Minutes

Low-carbon science day

This first low-carbon science seminar was organised by the work group « low carbon science » from the environment commission of IRAP. It took place on May 26th 2023 and gathered about 60 participants (in person and video-conference).

I] Introduction, national and local initiatives (9h-10h30)

First thing learned from IRAP GHG assessment : the carbon footprint is due in majority to infrastructures and to the heart of research activity.

❖ Presentation of actions and tools developed by Labo 1.5 (Olivier Berné, IRAP, 30 min)

International context: IPCC reports.

In France: Valérie Masson-Delmotte has been a whistle-blower about climate change on a national scale. There is a consensus in the research community to alert on this matter in 2018 and an urge to do something about the environmental footprint of scientific research.

In academia : few local initiatives, EPFL was a leader on these questions by creating tools to limit the labs' carbon footprint. University rankings also started to integrate environmental criteria. Working groups appeared in labs and research institutes.

Surveys organized in several research fields showed that 95% of research fellows agree on the fact that science practices need to be changed towards more sustainability. This led to the creation of Labo1.5, a bottom-up movement, representing researchers as well as the administrative and technical staff. The aim is to avoid a bureaucratic or institutional approach, preferring a science-based method (not pure activism either), and to keep a local governance (at the scale of the labs) and local expertise (tools created by and for the labs).

In 4 years of existence:

- Creation of a research group (GDR) supported by several institutions (ADEME, CNRS, INRAE) and of an independent think tank (political strategy).
- Creation of GES 1point5, a tool aiming at calculating the carbon footprint and building the greenhouse gas (GHG) inventory of a laboratory. It is a free, open source tool, with a shared scope for all laboratories, in order to collect data on a national scale[1]. It also gives the possibility to design GHG emissions reduction scenarios based on reduction measures. The objective of this method is to allow the lab teams to take ownership of the stakes and tools to reduce the impact of research activities.

An experimental phase gave birth to a "Labs in transition" network : a community of French labs that have used the tool and engaged a transition policy, using various levers. Enables networking, sharing experiences.

Diffusion of this shared tool : allows to collect data on a national scale (GES1.5 has been used by over 700 research units, representing 1/3 of the total research units in France). 1300 GHG assessments are available on the data base. We can notice that social sciences are under-represented (only 15% of the assessments).

Some data (national average):

- 8t CO_2 / person working in the labs
- Public research represents 1% of France GHG emissions (2 million t), and that is without taking into account the research infrastructures (telescopes, particle accelerators...)

However, we observe a strong heterogeneity from one lab to another so the national data must be used carefully.

The transportation (work travels) is a subject at the centre of the debates. The majority of carbon footprint is due to long-distance air travel. Air travel represents 96% of the carbon footprint of work trips. There are strong inequalities in the staff : 50% of laboratories staff never travel, when 54% of flights are made by 10% of the personnel. There are also gender-based inequalities. There is a correlation between scientific visibility and number of flights (scientific publications and h-index).

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[1] See : *An open-source tool to assess the carbon footprint of research.* J. Mariette, O. Blanchard, O. Berné, O. Aumont, J. Carrey, A.-L. Ligozat, E. Lellouch, P.-E. Roche, G. Guennebaud, J. Thanwerdas, P. Bardou, G. Salin, E. Maigne, S. Servan and T. Ben-Ari. 2022 Environ. Res.: Infrastruct. Sustain. **2** 0350080 10.1088/2634-4505/ac84a4 .

Important to question research practices and purpose, define priorities and research areas that have a smaller impact on environment. Ask the question of ethics and limits = how to define an environmental ethic for research ? (the CNRS ethics committee published a report on this subject).

Some questions remain:

- Recruitment and evaluation of research (environmental criteria)
- Funding from fossil fuel industries in public research
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- Moving to a *frugal* research ?

Debate:

Carbon footprint of research is part of the national public service footprint that have an impact on the whole population, which means that there is a duty of being exemplary / responsibility to act.

It is a privilege of research to be able to question its own methods and objectives.

About good and services : thinking of how to design and make instruments / infrastructures more sustainably, with less resources and materials, and by optimizing budgets.

Resources :

- Labo1point5 : https://labos1point5.org/
- Rapport du COMETS : https://comite-ethique.cnrs.fr/avis-du-comets-integrer-les-enjeux-environnementaux-a-la-conduite-de-la-recherche-une-responsabilite-ethique/

❖ Presentation of GHG assessment of IRAP and particularities of astrophysics research (Victor Réville, IRAP, 30 min)

The environmental commission of IRAP performed a GHG assessment carried out in 2021-2022, based on 2019 data.

Ambition to keep global warming under 1.5°C seems unreachable. It would require to reduce GHG emission by 7,6%/year (compared to 2015). In 2020 during the lock-down, we observed a reduction of 6% = shows the effort that should be made each year.

Method: use of the “Bilan Carbone” method developed by ADEME (French agency for environmental transition), identifying and quantifying every emission source of IRAP. Contrary to GES1.5 method, IRAP’s GHG assessment considered all research infrastructures (ground-based and space-based). It was based on 2019 data (pre-Covid19 period), all of the 3 facilities were considered (Roche, Belin, Tarbes), all the staff (263 people in 2019), and all activities except from academic teaching (counted in Paul Sabatier University’s assessment).

Main results :

- Observatories (ground + space) = 55% of GHG emissions of IRAP
- GHG Emissions of IRAP = 30 tCO_2eq / person

Next step : defining reduction goals following the national trajectory recommended by ADEME. The objective is -50% emissions by 2030 / carbon neutrality by 2050.

Debate :

INSU-AA (National Institute for Universe Science – Astronomy and Astrophysics) :

- Forward planning (prospective): does it include a reflection on low-carbon science?
- Reliability of carbon footprint indicators for observation infrastructures?
- Many members of the astronomy community might clear themselves from these responsibilities?
- Important to anticipate in order not to be powerless in case of energetic crises for instance. But very complicated to address this subject with decision-makers.

- Important to make strong choices to promote some instruments rather than others, to reduce our environmental footprint.

GHG assessment results: infrastructures data are made on a cost-based approach, is it really reliable? Actually the carbon footprint of an instrument is also calculated based on its size and weight with carbon emission factors, and it leads to the same results as the cost-based approach.

Important to have more detailed analysis (especially Life Cycle Assessments) on astronomy/astrophysics projects in order to get data on environmental footprint and to have reusable indicators to develop new projects.

Reusable spacecrafts (e.g. SpaceX): for an equal performance, the carbon footprint is much higher than for a single-use spacecraft (due to the amount of fuel necessary to bring back the spacecraft on Earth and other specific processes). As the cost is lower, there is an important risk of "rebound effect". For instance : 180 launches in 2022, which is not a sustainable trajectory. The Starlink program plans 4000 launches in a few years, which represent 60 millions tCO_2. By comparison, the total of all scientific observation satellites represent 5 millions tCO_2. Hence, it is very important for governments / public agencies to regulate private space agencies.

Cut back on projects: the biggest projects are decided by committees on an international scale, outside of labs. So choices must be made between apply for theses projects and try to do things right, or don't go (for environmental reasons) and let someone else do it anyway. Yet, we can adopt a revolutionary approach: who is going to built and use new instruments if researchers don't want to?. Need to encourage this debate within scientific communities.

Resources :

- A comprehensive assessment of the carbon footprint of an astronomical institute, by Pierrick Martin, Sylvie Brau-Nogué, Mickael Coriat, Philippe Garnier, Annie Hughes, Jürgen Knödlseder & Luigi Tibaldo Nature Astronomy, DOI : 10.1038/s41550-022-01771-3
- The carbon footprint of IRAP, by Pierrick Martin, Sylvie Brau-Nogué, Mickael Coriat, Philippe Garnier, Annie Hughes, Jürgen Knödlseder, Luigi Tibaldo, http://arxiv.org/abs/2204.12362
- Estimate of the carbon footprint of astronomical research infrastructures. Knödlseder, J., Brau-Nogué, S., Coriat, M. et al. Nat Astron 6, 503–513 (2022).

II] **Science within society and its relations with industry** (11h – 12h30)

❖ Science, an extra touch of soul for space industry? (Arnaud Saint Martin, CESSP, 30 min)

Study of American spatial policy from the 1980s and the emergence of the *New Space:* funding, financial speculation, privatization, operating standards that are really not energy efficient. The point of this presentation is to show how spatial research can be done differently (by contrast with the New Space policy).

From the 1980s: "new neoliberal regime of astronautics" : the focus is put on business, privatization, patents… Make science a profitable business. Young researchers are encouraged to create start-ups. This is due to a long lobbying process that led to a degradation of science values and ethics (cf. R. Merton).

This vision is completed by the idea to reorganize scientific program with a new distribution between public and private stakeholders. The role of governments is reduced (become clients of private contractors) with huge public funding to support start-up creations. This has an effect on how science is produced (cf. Steven Shapin). The aim of private actors is to occupy space, to make it attractive for business, with the belief of an infinite growth.

Ex: attempt to privatize NASA in 2004/2005, many start-ups emerged from this experience and became very powerful private actors in the space economy.

From the point of view of space industry : industries see science as a "client" : selling ready-to-use systems or tools, with the conviction that it is good because it is for science. These are "win-win" partnerships, for the private actors it allows to develop public relations. Most of the space business is for military applications, but there are also other specific markets such as agriculture.

Science is no longer the at the heart of most space projects. Space engineering has an ambivalent relation to science. Disappointment or frustration for scientists who tried to start a business and failed. Science is an indicator of one's perception of social utility, and science has become an "extra touch of soul" for space industry and a support for capitalist philanthropy.

From the point of view of science : no binary vision in the scientific community regarding space industry. It can go from hostility toward very powerful private actors, to embarrassment, fatalism, enthusiasm... Idea that "why not, if

they do a good job, we can still regulate them" and that if some private projects work, it could be revolutionary for astronomy.

However, the question of the environmental cost remains, as well as the political cost (let to the private sector the glory of the new big advances and space conquest).

Debate :

Question of inhabited flights : astronauts are seen as "space ambassadors" (serve objectives of soft power, to gain or keep compliance from the population). Space agencies are so huge they need embodiment.

To see the birth of a "French SpaceX or Falcon" seem complicated, despite the wishes of the government. French space policy is making feeble attempts but so far it does not succeed. One of the reasons is that financial risk-taking is not part of the French culture and not compatible with its social system.

Resources :

- Publications et travaux d'Arnaud Saint-Martin : https://cessp.cnrs.fr/-SAINT-MARTIN-Arnaud-
- « L'histoire longue des promesses du New Space », Arnaud Saint-Martin (CESSP), *Humanités spatiales*, 19 novembre 2019.

❖ Environmental emergency, responsibility of the scientific community and relevance of researcher's engagement (Odin Marc, GET/Atécopol, 30 min)

Following Naomi Oreskes (Harvard University), the main purpose of scientists is to bring an enlightened information to the public. So the speech on climate change needs to be comprehensible, but also that people agree to hear it. There are contradictory or even wrong informations spread to sow doubt or confusion (from the lobbies for instance). So this position of bringing scientific knowledge is not enough.

Environmental crises is not an ideological or scientific fight, it is about how to completely reorganize the entire society.

A Technical / management vision, finding techno-solutions is often proposed with the idea that "it will work later". This vision is discarding alternatives, and there is a path dependence for the next years or even decades.

A mental barrier to blow away is science neutrality. It is known that science is not neutral, and should never be. Individual and collective values have an influence on science.

Scientists can involve themselves by different ways :

- Write papers
- Stand for their opinion publicly
- Take part in fighting actions

The privilege to know, the duty to act

Debate :

Which arguments can scientists use to base their legitimacy? To be able to use and explain scientific method, present data that have achieved a scientific consensus => these are not arguments from authority ; scientists do have a legitimacy to share other scientists' work.

Risk of technocratic position. Societal choices must be made collectively and democratically but also informed by scientists. Important to keep objectivity and scientific rigour, which require the work to stay collective.

IRD meeting about scientific communication :

- Rights : academic freedom
- Duties : duty of reserve (as part of a public service)

However the duty of reserve does not apply for researchers as it does for other civil servants (more freedom of speech for scientists). There is also a duty of individual ethics (new COMETS report on the matter).

Resources :

- Jérôme Baschet, Basculements. Mondes émergents, possibles désirables, Paris, La Découverte, coll. « Petits cahiers libres », 2021, 256 p., ISBN : 9782348066733.
- Three Decades of Climate Mitigation: Why Haven't We Bent the Global Emissions Curve?. Stoddard, Isak ; Anderson, Kevin ; Capstick, Stuart et al. / In: Annual Review of Environment and Resources. 2021 ; Vol. 46, No. 1.
- COMETS Report https://comite-ethique.cnrs.fr/wp-content/uploads/2023/07/AVIS-2023-44.pdf

II] **Low carbon initiatives at IRAP** (13h30 – 15h30)

❖ Reusing instruments: the PILOT balloon experiment (Jean-Philippe Bernard, IRAP, 20 min)

Airborne astrophysics observations use mobile telescopes, which are reusable as they are brought back on Earth. These have a very high carbon footprint as they are carried by plane. Very expensive and complex operations.

Another option is to use balloons. Using the buoyancy force, it is possible to move several tons of scientific equipment up to 40km; and the equipment is reusable. It is an unusual method but an interesting one ; well developed in France thanks to the CNES balloon program. This program was threatened many times because of the systematic recourse to satellites. But environmental considerations “saved” these experiments.

CNES has developed a great experience with balloons so there are very few incidents. These experiments are very reliable.

GHG impact : about 1.4 tCO_2 per flying hour (average flight = 20h). By comparison, a satellite releases 4 tCO2 per hour. Flights are conducted in Canada, Australia or Sweden (low population density areas to avoid accident risk), and most of the footprint is related to the transportation of the equipment in these areas. The flights used to be carried out in France but the rules were modified for risk prevention reasons, however thanks to the high level of control of this technology, it would be possible to bring back the campaigns here with very low risk.

Concerning the PILOT experiment, it appeared that with simple modifications of the instruments, its purpose could be changed (remaining in infrared observation), multiplying the possible applications for a single equipment.

At some point decision-makers where not convinced to continue the program, despite the arguments of researcher who wanted to implement new balloon-borne campaigns for other scientific purpose. Idea that if the technology is not used for a while, expertise gets lost, would require to start all over again later.

Balloon-borne experiments are a very low-carbon way to access space, but requires to unlock some technical or regulatory barriers that (unnecessarily) complicate projects.

Long-period flights are possible but require to fly in very low density areas (such as Antarctica), so it’s very expensive and it’s less easy to get the equipment back. But extending a campaign can avoid to multiply missions. Another advantage of balloons is the possibility to change instruments between 2 campaigns (unlike satellites).

Resources :

- Website PILOT project : http://pilot.irap.omp.eu/PAGE_PILOT/index.html

❖ The value of exploiting archival data – An example of reducing our dependency on new research infrastructures (Jürgen Knödlseder, IRAP, 20 min)

The objective is to show how a new scientific question can be answered without a new mission (for this work : gamma-rays observation in the crab nebula). Reducing GHG footprint of astrophysics research will require reducing the rhythm of new instrument developments, and building new infrastructures compatible with planetary boundaries.

Example of the Comptel program (gamma-rays observation satellite). Its data system was so rigid that it was no longer usable after the mission (inoperable data). However the code and associated documentation were saved. Thinking of how to make science differently (“slow science”) by reusing Comptel data (from the 1990s). It represented a 10 year work from 2012 to 2022. Thanks to an improved computing capacity (compared to when the data were produced), it was possible to get unexpected results based on old data.

Simultaneously, development of a “carbon tracker” tool for data analysis activities. Allowed to get a carbon assessments of the research activity (for example to estimate the carbon footprint of a scientific paper) :

- Paper using data from a new space mission: 23 tCO_2
- Paper using archival data: about 2 tCO_2

Debate:

Is astronomy going to lack astronomers, because of the exponential increase of data?

Recruitment commissions need to change criteria to value projects based on archival data rather than promote new projects only.

It is easier for senior and permanent researchers to have time for slow-science projects. Senior researchers can also demonstrate that it is possible to make things differently: responsibility of the elders to promote other methods than the traditional “always bigger, always further”. It can be a good incentive to younger researchers that have a stronger ecological awareness, a change of mindset needs to be boosted.

How many big discoveries were missed because the data were only partially exploited? And how many expensive projects are initiated for almost zero results? It’s easier today to re-analyze old data thanks to a bigger computing power, but this research field is not promoted in France (contrary to the US for instance).

❖ Future of numerical calculation (Pierre Marchand, IRAP, 20 min)

In France : 3 national computing center + 40 meso-centers = 1 million CPU cores. Each year 2 billions CPU hours are requested. Astrophysics represents 300 millions CPU hours per year. That is without considering French researcher who use foreign calculators.

How to estimate the carbon footprint of 1 hour CPU ?

- Life Cycle Assessment (LCA) of GRICAD meso-centers in Grenoble = 50% electricity consumption / 33% fabrication
- 1h CPU = 5g CO_2 eq
- 200 000 h CPU = 1t CO_2 eq
- Then data obtained need to be transferred and stored, which also has a carbon impact. “hot” storage use much more energy than “cold storage”.
- After a few years: more efficient (in terms of CO_2 emissions) to redo the calculations rather than storing the data.

Between 2010 and 2018, energy efficiency was improved by a factor 9, but the number of computing installations also increased a lot (rebound effect). The energy consumption for computing stays at the same level.

Debate :

Energy sobriety also implies to stop using code systematically ; use physical modelling instead, and always think about the need / the goal before starting simulations. Requires to change numerical analysts/physicists profile (numerical analysts training diverges from physicists training).

Numerical simulation does not appear in the carbon footprint assessment of IRAP as the data were insufficient for the reference year.

Machine learning and AI also take a substantial part in data production / consumption.

Resources :

- *The Ecological Impact of High-performance Computing in Astrophysics* - https://arxiv.org/pdf/2009.11295.pdf
- https://presse.ademe.fr/2023/03/impact-environnemental-du-numerique-en-2030-et-2050-lademe-et-larcep-publient-une-evaluation-prospective.html
- https://theshiftproject.org/lean-ict/

IV] Valuing and funding low carbon science (16h00 – 17h30)

- ❖ Role of agencies and supervision institution : CNES, INSU, CNRS, SNO, doctoral schools (free discussion)

How to make decision-makers change at every level?

Senior researchers have a greater and easier role to play as they are recognized by the community and are involved in decision-making entities. They have a duty to commit themselves to convince the majority to change the mindset. We are running out of time given the emergency of the problems and the inertia of mentality change.

What freedom do doctoral schools have to promote some positions over others? Does it depends on the ministry? Doctoral schools make their own rules regarding scholarships, with only one imponderable : scientific excellence. It would be a good thing to save some choices for low-carbon science projects, and labs can also encourage that. However there is a risk that young researchers who choose theses options would be then "blocked" for further hirings. It is also a responsibility of recruitment commissions to change criteria (for instance, not taking into account the number of international conferences the candidate attended), and admit that a scientific project can be challenging even if it is based on archival data.

Observation services: a hundred services exist in France. An interesting evolution could be to consider an observation service as it was originally thought (to have instruments used on a long-term, with data used and shared widely and for a long period). This vision is going against the current dynamics that tends to create a new observation service for each instrument and, doing so, narrows the possibilities of sharing data.

Instruments fabrication : labs boards should be at the forefront of decision. IRAP : its main purpose is to design and build instruments, yet to reduce astrophysics' carbon footprint the number of instrument produced should be reduced => paradox ?

No more time for R&D, the priority is put on producing more and more instruments. It could be beneficial to value a method, an expertise (through R&D) rather than one by one instruments. Enables to look deeper into the expertise and to space out missions (less missions but more qualitative).

Change of mindset and professional vision => the funding agencies would be asked for less funding for instrument building and more for data analysis. This change of direction must be implemented collectively, with lobbying operated by the labs (go over individual initiatives). Before INSU forecasting periods (« prospectives», every 5 years), there is a large consultation that could be a good channel for labs and researcher to rally.

Funding low-carbon research: little budget is given for instruments or data that already exists (for instance : little money to analyze the data from an orbiting satellite, once it has been launched there is much less funding), the priority is always given to innovation, even if the experiments are still used, are functional and still give interesting results. Plus there would be a self-censorship, researchers don't even try to ask funding for archival data projects? In other countries, these kind of projects are much more valued than in France (in the US for instance).

Planetary boundaries will impose to make societal choices. It would be best to anticipate, to create a new, frugal and resilient scientific research (meaning to find another way to achieve the objectives, not to lower the quality of research). Also it's important to consider all environmental impacts, not only carbon footprint which is only a part of the problem.

Researchers do decide which fundamental questions they want to work on. They can choose collectively which priorities they want for scientific research. An "ideal" situation for a scientist is to produce few fundamental contributions rather than be involved in many projects that lead to no major scientific results. This is not the vision of financial institutions who expect high visibility through many publications.

Conclusions

- **At IRAP's level : the carbon footprint assessment has been done and shared => now is the time for action.**
- **Important to be aware of the *path dependency* in astronomy/astrophysics research and try to find another way out of it.**
- **Many initiatives are getting structured in France in the scientific field to improve practices regarding environmental impact (mostly bottom-up initiatives).**
- **Science has a duty of exemplarity as a public institution, and has all the knowledge and technique necessary to propose a new model for its own activities.**
- **Militancy as a scientist: different ways to get involved, the scientist position is valued in the society and media so it makes it easier to take the floor, however it remains an individual and civic choice.**
- **Important to multiply more sustainable experiments with projects such as those presented during this seminar, to use those examples to show (especially to decision-makers) that it's possible to do better with less.**
- **Some initiative can already be started. For instance, use the prospectives INSU to notify the instance of the urge of a pradigm shift in the selection and funding of projects. A reorganization of the Services Nationaux d'Observations can be advocated for, to make them more in phase with low carbon science.**

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