

Report on public feedback on the initial FUAP Science Strategy document.

We present here a brief overview of the comments we received on our initial FUAP Science Strategy document. We have collected these comments via a web-based public consultation during June/July 2009. In total, we received 98 submissions and provide a summary of these submissions below. We apologise that FUAP can not provide individual replies to any submission but wish to thank the community for their time and interest in commenting on our initial document. Where appropriate below, we do provide a brief reply to some of the common and/or important comments (given in italics).

General Comments

We provide here a summary of general comments made by the community on the structure of our initial document and the FUAP approach in general. Again, we provide some replies (in italics) where appropriate.

- Overall, most people appeared happy with our present approach. Specific supportive comments included agreement that it was best to define the important UK science questions first and then prioritize the facilities, it was re-assuring that the panel was composed of younger astronomers, and people saw synergy with other reports (which is encouraging).
- Several people were concerned about the broadness of the science themes, with no apparent prioritization. Therefore, the science strategy could become useless as it does not inform decisions on funding and facilities.

FUAP agreed with this criticism and have now implemented a science prioritization of the key questions in each theme. However, we decided not to rank the four science themes themselves, as this seemed impossible to agree on. We considered using publication/citation statistics to guide us in the prioritization, but a preliminary investigation of such methods convinced us that this was fraught with difficulty, especially when dealing with different sized communities and groups in cosmology and extra-galactic astronomy. Also, such methods are biased against emerging areas of research e.g., "First Light" in our document. In the end, we individually ranked all the science questions using our best judgment for the present and future excitement of each research question, and the UK's reputation and leadership in the associated area of research. We then averaged these rankings to provide the basis for one of three possible priorities (A, B or C; with A being the highest). Overall, the agreement within the panel was remarkably

good and we have used this science prioritization to better inform our prioritization of facilities and research priorities. We now provide the prioritization of the science question in the final FUAP Science Strategy document.

- Many people highlighted the need to plan for the unknown or unexpected. Many worried that our document reflected the conventional wisdom and missed the wonder of astronomy in finding amazing new phenomena in the Cosmos. Also, people stressed the importance of multi-disciplinary science.

FUAP agreed with this sentiment and have added a statement to this effect in the revised document. However, beyond highlighting this issue, it is unclear how one can plan for the unexpected and prioritize it against the clearer objectives of other (conventional) areas.

- Overlap with other panels and the fear of science areas falling between the cracks, e.g., extreme objects (X-ray binaries, SNe, etc.) both in our Galaxy and in distant galaxies, structures in our Galaxy and the (very) local dwarf galaxy population, importance of stellar astronomy to both far and near universe, gravitational wave astronomy, and particle astrophysics and CMB research.

FUAP acknowledges this concern and is working to mitigate such problems. For example, NUAP and FUAP have since held a joint phone conference, and members of both panels are encouraged to exchange information. FUAP has also offered informal membership to all NUAP and PAAP members, with two NUAP members now participating regularly in the FUAP email list. We will continue to discuss with STFC the membership and structure of these panels, which could be changed in the long-term. We also encourage any concerned stakeholders to contact the appropriate panel chairs.

- Several people stressed the importance of theory and computational science. They stressed it had high international impact and was cost-effective. There is much fear that with cuts to STFC research spending, this area will be disproportionately affected.

FUAP agrees with this assessment and shares the concerns expressed. It is clearly an area of significant UK leadership. We have stressed the importance of theoretical work (including simulations) in our Science Strategy document and plan to directly address this issue when we discuss facilities.

- Several smaller, but important, comments included:

- i. More funding for young people to stay involved and use future facilities,
(FUAP will address this when prioritizing facilities)
- ii. Attempts to measure the relative strengths of UK science areas (e.g. citation statistics),
(See comments above about the difficulty of using such metrics)
- iii. Weigh all comments equally, from professors to graduate students
(FUAP weighted all comments equally)
- iv. No need to always build new facilities. Existing ones can be put to good use,
- v. Outreach is important and can inspire young people,
- vi. In the harsh reality of the UK budget, economic impact must be stressed, as just performing good science is not enough.

Extreme Astrophysics

Overall there was broad support for Extreme Astrophysics as a theme and its importance among the UK research community. Several comments emphasised cross-theme research, multi-wavelength research, the importance of computational support and the need to maintain UK access to multi-wavelength facilities.

Some specific areas of concern are highlighted below:

- Overlap with NUAP and PAAP: Several comments were addressed at whether some topics would “fall between the cracks” among the various panels. Of particular concern were those Galactic sources, which emit high-energy radiation such as pulsars, X-ray binaries and the like. Example comments include:

“While I am quite glad to see support for research on pulsars and X-ray binaries in this document, I think the formal remit for the panels indicates that the NUAP should be the one doing that.”

“As massive stars find themselves at the boundary between the Near and Far Universe, there might be a risk that both panels (Near and Far) assume the other panel will take care of it.”

“In your extreme astrophysics section, all of these questions (perhaps excluding gravitational waves) can be also asked within our galaxy.”

“I must admit to being slightly confused when I was informed by the powers that be that extreme physics in galactic sources should not be covered in the near universe panel, but in the far universe panel.”

"I think all four themes could give greater prominence to stellar astronomy and the need for continued work in stellar evolution."

- Suggestions for changes to questions: As expected, many responses were objections to particular questions or the emphasis (or not) given to some topics. Examples are given below and we have revisited the text appropriately if we feel there is merit.

"I really don't believe the relativistic particle acceleration question is a key one for UK science - it's much more of a niche area."

"We don't need to know what the sources are of gravitational waves and neutrinos, we need the answers to physics questions, and you need to identify what these physics questions are."

"Feedback is a hot topic, but the way the proposal handles this seems to presuppose that it is all down to AGN, so it's in 'Extreme Astrophysics'. In practice, a lot could be down to supernovae."

"Cosmic magnetism is going to be a growing field of astrophysics in the next decade."

"The only question that seems out of place is: "How and where does particle acceleration occur?" Although interesting, I feel that this is a detailed issue that could be subsumed into the second question of Extreme Astrophysics".

"Supernovae are only mentioned with respect to gravitational waves. However there is major interest in the UK."

"[Change the 1st question to] Can the known laws of physics explain the most extreme conditions and processes in the Universe?"

"I would like to see the probes of fundamental physics using high energy observation of the Universe given perhaps more emphasis."

- The importance of particular types of observation: Given that some decisions will have to be made as to the importance of particular facilities and observational strengths/weaknesses, some responses mentioned the need for access to a particular waveband or type of observation. These issues will be addressed in our prioritization of facilities, but we provide some examples below.

"TeV observations are becoming increasingly important. Unless we can study variability in detail we won't go far"

“Detection of the energy scale of quantum gravity by ground and satellite based observations of GeV/TeV photon emission from distant GRBs and AGN is not implicitly mentioned and this should certainly be included.”

“GRBs offer a particular example where we benefit from multi-wavelength AND wide geographical coverage.”

- An Additional theme: Only one area was commented on as a possible extra theme, namely the detection of gravitational waves.

This was considered by the panel but rejected as it was felt the emphasis should be on the astrophysics rather than the detection method.

Cosmology

Of the 97 web responses, 37 made specific comments on the Cosmology theme. Overall, most comments were generally positive, but specific issues are detailed below.

- Missed Science Questions: Most respondents were happy that we had covered the most important science questions. Suggestions for missing questions included
 - What is the physics of galaxy clusters?
 - Did primordial magnetic fields play a role in the origin of Galactic magnetism?
 - What are the masses of neutrinos?

We consider the physics of galaxy clusters belongs in the Galaxies theme and is covered by the question “What is the role of environment and interactions in galaxy evolution?” and “What lies between the galaxies”. We have added a reference to primordial magnetic fields to the sentence “Moreover, recent progress towards realising inflation in fundamental (e.g. string) theory suggests a richer phenomenology than the simplest models, including large non-Gaussianity, cosmic superstrings, and isocurvature modes” in the text, but also consider the role of primordial magnetic fields, in Galactic magnetism, to be covered by NUAP. Finally, our original document did mention the mass of neutrinos, but we have now added a sentence explicitly describing the role of observations of the small-scale clustering of matter in constraining absolute neutrino masses.

- Techniques: Several respondents stressed that some judgment on the relative strengths of various techniques should be made (for example, dark energy probes). We also received the following suggestions for techniques that should be worked into the text

- Gamma-ray bursts as standard sirens for geometric tests,
- Refining primary distance indicators for measurements of the expansion rate,
- Gravitational wave emission as tests of General Relativity,
- Peculiar velocity measurements (for example from Sunyaev-Zel'dovich observations of clusters) as tests of (modified) gravity,
- Near-field cosmology (i.e. Local Group) as a probe of the properties of dark matter,
- Gamma-rays from dark matter annihilation in our Galaxy as a probe of dark matter properties,
- Detecting the energy scale of quantum gravity with GeV/TeV emission from Gamma-ray bursts and AGN,
- CMB polarization for testing inflation and, via CMB lensing, for constraining neutrino masses and dark energy.

We have chose not to list all possible types of cosmological observations that could be used to constrain the nature of dark matter and dark energy. We have however highlighted the best techniques in our opinion (based on several recent dark energy reviews). We have expanded the text to include the important role of near-field cosmological observations can play in probing the properties of dark matter.

- Suggested changes to text: We received a few suggestions for improvements to the text.
 - Question 2: make this about the structure in the CMB rather than large-scale structure since the latter follows from the former by "well understood" physics.
 - Question 4 is too imprecise -- it would be helpful to specify over what epochs the question is referring (e.g. Planck time, inflation, nucleosynthesis, $z < 1$ etc.).
 - The theme would be better entitled "Origins" rather than "Cosmology".

We consider structure in the CMB as a tool rather than an end in itself. The origin of structure can be probed both by the CMB and large-scale structure, using the "well-understood" physics to tie them together. We considered making question 4 more precise, to properly distinguish it from question 1. We changed it to "Are the correct laws of physics and assumptions used when calculating cosmological evolution?" We disagree that the theme would be better entitled "Origins" since origins is often taken to include the origin of life as well as the origin of the universe.

Galaxies

Comments regarding the "Galaxies" theme of our document were overall positive. A few issues were raised by multiple responses, and thus warrant particular attention.

- The Galaxy, GAIA, resolved stellar populations: A number of people

commented on the importance of near-field cosmology, i.e., studying the global properties of the Galaxy (e.g. satellite streams), particularly with GAIA, and in the future, resolved stellar populations in nearby galaxies. The latter will become important when 30m class telescopes become available in the next decade. For example:

"My main concern here is that you have downplayed that part of your remit which covers "the global properties of our galaxy". It seems clear that, thanks to GAIA, this will be one area of astrophysics which is almost bound to be revolutionised in the next 15 years, and it would be a great pity for the UK to miss out on that by not being adequately prepared.

The upcoming GAIA (and other) mission will turn the Milky Way into the Rosetta stone for Galaxy evolution/formation/dynamics research. I feel that this should be explicitly emphasized in the science questions/themes."

We accept this was not clear in the original document and have emphasized the role of such surveys in our understanding of galaxy formation and near-field cosmology.

- Star formation in the Galaxy and external galaxies: A number of responses remark on the importance of studying star formation in the Milky Way and nearby galaxies, which many fear may have fallen between the remits of NUAP and FUAP.

"The importance of a better understanding of star formation in terms of galaxies and their structure should be emphasised.

Depending upon how the boundaries of NUAP and FUAP evolve, some areas are lacking a natural `home'. These include differing modes of star formation (quiescent within Milky Way; violent within starburst galaxies and ULIRGs), stellar populations in external galaxies (e.g. dwarf galaxies/ clusters within halo of M31 of relevance to galaxy assembly), ..."

We are coordinating with NUAP on this issue and will ensure it is not forgotten.

- Cosmic magnetism: A number of responses remark on the importance of cosmic magnetism in galaxy formation, and possibly in cosmology.

"Cosmic magnetism is going to be a growing field of astrophysics in the next decade (e.g. Key Science Projects for LOFAR, ASKAP, SKA and increasing use of MHD numerical simulations) and the UK is very active.

Although it was briefly mentioned at the end of one paragraph, I believe that in the next decades the emphasis of studies of the role of magnetic fields in high red-shift astrophysical objects and indeed in the primordial universe should be emphasized."

We have already mentioned this science area in this theme and others, and feel it is represented appropriately in the text.

- Multi-wavelength approach: Several people commented on the importance of using a multi-wavelength approach to study galaxies and cosmology, from radio to the gamma-ray, including in time-domain astrophysics.

"I would support a strategic plan that provides multi-wavelength imaging and spectroscopy from the ground in a coordinated way.

I strongly endorse the need to maintain a flexible multi-wavelength approach. Much of the success of UK astronomy has been in its ability to move into new wavelength regimes as and when technology allows."

This we feel is an issue of facilities rather than a science question. We think the text adequately reflects the science need for a diversity of observations in this theme, and this will be reflected in the prioritization of facilities.

- Central massive black holes and supernovae/AGN feedback: A number of responses emphasized the importance of probing massive black holes in our own Galaxy and in external galaxies, as an integral part of understanding galaxy formation and evolution. Feedback from supernovae and AGNs should be stressed on equal footing. Gravitational waves can potentially be used to study mergers of massive black holes at the centres of galaxies.

"You may want to explicitly mention the build-up/formation of the central super-massive black holes in galaxies.

I also think that the role of the black hole in Galaxy evolution should be one of the main galaxy questions.

Feedback is a hot topic, but the way the proposal handles this seems to presuppose that it is all down to AGN, so it's in "Extreme Astrophysics". In practice, a lot could be down to supernovae, so you should either make it clear that these are included under this heading (are they extreme enough?)."

First Light

Comments regard the First Light theme were overall positive, although not as numerous, in comparison, to the Cosmology or Galaxies themes. We provide a summary of comments and suggestions

- The chemical enrichment of the universe: We received most comments about this subject. Some thought that this should be in the Galaxies theme which is a fair comment. Most of the comments on specific science questions related to this issue, with some people even mentioning that this is the most important part of the "first light". Others thought a more interesting question is how the chemical evolution history evolves with time, although this is better covered in the Galaxies theme. Some mentioned that "complex elements" is an ambiguous term that should be better defined.

- Question 1: Several people commented that another important question, independent of stars and AGN, is the initial formation of the first galaxies and indeed it is probably worth mentioning the first galaxies as well here in future lists of questions. While it is likely the case that the first AGN and stars were formed within galaxies, and thereby creating the first galaxies in the process, this is not definitely the case and the processes could be decoupled.
- Question 3: A number of people took issue with this question regarding techniques for finding the first objects in the universe. Those who mentioned this brought up the fact that this question is not like the others in that it is a technique question rather than a "hard" science question. It is worth pointing out that others mentioned in the questionnaire that new techniques and ideas were not mentioned enough, so this is an example where addressing a technique is include in our list of problems/questions.
- Other ideas: Many respondents mentioned other techniques for studying the "first light" including Gamma-gamma absorption through extragalactic background light to study the first physical processes, as well as using statistical properties of the last scattering surface to determine properties of the first objects. The impression here is that we have determined the best ways to observationally study the first objects in the universe, while we have left this open as a separate question.
- Comments on 21cm science: A few people stressed that 21cm science will be a major focus of 21st century astronomy. It is possible that our question about studying the re-ionization implies 21cm observations quite strongly to those interested in this area.