INTERVIEW WITH Stephen S. Eikenberry

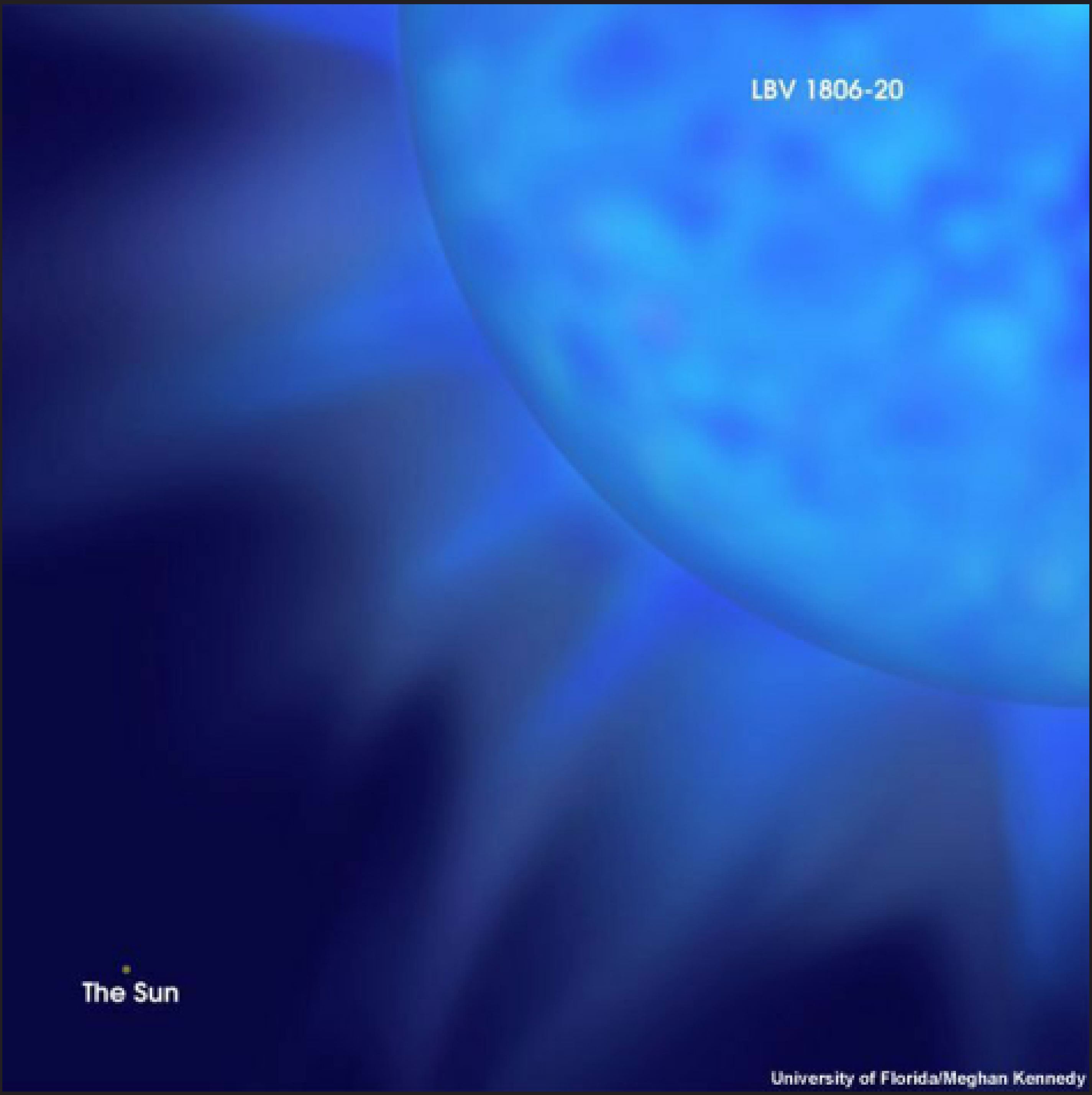
MONSTERS OF THE DEEP

<<The most massive stars pose problems that current theories cannot explain>>

By IVÁN JIMÉNEZ, of the IAC Director's Support Team

Sight, like our other senses, is barely capable of capturing the thin sliver of reality that surrounds us. That is to say, a thick blob, called our body, intervenes between us and reality. We cannot go anywhere without it, but neither can we penetrate too deeply because of its opacity. Astronomers, who specialize in distant objects, are very conscious of this problem. They have gradually perfected instruments that enable us to observe the night sky in the most efficient way until eventually arriving at spectroscopy, a powerful means of recording spectra, the rainbow in a drop of light. It seems that we can compensate for our myopia if, instead of looking at objects as mere images, we split their light into its component colours. The potential of spectroscopy is enormous, enabling us gather a great deal of information on any object, from the Galactic Centre to the most distant parts of the Universe.

Nevertheless, some celestial species remain hidden behind a sheet of cosmic dust, which impedes their detection. Such is the case, for example, with the «most massive stars», rare objects whose dimensions far exceed our imagination. As you might imagine, a universe without skirts is more exciting and to see it naked you need a key called infrared instrumentation. That is precisely the main area in which astrophysicist Stephen Eikenberry (University of Florida, USA) works; his fascination for everything related to what cannot be seen led him to specialize in the development of this kind of instrumentation, which is complex and still immature but promises to transform what we currently know about star formation.



At a distance of 49,000 lightyears, LBV 1806-20 is one of the most massive stars in the Milky Way, possibly weighing in at 200 solar masses (provided that it really is a single star).
Credits: University of Florida/Meghan Kennedy/Steve S. Eikenberry

How did you arrive at astronomy? Was it something you always wanted to do?
When I was a kid I was really interested in science. My mother says that at twelve years old, when I found out what an astronomer was I wanted to be one. I always liked the idea of being a scientist and working as an astronomer, but after majoring in physics at Massachusetts Institute of Technology (MIT) I decided to change to law in order to become a lawyer. After the first semester I knew that law was not for me and I went to work in Boston as a business consultant. Two years later, I finally completed the circle and arrive once more at astronomy. I studied at Harvard for my doctorate and am now happy to be an astrophysicist at last. I always had a great love for the night sky and astronomy, but the path I followed to reach my goal was a jagged one.

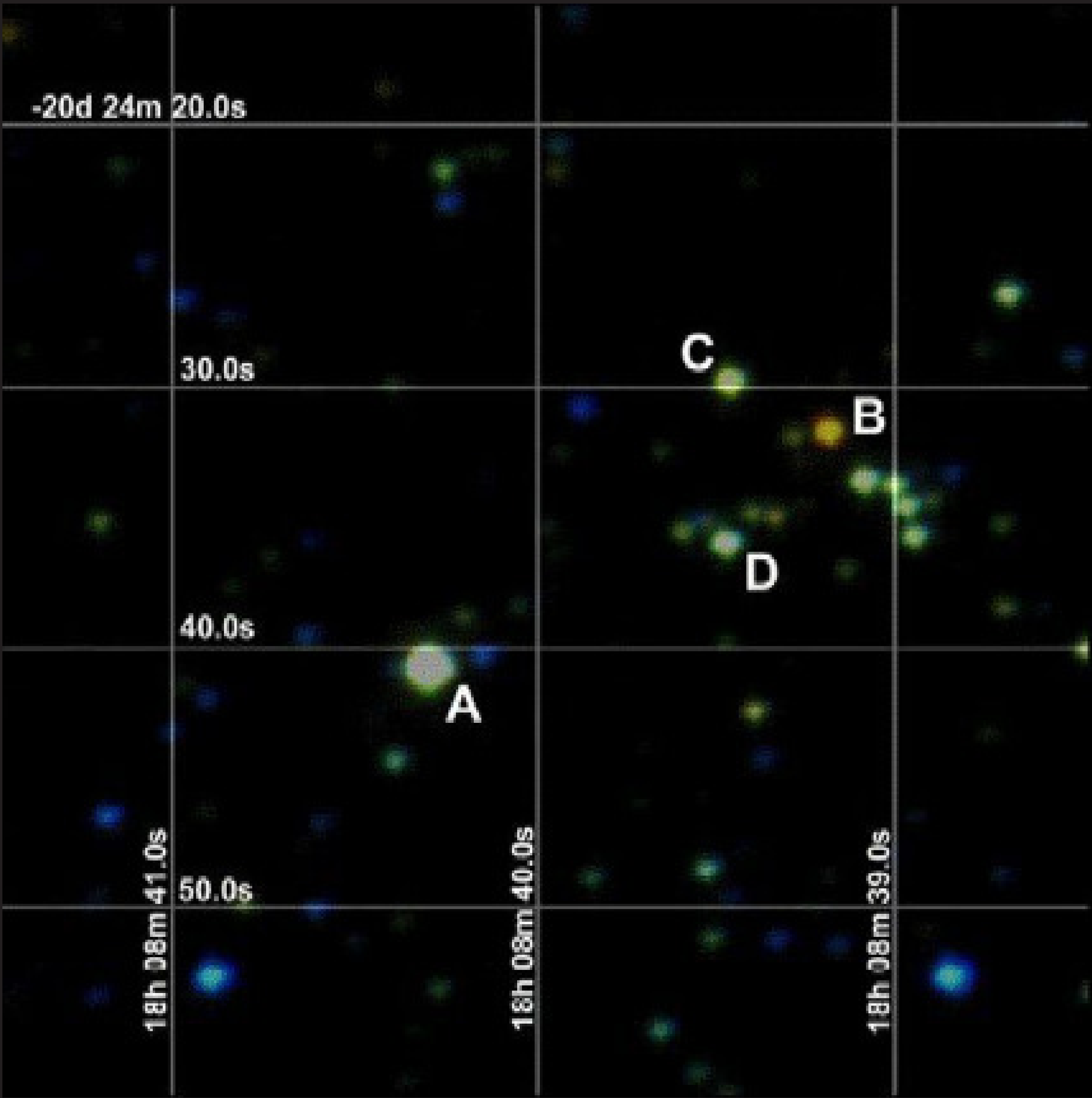
And what made you study law? Was it family pressure?
At the time I wanted to study law to get a job later; law is interesting, but above all the pay is very good. So I thought I would better be a lawyer, but it took only a few weeks for me to realize that I preferred trying to puzzle out the Cosmos. In the USA, intellectual lawyers do not earn a lot, so if the pay was the same I preferred astrophysics since it was entertaining and held greater intellectual attractions for me.

In your MIT phase you did two first degrees, one in physics and the other in literature. What attracts you to these two worlds, given that at the present time specialization has divorced them?
In the USA it is usual for us to study literature before doing a postgraduate degree in law. As I had not quite made up my mind, I did two degrees, one in physics and another in law; I then opted to study law for some time. Nevertheless, I have always been interested in the humanities and we are now incorporating them into our work in astrophysics. In September, for example, in Gainesville, where the University of Florida is located, we organized an event that combined art, music and dance with astrophysics. It was a great success and I believe that the integration of the humanities and the sciences is a very prosperous path that we should follow.

In your research you are particularly interested in black holes, microquasars, pulsars neutron stars, the most massive stars . . . all the least understood beasts in the Universe. Why this predilection for exotica?
Well, I am not sure why that is. I am drawn to strange things with extreme conditions. I have always had a liking for them. For example, in my talks I usually compare the most massive stars with the largest sharks in the sea, which I also feel a fascination for.

Not only do the rarest objects in the Universe fascinate you, but you have also specialized in the development of astronomical instrumentation, above all the most complex and least known, the infrared.
I regard instrumentation as a tool for doing the kind of science I want to do. For example, the most massive stars, black holes, neutron stars and microquasars are usually enveloped in the dust of galaxies and cannot be seen directly with optical instruments, whereas infrared has no problem in cutting through the dust. We also use X-rays in our research. I was originally working in that part of the spectrum, but I am now concentrating on the infrared.

The technique that has produced most results has been the use of infrared with the most massive stars. What are the properties of these stars and why are they so difficult to study?
Mass is the most important property of stars since it defines their temperature, colour, luminosity, brightness, how long they are going to live and what will happen when they die. The most massive stars are more luminous than other stars. For example, a star 10 times more massive than the Sun produces a thousand times more light per second than our star, and a star a hundred times more massive than the Sun is a million times more luminous. Galaxies are dominated in their light production by many more massive stars that have the property that, when they die, after a short life, they explode as a supernova, the most powerful kind of explosion next to the Big Bang. The most massive stars create elements



Near-infrared image. LVB 1806-20 (A) is located in a star cluster that contains other extemely massive stars.
Credits: University of Florida/Eikenberry

in their centres that are heavier than hydrogen and helium - elements such as oxygen, nitrogen, carbon, iron and silicon. which are important elements for us. For example, we breathe a mixture of nitrogen and oxygen. Your skin and body contain carbon. If you go to the beach the sand is made of silicon and the seats on which we are sitting now are made of iron. We are dealing, in other words, with the main ingredients of the Earth and they all originate in the centres of the most massive stars - hence the expression that we are made of stardust. We think that all stars are formed in molecular clouds in galaxies, highly dense regions containing a lot of dust, making it difficult to see them in the visible, but they are easily seen in the infrared. The most massive stars also have very brief lives and die before they can leave the cloud.

How do these stars fit into current theories of star formation? Do they challenge the models?

Yes, they certainly do. We don not yet know the details. The most massive stars form from the lowest mass stars like the Sun. We have some simple theories for the limits on star formation that say stars cannot be more than a 100 times the mass of the Sun. In practice, though, we are finding stars between 130 and 150 times the mass of the Sun. The truth is, there is not just one but we have found three, two of them recently discovered using infrared technology, which shows the importance of continuing with this mode of observation. So theories are not yet clear enough to explain the Universe we are observing; there are stars more massive and stars that are smaller than the Sun.

At first doubts arose as to whether we were dealing with a single star or a group of stars. Do we really have an answer to this problem yet?

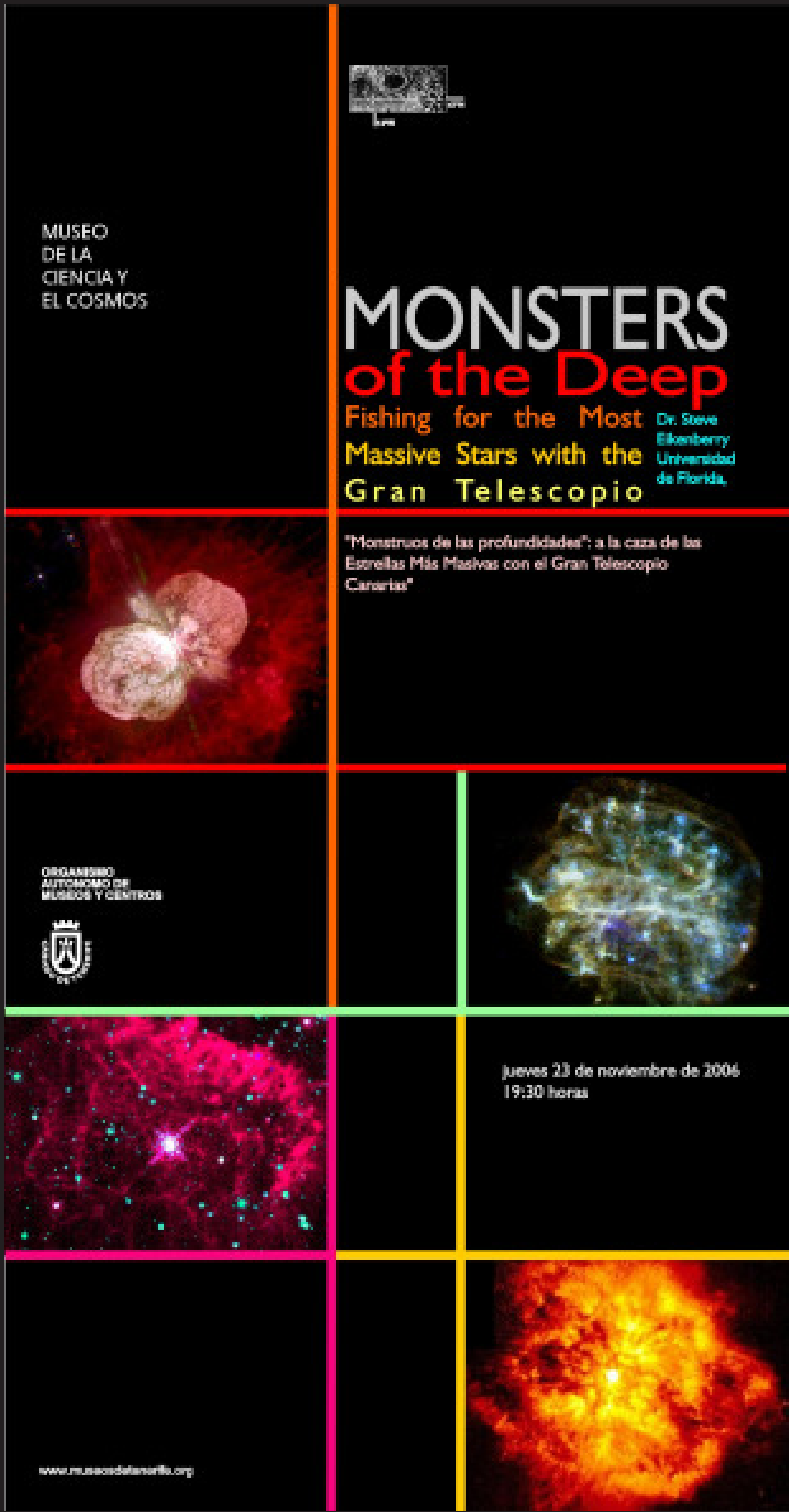
Of the three most massive stars we have discovered, we know that one is a binary system, the second is also possibly binary and the third, we don not know. It is highly probable that all three are binaries, but the problem is still unresolved. If they are binaries, they are very close and it does not matter whether they are two stars with 80 solar masses or one star with 160 solar masses. Theory says that neither case is possible. We also know that the radiation pressure and luminosity of a star depend on its mass, so you cannot just divide a 150 solar mass star into two 75 solar mass stars because that would give only half the luminosity that we see. To get a star of 150 solar masses you would need at least two of 100 solar masses, and that is almost theoretically impossible.

For the last year you have been involved in the development of Flamingos 2 for the Gemini Observatory. What is the main new aspect of this instrument compared with others in its class? What sort of science will be able to be done with it?

As its name suggests, Flamingos 2 is the second in a series. Flamingos was the first cryogenically cooled multi-object spectrograph for the infrared. It can take an hour to get the spectrum of a galaxy or star, so you would need three hours to study three objects. Well, with Flamingos you can study around 45 stars simultaneously, so in eight hours you can capture 450 stars. Flamingos 2 is similar to Flamingos but is much bigger and is optimized for 10 metre-class telescopes (the first Flamingos was built for 4 metre telescopes). In other words, it is four times more powerful than Flamingos and, because of that, it is going to do things that we could not do before. For example, in the centre of our Galaxy we want to study how it can be possible for there to be a black hole of more than 3 million solar masses. It turns out that almost all galaxies have black holes at their centres, but we do not know why. How can black holes of this mass be created? The theories tell us that the stars surrounding the black hole can give us information about this question. At the moment, with telescopes like Gemini and the GTC, you need an hour to study one star. If we wanted to study thousands of stars to understand the process that made the black hole it would be impossible since it would require almost 300 nights, a year´s large telescope time just to pursue one project. But with Flamingos 2, we can study more than 4000 stars in a single week.

A year ago you also presented the CIRCE project to the Scientific Committee of the GTC. What is CIRCE and what progress has there been in the project?

It is a cryogenically cooled infrared instrument for the GTC. It is an imaging camera and is designed to complement the capabilities of EMIR, an instrument similar to Flamingos 2, but it is envisaged that it will be available one or two years


MUSEO
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Fishing for the Most
Massive Stars with the
Gran Telescopio
Dr. Steve
Eikenberry
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de Florida.
"Monstruos de las profundidades": a la caza de las
Estrellas Más Masivas con el Gran Telescopio
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into the active life of the telescope. Hence, in the telescope's first years there will be no near-infrared project. But the role of CIRCE is going to be to provide a bridge between the first days of the GTC and EMIR.
EMIR is going to be very powerful, but the imaging of the GTC will be limited by the instrument and not the atmosphere. CIRCE is not so powerful, but it has a very fine pixel scale and a very good image quality, limited only by the atmosphere. In other words, when the observing conditions are especially good CIRCE will be able to do things that EMIR cannot. There are also projects that require the use of narrow-band filters; for example, the most distant galaxies in the Universe. EMIR, because of its optical design, cannot work with these kinds of filters, whereas CIRCE is specifically designed for them. In short, CIRCE will be a very important instrument and will be available before EMIR is commissioned, but even when EMIR is up and running CIRCE will still offer capabilities that will serve to complement those of EMIR.

Out of curiosity, does the name bear any relation to that of the witch in the *Odyssey* who turned Odysseus' crew into swine?

(Laughs) I came here in November four years ago to propose this project, but I did not have a name for it and it is always a good thing to have one to identify a project. So I was thinking of a way to relate the Canaries with the infrared, and I recalled that Circe was a witch who lived on an island in the middle of the sea. It was my first trip to the Canaries, a group of islands in the middle of the sea, so I decided to give the project that name. Regarding the pigs, it is possible that many astronomers will want to use the instrument and will fight among themselves and behave in a way to warrant the name!

Some months ago you participated in the third international conference on *Science with the GTC*, which took place in Florida. How do you rate the suit of instruments that will be launched together with the telescope?

The conference was a great success in that it enabled us to share perspectives. I think the instruments are now on schedule and will be very powerful. Last week I went to La Palma to see the telescope and I was very excited after the visit. We now have a telescope and soon there will be mirrors! We are very happy. People are now more enthusiastic. For that reason the meeting was very important in terms of planning and establishing scientific collaborations that will be fundamental in the first days of the telescope and will demonstrate the success of the GTC.

Do you think the delay the GTC has suffered is usual in any project of this scope?

Yes, of course. On the level of funding, human resources and time, these are projects that can be compared with any large engineering project such as building a bridge or a nuclear power station, but they also represent a totally new kind of technology. With projects involving technological development, it is much more difficult to predict how much time will be needed. Historically, all big projects have experienced overruns. For example, the Palomar 200 inch, one of the most famous telescopes in history, was 10 years late; the Kecks were also delayed by some years; the famous Hubble was delayed by almost ten years; and ESO's VLT, probably currently the best telescope in the world, were ready 4 or 5 years later than planned. The 2 or 3 years' delay of the GTC is not at all unusual; in fact, it is quite normal.

You also participated in the Telescope Evaluation Committee meeting that took place in the IAC. What was the meeting about and what conclusions were reached?

It was a very good meeting and a very important one for the IAC. Our main conclusion was that the GTC and the recent incorporation of Spain into ESO will revolutionize astrophysics in Spain, and the panorama will be very different from what it is now. A series of recommendations was made about how Spain and the IAC should prepare for this revolution, which will occur in the coming years. Besides debating what this future would be, we also interviewed scientists and technicians in the IAC to get their ideas and to assess which of these might better optimize the scientific returns.

Let us talk about the Winter School. What do you consider to be its main virtue?

Its main advantage, I think, is that it last for a fairly long period - two weeks - and the lecturers can spend a lot of time with the students; they eat together, carry out activities together and live in the same hotel, so a good rapport is struck up. It is a great opportunity for the students and one that is hard to find in other surroundings.

This year's theme is emission lines. In what way are these useful and what can they tell us about the Universe?
They are fundamental in their capacity to provide information about a wide range of celestial objects. For example, the Sun might seem like a plain yellow disc, but from its iron emission lines, just to give an example, you can learn about the magnetic storms on its surface. With emission lines we can also learn what celestial objects are made of, how they move, their velocities, their temperatures. . . from massive stars, to the Sun, the galaxies themselves or the end of the Universe.

There is no doubt that, with your experience in astronomical instrumentation, your presence at the School is a great privilege for the students. How have you planned the course you are about to impart? What aspects will you insist on?
I am going to talk about Galactic objects. But there are many completely different kinds of Galactic objects, so I will give a panoramic overview of planetary nebulae, supernovae, massive stars, star formation and black holes, and then I shall concentrate on the infrared, since to study these objects a considerable amount of dust must be penetrated. I wil only give a bit of theory -other lecturers will be covering these aspects - and I prefer to deal with practical information.

What is the main idea that you would like to share with the students, and that you would like them to take with them at the end of the course?
They should know that there are things in our Galaxy that are worth studying. They should also understand the usefulness of the infrared, which is a new field based on a technology that is not very mature, developed over the past decade. Many astronomers tend to avoid the infrared because they do not understand it. And I would like the students to return to their home institutions knowing that it is very important to do research in the infrared, and that the technology is there to do it.