ANDREW LAWRENCE

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The IfA is part of the University's School of Physics and Astronomy and co-located with STFC's UK Astronomy Technology Centre, on the historic site of the Royal Observatory Edinburgh (ROE). Today, the term "ROE" refers to the combination of IfA, ATC, and the ROE Visitor Centre.

Career

Born Margate, Kent, England April 23rd 1954.

Schools	Drapers Mills Infants and Juniors, Margate, Kent Chatham House Grammar School, Ramsgate, Kent
1972-76	Dept of Astronomy, University of Edinburgh BSc Astrophysics
1976-80	Dept of Physics, University of Leicester PhD in X-ray Astronomy
1980-81	Centre for Space Research, Massachusetts Institute of Technology Exchange Scientist
1981-84	Royal Greenwich Observatory Senior Research Fellow
1984-87	School of Mathematical Sciences, Queen Mary College, Univ. London SERC PDRA
1987-89	School of Mathematical Sciences, Queen Mary College, Univ. London SERC Advanced Fellow
1989-94	Dept of Physics, Queen Mary and Westfield College, Univ. London Lecturer
1994 -	Institute for Astronomy, Univ. Edinburgh Regius Professor of Astronomy
1994-03	Head of Institute for Astronomy, University of Edinburgh
2003-08	Head of School of Physics, Univ. Edinburgh
2008-09	Visiting Scientist, Kavli Institute for Particle Astrophysics and Cosmology (KIPAC), Univ. Stanford
2009-	Affiliate member, KIPAC, Univ. Stanford

Professional Bodies etc

Fellow of Royal Society of Edinburgh
Past Fellow of Royal Astronomical Society (have been Vice President)
Trustee of Royal Observatory (Edinburgh) Trust (currently Chairman)

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Summary of Interests and Activities

- Active galaxies and quasars
- Survey Astronomy
- Space Environmentalism
- Observational cosmology
- Astronomical e-science
- Public Engagement and Outreach
- Teaching: especially Introductory Astrophysics; and Statistics
- University Management and Administration
- Science Policy and Governance

Publications

Over 320 published articles, reports, etc in scientific journals.
Over 22,000 citations; h=75; 54 papers with >100 citations
Two textbooks, one popular book, and one short historical book.
List of refereed papers below. A live linked list can be found at
https://ui.adsabs.harvard.edu/public-libraries/mlwlel8sQyKz47t84JAEZg

Active Galaxies and Quasars

My main focus at the moment is on time domain studies – extreme variability such as Changing Look Quasars (eg MacLeod et al 2019), slow-blue hypervariables (Lawrence et al 2016), long term evolution of AGN emission lines (Homan et al 2022), and Tidal Disruption Events (eg Short et al 2020, 2022). I also work on the fundamental problems of AGN models (Lawrence 2012, 2018).

Historically, I am an authority on AGN classification schemes, and their physical meaning. Highlights include one of the earliest papers on the importance of obscuration (Lawrence and Elvis 1982), an influential review paper (Lawrence 1987), the receding torus model (Lawrence 1991), and more recent papers proposing that AGN obscuration is not caused by a molecular "donut" but by a warped disc arising naturally from chaotic accretion (Lawrence and Elvis 2010; Roseboom et al 2013). A second long term interest is AGN variability. I showed that AGN X-ray light curves are scale free "1/f" noise (Lawrence et al 1987), showing a power spectrum with universal shape but amplitude depending on luminosity (Lawrence and Padakis 1993) and cosmic epoch (Almaini et al 1991). With Iossif Papadakis I developed an improved method of estimating power spectra in the presence of "red noise", which has been applied in other areas of astrophysics (Papadakis and Lawrence 1993). This area has been recently revived with the study of Tidal Disruption Events (Gezari et al 2012, 2016), changing look quasars (MacLeod et al 2016) and the discovery and study of AGN "hypervariables" (Lawrence et al 2016) which will be the main focus of my research for the next few years. I have also done innovative work on Spectral Energy Distributions (SEDs) and their explanation. In Rokaki et al (2003) we showed that brightness and velocity width versus viewing angle in superluminal sources agrees well with accretion disc predictions; in Kishimoto et al (2008) we used spectropolarimetry to finally reveal the long sought $\nu^{1/3}$ spectrum expected from accretion disc models. These accretion disc successes apply to long wavelength; in the ultraviolet, accretion disc models fail several key tests. In Lawrence (2012) I set out a new model proposing that the observed UV peak is a local maximum caused by refection from clouds surrounding the accretion disc, with the true peak in the EUV .

Survey Astronomy

My main current activity is working as part of the LSST:UK consortium, the UK's contribution to the Vera Rubin Observatory and the associated Legacy Survey of Space and Time (LSST). In Edinburgh we are constructing a full Data Access Centre (DAC). As well being part of the DAC team, I am co-PI for Lasair, the UK's event broker – a collaboration between Edinburgh and Queens University Belfast. Lasair has been prototyped on the Zwicky Transient Facility (ZTF) data stream, and so is already being used for science on a daily basis, producing supernova, TDE, variable star, and AGN alerts.

From my PhD studies onward, I have been involved in ground-breaking large scale surveys of various kinds - all sky X-ray surveys with Ariel V (Warwick et al 1991, McHardy et al 1991); IRAS galaxy redshift surveys (Lawrence et al 1986, 1999); faint radio galaxy surveys (Benn et al 1993); SCUBA submm surveys (Hughes et al 1998, Scott et al 2002); and large scale IR surveys (Lawrence et al 2007). My involvement has been in all of survey construction, scientific exploitation, and the technical issues of curating and serving extremely large databases, which led into my interest in e-science. In more recent times my role has been in survey leadership and management. This came about through the creation of the Edinburgh Wide Field Astronomy Unit (WFAU) during the reconstruction of the UK observatories. I pushed three key projects - using SuperCOSMOS to complete an all-sky multi-colour online digital sky survey from UK Schmidt and Palomar plates (Hambly et al 2001); carrying out a 2MASS-based southern sky redshift survey with 6dF; and a large area deep IR sky survey, the equivalent of SDSS for the IR. The latter snowballed into a project involving the majority of UKIRT time and a hundred and thirty astronomers from across Europe : the UKIDSS project, of which I am the PI (Lawrence et al 2007). The data are available through a public database. UKIDSS has produced hundreds of papers, and even several years after survey completion, the UKIDSS database receives several thousand queries per day. There have been many scientifc achievements, but the best publicised was the discovery (as planned) of the first $z>7$ quasar (Mortlock et al 2011).

The WFAU now also delivers data and technical solutions for VISTA and GAIA, and is building next generation databases for EUCLID and the Vera Rubin Observatory/LSST.

Space Environmentalism

This is a relatively new activity. During 2019, like many other astronomers, I became alarmed at the sudden increase in streaks appearing in optical astronomy images, and especially the possible impact on LSST. As I researched the issue, I realised there are much broader issues – for radio astronomy, for public stargazing, indigenous rights to the sky, runaway debris danger, commercial fairness, damage liability, and more. I wrote a popular book (Losing The Sky) and have carried out many associated public awareness raising events, including developing plans with several collaborators for a UN-backed "Near Space Environment Day". I then became involved in a US legal case, writing an "Amicus Brief" arguing that space licensing should be subject to standard environmental legislation. This then morphed into a scientific article "The Case for Space Enviromentalism" (Lawrence et al 2022), and as a result of that, I have joined the Satellites and Space Working Group of the "Digital Environmental System Coalition" which is part of the UNESCO Chair on ICT4D.

In the near future, my aim is to begin more technical work in this area, including using a rooftop camera at ROE for Space Situational Awareness studies, building on earlier WFAU work with Lockheed Martin software for orbital debris recognition and characterisation.

Observational Cosmology

With Michael Rowan-Robinson, I made the frst spectroscopic survey of IRAS galaxies (Lawrence et al 1986), producing the first FIR galaxy luminosity function, and showing that ultraluminous IR galaxies are far more numerous than quasars. This work led onto the QDOT redshift survey collaboration with a number of luminaries (Lawrence et al 1999), with key results on large scale structure and its disagreement with cold dark matter (Efstathiou et al 1990, Saunders et al 1991), the IRAS galaxy dipole and the value of Omega (Rowan-Robinson et al 1990), and the local galaxy velocity feld (Kaiser et al 1991). Follow on survey work led to the discovery of the most luminous object in the Universe, IRAS F10214+4724 (Rowan- Robinson et al 1991) which I argued was roughly fifty-fifty starburst and hidden quasar (Lawrence et al 1994). This z=2 object was the precursor of the submm galaxies discovered by SCUBA. The UK submm survey team (including myself) showed that such "hyperluminous" galaxies dominate the total star formation rate at z=2-5, a crucial result for understanding galaxy formation (Hughes et al 1998, Scott et al 2002). I also wrote a paper which examined carefully the possibility that the large fraction of unidentifed SCUBA sources might not be high redshift dusty galaxies, but cold dark clouds inside the Galaxy, and a key component of dark matter (Lawrence 2001). During the 1990s I also worked with collaborators on the nature of faint radio sources, making the frst spectroscopic confrmation that submJy radio sources were starburst galaxies (Benn et al 1993) and that they evolved strongly (Rowan-Robinson et al 1993). I later returned to this issue, co-writing a paper (Singal et al 2010) showing that the recently discovered cosmic radio background requires extremely large numbers of high redshift but low luminosity galaxies. This is apparently in confict with the idea that mega-starbursts dominate high-z star formation, and is a signifcant puzzle.

Astronomical e-Science

Since 2002 I have been an international leader in the development of the Virtual Observatory (VO) concept, which is part of a wider multi-disciplinary push towards e-Science. My involvement came partly from my long standing preference for multi-wavelength astronomy, leading to a desire to design ways to make it easier to find, combine, and analyse data from many different facilities in a seamless fashion over the internet; and partly from wishing to solve the technical problems caused by increasingly large datasets such as UKIDSS and SDSS. The VO vision developed very rapidly. I led the UK AstroGrid project over 2002-2009 which developed a complete technical infrastructure, working services, and VO tools for astronomers. This led on to a related Europe-wide initiative, Euro-VO, and involvement in a sequence of EC-funded data science projects, the latest of which is ESCAPE, which combines developments in particle physics, nuclear physics, and astronomy. AstroGrid was a founder member of the International Virtual Observatory Alliance , the global standards body. I am a member of the IVOA Executive and was for a while its Chair. As well as leadership, management, and fund raising, my key role in AstroGrid was in working closely with engineers on tool design.

The various e-science initiatives led me into collaborating with computer science colleagues, both on the academic side, and in industry, especially with Microsoft, Oracle, and Google, with the emphasis on database performance and AI approaches to "junk" filtering. We also had many interactions with colleagues in bio-informatics and particle physics, trying to identify commonalities and differences in our e-science issues – for example I was co-PI of an STFC funded project called Astrotrop, partnering with scientists working in tropical forest monitoring and related issues such as biomass and carbon density measurement, and aimed at re-purposing VO concepts and technologies to advance data access and exploitation in these key areas.

Public Engagement and Outreach

I maintain a keen interest in Public Engagement. As well as schools and society talks and so on, I have been involved in several arts collaborations, including a multi-media show with composer Matt Giannotti, helping Guillermo Carnero-Rosell to make a film about Charles Piazzi Smyth, and setting up an exhibition at the Nelson Monument that had 63,000 visitors. Most recently this has led to a policy role, acting as Director of Community and Public Engagement for the School of Physics and Astronomy.

Over my career, I have given many public talks - to science festivals, on schools visits, to amateur astronomy societies, and as part of programmes organised by the Royal Observatory Edinburgh Visitor Centre, such as the regular Winter Talks series, and the annual open days, which attract several thousand local residents over a single weekend. I also participate in other ROE Visitor Centre activities such as the use of rooftop telescopes and touring the inflateable planetarium to schools. (These two activities were originally initiated by project funds raised by me.) There are three recent activities I am particularly proud of. (i) I have developed a forty minute multi-media show in collaboration with a local composer and a 3D projection artist, exploring emotional responses to a vast and violent universe. (ii) I participated extensively in a Spanish TV documentary and full lenth film about Charles Piazzi Smyth and his 1856 trip to Tenerife, seen as the origin of mountain-top astronomy. (iii) With my graduate student, Alastair Bruce, we have adapted planetarium software for the Oculus Rift virtual reality headset.

I am currently the chairman of the Royal Observatory Edinburgh Trust, a charitable trust established as a company limited by guarantee, which for many years operated the ROE Visitor Centre, and now acts to support activities in heritage and outreach. Our current goals include raising funds to build a planetarium in the ROE West Tower, and a programme of digitisation and preservation of unique historical books and documents in the world famous Crawford Collection.

Teaching

I am very interested in innovative teaching methods, and the problem of the role of Universities in the Internet age.

PhD supervision I have supervised fifteen PhD students, six of whom are still active in astronomical research or outreach. My current PhD students are Harry Rendell-Bhatti (AGN variability) Charles Yin (Tidal Disruption Events), and Amanda Ibsen (Machine Learning for transient classification).

Undergraduate teaching At the University of Edinburgh, and previously at QMW. I have taught a variety of undergraduate courses in both physics and astronomy, at all levels, including Vibrations and Waves, Introductory Astrophysics, Statistics, the Physics of Galaxies, and Astronomical Measurement (i.e. telescopes and detectors) in class sizes ranging from 10 to 200. I have also offered a range of project supervisions, small group tutorials, and large group "walk round" problem classes. I have experimented with a range of teaching methods and technologies, including "flipped classroom" methods, pre-recorded videos, and Jupyter notebooks. Two of these courses have led to textbooks – Astronomical Measurement (2014) and Probability in Physics (2019).

MOOC Together with Catherine Heymans I constructed a Massive Open Online Course (MOOC) for the Coursera Platform called "Astrotech: The Science and Technology behind Astronomical Discovery", which on its first run got 21,000 students, and a much higher than average completion

rate. Rather than attempting to make this a "blended course" as some of our other University colleagues have done, we saw this as the opportunity provide genuine mass education, at a technical level below university courses but well above normal outreach products. In the near future, I plan to experiment further in remote learning and innovative technology approaches.

MSc teaching In the recent past I ran MSc dissertation projects for the Edinburgh MSc in Distributed Scientific Computing, and further in the past at QMW, I have taught advanced astronomy courses in an unnusal MSc course in Astrophysics for part time students, run mostly in evening classes, which takes two years.

University Management and Administration.

In Edinburgh, along with a standard mix of University committees and administrative responsibilities, I have been in turn the **Head of the Institute for Astronomy (IfA)** and the **Head of the School of Physics**, since renamed the **School of Physics and Astronomy (SoPA)**.

I was Head of the IfA from 1994 until becoming Head of Physics in 2003. Historically there was a small but independent Department of Astronomy, which shared the Blackford Hill site with the Royal Observatory Edinburgh, an establishment of the Particle Physics and Astrophysics Research Council (PPARC). When I arrived, the Department had been absorbed into Physics as the Institute for Astronomy, but not physically moved, and a difficult national debate had begun concerning the support of astronomical facilities (see below). It became clear that the IfA needed to become much stronger on its own terms. During my leadership, the IfA grew by roughly a factor of three overall, doubling the number of academic staff, and quadrupling the grant income (from an admittedly low base). This was achieved partly by competition and negotiation with our physics colleagues, arguing for recognition of our teaching volume, partly by competitive external grant awards, and partly by absorption of wide feld astronomy activity from the ROE when the Astronomy Technology Centre was created. The Wide Field Astronomy Unit, which I personally created and led, has since continued at a healthy level on a full competitive basis. The IfA now contains 137 members - 27 academic staff, 48 externally funded or self funded research staff (fellows, RAs, and software engineers), 56 PhD students, and 6 administrators and project management staff.

In 2003 I became Head of SoPA. By UK standards this was at the time medium-sized in terms of permanent academic staff (65 – it is much bigger now), but quite large in total volume, as it was research intensive, and for historical reasons contained responsibility for the Edinburgh Parallel Computing Centre (EPCC), including a sequence of national supercomputing facilities, the National e-Science Centre (NesC), and a lead role in some multi-School organisations, such as the Centre for Science at Extreme Conditions (CSEC). By 2008 the School had 468 members, including 65 academic staff, 132 PhD students, 212 research staff, 34 technical and computing support staff, and 24 administrative support staff. The large ratio of research to academic staff is mostly due to external grant and facility operations income, but EPCC earns a large fraction of its income from commercial activities. The total turnover of the School at that point was ~£30M/year. During my five years as Head of School there were several clear achievements. (i) I restructured the School into a set of semi-autonomous Institutes. (ii) I closed the Fluids and Acoustics research group, and some unprofitable courses, while growing our teaching and research strengths. (iii) I led our submission to the national Research Assessment Exercise, the first for several years, which led to a substantial improvement in our national ranking, to 6th in the UK. (iv) I co-led the creation of a unique new entity, the Scottish Universities Physics Alliance (see below). (v) I oversaw a transition (along with the six other Schools in Science and Engineering) from the old financial system to a new highly devolved "single line budget" system.

SUPA is an alliance of the Physics Departments of eight universities - all such departments in Scotland. It is more than a club, but less than a complete merger. We undertake joint planning and some shared management; has made some strategic recruitments in common, with the final location of successful candidates a careful negotiation; present a unified external face, especially for industrial collaborators, through the SUPA website; operate a joint distinguished visitor programme, and a series of summer schools; run a joint Graduate School in Physics, with a programme of shared advanced courses using video-linked classrooms, and fully funded international studentships. The idea of SUPA is to achieve larger mass and international competitiveness at a disciplinary level, without the disruption that comes with physical mergers of entire universities. The original idea of "research pooling" came from senior Edinburgh University figures (Tim O'Shea and Richard Kenway), but SUPA was designed, planned and implemented by myself and five other Heads of Scottish Physics during 2003-2005. Since then, other disciplines have followed suit, and recently similar physics alliances have been formed in various English regions.

Science Policy and Governance

I have had considerable experience on external advisory bodies. Probably most signifcant has been membership of PPARC Council, and my recent chairmanship of the Astronomy Grants Panel of STFC. Below is a list of some of the key bodies I have been part of during the last twenty years :

Key Committee membership 2000-2018

• STFC	:	Chair, Astronomy Grants Panel
• PPARC	:	Astronomy Committee
• PPARC	:	Council Member
• Royal Astronomical Society	:	RAS Council (Vice President)
• European Space Agency	:	Astronomy Working Group
• European Southern Observatory	:	Surveys Working Group
• BNSC/PPARC	:	Chair, Space Science Advisory Committee
• VISTA project	:	Chairman, VISTA Science Committee
• AURA	:	Gemini Oversight Committee
• PPARC	:	ATC Management Board
• IVOA	:	Executive Chair (for one year)
• Gemini Project	:	Gemini Science Committee
• Euro-VO	:	Executive Board
• CCLRC (RAL and Daresbury)	:	eScience Advisory Board
• ASTRON (Netherlands)	:	Visiting Review Panel

• various ad hoc review panels, mostly for PPARC and STFC, also for OECD

(STFC = Science and Technology Facilities Council)
(PPARC = Particle Physics and Astrophysics Research Council)
(BNSC = British National Space Centre)
(VISTA = Visible and Infrared Survey Telescope for Astronomy)
(AURA = Asssociation of Universities for Research in Astronomy (USA))

PPARC and ESO. I was a member of PPARC Council at the time that PPARC was negotiating to join the European Southern Observatory (ESO), and negotiating with the UK Science Minister (then Lord Sainsbury) for an uplift in funds, and protection against exchange rate fluctuations. This was a positive but very diffcult time for PPARC and its community; ESO looked like the right future, but it involved putting a lot more eggs in one basket, and working out how to ramp down and withdraw from smaller facilities. As well as advising PPARC along with the academics, captains of industry,

and civil servants on the Council at the time, I was part of a small team that went with PPARC officials to negotiate with ESO Council and management.

STFC and grant restructuring. My four years as chair of the STFC Astronomy Grant Panel involved much more than advice on funding choices. As part of an RCUK-wide debate on funding policy and mechanisms, STFC was minded to convert *all* grant funding to departmental consolidated grants. I worked with STFC offcials and community colleagues to develop a working scheme and a variety of compromises that would implement their intentions whilst being understood by, and acceptable to, the astronomical community. At the same time, at annual reports to STFC Science Board, I presented stark facts and implications concerning the near-collapse of community grant funding.

Establishment of the UK Astronomy Technology Centre. Most of my policy experience has been in an advisory capacity, but there was a period of several years when I was closely involved in concerted political action. This concerned the restructuring of UK astronomy support in the late 90s, in which the ground-based observatories became independent of the historic Royal Observatories (Greenwich and Edinburgh) which created them, and the Royal Observatories themselves were replaced by a single "UK Astronomy Technology Centre (UKATC)", which after a long and difficult process, was established in Edinburgh. This was a high profile public situation, taking place within the context of a controversial government programme aiming to privatise as many public institutions as possible. This led me into official discussions with PPARC, briefing discussions at Ministerial level, and negotiations with a commercial organisation (SERCO) over the possibility of entering into a partnership with the University to operate the ATC under contract. In the end this commercial arrangement did not happen, but willingness to discuss such options was a kind of catalyst that helped the political battle to be won, and some functions of the old Royal Observatory establishment were transferred to the IfA as grant-based activities.

Personal

I live in Marchmont, Edinburgh and have four children called Zoë, Kit, and Dylan and Jake, who are all grown up now. My partner Emma Griffiths is a Heritage Learning consultant and my ex Debbie Capel lives nearby. Apart from astronomy and family, the biggest love of my life is drama. I used to be a keen amateur actor, but life is too busy now so I don't really do it anymore. Like most other people of course I like literature, art and music as well. My tastes are broad, but because of my love for serious drama, I find opera impossible to watch.

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As at August 2022. Papers in refereed journals only. For a full list of all refereed publications, citations, and links to PDFs etc, see the personal library I maintain at ADS:

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and other publications are here:

https://ui.adsabs.harvard.edu/public-libraries/7AyyeUSbQdWvAZfftZVgfQ

For a handy list of my top ten papers etc, see this page at my personal website:

https://andyxlastro.me/output/papers/

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