科学英語論文の書き方

滋賀大学教育学部 穂積俊輔

1　論文の目的

〇論文＝科学的研究成果の公表 → 人類の共通財産

(0) 研究成果の記録

(1) 研究成果の優先権 (帰属権) の主張

(2) 業績の確立

(3) 研究の継承

(4) 研究結果の利用

(3), (4)→ 論文の引用回数

2　論文執筆の基本精神

〇読者に理解してもらう

- わかりやすく
- 論理を明瞭に
- 正しい英語で

3　論文を書く前に

〇科学者としての観点 (Philosophy) の確立

(1) 現在までにわかっていることは何か

(2) 何を新しく知ろうとしてこの仕事をしたのか

(3) なぜこの仕事の結果が重要なのか (何が面白いのか)

(4) 実際の仕事の結果としてわかったことは何か

(5) この結果はその分野の中でどのような意味があるのか

4　科学論文の基本的構成

(1) Title
適切なタイトルをつける．論文の要点を的確に表現する．

(2) Author(s) and Affiliation
full name を使う．Affiliation は郵便が届く程度に簡潔に．

(3) Abstract

- 「どういう方法で, 何を調べて, 何がわかったか」を明確に述べる．
- この論文が扱っている問題についてある程度の知識を持っているが, この論文をまだ読んでいない読者を対象に書く．
- Abstract 自身で完結していること．本文中の図, 表, 式等を引用してはいけない．文献も基本的に引用してはならない．
- 表題を繰り返さない．
- not descriptive but informational
- 大体 200 語を目安に．
- 必ずしも受動態にする必要はない．we から始めてよい．
- 時制の選択と一致．

(4) Introduction

- この論文で扱う問題の背景や現状, 問題点, 取り組まなければならない理由や意義など．特に何に焦点を当てたのか．
- 著者の観点を明確にする．

(5) Model (Theory, Experiment, Observation, Basic Equation, . . .)

- 使ったモデル, 理論, 観測等

(6) Method

- 数値計算の場合, 使った計算コードなど．短い場合は, Models and Method という章名にしてもよい．

(7) Results

- 理論, 観測, 数値計算等で得られた結果を記述．数値計算であれば, 計算精度もつける．
- Discussion の章で論じようとする問題は, 議論しやすい形に結果をまとめておく．

(8) Discussion

- Results で述べた結果に基づいてどのようなことが導き出されるのか．
- 緻密な論理で自身の観点を展開する．
- 単なる speculation に陥らないように．

- Introduction で提起した問題に答えているか.
- future work の方向性.

(9) Conclusion(s)

- この論文でいえることを端的に要約する.
- その結論に達した理由まで述べない.

(10) Acknowledgments

- 仕事の協力者, 議論の手助けとなった人への謝辞.

(11) References

- 公平に引用する.
- in preparation, private communication (, preprint) は避ける.

(12) Tables and their captions

- 使用したモデルの提示
- 正確な数値を必要とする場合
- 縦線は引かない

(13) Figures and their captions

- わかりやすい図
  - 多くの内容を 1 つの図に押し込めない.
  - 線の太さと相対的バランス, 素材の一様な分布
  - 記号の明解さ
  - 文字の大きさと読みやすさ
- 図の意味がわかるように caption を書く.
- caption の最初は完全な文にしない.

(14) Appendices

- 本文に収めるには長く論文の流れを妨げるが, 必要な記録として残したいこと (計算の詳細など).

5 英語による論文作成

5.1 作成手順

(1) 論文の構成

- タイトル, 章立て

(2) 各章の構成

- 段落分け
- 各段落のキーワード

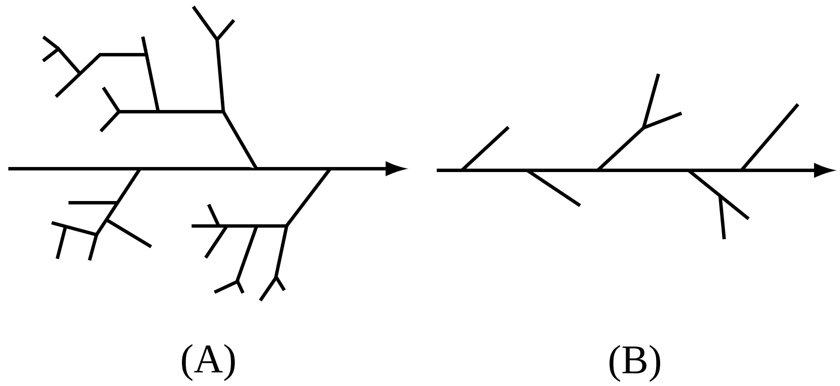

図 1: 英語の文章構造 (A.J.Leggett, 日本物理学会誌第 21 巻第 11 号 790-805 頁). 矢印は話の流れる方向を示す. (A), (B) はそれぞれ日本語と英語の話の流れ方を表す.

5.2 英語の構造

- 英語では、それぞれの文章は既に書かれているものだけに照らして完全に理解できる (図 1 参照).
- 一つの考えと次の考えとの間の関係はそれを読んだときに完全に明確である.
- 本筋から遥かに離れて話を進めない (図 1 参照).
- 思考のつながりはいつでも明確である (読者にある思考と別の思考との関連を想像して補わせてはいけない).
- 明確で紛らわしくないことが絶対必要.
- できる限り明確に断定的に言い切る.
- 実質的に何も新しい意味を付け加えない文などは省く.

5.3 英語文章法の基本

- 機械的な文法の誤りはなくすこと.
- 受動態より能動態を使うこと.
- 否定文より肯定文を使うこと.
- 分詞構文においては主語を一致させること.
- 長い文を避けること. 一文の平均は 20 語程度を目標にすること.
- 口語的用法を避けること.

5.4 日本人のよくある誤り

【練習問題】次の英文はどこが間違っているだろうか.

1. Table 1 summarizes the results.
2. This parameter is estimated by the observations.
3. We give informations of this model in table 1.
4. The increase of temperature became significant.
5. Assuming that the radiation pressure is dominant, the disk flux and disk central temprature is obtained.
6. The temperature and sound speed became asymptotically constant at large distance from the center.
7. In appendix 1, we discuss a restriction on k-space, which enables us the development in terms of the orthogonal functions we are concerned.

5.5 日本人にとっての問題点

(1) 冠詞と数

- 「名詞に a (the) がつく」→「a (the) に名詞をつける」
  - a ··· 1 つの形の決まった単位性をもつものにつく.
  - 無冠詞 ··· 決まった形のない単位性をもたないものにつく.
- the ··· 限定されたもの, 読者との間に了解があるものにつく.
- 数えられる名詞は複数でない限りその前には a か the が来る.
- a か the かは, “a certain”(ある一つの) で置き換えられるか, this または that で置き換えられるかを考えるとよい.
- 不加算名詞 ··· information, equipment, knowledge, encouragement, trouble, the following, advice, evidence, literature, assistance, dependence
- 通常不加算名詞 ··· staff, damage, agreement, interest, support, light, work
- 加算名詞 ··· extension, description

(2) 前置詞 → 慣用に従う

(3) 時制

- 過去形 → 過去の事実 (現在との関係はない)
- 現在完了形 → 過去の事実や結果が現在において影響をもつ

(4) 関係代名詞

- 制限用法 → 名詞を限定する
- 非制限用法 → ある事柄についての付加的記述

- 関係代名詞とその先行詞を離さない

(5) 受動態

- 能動態に変えられないか (describe, explain, present, discuss, determine などは無生物主語を許す)
- It is consdered that, It is thought that のような文はできる限り避ける.

(6) 論理関係を表す言葉

- 文頭に Especially, Particularly はこない
- accordingly (それに応じて), consequently (ある状態の当然の結果として)≈ as a result
- therefore (非常に堅い論理的関係; 推論の正確さや精密さを表す)
- 理由の Since は文頭のみ, Because はどちらでも
- 理由に for は使わない
- アメリカ英語では理由に as を使わない
- 「だから」と言う意味で so を使わない (口語的)
- thus, therefore, hence などを and のような接続詞として使わない
- thereby = by way of that place は使う価値あり

6 間違いやすい英語表現の練習問題

1. The density of model A is different from model B.
2. The temperature of sample 1 is much higher than sample 2.
3. The velocity approaches to the light speed.
4. In the case of the present method, we used 10,000 particles of equal mass.
5. We discuss about detailed structures of this system.
6. We measure on the temperature of this state.
7. We applied this method, threfore we obtained these results.
8. The pressure increased due to this instability.
9. The followings are obtained.
10. The parameters are the followings.
11. This is explained in details in section 4.
12. This effect can be negligible.
13. This is found in a HII region.

14. The effect of mass stripping of these systems are shown below.
15. We found an excellent agreement with the experiment by Landau.
16. Different from model A, model B has another parameter.
17. In this equation, M and L represent the mass and angular momentum of the system.
18. The galaxy was observed by HST.
19. The density increases monotonously.
20. The dependency of this value on the final density is explained.
21. In the previous paper, we showed a mass stripping rate of merging galaxies.
22. We obtained knowledge on the phase transition.
23. An investigation was made concerning this mechanism.
24. The procedure of this analysis is described.
25. The paper is referred as Paper I.
26. This model resemble to model A.
27. The temperature was changed in a range from 5,000K to 10,000K.
28. These objects are observed at high temperature regions.
29. These experiments are planned in similar conditions.
30. The object was observed with a regular interval.
31. The deferences of these models are described.
32. Assuming that this theory holds, an infinite amount of light is generated.

6.1 よくある英語の表現

(A) 文章の最初に使う接続詞

Furthermore, . . .; Moreover, . . .; In addition, . . .	さらに
Similarly, . . .; In a similar way, . . .	同様に
Therefore, . . .	それゆえに
Whence, . . .	それゆえに (主に数式の前に使う)
Nevertheless, . . .	それにもかかわらず, それでもやはり
However, . . .	しかしながら
On the contrary, . . .	これに反して
Conversely, . . .	反対に
Again, . . .	再び
That is, . . .	すなわち
Then,. . .	すると
In addition to . . .	. . . に加えて
On the basis of . . .	. . . に基づいて
In contrast to . . .	. . . に反して
On the other hand, . . .	他方
For instance, . . .For example, . . .	たとえば
In fact, . . .	事実
In practice, . . .	実際上
In reality, . . .	現実に
According to . . .	· · · によると
Consequently,	その結果として (ゆえに)

(B) 説明文

○ . . . がわかる → ∼ tourns out to be . . .

○ ∼ の結果 . . . となる → ∼ results in; ∼ leads to . . .; As a result of ∼, it becomes . . .; It follows that . . .

○ ∼ の原因は . . . である → ∼ is due to . . .; ∼ is caused by . . .; ∼ originates in; ∼ results from . . .; ∼ is ascribed to . . .; ∼ is attributable to . . .

○ ∼ が必要である → ∼ is necessary for ∼; ∼ needs ∼; ∼ is a prerequisite for . . .; ∼ is indispensable for ∼ ing (to do) · · ·; ∼ is required for ∼ ing (to do) . . .

(C) 条件文

○ もし ∼ ならば · · · となる → If A is B, C is D (C will be D).; Provided A is B, C is D.

○ ∼ にもかかわらず → In spite of ∼, A · · ·; Notwithstanding ∼, A · · ·; Despite · · ·, A · · ·; Disregarding ∼, A · · ·; Now matter how A is ∼, B · · ·; Regardless of ∼; Irrespective of ∼

○ ∼ 他方 → · · ·, whereas · · ·; · · · while · · ·

○ ∼ だから · · · → Since · · ·, · · ·; · · ·, because · · ·; · · ·, so that

7　論文添削の実例

ここでは, *The Astrophysical Journal* 第 440 巻 60 頁に掲載された論文 “A Comparison of Two Algorithms for Simulating Collisionless Systems” の日本人著者による原稿が, ネイティブスピーカーであるもう一人の著者によってどのように書き直されていったのかを, TITLE と ABSTRACT, INTRODUCTION, CONCLUSIONS の各章について具体的に対比して示す. これによって, 日本人的英文とアメリカ人的英文の違いを具体的に吟味する.

この論文は, 無衝突恒星系の計算方法として, 従来使われている N 体計算とは異なる SCF method と言われる方法を力学平衡にない系に適用して, その力学進化を他の計算コードを使った結果と比較することによって, SCF method の信頼性を議論したものである. SCF method は, いわゆる softening length を含まないものであるため, 比較する計算コードとして無衝突 Boltzmann 方程式を直接解くコードを使用した.

7.1　TITLE

Hozumi:	A Test on the Accuracy of a Self-Consistent Field Method for Spherical Stellar Systems
Hernquist:	A Comparison of Two Algorithms for Simulating Collisionless Systems

7.2 ABSTRACT

Hozumi

The accuracy of a self-consistent field (SCF) method **which solves** Poisson's equation by expanding the density and potential in a set of basis functions **is presented**.

The results of collpase simulations for spherical stellar systems with the SCF method **are compared to** those with a phase space method **which integrates** the collisionless Boltzmann equation directly.

The models used are uniform-density spheres and Plummer models whose velocity dispersions are assigned according to **given initial** virial ratios.

The comparison provides excellent agreement about the density and velocity dispersion profiles between the two methods.

Therefore, the results with the SCF method are considered to correspond to the $N \to \infty$ limit.

The choice of a set of basis functions is also discussed.

Hernquist

Two completely different simulation algorithms are compared by applying them to the same stellar dynamical problems: one is a self-consistent field (SCF) **method for solving** Poisson's equation and the other is a phase-space **method for integrating** the collisionless Boltzmann equation. We consider simulations of spherical stellar systems **which are initially far from equilibrium and relax to their final states** by gravitational collapse. The initial conditions consist of either uniform-density spheres or non-equilibrium models having Plummer density profiles, in which velocity dispersions are assigned according to **given** virial ratios. If a few tens of radial expansion terms with hundreds of thousands of particles are used in the SCF code, excellent agreement is found between the results it generates and those obtained with the phase-space solver, provided that a sufficiently large number of grid cells are employed with the latter. These findings imply that for simulating collisionless systems over many dynamical times, the SCF approach based on sampling phase space is competitive with the approach treating phase space as a continuous fluid. The results of our tests make it possible to estimate the number of particles and basis functions required in situations like those modeled. Limitations of the SCF method and **the choice of an optimal set** of basis functions are also discussed.

7.3 INTRODUCTION

第 1 段落

Hozumi	*Hernquist*
In general, it is necessary to solve Poisson's equation numerically **in simulations of** self-gravitating stellar systems.	In general, it is necessary to solve Poisson's equation numerically **when simulating** self-gravitating collisionless systems.
One of the most desirable numerical methods **comes from** calculating the gravitational field by expanding the density and potential in a set of basis functions.	One approach, termed the self-consistent field (SCF) method by Hernquist & Ostriker (1992; hereafter HO), owing to its similarity to Hartree-Fock techniques from quantum theory, calculates the gravitational field by expanding the density and potential in a set of basis functions.
In particular, when **the radial dependence as well as the angular one** is expanded, this approach **gives the closer spirit** to the collisionless dynamics in that particles interact with the field which they experience. Hernquist & Ostriker (1992) named it a self-consistent field (SCF) method and discussed its advantages in detail in comparison to conventional N-body methods (see also Sellwood 1987).	In particular, when **the full spatial dependence** of the potential and density is expanded, this scheme represents the gravity in a mean-field sense and, so, **is closer in spirit** to collisionless dynamics than other N-body algorithms in which particles interact with one another directly (for a discussion see, *e.g.* Sellwood 1987, Barnes & Hernquist 1992).

第 2 段落

Hozumi	*Hernquist*
Although SCF methods cannot describe the small-scale structure of a stellar system, they can overcome the difficulties confronted with N-body methods.	Although SCF methods cannot describe the small-scale structure of a stellar system **unless a prohibitively large number of basis functions are used**, they have several potential advantages over direct N-body methods when applied to collisionless dynamics.
Above all, the conspicuous characteristic is no need for softening length. Consequently, it brings the pure Newtonian force field of a smoothed density distribution.	For example, SCF codes do not require the introduction of a softening length to smooth out local irregularities in the density arising from the use of finite numbers of particles
It is true that the introduction of softening length saves N-body simulations from an excessive two-body relaxation (Sellwood 1987; Huang, Dubinski, & Carlberg 1993). However, as a side effect, softening length makes a system spherical (Cannizzo & Hollister 1993). In addition, the usual form of softening length **which changes a point mass to an extended sphere** becomes physically inconsistent with force law between two spheres (Dyer and Ip 1993).	**More important**, the elegant structure of the SCF method makes possible highly efficient implementations of it on a variety of computer architectures. Preliminary tests of the HO algorithm on a Connection Machine 5 demonstrate the feasibility of simulations employing $\sim 10^8$ particles with existing hardware (Bryan & Hernquist 1993; see Hillis & Boghosian 1993). Given the explosive growth of parallel computing and the perfectly scalable nature of the SCF approach, it seems likely that simulations with particle numbers comparable to the actual number of stars in galaxies will be possible in the near future.

第 3 段落

Hozumi	*Hernquist*
In spite of no such problems mentioned above in SCF methods, they have hardly been applied to stellar dynamical simulations.	**In spite of such advantages**, SCF methods have been used only sparingly in applications to stellar dynamics. In large measure, this may be due to the inflexibility of this technique, in that the basis set must be chosen so that the lowest order terms are capable of reproducing the global structure of the system under investigation.
Recently, Hernquist & Ostriker (1992) have devised a new set of basis functions which well represents a galaxy obeying the de Vaucouleurs $R^{1/4}$ law. Their basis set will be useful for **investigating** spheroidal systems like elliptical galaxies, because the first few members of the basis set can reproduce such systems.	Recently, HO proposed a new set of basis functions whose lowest order members accurately describe galaxies obeying the de Vaucouleurs $R^{1/4}$ law in projection. Their basis set will be useful, therefore, for **studying** spheroidal objects like elliptical galaxies.
Some tests of the SCF method about systems in equilibrium have been done (Hernquist & Ostriker 1992). However, the applicability to the dynamical evolution of stellar systems has never been proved. Most of interesting problems are concerned with the dynamical aspects of stellar systems.	Crude empirical tests of the SCF method when applied to systems in equilibrium were done by HO. However, the reliability of this technique for simulating the dynamical evolution of systems **far from equilibrium** has never been proved.
Therefore, it is indispensable to demonstrate the accuracy of the SCF method for the application to stellar dynamical problems.	**Clearly**, it is crucial to demonstrate that the SCF method can handle such cases **in view of the fact that** many interesting problems involve, *e.g.* the evolution of systems towards equilibrium.

第 4 段落

Hozumi	*Hernquist*
	Regorous proofs of the reliability of numerical codes like the SCF method are generally not feasible for highly non-linear problems.
Fortunately, there is another simulation method which by no means depends on softening length: **it** is a phase space method **that** solves the collisionless Boltzmann equation directly.	Fortunately, progress can be made by relying on empirical tests in which different techniques are applied to the same problem and comparing the results obtained with them in detail, as was done by Inagaki, Nishida, & Sellwood (1984) who studied the non-linear evolution of thin stellar disks. For modeling collisionless systems, there is another approach which neither employs particles nor depends on a softening length: phase-space methods in which the collisionless Boltzmann equation is solved directly.
As Fujiwara (1983) has demonstrated, the method can precisely describe violent relaxation of stellar systems, although the systems are exactly spherical symmetric.	As Fujiwara (1983) has demonstrated, although spherical symmetry is assumed, this method can describe the violent relaxation of stellar systems accurately in the sense that the results are not subject to random fluctuations.
Since collisionless Boltzmann simulations are **considered** a limiting case of an infinite number of particles, their results can be used **as a measure of the accuracy** of the SCF method which still has discreteness noise.	Since collisionless Boltzmann simulations are a limiting case of a particle-based scheme in which the particle number goes to infinity, their results can be used **to measure the validity** of the SCF method when a finite number of particles are used.
In this paper, we compare the results of collapse simulations between the two methods and demonstrate the **power** of the SCF method.	In this paper, we compare the results of collapse simulations between the two methods to study the reliability of the SCF method **although we are forced to examine spherical symmetric systems owing to limitations of the computer memory necessary for the phase-space method**.

7.4 CONCLUSIONS

第 1 段落

Hozumi	*Hernquist*
We have **presented** the collapse simulations of uniform-density spheres and cooled Plummer models to demonstrate the power of the SCF method.	We have **studied** the collapse of uniform-density spheres and cooled Plummer models to demonstrate the reliability of the SCF method for modeling the dynamics of collisionless systems initially far from equilibrium.
It has been proved that the method can give high accuracy for such simulations.	**We have shown** that, in principle, this approach can successfully reproduce the time-evolution of such a system, when compared with results obtained with a method which solves the collisionless Boltzmann equation using a finite-difference scheme.
In particular, it can practically provide the continuous limit obtained from the collisionless Boltzmann simulations about **such information as** density profiles and velocity dispersion profiles.	**With only a modest number of particles and basis terms,** the SCF method can practically attain the continuous limit when predicting **information such as** density profiles and velocity dispersion profiles.
In addition, if **the large enough number** of particles is used, the time evolution of virial ratios can also be reproduced almost exactly.	In addition, if **a sufficiently large number** of particles are used, more detailed properties, such as the time evolution of the virial ratio can be reproduced almost exactly.

第 2 段落

Hozumi	*Hernquist*
The success of simulations with SCF methods strongly depends on **a basis set chosen**.	The success of simulations with the SCF method depends on **the basis set chosen**.
As shown in §4, the basis set should be selected from the viewpoint where the density profiles in relaxed systems rather than in initial systems can be well approximated.	As suggested in §4, **for collapse simulations like those reported here,** the basis set should probably be selected so that the basis set gives an accurate description of the final relaxed state, rather than the initial conditions.
One of the appropriate basis sets is that given by Hernquist & Ostriker (1992) which is based on a galaxy obeying the de Vaucouleurs law because in usual collapse simulations the density profiles in a relaxed state **end up** $R^{1/4}$ law closely.	One example of such a basis set is that suggested by HO, which is based on a galaxy obeying the de Vaucouleurs law in projection. As is well-known, collapse simulations typically produce end-states whose density profiles are well-described by $R^{1/4}$ laws in projection.

第 3 段落

Hozumi	*Hernquist*
Once a basis set is determined, the simulation accuracy of SCF methods is gained from **the** suitable choice of the maximum numbers of expansion coefficients such as $n_{\max}$ and $l_{\max}$ for a given particle number. The degree of the reproduction in acceleration is useful **as a measure of accuracy**.	Once a basis set is determined, the accuracy of the SCF method is **determined by** a suitable choice of the maximum number of expansion coefficients such as $n_{\max}$ and $l_{\max}$, and the particle number. Clearly, the appropriate choices of $n_{\max}$, $l_{\max}$, and N are problem–dependent. Our results in §3.2 suggest that even in some extreme cases values of $n_{\max}$ in the range 10–30 are adequate to describe the evolution of some non–equilibrium systems in detail if hundreds of thousands of particles are used.

8 参考書

1. 日本物理学会編, 「科学英語論文のすべて 第 2 版」(丸善株式会社)

2. William Strunk Jr. and E.B.White, "The Elements of Style Fourth Edition" (MACMILLAN PUBLISHING CO., INC.), http://www.bartleby.com/141/

3. マーク・ピーターセン, 「日本人の英語」(岩波新書)

4. マーク・ピーターセン, 「続日本人の英語」(岩波新書)

5. マーク・ピーターセン, 「心にとどく英語」(岩波新書)

6. プログレッシブ英和中辞典 (小学館)

7. ロングマン現代英英辞典 (桐原書店)