazil joins, it would become the 16th member of the organization, which runs a number of telescopes in South America including the Very Large Telescope (VLT).

Brazilian astronomers first expressed an interest in joining ESO several years ago so that they could gain improved access to ESO's current and future facilities, such as the planned European Extremely Large Telescope (E-ELT) and the proposed Thirty Meter Telescope. They made a formal recommendation to the Brazilian government in May 2010, which received a favourable response with the country keen to improve the quality of its science.

ESO and Brazil then signed an official agreement later in the same year, which was expected to be ratified by Brazil's Congress in 2013. Although ratification stalled in parliament, ESO director general Tim de Zeeuw told *Physics World* that



ESO/L Calçada

Access all areas
Brazil's membership of the European Southern Observatory will see it gain access to telescopes such as the planned European Extremely Large Telescope.

Brazil is expected to complete that process by June or July. "Several of the steps in the ESO membership-ratification process in the Brazilian parliament have already been completed and few remain," says De Zeeuw. "We are expecting further progress over the next few months."

ESO's 15 members currently give the organization around R$480m ($200m) per year. Under the agreement Brazil will pay an entrance fee of R$416m over 10 years, as well as paying an annual contribution, which is normally proportional to a member state's gross domestic product (GDP). But because Brazil has a relatively low GDP per capita, ESO has decided to gradually increase the country's annual payments so that in the first year Brazil will pay 25% of the value based on its GDP, rising to 100% by 2021.

The deal to join would also grant Brazil full eligibility for its companies to receive contracts from ESO, covering all business areas such as providing and delivering advanced equipment. "Being an ESO member will boost Brazilian astronomy," says João dos Anjos, director of Brazil's National Observatory in Rio de Janeiro. "It will also allow the next generation of Brazilian astronomers to be formed at the frontier of the field."

However, any further delay to Brazil's membership of ESO could hit the construction of the E-ELT because Brazil's cash was designed to let ESO start building the giant telescope, which is expected to be complete by 2021 and be four times more powerful than ESO's existing VLT. If the agreement between ESO and Brazil is not passed, then ESO would need to delay, or recruit new members to pay for, the E-ELT.

Michael Banks

Facilities

Researchers target underground lab

Researchers from Brazil are helping to draw up plans for the first deep underground laboratory in the southern hemisphere. Designed to study neutrinos and the nature of dark matter, the ANDES laboratory would – if approved – be sited 1750 m below the Andes mountain range in the planned Agua Negra road tunnel between Argentina and Chile. The facility, which is a joint project between Argentina, Brazil, Chile and Mexico, could be complete by 2021.

The road project, which is set to begin by the end of 2014, will involve the construction of two 15 km tunnels, each 12 m in diameter. Although the tunnels are meant to help Brazil and Argentina to export goods more quickly to Asia by providing rapid access to parts of Chile's Pacific coast, researchers want to

Going underground
Brazil wants to exploit the Agua Negra road tunnel between Argentina and Chile, which is set to host the southern hemisphere's first deep underground laboratory.

Joe Marlo

bolt an underground lab onto one of the tunnels. Costing about R$40m ($17m) – or about 2% of the tunnel's total price tag – the lab would include three experimental halls.

Xavier Bertou from the Bariloche Atomic Centre at San Carlos de Bariloche in Argentina, who is international co-ordinator for the ANDES lab, says that the project now has the official support of the Argentine science ministry as well as backing from EBITAN – the technical and political body in charge of the tunnel. In January ANDES also became part of the Latin American Centre for Physics (CLAF), which promotes physics in the region and will help to manage the project.

Although experiments for the lab have not yet been finalized, the ANDES facility will include a large detector for spotting neutrinos generated from supernovae and particle accelerators, as well as "geoneutrinos" generated inside the Earth. ANDES will also be able to study whether the dark-matter signal varies during the course of the year, as suggested by similar experiments, such as DAMA/LIBRA at the Gran Sasso lab in Italy, which is also housed in a road tunnel. The lab could even carry out biology experiments to study micro-organisms living in extreme conditions or the impact of cosmic rays on cell ageing.

Matin Durrani

Space science

New missions eye Earth and asteroids

Space scientists from Brazil and China have begun planning their next joint environmental-monitoring satellite – despite their most recent craft failing to enter orbit after launch in December 2013. The two countries have been building remote-sensing satellites together since 1988, but the rocket carrying their fourth craft – China Brazil Earth Research Satellite 3 (CBERS-3) – failed shortly after take-off from the Taiyuan Satellite Launch Centre in China. The craft, which had four cameras, would have let Brazil obtain high-resolution images of the Earth's surface – for example to help monitor the Amazon rainforest.

But following a meeting between Chinese representatives and the Brazilian science minister Marco Antonio Raupp – along with the president of the Brazilian Space Agency José Raimundo Bragao Coelho and the director of the National Institute for Space Research (INPE) Leonel Fernando Perondi – the two countries agreed to launch their next craft, CBERS-4, this year. It will be similar in size to CBERS-3 – about 2 m^3 – and will include solar panels to power it that unfurl when launched. The CBERS satellites are assembled, integrated and tested at INPE headquarters in the city of Sao José dos Campos, which hosts a wide range of satellite-testing facilities, including studying the effects of vibration, low pressure and sound.

Brazil and China have been building remote-sensing satellites together since 1988

Meanwhile, researchers from several Brazilian universities, under the leadership of INPE, are drawing up plans for the country's first deep-space mission. Dubbed ASTER, the 150 kg craft is scheduled for launch in 2019 and will study – for the first time – a system of three asteroids orbiting each other. The craft will spend three years travelling to the triple system, called 2001 SN263, and its seven on-board instruments will seek to understand the three objects' origin, evolution and composition.

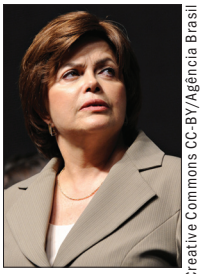
Matin Durrani

Education

Brazil offers grants to send students abroad

Brazil has launched a four-year R$3.5bn ($1.5bn) programme to help more than 100 000 students and researchers gain experience of studying and working abroad. "Science Without Borders" aims to boost science and technology in Brazil by increasing the presence of Brazilian researchers and students in overseas academic institutions. The programme, which began in 2012, also seeks to attract talented young researchers to universities in Brazil.

Announced by Aloizio Mercadante, Brazil's science and technology minister, in 2011, the programme will provide 75 000 grants for students to spend time abroad – including undergraduates, PhD students and postdoctoral researchers. The private sector will be expected to provide another 26 000 grants. The government will also offer 390 scholarships and 860 early-career grants to attract foreign researchers to work in Brazil in key areas such as engineering, physics, nuclear technology and nanotechnology.



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Targeting growth
The Brazilian government is funding scholarships to attract foreign researchers to work in key areas such as nuclear and nanotechnology, says Dilma Rousseff.

"Science Without Borders is an effort to give a quantum leap in the process of building a scientific and technological elite," Mercadante said at a press conference announcing the programme. Brazil's president, Dilma Rousseff, said that a better-educated workforce is essential if Brazil – the world's seventh largest economy – wants to improve further still. "This will educate professionals as part of a global programme to promote innovation in Brazil," she says.

The initiative has received a positive response from researchers. "Brazil is facing several challenges and it needs more engineers, scientists, laboratories and state-of-the-art technology," says Jacob Palis, president of the Brazilian Academy of Sciences. "We have to take advantage of the window of opportunity that economic growth is giving us to go to the next level of development."

Gabriela Frías Villegas

Sidebands

Brazil sets its sights on CERN

Brazil has been formally invited to become an associate member of the CERN particle-physics laboratory near Geneva. The invitation to join was made following a meeting of the CERN council in December 2013 and came after a year of negotiations that began in October 2012 when a delegation from CERN visited Brazil to discuss closer ties. The taskforce from CERN reported its findings to the CERN council, which then agreed that Brazil met the criteria for associate membership. CERN has since submitted a proposal to Brazil, with the particle-physics lab waiting to hear back from the government. CERN currently has 21 members, with Romania in the process of becoming a fully fledged member. Serbia is currently the only associate member – a new category of membership created in 2010 to open CERN up to other countries. Associate members have no voting rights on the CERN council but take responsibility for a share of the annual budget for the lab – set at a lower limit of about $1m.

Graphene centre set to open

A new R$47m ($20m) programme in graphene has been launched that includes the construction of a graphene centre based at the Mackenzie Presbyterian University in São Paulo. The new centre – dubbed MackGrafe – will open later this year and will carry out research into the so-called "wonder material", including the synthesis of graphene, its characterization, with a focus on photonic and optoelectronic properties, as well as its potential use in devices such as those for ultrafast optical communication. Led by physicist Eunézio De Souza, who has been at Mackenzie since 2003, MackGrafe will contain 4230 m^2 of floor space for offices and labs. The centre will also collaborate with the R$74m Graphene Research Center at the National University of Singapore, which was established in 2010 and has a particular focus on nanoelectronics. Graphene – a sheet of crystalline carbon just one atom thick – was first isolated in 2003 by Andre Geim and Konstantin Novoselov from the University of Manchester, for which the duo won the Nobel Prize for Physics in 2010. Many physicists originally believed that a 2D crystal like graphene would always roll up rather than stand free in a planar form, but Geim and Novoselov managed to obtain micrometre-sized graphene crystallites, the electronic properties of which could easily be studied.

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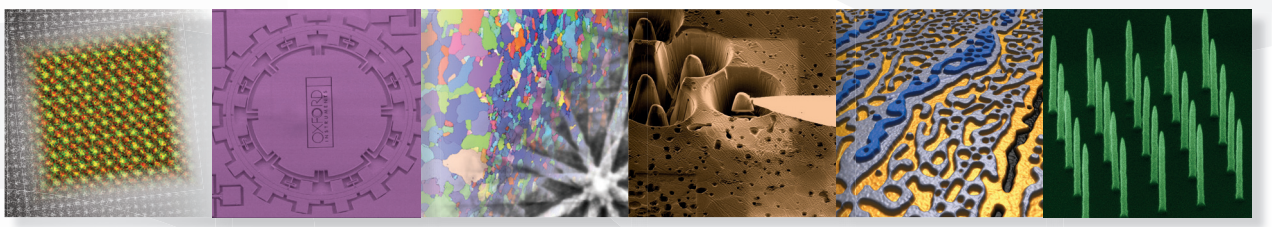

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Introduction

Brazil takes centre stage

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As Brazil climbs up the global economic leaderboard, **Susan Curtis** discovers how a rapid increase in science funding is transforming the country's research landscape

On 12 June the eyes of the world will turn towards Brazil, as the host nation kicks off the opening football match of this year's FIFA World Cup against Croatia at the Itaquerão Stadium in São Paulo. With the 2016 Olympic Games being held in Rio de Janeiro just two years later, the world's fifth-largest country and seventh-biggest economy can finally claim to have become a leading player on the global stage. "Our hour has arrived," proclaimed the then-president Luiz Inácio Lula da Silva in 2009, after Brazil had been chosen to host the two largest sporting events on Earth.

Despite protests at the cost of staging these huge occasions, scientists in Brazil have benefited greatly from the government's public spending in recent times. Investment in scientific research has shot up from R$12bn in 2000 to R$50bn (about $21bn) in 2011, boosting Brazil from 17th in the global rankings for published scientific papers in 2000 to 13th just a decade later. According to the SCImago Journal & Country Rank, a bibliometric-analysis service, scientists in Brazil published more than 56 000 research articles in 2012 – just over 2.0% of the global research output and up from 1.2% in 2000.

Brazil's physicists are also enhancing their scientific credentials through a growing presence in large international collaborations. Ongoing negotiations with the CERN particle-physics lab in Geneva should see Brazil become an associate member within the next year or two, while the country is also taking a leading role in ambitious projects such as the Auger Observatory, which opened in 2008 in a remote part of Argentina for the study of ultrahigh-energy cosmic rays. "Physics has become more important," says Sérgio Rezende, a physicist at the Federal University of Pernambuco (UFPE), who was Brazil's minister for science and technology from 2005 to 2010. "We are making good progress."

The rapid rise in Brazilian physics is particularly impressive in a country where academic research is a relatively recent pursuit. The first modern university – the University of São Paulo – was established in 1934 and graduate programmes in physics did not emerge until the 1960s. "In 1950 there were only two undergraduate courses in physics and less than 12 Brazilian physicists with a PhD," recalls Rezende. Formal funding for university research only became available in 1951, when two federal agencies were created: CNPq, the National Research Council; and CAPES, which was connected to the ministry of education.

Even then, most of the money was linked to individual scientists rather than research projects. "The two federal agencies had the mission of providing fellowships to the best students and funding for the best researchers to go abroad," says Celso Pinto de Melo, a UFPE physicist who was president of the Brazilian Physical Society (SBF) until 2013. "The attitude in government then was that science is expensive and there's no need to invest, so instead individual researchers were given grants to work at leading overseas institutions such as Harvard and Cambridge," he says.

From small beginnings

It was not until the 1960s and 1970s that Brazil started to develop its domestic science base. One key development was the state of São Paulo's decision to set up its own research foundation, FAPESP, in 1962 (see box). "Scientists and politicians somehow managed to write it into the constitution that FAPESP would receive 1% of all tax receipts in the state," says Rezende. "Since then, FAPESP has always funded good science, and São Paulo now accounts for 40–50% of Brazil's scientific output."

Then, in 1967, the military dictatorship – which controlled Brazil from 1964 to 1985 – embarked on a major reform of the university system. The generals decided that CNPq and CAPES were too close to a scientific community that had become critical of their regime, and so a new funding agency, FINEP, was set up to provide research grants to both industry and academia. "FINEP was very powerful, and provided some funds to CNPq and CAPES," recalls Rezende. They had ample grants to begin with, allowing powerful new physics departments to be created."

These new departments were formed as part of a rapid expansion in the federal university system. Full-time faculty positions were created, along with graduate programmes overseen by CAPES. But in the 1990s the now democratic government faced a catastrophic combination of massive public debt, hyperinflation and a stagnant economy. "Federal funds were very tight and at one time FAPESP had more funds than FINEP and CNPq put together. It was FAPESP that kept science going in Brazil," says Rezende.

Money started to flow back into scientific research when Lula was made president in 2002, and really gathered momentum when Rezende became science minister in 2005. Additional federal funding was mirrored by increased contributions from companies and state governments, with the

Introduction

result that in 2011 the total investment in R&D was more than four times that of a decade earlier.

Brazil's spending on R&D now accounts for 1.2% of gross domestic product (GDP) and 40% of that total funding comes from companies. Large firms such as the national oil company Petrobras and energy utilities are also required by law to contribute 1% of their income to scientific research.

That additional funding has brought fundamental change to the Brazilian physics community. "The investment in basic physics has grown," says Eduardo Miranda, a theoretical condensed-matter physicist at the State University of Campinas. "FAPESP has always been steady and strong, while federal funding has been good for the last 10–15 years. That makes it possible to plan longer-term investments in research programmes."

Theory has traditionally dominated Brazilian physics because it is much cheaper, but more universities are now investing in experimental facilities and young physicists are being trained in practical techniques. As a result, there is an almost even split between theory and experiment, and in areas such as condensed matter and optics the number of experimental physicists outnumber theorists by three to two.

Brazil also has sufficient funding to develop large-scale research infrastructure, such as the Sirius next-generation synchrotron source now being built in Campinas (see p11), and for the country to make more substantial contributions to international collaborations. "Our expectation is that Brazilian scientists should take a leadership role in large research projects and not just watch on as mere participants," says Carlos Henrique de Brito Cruz, scientific director of FAPESP and a physicist at the University of Campinas. "The analysis of two five-year projects at CERN required two workshops to assess the scientific contribution that Brazil could make. Both were approved with flying colours."

Physicists are generally well placed to take advantage of the improved funding regime, says Brito Cruz, because they tend to be well connected and have high professional standards. In fact, the SBF, which was formed in 1966, now has about 6000 members, including almost all research physicists plus many physics teachers. With enough critical mass to influence science policy, the SBF has helped to raise the profile of physics in Brazil, improving science education and mobilizing support for Brazil's participation in international projects.

As a result, the number of physicists at PhD level has grown fourfold over the last 20 years – reaching almost 4000 in 2010 – while Brazilian physicists wrote almost 25 000 research articles in international science journals between 2007 and 2010. Moreover, according to Brito Cruz, articles by Brazilian physicists receive twice as many citations per paper as the global average, which he thinks is partly because of the physics community's growing involvement in large projects such as CERN and Auger. "Overall, physics has a greater impact because researchers in all sub-disciplines are better connected and have greater visibility internationally," he says.

Creating global leaders

Yet despite such progress over the last 30 years, Brazilian physicists still have a number of long-standing problems to deal with. Low standards of science education in high schools limit the number of physics students who can complete an undergraduate degree, while many physicists lament a fundamental disconnect between academic research and industrial development. "People at university don't know how to handle spin-offs and companies are suspicious of universities," says Melo back at the UFPE. "Industry doesn't recognize the value that physicists can bring."

There is also a sense that the physics community needs to be more ambitious and more audacious. "We need to believe that important things can happen here," says George Matsas, a theoretical physicist at São Paulo State University (UNESP) and a scientific committee member at FAPESP. "We have people with real talent, but the last step for Brazil is to create global scientific leaders." One issue is that research success is too often measured by the number of papers published in scholarly journals, which many physicists think leads to conservatism rather than bold new ideas.

As a result, Nathan Berkovits, the US-born string theorist who works alongside Matsas at UNESP, feels that researchers in Brazil publish lots of papers but of questionable quality. In fact, Berkovits complains that many of the processes governing academic research in Brazil do not encourage excellence. "No-one from outside Brazil is involved in the committees that assess research quality," he says. "Competitions for permanent university posts are mostly decided by written exams rather than research accomplishments, while salaries are generally independent of the quality of the research."

More broadly, there is a feeling among the physics community that Brazilian society does not recognize the value of science. There are few iconic physicists or research institutions to fire students' imaginations, while in soap opera – Brazil's national obsession – scientists are portrayed as crazy "boffins", not normal people. In fact, despite the increased funding, Brazil's commitment to research still lags behind more-developed scientific nations. Rezende estimates that 0.8 per 1000 inhabitants currently work in research, compared with two per 1000 in the US and Europe.

What stands in Brazil's favour is its demographic. The population is still young and projections suggest that by 2022, when Brazil celebrates 200 years of independence, the country will reach the benchmark of two researchers for every 1000 inhabitants. And with the numbers of new PhD students continuing to rise, Brazilian physics is likely to continue to have a growing worldwide impact. What would really help to bring the feel-good factor back, though, is if Brazil can win the World Cup.

FAPESP blazes a trail

Apart from playing host to six matches at this year's World Cup, the state of São Paulo is also the powerhouse of Brazilian science, accounting for almost half of the country's research output. The state supports three public universities – including the University of São Paulo, the largest and highest ranking university in Latin America – while by law 1% of all state tax revenues is invested in the São Paulo Research Foundation (FAPESP) to spend on research, education and innovation.

With an annual budget of around R$1.1bn, FAPESP funds research projects lasting from two to 11 years and offers about 12 000 fellowships for undergraduates, research students and postdocs. To encourage international collaboration, fellowships are also available to overseas scientists, provided the lead researcher is based in the state of São Paulo.

When combined with funding from federal agencies and the business sector, research spend in the state of São Paulo is 1.6% of gross domestic product, compared with 1% in other parts of the country. Indeed, FAPESP has been something of a role model for other Brazilian states and today there are at least 15 state-level research foundations that offer some degree of autonomy from federal regulations as well as an independent source of income.

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Streets ahead The state of São Paulo has led the way in boosting science in Brazil.

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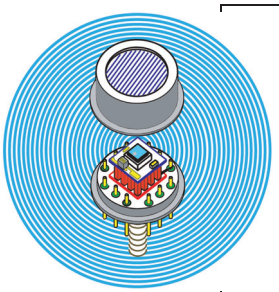

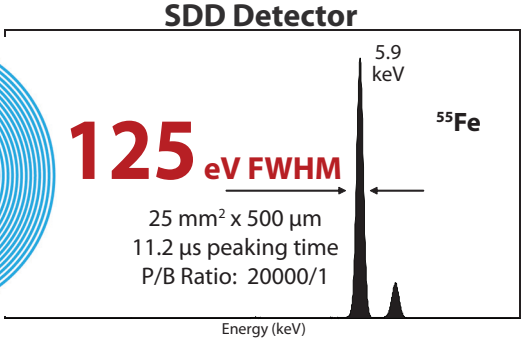

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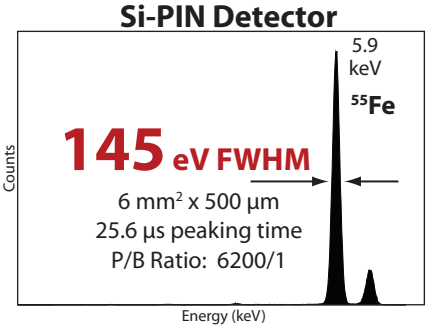

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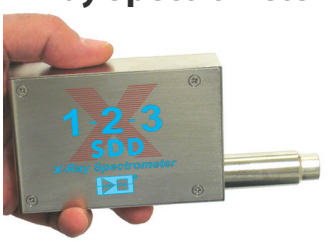

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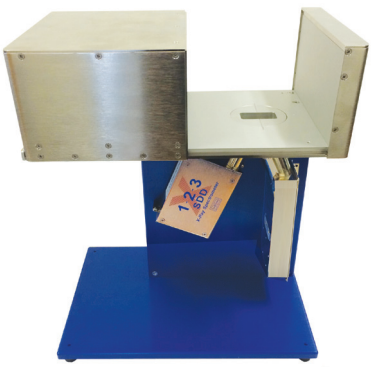

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Interview: Marco Antonio Raupp

Meet the science minister

Marco Antonio Raupp, the mathematical physicist who is now Brazil's minister of science, technology and innovation, talks to *Physics World* about the challenges and opportunities for Brazilian research

What is your top priority for science funding?
Broadly speaking, organized science in Brazil began about 50 years ago; that is, we have been doing science for a relatively short time. On the other hand, Brazil is a huge country with enormous challenges, many of which demand the contribution of science. Thus we not only have to "make ends meet", but also meet the needs of basic research, and those of technological development and innovation.

Brazilian science has to be developed as a whole, implying that all areas of knowledge need funding. Of course, there are always specific priority needs, such as a few large research infrastructure projects. One such project is the construction of the Brazilian Multipurpose Reactor, which is designed to enhance the country's capacity for producing radiopharmaceuticals and training people for nuclear research for peaceful uses. Another large project is the new Sirius synchrotron light ring, which will be among the largest in the world and let Brazil leap forward in materials research. A third project is to set up an ocean research institute, which includes buying a modern oceanographic research vessel. These projects will all be open to researchers from academia and industry.

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Targeting science Marco Antonio Raupp.

How much is Brazil investing in research?
The most recent data available refer to 2011, when federal funding was R$17.8bn ($7.6bn) and state funding was R$8.6bn – totalling R$26.4bn of public investment in R&D. Companies, both public and private, spent R$23.6bn, bringing the overall total up to R$50bn. R&D spending in 2011 was 14.5% higher than the previous year, which in turn was 15.5% up on 2009. In fact, from 2000 to 2011 Brazilian investment in R&D quadrupled. Of course, we would like this growth to have been bigger, but considering the country's general conditions and its needs in other vital areas such as basic education and health, R&D investments have been evolving satisfactorily.

What is the biggest challenge for Brazil's scientific community?
Over the last 50 years – supported by public funding – the Brazilian scientific community set up and organized, starting from a very small base, a science and technology (S&T) system of considerable size and complexity. Brazil now has 235 000 active researchers and, according to the Scopus database, they published 53 083 scientific articles in international journals in 2012, amounting to 2.45% of the world's total. In 1990, in contrast, they published just 3539 articles internationally, or 0.63% of the total. Meanwhile, in 2012, some 12 217 PhD students graduated – more than twice that of a decade earlier. As you can appreciate, these figures show a significant growth over a relatively short time and the challenge now is to improve the quality of those people to increase the impact of Brazil on world science. Another challenge is to enlarge the S&T system, which is today predominantly academic, so that it can reach the business sector. We have already learned to do S&T in universities and research institutes – we now need companies to also engage in R&D to enhance their competitiveness.

How are you improving the international impact of Brazilian research?
I believe this must come as the result of a sustained process – in other words, it is the evolution of the system as a whole that will result in greater international impact of Brazilian research. In this sense, one can see a series of developments under way, progressing year after year: number of PhD graduates; fellowships for Brazilian researchers to go abroad; foreign researchers in Brazil; publication of scientific articles by Brazilian researchers in international journals; and so on. An important recent step taken by the Brazilian government was to create the "Science without Borders" programme, which by 2015 will have offered 100 000 fellowships for Brazilian students and young researchers to go abroad. Brazilian research institutions are also increasingly incorporating an international dimension to their activities. In short, the Brazilian scientific community is aware of the need to deploy greater participation in the world science scene and has been acting accordingly.

How will you ensure research spending drives innovation and economic growth?
By sound government policy and the involvement of the scientific community. Until the second half of the 20th century, Brazilian S&T was generally confined to academia, mostly because industrial development between the 1950s and 1970s tended to rely on foreign technology, leaving no "cross talk" between S&T. Nevertheless, through the concerted effort of public companies and universities, Brazil managed to achieve some important technological results in strategic developmental areas, such as technologies for offshore oil and gas production, aircraft manufacturing, and a very competitive agribusiness.

There is now, though, a clear awareness that S&T makes a vigorous contribution to Brazil's economic development. Towards this end, a legal framework is being built for science and technology, at the centre of which is the 2004 Innovation Law. Federal and state governments, meanwhile, have established a number of programmes for promoting and financing research, development and innovation activities.

At the same time, a new rapport is developing between industrial and S&T policies. This is officially reflected in the acknowledgment – embodied in President Dilma Rousseff's government policies – that science, technology and innovation are the thrust of sustainable development, whether in economic, social or environmental terms. At the same time, our researchers and research institutions are fully aware of the importance of carrying out projects in partnership with private companies.

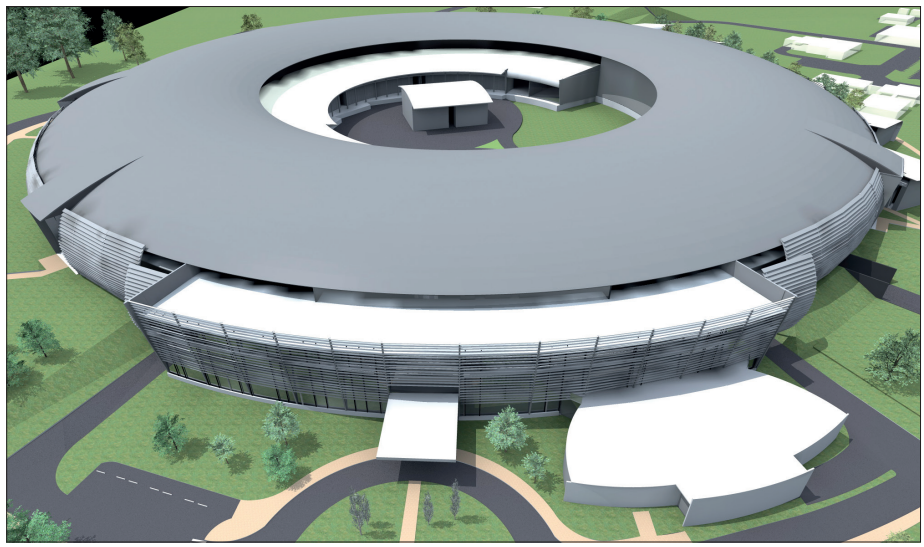
Sirius shines brightly for Brazil

Brazil's scientific ambitions are epitomized by a plan to build a world-leading synchrotron. **Susan Curtis** travels to Campinas to find out what will make the Sirius source so special

Just outside Campinas – the third-largest city in the state of São Paulo – the diggers are excavating huge piles of dark, red soil in preparation for one of Brazil's biggest scientific endeavours. The large hole is destined to become Sirius, a next-generation synchrotron source estimated to cost R$650m ($280m) that promises to be one of the world's first "ultimate storage rings". When complete in 2017, it will boast the lowest ever emittance – confining its photons to a beam narrower than any other in the world – to let scientists probe the structure and properties of materials with unprecedented detail.

Antonio José Roque da Silva, director of Brazil's National Synchrotron Light Laboratory (LNLS), which houses the country's existing second-generation light source UVX, says that the aim is to achieve an emittance of 0.28 nm rad. "The best synchrotrons in the world go down to 1 nm rad and only MAX IV [being built in Sweden] will be comparable in terms of emittance," he says. But more than just providing a powerful new tool, Roque believes that Sirius confirms a shift in ambition among the Brazilian scientific community. "Sirius shows that Brazil can be a leader, not just a follower," he adds. "We can share knowledge on the same level as other countries, rather than just learning from what others have done."

Roque's view is backed by Yves Petroff – a former head of the European Synchrotron Research Facility (ESRF) and long-time advisor to the LNLS – who says that Sirius is part of a "small revolution in synchrotron technology". It will be one of the first light sources to exploit groups of magnets known as multi-bend achromats to focus a coherent, high-brightness beam more tightly than ever. Researchers will for the first time be able to resolve complex biological structures, even when the sample size is small, and to track spatial and temporal changes in materials with nanoscale resolution.


LNLS

Stellar attraction The Sirius synchrotron shares its name with one of the 27 stars on the Brazilian flag.

Time is money

With work starting by mid-2014, Roque admits that the construction schedule will be tight. If all goes to plan, commissioning will get under way in mid-2016, with the first beamlines open to users a year later. But that plan assumes that the LNLS can raise all the funds it needs for the project. Although the R$650m price tag has been approved in principle, the Ministry for Science, Technology and Innovation has committed less than half of the overall budget. Negotiations are still under way with other contributors, including the National Bank for Development, the São Paulo Research Foundation (FAPESP) and major industrial users such as national oil giant Petrobras.

But even the funding for this year is not yet secure. "What is certain is that the science ministry has committed R$137m for 2014, while R$230m is needed to maintain the target schedule," says Carlos Alberto Aragão de Carvalho, director general of the National Centre for Research in Energy and Materials, which comprises the LNLS plus three other national laboratories for nanotechnology, biosciences and ethanol production. Warning that "there are no guaranteed commitments", Aragão is nevertheless confident that the money will be found. "Money flows more quickly from the ministry because the agreement is already in place, but for other contributors it takes time to complete their evaluation processes and establish the necessary infrastructure," he says.

Petroff, however, strikes a note of caution, adding that secure financing is crucial for building a machine like Sirius on time and on budget. "You need to know your budget for a new project in advance, since it influences your design choices and makes it possible to place bulk orders," he says. "If the budget needs to be negotiated and supplied each year, purchasing must be piecemeal and will increase costs."

But even if the money does not come through right away, all three researchers agree that Sirius will still happen, although it might take longer to complete. Indeed, when the existing UVX synchrotron was built at Campinas in the 1980s, it was handcrafted by scientists and engineers at the LNLS, partly to reduce costs and partly because there were no Brazilian firms that could supply parts and components. "No-one in Brazil had any experience of using or building synchrotrons," recalls Petroff, who advised on that project too. "Everything was built in-house and so it took almost eight years to construct. The upside is that the staff at the lab have a deep understanding of the technology."

Today, that knowledge is being used to help Brazilian companies develop a commercial capability in building the core components for Sirius. Roque and his LNLS colleagues have, for example, been working with WEG, a large electrical-motor business based in Santa Catarina in southern Brazil, to develop high-performance magnets, with production having started in January. Meanwhile, Brazilian metals manufacturer Termomecanica is supply-

Facilities

ing the alloy for the vacuum chamber and discussions are ongoing with several other potential partners too.

Creating a domestic supply chain is in fact a key objective for the project. "Sirius is a big investment in basic science, but that investment should also yield positive outcomes for the entrepreneurial community," says Aragão. "We are inviting companies to take part in the challenge, to develop new technologies, to train their engineers in specialist technology and ultimately to boost their international competitiveness."

Try something special

Designing and building a synchrotron with an emittance of just 0.28 nm rad is quite a challenge. In fact, Sirius was originally meant to have an emittance of 1.7 nm rad, similar to the PETRA machine in Germany, but in July 2012 an international advisory committee recommended a more ambitious target. "The committee questioned whether the previous target would stand the test of time," says Liu Lin, head of accelerator physics at the LNLS who has worked at the lab since the initial feasibility studies for the current UVX. "We all thought it was worth taking the opportunity to try for something special."

Once the decision was taken, it took Liu and her team about a month to come up with an optical design that reached the target emittance while working within other key constraints, such as the size of the ring. "We chose to use multi-bend achromats, which exploit multiple dipole magnets to bend the beam through successive angles. Most new projects such as MAX IV and the planned ESRF upgrade have been designed with this approach, while existing machines and projects that got under way some time ago are based on double-bend or triple-bend achromats," she says.

Strong focusing is needed between the dipoles because multiple deflections of the electron beam create dispersion that must be controlled. Sirius will use five groups of bending and focusing magnets, and Liu says it should deliver a slightly lower emittance than the seven-bend lattice at MAX IV because it has tighter focusing between the dipoles. Although Sirius and MAX IV incorporate 20 multi-bend achromats and have rings with a similar circumference, Sirius has fewer dipoles and longer straight sections to make it easier to insert devices, such as undulators and wigglers, to modify and enhance the beam.

The need for such strong focusing has led to some creative engineering solutions. For example, vibrations under the focusing quadrupole magnets must be kept within a few nanometres because any external movement is effectively magnified in the beam by a factor of about 50. And as such narrow apertures are also difficult to pump, it in turn forced an entire rethink of Sirius's vacuum system. In particular, stainless steel had to be replaced by copper coated with non-evaporable getters (NEGs) – a technology originally developed for the Large Hadron Collider at CERN. Staff visited CERN for guidance and training, and the LNLS is now one of the few places in the world where the technology has been installed. Moreover, Rafael Seraphim – head of vacuum at the LNLS – says that CERN is now interested in working with his team to study the behaviour of vacuum systems when exposed to synchrotron radiation.

Putting Brazil on the map

There is no doubt that Sirius will be breaking new technology ground, but future users will be more concerned with its scientific potential. Harry Westfahl Jr, scientific director at the LNLS, says that 13 experimental stations will be up and running when Sirius opens, with a capacity to expand to 40 beamlines over time. "We want users to have access to the newest technology," he says. "Our initial focus will be to develop five undulator-based soft and hard X-ray beamlines, since these will offer improvement to the beam of several orders of magnitude."

One potential challenge, says Westfahl, will be producing X-ray mirrors to the exacting standards needed to conserve low emittance through the beamline. "We have opted to exploit mirrors rather than specialist lenses for focusing, partly because mirrors are more flexible and partly because we have industry expertise in Brazil," he says. "We are now working with industrial suppliers to produce mirrors with very low slope errors, but they could become a bottleneck because of the time needed to fabricate them."

Westfahl's team has also been busy refurbishing the beamlines of the existing UVX synchrotron, with the aim of transferring some of the new experiments to Sirius. One recent success has been the installation of an infrared beamline with a diffraction-beating resolution of 20 nm, achieved by making the light interact with the tip of an atomic force microscope. "Infrared light is ideal for probing delicate biological samples, but its resolution is normally limited to the micrometre range," says Westfahl. "This technique has already been shown to achieve an imaging resolution of 100 nm and we are hoping to push it one step further."

In fact, Westfahl's ambition reflects the commitment of the whole LNLS team to make something special happen here in Campinas. "Sirius will put Brazil on the scientific map," says Aragão. "Every detail requires creativity and opens up new areas of research. We want to enlarge our scientific community around our new star."

São Paulo realizes Salam's dream

São Paulo is the proud host of the first overseas offshoot of the International Centre for Theoretical Physics, which was set up by Abdus Salam 50 years ago. **Matin Durrani** finds out about the new institute

Nathan Berkovits has a very simple office. There's a desk with a computer, a crumpled sofa, a few chairs and a whiteboard covered with equations. But then you don't really need anything too fancy if you're a string theorist – apart from an innate mathematical aptitude for describing the fundamental interactions of nature in terms of 1D strings. In fact, the relatively low cost of theoretical physics has always made it a popular choice for emerging nations to kick-start their scientific efforts. Brazil is no exception: the Institute for Theoretical Physics (IFT) at São Paulo State University (UNESP), where Berkovits is based, dates back to 1951, when Brazilian science was just getting off the ground.

But for the past two years, Berkovits has had new things on his mind other than wondering why string theory only holds true in a 10D world or figuring out how to "compactify" the extra dimensions so that it tallies with our familiar 4D world. That's because in February 2012 he took over as acting head of the first overseas offshoot of the renowned International Centre for Theoretical Physics (ICTP) in Italy. Rather cumbersomely known as the ICTP South American Institute for Fundamental Research, the ICTP-SAIFR has the same aims as its parent institute, which are to carry out top-quality theoretical physics, host scientific schools and workshops, and invite leading scientists to stay.

The ICTP-SAIFR is located on the first floor of the existing six-storey IFT building in the downtown Barra Funda district of São Paulo – the largest city in South America. It may look like many other university buildings, but the institute is remarkable in that it is the physical realization of the ICTP's founding father Abdus Salam. When he set up the ICTP on Italy's Adriatic coast in 1964, Salam wanted it to pursue world-class research and nurture scientists in the developing world, which it has done to great effect in the intervening 50 years. But Salam, who died in 1996, also wanted the ICTP to set up regional satellite centres in developing nations.

Salam's vision was finally realized in 2012 with the founding of ICTP-SAIFR, which receives most of its budget from the São Paulo Research Foundation (FAPESP), with additional support from the ICTP and UNESP. Some 20 UNESP professors are affiliated to the IFT, and the first of a further five permanent faculty members of the new institute – particle theorist Eduardo Pontón from Columbia – has already been recruited. These faculty are being unearthed by a prestigious international search committee featuring star names like string theorist Ed Witten, cosmologist Martin Rees and particle theorist David Gross. "We are interested in experienced people who can come and set up a new group of promising theorists at the start of their careers," says Berkovits.

Danilo Rodrigues Ramos

Centre of attention International students at a summer school on mathematical biology at ICTP-SAIFR.

International appeal

The ICTP-SAIFR has so far run 10 international schools, eight mini-courses and seven workshops attended by some 1000 visitors. It is also home to nine full-time postdocs, one of whom is Riccardo Sturani, who moved to São Paulo from Italy in March 2013 after his contract at the University of Urbino ended. Sturani models cosmological sources of gravitational waves and calculates what these signals might look like if seen at detectors such as LIGO in the US and VIRGO in Italy. But with no previous connection with the ICTP, Sturani certainly would not be living and working in São Paulo were it not for the new institute. "The institute is very good – it's active and you can discuss your work a lot," he says. "The only drawback is that living in São Paulo is very hard for me – I'm not used to big cities and I don't often get to see my friends back home."

Despite the loud, noisy, big-city vibe, Sturani admits he would consider staying in São Paulo once his contract is up. In fact, the many charms of the city – including its friendly people and vibrant cultural life – can be hard to resist. Just ask the US-born Berkovits, who studied physics at Harvard University and did a PhD at the University of California, Berkeley before moving to Brazil in the mid-1990s. Back then, many home-grown Brazilian physicists still opted to further their careers by working abroad, so going in the opposite direction might have seemed an odd move for a young researcher. "Actually, I saw it as a challenge," he recalls. "It felt like something new for me, plus I like Brazil and it's enjoyable living here. People are optimistic, friendly and helpful, and see the country getting better."

But one thing that has not changed in the 20 years since Berkovits first came to Brazil is that it is still a highly bureaucratic nation. Dealing with paperwork can be infuriating and time-consuming for university researchers, reducing their time for science. The bureaucracy can also mean that people get selected for academic posts for reasons that are not always transparent. But with its unique form of funding, the ICTP-SAIFR can "get round" the system, for example by letting Berkovits recruit scientists in a clear and rigorous way. And in a relatively conservative nation where there is a wide resistance to change, the presence of a new, outward-looking institute can only be a good thing for Brazil.

Interview: Vanderlei Bagnato

Promoting innovation

As head of the innovation agency at the University of São Paulo, cold-atom physicist **Vanderlei Bagnato** tells Susan Curtis about creating a culture where research can be converted into practical applications

What made you interested in running an innovation agency?
I was a graduate student at the Massachusetts Institute of Technology in the 1980s and saw first hand the culture of innovation. I believe in fundamental science, but investment in research should benefit the economy as well as advancing knowledge. Scientists need to be alert to applications that could emerge from their work and should ensure that any ideas are pursued – if not by themselves, then by passing the ideas on.

From atoms to applications Vanderlei Bagnato.

How does your experience equip you for that task?
I spend half of my time running the Optics and Photonics Research Centre at the Physics Institute in São Carlos (IFSC), part of the University of São Paulo (USP). One goal of the centre is to advance our fundamental knowledge of cold-matter physics, plasmonics and biophotonics, and another is to develop innovative products and applications that exploit our new scientific insights. This has meant that several new businesses have been spun off from the centre, plus we also collaborate with existing optics companies on some of our research projects.

Do you feel that enough spin-offs are emerging from physics research in Brazil?
Here in São Paulo, it seems there is more innovation in physics than in the engineering schools – in particular in electronics at the University of Campinas and optics at the IFSC. This has driven more start-up activity and now there are more than 40 optics companies in the São Carlos region. One of the most successful is Opto Electrônica, founded by IFSC researchers in 1986 to develop imaging systems for satellites, while other companies are making lasers for medical applications. Laser dentistry is a particular specialism for Brazil, with several firms selling products into Europe, and we are now a net exporter of opthalmic equipment for eye tests. As well as creating new wealth, these companies are producing medical equipment that otherwise would not be available in Brazil.

How do you promote innovation within a research environment?
Universities create people and knowledge, and they need to be serious about the interface between research and economic development. At the agency, we have almost 30 different initiatives to promote innovation to researchers and students, which encourages them always to think about practical applications of their work. Some become so enthusiastic that they want to work for a company or even start their own business, but we are always quite clear that innovation results from good science and education, and that it should not be a replacement for academic research.

How do you help scientists to commercialize their research?
The innovation agency operates at the delicate borderline between research, money, application and intellectual property. We offer an open house to anyone at the university who wants to discuss ideas, and specialist support to students and researchers who want to start a company. The USP has so far incubated around 300 firms and is creating technology parks at each of its campuses to support small businesses and provide a catalyst for commercial growth.

How does your agency help firms to exploit university research?
It's too expensive for companies to invest in the infrastructure for R&D, and so industry has to work with universities on exploratory research. We are currently developing a map of knowledge within the USP so that companies can gain access to our expertise more easily. Research projects funded by the commercial sector currently bring in a few hundred million Brazilian reals, but that's just a small proportion of the USP budget of around R$3.5bn ($1.5bn).

Does the USP want to generate more income from its intellectual property?
Not necessarily. In some cases, scientific advances can create knowledge with a wider social impact and the benefit for society may be more important than any financial benefit for the university. Part of my role is to identify those needs and to direct innovation at the university to address some of our big challenges in Brazil. For example, there are 400 000 new cancer patients every year, but we still import diagnostic equipment that we could produce ourselves. We are already working with the ministry of education to create a programme of mobile labs that will give high-school students more opportunities to practise science and we are looking at technologies to help individuals with special needs to progress through university.

How does your approach to innovation differ from that in other nations?
Our agency's goal is to do innovation, not just manage it. In some parts of the world the approach is to create clusters, but this can generate lots of talk with no action. At the USP we want science to contribute to the core industries that drive economic and social development. For example, at the IFSC we have a strong research programme in atomic clocks, which is important for aerospace firms such as Embraer. And laser technology originally confined to research labs has now become affordable for medical applications that will benefit everyone. We believe we can drive innovation without compromising science; in fact, only research institutes seriously engaged with basic science can generate exciting new ideas with the power to transform people's lives.

Nurturing top talent in Brazil

Brazil's aspiration to become a leading scientific nation hinges on its ability to produce world-class research talent. As **Susan Curtis** discovers, that means improving school education, helping students at university and boosting international research initiatives

Matin Durrani

Easing the transition Brazilian physics students need more help when they move from school to university.

To the outside observer, Brazil would appear to be in robust shape when it comes to educating and developing its scientists and engineers. The headline numbers are impressive enough, with Brazil's spending on R&D more than quadrupling to R$50bn ($21bn) in the decade to 2011 and the country's share of the world's annual output of scholarly papers rising from 1.2% to 1.9% over the same period. Within physics, the citation impact of that research is twice the global average, helped by a strong tradition of collaboration with leading scientists in other nations.

Scratch beneath the surface, however, and a more troubling picture comes into focus. Eduardo Gomez, a seasoned Brazil-watcher at Rutgers University in the US, summed up the situation neatly in a 2012 Viewpoint column for BBC News Latin America and Caribbean. "Before aspiring to build a world-renowned, technically sophisticated workforce," he wrote, "perhaps President [Dilma] Rousseff should invest more in primary and secondary schools, where the future of Brazil's scientific and technological progress truly resides."

Gomez's take is not an isolated view. In fact, the poor quality of science education in Brazilian schools is a recurring theme highlighted by the country's physicists, who cite low pay and lack of recognition as the underlying reasons for a chronic lack of qualified physics teachers at high-school level. "We have many problems in relation to physics teaching in Brazil," says Silvania Nascimento, a researcher who specializes in science education at the Federal University of Minas Gerais in Belo Horizonte. "We have a serious shortage of physics teachers in our public schools, and physics is also losing out to engineering and other better-paid professions as a career choice."

Physicists, teachers, educationalists – as well as state and federal funding agencies – are, though, trying to improve physics teaching and learning. One initiative is a new national professional Masters degree in physics teaching, which is coordinated by the Brazilian Physical Society (SBF) thanks to support worth R$3.6m per year from the Federal Agency for the Support and Evaluation of Graduate Education (CAPES). So far, 21 universities across Brazil have signed up to run the two-year course, with CAPES allocating fellowships to 400 students each year – all of whom must be practising physics teachers in middle or high schools.

Rita de Almeida, who set up the Masters programme for the SBF, expects it to have "a huge impact" on physics education across Brazil. "The physics teachers will take the professional Masters course on a part-time basis over two years, so they need to schedule the coursework and dissertation around their existing teaching commitments," she says. "We're trying to promote creative and progressive ways to teach physics, with the help of more engaging course materials that will be developed by the Masters students themselves."

On a smaller scale, the CERN Portuguese Language Teachers' Programme has helped to enrich the professional development of more than 80 Brazilian high-school teachers over the past six years. Together with nearly 300 of their peers from other Portuguese-speaking nations, the teachers attend an intensive week-long session at the particle-physics laboratory in Geneva, which includes lectures and workshops delivered by Portuguese-speaking scientists.

Lectures cover the basics of particle physics, cosmology, astroparticle physics, data acquisition and medical physics, while the teachers also take part in hands-on activities at CERN's accelerator and detector installations. The programme benefits physics teachers, who return home fired up by their interactions with CERN scientists and colleagues from other countries, while CERN reinforces its relationships with a number of developing countries – a useful exercise in the lab's efforts to become a truly global initiative.

Brazil's federal government also has a number of initiatives for promoting science education. A national teaching initiation programme, for example, awards scholarships to students embarking on teacher-training courses, and also provides a significant salary uplift to teachers who mentor these students in their classrooms. Other government programmes focus on providing extra support for high-school students with an aptitude for scientific research. As well as gaining access to scholarships to fast-track their studies, these students will often get to work directly with academic advisers in the research community.

Long, hard road

Vitor de Souza, an astrophysicist at the Physics Institute at São Carlos, which is part of the University of São Paulo (USP), thinks that any mechanism to ease the transition from high school to university will benefit students, who are often under-prepared for the rigours of an undergraduate physics course. Indeed, he finds that only 10 to 20 of the 120 students who start a four-year physics degree at USP actually graduate.

Careers and education

"About 30% of students drop out after the first semester, but the third semester is the real test," he says, pointing out that it is at this stage that more advanced topics, such as electrodynamics, enter the curriculum.

The problems in high-school science certainly contribute to this high drop-out rate, but so does the fact that students who excel at science and mathematics are often lured by the greater rewards on offer to qualified engineers. As well as higher salaries, graduate engineers can expect to secure a well-paid job straight out of university, while would-be physicists need to continue their education with a two-years Masters programme, a four-year PhD and at least two postdocs. "It's a long, hard road to become a professional physicist in Brazil," says de Souza." Only those who are really passionate about physics will choose to make a career out of it."

As a result, there is growing competition for the best graduate talent, says Antônio Azevedo, who is head of physics at the Federal University of Pernambuco (UFPE) in Recife, in the north-east of Brazil. He believes that increasing numbers of physics graduates are now recruited by industry – particularly Petrobras and the oil companies – straight after their first degree. "Many graduates also choose to work abroad for their PhD or postdoctoral experience, which contributes to a shortage of graduate students," says Azevedo.

Global approach

Although department heads such as Azevedo may want more graduate students to stay in Brazil, time overseas is still a vital rite of passage for many young Brazilian physicists. A spell abroad as a postdoc gives researchers valuable skills and experience with world-leading groups, which they can then exploit on their return to initiate new research fields in Brazil. Indeed, many physicists go on to have long-standing collaborations with their overseas colleagues that continue to stimulate research ideas long after they come back home.

One example is Leonardo Menezes from UFPE, who spent two years as a postdoc with Oliver Benson's nano-optics group at Humboldt University in Berlin. On returning to Brazil, Menezes set up his own nano-optics research lab and has since maintained close links with Benson's group. "When I first arrived at UFPE, this collaboration allowed me to access experimental equipment that wasn't available to me in Brazil," he says. Menezes has since published with the Humboldt group and Benson is keen to spend some time at UFPE as a visiting professor.

The benefits to Brazilian science of students going abroad are so significant in fact that the government has launched a R$3.5bn programme called Science Without Borders, which aims to send 100 000 of the top Brazilian undergraduates and PhD students to leading institutions around the world by 2016. The programme will in addition fund "inbound fellowships" to bring 860 early-career scientists and 390 senior scholars to Brazil to complete a two- or three-year research programme.

Meanwhile, many physicists in Brazil are increasingly contributing to international "big science" research projects (see box), but for non-Brazilian researchers seeking to work in the country, it can still be hard to compete for permanent research posts. Candidates not only have to prepare a lecture for teaching and give a seminar on their research, but also need to sit an exam, in Portuguese, on degree-level physics. These requirements can deter all but the most willing, which is what prompted an alternative recruitment strategy at the ICTP South American Institute for Fundamental Research in Saõ Paulo – a new joint venture between FAPESP and Italy's International Centre for Theoretical Physics (see p13). Faculty members there are being recruited by an international search committee based on a call for CVs, letters of recommendation and an interview, the idea being to allow a strong, open competition.

A similar approach is also being taken at the International Institute of Physics (IIP) – a theoretical-physics centre linked to the Federal University of Rio Grande de Norte. Backed by an international advisory council chaired by Itamar Procaccia of the Weizmann Institute of Science in Israel, the IIP is currently home to three senior visiting researchers from Italy, Japan and Russia, as well as a number of postdocs from the US and Europe. "Our selection process follows international rules under the guidance of our international advisors," says IIP director Alvaro Ferraz. "We also run regular international workshops, conferences and schools, which attract many other international visitors during the year."

Brazil's international dimension

Alongside the connections made by individual scientists with colleagues around the world, the Brazilian government's increased funding for science is also transforming Brazil from a mere participant in large international scientific projects to a strategic partner that can influence the experiments' designs and scientific aims. Brazilian scientists are, for example, currently involved in each of the major experiments at the Large Hadron Collider (LHC) at CERN in Geneva, while São Paulo hosts a powerful "Tier2" computer that helps analyse the reams of data emerging from the LHC. Brazil's impending "associate membership" will, if approved, formalize the government's commitment and open up new opportunities for Brazilian companies to supply instrumentation to CERN.

Brazil is also one of 17 partners in the Auger Observatory, a facility in a remote part of western Argentina for the study of ultrahigh-energy cosmic rays. Its participation builds on Brazil's long history of cosmic-ray research, which dates back to the late 1940s when César Lattes developed techniques with Cecil Powell at the University of Bristol in the UK to detect atmospheric cosmic rays that eventually led to the pair discovering the π-meson. But the country's contribution to Auger was different because it allowed Brazilian firms to supply technology to a major international project for the first time – including a 2.2 m diameter lens and half of its 1600 giant water tanks. There are hopes of matching that success with the Cherenkov Telescope Array, a gamma-ray observatory being planned by 27 countries for sites in the northern and southern hemispheres.

Researchers in Brazil have also started to take part in various galaxy surveys. At its simplest level, this has involved the country providing a financial contribution to projects such as the US-led Sloan Digital Sky Survey and the Dark Energy Survey in exchange for obtaining access to their data. For newer projects, however, Brazil has been involved right from the start of the design phase. "By contributing instrumentation to international projects, we understand exactly how the instrument works, what can be extracted from the data and the limitations of the experiment," explains Raul Abramo, a cosmologist at USP.

That focus on developing international partnerships is also a key driver for the São Paulo Research Foundation (FAPESP). "Since 2007 there has been a greater focus on creating international collaborations, provided that Brazilian scientists can make a real contribution to the project," says Carlos Henrique de Brito Cruz, FAPESP's scientific director. "FAPESP will offer part-funding for projects where overseas scientists establish a link with a lead researcher at one of the universities in the state."

CERN

Seeking a partnership The Brazilian ambassador to the United Nations Office in Geneva, Regina Maria Cordero Dunlop, meeting CERN boss Rolf-Dieter Heuer in December 2013.

Astronomy and geophysics

Long history, bright future

The National Observatory in Rio de Janeiro is where Brazil's scientific effort pretty much began. But as **Matin Durrani** finds out, staff there are still at the forefront of research

If there is one spot that can claim to be the birthplace of Brazilian science, it is the National Observatory in Rio de Janeiro. Nestled between narrow streets in the hilly São Cristóvão district with spectacular views over the city and the sea, the observatory is the country's oldest scientific institution. Founded in 1827 by Emperor Dom Pedro I just five years after Brazil won independence from Portugal, its initial role was to measure and record time, which was essential for ships seeking to determine their longitude and so navigate into Rio's congested harbour.

The observatory is still the official timekeeper of Brazil, but it no longer announces time in the original fashion, which involved raising an inflated balloon to the top of a mast on the observatory's main building and deflating it at precisely midday. That technique endured until 1920, when the balloon was replaced by a flashing electric light bulb, although the official "Brazilian hour" is now generated by seven caesium- and two hydrogen-maser atomic clocks. These measurements in turn contribute to International Atomic Time – a weighted average of the time kept by more than 200 clocks in 50 labs around the world.

In addition to its work in metrology, the observatory has long been active in astronomy. In the 1890s, for example, staff used an on-site telescope to contribute to one of the earliest international astronomical projects, which saw 18 nations mapping the sky for stars up to magnitude 14. In 1909 astronomers at the National Observatory monitored the passing of Halley's comet using its 25 cm refracting telescope, while in 1919 they took part in studies of that year's solar eclipse, which helped to confirm Einstein's general theory of relativity. In fact, Einstein himself visited the observatory in 1925.

Although the on-site telescopes are no longer in active use, astronomy is still a central activity, says current director João dos Anjos. The observatory employs some 140 staff, including 40 full-time researchers, with most astronomers routinely working at major international facilities, such as the Very Large Telescope, run by the European Southern Observatory, and the international Gemini South telescope, both in Chile. Staff are also involved in the US SLOAN Digital Sky Survey and in the Dark Energy Survey to study, among other things, the nature of dark energy, galaxy evolution and exoplanets.

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Proud tradition The National Observatory in Rio de Janeiro has spearheaded Brazil's efforts in astronomy, metrology and geophysics.

To support Brazil's participation in such projects, the observatory has created an "e-astronomy" laboratory called LIneA, which consists of tools to help astronomers to process, store, analyse and reduce in size the reams of data from such surveys. An international collaboration has also been set up with Spain called the Javalambre Physics of the Accelerating Universe (JPAS) astrophysical survey, which will start taking data in 2015. Astronomers from the observatory are providing CCD cameras for JPAS's two robotic telescopes, currently being installed in Spain.

Small is beautiful

With attractive buildings and a delightful astronomy museum housed in the original main building, the observatory seems to be a pleasant place to work. "The good thing is that the observatory is relatively small and so it's easy to get things done," says deputy director Daniela Lazzaro. For example, she and her group installed a 1 m telescope at the OASI observatory in a remote corner of north-east Brazil – one of the few parts of the country that is dry enough to do astronomy. The telescope, which saw first light in 2011, is designed to study small bodies in the solar system and has so far surveyed several dozen asteroids in near-Earth orbits.

Lazzaro also organized the general assembly of the International Astronomical Union (IAU) in Rio in 2009, which was the centrepiece of the International Year of Astronomy. But she is perhaps best known as being one of a small group of astronomers that in 2006 spoke out against a motion at that year's IAU assembly to redefine the term "planet". Unhappy with the proposed definition, Lazzaro and colleagues suggested an alternative that led to Pluto being renamed a "dwarf planet". "I never particularly wanted to redefine Pluto, it's just that the original definition was so terrible," she admits.

The observatory also carries out a good deal of work with industry, including several projects using electro- and geo-magnetic techniques to map potential onshore and offshore oil reserves. These include projects with Brazilian oil giant Petrobras and the multinational BP, which bring in about R$6m ($2.5m) a year to the observatory's coffers. Indeed, Petrobras has already invested in a network of 80 seismology stations around the country to gain insight into the crust and upper mantle – information that could shed light on the structure of oil-bearing sedimentary basins.

One physicist working in this area is Sergio Luiz Fontes, who spent 10 years as observatory director until dos Anjos took over in 2013. Fontes thinks that many of his students enjoy working with industry and that jobs for technically skilled graduates are currently in ready supply. Indeed, he finds that his students are often tempted to leave while doing their Masters or PhD degrees. "They like going into industry and because unemployment in geophysics in Brazil is low, firms face stiff competition to pick the best graduates," says Fontes.

The work in geophysics has emerged from another of the observatory's original roles, which was to determine geographical locations in the country and study its climate. Staff went on many surveys early on to look for possible natural resources – indeed, Louis Ferdinand Cruls, who was director from 1881 to 1908, died after successive bouts of malaria while on trips to mark the border between Bolivia and Brazil. Thankfully, the current director faces few such personal dangers, although making the case for more government money given the huge sums being spent on the World Cup and Olympic Games in Brazil is perhaps an even bigger task.

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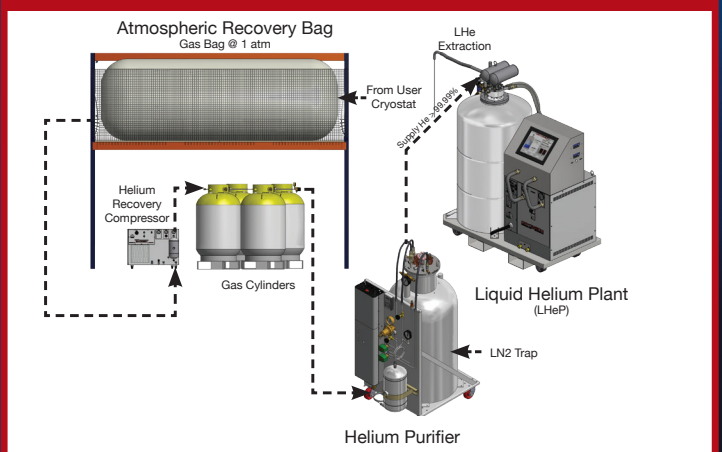

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