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A Sky to Work With: Astronomers, Media, Infrastructures

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A few years ago, while doing ethnographic fieldwork on data uses in astronomy, I was struck by a remark made by the astronomer David Hogg. He wrote in a blog post that "[a]ll of astronomy and astrophysics is built on the observation and reobservation of sources on the sky."[1] This apparently self-evident statement intrigued me as I witnessed research carried out at an institute in Germany and observatories in Chile and Spain. I noticed that the phenomenal properties of the sky – its apparent immutability and the richness of its visible features – pervaded astronomical work and provided infrastructural resources for actions that astronomers rarely acknowledged in their publications.

If time-keeping and navigation count as infrastructural practices, as John Durham Peters (2015) contends, the sky has been an infrastructural medium for many societies since time immemorial. Here I argue that, thanks to the use of recording media, the sky is not only a topic of scientific curiosity and research but also an infrastructural resource for astronomical work that is essential but easy to overlook. Having a shared sky to work with can be a hard-won achievement for an epistemic community.

Figure 1: The dome of the 3.5m telescope at Calar Alto Observatory (Andalusia, Spain) at twilight.
Photo: Götz Hoeppe.

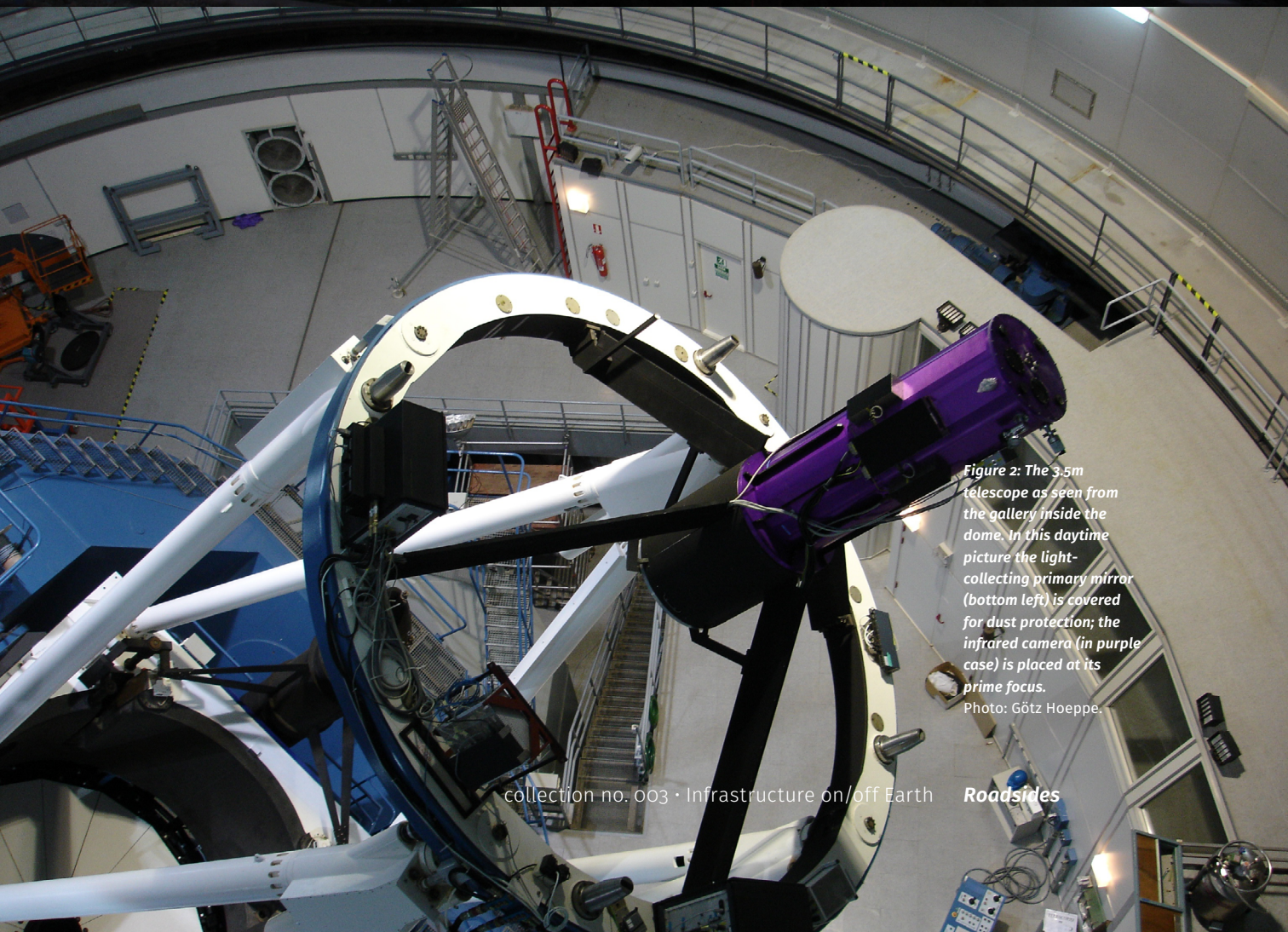

Figure 2: The 3.5m telescope as seen from the gallery inside the dome. In this daytime picture the light-collecting primary mirror (bottom left) is covered for dust protection; the infrared camera (in purple case) is placed at its prime focus.
Photo: Götz Hoeppe.

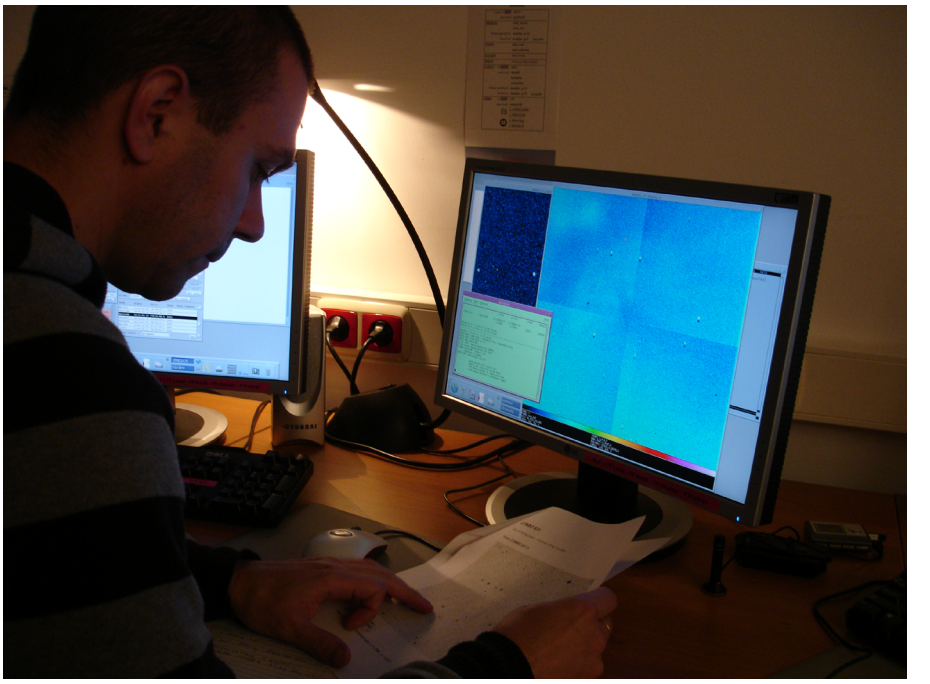

Figure 3: At night in the control room of the 3.5m telescope: Jorge aligns a snapshot exposure (on screen) with a finding chart.
Photo: Götz Hoeppe.

I begin with a night of observing, at the controls of the 3.5m telescope of Calar Alto Observatory in Spain (Fig. 1 and 2). Jorge (pseudonym), a staff astronomer, is about to take photographic exposures of a distant galaxy cluster in infrared light for a research astronomer who has not come to the mountain. After Jorge enters the cluster's celestial coordinates, the telescope slews to the cluster location in the sky. Jorge then captures a brief exposure and brings it up on screen (Fig. 3). Now he can compare the pattern of stars – visible as black dots on a blue background – with those seen on a photographic negative, a finding chart prepared years ago at another observatory. Thus, Jorge can determine the position for the long exposures that he will subsequently take. Materializing it on paper and a computer screen – two dominant media of contemporary scientific work – Jorge aligns the otherwise immaterial pattern of cosmic radiation with a substratum of existing data.

Months later, Nadine (pseudonym), a PhD student, combines Jorge's exposures of the galaxy cluster with some made previously in visible light using a telescope in Chile (Fig. 4). Instructed by senior scientists, she soon discovers that all "raw data" contain artefacts, caused, for example, by stray light in the telescope, cosmic rays or radioactivity in the ground nearby. Seeking to distinguish signals from noise, she proceeds in her data analysis, but has to retrace her steps occasionally, such as when encountering implausible or contradictory consequences. Then she refines her data reductions and proceeds again from there – a sort of reflexivity.[2] Mediated through digital exposures and tabulations of measurements, the sky provides various saliences for this work. For example, stars seen in multiple digital images can be used secondary calibration sources. Nadine learns to decide what to take as the stable background (a resource for her research) and what as foreground (its topic), using the sky as an organizational resource. Such work is therefore fundamentally relational and context dependent (Hoeppe 2014).

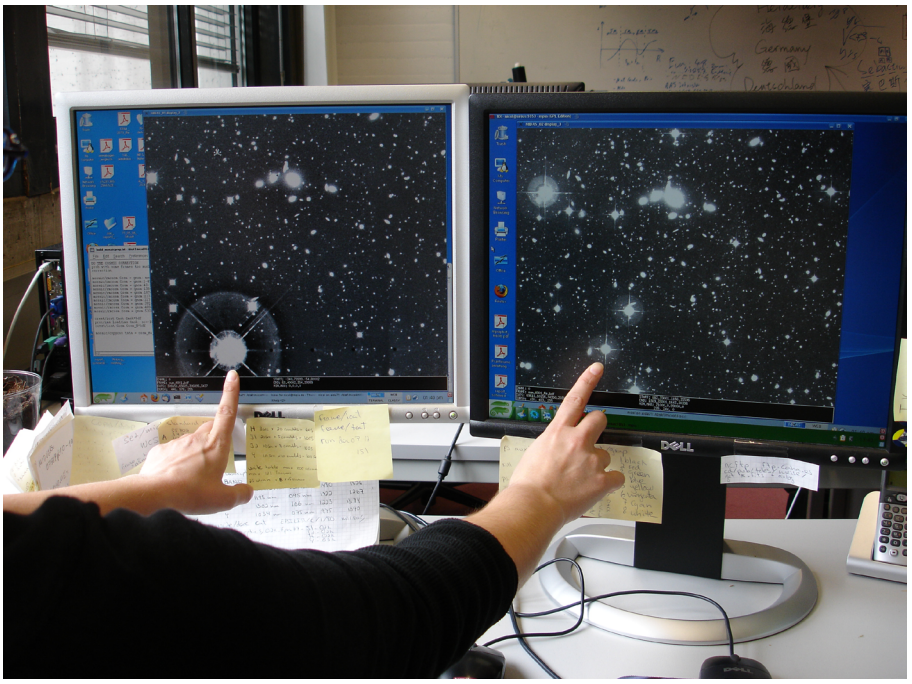

Figure 4: Nadine compares her newly reduced digital infrared image of a galaxy cluster (left) with an image reduced by a former PhD student in the research group (right).
Photo: Götz Hoeppe.

Having a sky to work with, as Jorge and Nadine do, is not something that all astronomers are used to. Various kinds of radiation – be it radio, infrared or ultraviolet waves – are detected using distinct technologies. Each constitutes a separate window on the Universe, and a distinct sky, if the latter is defined as "a two-dimensional distribution of intensity of electromagnetic radiation" (Léna 1989: 245). That astronomers speak with ease of the "radio sky," the "infrared sky" and the "ultraviolet sky" reveals how profoundly their access to the universe is mediated technologically.[3]

One of the newest skies assembled by astronomers is the cosmic microwave background (CMB) radiation of the '"microwave sky," interpreted as relic radiation of the Big Bang almost 14 billion years ago. Astronomers measure its intensity and polarization patterns to gain clues about the early Universe. In March 2014, Princeton University astrophysicist David Spergel gave a talk on the state of this field. Somewhat reminiscent of Jorge's alignment of finding chart and snapshot exposure, Spergel began his presentation by comparing two greyscale pixel maps of the fluctuation pattern of the microwave background in a patch of the sky. One was based on measurements taken with the Atacama Cosmology Telescope in Chile using a very sensitive semi-conducting detector; the other was made using a different detector design (a bolometer) onboard the Planck satellite (see Fig. 5). Pointing to similarities of the patterns visible in the two maps, Spergel explains (underscoring indicates emphasis):

> *These are* completely *different experimental set-ups … and [yet] you see the* same thing *… and this is true with a host of experiments … One of the things I want you to take away from this is the remarkable* agreement *we have between independent experiments at this point … making these measurements … So if you actually look at the same part of the sky the* agreement *here is really remarkably good.*[4]

Improvements in the sensitivity and angular resolution of microwave observations make such an agreement possible. Seeing "the same" sky again through different technologies has made these technologies trustworthy for Spergel. This is what philosophers of science call "robustness reasoning" (Wimsatt 2012).

Note that Spergel talks about experiments – reminiscent of laboratory work in science – whose phenomena are contingent on lab infrastructures. Of course, literally speaking, the Big Bang (as the object of these studies) is unavailable for scientific experimentation. Earlier "CMB experiments" were designed for measuring specific observables in single campaigns of observing patches of the sky that, typically, no other team studied. By contrast, observatories are now made to "observe and re-observe" signals from an ambient, shared environment again and again. What Spergel thus describes is a step in the maturation of this scientific field. This entails novel possibilities for reflexive data uses.

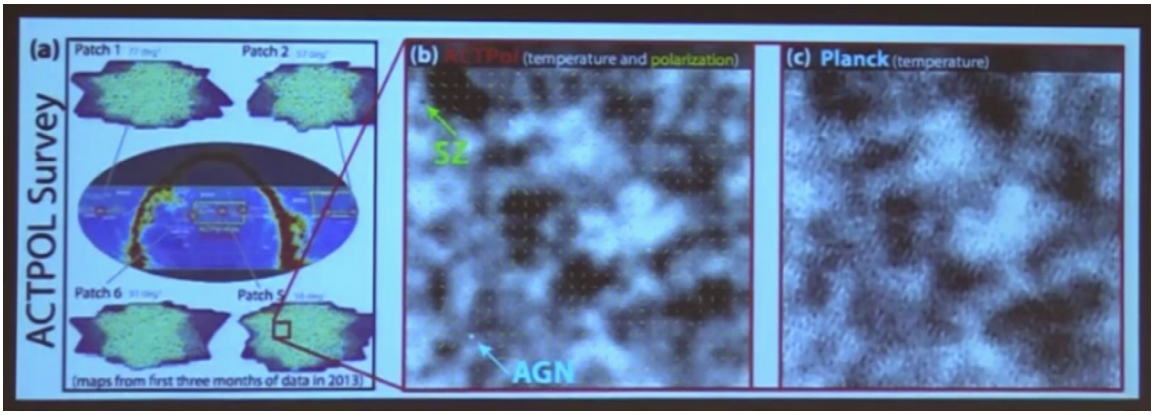

Figure 5: A slide from David Spergel's presentation: two greyscale pixel maps of the fluctuation pattern of the microwave background in a patch in the sky, one made with the Atacama Cosmology Telescope (center), the other with the Planck satellite (right). Source: https://www.youtube.com/watch?v=j3fHkQa6818.

A month after Spergel's lecture, at a discussion at the Perimeter Institute for Theoretical Physics in Waterloo (Canada), other CMB researchers shared his excitement. Addressing fellow panellist Barth Netterfield, a physicist from the University of Toronto, McGill University astronomer Matt Dobbs said:

> *We can make a measurement and other people can go out and verify that measurement and show real science, Barth! [laughter] … and show that that is a reproducible thing that is on the sky.*[5]

Spergel's talk and this discussion happened in the wake of the announcement of the BICEP2 collaboration, which had claimed the detection of a weak but characteristic polarization pattern in the microwave sky that was presented as evidence of cosmic inflation, a previously theorized phase of rapid expansion of the early Universe.[6] Spergel criticized the BICEP2 interpretation by demonstrating the researchers had ignored the fact that their processed data did not show a consistent, immutable sky. Arguably, the BICEP2 team – perhaps still bound by an experimental attitude – had not properly used the sky as an organizational resource for its data analysis (Hoeppe 2019).

The progress from making experiments to observing and re-observing the sky as a shared environment allows for a new reflexivity of data work that scientists regard as essential for "doing astronomy" – in distinction to "doing lab physics." It also marks an extension of the "instrumental communities" (Mody 2011) involved – such as the users of the Atacama Cosmology Telescope, the Planck satellite and BICEP2 – opening up new possibilities for sharing expertise and securing scientific robustness.

A century ago, writing in a quite different context, sociologist Georg Simmel noticed:

> *That a sense like vision, which alters that which is seen simultaneously for everyone due to their specific viewpoint, nevertheless has an object in common – the sky, the sun, the stars – must imply on the one hand the transcendence from the confinement and particularity of the subject that marks any religion. On the other hand it carries and enables a moment of the union of believers that also pertains to any religion* (Simmel 1992: 731; translated by author).

I like to think that Simmel's point extends beyond religion. Infrastructuring always creates and reconstitutes inclusions and exclusions (Star and Bowker 2006). Yet there is also the possibility that observing a shared environment allows the creation of more inclusive communities of those who learn and know. The hope remains that this could be a lesson for the human exploration of space, on and off Earth.

Notes:

[1] http://hoggresearch.blogspot.ca/2008/03/budavari-and-szalay.html Accessed 11 January 2020.

[2] This view of reflexivity is informed by ethnomethodology (Garfinkel 1967). As Rawls (2008: 713) puts it, "[b]y 'reflexivity' Garfinkel means that the next thing said, done or seen reflects back on the last thing and has the potential to show it in a new light." Always temporal, sequential and witnessable, it is different, for example, from the postmodern concern of ethnographers about their role in doing fieldwork.

[3] The difference of these perspectives is illustrated, for instance, by representations of the Milky Way as observed at different wavelengths: https://asd.gsfc.nasa.gov/archive/mwmw/mmw_images.html Accessed 19 February 2020.

[4] David Spergel, "Cosmology after Planck", lecture at New York University, 27 March 2014, https://www.youtube.com/watch?v=j3fHkQa6818, *c.* minute 6 and 10. Accessed 11 January 2020.

[5] http://www.perimeterinstitute.ca/videos/prospects-future-measurements, *c.* minute 38. Accessed 11 January 2020.

[6] This discovery claim is discussed in greater detail in Hoeppe 2019.

[7] Note that laboratory experiments rely on artificial, human-made infrastructures, whereas the sky is the most stable (infrastructural) element of astronomical practice.

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