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ARE SPACE STUDIES A SCIENTIFIC DISCIPLINE IN ITS OWN RIGHT?

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Abstract: In this paper we present a bibliometric analysis of the disciplinary composition of space studies, which specifically targets French participation in space research. We used as our database all the scientific papers resulting from space experiments that occurred between 1965 and 1990 in which French researchers were involved. Our aim is to characterize the disciplinary behaviour of participants in space studies, involved in a field in which instrumental specialization could provoke segmentation, if not relative cognitive autonomy. Our sample is compared to a reference sample of all the publications in the field of astronomy and astrophysics in 1980, and to a sample of publications in radio astronomy.

The editorial behaviour of the scientists involved in space studies is barely different from that of other astronomers or astrophysicists, except for the larger number of co-authors. The distribution of papers (as opposed to technical reports and conference proceedings) dealing with space studies in scientific journals does not differ significantly from that in the reference sample. To explain this disciplinary non-differentiation of space studies we propose that it is essentially a scientific area of transitory opportunity for astrophysicists and astronomers who want to use all the available frequency bands of the electromagnetic spectrum.

Keywords:space studies, discipline, instruments, journals

1 INTRODUCTION

The concept of a discipline is frequently discussed in social sciences. The debate is organized around three main theoretical suggestions.

The first consists in an *a priori* definition of a discipline. Functionalists like Rudolf Stichweh (1992) circumscribed the discipline within the contemporary era, arguing for a global logic in the distribution of knowledge. In contrast to this very restrictive definition, although still under the influence of an *a priori* analytical undertaking, Donald Kelley (2006) conceived of disciplines as fields of constituted knowledge, at least since the Middle Ages, in and through methods of transmission.

Another broad orientation for understanding the idea of discipline is organized around an empirical approach. A series of very fine studies centered on concrete practices of sharing knowledge define the salient features of disciplinary structuring. The structuring of specific places (laboratories, universities, observatories), the editorial density, the construction of exchange networks and the emergence of common organizational rules, provide the real outlines of a discipline (Findlen, 1999; Pantin, 2002). This theoretical proposal was subsequently reconstituted by several sociologists (Heilbron, 2006; Lamy and Saint-Martin, 2011; Shinn and Ragouet, 2005). Terry Shinn in particular emphasized the possible transformations of communities centered around stock instruments that can lead to a specific discipline. For example, Jesse Beams' ultracentrifuge led to the restructuring of biomedical research (Shinn and Ragouet, 2005: 174). This tool, a local spin-off of a generic instrument, allowed the organization and solidification of a community of practitioners. Bruno J. Strasser (2002) also showed how the concentration of a team of biophysicists in Geneva around an electron microscope (a real 'laboratory totem') after WWII led to the struc-turing of molecular biology as an autonomous and legitimate discipline.

Space studies, like radio astronomy (Edge and Mulkay, 1976) are a case study of these fields of knowledge that a technical transformation allows to emerge and grow. In fact, it is not so much the introduction of new instruments that define space research as the genesis of a new approach, i.e., reaching beyond the absorbing screen of the atmosphere. Researchers can thus access a very wide range of wavelengths—from the visible and radio centimetric-kilometric domain to the whole electromagnetic spectrum. Hence, for space research, a certain spontaneous sociology of scientists confirms a kind of obvious congruence between overcoming atmospheric perturbations (and the technical and methodological issues linked to them) and the identification of an autonomous discipline. James Lequeux (2005: 46) claims that the arrival of radio astronomy and space tools transformed the field of astrophysics, dividing it into fragmented sub-disciplines. Space and radioastronomical observations would therefore supposedly be better organized and better financed than the sub-disciplines restricted to traditional observatories.

The aim of this paper is to determine empirically whether space studies has become an autonomous discipline. Has the introduction of instruments enabling access to wavelengths unreachable from Earth (particularly X- and γ rays) led to the organization of a specific community centered around particular instruments? Has the particularly massive spatial infrastructure led to the development of one or several cognitive spheres that are autonomous within a hypothetical 'space discipline'? Above all, beyond studies on the exchanges between disciplines and cases of interdisciplinary studies (Larivière and Gingras, 2011; Sugimoto et al., 2011), we want to test the relevance of the (essentialized) link between discipline and instrumental matrix.

To answer the above questions, we have adopted the methods of bibliometry, which have already been applied to the field of astrophysics, with the pioneering studies of Abt (1981, 1982, 1987); our own study (Davoust and Schmadel, 1987) on the world production of papers in astronomy; and papers by Girard and Davoust (1997) on the role of references in the astronomical discourse, and Davoust et al.(1993) aimed specifically at the output of French astronomers.

We have determined the editorial behaviour of astronomers participating in space experiments by asking more specific questions: Do they publish like other astronomers and astrophysicists? Do they have recognizable areas of publication? Do they specifically organize the production and circulation of their results, independently of the rest of the astronomical community?

We have voluntarily limited our scope to publications with French authors or co-authors, considering that they are representative of the scientific community. They generally contribute ~5–10% of the publications in the field (Davoust, 1987). By'French astronomers' we mean all astronomers and astrophysicists in a French astronomical institute, whether an observatory, a CNRS laboratory or a university, regardless of their nationality.

2 METHODOLOGY

In order to gather the totality of publications with French contributors dedicated to space studies, we used as starting point Appendix VIII of the publication by Carlier and Gilli (1995: 333–334), which collects French space-borne experiments. We established the list of the programs they participated in, from 1965 (the first observations, carried out with American researchers on OGO2) to 1991 (the launch of ULYSSE and the closing of Carlier and Gilli's list [1995]). This first list brought together experi-ments in astronomy (as such), solar physics and external geophysics. These three themes do not of course cover the totality of fields of exploration covered by space astronomy. We left aside planetology, first of all because the recurrence of Martian and Venusian exploration, which have no equivalence in terrestrial astron-omy, would have prevented pertinent compari-sons, and secondly because this field covers the discipline of internal geophysics of the Earth. We were specifically interested in astronomy, also leaving aside scientific fields such as biol-ogy, in which French researchers were particu-larly active.

The period chosen—from 1965 to 1992—corresponds to the second part of the Cold War. This geopolitical context, in which geopolitical bipolarity organized global scientific space, is important for the proper understanding of the particular (but not exclusive) relations that French astronomers had with their Russian colleagues within the framework of agreements on space cooperation, signed in 1966 by France and the USSR. Links with American researchers were just as important during the same period. This scientific concentration around Soviet and American poles also had the corollary (at least at the beginning) of fewer collaborations with European researchers. The corpus of experiments (taken from Carlier and Gilli, 1995) is synthesized in Table 1.

We have located all the published papers relating to the experiments listed in Table 1 in which at least one French astronomer (i.e. attached to a French institute), was an author or co-author. The search was carried out using NASA's ADS database. Citations and references were extracted from the same database. This produced a total of 541 papers, 8,813 citations and 6,066 references. Each bibliographical entry consisted of a bibcode, a title, a list of authors, a journal name, year, volume and pages. The bibcode is the unique identifier of a paper that is used in the large astronomical databases.

As coherent reference points, we have extracted from NASA's ADS database all the papers (as opposed to papers in conference proceedings, book and technical papers) published in 1980. We have also compared our numbers with those of Davoust and Schmadel (1987) for the world community of astronomers.

3 RESULTS

The downloaded bibliographical database was processed in the following way: we associated each bibcode with an experiment, and then computed the number of papers, citations, references, etc. for each experiment. We also identified the dominant theme of each paper and each journal. The statistical treatment was done with small procedures in perl language or with commands or scripts under UNIX. We had to manually process a certain number of papers that included two references (the original article in Russian and the translation into English) and find by hand the page numbers of a certain number ofpapers when they were missing. We also corrected some errors in the ADS database (in particular, merging the bibcodes of some papers with multiple authors that had been classified under several distinct bibcodes).

Table 2 presents the results of the data extraction. It gives the number of papers, refereed papers, books, proceedings, the number of citations and references (the total and those published in a journal of space research) and dominant theme for the different space experiments in which French astronomers were involved.

In order to test the strength of our corpus, we globally compared the 'publishing behaviour' of the researchers in our sample with that of the authors of all the astronomical papers produced in 1980. For the sake of simplicity, we retained only actual papers, eliminating publications in proceedings of colloquia, technical notes, articles with no identified authors, books and a few single references to all the proceedings of a colloquium (which usually referred to the editors of the whole proceedings) in both the space science sample and the comparison sample. For the latter, we chose only one year because the volume of publications thus considered was sufficient. We chose 1980 because it is in the middle of the period under study. We thus created a comparison sample of 8,951 papers.

Table 3 highlights a difference in the number of authors per paper. The large number of authors in space studies simply reflects the fact that the teams are very large since, as in all scientific fields, the size of the teams is proportional to the financial investment.

The histogram of the number of authors (Figure1) shows a peak for 16 authors. This is neither an artifact nor an error. 56 articles were indeed co-signed by 8 French authors (4 from CESR, 4 from CEA) and 8 Russian authors. A Franco-Russian agreement on the publication of the results from SIGMA, on which the CEA and CESR had worked equally, stipulated a strict allocation of authors: 16 per article, 8 French and 8 Russian.

In total, for the space experiments we counted 4,071 author names, 1,568 of which were French, or 39%. We specify that this number of 1,568 is not the total number of different French authors, which is 342, but the total number of times a French name appears on a publication. When the number of publications is reduced to refereed (n = 413), the number of authors reaches 3,174, of whom 1,155, or 36%, are French. This proportion is nearly identical to that of the global corpus. The difference is not significant and indeed shows the structural homogeneity of French signatures for papers, whether they are refereed or not.

We then calculated the degree of French participation in the publications by counting the relative number of French names in each publication. This proportion is 52% for the 413 refereed papers. In other words, the proportion of French authors that is most frequent in A-level papers is ~50%. This is not the same as counting the total number of occurrences of French names, because in the present case, the degree of participation is weighed by the number of papers with the given proportion, and, as demonstrated below, that of 50% is the most frequent one.

Table 1: Vehicles and space experiments (1965–1990).

Vehicle	Launch year	Experiment
OGO-2	1965	
OGO-4	1967	
OGO-5	1968, 1969	
ESRO	1968	S72
HEOS A-1	1968	S72, S 79
HEOS A-2	1972	S 209
TD-1	1972	S 67, S 77, S 133
Skylab	1973	S 183
Prognoz 2	1972	Signe
Prognoz 6, 7	1977, 1978	Galactica
IUE	1978	IUE
ISEE-C	1978	ISEE-C
Venera 11, 12, 13	1978, 1981	Signe-2MS
HEAO-3	1979	HEOA-C
Saliout-7	1982	Piramig, Sirene
Spacelab-1	1983	Wide Field Camera
ACTION-A	1985	UFT
Spacelab-3	1985	FAUST
Phobos	1988	IPHIR, Lilas
Hipparcos	1989	
Granat	1989	Sigma
Gamma	1990	Gamma-1, Spectre-2
Ulysse	1990	KET, STP, HUS

Indeed, we find that 111 articles out of the 413 have a proportion of 50% French authors. When we remove articles with Russian researchers (for which the co-signature rule was strict andsomewhat constraining), there remain 32 papers where the proportion of French authors reached 50%. No other proportion of French authors appears so frequently, showing that French researchers participated 50% on the aver-

Table 2: The numbers of publications, citations, references and dominant themes for the different space experiments.

Space Experiment	Total No.	Total No. Space	No. ofPapers	No. of Refer-eed Papers	No. of Other Publ'ns (Proceed-ings, Books, Technical Reports)	No. of Citatns	No. of Citatns in Space Publns	No. of Refer-ences	No. of Refer-ences in Space Publns	Dominant theme*
ARCAD	18	3	17	17	1	79	12	58	9	GGG
FAUST	18	3	11	9	8	137	1	95	5	AAA
GALACTICA	5	1	2	2	0	18	0	42	1	AAA
GAMMA	18	8	16	15	2	88	4	41	7	AO-A-A
GRANAT-SIGMA	147	20	119	80	28	1727	99	1380	109	AAA
HEOS A1 and A2	24	0	6	5	18	71	3	82	1	AAA
HIPPARCOS-team	30	0	29	29	1	2760	38	956	75	AAA
HIPPARCOS	57	1	57	57	0	1789	29	1952	113	AAA
IPHIR	25	5	16	15	9	475	67	252	22	AAA
ISEE-C	44	?	33	29	11	713	?	301	?	?
IUE	48	13	20	20	28	391	24	220	12	AAA
Lilas	8	2	5	5	2	41	3	62	2	AAA
OGO	13	5	13	13	0	57	6	55	14	GGG
Piramig	2	1	2	2	0	14	0	8	0	AA?
SIGNE 2	18	3	14	14	4	112	10	112	3	AAA
S183	2	0	2	2	0	6	0	16	0	AA?
SIRENE	0	0	0	0	0	0	0	0	0	
SMM	15	2	12	12	3	514	20	170	2	AAA
Wide Field Camera	11	2	10	9	1	63	4	201	13	AAA
STEREO1	5	1	5	5	0	104	6	55	2	AAA
TD1	13	2	9	9	4	173	1	214	0	AAA
UFT	2	1	2	1	0	0	0	0	0	A?
Ulysse	5	0	5	2	0	51	0	19	0	AAA
VENERA-SIGNE	12	1	9	9	3	142	6	76	1	AAA
Total	541	497	413			8813	331	6066		75
% space studies		15%					3.7%		6.4%	

* Key: A: astrophysics, G: geophysics, O: oceanography and P: physics. The question marks correspond to samples of items too small to be significant and for which a dominant designation has no sense.

age, even though the standard was artificial with Soviet astronomers.

This global structure of space publications by French researchers allows us to understand the general behaviour of those who publish. It is nevertheless necessary to refine the identification of editorial practices to better define the characteristics of space publications.

We therefore classified the journals thematically. By theme we mean the cognitive subsets linked to a specific object (e.g. planets, the Sun) or to specific methodologies (e.g. optics, instrumentation). Because they cannot be reduced to strict disciplinary fragmentation, these themes require a wider level of analysis than the classic limits such as astrophysics, geophysics, physics, etc. They nonetheless provide a satisfactory approach for locating the papers concerning space studies in the disciplinary territory. We thus tried to determine the editorial choices made by researchers working on themes dealing with space research.

Table 3: The numbers of papers and authors.

Parameter	1980	Space Experiments
Number of Papers	8,951	413
Authors per Paper	2.27	7.66
Average Page	7.55	7.91

* Note that for the space experiments, the sample was 401 instead of 413 papers, because the database did not provide the number of pages for 12 of the papers.

Table 4 gives the number of different journals represented in each thematic field. The list is limited to fields with 5 journals or more. Hence are excluded from this list the following themes, which are less present in editorial surfaces: electronics, instruments, fluid mechanics, astroparticles, computer science, radiophysics, astrobiology, astronautics, climatology, cosmology, geochemistry, geodesics, nanotechnologies, physiology and spectroscopy, which each count between 1 and 4 journals. The overwhelming majority of papers are published in astrophysics, followed by physics.

Journals of 'space research' make up only 5.5% of the editorial surface (15 out of 271 journals). Of course, this very low percentage cannot tell us whether the bulk of publications transfer preferentially to astrophysics whose editorial

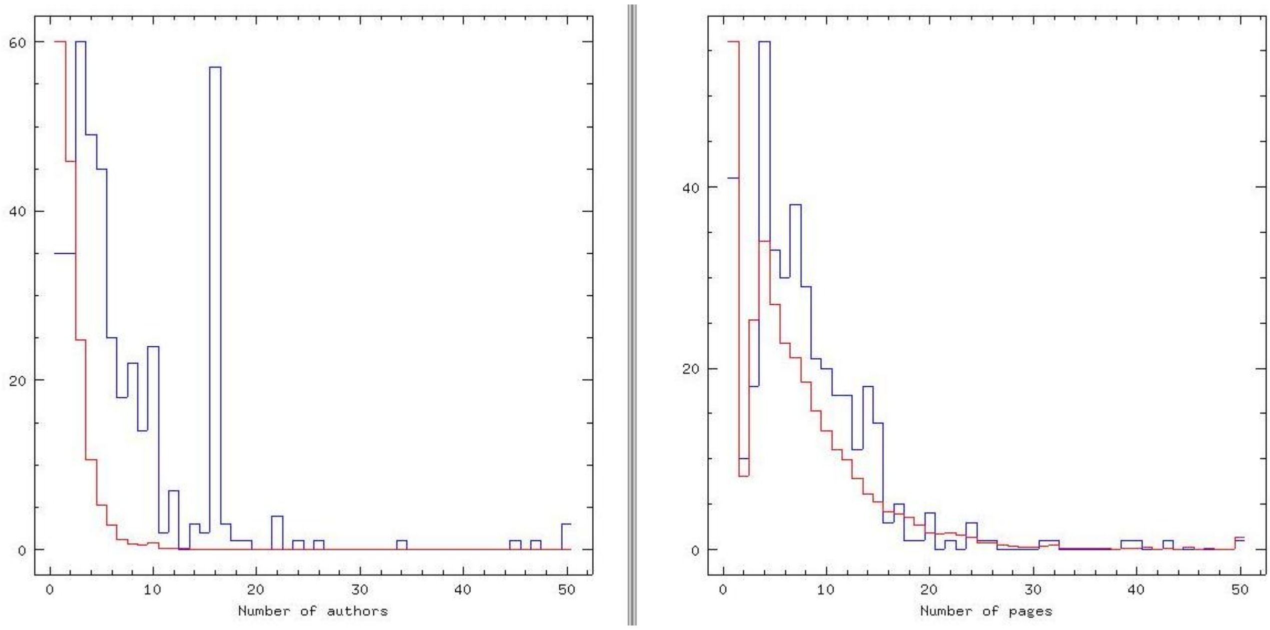

Figure 1: Plots showing the number of authors of the different papers and the lengths of the papers. The black and red histograms are for the space papers and the 1980 papers respectively. The vertical scale refers to the space data.

offer (42.8%) is huge. We can however note that there is no solid editorial core of space science. We must also note that while looking for the specifics of 'space', we assumed that the journals whose titles included the word 'space' represented this hypothetical discipline. But we did not consider the journal *Astrophysics and Space Science* as a journal dedicated to space studies, because of the absence of editorial policy and peer review during that period.

We then looked for more precise locations of publication of 'space studies' articles, the thematic origin of the publications, citations and references (see Table 1). We notice that the number of papers dealing with space studies published in journals whose theme is space science is low, but not negligible (15%). They take few references from journals dedicated to space studies (6.4%) and are even less frequently cited in these same journals (3.7%). Furthermore, we note that among all the experiments, not one concentrated its publications preferentially in space study journals. Astrophysics is a main theme, polarizing editorial offer and absorbing (with, to a lesser extent, geophysics) the greatest amount of publications dedicated to space experiments.

The structure of the editorial field in which publications are distributed thus seems to be globally organized around astrophysics. It is nevertheless necessary to refine this mapping of publications by examining the precise distribution of publications dedicated to space in scientific journals. By comparing this distribution to that of the totality of articles published in 1980 (our reference sample), we wanted to evaluate the behaviour within the editorial field of authors working in space studies. Although astrophysical polarity is undeniable, perhaps the publishing practices of space scientists studies is relatively different within astrophysics itself?

In Table 5, we listed the ten most frequent journals in which space science studies have published and the ten most solicited journals in 1980.

ApJ and A&A are the two central journals in the discipline of astronomy. From this point of view, space scientists do not behave differently from their other colleagues. These two journals polarize (to a great extent) publication intentions and dominate production. Similarly, for research in geophysics, the JGR remains the principal place of publication for the community. The main difference is first of all the emergence of AdSpR for specialists in space studies, showing an important orientation, but not essential, since it does not represent the preferred editorial choice. On the contrary, multidisciplinary journals (like *Nature*) do not accrete 'space research'. We can therefore consider that editorial practices in space studies differ very little from those of astrophysicists in general: a more specialized sub-discipline and weakly polarized by a single specific emerging journal. The major trends of the discipline of astrophysics (through the two principal journals ApJ and A&A) quite

Table 4: The number of different journals represented in each thematic field.

Domain	Number of Journals
Astrophysics	116
Physics	62
Geophysics	26
Space Research	15
Optics	9
Multidisciplinary	6
Total	235

Table 5: The numbers of space research papers published in the different journals.

Editorial behaviour of space scientists		Behaviour of the astrophysical community in 1980	
Journals	Number of papers	Journals	Number of papers
A&A	115	ApJ	1138
ApJ	38	A&A	729
IAUC	36	JGR	435
AdSpR	32	MNRAS	361
A&AS	27	Natur	324
AstL	11	ApS&SS	296
JGR	10	Geo CoA	213
AnGeo	10	E&PSL	213
SoPh	8	AJ	205
P&SS	7	Metic	204

clearly predominate in the context of space study practices.

4 THE CASE FOR RADIO ASTRONOMY AS A DISTINCT COMMUNITY

Space science is not the only scientific community that might distinguish itself from the general astronomical community. Since radio astronomy essentially started with physicists and engineers after WWII, it was worth examining whether this other community had a different editorial behaviour. To that end, we proceeded along two different routes.

We first analysed the corpus of papers published by French radio astronomers associated with the three large radioastronomical institutes: IRAM (Institut de Radioastronomie Millimétrique), Laboratoire d'Astrophysique de Bordeaux and the Nançay radioastronomical station. We queried ADS with the keywords 'IRAM', 'Bordeaux' and 'Nançay' over the period 1965–1992, and removed irrelevant papers. For Nançay, we also queried ADS with the author names (Biraud, Bottinelli, G. Bourgois, Crovizier, P. Encrenaz, Guelin, Heidmann, Kazès, Lequeux, Rieu and Weliachew), because some French radio astronomy papers (mostly in French) are not in ADS. Thus we were able to identify all the papers of French radio astronomers who used the national radio astronomy instruments and IRAM. We did not consider the few papers by French radio astronomers who used radio telescopes in the USA, Australia or the UK. We ended up gathered 399 papers, 94 proceedings, 9 technical reports and 2 books.

In order to put the editorial policy of French radio astronomers in context, we then analysed in the same way the radio astronomers using the Very Large Array (VLA), by querying ADS with the keyword 'VLA' over the same period, and obtained 1,451 papers, 633 proceedings, 25 technical reports and 12 books.

Table 6 gives the distribution of papers of the French radio astronomers and of the users of the VLA, restricted to those journals with ≥5 papers, as well as the total number of papers in the respective journals in 1980, for comparison. It shows that the radio astronomers do not form a scientific community with a distinct editorial policy from the world astronomers. The VLA users and the world community both have a prefer-ence for ApJ and AJ. The explanation is that most VLA users and most astronomers are in the USA. The French radio astronomers have a different behaviour, in that they predominantly publish in the European journals A&A and A&AS. They also publish in SoPh, because Nançay radio observatory has a radioheliograph, which is used daily to monitor the solar corona, and in IAUC to announce new OH megamasers or radio detection of comets, two domains that are not relevant at the VLA.

We also found that only 14 proceedings (out of 633) and one technical report (out of 25) were on subjects of engineering, meaning that the radio astronomers are indeed astronomers, not engineers.

5 ANALYSIS AND DISCUSSION

Space instruments have opened a new window in the electromagnetic spectrum, particularly in the X-rays and the infrared. We could have expected a technical and cognitive structuring of a community of specialists, independent of other astrophysicists. But in fact, there are no astrophysical or astronomical journals that focus on particular wavelengths. The disciplinary distribution is therefore not associated with this reconfiguration of available spectral windows. In the fields of X-rays and γ rays new phenomena have been revealed, such as the emission of highly-energetic rays coming from the shearing of matter spiralling towards the black hole or the compact object in a binary star. We could legitimately have thought that these discoveries implied new conceptual tools and, associated with an *ad hoc* methodology, they would define an autonomous epistemological place (or at least about to become such a place). In this particular case, we have both concepts drawn from fluid mechanics and a specific instrumentation (special receivers). However, this field of research has not produced a specific community structured by its own techno-cognitive issues. Similarly for the infrared, thanks to space probes, it is pos-

Table 6: The distribution of papers for radio astronomers and other astronomers.

Journal	World 1980	French Radio Astronomers		VLA Users	
A&A	795	177	44.3%	156	10.8%
IAUC	317	41	10.3%	25	1.7%
SoPh	146	25	6.3%	27	1.9%
A&AS	174	22	5.5%	25	1.7%
ApJ	1245	16	4.0%	527	36.3%
AnAp	0	11	2.8%	0	0.0%
LAstr	57	9	2.3%	2	0.1%
P&SS	124	7	1.5%	0	0.0%
AdSpR	53	6	1.5%	13	0.9%
ApL	63	6	1.5%	3	0.06%
MNRAS	390	0	0.0%	114	7.9%
AJ	227	1	0.3%	224	15.4%
NRAON	0	1	0.3%	39	2.7%
Natur	156	3	1.0%	35	2.4%

sible to research the chemistry of dark clouds. Despite its proximity to classical organic chemistry, IR astronomy still presents distinctive features that could have separated it from its sister discipline.

The spread of knowledge relative to space research thus remains confined to astrophysics. We can of course note a ‘big science’ effect in the large number of signatures in space study articles. The technicalities of space research are visible in the low number of accounts in multidisciplinary journals. At the same time, a journal (AdSpR) is emerging that weakly polarizes the disciplinary sub-field, without however rivalling the principal journals, ApJ and A&A. This is not a new discipline emerging, but merely a specialization.

The disciplinary positioning of ‘space research’ is counter-intuitive compared to other disciplinary examples, as it is a sub-discipline that is subservient to the general framework of the discipline of astrophysics. Space instrumentation has not really had any effect on astrophysicists’ editorial practices.

Putting our results into perspective, we can consider that space studies constitute a cognitive field of opportunity that provisionally or temporarily brings together researchers interested in a specific object. The diffusion of information in the space studies field partly explains this disciplinary void. The small group of astrophysicists who developed an on-board instrument is assured of a certain amount of guaranteed observing time (which typically lasts from six months to a year) during which they have the exclusivity of the results obtained, but the data are subsequently available to a much wider community through requests for observing time or open archives. In the case of the so-called legacy surveys, the data are available almost immediately to the world community through an internet site. On the contrary, in the terrestrial field, the results of proprietary experiments can well remain the property of a group for a very long period, if not forever.

The specificity of space scientists is confirmed by the comparison with the community of radio astronomers. The latter overwhelmingly publish in classical astrophysics journals, and their editorial behaviour is similar to that of other astronomers. Contrary to space research, radio astronomy does not appear as an editorially-specialized field of research: it is definitely an integral part of astrophysics.

Scientists can seize the opportunities offered by spatial instruments through calls for proposals. But other opportunities (via terrestrial instruments) can follow a ‘space episode’, which explains the non-specificity of this type of research. Let us add that astrophysical phenomena are best understood by analysing them in the greatest number of wavelength bands possible. This necessity of panchromatic studies reinforces the spatial opportunism that can complement analyses in other parts of the spectrum.

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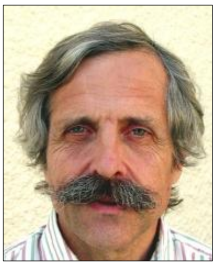

scopes and multivariate statistical analyses. He was involved in numerous public outreach activities, and published two books, one on the search for life in the Universe and one about the history of Pic du Midi Observatory. Since 2012, he has been an astronomer emeritus at Observatoire Midi-Pyrenees in Toulouse (France), participating in the many activities of the heritage commission of the Observatory: salvaging old instruments, and contributing to exhibitions, to conferences and talks, and to an astronomy museum project.