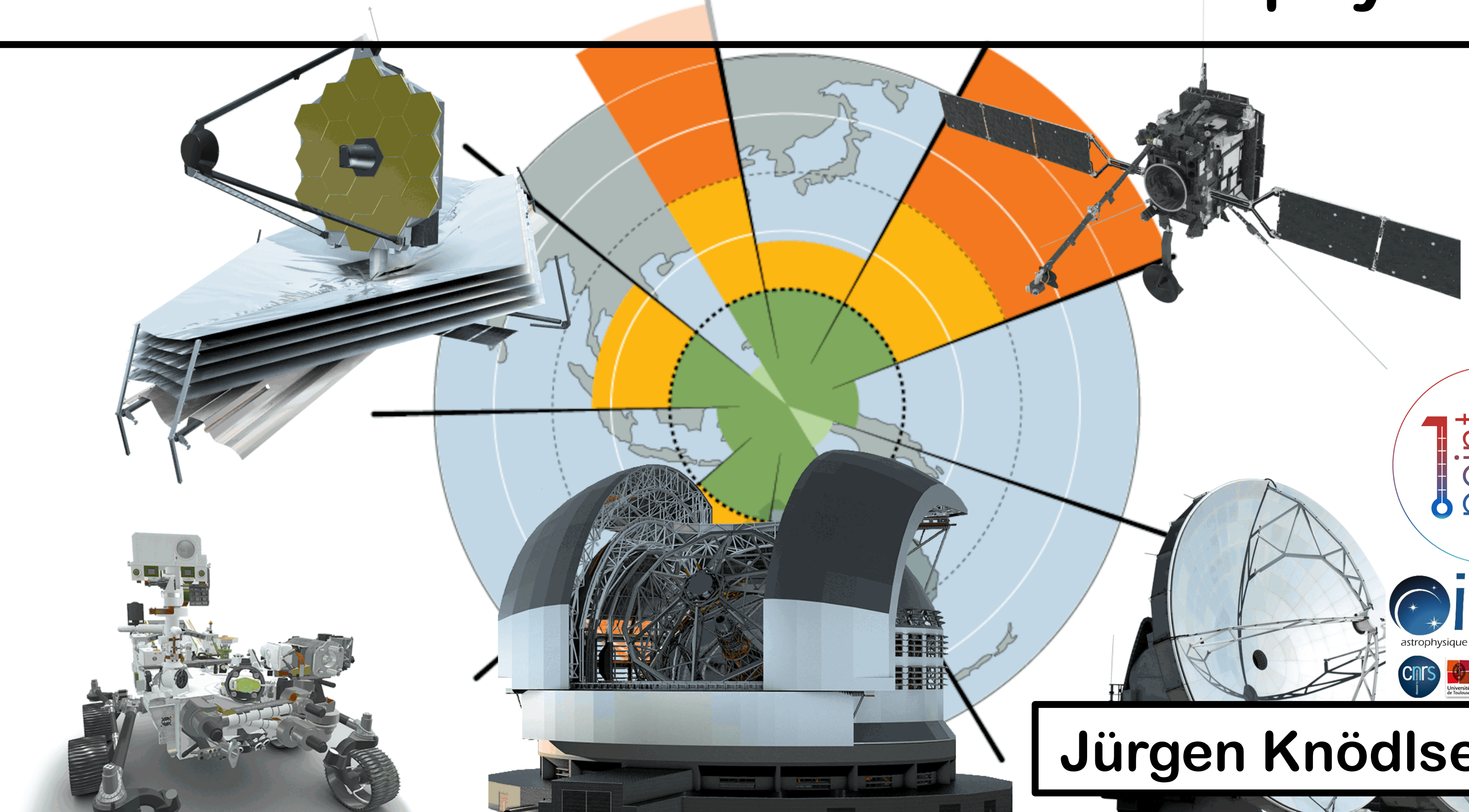
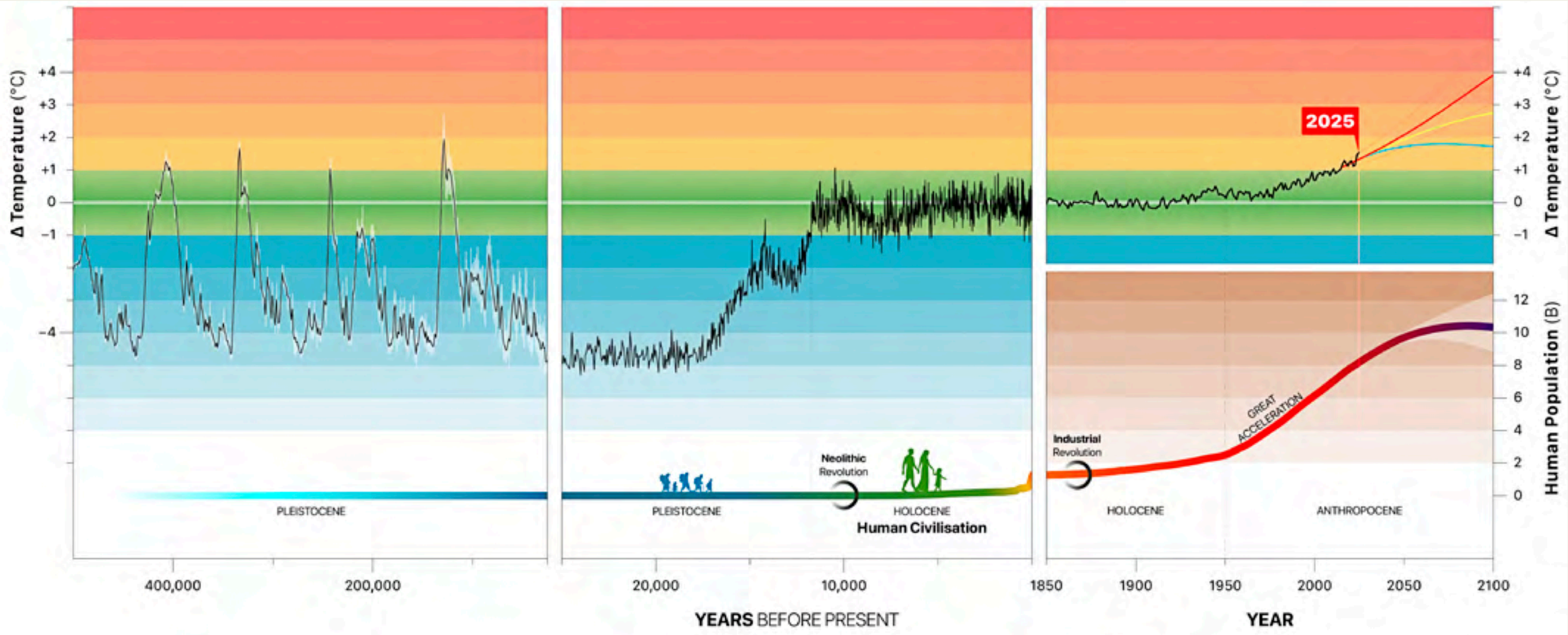
Climate crises and the role of astrophysics



irap
astrophysique & planétologie
Université Paul Sabatier

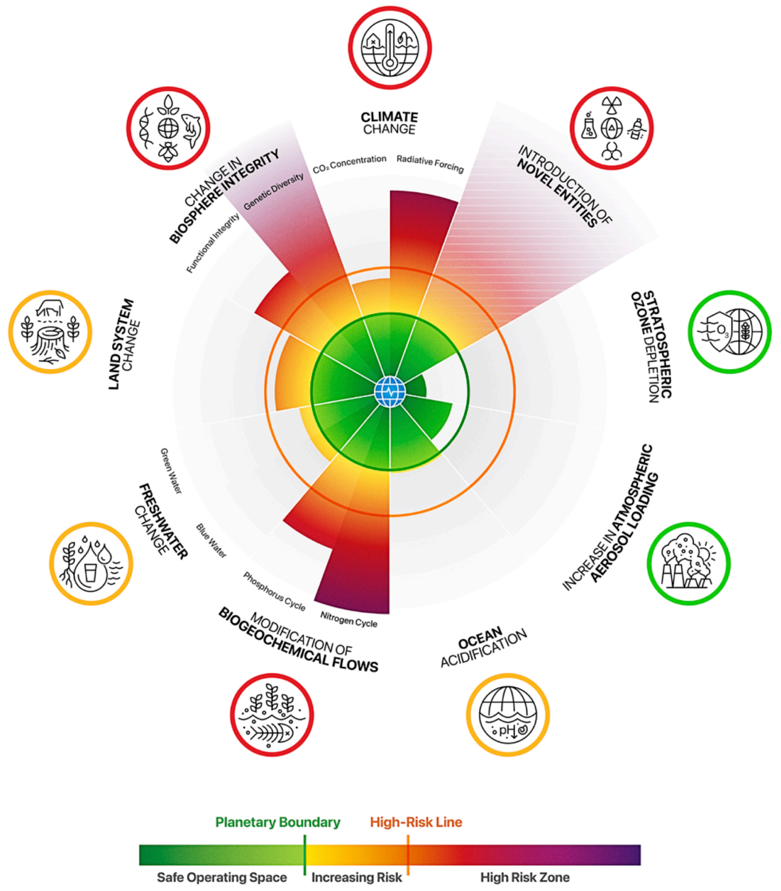
Jürgen Knödlseder

The climate history of Homo Sapiens



Planetary Health Check (2025)

Planetary Boundaries

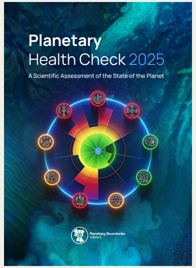


Human activities are destabilising the Earth system at the planetary scale

We are no longer in the safe* operating space for 7 out of 9 planetary boundaries**

*risk of destabilising key Earth system processes and disrupting life-support function

**introduction of novel entities, climate change, change in biosphere integrity, land system change, freshwater change, modification of biogeochemical flows, ocean acidification



Planetary Health Check 2025

Climate change: the evidence

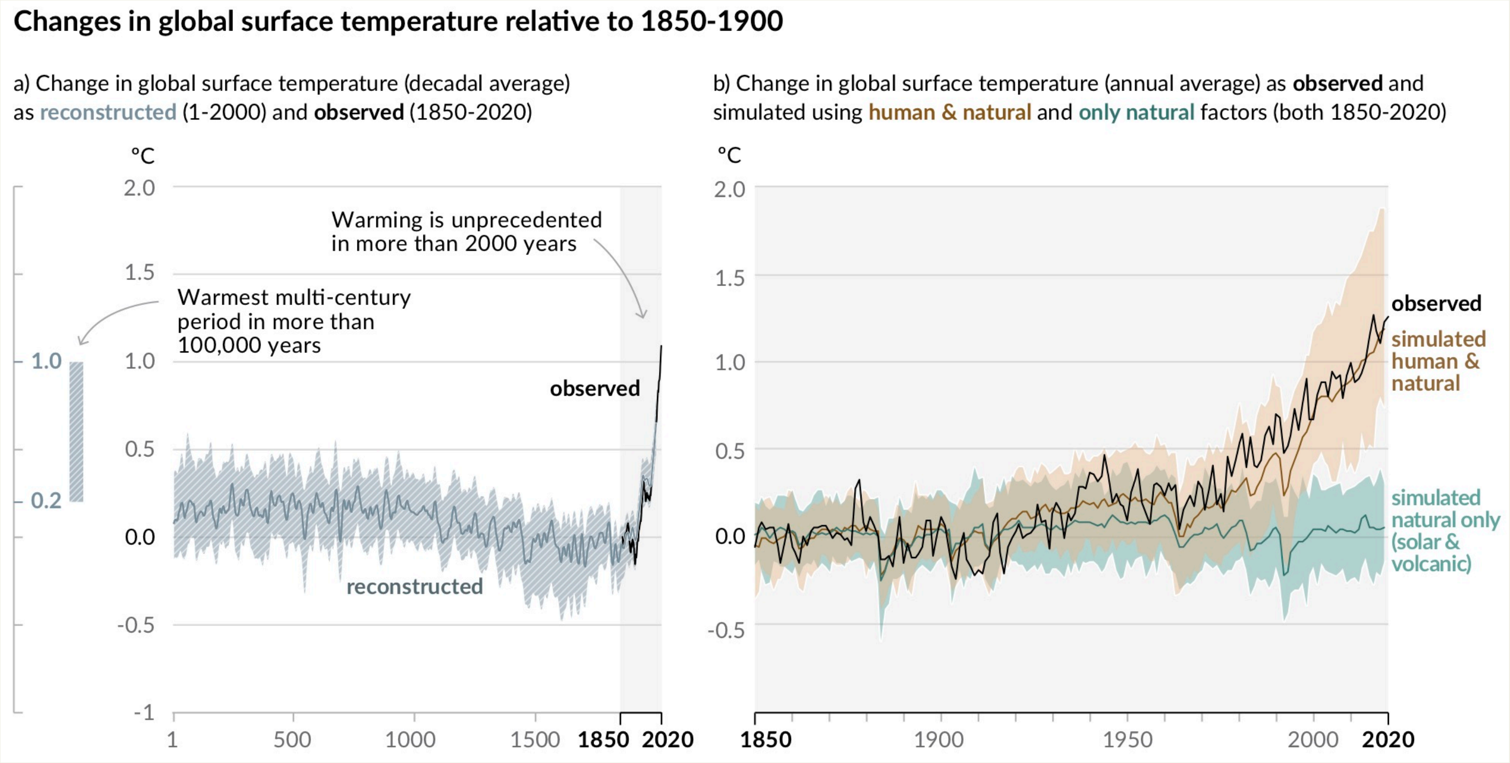


Figure 1 of Summary Report for Policy Makers of the IPCC 6th assessment report of Working Group 1

Climate change: the risks

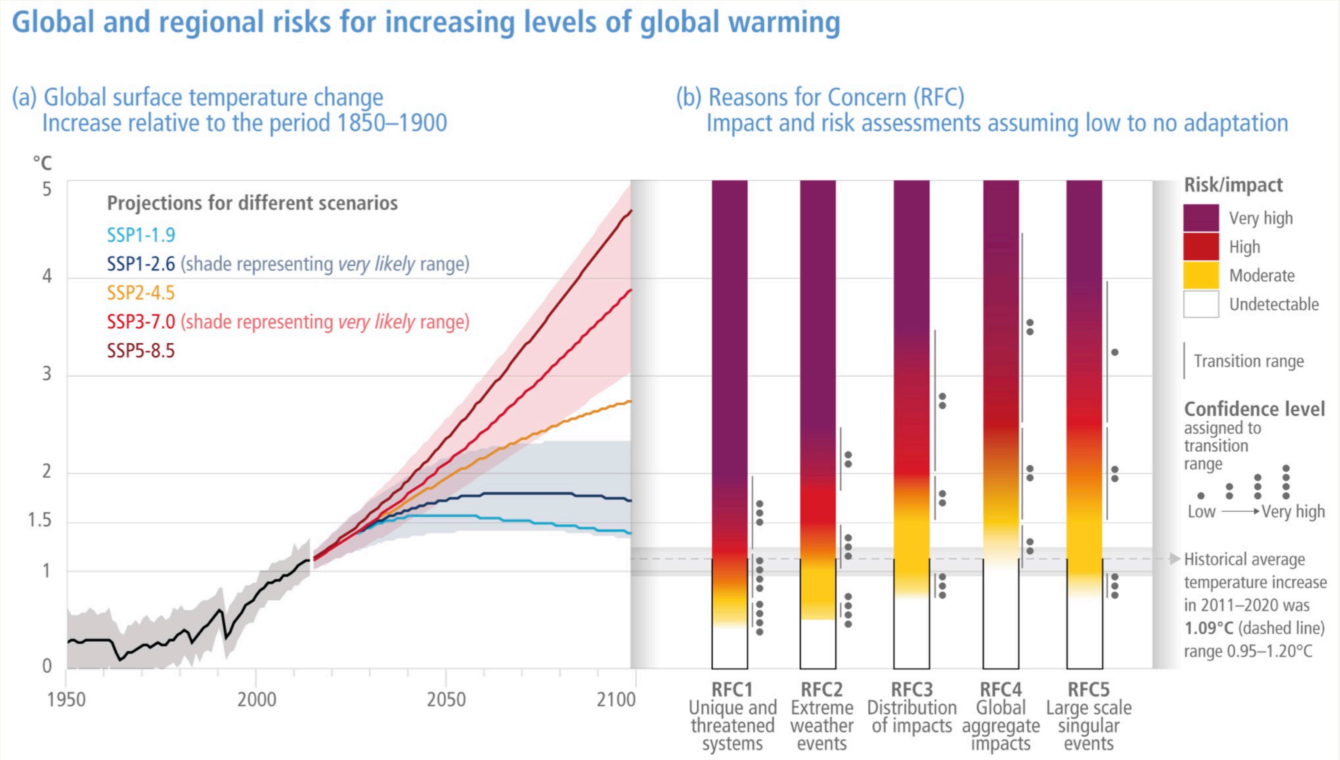


Figure 3 of Summary Report for Policy Makers of the IPCC 6th assessment report of Working Group 2

Implications for scientific research

Ethical responsibility of scientists

COMETS
Comité d'éthique du CNRS

AVIS n°2022-43

« Intégrer les enjeux environnementaux à la conduite de la recherche – Une responsabilité éthique »

Approbation en séance plénière le 5 décembre 2022

COMETS – CNRS ethics committee

Integrating environmental implications into the conduct of research is an ethical responsibility

5 December 2022

Institutional obligations

-46% / 11 yrs*

Resolution adopted on 23/11/2022 during Council meeting at ministerial level

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA RECHERCHE
Liberté Égalité Fraternité

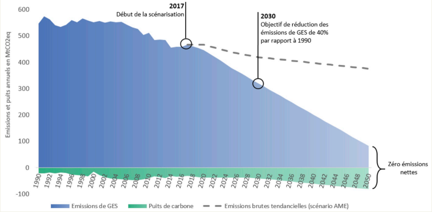
-5% / yr*

Climate-biodiversity plan and ecological transition of higher education and research

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE ET SOLIDAIRE

-82% / 32 yrs*

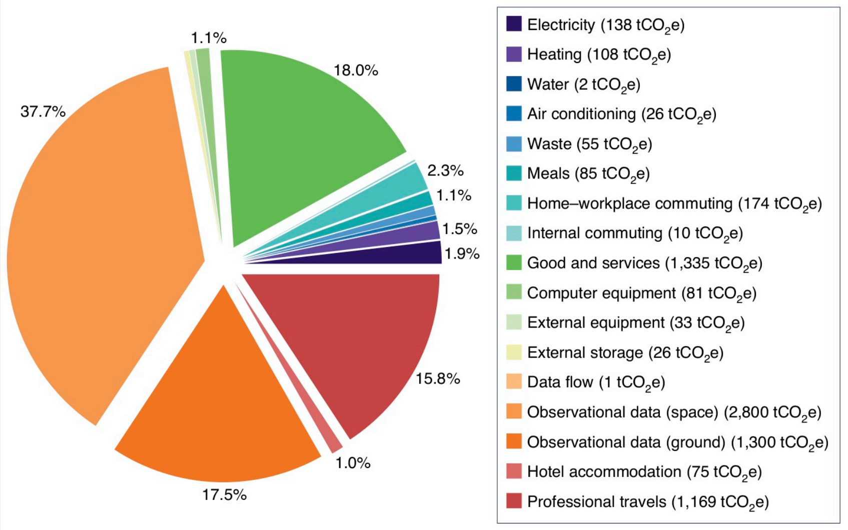


French national carbon strategic plan

*Greenhouse gas emission reductions

The carbon footprint of astronomy

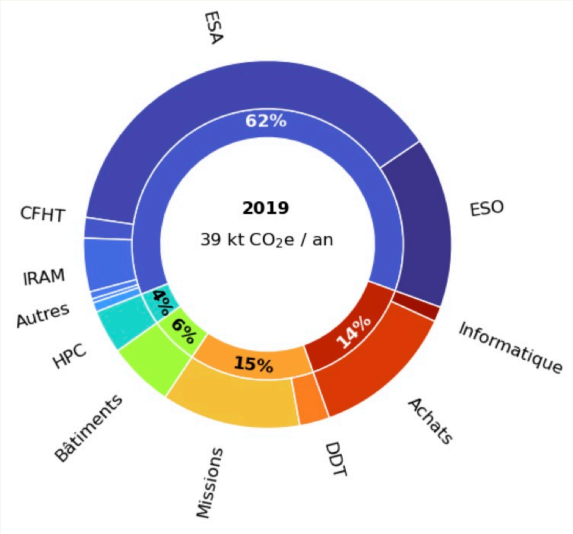
IRAP



Martin et al. (2022), Nature Astronomy, 6, 1219 (arXiv:2204.12362)

28 tCO_2e / capita
55% originating from astronomical facilities

France

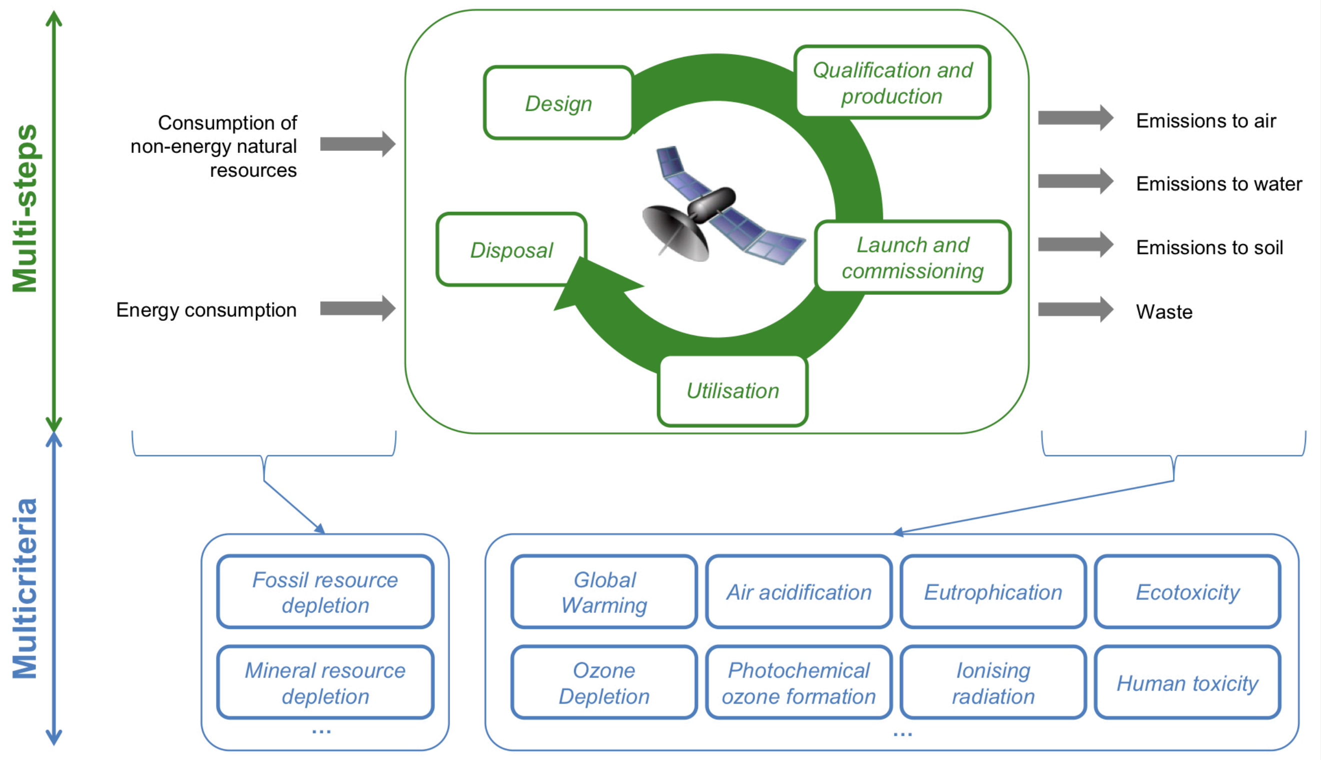


Synthesis report of the working group I.2: Carbon and ecological transition (CNRS/INSU AA)

20 tCO_2e / capita
62% originating from astronomical facilities

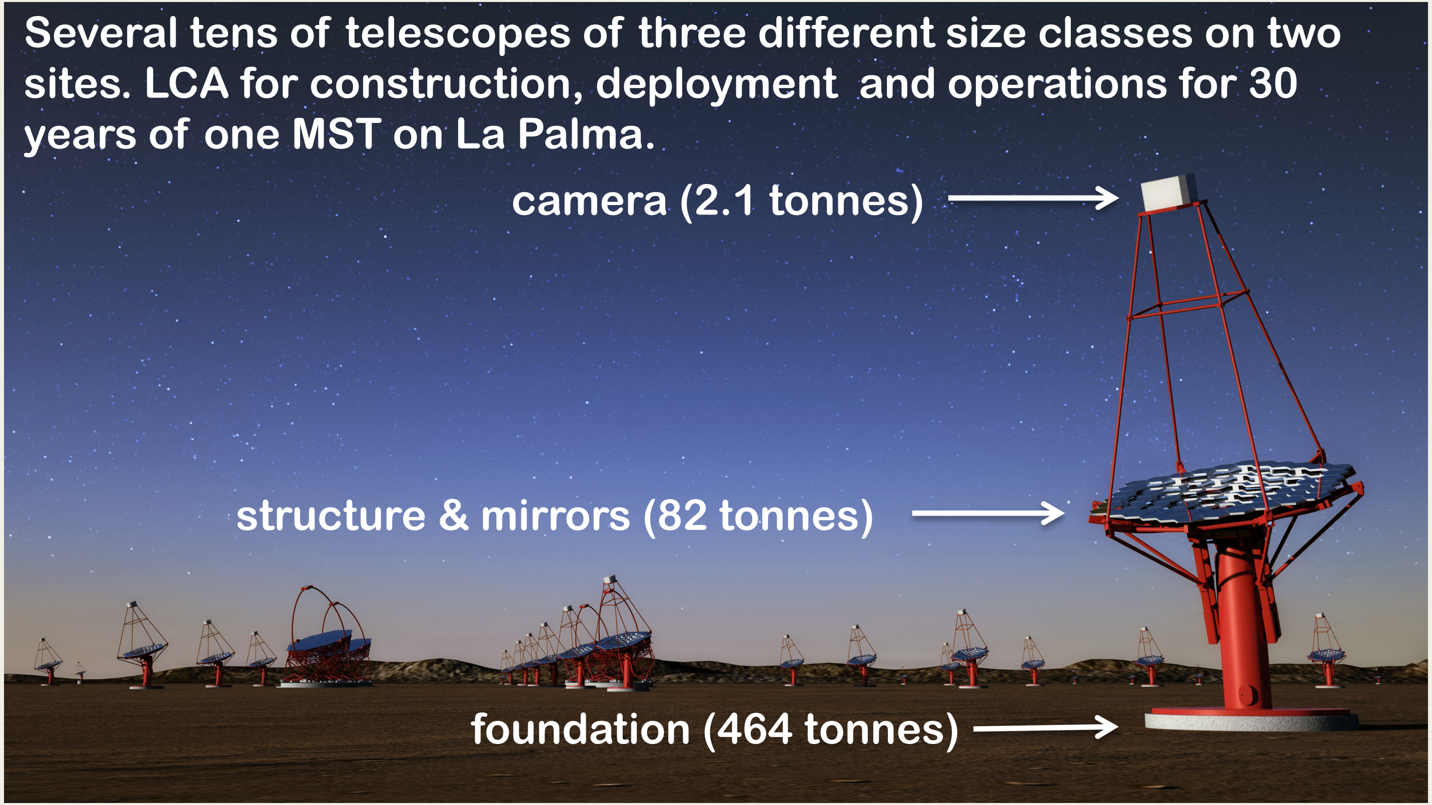
Assessing environmental impacts

Life Cycle Assessment (LCA, e.g. ISO 14040)

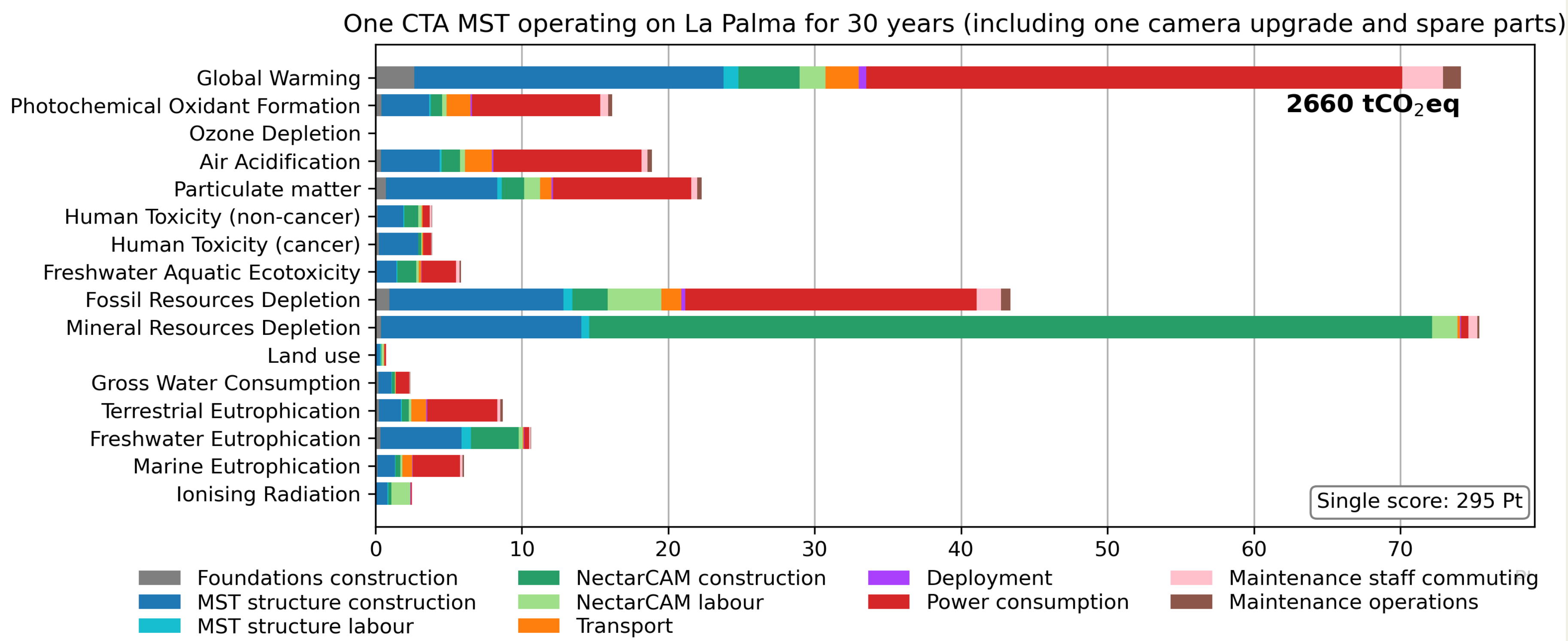


Austin (2015), 5th CEAS Air & Space Conference

Example 1: Cherenkov Telescope Array

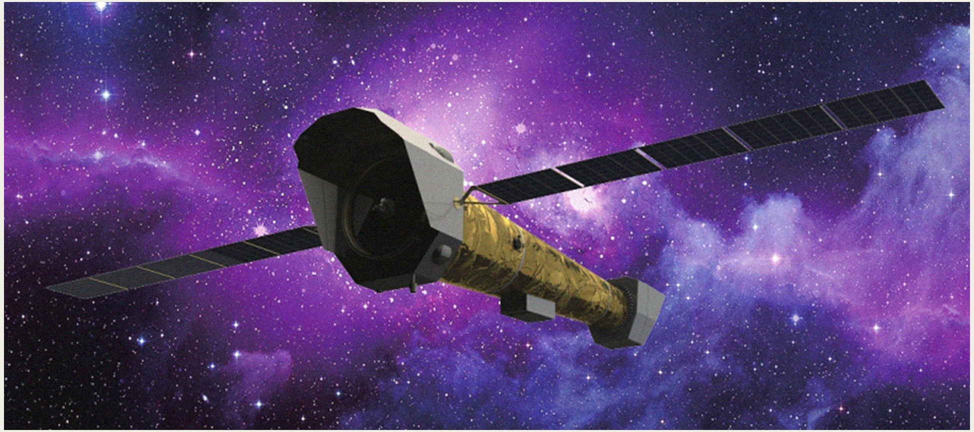


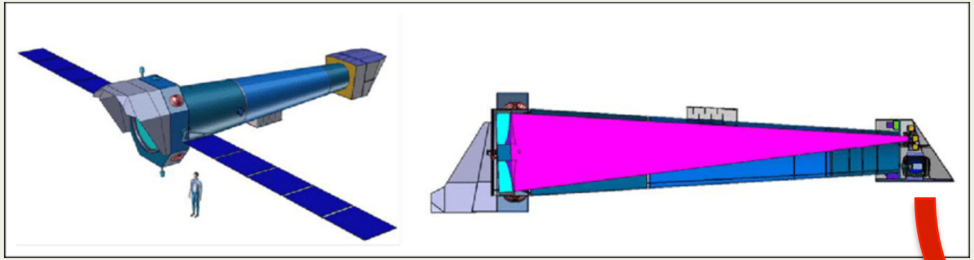
Example 1: Cherenkov Telescope Array



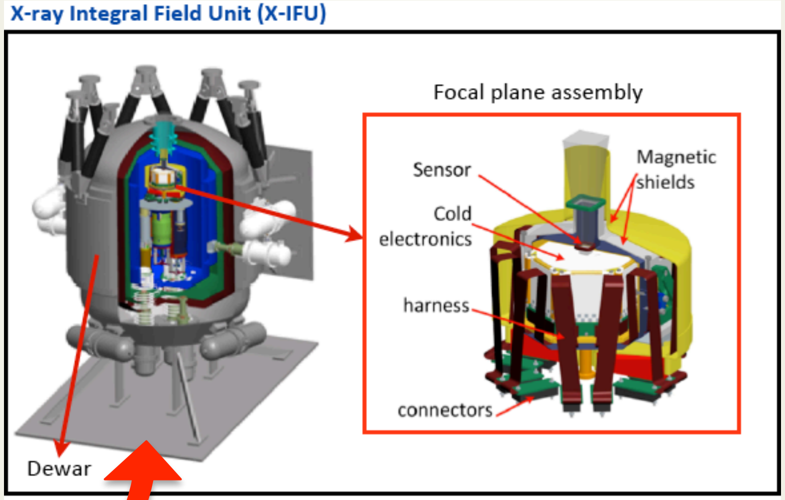
Adapted from Dos Santhos Ilha et al. (2024), Nature Astronomy, 8, 1468 (arXiv:2406.17589)

Example 2: X-IFU aboard ESA's Athena mission

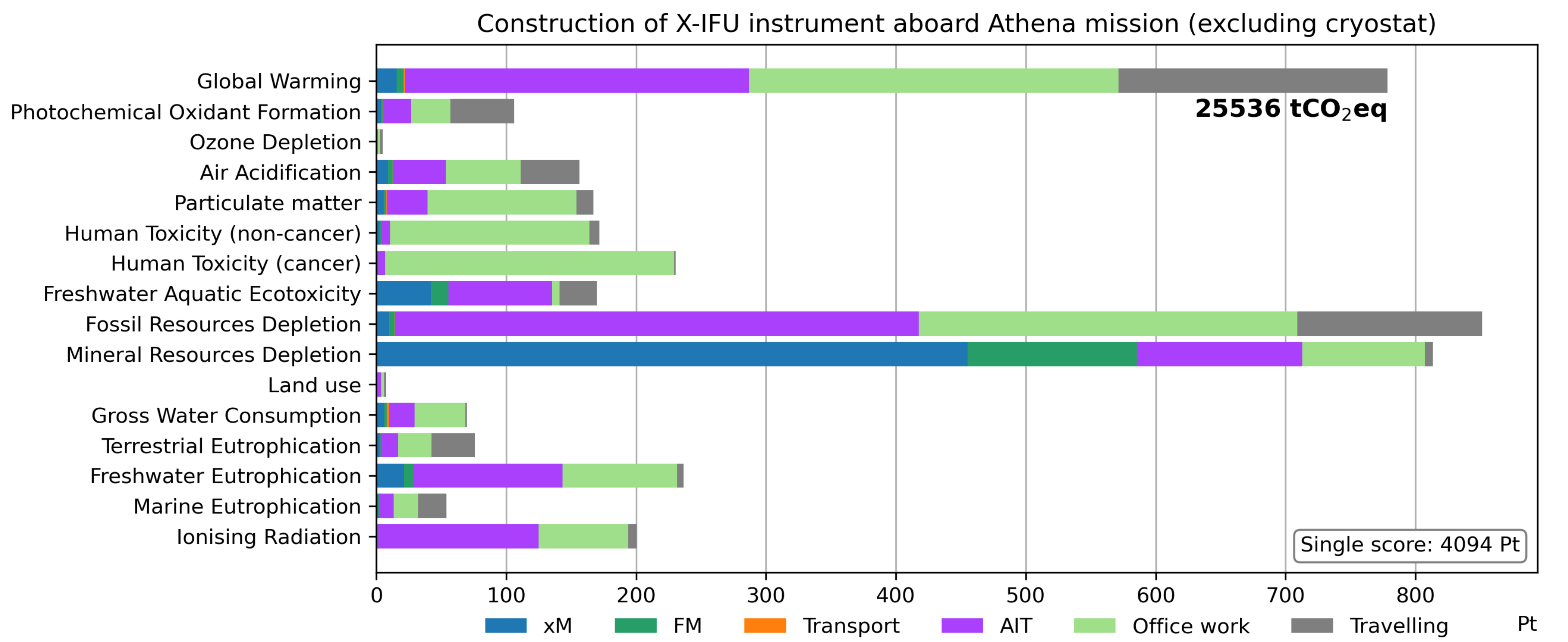




Weight: 221.3 kg
Development & Construction

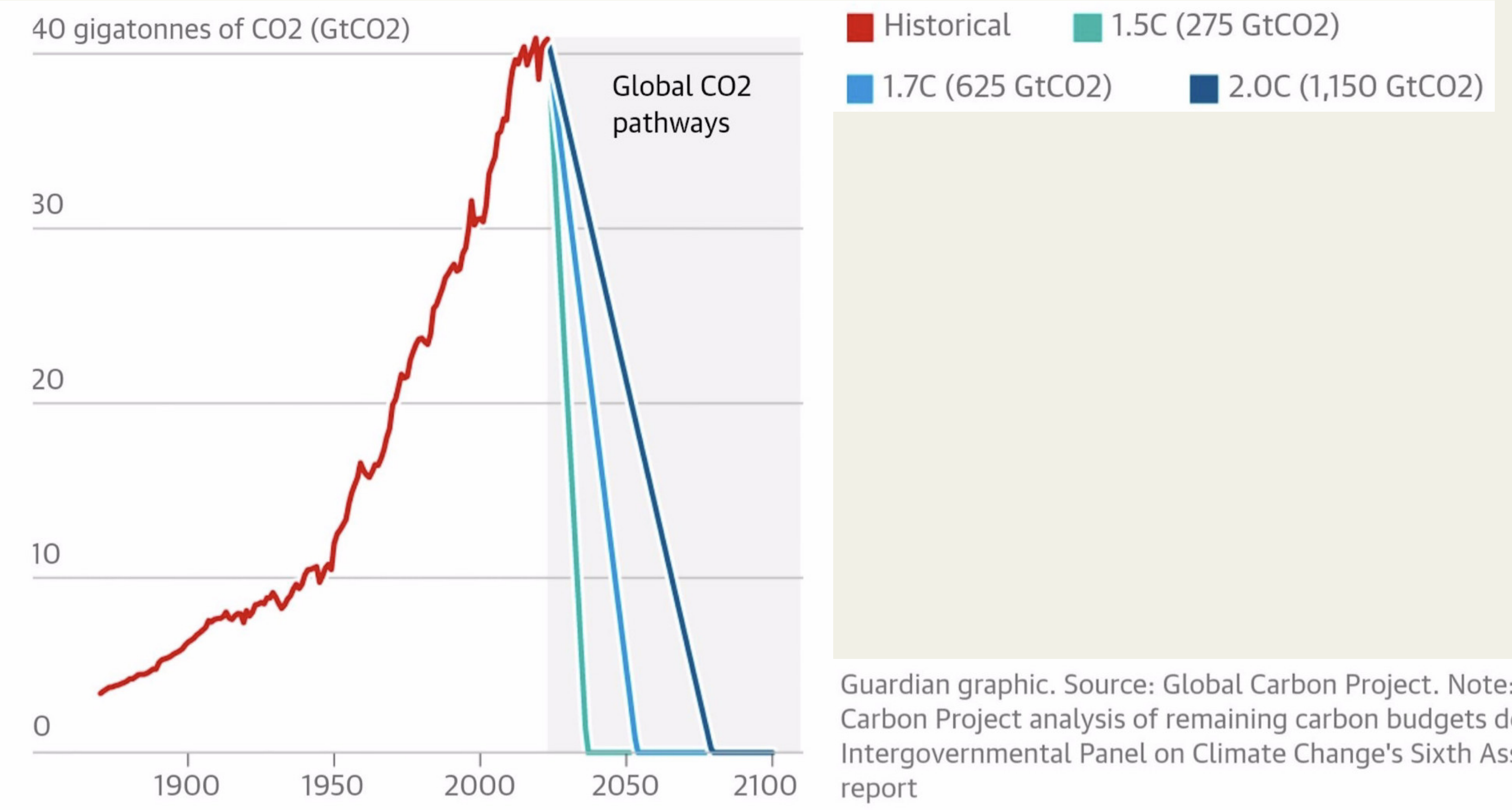


Example 2: X-IFU aboard ESA's Athena mission



Adapted from Barret et al. (2024), Exp. Astron., 57, 19 (arXiv:2404.15122)

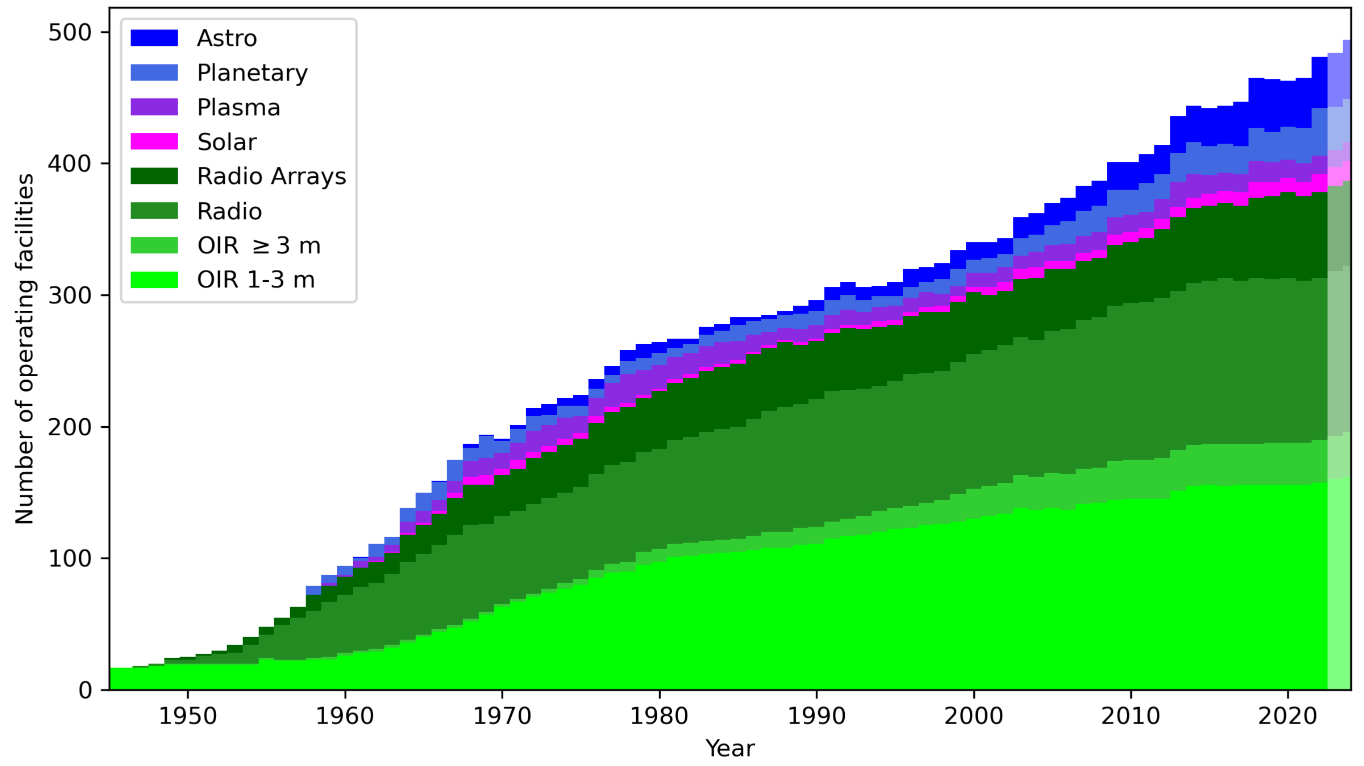
Quo vadis, astronomical research ?



Guardian graphic. Source: Global Carbon Project. Note: Global Carbon Project analysis of remaining carbon budgets defined in the Intergovernmental Panel on Climate Change's Sixth Assessment report

The growth of astronomy facilities

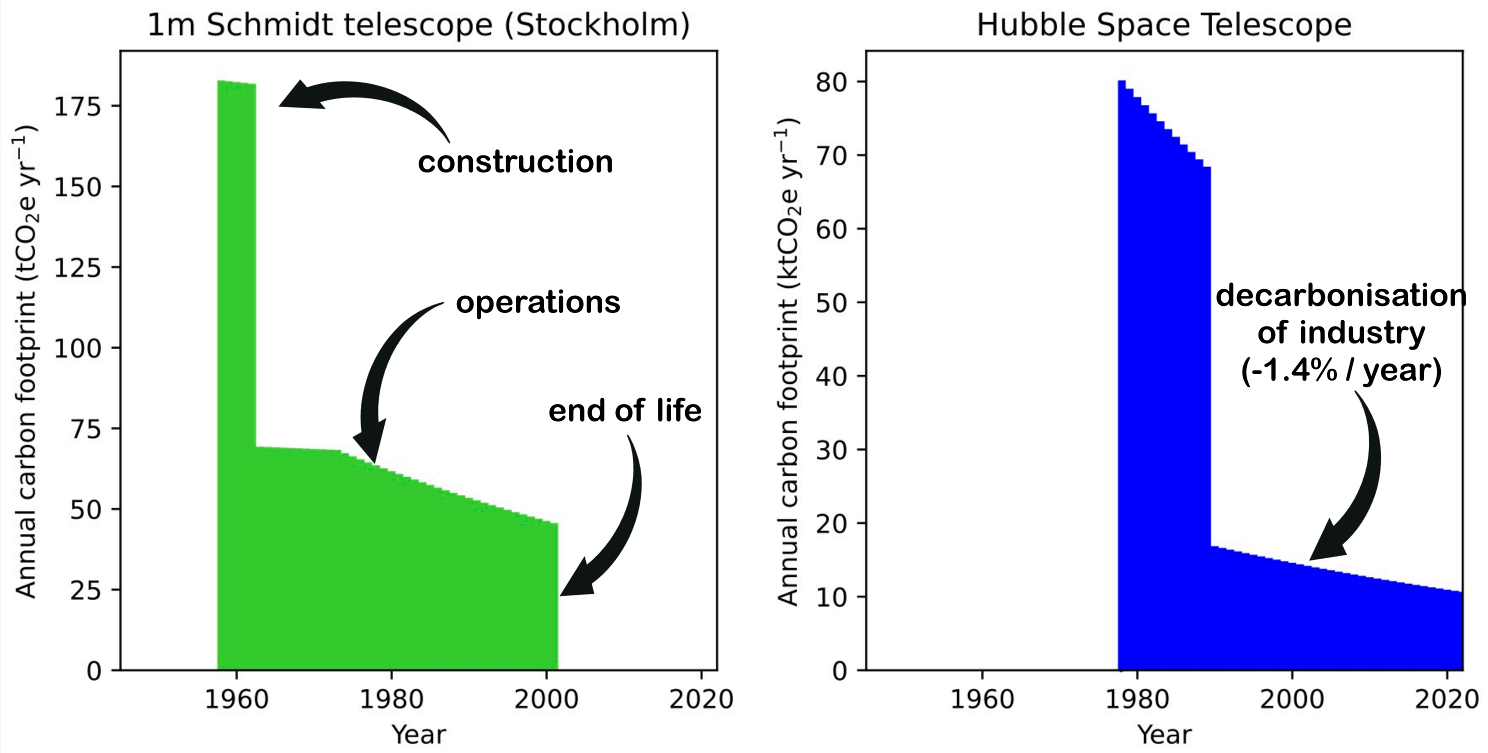
based on 652 space missions and 596 ground-based observatories



Adapted from Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

Modelling the facilities' carbon footprints

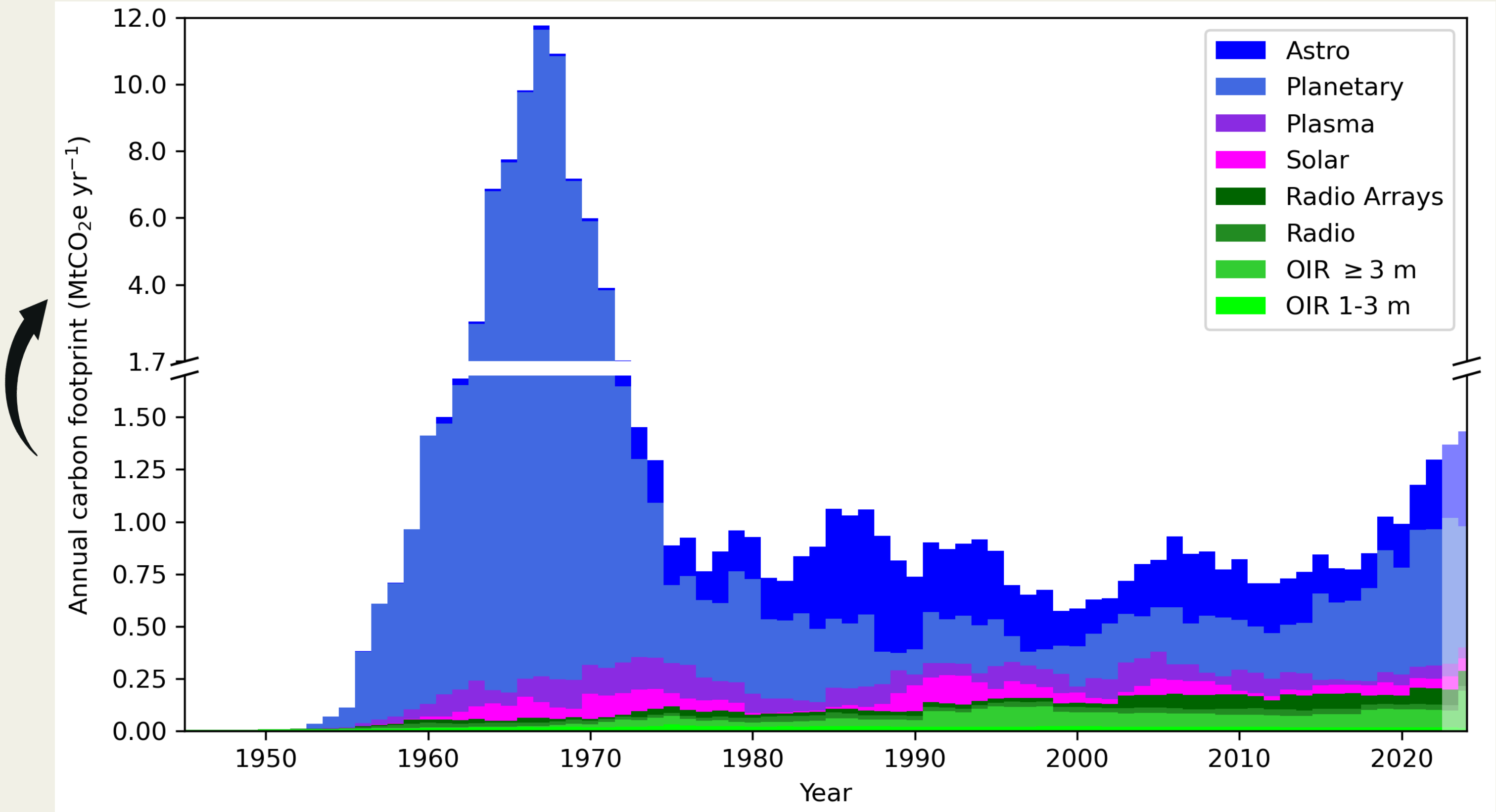
example ground-based and space facility



Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

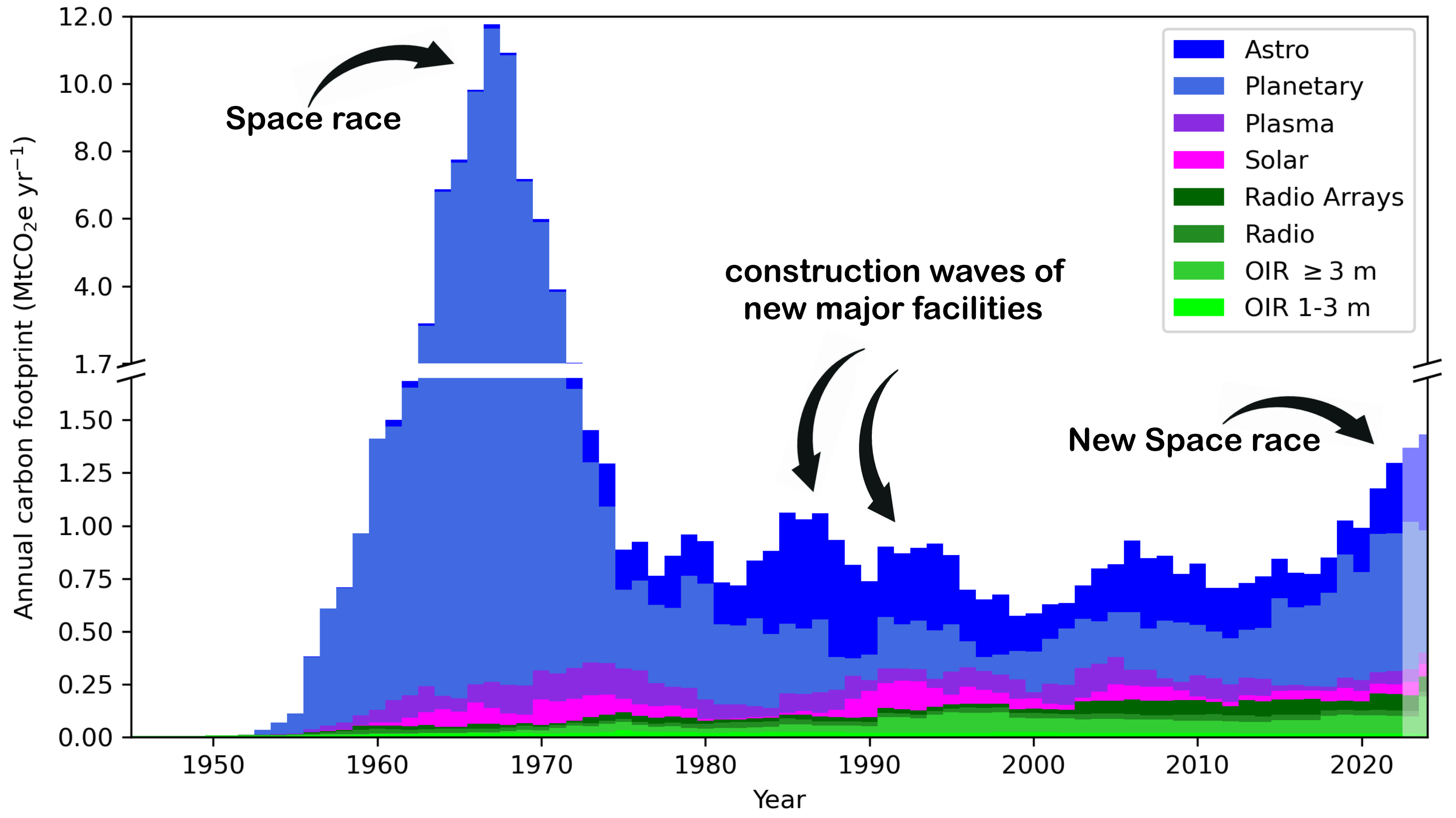
Evolution of the facilities' carbon footprint

change of y axis scale



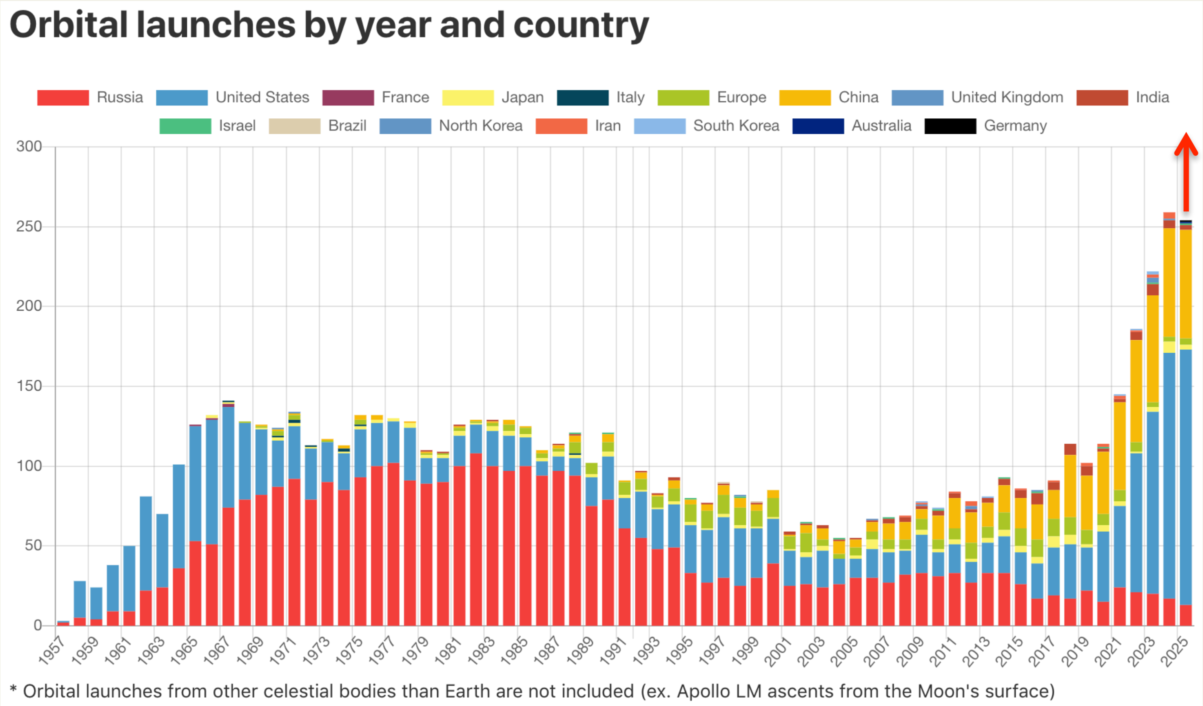
Adapted from Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

Evolution of the facilities' carbon footprint



Adapted from Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

Newspace!

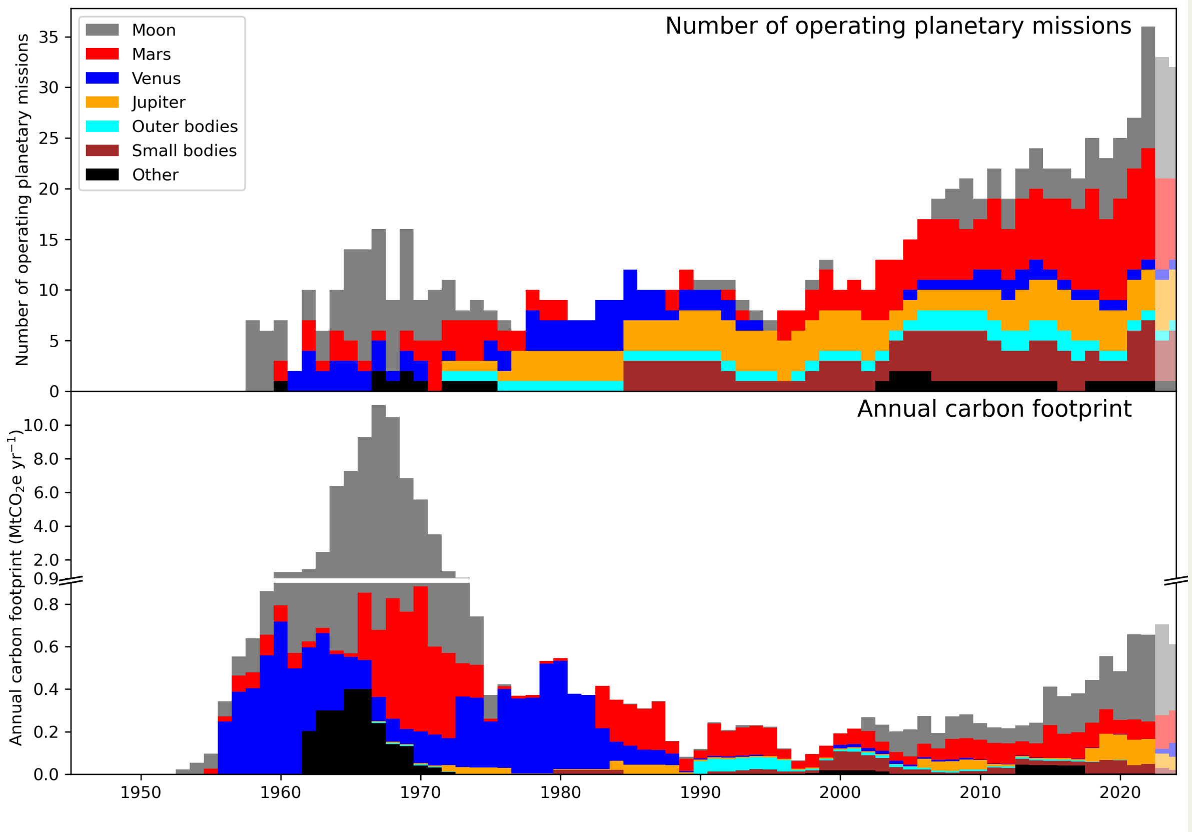


https://spacestatsonline.com/launches/country/ (as of 2 November 2025)

Space activities entered a phase of exponential growth, owing primarily due to expectations for large financial benefits and also new actors (China, India).

Astronomical research opportunistically benefits from this growth.

A new race to the Moon and Mars



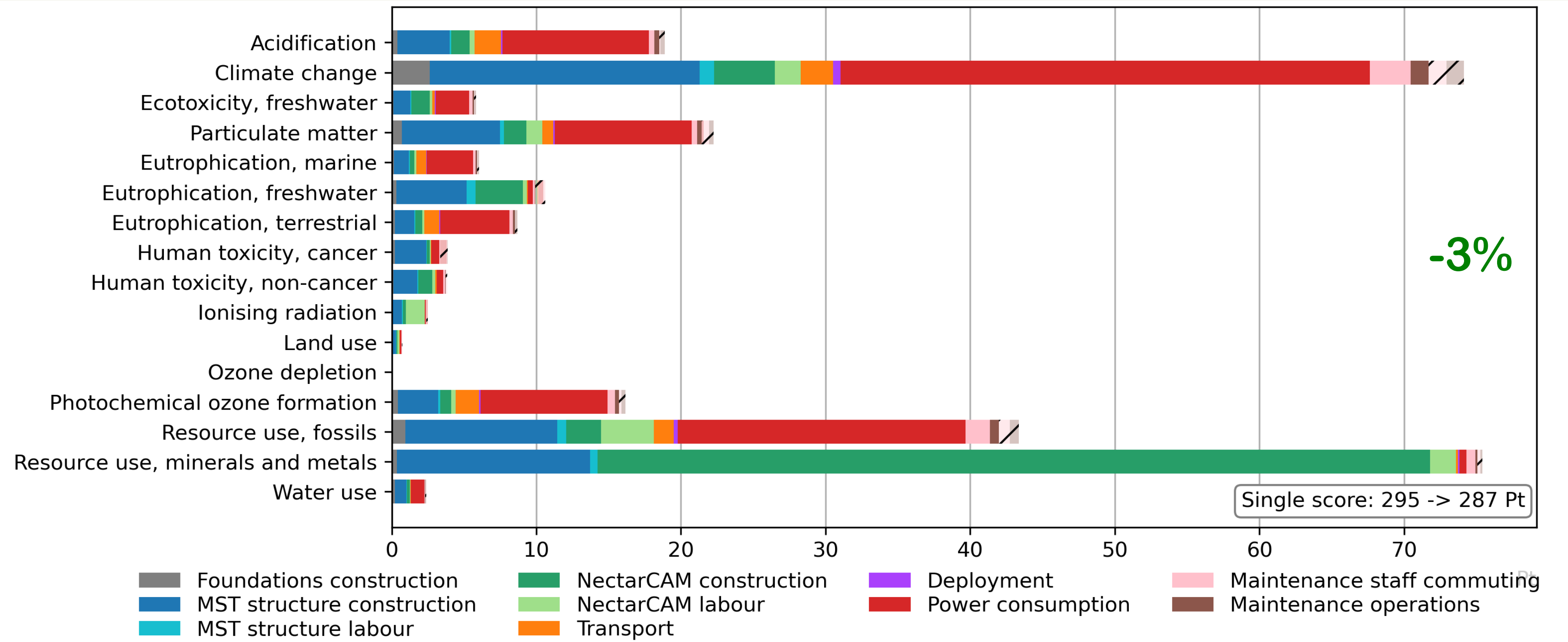
Adapted from Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

Can we decarbonise astronomy?

Is there a technical fix?

Replace steel by concrete counterweights

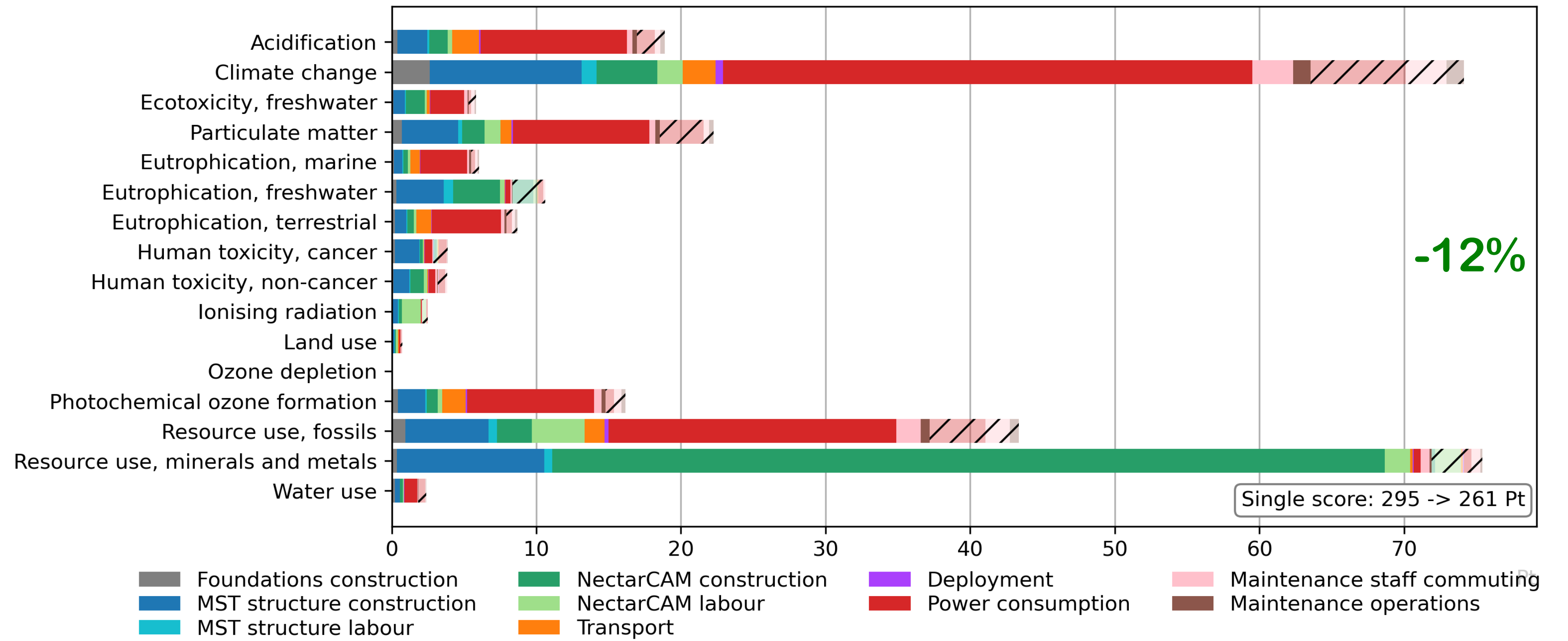
Replace steel by concrete counterweights



Adapted from Dos Santhos Ilha et al. (2024), Nature Astronomy, 8, 1468 (arXiv:2406.17589)

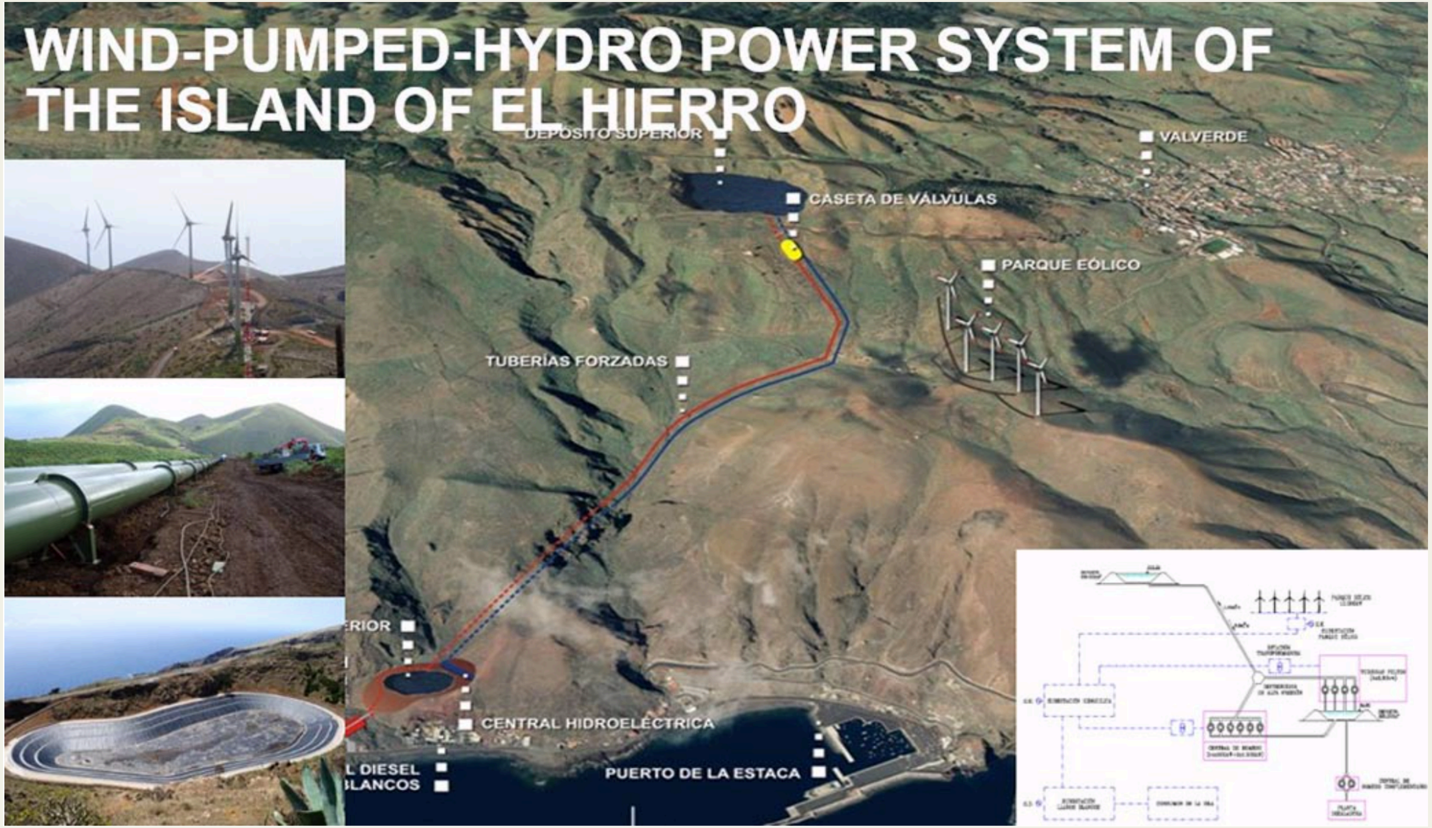
Use machining instead of casting

Use machining instead of casting

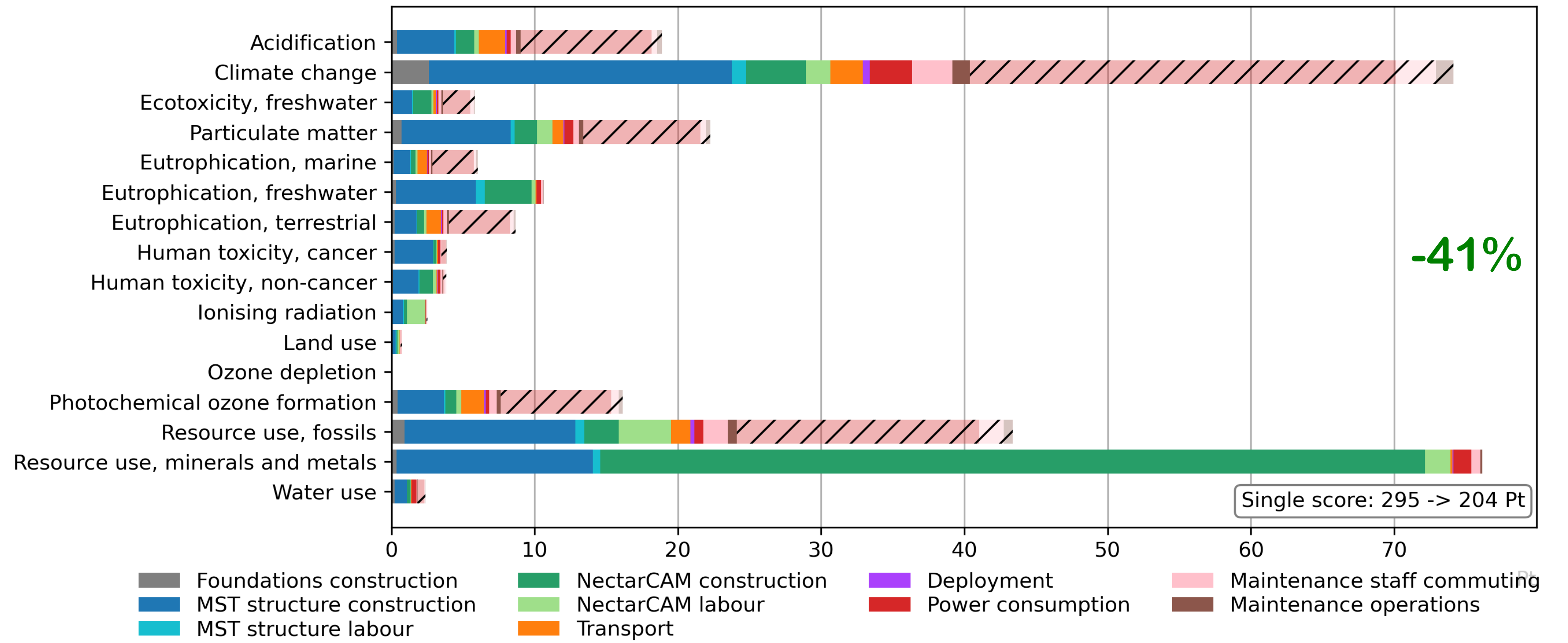


Adapted from Dos Santhos Ilha et al. (2024), Nature Astronomy, 8, 1468 (arXiv:2406.17589)

Use renewable energies



Use renewable energies



Adapted from Dos Santhos Ilha et al. (2024), Nature Astronomy, 8, 1468 (arXiv:2406.17589)

We can reduce the carbon footprint of astronomy

But…

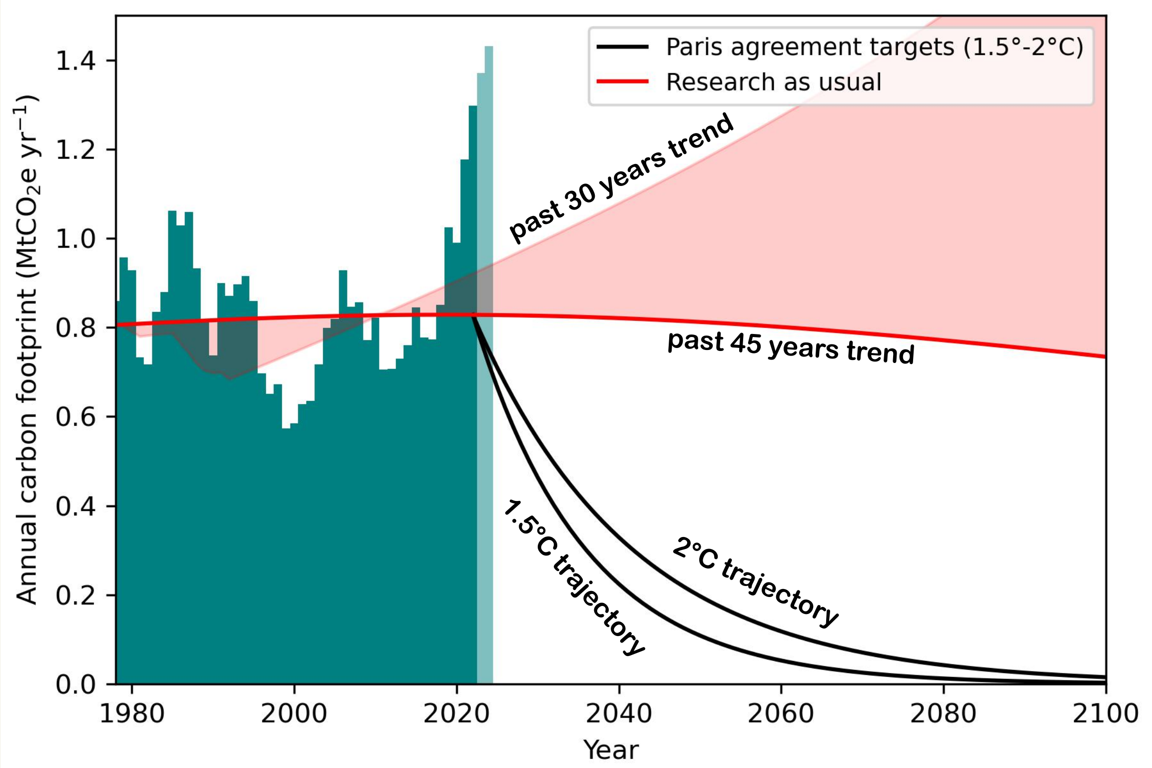
…the reduction potential is limited

…it costs money

…it's difficult to balance a continued growth of new facilities

Scenarios of future annual carbon footprints

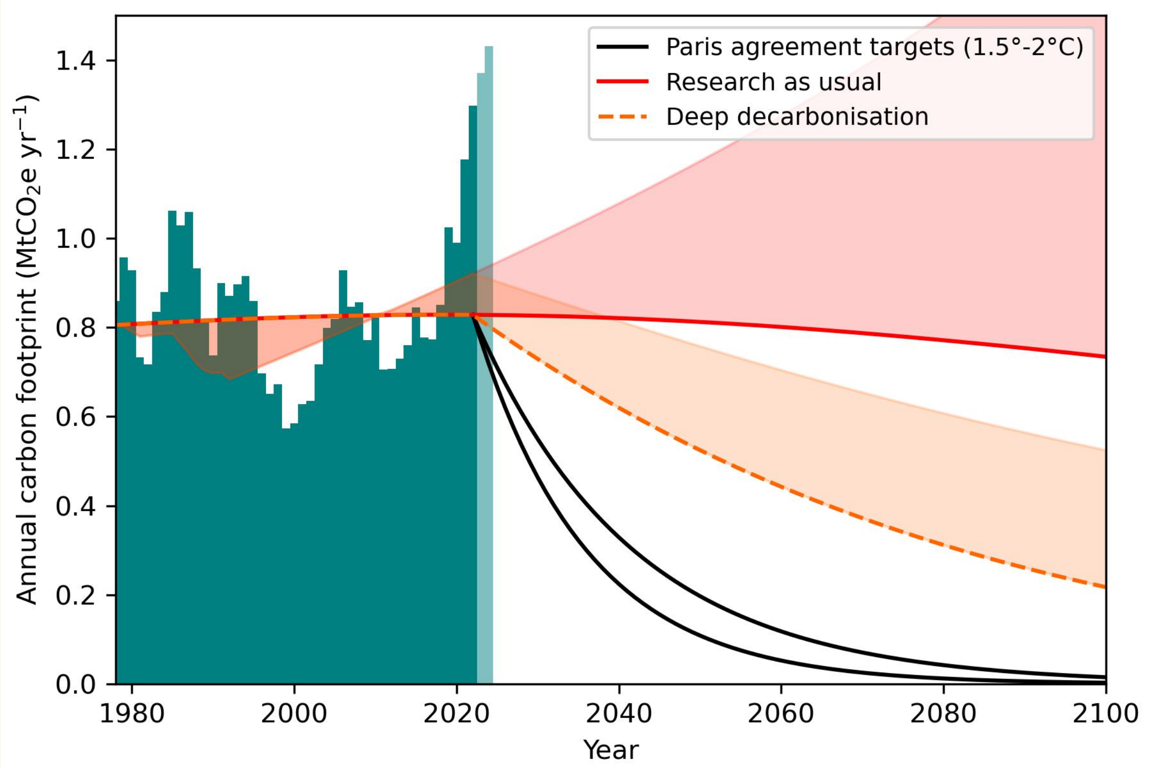
We continue with research as usual



Adapted from Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

Scenarios of future annual carbon footprints

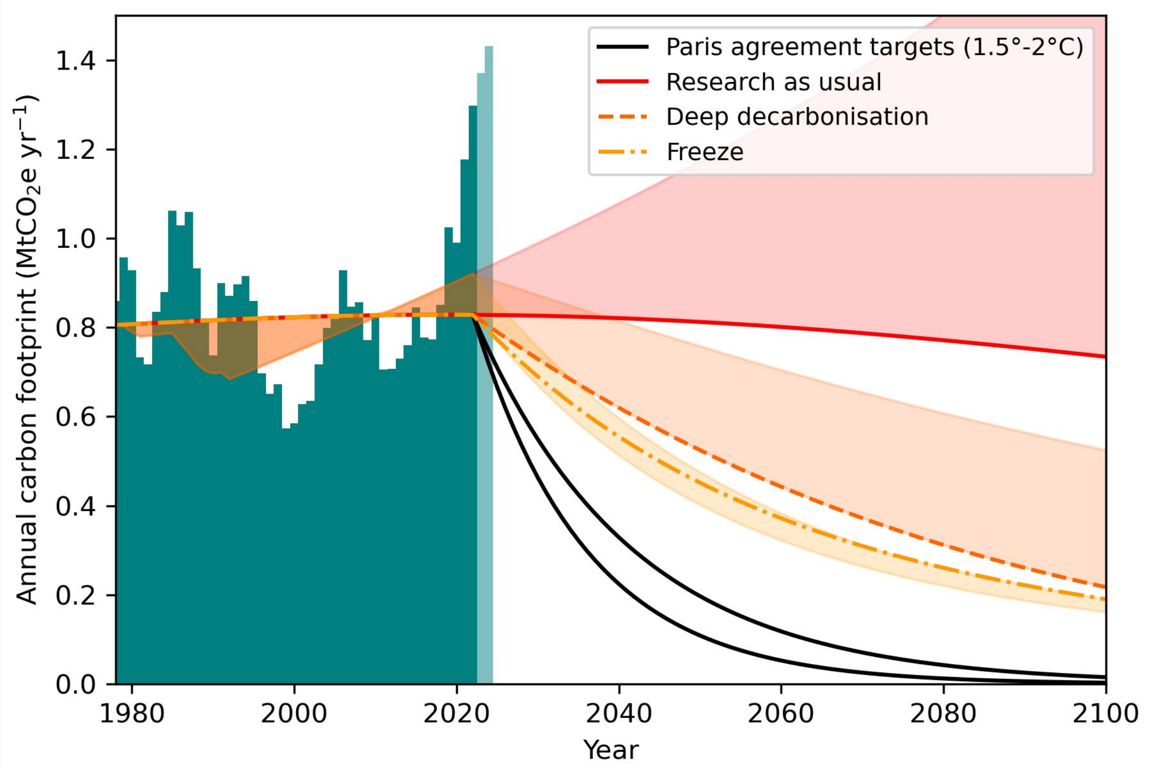
We double the decarbonisation rate (-3% / yr)



Adapted from Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

Scenarios of future annual carbon footprints

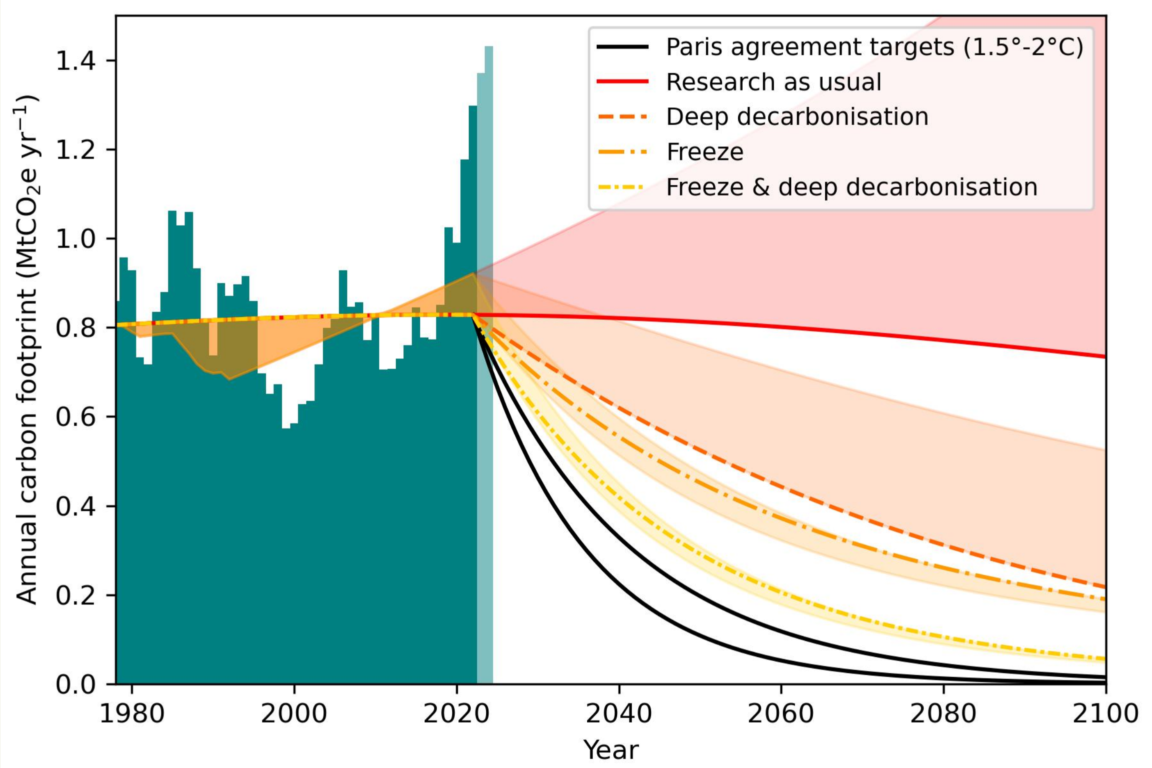
We freeze the number of astronomical facilities



Adapted from Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

Scenarios of future annual carbon footprints

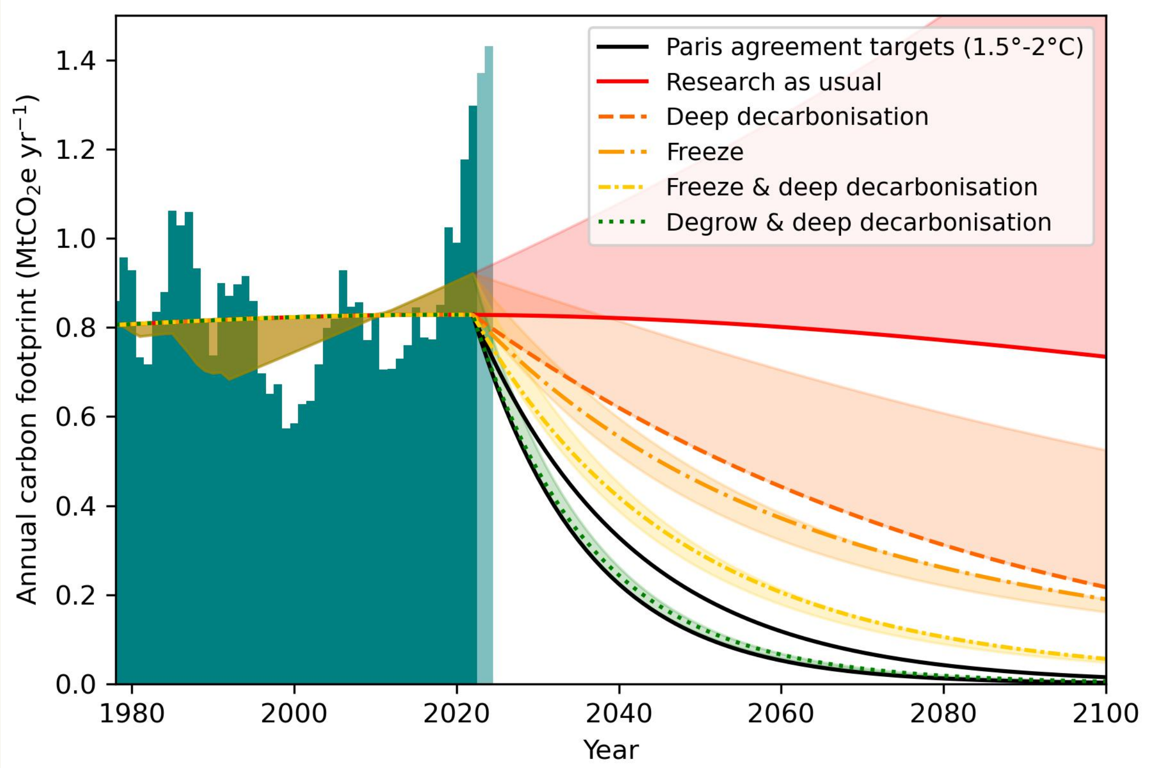
We freeze the number of astronomical facilities and double the decarbonisation



Adapted from Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

Scenarios of future annual carbon footprints

We reduce the number of astronomical facilities by -3% / yr and double the decarbonisation



Adapted from Knödlseder et al. (2024), Nature Astronomy, 8, 1478 (arXiv:2407.16011)

Towards sustainability

Making astronomical research sustainable requires a degrowth in the number of operating facilities

In addition:

- purchases need to be reduced
- professional air travelling needs to decrease
- home-to-office commuting needs to be decarbonised
- energy consumption of office buildings need to be reduced and decarbonised

This implies that current research practices need to change, for example

- collaboration instead of competition
- use of already existing data
- more investment in decarbonisation, less in new facilities
- better use of existing facilities

Without a change of research practices, astronomy will not become sustainable
(calling for more online meetings is great, but will by far not be enough)