attract the most clever minds among future generations.

The UK has a long and successful history in our science, with many trailblazing results by theoreticians and observers, and we are proud and happy to welcome it to ESO. Together we have an enormous potential for new breakthroughs.

Minister Sainsbury, we would be very happy to welcome you at Paranal. Do come and experience that unique atmosphere. Do sit down at the telescope controls and let us look together towards the end of the universe and the beginnings of time!

ESO AND THE UK

Why Does the UK Need More Astronomy?

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"What was God doing before he made heaven and earth? … He was preparing hell for those who would pry into such profound mysteries."[1] This joke was already venerable when quoted by Augustine, in his analysis of the ancient and still modern problem, time.

Understanding the origin(s), meaning(s), future(s), and significance(s) of time, space, existence, mass, matter, geometry, of origins and endings, of what and where, remains one of the greatest intellectual endeavours of the human mind. From the caves of Lascaux, through the megaliths of Stonehenge to the dreamtime of Australia, mankind has striven to understand his origins and future. Our generation has the exceptional good fortune to be living through the greatest increase in knowledge relevant to these fundamental questions since someone first looked up at night. We are also increasing understanding, while realizing how much more there is in the Universe still be learned and understood.

Even more wonderful (*sic*) for us, our rate of progress in knowledge is accelerating, as the technological advances resulting from research into basic science feed back positively in turn to advance basic knowledge more rapidly. This is truly a golden age of discovery in astronomy, with almost every class of object we study having been discovered in our working lifetimes.

Why is it so? There are two dominant reasons: technology and people, but only one explanation: efficiency. The astronomical community is at most one order of magnitude larger by number than it was a generation ago: a significant, but not huge advance. Astronomical telescopes today provide the real advance, with not only a very considerable increase in mirror collecting area, but a vast increase in detector area, detector quantum efficiency/sensitivity, and image quality. Each modern large telescope is both vastly more sensitive, and vastly more efficient, than were 4-metre-class telescopes 20 years ago.

It is this huge increase in generation of high-quality data which drives current progress in astronomy. Consequently, the community with the best technology has the best opportunity to discover the new, and has a head-start in attracting bright young people to science. But it is not just a question of wealth buying power: the huge technological investment of Tycho and Kepler reached its scientific fruition with Newton. Real scientific progress, as that example reminds us, requires both technology and people, complementary approaches, and trans-national collaborations. And it works best with a spice of competition.

Considerations like those above led to the formation of ESO (cf. *ESO's Early History*. A. Blaauw) and the formation of La Silla Observatory, and led the UK to found collaborative observatories in Australia, South Africa, the Canary Islands, Hawaii and Chile. (Radio and space astronomy have their own history and set of personalities, and are not considered in this article.)

A significant motivation in development of these observatories was an attempt to regain international research leadership in astronomy. For whatever mix of reasons, Europe, including the UK, fared much less well relative to the US in astrophysics research in the early 20th century than it did in, for example, quantum theory and relativity.

UK and European astronomy: a micro-history

I am not aware of the factors considered when the UK decided to develop its astronomy independently from ESO, through bilateral partnerships, but by 1980, when I arrived in the UK, it was obviously a successful policy. The Anglo-Australian telescope, with its marvellous IPCS photon-counting system, the UK Schmidt Telescope, complemented by the APM (Cambridge) and COSMOS (Edinburgh) measuring machines, the UK InfraRed Telescope (UKIRT) and the beginnings of the JCMT sub-mm telescope on Hawaii, and the Isaac Newton Group on La Palma were world-quality facilities quite sufficient to challenge those of us fortunate enough to be let loose on them.

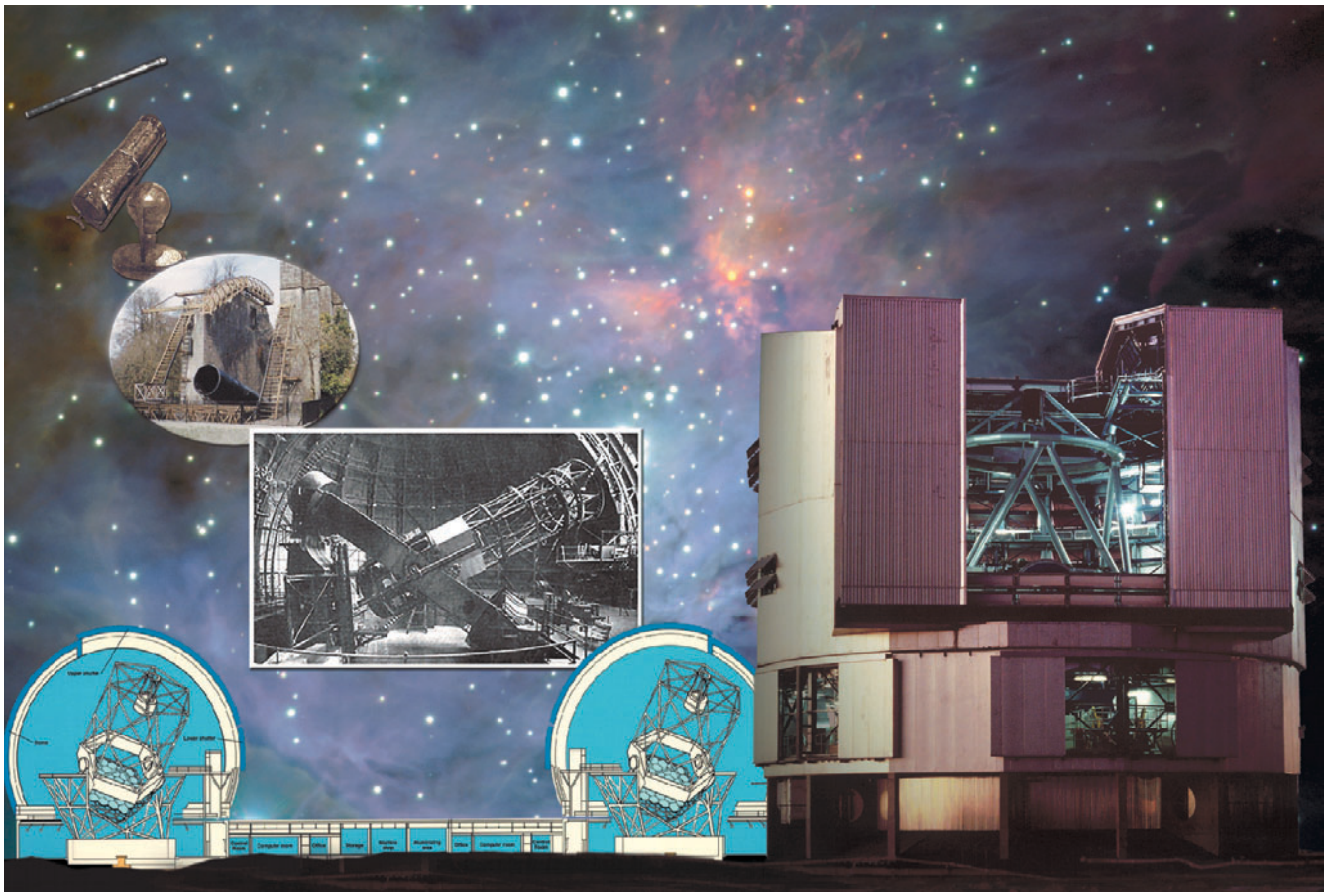
These observatories were (mostly) international partnerships, with the UK the largest partner. Next came Gemini, two superb 8-m telescopes, with the UK as a 25 per cent partner. And most recently ALMA, with the UK as (roughly) 20 per cent partner inside the European-wide 50 per cent share. Why the systematic decrease in share? Why is Gemini on-line so long after Keck? Simple: money.

Sometime around 1990 optical/IR astronomy became too expensive for one country, even one as large as the UK. But something else more fundamental changed too. 'International astronomy' began to mean more to UK astronomers than 'astronomy in the former British Empire', or 'trans-atlantic astronomy'. Routine collaboration between institutes in the UK and in continental Europe was less common than was collaboration with the US. But this began to change.

Of course, many European countries besides the UK had close scientific links across the Atlantic: the effect of the Netherlands on US astronomy is a famous exemplum. The European (largely Italian) *diaspora* who made the Space Telescope Science Institute in Baltimore so much more than just another NASA center is a major example of the happy internationalization of astronomy. Cheap and easy travel was of course another factor. As was the lesson from space science and radio astronomy, which had much earlier crossed the 'unaffordable by one country' barrier. All these factors changed the assumption, and encouraged UK astronomers to look more widely for competition, and for colleagues.

And what did we see happening in

[1] *'Quod faciebat Deus, antequam faceret caelum et terram?' Respondeo non illud quod quidam respondisse perhibetur, ioculariter eludens quaestionis violentiam: 'Alta' inquit 'scrutantibus gehennas parabat'*. Augustine, *Confessions* XI xii 14.



An illustrative view of the development of astronomical telescopes. From the top left, the telescopes of Galileo, Newton and Birr Castle, reflecting European technological innovation and dominance in astronomy until the twentieth century. Mt Wilson and the two Keck telescopes are typical of the dominance of telescope technology by the private US observatories through the twentieth century. Finally, the VLT sets the standard of excellence at the start of the 21st century.

continental Europe: by the late 1990s European astronomy was not only not ignorable, it was seriously good, and about to become outstanding. This was only in part a technological change. There was one other structural change, still only in its earliest stages in some countries, which perhaps had the largest positive effect: the move away from tenured positions on completion of a PhD to an assumption of a postdoctoral position, or several, in different institutes and countries, between degree and job. It is postdocs who really move around, who naturally, through re-location, become part of multi-Institute collaborations, and who really link communities.

Also important was the effort made by key individuals: for example, Simon White (then in Cambridge), Alain Omont and George Miley founded EARA, the European Association for Research in Astronomy, a formal link between Cambridge, Paris and Leiden (now extended to include MPA Garching and IAC Tenerife). Specific initiatives such as EARA, together with the sociological change which forced young astronomers to move around, had a big and positive impact. The Institute of Astronomy in Cambridge provides one very clear illustration of the changed balance between the UK and continental Europe. In 1992, the IoA had 50 postdoctoral fellows, about one-half from outside the UK, of whom 4 were from Western Europe (one each from Greece, Italy, Norway and Spain). In 2002 the IoA has 70 postdoctoral fellows, of whom 22 are from Western Europe. In addition, 6 European-registered PhD students (on an EARA/Marie Curie EU-funded programme) are visiting. The change is dramatic, from 8 per cent to 30 per cent, and UK astronomy is very much better for it.

With this background, one can now answer the question: why did the UK join ESO. As shown above, over a decade close and real scientific partnerships were developed. The unknown was replaced by mutual respect. This was a necessary but not sufficient condition. Then something much more important happened: the VLT.

The VLT changed everything

As it became clear that ESO really was delivering the world's finest large telescopes, UK astronomers realized they needed to be part of ESO. This unfunded ambition was complemented by development of ALMA, in which the UK was an active participant. It was always clear that ALMA would be a world-scale facility, and that ESO was the natural Europe-wide organization to build and operate it, so that some sort of a partnership between the UK and ESO would happen. Fortunately, the UK is currently in a period of relative wealth, and has a government supportive of all of excellence, science, and Europe. The conditions came into phase ideally, and here we are in ESO!

Will the UK change ESO?

This question has been raised a few times! My answer is purely personal. I think the UK will change ESO: the last big European country is in, this is the biggest change ESO will experience in the forseeable future. Much of the change will be cultural. UK astronomers have a somewhat more aggressive attitude to publishing than do some other communities. There is in the UK a significantly larger bias than in some countries towards studies of the poorly known: dark matter, inflation, galaxy formation… rather than more detailed studies of known objects. UK astronomers tend to question extant structures and priorities rather more than do some other communities. For example, some have asked if VLTI developments are proceeding on a timescale and scientific cost-benefit basis which is maximally appropriate to

today's financial and facility situation. I know many UK astronomers want the next-generation European Large Telescope sooner rather than later, even at the cost of other priorities. "We didn't join ESO to let the US leave us behind again", is a common refrain. ALMA must be made a success. But, most of all, the astounding VLT must be used to deliver the exciting science for which it was built. On that, I am sure all of us in ESO agree.

What does Europe get from the UK

In the preface to his translation of St Gregory's 'Pastoral Care', King Alfred (c. 890) commented "Learning had declined so thoroughly in England that there were few men on this side of the Humber who [could] even translate a single letter from Latin into English. There were so few [men of learning] that I cannot recollect even a single one south of the Thames… I recollected how – before everything was ransacked and burned – the churches throughout England stood filled with treasures and books. … And they derived very little benefit from them because they could understand nothing of them, since they were not written in their own language. I wondered exceedingly why the good wise men who were formerly found throughout England, and who had thoroughly studied all those books, did not wish to translate any part of them into their own language. But I immediately answered myself, and said: 'they did not think that men would ever become so careless, and that learning would decay like this.'" [Ref. King Alfred's Preface to Gregory's 'Pastoral Care', tr. M. Lapidge and S. Keynes.]

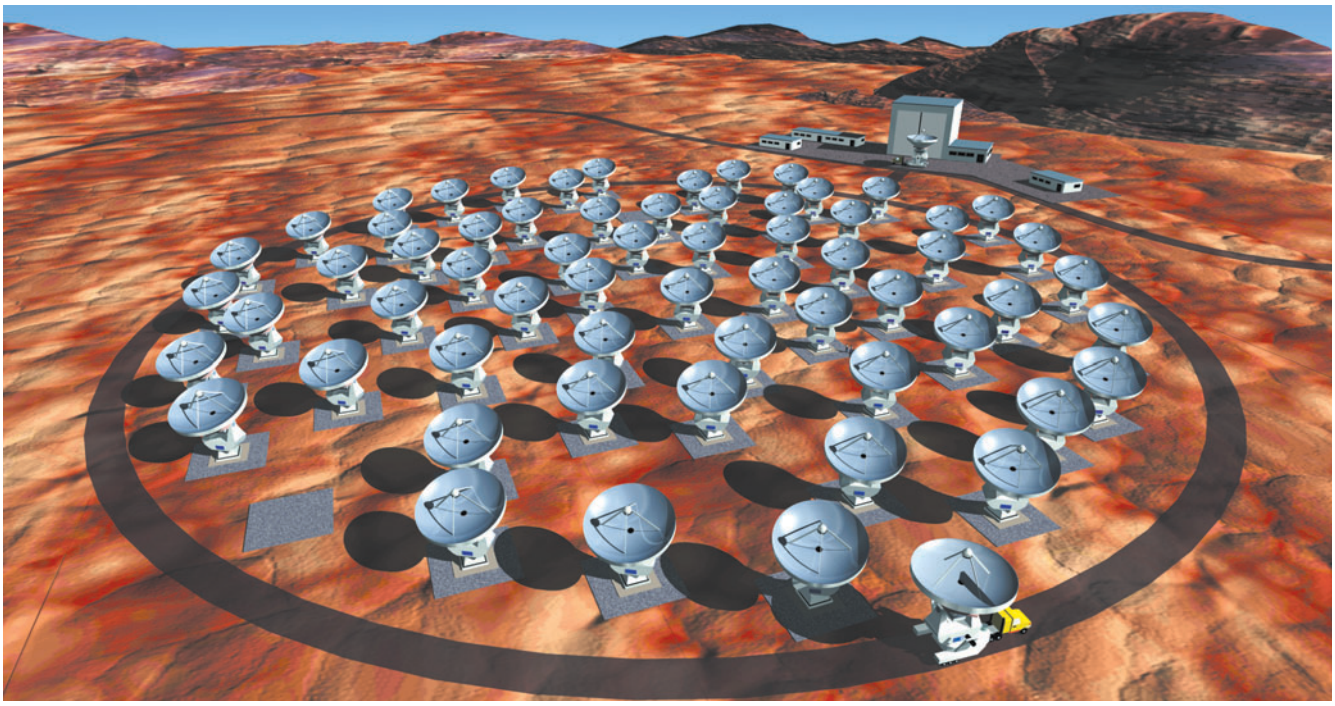
There is a school of thought which asserts that Britain's occasional drifts into barbarity and ignorance correspond to isolation from Europe: Romans civilizing, post Roman Dark Ages; Vikings exciting, later Alfred's lament; Normans enlivening, medieval black death. Even the quintessential British hero, King Arthur, is associated with Saxon and Angle introductions of new ideas. Gildas, in his subtly-titled *De Excidio Britanniae* (On the ruin of Britain), writing c. 540, at the time Arthur is frequently supposed to have existed, describes the coexistence of Saxons and Britons, leading to the rise of Anglo-Saxon England.

We look forward to the next stage of coexistence: astronomers across Europe, now including the UK, uniting in progress, and working together for the future across a whole continent.

***TABLE: Who does astronomy in the UK**. Astronomy research groups exist in many UK universities. An approximate identification list, with a crude indicator of size, can be found by noting which groups are supported by PPARC (the sole national UK funding agency for astronomy). The table lists all groups funded by PPARC at present, and the number of associated grants. The number of grants is a very crude indicator of group size, but it must be noted that this list includes space hardware groups, solar system research, and some upper-atmospheric physics. More specific information can usually be found on www pages.*

Organization	Number of grants	Organization	Number of grants
Armagh Observatory	6	Nottingham University	10
Bath University	1	Open University	9
Birmingham University	12	Oxford University	12
Bristol University	7	Portsmouth University	2
Cambridge University	35	Queen Mary and Westfield College	12
CCLRC (Rutherford Laboratories)	2	Queen's University of Belfast	8
Durham University	17	Reading University	1
Edinburgh University	10	Sheffield University	8
Exeter University	4	Sheffield Hallam University	1
Glasgow University	5	Southampton University	15
Hertfordshire University	5	St Andrews University	15
Imperial College	20	Surrey University	1
Keele University	2	Sussex University	3
Kent University	7	UK Astronomy Technology Centre	3
Lancaster University	4	UMIST	4
Leeds University	9	Univ of Central Lancashire	5
Leicester University	19	University College London	40
Liverpool John Moores Univ	8	University of Wales Cardiff	17
Manchester University	8	Univ of Wales, Aberystwyth	2
Natural History Museum	2	Warwick University	2
Newcastle University	1	York University	3

Note: 'Number' is the number of current grants at the institution; taken from the PPARC webpage http://www.pparc.ac.uk



ALMA: the next major ESO project.