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The Use of Verbs in Astrophysical Research Paper Abstracts: Sociolinguistic Implications

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ABSTRACT

This study aims to explore the use of verbs in a corpus of research paper abstracts retrieved from four English-written top journals published in astrophysics during 2011-2021. From a diachronic point of view, we notice an overall decrease in the use of the passive voice and fluctuating patterns in the verbal parameters analysed, with no substantial statistically significant differences among them. By contrast, from a cross-journal standpoint, we observe some significant differences in the use of verbs between the journals studied. These discrepancies could be interpreted in terms of distinct sociolinguistic frameworks since astrophysicists may employ verbal constructions differently depending on whether they are native or non-native English speakers, but also whether they are associated with British or US-based linguistic environments. Further linguistic differences can also be noted depending on the specific scope of each journal. In average, non-native English researchers are likely to create longer abstracts with more purpose and linking clauses, more verbs and variants and also more passive voices, more past and future tenses and fewer modal verbs per number of authors. Conversely, native English writers would use fewer auxiliary verbs and more direct and assertive language.
Keywords: *verbs, abstracts, research papers, astrophysics*

INTRODUCTION

To transmit information, human beings can use two main types of language: verbal and non-verbal. Non-verbal language is performed through body language: signs, tactile/braille and kinesic -tone of voice, body movements and posture, looks, silence, or smiles- (Sapir, 1949; Birdwhistell, 1952; Birdwhistell, 1970). Verbal language, on its hand, conveys a message either in spoken or written form: sounds, written letters, symbols and visuals -images, charts, graphics, videos, etc.- (Meyer et al., 2018; Doughty, 2020). In today's world of modern science, where it is so important to discuss and disseminate the results of the progress achieved to gain visibility, verbal language is used in many ways not only in informal conversations with colleagues from the same branch of knowledge, but also in more formal ways through conference presentations/posters, technical reports/briefs, graphical/visual abstracts, audio slide presentations, webinars, explainer videos, science blogs, white papers and mainly in the traditional research papers published in specialized journals.

One of the most important parts of a research paper is the abstract as editors and readers always focus on it when deciding if the research carried out in the articles fulfills their expectations. In general terms, an abstract is a short piece of text, usually freely accessible online, which provides an overview of the research paper that follows to help potential readers know if the topic discussed in it is of interest to their own research. It also communicates key findings for those who have time constraints in reading papers and helps rank the article on search engines based on keywords in academic databases.

Since abstracts are so important when communicating advances in academic and scientific contexts, where millions of research papers are being published every year, it should come as no surprise that they have been the object of a significant and diversified amount of research, mainly with pedagogical purposes. In this sense, the vast majority of studies on research paper abstracts (from now one abbreviated as 'RPAs') has analyzed the rhetorical or move structure established by Swales (1990) and Hyland (2000) and has been conducted in different disciplines. It will suffice to search in a useful tool such as Google Scholar to find countless references about the

issue. There are also plenty of guidelines that contain important tips on how to write and structure RPAs appropriately.

A quite significant part of these guidelines follow the publication standards of English-written 'mainstream' journals (Guédon, 2007) and are addressed to non-native English (L2/L3) researchers so that they can publish their articles in these journals. In this way, they will be given greater visibility and become fully integrated in the worldwide network of science. A practical and more recent guide on how to practice and publish from developing countries is that published by Nundi et al. (2022).

Although, and as we have just said that the study of abstracts has been approached from many angles and in different disciplines and languages, to the best of our knowledge there is however a branch of knowledge in which their study has been overlooked, and it is that of astrophysics. The scarcity of linguistic research in this domain pushed us to launch a large research project on RPAs, which started with a pilot diachronic analysis (1943-2018) of the linguistic and authorial implications in RPAs retrieved from *Monthly Notices of the Royal Astronomical Society*, one of the leading journals in the mentioned field (Méndez & Alcaraz, 2020). That first article was followed by a second one where we analyzed a series of content words (nouns, adjectives, mathematical symbols) and compound groups collected from RPAs published between 2011 and 2021, not only from MNRAS but also from other three high-ranked international astrophysical journals written in English, namely *Astronomy & Astrophysics* (A&A), *Astronomical Journal* (AJ) and *Astrophysical Journal* (ApJ) (Méndez & Alcaraz, 2025). In this third paper, we are going to deal with verbs in the same corpus.

According to their usual definition, verbs are doing words that convey actions, events, processes, states of being, thoughts, feelings, and relationships. This is the reason why their study has been so important to develop educational programs involved in learning processes within the paradigm of cognitive science, an interdisciplinary discipline which incorporates philosophy, psychology, computer/artificial intelligence, linguistics, anthropology, and neuroscience (Bender & Beller, 2023). Among the numerous scholars that have approached the

issue of verbs from a cognitive point of view, we can cite Faber & Mairal (1999), who proposed a semantic classification of English verbs, or Negro (1999), who compared the lexical domain of 'existence' in French and English. The semantic parameter was also followed by López Rodríguez (2002) in her study of English verbs in RPAs published in the field of oncology.

Another research within the semantic framework was that carried out by Kersten & Earles (2004), who demonstrated that the semantic context influences memory for verbs more than memory for nouns because the meanings of verbs are more variable when compared with the meanings of nouns. Soto et al. (2005) also contrasted nouns with verbs and proposed that the ratio of nouns to verbs in a given text may predict an opposition between academic/scientific and letters to the editor/journalistic texts. This index appeared to be sensitive only in the case of applied and natural sciences when differentiating between expert and novice writers.

Reimerink (2007), for her part, used Rodríguez's methodology and Faber & Mairal's semantic classification in her analysis of verbs in the different sections of research papers with the purpose to help professionals and translators when writing and translating them in the field of medicine. A useful volume about the important role played by verbs in the lexicalization of events and states from an interdisciplinary perspective (theoretical linguistics, philosophy, psycholinguistics and neuroscience) of cognitive science is the one edited by de Almeida & Manouilidou (2015).

The importance and challenges of verbs in language use and acquisition have also been approached from their lexical, semantic and syntactic classification in different languages in view of developing useful teaching materials. For example, Hartanska et al. (2018) tackled the issue of teaching verb tenses in Slovak lower and upper secondary schools by using quantitative (questionnaire and achievement test) and qualitative (lesson observation and semi-structured interview) methods. Similarly, Polatovná (2019) used modular technology to teach different types of English verbs (auxiliary and modal verbs, verbs of expressions, feelings, movement,

perceptions, etc.) to L2/L3 students of B1 level and to develop educational-language assignments.

Additionally, Un-udom & Un-udom (2020) contrasted the use of General and Technical English reporting verbs in their preparation of teaching material for L2/L3 undergraduate writers in the Academic Context. Moreover, Deng et al. (2022) proposed to differentiate between general academic verbs, borderline general academic verbs, and discipline-specific verbs according to their frequency, order of frequency, and dispersion. Furthermore, Lopes Amaral (2022) provided an overview of online open access resources for the syntactic-semantic classification of verbs and demonstrated that these resources share many theoretical assumptions, especially regarding the criteria to be used in verb classification. Finally, Li (2023) focused on the various methodologies involved in English verb teaching and learning from a lexical standpoint.

Turning back to the main purpose of our research, which is the presence of verbs in RPAs, in the next lines we are doing a brief review of some studies on verbs conducted by L2/L3 researchers who were mainly interested in pedagogical implications. Generally, these authors dealt with the topic by analyzing their rhetorical organization following the move pattern introduced by Swales (1990) and Hyland (2000) as mentioned above.

Salager-Meyer (1992) reported the functions performed by the different tenses of verbs in medical RPAs, case reports and review articles, and noted that the past tense was widely used in the moves of “Purpose”, “Methods”, “Results” and “Case presentation” while the present tense was prevalent in the moves of “Conclusion”, “Recommendation” and “Data synthesis”.

Tseng (2011) observed that in RPAs published in applied linguistics the present tense usually occurred in the first (“Introduction”), second (“Purpose”) and fifth moves (“Conclusion”), whereas the past tense was often used in the third (“Method”) and fourth moves (“Results”).

Kwary el al. (2017) informed about the similarities and differences in the use of verb tenses and modal verbs in RPAs published in health, life, physical and social sciences. Their findings showed that most of the sentences used the present simple

and the past simple although the present perfect also appeared on some occasions. The past perfect was occasionally employed in health sciences and life sciences while physical sciences contained one occurrence of the present progressive. Their research also discovered that health sciences contained more verbs than the other disciplines. As for modal auxiliary verbs, they found eight modal auxiliary verbs, the auxiliary modal "can" being the most frequently reported.

Keartikul & Wimolkasem (2017) also investigated the move structure, tense, and voice in RPAs published in the fields of linguistics and applied linguistics. Their findings disclosed that in both disciplines, the simple present was the most frequent tense and the simple past was the second most commonly used tense. The present perfect was the third most used tense in linguistics but was rarely found in applied linguistics. Another tense that they registered was the present perfect continuous in linguistics (one occurrence), whereas the future was found on two occasions in linguistics against one in applied linguistics. As for voices, they observed that the active voice was used in the "Purpose" move while the passive voice usually appeared in the "Methodology" move, either in Linguistics or applied linguistics.

Nurhayati (2017) analyzed the verb tense of each move in RPAs published between 2005 and 2006 in an Asian EFL (English as a foreign language) journal. Her study revealed that the present simple was frequently used in Moves 1 ("Introduction"), 2 ("Purpose"), 4 ("Results") and 5 ("Conclusion") and the past tense was prominent in Move 3 ("Method"). The present perfect and the future tense were other verb tenses employed in Moves 1, 4, and 5. She also noted that double tenses were applied in Move 1 (present simple+present perfect, present+future simple), in Moves 2, 3 and 4 (present+past simple) and that the active voice was dominant in all the moves.

Kholili (2022) analyzed the tenses, voices, and moves in RPAs published in the ELT (English for Language Teaching) sphere. She discovered that the present was employed in the "Introduction" and "Results" moves and that the past was frequently used in the "Aims", "Methods" and "Results" moves. As for voices, the active one was found in the "Introduction", "Purpose', "Results" and "Conclusion" moves, the passive voice being included in the "Method" move.

RESEARCH METHODS

Purpose

As already stated in the "Introduction" section, and due to the lack of linguistic studies in RPAs in astrophysics, back in 2020 we decided to start research in this field. Our aim now is to focus on the verbs found in RPAs in the same four journals, complementing then the two previous ones on linguistic and authorial implications as well as on some content words and compound groups.

More precisely, the questions guiding our study are the following ones: a) What is the total number of verbs, their variants and their proportion in relationship with the total number of words? b) What are the most used verbs, tenses and voices? c) Is there any relationship between the number of verbs and the number of authors?

To answer question (a), we first counted the total number of words and then the total number of verbs that we classified into main verbs (including infinitive verbs, -*ing* verbs and past participles), auxiliary verbs ('be', 'do', 'have') and modal verbs in their different forms.

A clarification is in order here: i) When registering the verbs that we were going to analyze, we did not include some derived verbal forms (-*ing* adjectives and -*ing* nouns) that had already changed of grammatical category and that we had analyzed in our previous paper on content words (Méndez & Alcaraz, 2025), ii) Although auxiliary verbs have usually been categorized as function words because they cannot act on their own (unlike main verbs which are content words), we incorporated them in our analysis because they are used to form verb constructions (Aarts et al., 2014). Auxiliary verbs add grammatical or functional meaning to the clauses in which they appear. They can be used to express aspects, tenses, and voices. By the way, no emphatic or interrogative forms have been found in our corpus, which is quite understandable if we take into account that we are dealing with written scientific discourse where objectivity, precision and formality are its main characteristics, iii) The same circumstance occurs with modal verbs, which cannot be isolated from main verbs and henceforth have been categorized as

function words. Nevertheless, modal verbs are also necessary to form tenses and to express modality (ability, advice, certainty, likelihood, necessity, obligation permission, possibility, probability, speculation, or willingness), apart from expressing authors' commitments to the information conveyed, iv) Although infinitives have no mark of tense or person, we decided to include them in our list of main verbs because they are the base form of conjugated verbs, v) When making up our sample we also determined to consider *-ing* verbs and past participles which, like infinitives, are other non-personal forms of main verbs that are used to transmit an action but without referring to any agent directly. *-Ing* verbs are needed to form progressive tenses while past participles are necessary to build active and passive voices. Past participles also give additional information in participial clauses coming from relative clauses with a passive meaning, as illustrated in the following example:

"All the experiments were conducted in a closed-cycle helium cryostat *coupled* to a Fourier transform infrared spectrometer." (A&A, December 2018).

To answer question (b), we recorded the 10 main verbs with the highest number of appearances as well as the different tenses (present, simple past, present perfect, etc.) and voices (active, passive) in the RPAs in the whole corpus.

To reply to question (c), we recorded the total number of authors indicated in the bylines of each RPA.

In order to obtain a more complete panorama on verbs in astrophysical RPAs, we also conducted a somewhat restricted 'diachronic' (due to the short period analyzed) and a cross-journal analyses that would allow us to know any variations over time and any quantitative differences among the RPAs in the four journals concerning the use of the studied items.

Corpus

In the present study, we randomly collected our RPAs from the accessible on-line version of the four high-ranked international astrophysics journals mentioned here-above, i.e. *Astronomy & Astrophysics* (A&A), *The Astronomical Journal* (AJ), *The Astrophysical Journal* (ApJ) and *Monthly Notices of the Royal Astronomical Society* (MNRAS). A&A (Impact Factor: 6.5 in 2022) is an originally European-based journal

that publishes papers on theoretical, observational, and instrumental astronomy and astrophysics. Back in 2001, the expression "A European Journal" was removed from the front cover of A&A because the journal was becoming increasingly global in scope. A&A is published and distributed by EDP Sciences (Édition Diffusion Presse Sciences) on behalf of the European Southern Observatory. EDP Sciences was acquired in 2019 by China Science Publishing & Media. AJ (Impact Factor: 5.3 in 2022) primarily publishes papers of astronomical research. ApJ (Impact Factor: 4.9 in 2022) has a more theoretical trend and publishes papers in astronomy and astrophysics. Both AJ and ApJ are US-based and are published on behalf of the American Astronomical Society. MNRAS (Impact Factor: 5.2 in 2023) covers research on astronomy and astrophysics and is published in the name of the Royal Astronomical Society. MNRAS is often preferred by astronomers from the United Kingdom and the Commonwealth.

To have a more diversified corpus, our analysis covers a period extending from the year 2011 to the year 2021 (11 years), at the rate of five RPAs per year and journal, i.e. 55 RPAs per journal, which gives a total of 220 RPAs. Considering the counting methodology that we adopted (as mentioned in the following section), our whole sample amounts to a total of 57,972 running words (see Table 1), distributed as follows: A&A (17,076 words), AJ (13,038 words), ApJ (14,341 words) and MNRAS (13,517 words).

When randomly selecting the RPAs we were going to analyze and to retrieve them every month throughout the year, we followed a fairly regular approach despite its randomness. For example, in the year 2011, we selected our five RPAs from January, March, May, July, and September. In the year 2012, we chose our five RPAs from February, April, June, August, and October. In the following years, we also included the months of November and December. Besides, in the case of A&A, since RPs are grouped in different topics inside astrophysics (cosmology, extragalactic astronomy, stellar structure, planets, etc.), we tried to choose articles covering all of them. Moreover, it is worth mentioning that contrary to AJ, ApJ and MNRAS RPAs, which consist in only one paragraph, A&A is the only journal in which they are structured into the following parts: 'Context', 'Aims', 'Methods', 'Results' and

'Conclusions'. In this sense, the authors who publish the results of their research in A&A follow the rules of this journal that encourage the use of structured RPAs (see Bertout & Schneider, 2004).

Methodology

Once our corpus was collected, we registered the total number of running words included in each of the RPAs. Apart from the single words that were easy to compute, on some occasions the counting task was quite difficult because we found different types of expressions: groups of words separated by hyphens, combinations of uppercase and lowercase letters, abbreviations including words and numbers and, last but not least, more complex expressions formed by words or by numbers and/or chemical/mathematical symbols. Given the complex set of cases involved, we decided to do our word calculation manually because the use of any Natural Language Processing (NLP) software would have entailed a great deal of effort over time to train it. In other words, our study can be characterized as a pilot study whose strategies could be applied in the future to instruct NLP programs to reach reliable results for larger corpora.

So we counted the expression 'counts-in-cylinders' (ApJ, January 2011) and the abbreviation 'CME' [(< 'Coronal Mass Ejection') (A&A, May 2021) as three words each according to the number of their semantic components. Acronyms, i.e. strings of letters with a syllabic structure that are usually pronounced as a word and not letter-by-letter like abbreviations, such as 'KELT' [< 'Kilo degree Extremely Little Telescope'] (ApJ, December 2012) and '1SWASP' [< 'First Super Wide-Angle Search for Planets'] (AJ, February 2014) were considered as one word each. A more complicated group containing numbers, abbreviations (including common names and mathematical symbols) like the following one was computed as 32 words:

'inner- ($\frac{dN}{d\tau} \propto \tau^{-1.07+/-0.12}$) and outer-disk ($\frac{dN}{d\tau} \propto \tau^{-0.37+/-0.09}$) star clusters' (ApJ, December 2021).

[the derivative of the number of stars in the cluster concerning their age, i.e. the number of stars for a given age interval is proportional to the age of the stars raised to -1.07 (+/- indicates an uncertainty in that exponent, plus or minus 0.12)]

Finally, to complement our quantitative analysis and to determine whether the differences observed in the numerical variables were statistically significant or not, we exported them to a Microsoft Excel sheet and submitted them to the parametric Student's t-test. The alpha value was set at 0.05. That is, our study combined both manual and computer analyses.

RESULTS AND DISCUSSION

General Approach

Table 1 displays a cross-journal analysis of the number of words, main, auxiliary and modal verbs.

Table 1: Number of words, main, auxiliary and modal verbs across journals.

Journal	Number of Words	Number of Main Verbs	Variants Main Verbs	Number of Auxiliary Verbs	Number of Modal Verbs
A&A	17,076	1,539	333	324	84
ApJ	14,341	1,146	311	205	60
MNRAS	13,517	1,189	296	182	75
AJ	13,038	1,082	282	188	65
TOTAL	57,972	4,956	591	899	284

If we compare all the RPAs under study, we can see that A&A RPAs are the longest ones, with the highest number of main verbs (and their variants) as well as auxiliary and modal verbs. ApJ RPAs present the second highest number of words, main verb variants and auxiliary verbs together with the lowest number of modal verbs. By contrast, MNRAS RPAs show the second highest number of main and modal verbs and the lowest number of auxiliary verbs. On the other hand, AJ RPAs contain the lowest number of words and main verbs together with their variants.

According to the data displayed in Table 1, main verbs account for a 8.54% of the total number of words in astrophysical RPAs, being A&A and MNRAS the journals with the highest percentages (9.01% and 8.79%, respectively) and AJ and ApJ with the lowest ones (8.30% and 7.99%, respectively). These results are considerably lower than the averages obtained by Netzel et al. (2003) in their study of biomedical abstracts published in the MEDLINE database, which were closer to a 13-14%.

Regarding auxiliary verbs, they account for a 1.55% of the total number of words and for a 14.64% of the total number of verbs, with A&A topping the scale once again (1.90% and 16.64%, respectively). MNRAS now appears in the lowest place (1.35% of the total number of words and 12.57% of the total number of verbs) with the two US-based journals lying in between (1.44% and 14.08% in AJ and 1.43 % and 14.53% in ApJ).

As for modal verbs, the percentages are considerably smaller, reaching only 0.49% of the total number of words and 4.63% of the total number of verbs. The highest percentages correspond to MNRAS (0.55% and 5.19% of the total number of words and the total number of verbs, respectively) and the lowest ones to ApJ (0.42% and 4.25%, respectively). AJ and A&A RPAs reach similar percentages (0.50% and 0.49% concerning the number of words and 4.87% and 4.31% regarding the total number of verbs). These results are in agreement with the ones obtained in Netzel et al. (2003)'s study, where the incidence of modal verbs per total number of words was always smaller than 1%. Similar values are found in the mean number of main verbs per total number of words and the mean number of auxiliary and modal verbs per total number of main verbs (see Graphs 1, 2 and 4).

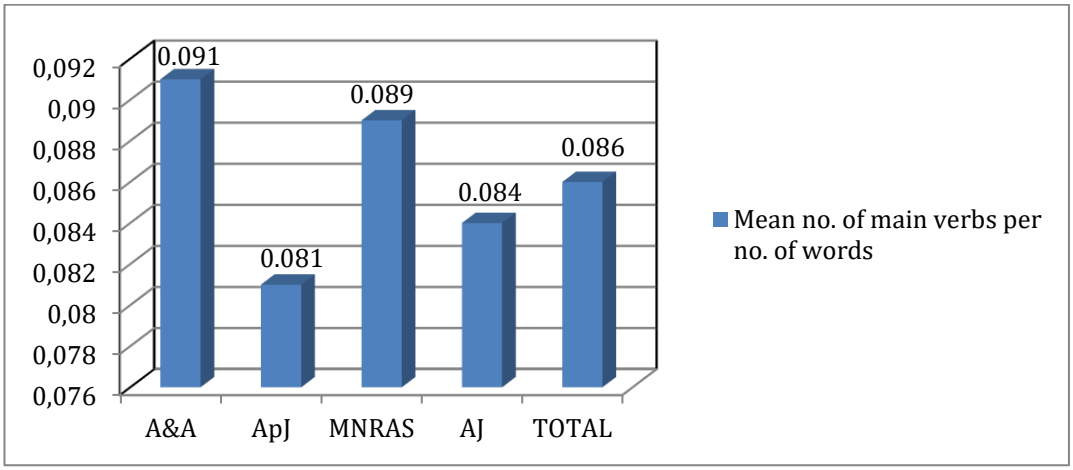
Table 2 shows the percentages of infinitives, -*ing* verbs and past participles with respect to the total number of words.

Table 2: Percentages of infinitives, -*ing* verbs and past participles with respect to the total number of words.

JOURNAL	INFINITIVES	-*ING* VERBS	PAST PARTICIPLES
A&A	1.12%	1.30%	0.90%
ApJ	0.69%	0.84%	0.90%
MNRAS	0.70%	1.18%	0.91%
AJ	0.61%	1.18%	0.85%
TOTAL	0.80%	1.13%	0.89%

A&A RPAs present the highest percentages of infinitives and *-ing* verbs, whereas MNRAS RPAs show the highest one of past participles. Moreover, the lowest percentages of infinitives and past participles are found in AJ and the lowest percentage of *–ing* verbs in ApJ. As for infinitives and *-ing* verbs, the results imply a higher presence of purpose and linking clauses in A&A compared with MNRAS and the two US-based journals, especially ApJ. In addition, the results yielded by *-ing* verbs are slightly higher than the ones obtained by Netzel et al. (2003) but within the same order of magnitude. On the other hand, the frequency of appearance of past participles seems to be more than three times lower in our sample. This can be understood in terms of a lower presence of passive voices and perfect tenses, a fact even more remarkable in the case of AJ.

Graph 1 depicts the mean number of main verbs per number of words in each journal and in the whole sample.



Graph 1: Mean number of main verbs per number of words.

A&A RPAs present the highest mean number of main verbs per number of words while the lowest one corresponds to ApJ RPAs. Statistically significant differences are found between A&A and ApJ (p=0.011), and AJ (p=0.020) RPAs. MNRAS RPAs show the second highest mean number of main verbs per number of words, with statistically significant differences with ApJ RPAs (p=0.011). From a diachronic point of view, 2021 is the year with the highest mean number of main verbs per number of words (0.089), 2013 being the year with the lowest one (0.082), with no statistically significant differences in the whole period studied.

Lexical Verbs

The 10 main verbs with a higher frequency of appearance and their corresponding percentages are illustrated in Table 3.

Table 3: Verbs with a higher frequency of appearance.

Verbs	Number Of Appearances	Percentage (%)
Be	676	13.64
Use	206	4.16
Find	186	3.75
Show	147	2.97
Have	87	1.76
Present	81	1.63
Suggest	73	1.47
Obtain	69	1.39
Compare	68	1.37
Provide	65	1.31

As can be seen, the verb "be" occupies by far the first position (13.64%) in the scale of main verbs while the rest of verbs show much smaller percentages, "use" (4.16%), "find" (3.75%) and "show" (2.97%) being the only ones with a percentage higher than 2%.

From a cross-journal point of view, "be" goes on standing in the first position and it is followed by "find" but for A&A, where this second place is occupied by "use". Focusing on verbs with more than a 2%, worth mentioning is the appearance of "present" (2.96%) and "obtain" (2.03%) in AJ and of "have" (2.27%) in MNRAS.

If we compare our results with those obtained by Hartwell (2013) in her study of biology and medical abstracts written in English, we can see that six of the 10 most common verbs are the same in both samples. In addition, if we do not take the verb "find" into account, the four most common verbs are exactly the same, although the third and fourth places are interchanged. This result should perhaps come as no surprise since both samples include natural sciences. By contrast the verbs "find" (third place in our sample) and "obtain" (eighth place in our sample) do not appear in the list of the fifty most frequent verbs of Hartwell's sample. This discrepancy could lay in the intrinsic relationship between astrophysics and both physics and

mathematics, which are clearly more basic and even more formal sciences than medicine and biology.

Auxiliary Verbs

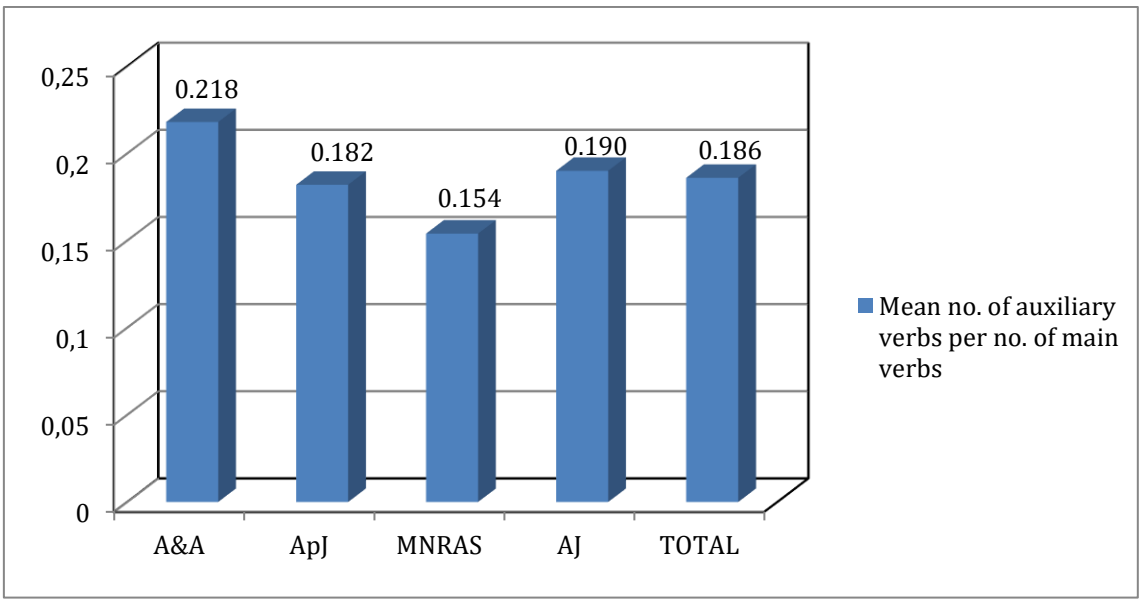
Table 4 displays a cross-journal breakdown, in terms of percentages, of the three different variants ("be", "have" and "do") of auxiliary verbs in our corpus.

Table 4: Percentage breakdown of auxiliary verbs per journal.

Journals	Be (%)	Have (%)	Do (%)	Total (%)
A&A	83.02	13.89	3.09	36.04
ApJ	80.49	13.17	6.34	22.80
MNRAS	80.22	15.38	4.40	20.25
AJ	72.34	23.40	4.26	20.91
TOTAL	79.64	16.02	4.32	100

"Be" tops the scale of auxiliary verbs in the four journals, followed by "have" and "do". The highest percentage of "have" is found in AJ RPAs (23.40%) and the highest one of "do" in ApJ RPAs (6.34%).

On the other hand, and as Graph 2 exhibits, A&A is the journal with the highest mean number of auxiliary verbs per number of main verbs and MNRAS the journal with the lowest one. Statistically significant differences are found between A&A and MNRAS (p=0.0008) and between A&A and ApJ (p=0.049) RPAs.



Graph 2: Mean number of auxiliary verbs per number of main verbs.

From a diachronic point of view, 2019 is the year with the highest mean number of auxiliary verbs per number of main verbs (0.213), 2011 being the year with the lowest one (0.163). The whole period studied shows no statistically significant differences.

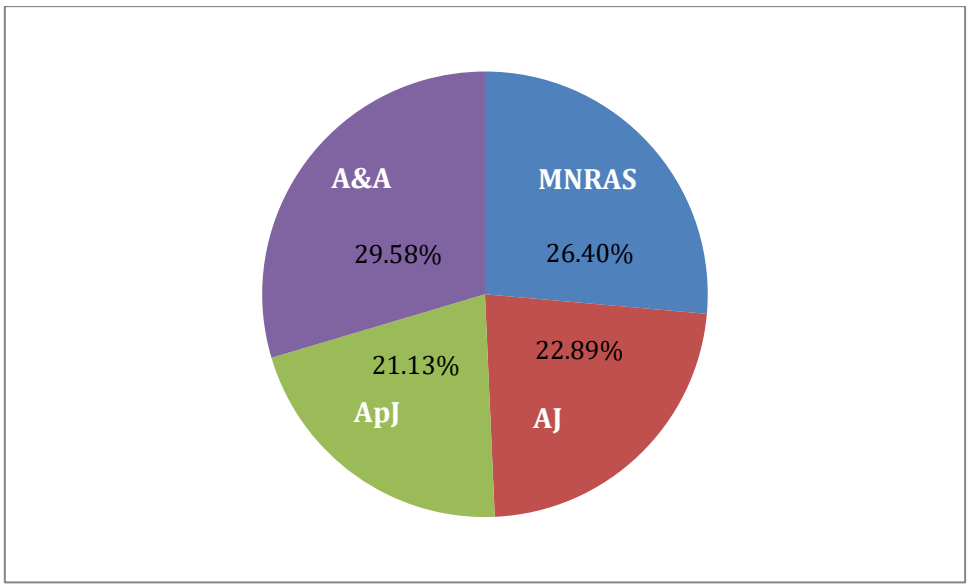
Modal Verbs

Table 5 and Graph 3 illustrate a percentage breakdown of modal verbs per journal.

Table 5: Percentage breakdown of modal verbs per journal in relation of the total number of modal verbs.

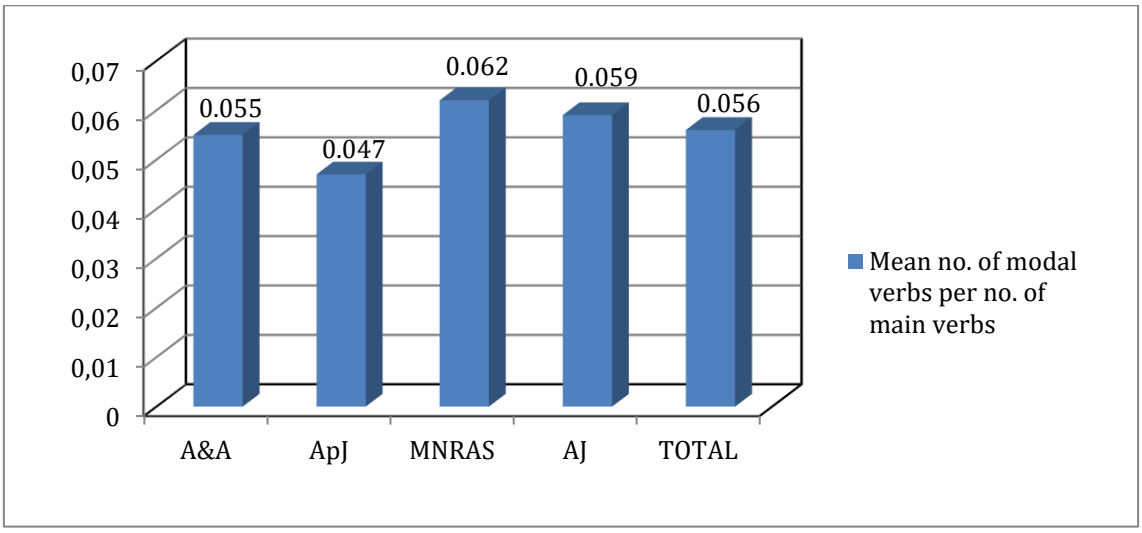
Jour.	Can (%)	May (%)	Will (%)	Could (%)	Should (%)	Would (%)	Cannot (%)	Might (%)	Must (%)
A&A	39.23	14.29	23.81	11.90	5.95	1.19	1.19	2.38	0
ApJ	31.66	25	3.33	15.00	3.33	11.67	6.67	1.67	1.67
MNRAS	44	17.33	12	10.67	4	5.33	2.67	4	0
AJ	26.15	12.31	21.54	12.31	9.23	4.62	9.23	3.07	1.54
TOTAL	35.92	16.90	15.85	12.32	5.63	5.28	4.58	2.82	0.70

"Can" tops the global scale of modal verbs, followed by "may", "will" and "could", all of them with percentages higher than 10%. "Should, "would" "cannot", "might" and "must" present overall percentages lower than 10%. From a cross-journal standpoint, the highest percentages of "can" and "might" are found in MNRAS, whereas "may", "could" "would" and "must" maximum ones correspond to ApJ. As for "will" and "could", the highest percentages are reached in A&A while AJ contains the highest percentages of "should" and "cannot". Moreover, it is worth mentioning that "must" only appears in the two US-based journals. In addition, as can be seen in Graph 3, A&A shows the highest global percentage of modal verbs and ApJ the lowest one.



Graph 3: Cross-journal percentages of modal verbs.

When comparing the data in Table 5 with those of Hartwell (2013), it is noticeable that the percentages of the verbs "can", "may", "could" and "would" are very similar in both samples, with differences smaller than 1.6%. In the cases of "will" and "should", the percentages are closer to the ones obtained in the *Natural and Pure Sciences British National Corpus* (Kennedy, 2002) and the *Collins' Corpus of General Oral and Written Texts in English* (2009), respectively. As for "might", its percentage approaches the one found in the *Applied Sciences British National Corpus* (Kennedy, 2002). The predominant use of "can" was also noticed previously by Kwary et al. (2017) as stated in the "Introduction" section of our paper.



Graph 4: Mean number of modal verbs per number of main verbs.

Graph 4 indicates that the highest mean number of modal verbs per number of main verbs is found in MNRAS RPAs while the lowest one corresponds to ApJ RPAs, with no statistically significant differences.

From a diachronic point of view, the highest mean number of modal verbs per number of main verbs (0.098) is reached in 2014 and the lowest one in 2016 (0.032), the difference between both being statistically significant (p=0.008). More statistically significant differences are found between 2014 and the following years: 2012 [0.040] (p=0.022), 2015 [0.051] (p=0.031), 2017 [0.052] (p=0.047) and 2020 [0.040] (p=0.023). There are also statistically significant differences between 2016 and 2019 [0.070] (p=0.047).

Tenses and Voices

Table 6 shows a cross-journal analysis of the different tenses found in our corpus.

Table 6: Cross-journal analysis of verb tenses.

Journal	Present (%)	Past (%)	Conditional (%)	Future (%)
A&A	83.66	13.59	1.30	1.45
ApJ	87.68	10.16	1.95	0.21
MNRAS	91.78	5.67	1.70	0.85
AJ	85.02	11.67	1.86	1.45
TOTAL	86.81	10.49	1.67	1.03

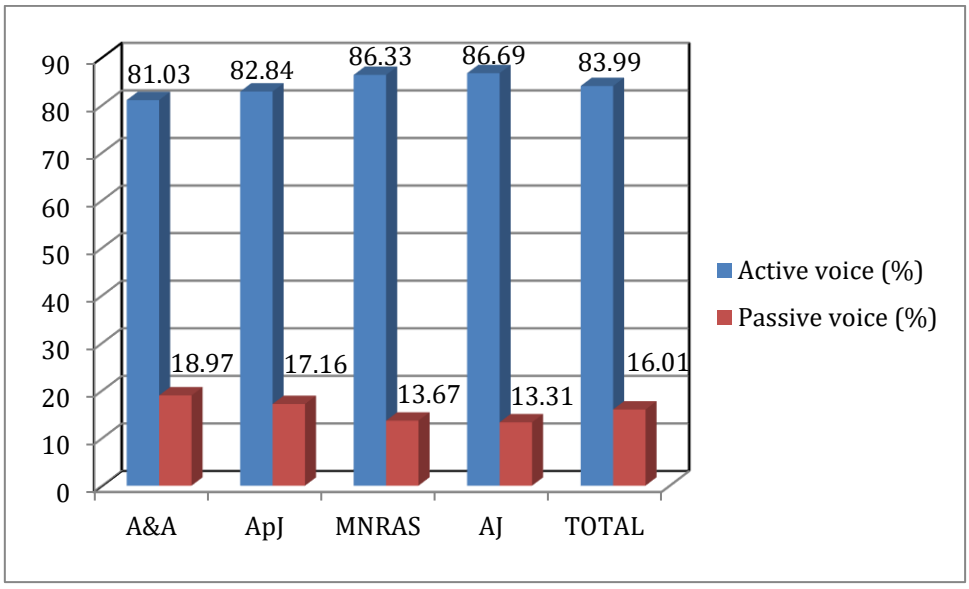
The “present” is the most common tense in the four journals, followed by the “past”, “conditional” and “future” tenses. 99.5% of the “present” tenses correspond to the “simple present” and the remaining 0.5% to the “present continuous”. In the case of “past” tenses, 69.57% correspond to the “simple past”, 28.48% to the “present perfect”, 0.87% to the “present perfect continuous”, 0.65% to the “past perfect” and finally 0.43% to the “past continuous”.

Regarding “conditional” tenses, 94.52% belongs to the “simple conditional”, 2.74% to the “past conditional”, 1.37% to the “conditional continuous” as well as to the “present perfect conditional”. From a cross-journal point of view, the highest percentage of “present” tenses is found in MNRAS RPAs and the lowest one in A&A

RPAs. Conversely, the highest percentage of "past" tenses corresponds to A&A RPAs and the lowest one to MNRAS RPAs. As for "conditional" tenses, the highest percentage corresponds to ApJ RPAs and the lowest one to A&A RPAs. Finally, AJ and A&A RPAs share the maximum percentages of "future" tenses while ApJ is the journal with the minimum one.

The overall percentages are in agreement, within the margin of errors, with the results obtained by Krámský (1969) and Alzuhairy (2016) in scientific specialized texts. Kearttikul & Wimolkasem (2017) also observed the prevalence of the "present", followed by the "past" in RPAs published in the fields of linguistics and applied linguistics. Similar findings were obtained by Kwary et al. (2017) in health, life, physical and social sciences. Moreover, the predominance of the "present" and "past" tenses in RPAs corroborates the results obtained by Salager-Meyer (1992), Tseng (2011), Nurhayati (2017) and Kholili (2022) in different disciplines as already stated in the "Introduction" section.

Graph 5 displays the percentages of active and passive voices in the four journals analyzed.



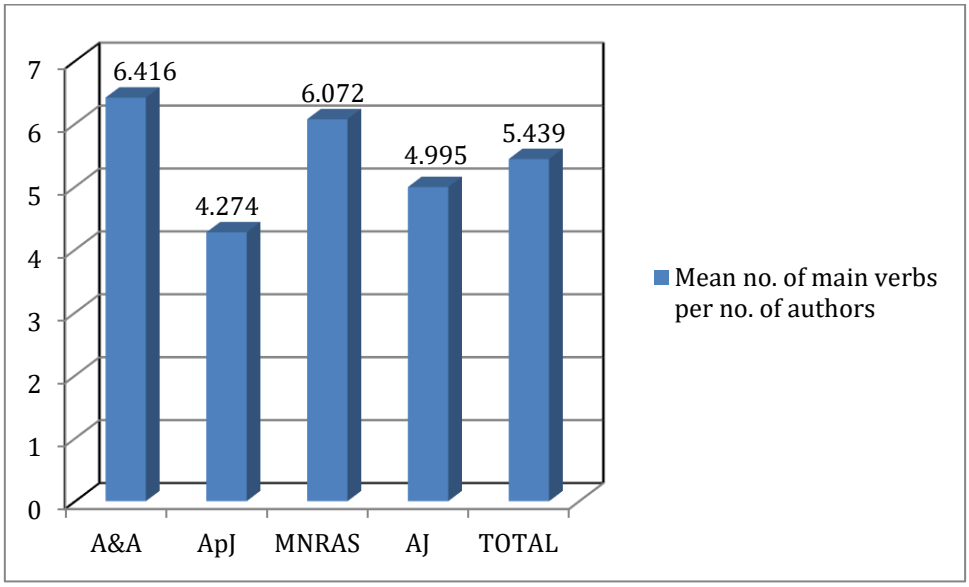
Graph 5: Verb voices across journals.

Active voice always outweighs passive voice, this phenomenon being more dramatic in AJ RPAs and somehow less striking in A&A RPAs. These findings coincide with those obtained by Tarone et al. (1981, 1998) in astrophysics and

Kearttikul & Wimolkasem (2017) in linguistics and applied linguistics. Nurhayati (2017) and Kholili (2022) also report the same result in their studies in the domain of English for language teaching. From a diachronic perspective, we detect an overall decrease of the passive voice percentage from the year 2011 (15.20%) to the year 2021 (14.58%). The decrease is especially striking in the cases of MNRAS (from 13% in the year 2011 to 8.33% in the year 2021) and ApJ (from 17.58% in the year 2011 to 13.51% in the year 2021). By contrast, there is a slight increase in the case of A&A (from 17.56% in the year 2011 to 17.82% in the year 2021) and a considerable one in AJ (from 11.63% in the year 2011 to 15% in the year 2021). But for AJ and A&A individually, these results should come as no surprise since many authors have reported that the use of the passive voice in scientific writing is becoming less and less frequent over the years (Banks, 2017, 2021; Subagio et al., 2019; Hundt et al., 2021, among others).

Verbs and Authors

Graph 6 illustrates a cross-journal analysis of the mean number of main verbs per number of authors.

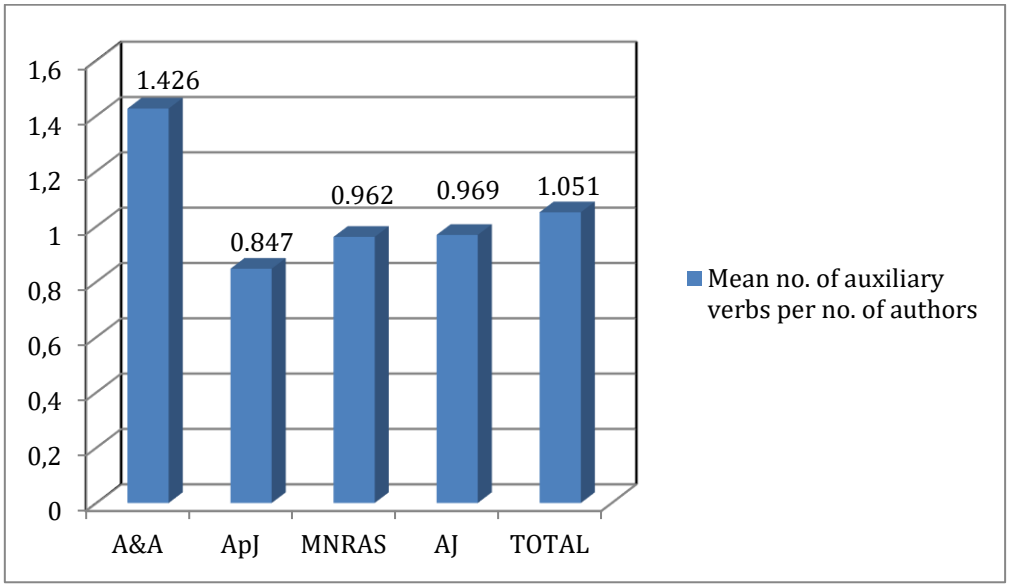


Graph 6: Mean number of main verbs per number of authors across journals.

A&A RPAs show the maximum value of the mean number of main verbs per number of authors, the minimum one corresponding to ApJ RPAs. Statistically significant differences are found between ApJ RPAs and A&A RPAs (p=0.019) and MNRAS (p=0.032) RPAs.

From a diachronic point of view, 2012 is the year with the highest mean number of main verbs per number of authors (6.783) and 2016 the one with the minimum value of this parameter (3.301). Statistically significant differences are found between 2016 and the following years: 2011[5.698] (p=0.010), 2012 (p=0.003), 2013 [5.779] (p=0.027), 2014 [5.915] (p=0.042), 2018 [6.457] (p=0.030) and 2019 [5.987] (p=0.012), and also between 2012 and 2015 [4.315] (p=0.045).

Graph 7 displays the mean number of auxiliary verbs per number of authors.



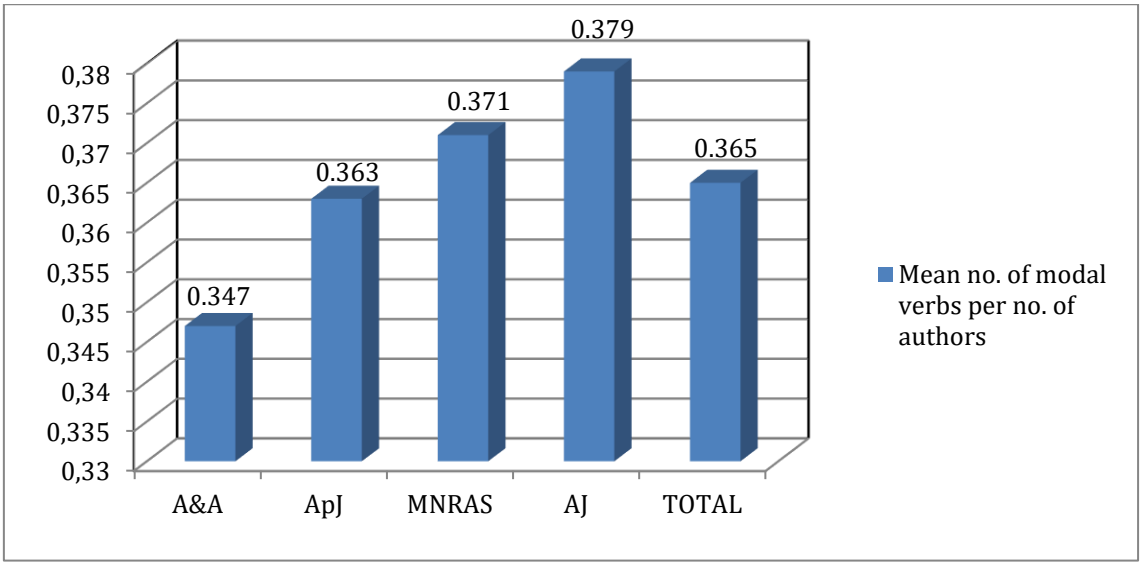
Graph 7: Mean number of auxiliary verbs per number of authors across journals.

Similarly to the case of the mean number of main verbs per number of authors, A&A RPAs show the maximum value of the mean number of auxiliary verbs per number of authors, the minimum one corresponding once again to ApJ RPAs. Statistically significant differences are found between A&A RPAs and ApJ RPAs (p=0.028).

From a diachronic standpoint, 2013 is the year with the highest mean number of main verbs per number of authors (1.425) and 2016 the one with the minimum

value of this parameter (0.553). Statistically significant differences are found between 2016 and the following years: 2012 [1.219] (p=0.014), 2013 (p=0.011) and 2018 [1.270] (p=0.043). There are also statistically significant differences between 2020 [0.712] and 2013 (p=0.040) and between 2020 and 2019 [1.238] (p=0.018).

Finally, Graph 8 displays the mean number of modal verbs per number of authors.



Graph 8: Mean number of modal verbs per number of authors across journals.

As can be seen in Graph 8, AJ RPAs top the scale of the mean number of modal verbs per number of authors, the minimum value of this parameter being reached in A&A RPAs although with no statistically significant differences among any of the journals under study.

From a diachronic point of view, the maximum value is reached in the year 2014 (0.681) while the minimum one corresponds to the year 2016 (0.113), again with no statistically significant differences between any of the years analyzed.

Cross-Journal Final Remarks: Different Sociolinguistic Scenarios

A&A RPAs are the longest ones, they contain the highest numbers of main verbs and variants, the highest numbers of auxiliary and modal verbs, the highest percentages of infinitives, and *-ing* verbs, together with the second highest percentage of past participles (shared with ApJ RPAs). A&A RPAs also account for

the highest mean number of main verbs per number of words, the highest mean number of auxiliary verbs per number of main verbs, the highest percentages of passive voices and past and future tenses, the last one shared with AJ RPAs. Conversely, they present the lowest percentages of present and conditional tenses. A&A RPAs are the only ones where the verbs "use" and "show" outnumber the verb "find". Regarding auxiliary verbs, A&A RPAs also display the highest percentage of the auxiliary verb "be", in agreement with the most frequent use of the passive voice, along with the lowest one of the auxiliary verb "do". In addition, A&A RPAs show the highest percentage of the modal verb "will" and the lowest ones of the modal verbs "would" and "cannot". Finally, A&A RPAs show the highest mean numbers of main and auxiliary verbs per number of authors together with the lowest mean number of modal verbs per number of authors.

ApJ RPAs are the second longest ones. They contain the second highest numbers of main verb variants and auxiliary verbs along with the lowest number of modal verbs. They also show the lowest percentage of *-ing* verbs and the second highest one of past participles, shared with A&A RPAs. ApJ RPAs also account for the lowest mean number of main verbs per number of words, the second highest percentage of passive voices as well as the highest percentage of conditional tenses and the lowest of future ones. As for lexical verbs, they present the lowest percentage of the verb "be". Regarding auxiliary verbs, ApJ RPAs display the minimum percentage of the verb "have" and the maximum of the verb "do". In addition, ApJ RPAs show the highest percentages of the modal verbs "may", "could", "would" and "must", together with the lowest ones of "will", "should" and "might". Finally, ApJ RPAs show the lowest mean numbers of main and auxiliary verbs per number of authors.

MNRAS RPAs display the lowest number of auxiliary verbs and mean number of auxiliary verbs per number of main verbs. They also contain the second highest number of main verbs as well as the second highest mean number of main verbs per number of words. They show the highest percentage of past participles and the second highest percentages of infinitives and *-ing* verbs, this last one shared with AJ RPAs. Moreover, they display the second highest percentage of active voices and the

highest percentage of present tenses along with the lowest percentage of past tenses. As for lexical verbs, MNRAS RPAs reveal the highest percentage of the verb "find" and the lowest percentage of the verb "show". MNRAS RPAs exhibit the second highest number of modal verbs and the highest mean number of modal verbs per number of main verbs. In addition, MNRAS RPAs present the highest percentages of the modal verbs "can" and "might" together with the lowest percentage of "could". Finally, MNRAS RPAs show the second highest mean numbers of main and modal verbs per number of authors.

AJ RPAs are the shortest ones with the lowest numbers of main verbs and variants, the lowest percentages of infinitives and past participles, the second lowest mean number of main verbs per number of words and the lowest percentage of passive voices. Moreover, they show the highest percentages of the lexical verb "be" and the auxiliary verb "have". Conversely, AJ RPAs display the lowest percentage of the auxiliary verb "be". As for modal verbs, AJ RPAs contain the highest percentages of "should" and "cannot" and the lowest percentages of "can" and "may". Finally, AJ RPAs show the second lowest mean number of main verbs per number of authors, the second highest mean number of auxiliary verbs per number of authors and the highest mean number of modal verbs per number of authors.

If we take into account the different geographic scenarios inherent to the four journals, as already stated in the "Corpus" section of our paper, it seems that they could strongly influence the way authors use verbs in astrophysical RPAs. On the one hand, authors who choose A&A to publish their papers are generally English L2/L3 researchers, and even on many occasions are not of European origin, tend to express their ideas with more words and more purpose and linking clauses. Moreover, they are not always experts in the English language in comparison to native English (L1) writers who usually master a more developed linguistic repertoire (Ruan, 2018; Xue & Ge, 2021) and lean towards choosing journals of their own geographic environment. A&A writers are likely to use a less direct language with more verbs and variants but also more passive voices, more past and future tenses and fewer modal verbs in relation to the number of authors involved in the writing of the abstracts. However, the fact that A&A RPAs are the only structured

ones, which implies that more full sentences are encouraged (and so more words and verbs) could also shape this result. On the other hand, English L1 researchers who, in average, usually write in MNRAS, ApJ and AJ, prefer to express their ideas with fewer words, verbs and auxiliary verbs as well as more direct and assertive language. This fact appears to be reinforced in the case of US-based writers, and particularly with regard to more experimentally and technically-oriented researchers like those who frequently choose AJ to publish the results of their investigation.

Furthermore, the most common modal verbs used also differ from one scenario to the other as already observed by Kafes (2009), Vázquez Orta (2010), Li (2017) or Ahmed (2021), to name just a few. Some discrepancies may also be noticed among English L1 researchers, i.e. between US- and British-based authors, the former being more inclined to use conditional tenses and even more assertive language.

As already stated in Méndez & Alcaraz (2025) as well as in the "Corpus" section of this paper, the considerable rise of A&A impact factor from 4.8 in 2017-2018 to 6.5 in 2021-2022 may also be understood as a consequence of the growing number of research papers written by English L2/L3 authors that come from countries all over the world. It is worth remembering that EDP Sciences, the publisher of A&A, was acquired in 2019 by Science China Press which is itself majority-owned by the Chinese Academy of Sciences (CAS), the world's largest research organization.

Within this interpretation, it would seem clear that the way the most read and influential research papers in astrophysics are written has changed over the years, at least in terms of the use of verbs and other content words (Méndez & Alcaraz, 2025). English L2/L3 researchers have become then more visible as they are taking a highly active role in the development of English (Modiano, 1999), i.e in this day and age Global English rules how highest impact astrophysical papers are being written. All these ideas would connect directly to the conspicuous and somehow controversial "woke" conception. In a constantly changing world, it seems that not only is society changing, but also that the English language, although still a lingua franca in science, cannot escape such significant linguistic changes.

In short, any L2/L3 English-speaking astrophysics researcher who is not fluent in English as an L1 English speaker would not gain less visibility for their work, a fact that may clearly influence the evolution of the English language itself over time.

CONCLUSIONS

In our study we have explored the use of verbs in a corpus of RPAs retrieved from four top journals written in English (A&A, AJ, MNRAS and ApJ) published during the period (2011-2021) in astrophysics, a field in which not much linguistic research has been carried out till now. From a diachronic point of view, we have noticed an overall decrease in the use of the passive voice and fluctuating patterns in the verbal parameters studied, with no substantial statistically significant differences among them.

From a cross-journal standpoint, we have observed that there are significant differences in the use of verbs between the four journals analysed. These discrepancies could be interpreted in terms of distinct sociolinguistic frameworks since astrophysicists may employ verbal constructions differently depending on whether they are writers of English as their L1 or L2/L3, but also whether they are associated with British or US-based linguistic environments.

Explicitly stated, English-speaking L2/L3 astrophysics authors tend to write longer abstracts with more purpose and linking clauses, more verbs and variants and also more passive voices, more past and future tenses and fewer modal verbs in relative terms. By contrast, authors who speak English as their L1 would prefer to use fewer auxiliary verbs and more direct and assertive language. Within L1s, linguistic differences among researchers may be attributed to their US or British areas of influence as well as to the specific scope of each journal.

It should be noted that our quantitative and qualitative analysis has some limitations as it has focused on a small corpus retrieved over only 11 years. Further studies with NLP programs and larger samples covering longer periods would be desirable to obtain more conclusive results. It would also be interesting to apply the methodology used in our research to other disciplines to verify the validity of our findings through comparative analyses.

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