European Task Force for Laboratory Astrophysics (ETFLA)

Midterm report on recommendations regarding the establishment of a European Laboratory Astrophysics Network

November 2013

www.labastro.eu

Executive summary

Laboratory astrophysics provides vital underpinning to observational astronomy as well as being a vibrant and scientifically challenging discipline in its own right. There is considerable laboratory astrophysics activity in Europe, much of it world leading. However, the work is fragmented and, with the exception of the area of nuclear astrophysics, poorly coordinated and patchily funded, and, in places, poorly recognised. To address these issues we recommend:

A. Community building measures both within the laboratory astrophysics community itself and between astronomers and laboratory astrophysics researchers working on common themes. These activities should form a natural part of any planning for future astronomical missions. For this we propose European-scale networking activities and fellowships which will allow young scientists to move between laboratory astrophysics and observational astronomy groups, and help attract other institutions to laboratory astrophysics.

B. 2% of all funding for major space missions and ground based observatories should be dedicated to supporting laboratory astrophysics activity.

C. Building on the work performed by the Virtual Atomic and Molecular Data Center (VAMDC) consortium to provide access to data in all key areas of laboratory astrophysics. This work should be integrated with that of the Virtual Observatory (VO).

D. Working with publishers to ensure due recognition of data providers and to allow for better integration of laboratory astrophysics within the astronomy literature.

E. Raising the profile and visibility of European laboratory astrophysics.

F. Curacy of various Solar System material returned by space missions by establishment of European facilities.

1. The need for Laboratory Astrophysics

Laboratory Astrophysics is an essential prerequisite for all aspects of astronomical investigation. It provides the physical, chemical and/or biological underpinning necessary to plan, design and interpret astronomical observations. Without a deep and detailed understanding of the underlying science of the processes being observed, it is not possible to fully interpret astronomical observations. Similarly, laboratory data provides much of the input for astrophysical models. A vibrant and focused astrophysical laboratory community is therefore essential to provide the necessary data and scientific foundations, without which the true return from investment in expensive astronomical facilities and probes cannot be realised. Laboratory astrophysics is thus a central part of astronomy and the requirement for it needs to be incorporated in the strategic planning for all missions both ground-based and space-borne. These missions often involve the investments in excess of a billion Euros, yet there are no European-level structural budgets in place for any corresponding investment in supporting laboratory studies.

While laboratory astrophysics should be regarded as a necessary support activity for wider astronomical investigations, it is also a discipline in its own right. Laboratory astrophysics probes the properties of matter at all extremes: extremes of temperatures, extremes of pressure and extremes of energy. This work is therefore intellectually challenging and driven by curiosity about the fundamental behaviour of matter in environments not routinely encountered on Earth. This work naturally leads to discoveries which impact on other disciplines as well as society, sometimes very significantly. We cite, for example, the discovery of C_{60} by Kroto et al., who were attempting to explain interstellar medium absorptions by diffuse interstellar bands. This work led to the foundation of a whole new discipline in the physical sciences and the award of a Nobel Prize, with important extensions into material sciences including the development of carbon nanotubes, as well as the further discovery of graphene, for which another Nobel Prize was awarded in 2010. C_{60} and recently its ion C_{60}^{+} have since been identified in astrophysical sources ranging from planetary nebulae to young stellar objects.

Laboratory astrophysics is by its very nature interdisciplinary, requiring a deep understanding of core laboratory science plus knowledge of astronomy, and often much more besides. It therefore offers excellent training opportunities as it produces multi-skilled and flexible scientists who are experienced in interacting with scientists from other disciplines.

2. What is Laboratory Astrophysics?

The ASTRONET project developed a strategic plan for European astronomy[1], henceforth referred to as the astronomy Infrastructure Roadmap. The Roadmap identified laboratory astrophysics as an area in need of attention and created the European Task Force for Laboratory Astrophysics (ETFLA) to help shape this agenda. The ETFLA, the membership of which is given in Table 1, and which has met six times, are the authors of the present report.

Table 1 : ETFLA Membership

Jonathan Tennysson (co-chair)	University College London (UK)
Louis d'Hendecourt (co-chair)	Institut d'Astrophysique Spatiale (FR)
Jürgen Blum	University of Braunschweig (GER)
Thomas Giesen	Universität Kassel (GER)
Jordi Jose	UPC BarcelonaTech (SP)
Maxim Khodachenko	Space Research Institute – IWF (AU)
Harold Linnartz	Leiden University (NL)
Mats Larsson	Stockholm University (SE)
Äke Nordlund	University of Copenhagen (DK)
Pascal Quinet	Université de Mons (B)
Alessandra Rotundi	Universita di Napoli 'Parthenope' (IT)
Peter Sarre	The University of Nottingham (UK)
Valentine Wakelam	Laboratoire d'Astrophysique de Bordeaux (FR)
Saskia Matheussen (Exec. Secretary)	Netherlands Organsation for Scientifc Research (NL)

The astronomy infrastructure roadmap defines laboratory astrophysics as "laboratory physics, chemistry and biology, and theoretical calculations and modelling, of atomic, molecular, nuclear and solid-state properties, processes and associated astrophysical phenomena that are required to ensure the success of current and future research programmes in … astronomy". We are happy to endorse this definition.

For purposes of collecting data and analysing different scientific issues we divided laboratory astrophysics into nine scientific themes and ETFLA members each took responsibility to examine one or two of these in detail:

A. Gas-Phase astrochemistry (Interstellar Medium, ISM, and planetary atmospheres);
B. Spectroscopy of the ISM;
C. Spectroscopy in hot bodies (opacities) ;
D. Solid state and molecular complexity;
E. Stellar and planetary formation;
F. Primitive and planetary material;
G. High-energy processes and space plasmas;
H. Stellar evolution and nuclear astrophysics;
I. Astrophysical conditions for the emergence of life;
   all of which are augmented by one underpinning theme:
J. Databases.

[1] The ASTRONET Infrastructure Roadmap: A Strategic Plan for European Astronomy. Editors: Michael F. Bode, Maria J. Cruz & Frank J. Molster, ISBN: 978-3-923524-63-1 (ASTRONET, 2008).

3. The international perspective

Internationally, laboratory astrophysics is increasingly recognised as a core underpinning activity. From an organisational point-of-view, the USA has taken the international lead with (a) the formation of a Laboratory Astrophysics Division (LAD) as part of the American Astronomical Society (AAS), (b) the formation of the Subdivision of Astrochemistry of the American Chemical Society (ACS) Division, (c) the National Aeronautics and Space Administration (NASA)'s long-standing Astrophysics and Astrochemistry Laboratory at their Ames and Goddard Space Flight Research Centres and (d) a series of NASA workshops and white papers coordinating activity and funding in laboratory astrophysics with core astronomical objectives. We cite the co-ordinated laboratory programme to characterise the spectra of the ISM "weed" molecules prior to the commissioning of the Atacama Large Millimeter/submillimeter Array (ALMA) to maximise the discovery potential of this facility as an exemplar of this. An earlier example was co-ordinated funding for laboratory studies in the USA in connection with the European Space Agency (ESA)-led Herschel mission.

By contrast, coordination between astrophysical objectives and laboratory work in Europe has remained relatively weak. There has been some networking activity at the national level, and EU training networks (notably the Laboratory Astrochemical Surface Science In Europe (LASSIE) interdisciplinary training network in the field of solid state astrochemistry and the European Cooperation in Science and Technology (COST) action – the Chemical Cosmos have been funded). In the nuclear astrophysics area, the EuroGENESIS – Origin of the Elements and Nuclear History of the Universe – collaborative research programme provides something of a role model for other areas.

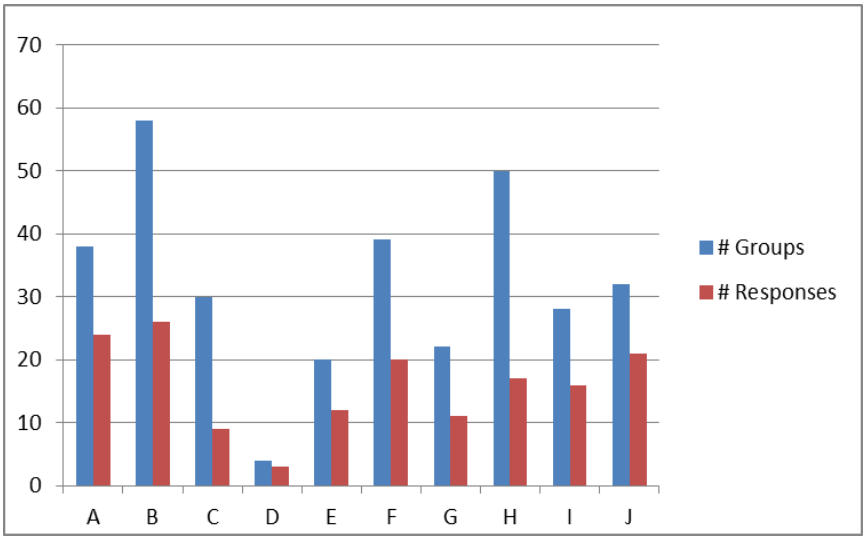
On the observational side much astronomical activity is highly coordinated by the European Southern Observatory (ESO) and astronomical space missions are coordinated by ESA. This level of organisation and focus on key astronomical objectives has not been reflected in laboratory work in Europe.

4. Laboratory astrophysics in Europe

In order to assess European activity in laboratory astrophysics and to identify the issues involved in doing such work in Europe, ETFLA undertook a study to identify the groups performing laboratory astrophysics research in Europe, and survey them; a copy of the survey is given in Appendix 1. Before sending out the survey we compiled a list of European groups we identified as performing research in the area of laboratory astrophysics. We identified approximately 250 groups although this figure has some double counting as some groups work in more than one theme. A list of these can be found on the ETFLA website (www.labastro.eu). However, there are undoubtedly groups missing at this stage as it proved difficult to identify all those working in the area. A complication is that only a minority of groups define their main activity as laboratory astrophysics with many more doing astrophysically-related work alongside scientific activities performed with other objectives. We undertook the survey in an open manner and added new groups as they were identified.

We received returns from approximately half of the groups approached. Figure 1 gives some statistics on the groups surveyed by theme. The individual surveys contain a lot of detail and here we will only consider common themes.

Figure 1 : Number of groups surveyed per theme and response rate



A. Gas-Phase astrochemistry; B. Spectroscopy of the ISM; C. Spectroscopy in hot bodies; D. Solid state and molecular complexity; E. Stellar and planetary formation; F. Primitive and planetary material; G. High-energy processes and space plasmas; H. Stellar evolution and nuclear astrophysics; I. Astrophysical conditions for the emergence of life; J. Databases.

A. The overall picture is that there is quite a lot of activity in laboratory astrophysics in Europe, though with some notable gaps, that much of it is of high quality and some even world leading.

B. However, the work is very fragmented. Most groups do not align their work with either major astronomical goals or current/forthcoming astronomical missions. The linkage between the demands of the European astronomical community and the laboratory activities is therefore very limited. Furthermore, on the European scale there appears to

be too few attempts to coordinate laboratory activities to really meet astronomical priorities. An important exception to this is the M€ 2.5 ESF-funded EuroGENESIS project which assembled about 200 experimental and theoretical nuclear physicists, stellar modellers, experimental and theoretical astrchemists, and observational astronomers from 30 research institutions and 16 countries.

C. Funding for laboratory astrophysics is overwhelmingly provided by national agencies and frequently through disciplines other than astrophysics. This makes the funding landscape uneven and with some countries (notably France, The Netherlands and Spain) committing considerably more funding to this area than others. Laboratory astrophysics suffers from the problems that tend to beset interdisciplinary science. For example, as recognised in the infrastructure roadmap, it rarely features in national astronomy road maps. The long-term curacy of key data and the development of novel experimental techniques designed for answering questions of astronomical importance were highlighted as particular funding issues.

D. France, Germany, The Netherlands, Spain (until affected by adverse economic conditions) and the Nordic countries have all funded some national/regional networks linking laboratory astrophysics in certain key areas with the relevant astronomers. Some of these networks also undertake collective training activities. The integration of laboratory and astronomical research on a particular activity, as exemplified by the EuroGENESIS project, is clearly to be encouraged. We regard these networking activities as role models that should be followed on a European scale.

E. Some scientists identified problems in publishing their results as (a) certain astronomy journals did not welcome work in the area of laboratory astrophysics and (b) results are often incorporated into databases leading to few citations even for heavily used original work (this also appears to be the underlying issue with problem (a)).

F. Europe appears to be successful in creating a set of highly used databases providing the results of laboratory astrophysics studies in a form ready to use for astronomers. We welcome the coordinating role undertaken by the EU funded Virtual Atomic and Molecular Data Centre (VAMDC, www.vamdc.eu) in developing and implementing an interoperable database whose portal provides single point access to a large range of validated data. VAMDC has also encouraged formalised standards in data storage and manipulation via the use of a specially developed schema, Extensible Markup Language (XML) scheme for Atoms, Molecules and Solids (XSAMS), which was originally developed by the International Atomic Energy Agency (IAEA); IAEA retains control over XSAMS standards and releases. However, long-term funding support for database maintenance and updating, so-called data curacy remains a serious and important issue.

G. Experimental research is often supported by extensive computational simulations which makes numerical modelling important for laboratory astrophysics. The scope of the computational tasks ranges from the direct simulation of physical processes and environments realised in laboratory experiments, which is aimed at interpreting or even superseding experimental results, to the development of virtual computer-based experimentation infrastructures accessing real and virtual equipment, systems and

analysis tools. The joint use of experimental and computationally simulated data requires development of a generalized approach for their description within a common standard, or data model (DM). The EU-funded project Integrated Medium for Planetary Exploration (IMPEx) has addressed this issue for a range of computational models and observational data in the field of space plasma astrophysics. The newly developed IMPEx DM extends the known standard of the Space Physics Archive Search and Extract (SPASE) Data Model which is widely used to describe observational data in space plasma research. Further development of this methodology is needed to provide a universal DM which will meet the needs of the whole spectrum of data products and services in laboratory astrophysics.

H. The fragmented nature of the activity means that there is also a lack of visibility in European laboratory astrophysics with astronomers often not knowing whom to ask for key laboratory data.

I. In its meetings ETFLA has been keenly aware of the impact of laboratory astrophysics on the training of young European researchers and its potential in improving female participation in science and technology. For reasons that at this stage are not completely clear and not uniform across all areas, the field attracts a higher proportion of female researchers than in pure physics. ETFLA is strongly supportive in seeking to extend this trend as well as promoting more general equality and diversity issues and the importance of science and technology in the public domain.

5. Recommendations

After considering the various inputs the task force makes the following recommendations:

A. As the laboratory astrophysics community is disparate and uncoordinated a number of community building measures need to be put in place. To this end we welcome the establishment of the European Conference on Laboratory Astrophysics (ECLA) which held its first meeting in Paris in 2011. We fully support the aim of making this a regular meeting. However, of equal importance is the establishment of links between laboratory astrophysicists and astronomers working on common themes. Initially this should involve meetings aimed at community building which in the longer term should form a natural part of any planning for future facilities, missions and other major astronomical initiatives. The meetings would also provide a basis for the formation of networks based on common, astronomically-motivated scientific goals but integrating laboratory work in the activity. We also propose the establishment of fellowships which will allow young scientists to move in either direction between laboratory astrophysics and observational astronomy groups. These could provide an important role in breaking down barriers and widening education at an early stage in scientific careers.

B. The unevenness of funding is an issue and while recommending more funding for the area we also recognise that this is simplistic and will not help solve structural problems. We strongly endorse the proposal made in the ASTRONET Infrastructure Roadmap that 2% of all funding for major space missions and ground based observatories should be dedicated to supporting laboratory astrophysics activity at all stages of a project (planning, execution and interpretation). This will not only provide a route to an appropriate level of funding but will act to ensure that the funded activities are structurally tied to future astronomical objectives.

C. VAMDC represents a significant step forward in database coordination and the implementation of uniform data standards. This is an area in which Europe has taken a lead. We recommend building on the work performed by the VAMDC consortium to extend the scope of its work to provide access to data in all key areas of laboratory astrophysics. Allied to this there should be a move towards greater integration of the work and standards developed by VAMDC with the Virtual Observatory (VO). Further work on the development standards as reflected by a rigorously defined data model are required for tasks involving computational modelling.

D. We note that VAMDC has already started to explore due recognition for data providers in discussion with various publishers. Work in this direction should continue.

E. ETFLA wishes to raise the profile of European laboratory astrophysics as an activity in itself and as an aid to astronomical understanding. To this end we developed a community website (www.labastro.eu) and are developing a new JISC educational and research email discussion list (JISCmail) as a start to coordinating communications. These measures are just a beginning and further profile raising activities are needed.

F. The task force did not specifically address the issue of curacy of Solar System materials returned by space missions but is supportive of the proposal in the ASTRONET infrastructure roadmap that proper European facilities need to be in place for this.

6. Conclusions.

Activity in laboratory astrophysics in Europe is widespread and in places world leading; yet it is fragmented, poorly coordinated and often not fully recognized as a discipline. In particular, laboratory activities often lack alignment with key astrophysical objectives. Mechanisms, including targeted funding streams, to facilitate this alignment do not generally exist at the European level. The ETFLA have made a series of recommendations to help address these issues. The ETFLA also discussed potential opportunities that may arise from Horizon2020 and is keen to position itself to respond to any call that embraces the field.

Appendix 1: ETFLA survey

European Task Force for Laboratory Astrophysics Laboratory Astrophysics
(includes computational- and theoretical astrochemistry and astrophysics)

Research Area†_____

1. Name of Research Group/Facility: (please give point of contact with an email)
2. Name of University/Research Organisation, Country etc.

3a. Any other Collaborating Establishment(s) in Europe and elsewhere, including role of each:

3b. Other European groups working in your area of Laboratory Astrophysics:

4. Relationships with other organisations such as ESA, ESO etc.:

5. Please provide a brief textual summary of:

5a. The principal scientific objectives (reference can be made to the ASTRONET Infrastructure Roadmap (see www.eso.org/public/archives/books/pdfsm/astronet.pdf).

5b. Principal activity e.g. type of laboratory spectroscopy, theoretical calculations, sample analysis etc.

5c. Astronomical data needs in your research area.

5d. Relationship between the laboratory and ground/space-based observational and/or mission programmes

5e. Current development status of the programme(s)

5f. The status and nature of any associated significant research and development required

6. Future Milestones (type and date):

6a. For existing research facilities, please include any major development/upgrade plans.

6b. For proposed major projects, e.g. Space missions or new ground-based facilities, include any associated laboratory milestones.

7. Outline Budget and direct Full Time Equivalent (FTE) staff on the project.
All figures should be in 2012 Euros if possible, and from the start of calendar year 2012 onwards. Figures given need only be approximate; costings should be direct costs, not including such items as university overheads. In order that meaningful comparisons between projects can be made, give details on what your costings include. Any additional information on how the figures are arrived is welcome.

7a. What is the current complement of FTE staff (including technical staff) and research students.

7b. What apparatus/instrumentation is currently in use?

7c. Do you use large facilities (eg synchrotron sources, national supercomputers etc)? If so, which and how much?

7d. Give a total Cost at Completion and FTE requirement for design and construction of any new facility, instrumentation etc.

7e. If possible, provide a cost and FTE requirement to each milestone given in 6.

7f. Provide an estimate of annual operating costs (in the case of a major upgrade, this should be in terms of any additional cost to existing operations).

7g. Provide, if possible, an estimate of the FTE scientific staff and research students needed to acquire and exploit the laboratory data.

7h. State what funding is already secured for each phase of the project (noting any funding decisions in the next 6 months that may affect this).

7i. What are your major sources of funding? Are there any specific problems with funding work in the Laboratory Astrophysics area?

7j. Give an estimate (can be in percentage terms) of the likely required European funding share of the research from 2013 onwards

8. What plans are there or currently exist for a Public Data Archive/Database of your results? (including corresponding estimated set-up and operational costs, FTE requirements for this and general publicly accessible archive needs)?

9. Please give details of any interaction with industry:

9a. What is the nature of any current or future major industrial involvement?

9b. Which kind of industry has been, or can be, involved?

9c. Please give the names of any existing major industrial partners.

10a. Do you have any associated educational and outreach activities, ongoing or planned?

10b. Please specify their nature and target audience(s).

10c. Do you produce or plan to produce any material for education? If so, is it interactive and who is it aimed at? (e.g. teachers/students; primary/secondary/university education levels)

10d. Do you evaluate or plan to evaluate the impact of your educational activities?

10e. Do you produce any multimedia material and/or material which is aimed at the media?

11. Please feel free to add any additional information on your research/facility that you feel may be useful to the Laboratory Astrophysics Roadmapping exercise

†Areas:

- Gas-Phase astrochemistry (ISM and planetary atmospheres)
- Spectroscopy of the ISM
- Spectroscopy in hot bodies (opacities)
- Solid state & molecular complexity
- Stellar & planetary formation
- Primitive & planetary material
- High-energy processes
- Space plasmas
- Stellar evolution and nuclear astrophysics
- Databases
- Astrophysical conditions for emergence of life

Appendix 2: List of Acronyms

AAS	American Astronomical Society
ACS	American Chemical Society
ALMA	Atacama Large Millimeter/submillimeter Array
ASTRONET	ERA-net aimed at strategic planning of European Astronomy
COST	European Cooperation in Science and Technology. Framework supporting Cooperation among scientists and researchers across Europe.
DM	Data Model
ECLA	European Conference on Laboratory Astrophysics
ESA	European Space Agency
ESO	European Southern Observatory
ETFLA	European Task Force for Laboratory Astrophysics
EuroGENESIS	Origin of the Elements and Nuclear History of the Universe – Collaborative research programme
IAEA	International Atomic Energy Agency
IMPEx	Integrated Medium for Planetary Exploration
ISM	Interstellar Medium
JISCMail	JISC educational and research email discussion list
LAD	Laboratory Astrophysics Division
LASSIE	Laboratory Astrochemical Surface Science In Europe – interdisciplinary training network in the field of solid state astrochemistry
NASA	National Aeronautics and Space Administration
SPASE	Space Physics Archive Search and Extract
VAMDC	Virtual Atomic and Molecular Data Center
VO	Virtual Observatory
XML	Extensible Markup Language
XSAMS	XML scheme for Atoms, Molecules and Solids