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Preliminary results of the SEA sustainability survey 2024: studying the carbon footprint of Spanish Astronomy

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Abstract

We present the preliminary results of the sustainability survey carried out by the "SEA Cero CO_2" working group among Spanish astronomers. The survey aimed at studying, within a limited scope, the carbon footprint of astronomical research carried out in Spain, as well as to collect the opinion of Spanish astronomers about possible ways to reduce it. We estimate greenhouse gas emissions correspond on average to $\simeq 0.54\,\mathrm{tCO_2eq/yr}$ per astronomer from home-office commuting, $\simeq 1.4\,\mathrm{tCO_2eq/yr}$ from super-computer usage and $\simeq 1.46\,\mathrm{tCO_2eq/yr}$ from work travel. A more detailed analysis, including a comparison with pre-pandemic results is under way. We emphasize that the activities studied here represent only a fraction of the emissions caused by astronomical research. An effort at the institutional and community level is needed to quantify in detail these emissions and make plans for its immediate reduction.

1 Introduction

We are in the middle of a climate crisis: the impacts of anthropogenic climate change are already affecting many weather and climate extremes and these are bound to greatly intensify with every increment of global warming (for a review see, e.g., [9]). According to the latest report from the Intergovernmental Panel on Climate Change (IPCC, [3]), any pathway with the possibility of limiting warming to 1.5°C or even 2°C "involve rapid and deep and, in most cases, immediate greenhouse gas emissions reductions in all sectors this decade". On a broader context, climate change is only one of several planetary boundaries that are being transgressed due to human activities [10].

Several works have studied at national or institute levels the greenhouse gas (GHG) emissions (or 'carbon footprint') associated with research in Astronomy (e.g. [13, 7], see [4] for a review). In Spain, the Instituto de Astrofísica de Canarias (IAC) did a sustainability study [6] that contained an analysis of its carbon footprint and presented a proposal for its reduction. We note that all these studies were carried out before the 2020 outbreak of the COVID-19 pandemic.

The "SEA Cero CO_2" working group of the Spanish Astronomical Society (SEA) organized in 2020 a sustainability survey to study the carbon footprint of astronomical research in Spain and to gather the opinion of the astronomical community about ways to reduce it. The results were presented at the 2020 Scientific Meeting of the SEA [2]. In 2024, the working group organized a new survey of the Spanish astronomical community. The aim of the new survey was to make a new assessment of the professional activities and opinions of the community, studying possible changes with respect to 2020. In particular, one of the aims was to investigate changes in the travelling habits related to the effect of the COVID-19 pandemic. Both surveys were limited to study the activities that were more directly related to the decisions of individual researchers (home-office commuting, use of super-computers and work travel). As discussed below, this implies that the carbon footprint estimates correspond only to a small fraction of the GHG emissions associated to astronomical research in Spain.

In this talk, we present a preliminary analysis of the results of the 2024 sustainability survey. A more thorough analysis, including a detailed comparison with the results of the 2020 survey is under way and will be published later.

2 Characteristics of the survey

The survey was conducted online between 20th March and 20th May, 2024. It was announced to $\sim$ 1300 recipients via the `sea-anuncios` mailing list[1] and to the members of the Spanish Astronomical Society (SEA). The survey contained different sections, asking about some personal data to characterize the respondent sample and about activities in three areas (commuting, work travel and computing) to estimate the GHG emissions. We also collected the opinion on possible actions to reduce the ecological impact. The data gathered for the carbon footprint estimate covered the activities during the two-year period 2022-2023.

A total of 126 people completed the survey. For comparison, the number of professional astronomers working in Spain is $\sim$ 1200 [12], so we estimate that $\sim$ 10% of the community answered the survey. To characterize the sample of astronomers that did answer the survey, we compared it to the total population, studied in detail in [12]. The main bias we observe in our sample corresponds to the staff category, as permanent staff are over-represented (56% vs. 41%) while pre-doctoral researchers are under-represented (11% vs. 29%). We corrected for this bias in the carbon footprint estimates by re-weighting the results according

[1] `sea-anuncios` is a mailing list devoted to general announcements and information of interest to the professional Spanish astronomical community

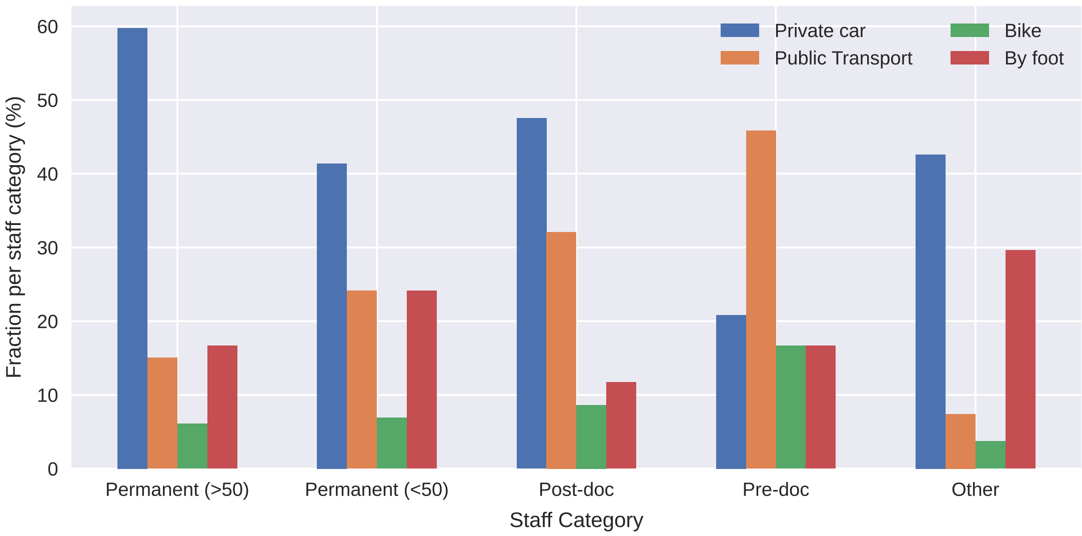

Figure 1: Mean of transport used for home-office commuting as function of the staff category, with permanent staff split between those aged over or under 50.

to the proportions in [12]. We did not observe significant differences when comparing other characteristics of the population such as the distribution by gender or by institution type.

3 Partial estimation of the carbon footprint of Spanish Astronomy

We used the information gathered from the survey to make an estimate of the GHG emissions of astronomers working in Spain in three areas of their professional activities —home-office commuting, super-computing usage, and work trips— in the two-year period 2022-2023. We estimate the footprint in terms of tons of CO_2-equivalent emissions per year (tCO_2-eq/yr) per astronomer. For reference, in 2022 the total per capita GHG emissions (including work and personal activities) were 5.2 tCO_2eq/yr in Spain, and 4.7 tCO_2eq/yr globally[2]. The emission factors we assume for each mode of transport come from the UK government recommended conversion factors for 2019[3]. For air travel, these include a 1.9 correction factor to take into account radiative forcing [11]. These factors will be updated in future analyses.

Participants were asked about their usual home-office commute (distance and means of transport) and their remote-working habits. The most used means of transport is the private car ($\sim$ 45% of displacements), while $\sim$ 26% of trips are made using public transport (bus, underground, train), $\sim$ 21% by foot and $\sim$ 7% by bicycle. As shown in Fig. 1, there are significant differences among the means of transport used depending on the staff category: the use of car is more prevalent among permanent staff and post-doctoral researchers, while

[2] `https://ourworldindata.org/co2-and-greenhouse-gas-emissions`, based on data from [1].
[3] `https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2019`

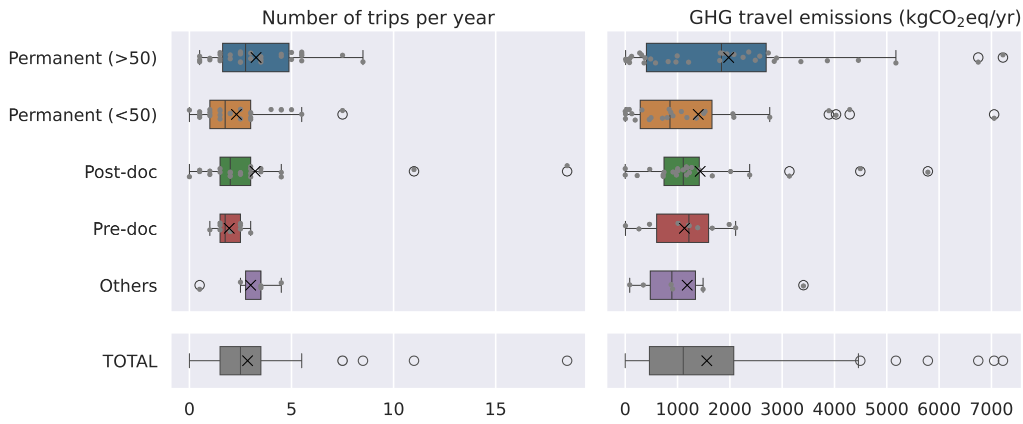

Figure 2: Distribution of the number of trips per year (left) and of the associated GHG estimated emissions (right) for each staff category. Light grey points show individual respondents. Black crosses correspond to the mean for each category.

pre-doctoral researchers use significantly more public transport.

Assuming five return trips per week and knowing the distance travelled, we estimate an overall carbon footprint from commuting of $\simeq 0.76\,\mathrm{tCO_2eq/yr}$ per astronomer. If we remove the trips corresponding to the reported remote-working days, this estimate goes down to $\simeq 0.54\,\mathrm{tCO_2eq/yr}$. This implies that remote work is reducing the commuting carbon footprint by a $\sim 30\%$. However, remote work could also imply an increase of the carbon footprint in other areas (such as heating/cooling) [14] which we do not study here.

We also used the survey data to estimate the GHG emissions from the usage of supercomputers, which is known to be an important contribution [13, 8]. Our estimate is hindered by the low fraction of respondents that are supercomputer users (17%) and may therefore be unreliable. In any case, using the data from the survey and extrapolating to the total population using [12], we estimate that astronomers in Spain use a total of ~ 170 million CPU-hours per year. We convert this usage to energy consumption and CO_2-equivalent emissions,[4] and obtain an average carbon footprint per astronomer of $1.4^{+1.7}_{-1.1}\,\mathrm{tCO_2eq/yr}$.[5]

The survey collected information about the work trips done by the participants in 2022-2023. On average, Spanish astronomers did 2.8 trips and travelled 6600 km per year during that period. As shown in Fig. 2, there is a large dispersion in the number of trips, the distance travelled and the associated GHG emissions among astronomers, even within the same staff category. However, we observe a general trend of increasing travelling with increasing seniority. From these data, we estimate an average carbon footprint of $1.46 \pm 0.23\,\mathrm{tCO_2eq/yr}$ per astronomer. As expected, a large majority ($\simeq 92\%$) of emissions come from air travel.

[4]We assume an energy consumption of 53 W per CPU [13], and a mean conversion factor of $188\,\mathrm{gCO_2eq/kWh}$ for the Spanish grid (following `https://app.electricitymaps.com`)

[5]The errors quoted correspond to a 90% confidence interval computed using bootstrap.

4 Survey on actions to take

The survey also gathered the opinion of Spanish astronomers about possible actions to reduce GHG emissions and fight against climate change with a especial emphasis on the activities of the SEA. Participants had to give their level of agreement about a list of possible actions, mostly focused on travels and conferences, and could also propose other possible measures.

Although a full analysis of these data is still in progress, we can highlight some general results. 74% of respondents consider attending 1 or 2 in-person conferences per year to be appropriate. Also, the majority (86%) would choose the train over the plane when an alternative exists that takes less than 5h (47% would still do if less than 7h). Regarding the SEA Scientific Meetings, the majority (76%) is in favour of making them fully hybrid, and 74% of respondents is also against making them fully online. Finally, a majority (60%) is in favour of including a carbon budget in grant applications. 78% support the organization by the SEA of outreach activities focused on the climate crisis.

Regarding additional proposed actions, some of the mentioned areas are the reduction of the energy consumption at office buildings and the need for institutional de-carbonisation plans; implementation of sustainability measures in conferences; the need of reducing or limiting the amount of travel; and awareness-raising among the research community and the general public, also making the link to campaigns against light pollution.

5 Summary and discussion

In summary, our results indicate that the GHG emissions of astronomers working in Spain during the period 2022-2023 amounted to $3.4^{+1.7}_{-1.2}\,\mathrm{tCO_2eq/yr}$ per astronomer for the three areas considered. At face value, this is a significant reduction of $\sim 50\%$ compared to the results obtained from the 2020 survey [2], which is probably related to the effects of the COVID-19 pandemic. In a future work, we will analyse these differences in detail.

The carbon footprint estimated here covers only a fraction of the total GHG emissions due to astronomical research. Other important emission sources are those associated to office buildings, to the purchase of goods and services, and to space- and ground-based astronomical observatories. Some of these are, in fact, larger contributors to the total emissions than the areas studied in our survey [4, 7]. The most important contribution probably comes from astronomical infrastructure: Knödlseder et al. [5] estimate an average carbon footprint of $36.6 \pm 14.0\,\mathrm{tCO_2eq/yr}$ per astronomer from active observatories worldwide.

This indicates that there is a need for an institutional effort to properly quantify the total footprint and make specific, immediate plans for its reduction. The EU target, in line with the IPCC reports [3], is to reduce the GHG emissions already by 55% by 2030, and by 90% by 2040, relative to the 1990 levels[6]. The reduction in emissions must therefore be at a large scale and very fast in order to limit the global increase in temperature. The contribution of astronomical research to the global GHG emissions is small in absolute terms. However astronomers, both individually and as a community, can play a role by raising awareness

[6] `https://climate.ec.europa.eu/eu-action/climate-strategies-targets`

about the scale and urgency of the climate crisis and by setting an example in reducing the footprint of their activities.

Acknowledgments

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