PROCEEDINGS OF SCIENCE

Expert prognosis of the future of astronomy

Oleg Malkov*
Institute of Astronomy, Moscow, Russia
E-mail: malkov@inasan.ru

Among other IYA2009 events in Russia, an expert prognosis of the future of astronomy was made. A list of 35 questions was compiled by Russian astronomy researchers and popularizers. Each question begins with "When will", e.g. "When will a man land on the Mars?" or "When will white holes be discovered?". The list was independently checked and corrected by scientific journalists. Russian astronomers then were asked to answer the questions, and the answers were collected, processed and averaged. For each event, the time and the probability were estimated. The questionnaire was also available to amateurs and enthusiasts of astronomy through the Internet. Their answers were processed separately and they were compared with the answers of professional astronomers. All results are presented in the paper.

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1. Russian astronomers opinion poll

UN has proclaimed 2009 the International Year of Astronomy. It was an initiative by the International Astronomical Union (IAU) and UNESCO. The International Year of Astronomy (IYA2009) is a great event in scientific and cultural life of all nations. The IYA2009 activities are on several levels, however, the majority of IYA2009 events takes place locally and nationally.

One of the IYA2009 events in Russia was an expert prognosis of the future of astronomy. A list of 35 questions was compiled by Russian astronomy researchers and popularizers. Each question begins with “When will”, e.g. “When will a man land on the Mars?” or “When will white holes be discovered?”. The list was independently checked and corrected by three scientific journalists, and it was approved by National Committee of Russian Astronomers and by Scientific Council on Astronomy of the Russian Academy of Sciences.

Russian professional astronomers were asked to answer the questions. The questionnaire was also available to amateurs and enthusiasts of astronomy through the “IYA2009 in Russia” site www.astronomy2009.ru. Their answers were processed separately and they were compared with the answers of professional astronomers.

The first group of experts contains 119 professionals: researchers, post-graduate and graduate students. 90 of them are PhD. This number can be compared with the number of Russian IAU members (350), which approximately corresponds to number of active Russian PhD astronomers. That means that our experts are about 1/4 of number of leading Russian researchers in astronomy.

The other group of experts contains 55 amateurs and enthusiasts of astronomy.

2. Answers processing

The answers (year of event, e.g., 2050) were collected, processed and averaged. For each event, the "expected date" was estimated by quantil method: 16% of earliest and 16% of latest dates were discarded, other 68% were averaged. The resulting dates are given in columns **D** of Table 1.

The answers "Never" and "I do not know" were allowed as well. Beside date, the probability of each event was also estimated (columns **P** in Table 1. It depends on number of "Never"-like answers. We have also estimated a complexity of each question (columns **C** in Table 1: the less the number of "I do not know"-like answers, the simpler the question is.

Experts sometimes gave non-standard answers. Such “forbidden” answers were replaced by “allowable” ones according to the following rules:

- Interval (e.g., 2015-2020 or 2040ties) was replaced by a mean value (2018 or 2045).
- Upper limit (e.g., "by 2100") was replaced by "pessimistic" 2100.
- Lower limit (e.g., "after 2050") was replaced by "optimistic" 2050.
- "Soon", "Today" or "Just about" were replaced by 2009.
- "Senselessly" or "Needless" were replaced by "Never".
- "At any moment" was replaced by "I do not know"

Answers like "Already" or "Already, in 2004" were considered as an evidence that a question is not quite correct. Such answers were not averaged and were processed separately; their fraction for each question is given in columns **A** of Table 1.

3. Results

Table 1: Results of the expertise

No	Event	Professionals				Amateurs			
		D	P	A	C	D	P	A	C
1	When will astronomy become an obligatory subject in Russian schools?	2018	81	0	76	2017	89	0	85
2	When will a sample of Martian soil be transported to the Earth?	2024	100	1	86	2023	100	2	96
3	When will water on the Moon be discovered?	2025	61	8	73	2104	35	14	78
4	When will a permanent astronomical observatory in the South Pole be established?	2026	90	9	89	2024	88	2	91
5	When will the nature of gamma-bursts be unraveled?	2027	100	14	74	2053	97	3	69
6	When will active study of Venus be recommenced?	2028	98	5	83	2037	94	0	87
7	When will intermediate mass black holes be discovered?	2030	85	10	58	2041	80	0	64
8	When will extremely massive (> 200 solar mass) stars be discovered?	2032	52	8	62	2037	66	3	64
9	When will gravitational waves be registered?	2032	96	3	68	2051	92	0	71
10	When will a 100-meter optical telescope be constructed?	2033	88	0	89	2029	78	0	89
11	When will regular flights of private spacecrafts begin?	2034	92	1	87	2043	98	2	98
12	When will satellites of satellites of planets be discovered?	2036	66	9	62	2192	51	0	64
13	When will the nature of dark matter be unraveled?	2036	96	1	78	2056	93	0	75
14	When will an exoplanet with all four biomarkers (water, carbonic acid, methane and oxygen) be discovered?	2036	97	3	73	2056	96	2	82

15	When will solar sail be used for space flights?	2039	78	1	80	2061	72	0	91
16	When will a man land on the Mars?	2039	96	0	88	2039	100	0	96
17	When will existence of black holes be unambiguously proved?	2040	89	30	77	2043	88	14	78
18	When will a permanent astronomical observatory on the Moon be established?	2046	96	0	88	2056	92	0	96
19	When will the nature of dark energy be unraveled?	2046	97	4	73	2070	88	0	73
20	When will nature of the Red Spot on the Jupiter be unraveled?	2048	99	14	74	2036	100	7	76
21	When will a new Solar System body larger than Mars be discovered?	2052	20	1	72	2195	22	2	75
22	When will tourist space flights be widely available?	2057	84	0	85	2055	98	0	96
23	When will white holes be discovered?	2059	34	0	51	2093	31	0	58
24	When will a manned flight beyond the Martian orbit take place?	2062	94	0	83	2061	100	0	91
25	When will a sample of Saturn atmosphere be obtained?	2064	88	4	82	2060	93	2	84
26	When will "worm holes" be discovered?	2065	58	0	64	2115	65	0	62
27	When will the mankind begin to use extraterrestrial sources of raw materials?	2066	92	2	83	2065	98	8	93
28	When will the mankind find assured protection of the Earth from asteroid and comet impact hazards?	2068	73	2	90	2171	66	0	80
29	When will a fraction of solar energy in the mankind’s industry exceed 50%?	2082	74	3	84	2090	78	0	91
30	When will a convincing proof of an extraterrestrial civilization’s visit to the Earth in the past be displayed?	2088	26	0	75	2060	69	4	87
31	When will public conveyances circulate on the "Earth-Moon" route?	2093	73	0	79	2129	78	0	93
32	When will the Earth encounter with an asteroid larger than the Tunguska body?	2096	80	1	68	2148	85	0	73

33	When will Dyson Spheres be discovered?	2098	37	0	55	2105	45	0	56
34	When will a radio signal of extraterrestrial intelligence be detected?	2108	51	1	66	2116	60	0	73
35	When will a contact with extraterrestrials be established?	2170	54	0	67	2265	70	0	73

D and **P** are year and probability of event, respectively. **A** is a fraction of experts who consider the event already occurred. **C** indicates the question complexity, it is a fraction of experts who answered this question. **P**, **A** and **C** are all in %.

The results, provided by professional astronomers, are listed and discussed in this Section. Event probabilities are given in brackets.

Four of the listed events were recognized as unlikely: they have a probability less than 50%. They are as follows:

- Discovery of a new Solar System body larger than Mars (20%)
- Displaying of a convincing proof of an extraterrestrial civilization's visit to the Earth in the past (26%)
- Discovery of white holes (34%)
- Discovery of Dyson Spheres (37%)

We can expect the following events to happen within the next few years (year and uncertainty are indicated):

- 2018+12-6: astronomy becomes an obligatory subject in Russian schools — as it was in the USSR ages (81%)
- 2024+11-7: a sample of Martian soil is transported to the Earth (100%). There are only two events in the list, which collected a 100% probability. The other is the nature of gamma-bursts: no expert has doubt it will be unraveled (see below).
- 2025+25-13: water on the Moon is discovered (61%). Apparently, this event already happened. The expert prognosis was completed in March 2009, and first evidences of water on the Moon detected by Cassini [1], by Deep Impact [2] and by Chandrayaan-1 [3] were appeared in literature a half-a-year later.
- 2026+24-11: a permanent astronomical observatory in the South Pole is established (90%)
- 2027+23-12: the nature of gamma-bursts is unraveled (100%) [notably, 14% of experts answered "already unraveled"]
- 2028+22-13: active study of Venus is recommenced (98%)

The following events will happen in the thirties and the fourties:

- 2030+42-15: intermediate mass black holes are discovered (85%)

- 2032+48-17: extremely massive (> 200 solar mass) stars are discovered (52%) [note a relatively small probability of the event]
- 2032+28-17: gravitational waves are registered (96%)
- 2033+17-13: a 100-meter optical telescope is constructed (88%)
- 2034+66-17: regular flights of private spacecrafts begin (92%)
- 2036+14-16: satellites of satellites of planets are discovered (66%)
- 2036+64-21: nature of dark matter is unraveled (96%)
- 2036+64-21: an exoplanet with all four biomarkers (water, carbonic acid, methane and oxygen) is discovered (97%)
- 2039+32-19: solar sail is used for space flights (78%)
- 2039+21-14: a man lands on the Mars (96%)
- 2040+60-25: existence of black holes is unambiguously proved (89%) [record-breaking high — 30% of experts consider it to be already proved]
- 2046+39-21: a permanent astronomical observatory on the Moon is established (96%)
- 2046+54-26: the nature of dark energy is unraveled (97%)
- 2048+52-28: the nature of the Red Spot on the Jupiter is unraveled (99%) [remarkably, 14% of experts said: "already unraveled"]

After some pause, in the sixties, the following events will happen:

- 2057+43-37: tourist space flights are widely available (84%)
- 2062+38-27: a manned flight beyond the Martian orbit takes place (94%)
- 2064+45-34: a sample of Saturn atmosphere is obtained (88%)
- 2065+135-45: "worm holes" are discovered (58%)
- 2066+34-31: the mankind begins to use extraterrestrial sources of raw materials (92%)
- 2068+32-32: the mankind finds assured protection of the Earth from asteroid and comet impact hazards (73%)

At the end of the XXI century we can expect the following events to happen:

- 2082+118-52: a fraction of solar energy in the mankind's industry exceeds 50% (74%)
- 2093+107-43: public conveyances circulates on the "Earth-Moon" route (73%)

- 2096+213-66: the Earth is expected to encounter with an asteroid larger than the Tunguska body (80%). Pleasantly, it will happen 30 years after the mankind protects the Earth from cosmic impact hazards (see above). However, according to amateurs' expectations (see Figure 1, left panel, points 28 and 32) these two events will happen in an opposite order...

The remaining two events in the list have very late dates, large uncertainties and rather small probabilities:

- 2108+209-83: a radio signal of extraterrestrial intelligence is detected (51%)
- 2170+330-120: a contact with extraterrestrials is established (54%)

All results of the expertise (professional and amateur) are presented in Table 1 and in Figure 1.

4. Difficult and simple questions

The answers "I do not know" were counted for each question to estimate its complexity. The most difficult questions were the following (fraction of experts who answered the question is given in brackets):

- When white holes will be discovered? (51%)
- When a Dyson Sphere will be discovered? (55%)
- When will we discover intermediate mass black holes? (58%)

And the most simple questions were:

- When a 100-meter optical telescope will be constructed? (89%)
- When a permanent astronomical observatory in the South Pole will be established? (89%)
- When the mankind will find an assured protection of the Earth from asteroid and comet impact hazards ? (90%)

It can be seen from these lists that to estimate an expected date for a discovery of hypothetical objects is more difficult than to answer a question on a new technology.

5. Comments to questionnaire

The experts were allowed to leave comments to all questionnaire or to particular questions. Most comments were skeptical, like "Very strange list of questions. A half of them are ambiguous", "2/3 of astronomy is not broached", "many questions are devoted to narrow particular problems", "solar activity problems are not touched", "the questionnaire is a game for theorists", "incorrect question", "what other proof do you need?". Altogether about 10% of experts express some kind of a scepticism.

Frankly speaking, we have met words of approval in comments as well: "Thank you. It is an interesting idea". Although sceptical comments quantitatively significantly exceed approving comments (just one!), we believe the expert prognosis of the future of astronomy was not a lost labour.

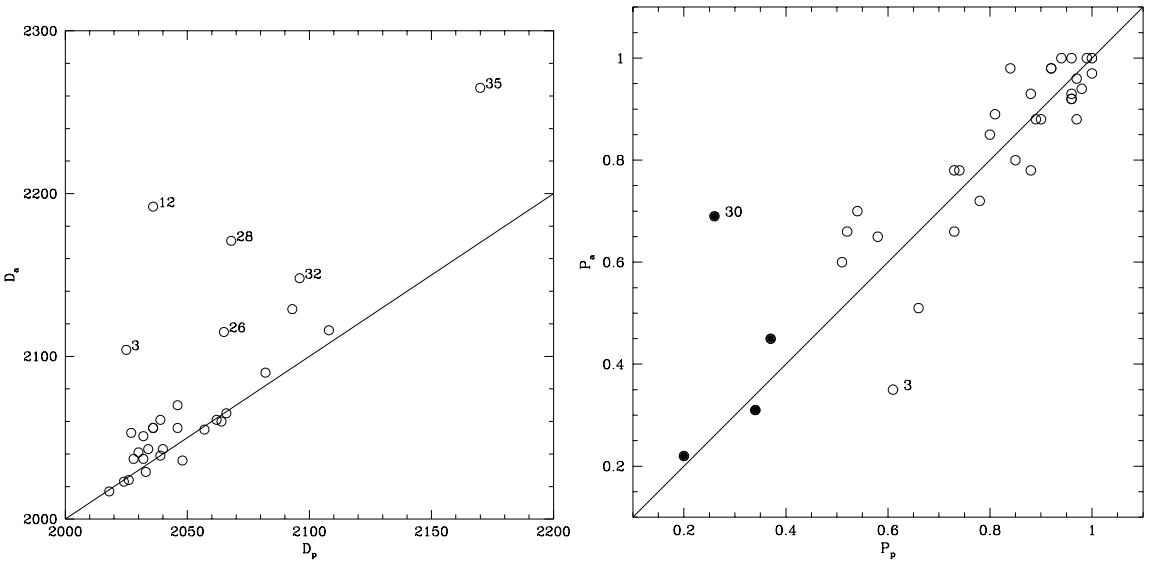

Figure 1: Professional vs. amateur estimations. Event numbers are taken from Table 1. Straight line indicates position of events of equal professional and amateur values. Left panel: event dates: D_p vs. D_a. It can be seen that in general the amateurs are much more "pessimistic" than the professionals. Right panel: event probabilities: P_p vs. P_a. One can see a surprisingly good agreement of estimations, with just a couple of exclusions. The most unlikely events (see beginning of Section 3) are not plotted in the left panel and indicated by filled circles in the right panel.

6. Conclusions

Such forecasts are always subjective. They rather indicate most interesting and strongly studied areas of knowledge. So it can be considered as a fun.

However, our experts are not any passers-by, but about a hundred of venerable professionals, who know problems and perspectives of present-day astronomy better than anybody else. So this forecast is the best that can be proposed today.

7. Acknowledgments

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References

[1] R. N. Clark 2009, Science 326, 562

[2] J. M. Sunshine et al. 2009, Science 326, 565

[3] C. M. Pieters et al. 2009, Science 326, 568