

# Results of an exploratory cosmology questionnaire among teachers of the nationwide teacher training at Haus der Astronomie in November 2019

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The questionnaire presented here was distributed on 14 November 2019 to the 99 participants of a three-day teacher training workshop on astronomy held at Haus der Astronomie, Heidelberg, Germany. 61 completed questionnaires were returned. The sample of (German) teachers attending the workshop can be expected to be biased strongly towards an interest in astronomy, and the sample of teachers returning their questionnaire can be expected to be biased even further towards an interest in cosmology.

Results of a first analysis of the answers were used as input for an interactive workshop on “Misconceptions in cosmology” held by the author as part of the same event on the afternoon of 15 November 2019, with a total of about 40 participants.

Page 1 and 2 of the questionnaire, in the original German, are reproduced here on p. 6 and 7, respectively. A data set encoding the answers for each of the 61 completed questionnaires that were returned can be downloaded from <http://www.haus-der-astronomie.de/kosmo-umfrage2019>. The encoding scheme is described on p. 8.

## 1 Previous experience with cosmology

The first item asks for the respondent’s level of familiarity with cosmology. Paraphrased from the original German, the respondent is asked to complete the statement “I have studied cosmology...” using one of these four possibilities:

How carefully have you studied cosmology?	
intensively	14 (23%)
not so much	39 (64%)
hardly	7 (11%)
not at all	0 (0%)

In hindsight, these choices evidently did not map the space of responses evenly, differentiating too finely at the lower end (hardly/not at all) and too coarsely at the upper end (intensively/not too much).

## 2 Teaching cosmology

The second question asked in what context the teachers had taught (high-school level) students about cosmology. The answers:

classroom teaching	43	(70%)
extracurricular activities	16	(26%)
not at all	10	(16%)

For extracurricular activities, an astronomy club was listed as an explicit example. Ten of the respondents (16%) indicated they had taught about cosmology both in a regular classroom and in an extracurricular setting.

## 3 Statements about cosmic expansion

Next followed a series of four statements about cosmic expansion, to be answered using a Likert scale: “Correct,” “Somewhat correct,” “Don’t know,” “Somewhat incorrect” and “Incorrect.” The statements referred to the two most important interpretations of cosmic expansion: the common expanding-space interpretation and the interpretation that regards cosmic expansion as a consequence of galaxies moving through space. The first statement incorporated a common misconception, namely that of an explosion that has galaxies moving outward from a uniquely defined center, the “center of the universe” (non-relativistic explosion). Here are the separate results for the four statements:

### 3.1 The universe is expanding: just like in an explosion, galaxies fly away from the center of the universe

correct	1	(2%)
somewhat correct	10	(16%)
don’t know	1	(2%)
somewhat incorrect	9	(15%)
incorrect	37	(61%)

### 3.2 The universe is expanding: Galaxies are moving through space, and in this way getting ever further away from each other

correct	15	(25%)
somewhat correct	8	(13%)
don’t know	2	(3%)
somewhat incorrect	5	(8%)
incorrect	27	(44%)

### 3.3 The universe is expanding: The space between the galaxies is stretching

correct	43	(70%)
somewhat correct	9	(15%)
don't know	4	(7%)
somewhat incorrect	1	(2%)
incorrect	2	(3%)

### 3.4 The universe is expanding: Between the galaxies, new space is being created continually

correct	12	(20%)
somewhat correct	4	(7%)
don't know	9	(15%)
somewhat incorrect	11	(18%)
incorrect	23	(38%)

Are most respondents adherents of one of the two interpretations, rejecting the other interpretation? In order to test that, we divided respondents into four groups. Those who agreed with either of the first two statements (choosing “correct” or “somewhat correct”) are classified as concurring with the “movement through space” interpretation. Those agreeing with either of the other two statements are classified as concurring with the “expanding space” interpretation. Depending on whether or not a respondent concurs with either interpretation, they are sorted into one of the four resulting groups. The result is as follows:

	Expanding space NO	Expanding space YES
Movement NO	4 (7%)	30 (49%)
Movement YES	1 (2%)	26 (43%)

Interestingly enough, there are hardly any respondents who agree that galaxies are moving through space, but at the same time reject the expansion of space itself. Within the group of those who accept the concept of space itself expanding, the subgroups of those accepting galaxy motion through space, and those rejecting galaxy motion through space, are of roughly equal size. At least in this sample, galaxy motion through space is seen at best as an additional aspect of cosmic expansion, but not as a replacement for the notion of expanding space.

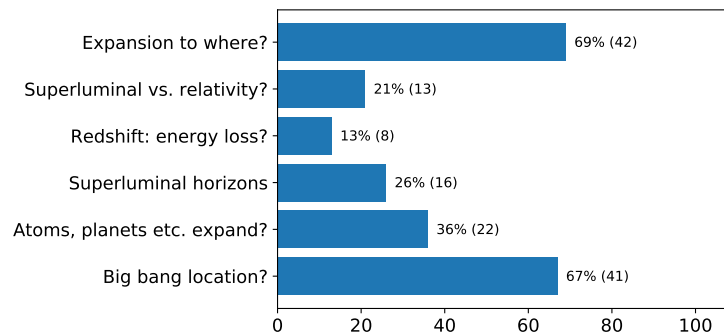
## 4 Questions about cosmology

Next, we listed six questions, and asked respondents to indicate by ticking a box, whether (a) students and (b) they themselves had asked those questions before. The six questions were as follows (plus a short version in italics, not present in the questionnaire, but used in the bar charts specifying the results, below):

1. Where is the universe expanding to? (*Expansion to where?*)
2. Is there a contradiction between superluminal galaxy recession speeds and relativity? (*Superluminal vs. relativity?*)
3. When light loses energy through the cosmological redshift, where does that energy go? (*Redshift: energy loss?*)
4. Can light from galaxies that have superluminal recession speeds even reach us? (*Superluminal horizons?*)
5. In an expanding universe, are atoms, planetary systems etc. getting larger over time, as well? (*Atoms, planets etc. expand?*)
6. Where in our universe did the big bang happen? (*Big bang location?*)

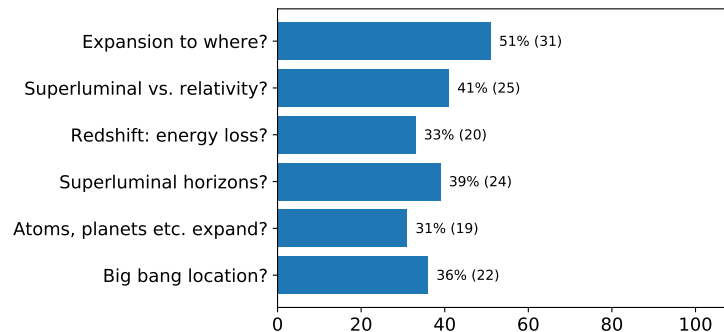
#### 4.1 Questions that students had asked

Asked which of those questions they had already been asked by students (although not necessarily with the same precise wording), respondents answered as follows (absolute numbers in parentheses):



#### 4.2 What teachers had already asked themselves

Asked which of those questions they had previously asked themselves (again, not necessarily with the same precise wording), the respondents answered as follows (absolute numbers once more in parentheses):



## 5 Tethered galaxy problem

The final question concerned a specific situation known as the tethered galaxy problem: “Assume that a distant galaxy is, at this very moment, at rest relative to our own galaxy. In an expanding cosmos, what do you think happens next?” Three options were given. Choosing multiple options was explicitly listed as permissible.

The choices were as follows:

The distance between that galaxy and us begins to grow	42	(69%)
Gravity pulls that other galaxy in our direction	23	(38%)
The distance between that other galaxy and us remains constant	7	(11%)

Taken separately, those options are not conclusive when it comes to diagnosing preconceptions or misconceptions about the tethered galaxy problem; in the specific context of the workshop, they served as the starting point for a more complete group discussion.

## A Original questionnaire text (in German), page 1

### Kurzumfrage Kosmologie

Ich habe mich bislang...

intensiv            eher weniger            kaum            gar nicht  
                                                                                   

...mit Kosmologie auseinandergesetzt.

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Ich habe die Expansion des Universums mit Schüler\*innen behandelt...

im Unterricht            außerschulisch, z.B. Astro-AG            gar nicht  
                                                       

### Aussagen zur kosmischen Expansion: Bitte bewerten

Der Kosmos expandiert: Wie bei einer Explosion fliegen die Galaxien vom Mittelpunkt des Universums weg.

Trifft zu            Trifft eher zu            Weiß nicht            Trifft eher nicht zu            Trifft nicht zu  
                                                                                                               

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Der Kosmos expandiert: Die Galaxien bewegen sich durch den Raum und entfernen sich auf diese Weise immer weiter voneinander.

Trifft zu            Trifft eher zu            Weiß nicht            Trifft eher nicht zu            Trifft nicht zu  
                                                                                                               

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Der Kosmos expandiert: Der Raum zwischen den Galaxien dehnt sich aus.

Trifft zu            Trifft eher zu            Weiß nicht            Trifft eher nicht zu            Trifft nicht zu  
                                                                                                               

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Der Kosmos expandiert: Zwischen den Galaxien entsteht fortwährend neuer Raum.

Trifft zu            Trifft eher zu            Weiß nicht            Trifft eher nicht zu            Trifft nicht zu  
                                                                                                               

**Bitte auch die Fragen auf der Rückseite beantworten!**

## B Original questionnaire text (in German), page 2

### Fragen zur Kosmologie

Bitte kreuzen Sie im Folgenden an, welche Fragen Ihnen **Schüler\*innen** sinngemäß bereits gestellt haben:

- Wohin dehnt sich das Universum eigentlich aus?
- Widersprechen Galaxien-Fluchtgeschwindigkeiten größer als Lichtgeschwindigkeit der Relativitätstheorie?
- Wenn Licht durch kosmologische Rotverschiebung Energie verliert, wohin geht diese Energie?
- Kann uns das Licht von Galaxien mit überlichtschnellen Fluchtgeschwindigkeiten überhaupt erreichen?
- Werden in einem expandierenden Universum auch Atome, Planetensysteme etc. mit der Zeit größer?
- Wo in unserem Kosmos hat der Urknall eigentlich stattgefunden?

Bitte kreuzen Sie im Folgenden an, welche Fragen **Sie selbst** sich sinngemäß bereits gestellt haben:

- Wohin dehnt sich das Universum eigentlich aus?
- Widersprechen Galaxien-Fluchtgeschwindigkeiten größer als Lichtgeschwindigkeit der Relativitätstheorie?
- Wenn Licht durch kosmologische Rotverschiebung Energie verliert, wohin geht diese Energie?
- Kann uns das Licht von Galaxien mit überlichtschnellen Fluchtgeschwindigkeiten überhaupt erreichen?
- Werden in einem expandierenden Universum auch Atome, Planetensysteme etc. mit der Zeit größer?
- Wo in unserem Kosmos hat der Urknall eigentlich stattgefunden?

### Was passiert in der folgenden Situation?

Angenommen, eine ferne Galaxie befände sich jetzt, in diesem Moment, relativ zu unserer eigenen Galaxie in Ruhe. Was schätzen Sie passiert in einem expandierenden Kosmos als nächstes? (Mehrfachnennungen möglich)

- Der Abstand der fernen Galaxie zu uns beginnt, größer zu werden
- Die Gravitationskraft zieht die ferne Galaxie in unsere Richtung
- Der Abstand der fernen Galaxie zu uns bleibt gleich

## C Encoding scheme

In the file `kosmo2019kodierung.txt`, available for download from <http://www.hausder-astronomie.de/kosmo-umfrage2019>, every line corresponds to one completed questionnaire. The answers are encoded in a string, where the separate characters of the string (counted from the beginning, with starting index 0) have the following meaning:

Character index no.	Meaning
0	options between a and d correspond to the four possibilities for answering the first question, namely how carefully the respondent has studied cosmology; a zero indicates that none of the four options were checked
1,2,3	Each of the next three characters corresponds to one of the three possible answers to the question in what context, if at all, the respondent has taught cosmology. If the possible answer was checked, that character is a 1; if the possible answer was left unchecked, a 0.
4,5,6,7	Each of the next four characters corresponds to one of the four statements about cosmology that are listed next. The value indicates which of the five possible answers was checked for that statement, from a for the first (leftmost) possibility to e for the last (rightmost).
8–13	Each of the next six characters corresponds to the six possible questions that teachers have, or have not, been asked by their students. 1 encodes a checked answer (yes, students have asked that particular question of the teacher), while 0 encodes an answer that was not checked.
14–19	Analogous to 8–13, but this time for questions that the respondent has, or has not, asked themselves
20–22	Analogous to the previous two cases, but this time for the three possible answers presented for the hypothetical situation with the galaxy that is momentarily at rest relative to us