Exploring Children's Creative Imagination in Conceptual Understanding of the Astronomical World

Felicita Gali* and Sudhakar Venukapalli**

Abstract

One of the fascinating traits is that children have inborn potentials and intrinsic qualities that often make them wonder about the terrestrial and celestial worlds and continuously explore the world they experience. Astronomy and space science can a strongly appeal to children. Astronomy is one of the best ways to introduce the spirit of science and creative imagination to children. The current study aims to examine how children's creative imagination contribute to their understanding of astronomical phenomena. The sample consisted of 36 Grade 9 students from a high school located in Hyderabad, India. An instrument called 'Test of Creative Imagery Abilities' (TCIA) was administered to assess children's ability to draw creative images. To test their knowledge of astronomy, 30 probes on different astronomical topics were administered. Children's explanations to the probes were categorised as naive, synthetic and scientific. The research was quantitative in nature. Correlational research has shown that children's conceptual understanding of astronomy is significantly correlated to their creative imagination. The correlation coefficient of the overall score of creative imagination and conceptual understanding in astronomy was found to be 0.482 ($p < .05$). Though this study had established a moderate but positive relationship between creative imagination and astronomy understanding, the researcher suggests that the introduction of visual creative imagination exercises allow students to gain a better understanding of abstract astronomical phenomena, and teachers should develop strategies that enhance children's imagination.

* *Assistant Professor*, St. Ann's College of Education, Secunderabad
** *Professor of Education* and *DEAN*, School of English Language Education

Introduction

Creativity requires imagination. It takes imagination to play with ideas, create unique and new connections, and explore different possibilities (Duffy, 2006). Imagination is the ability to imagine something that does not currently exist or is not visible (Gundoğan, 2019).

The ability to imagine, rearrange, and manipulate existing knowledge to transform it into a unique and original mental image is called creative imagination (Eberle, 2008). Imagination is a human being's inherent capacity. The roots of great inventions stem from human imagination (Vygotsky, 2004). Science is founded on human imagination, creativity and logical reasoning. This scientific development is based on observation and inferences from the environment. Creative literature offers numerous anecdotal and empirical examples of how significant visual images can be part of eminent scientists' creative achievements (Ho, Wang and Cheng, 2013). Creative imagination is the skill to form a mental image or concept of something that does not yet exist or is not currently perceived. It is expressed as "the ability to create and transform representations based on the material of past observations but significantly transcending them to so-called creative representations" (Dziedziewicz and Karwowski, 2015). It enables one to develop scientific theories and produce new ideas through the continuous process of reflection, reasoning and evaluation. Creative abilities play a prominent role, although at times they are overlooked in learning (Gajda, Beghetto and Karwowski, 2017).

Children's thought and imagination begin at a young age, and their creativity is without limits. Studies show that imagination is the engine of children's creativity (Vygotsky, 2004). Imagination helps children to change an object's perception from what it is, to what they can imagine. "Children can indeed form mental images of objects and events that do not exist in reality. These are products of their imagination, even though the material for these products is drawn from everyday reality" (Hadzigeorgiou, 2016). Creative skills play a significant role in learning (Gajda et al., 2017; Beghetto, 2016). According to Wang, Ho and Cheng (2015), scientific imagination is a mental process that involves creating new ideas associated with scientific principles relevant to daily life experiences. The relationship between creative imagination and knowledge was considered by Beghetto (2016) as a mutual relationship in which creativity promotes understanding and understanding unlocks new and imaginative ways of thinking. Hence, there are convincing reasons to hypothesise that creative imagery abilities would translate into understanding abstract concepts including basic astronomical experiences in children (Jankowska, Gajda and Karwowski, 2019).

(Creative Imagination and Conceptual Understanding in Astronomy)

According to Mintzes and Wandersee (1998), conceptual understanding is an "epistemological outcome of the conscious attempts by learners to make meanings". Conceptual understanding in science was defined by Mullis et al. (2003) as "having a grasp of the relationships that explain the behaviour of the physical world and relating the observable to more abstract or more general scientific concepts. It increases in sophistication as children progress through school and develop cognitively". Measuring conceptual understanding "requires children to extract and use scientific information and apply their understanding of science concepts and principles to find solutions and develop explanations".

Conceptual understanding in astronomy refers to both a cognitive aspect ranging from knowledge to application and reasoning, as well as a content aspect that includes a scientific understanding of key concepts in astronomy. These two aspects are considered when measuring the conceptual understanding of astronomy. It implies a profound understanding of the meaning of concepts, including knowledge of concepts and the skill to use this knowledge in different settings as well as in systems, including relationships with other concepts (Wellington, Osborne and Wellington, 2001). In this study, the term conceptual understanding refers to a process of developing varying levels of understanding, such as naive understanding, incomplete or partial understanding, and accurate scientific understanding.

According to the National Aeronautics and Space Administration (NASA), the foremost objective of teaching astronomy to young children should be to develop their imagination; and to stimulate their interest in space exploration. More specific is that the visual creative imagination develops, interprets, and transforms what is "seen with the mind's eye" (Gajda et al., 2017). Creative imagination is one of the essential competencies that impact creative potential effectively. The creative essence of visual imagination is represented by new and unique concepts, which are substantially different from the reality that exists in our minds. It takes creativity and verbal thinking to infer what is happening in the distance (Kikas, 2006). It is required to be more imaginative to learn astronomy as it is natural science (Bakhramovich, 2019). Imagination and thought come together to help young children understand the world around them. Instead of refraining from teaching concepts that seem too difficult for children to understand, we should look for ways to teach astronomy, such as the use of imagination. This form would be more accessible to younger children (Sharp, 1995).

Imagination is a human being's inherent capacity. The creativity literature offers numerous anecdotal and empirical examples of the significance of visual creative imagination for the innovative contributions of important scientists. Naturally, creative imagination plays a significant role in unravelling scientific problems (Ho, Wang and Cheng, 2013). Creative imagination enables one to develop scientific theories and produce new ideas through the continuous process of reflection, reasoning and evaluation. The roots of great inventions stem from human imagination (Vygotsky, 2004), and it is emphasised that imagination operates based on experiences of daily life that inspire creative activities.

There are some well-established examples of how famous scientists use visual imagination in a novel way: Discovery of gravity by Newton; theory of relativity by Einstein through the imagination of a light beam; Faraday's magnetic lines of force; Kekule's cyclical benzene structure; all of these evolved into visual imagery. The creative imagination helps scientists not only to visualise these phenomena, which are challenging and at times, impossible to observe directly but also to grasp and explain them (Hadzigeorgiou, 2016). Children's knowledge of astronomy is not directly related to experience. The motion of celestial bodies and planetary functions in our solar system is not easy for children to recognise and understand. As a result, their perceptions often contradict scientific assumptions. Because children believe that the earth's surface is flat (Ehrlen, 2008), and their naive astronomical concept is based on the mental model they created. This approach involves visualising, describing and transforming information for collection rather than relying on direct observation (Gilbert, 2005). Like scientists, creativity and imagination can help children visualise and explain basic astronomical facts, concepts and events.

The current study used the concept of creative imagination depicted in the new "Conjunctional Model of Creative Imagery Ability" (CMCIA) by Dziedziewicz and Karwowski (2015). This theoretical model highlights the three key features required for the effective working of imagination as given in Figure 1.

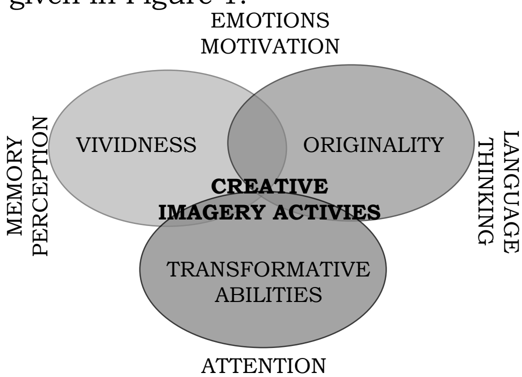

Fig. 1: Conjunctional Model of Creative Imaging Ability.
(Source: Dziedziewicz and Karwowski, 2015)

CMCIA considers three interrelated components of creative visual imagination:

- Vividness — the skill to generate highly complex and expressive images.
- Originality — the skill to create new images based on past experiences, but the ability to surpass them will be an important aspect.
- Transformative ability — the capability of transforming the images generated.

In the CMCIA model, the ability for creative imagination results from the combination of these three dimensions. Besides, it is assumed that these capacities are jointly dependent on perception, attention, memory, language, thought, emotions, and motivational processes. This model is one of the few scientific conceptualisations of creative imagination and accepted as the foundation for a reliable and valid tool for assessing these skills in children (Jankowska and Karwowski, 2015). Research findings have shown that even in young children, vividness, originality, and transformative ability can be achieved successfully (Dziedziewicz, Gajda and Karwowski, 2014).

Researchers have drawn attention to the potential benefits of harnessing visual imagination; primarily, the central role of visualisation and visuospatial abilities in learning astronomy (Kikas, 2003; Subramaniam and Padalkar, 2009). On reviewing the literature, it was found that there were no studies conducted to understand the relationship between creative imagination and conceptual understanding in astronomy. However, Jankowska et al. (2019) investigated how students could construct mental models of space through creative visual imagination and creative thinking. Both quantitative and qualitative approaches have been used for data collection. The research sample consisted of 98 children from a randomly selected pre-school in Warsaw, Poland. This study examined creative imagination centred on a conjunctive model of visual creative imagery abilities. They were defined as three interrelated components: the vividness of the image, the originality of the image, and the degree to which the image is altered or changed (Dziedziewicz and Karwowski, 2015). To identify the level of creative imagination, the Creative Imaginative Ability Test [CIAT] (Jankowska and Karwowski, 2015) was used. Creative thinking was measured, using the "Test of Creative Thinking-Drawing Production" (TCT-DP) (Urban and Jellen, 1996). To investigate students' knowledge about space, "The Drawing Task" (Jovchelovitch, Priego-Hernández and Glăveanu, 2013) was administered. Students were instructed to draw the space in a certain way. They were required to include as many space-related details as possible in the drawing. For analysis, the hierarchical SEM model was used to establish the association between creative imagination and mental models of space. The effect size indicated a strong positive relationship ($\beta = 0.52$, $p < 0.001$). This study showed that creative visual imagination is related to spatial understanding and knowledge. These findings supported the idea that students' understanding of basic celestial phenomena improves with visual creative imagination. Interestingly, imaginative thought was not related to knowing and understanding celestial phenomena. Qualitative analysis has demonstrated differences in student representation. Their understanding of space and their visual creative imagination had a positive correlation. Therefore, the researchers concluded that the strategies used by younger students to study basic astronomy, i.e., methods that promote innovative visual imagination, should be enriched.

Does creative imagination make the learning of astronomy easier? Based on these arguments, we presumed that creative skill, i.e., creative visual imagination, indeed promotes the learning of science, and in particular enables children to visualise and describe simple astronomical concepts. We hypothesised that creative abilities make learning easier, particularly the learning of elementary astronomy.

Objective of the Study

This study aims to investigate how an understanding of astronomical concepts relates to creative imagination. The research question which guided this study is: Is there any relationship that exists between creative imagination and understanding of astronomical phenomena?

Research Procedures

To achieve the objectives of this study, 36 students of Grade 9 from a CBSE school in Hyderabad were selected. The sample was drawn through a purposive sampling technique which is a non-probability sampling technique. The reason for selecting this school was that the students here come from families of moderate socioeconomic status, of various cultural and ethnic origins. All these children had received formal instruction from the same teacher on basic astronomical topics under the unit, "Stars and Solar System" in their previous academic year (8^{th} grade). The research design adopted in this study was a correlational study.

This study considers conceptual understanding in astronomy as the dependent variable and creative imagination as independent variables. To assess learners' conceptual understanding of astronomy, the researcher administered 30 probes under five sections (Keeley and Sneider, 2012) that focus on elementary astronomy to elicit students' ideas and data collection. "A probe reveals significant data about children's thinking— for example, their scientifically correct ideas, their misconceptions, their partially formed ideas, and the types of reasoning and connections they use to make sense of phenomena or concepts" (Keeley, 2011. The probes were selected from two sources: (a) Uncovering children's ideas in Astronomy by Keeley and Sneider (2012) and (b) Uncovering children's ideas in Science by Keeley, Eberle and Dorsey (2008). These 30 probes were divided into five sections or domains: "*Nature of planet Earth, Sun-Earth system, Earth-Moon-Sun system, Dynamic Solar system, and the Stars*". Each section consisted of six probes on various concepts related to astronomy. The first section addressed concepts related to the nature of planet earth, spherical earth, and gravity. The second section focussed on topics related to the sun-earth system, such as the formation of day and night, the seasons and shifts in the position of the sun during the day. The third section covered the EMS system which focused on moon modelling, and section four on the solar system. Finally, section five focused on ideas related to the stars.

All probes developed by Keeley have a common context; a set of choices of answers and an open segment where the study participants were invited to explain. The probe comprised of two parts, in the first part children were asked to select the correct claim from the list of statements given and in the second part to give their explanation as to why their claim is correct while supporting their claim with enough evidence, conceptual understanding and reasoning. Because constructing explanations and defending scientific ideas are essential scientific skills to be mastered by children in high school. Our primary interest was not in simple answers like the "agree" or "disagree" statement, but the second set of answers where children explain and clarify their thinking and reasoning. It was interesting to assess whether these explanations are naive explanations, partially scientific explanations (synthetic models) or correct scientific explanations (Vosniadou and Brewer, 1992). The study participants' written responses to the probes were analysed quantitatively to get the level of conceptual understanding inherent in their explanations. The data were analysed employing the procedure of putting descriptions with related meanings together, in other words, the descriptive content analysis technique. The explanations of students are classified into three types based on the criteria of analysis as given in Table 1.

To prepare the grading headings for the study, the researcher analysed the responses of students based on the scoring parameters, collected examples of the answers that should have been graded as 1, 2, or 3, and established a grading manual/ evaluation rubric for each probe.

Table 1
Criteria for Scoring Student's Level of Understanding

Types of explanations	Analysis criteria
Naive explanations	These explanations are developed based on children's own perception and experience. This includes: • Correct claim/incorrect reason • Description of the phenomena • The knowledge received from sources like adults, myths, religion, culture • Incomplete and contradictory explanation
Partially scientific explanations	These explanations are developed through one's own experience and learnt verbal knowledge. This includes: • Correct claim/partially correct reason statement • Factual knowledge received from teachers, textbooks, web • Correct explanation: mostly supports the response but has no concepts that support response
Accurate scientific explanation	These explanations closely match with scientific explanations and conceptual understanding. This includes: • Correct claim/correct reason • The explanation is correct; includes relevant concepts that support response

According to this rubric, student's explanation for each probe received a score; like scores of '0' if the claim itself is wrong, '1' for pre-scientific/ naive explanations based on one's everyday experiences, '2' for those explanations which are partially scientific (synthetic) and '3' for the responses which have correct scientific explanations. Scores were not given for those who selected incorrect claims and wrong reasons. Based on these criteria, a student can score a maximum score of '3', a minimum of '0' for each probe/question. The total score of six probes gives students conceptual understanding in a particular domain. The cumulative score of all five sections was taken as the score for students conceptual understanding of Astronomy.

The researcher conducted a "Test of Creative Imagery Ability" (TCIA) prepared by Jankowska and Karwowski (2015) to assess the creative imagination of learners. This instrument was chosen because it is currently the only measure that determines the creative imagination of children. He defined creative imagination as "the ability to create and transform representations that are based on the material of past observations but significantly exceed them— the so-called creative representations". Seven tasks make up the TCIA assessment. From a basic graphic sign called the initial figure, the respondent is required to create and explain as many images as possible orally or in writing. The participant then selects the most original of the images produced and generates a drawing with a short description. The instructions demonstrate the need to modify, change and add elements to the original image to produce something much more unique.

The three-point scale, namely the scale of vividness, originality and transformative ability were used to measure the sketches and descriptions. The vividness scale tests the level of visualisation or imagination and the quality of explanation given for the image created. A vivid image is one in which the original image has been integrated with a certain amount of detail. The scale of originality assesses the novelty of the generated images. Originality is expressed by

Table 2
TCIA Assessment Criteria

Scoring	Vividness	Originality	Transformative ability
0	The original figure has not been supplemented but was interpreted, i.e., it was given the title.	Presentation of common objects (things, plants, animals, people, places). Their shapes, functions, and properties are real, and their activities, processes, states, and events are typical.	Multiplication of the original figure.
1	Simple, frequently schematic completion of the original figure.	Individual, simple modifications of shape, functions, and properties of widely known objects (things, plants, animals, people, places) as well as typical activities, processes, states, and events.	Recreation, simple completion of the original figure, and adding to it a relatively independent object(s).
2	Complex, rich in detail completion of the original figure.	Complex, significantly altered concerning reality, modification of shape, functions, and properties of widely known objects (things, plants, animals, people, places) as well as typical activities, processes, states, and events.	Complex modification of the original figure—its multi-aspect elaboration.

the representation of new objects, actions, processes and events, distinct from existing ones. The transformative ability scale examines to what degree the original picture has been modified. The evaluation parameters are presented in Table 2. The final results shall be taken by adding the points obtained for each drawing on the scales of vividness, originality and transformative ability. In this study, creative imagination scores refer to the scores obtained from TCIA which gives the sum of the scores of TCIA subscales, namely originality, vividness and transformative ability. A participant can get a maximum score of 42 (14 per scale). TCIA is an untimed test that usually lasts less than 20 minutes. According to previous research, TCIA is a valid and reliable indicator of creative imagination (Jankowska and Karwowski, 2015; Karwowski and Jankowska, 2016).

To investigate the potential relationship between independent variables, namely children's creative imagination, and dependent variables such as conceptual understanding in astronomy, the researcher employed Pearson product-moment correlational analysis.

Findings

(i) Correlation between Conceptual Understanding in Astronomy and components of Creative Imagination

Creative imagination does indeed promote the learning of science, including the learning of elementary astronomical phenomena. Hence, we presumed that creative skill, i.e., creative visual imagination, enables people to visualise and describe simple astronomical concepts. To test if there exists any correlation between these three components of creative imagination (vividness, originality and transformative ability) and astronomy conceptual understanding, the following hypothesis was framed.

Research Hypothesis 1: There exists a significant correlation between children's conceptual understanding of astronomy and the components of creative imagination, namely vividness, originality and transformative ability.

To test the statistical testing, this research hypothesis was translated into the null form.

Null Hypothesis 1: There exists no significant correlation between children's conceptual understanding of astronomy and creative imagination (vividness, originality and transformative ability).

Pearson product-moment correlation was applied to the null hypothesis to test the correlation between elements of creative imagination and conceptual understanding in astronomy. The results are shown in Table 3.

Table 3 indicates that there is no significant correlation between vividness and conceptual understanding in astronomy (r *(34)* = 0.280, p >.01). Similarly, for originality and astronomy conceptual

Table 3
Correlation between Components of Creative Imagination (Vividness, Originality and Transformative Ability) and Conceptual Understanding in Astronomy

S. No.	Measures		1	2	3	4
1.	Vividness	Pearson Correlation	1	0.734**	0.698**	0.280
		Sig. (2-tailed)		0.000	0.000	0.099
		N	36	36	36	36
2.	Originality	Pearson Correlation	0.734**	1	0.669**	0.271
		Sig. (2-tailed)	0.000		0.000	0.110
		N	36	36	36	36
3.	Transformative Ability	Pearson Correlation	0.698**	0.669**	1	0.151
		Sig. (2-tailed)	0.000	0.000		0.380
		N	36	36	36	36
4.	Conceptual Understanding in Astronomy	Pearson Correlation	0.280	0.110	0.380	1
		Sig. (2-tailed)	0.436	0.786	0.247	
		N	36	36	36	36

** Correlation is significant at the 0.01 level (2-tailed)

understanding the value of $r = 0.271$ and p = 0.110 which is greater than 0.01 (r (34) = 0.271, p >0.01) and for transformative ability, the value of r = 0.151 and p =0.380 which is greater than 0.01 (r (34) = 0.151, p > 0.01). Thus, in all three cases, the null hypothesis is accepted, and it is concluded that there is a weak and insignificant correlation between the different elements of creative imagination and conceptual understanding in astronomy.

(ii) Correlation between Creative Imagination and Conceptual Understanding in Astronomy

Research Hypothesis 2: There exists a significant correlation between children's conceptual understanding of astronomy and creative imagination.

To test the statistical testing, this research hypothesis was translated into the null form.

Null Hypothesis 2: There exists no significant correlation between children's conceptual understanding of astronomy and creative imagination.

Table 4
Correlation between Creative Imagination and Conceptual Understanding in Astronomy

S. No.	Measures		1	2
1.	Creative Imagination	Pearson Correlation	1	0.482
		Sig. (2-tailed)		0.009
		N	36	36
2.	Conceptual Understanding in Astronomy	Pearson Correlation	0.482	1
		Sig. (2-tailed)	0.009	
		N	36	36

The Pearson product-moment correlation was computed to analyse the relationship between combined scores of creative imagination and conceptual understanding in astronomy, and the findings are presented in Table 4.

As shown in Table 4, the coefficient of correlation (*r*) between creative imagination and conceptual understanding in astronomy equals 0.482, and the *p*-value is 0.009, which is less than the significance level of 0.01. Hence, the null hypothesis is rejected. It is noted that a significant positive correlation exists between creative imagination and conceptual understanding in astronomy, signifying that children with creative ability often demonstrate conceptual understanding in astronomy.

Discussion and Conclusion

The current study detected a significant positive between creative imagination and astronomy conceptual understanding. The positive correlation between creative visual imagination and the conceptual understanding of astronomy has the potential to advance research in this field of study. Creative visual imagination tends to facilitate not only the application of knowledge but also the perception of abstract and dynamic phenomena like space itself. Our findings were consistent with the previous research which found a strong relationship between the ability to construct mental models of space and creative imagination (Jankowska et al., 2019; Jankowska and Karwowski, 2015). The researchers stated that students' knowledge and understanding of space might be supported by their creative imagery abilities (Jankowska et al., 2019). A greater level of imagination facilitates the acquisition of knowledge and the interpretation of abstract concepts such as space itself (Gajda et al., 2017).

Many abstract events are seen in everyday life, which children try to imagine and understand. They encounter real and imaginative situations regularly. As Russ has said, connecting the real and the imaginative world has essential functions for development (Russ, 2014). It enhances their thinking and helps them to consider and visualise objects that are comprehensible by observation, such as Earth and Moon, apparent motion of the celestial bodies, eclipses, and the lunar phases. The role of creative imagination in acquiring astronomical knowledge has been discussed in very few studies. In this study, we found a reasonable correlation between creative imagination and conceptual understanding. The reason might be due to the lack of variation in student performance in the drawing tests conducted to measure creative imagination. As Gajda et al. (2017) reported, "verbal tests of creativity might have yielded significantly stronger relationships with an understanding of space and related concepts than figural tests". This research was performed on small sample size. The findings can therefore be replicated and generalised by further analysis of large samples. The findings of this study may have far-reaching consequences. It is suggested that using enriching strategies and activities to develop creative imagination would help children to understand abstract areas of knowledge better. As stated by Hadzigeorgiou, Fokialis and Kabouropoulou (2012), "Perhaps if approached from this perspective, creativity in science education (including elementary astronomy) can create new opportunities for both teachers and students and increase students' engagement in science learning".

In the words of Einstein "Imagination is more important than knowledge". Therefore, teachers should provide opportunities for students to develop and expand their horizons of imagination by using various teaching strategies. To develop creative imagination and encourage interest in Astronomy, teachers can encourage children to visits Planetariums, arrange for sky watching, form Astro clubs with the collaboration of local astronomical societies, amateur astronomers and science teachers, celebrate World Science Day, National Science Day, National and International Space Day, etc., in schools by conducting various events to highlight the significant milestones in science, space science and technology and use various interactive simulation lessons available to teach astronomy interestingly and effectively. In Indian schools, the subject of astronomy is rarely taught. The typical situation is that at grade level 5–9 (ages 10–14), there is an astronomy unit that deals with basic topics such as day and night cycle, seasons, moon phases, planetary orbits, and some descriptive material about planets and stars. Apart from the rudimentary astronomy as part of science and geography, Indian children do not learn about the universe, the celestial bodies and basic astronomical figures in schools. Astronomy is one of the best ways to introduce the spirit of science to children. Therefore, it is a need to introduce more topics related to cosmology and astronomy in the school curriculum in a consistent manner and thus inculcate a scientific temper and creative imagination in our children. Creative imagination has no boundaries. It stimulates progress, gives birth to newness— discoveries, phenomena, concepts, etc. It is related to higher senses, beauty, astounding feelings, great curiosity and longing to search for reality. Astronomy which is real, mysterious and awe-inspiring correlates to creative imagination, and both go hand in hand. Introducing astronomy education as part of the curriculum in schools will doubtlessly enrich their imagination connected to the realities of astronomy.

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