

# **Kako funkcionira znanost?**

Dario Hrupec  
Institut Ruđer Bošković, Zagreb

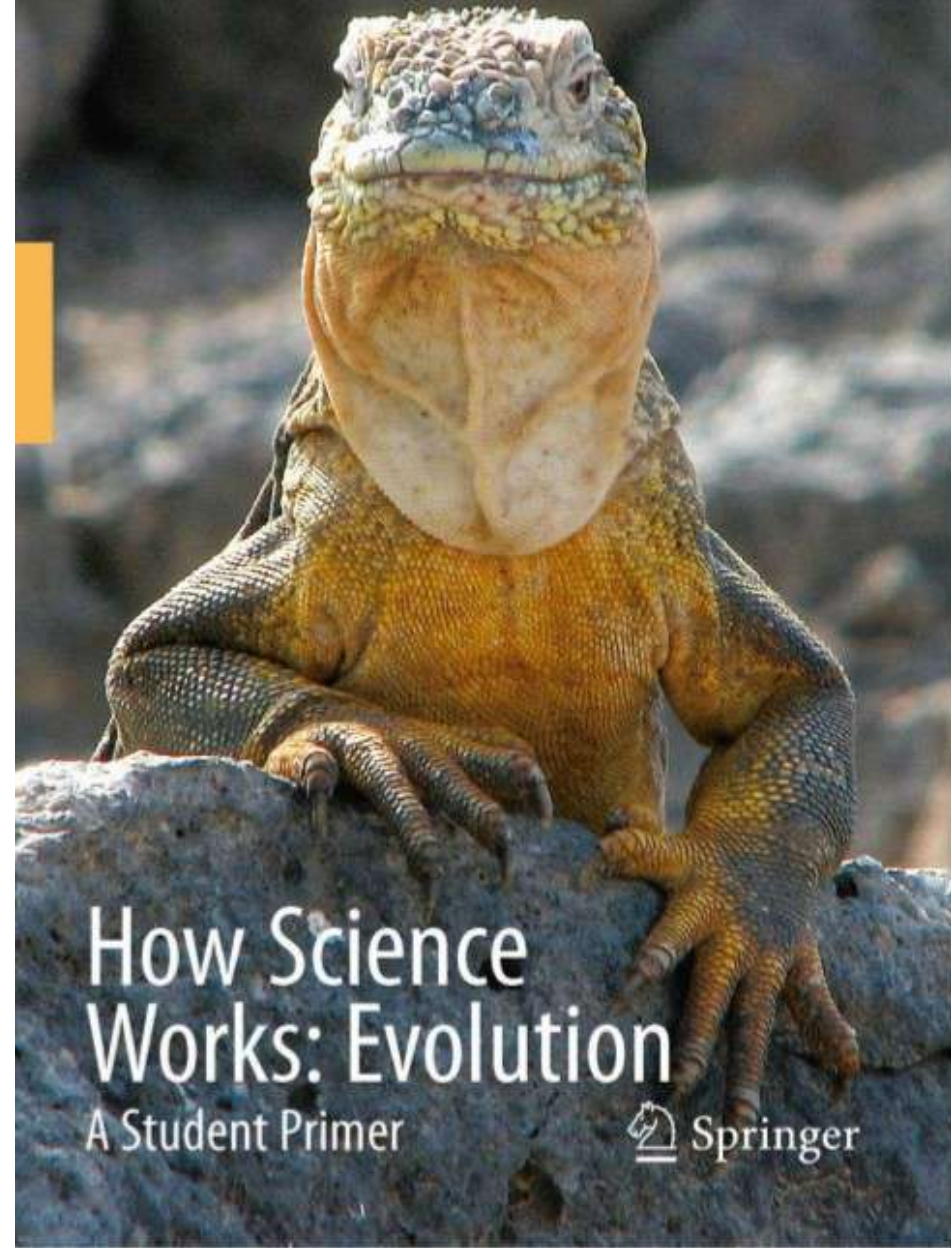
Festival znanosti, Sinj  
23. listopada 2012.

Inspirirano knjigom:

John Ellis

**How Science Works:  
Evolution: A Student Primer**  
Springer (2010)

John Ellis



How Science  
Works: Evolution

A Student Primer

 Springer

Izvorni slideovi s uvodnog predavanja  
koje je profesor Ellis održao 2. listopada 2012.  
bručošima biologije na University of Warwick



# KEEP THINGS IN PERSPECTIVE!



The Earth seen through the rings of Saturn by the Cassini spacecraft

# HOW SCIENCE WORKS: Evolution

Lecturer : Professor John Ellis

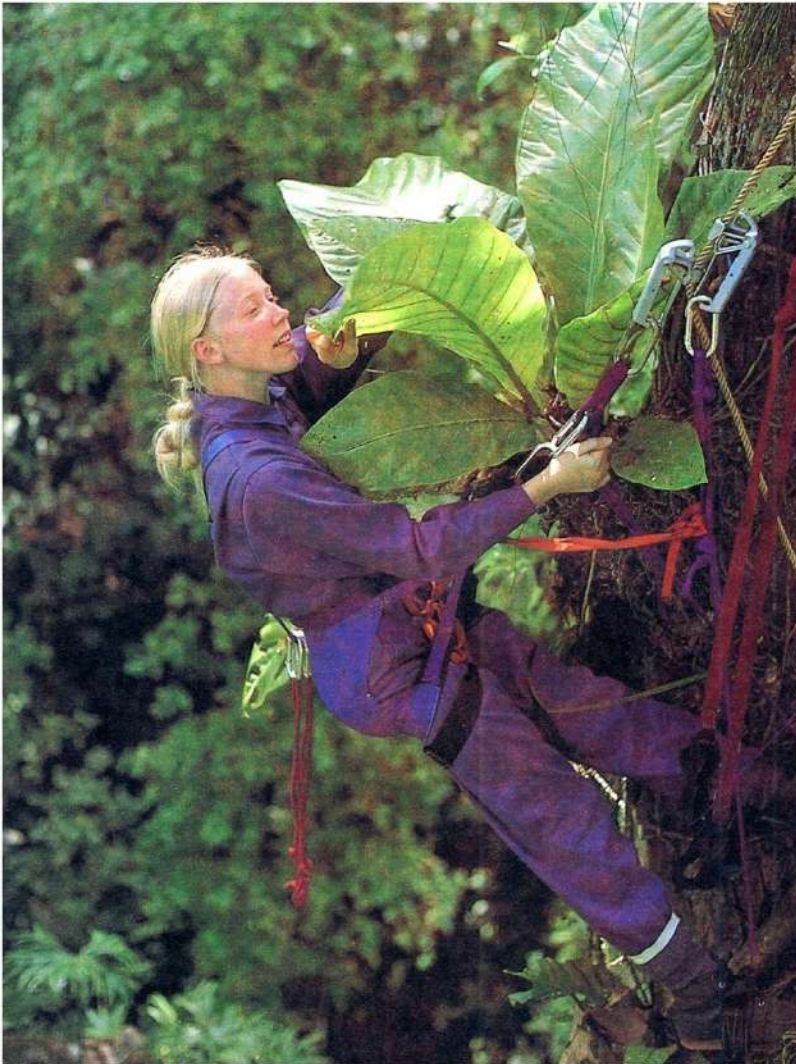
## AIMS

1. To discuss evolution as the most powerful unifying theory in biology.

*"Nothing in biology makes sense except in the light of evolution"*

Theodosius Dobzhansky, 1973

2. To explain how science works and differs from other ways of understanding the world, using examples from evolutionary theory.



# HOW SCIENCE WORKS: Evolution

Lecturer : Professor John Ellis

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## QUESTIONS DISCUSSED

Evolution is just a theory, isn't it?

What is a scientific theory anyway?

What is the difference between a fact, a theory and a hypothesis?

How does scientific thinking differ from religious thinking?

Why are there so many different religious beliefs but only one science?

Are science and religion compatible?

What is the evidence for evolution?

What is the mechanism of evolution?

**A FREE CD CONTAINING THIS BOOK IS AVAILABLE AT THE FRONT**

# TWO WAYS OF EXPLAINING THE WORLD

## 1. Supernaturalism:

Beyond the obvious physical world is another invisible world containing **active agents** that behave unpredictably

*All known human cultures throughout recorded history embrace this view that is based on **faith**, defined as accepting the authority of revelation, dogma and ancient texts.*



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Everything there is belongs to the physical world that we all experience and that behaves according to **unvarying regularities** ("laws of nature")

*This view is very recent, is the dominant view amongst leading scientists today, and is based on **reason** applied to observations and experiments accessible to all.*

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**THESE EXPLANATIONS ARE MUTUALLY EXCLUSIVE**

# **COMPARISON OF RELIGION AND SCIENCE**

**Religion is incompatible with the practice of science because science assumes that natural events have only natural causes.**

**Unlike science, religion lacks a methodology by which its claims can be tested.**

**This is why there are so many different religious beliefs but only one science.**

**SCIENCE IS THE ONLY UNIVERSAL HUMAN LANGUAGE**

# THE DISTINCTIVE ASPECTS OF SCIENCE

## 1. "Nullius in verba" - the motto of the Royal Society

Translation - "not in words"

*Or: Do not take anyone's  
word for it*



**NATIONAL ACADEMIES - national clubs of leading scientists**

**UK - The Royal Society: 1400 Fellows (44 elected each year)**

**USA - The National Academy of Sciences: 2000 Members,  
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**Fellows & Members are elected on the basis of the quality of  
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# THE DISTINCTIVE ASPECTS OF SCIENCE

## THE IMPORTANCE OF PEER-REVIEWED LITERATURE

**1. Scientists write papers to describe their observations and experiments in sufficient detail for others to repeat and extend them.**

**2. Each paper is submitted to one or more of about 20,000 journals who send it to 2-6 independent scientists (peers) for criticism.**

**These peer reviewers are anonymous experts in the field.**

***Are the experiments properly designed? Are further experiments necessary?  
Are the conclusions novel? Is previous relevant work referred to correctly?***

**3. In most cases the paper is returned to the author for improvement and may then go through the peer-review process again.**

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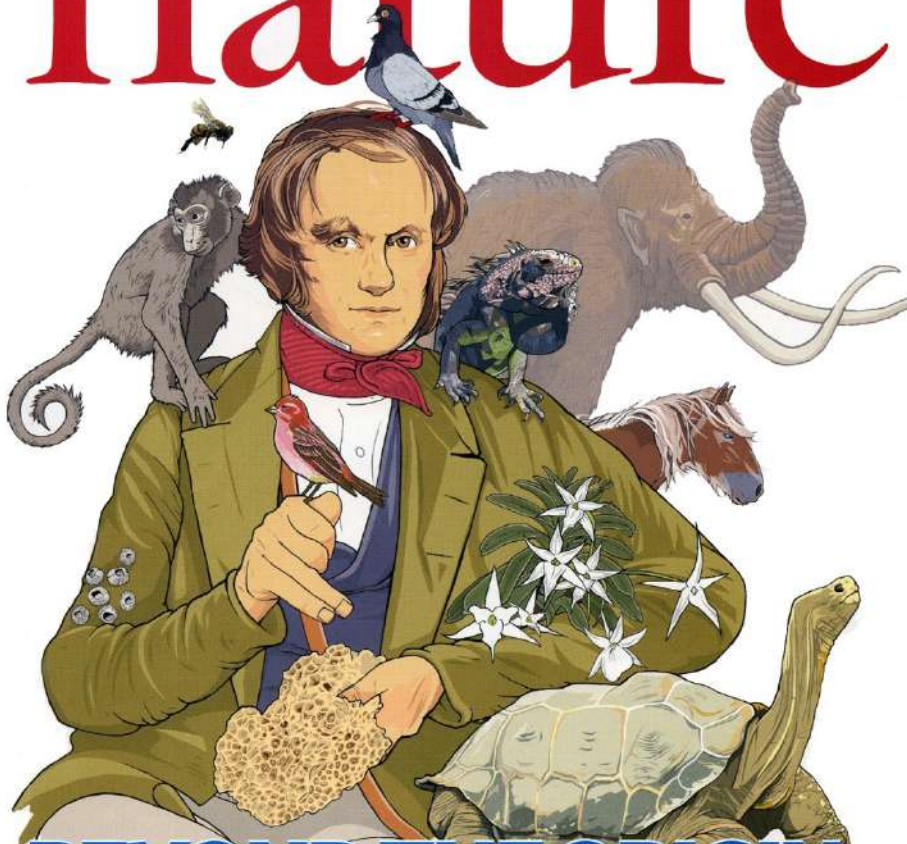
**EVEN AFTER THIS CONSTRUCTIVE CRITICISM THE BEST JOURNALS  
REJECT AROUND 80% OF THE PAPERS SENT TO THEM**

THE TOP TWO PEER-REVIEWED JOURNALS FOR SCIENCE

20 November 2008 | www.nature.com/nature | £10

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

# nature



## BEYOND THE ORIGIN

**DARWIN 200** Celebrating the man and the book

- Darwinian celebrations past
- Mammoth genome sequenced
- Evolution of the mammalian eye

NATUREJOBS  
NIH targets youth

# Science



## Darwin 200 Collection

AAAS



# THE DISTINCTIVE ASPECTS OF SCIENCE

## 2. Occam`s Razor

**William of Ockham**  
1288-1348



A medieval philosopher

### THE PROBLEM

For any given body of data, it is almost always possible to imagine several different potential interpretations, varying in complexity.

### OCCAM`S SOLUTION

*"Plurality should not be posited without necessity"*

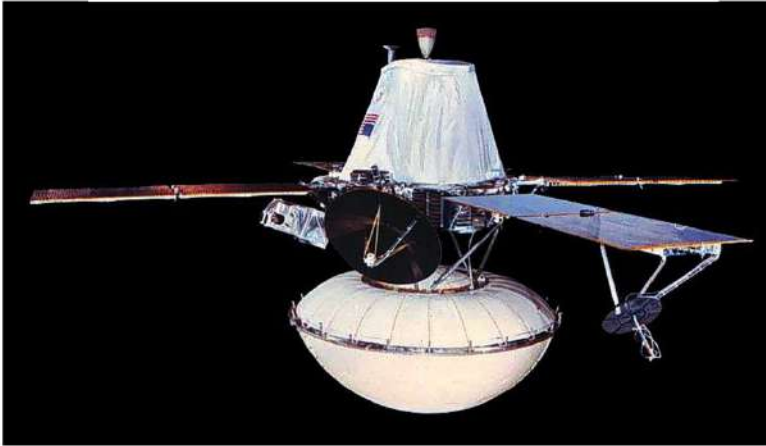
(Translation from Latin)

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*" When multiple explanations are possible,  
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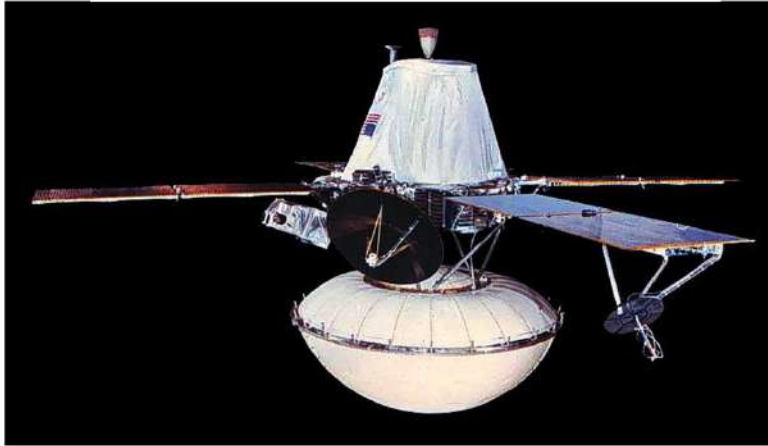
# GEOLOGICAL FORMATION ON THE PLANET MARS

## VIKING ORBITER 1976

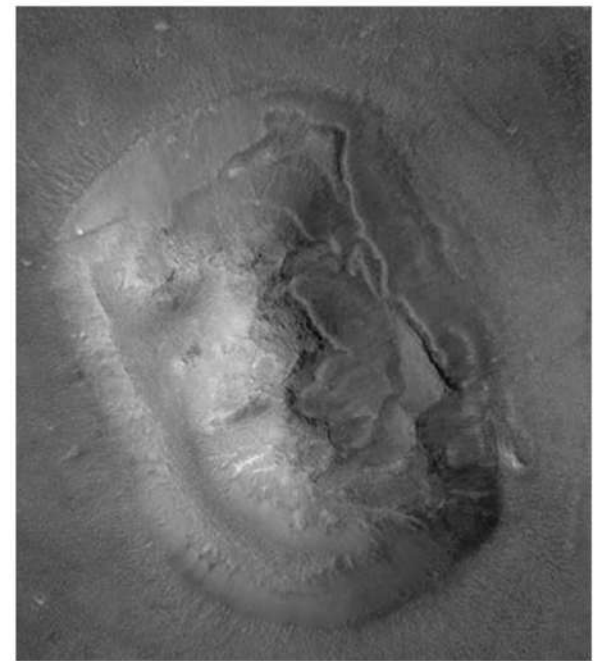


# GEOLOGICAL FORMATION ON THE PLANET MARS

**VIKING ORBITER 1976**



**GLOBAL SURVEYOR 1998**



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**OCCAM`S RAZOR IS THE HALLMARK OF SCIENCE**

# SCIENTISTS AND SUPERNATURALISM

THE INTERNATIONAL JOURNAL OF SCIENCE

**nature**

Vol. 394, JULY 23, p.313, 1998

correspondence

**"Leading scientists still reject God"**

**Survey of leading American scientists**

	<u>1914</u>	<u>1933</u>	<u>1998</u>
<i>Belief in a personal God</i>	27.7 %	15%	7.0%
<i>Disbelief in a personal God</i>	52.7%	68%	72.2%
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**BUT THIS IS A RECENT TREND**

# **SCIENTISTS AND SUPERNATURALISM**

**QUESTION: Who was the first scientist?**

## **THE METHOD OF EXPERIMENTAL SCIENCE**

- 1. Ask questions about some aspect of the Universe.**
- 2. Imagine a possible explanation i.e. formulate a hypothesis.**
- 3. Test the hypothesis with a suitable experiment.**
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**NEARLY ALL SUBSEQUENT LEADING SCIENTISTS, FROM GALILEO  
NEWTON & FARADAY TO BOHR, HEISENBERG & PLANCK, WERE  
SUPERNATURALISTS**

# **NATURALISTIC HYPOTHESES ABOUT SUPERNATURALISM**

## **PSYCHOLOGICAL PURPOSES OF THE MAJOR RELIGIONS**

- 1. To comfort people who are suffering.**
- 2. To allay the fear of death.**
- 3. To offer explanations of things we do not understand.**
- 4. To encourage social cohesion in a competitive world.**
- 5. To place power, wealth & influence in the hands of a small group of people.**

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## PATTERNICITY & AGENTICITY AS SURVIVAL TRAITS

Reference: *The Believing Brain* by Michael Shermer, Times Books 2011

1. Patternicity is the human tendency to find meaningful patterns in both meaningful and meaningless noise.
2. Agenticity is the human tendency to infuse patterns with meaning, intention and purpose. (Also called `intentionality` or `theory of mind`).

# THE DISTINCTIVE ASPECTS OF SCIENCE

## 3. Uncertainty

Contrary to popular opinion, all scientific understanding is

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SCIENCE IS A SET OF **IDEAS** ABOUT  
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These ideas are based on the best observational and experimental data available at the time but are always open to change to accommodate new data. Thus science has an inbuilt self-correcting mechanism that accounts for its unmatched success at improving the human condition.

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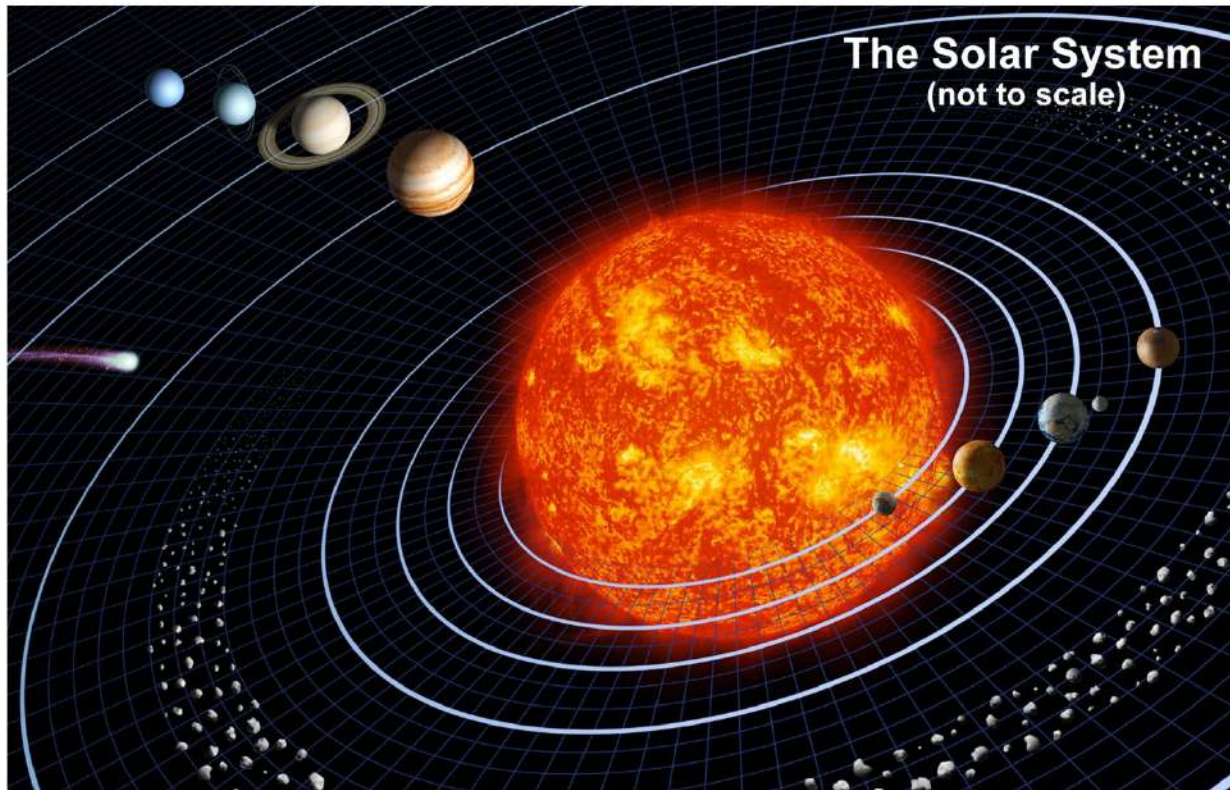
**BUT**

**BECAUSE FUTURE DISCOVERIES CANNOT BE PREDICTED  
WE CAN NEVER BE CERTAIN THAT NEW DATA WILL NOT  
CHANGE EXISTING IDEAS. THUS ALL SCIENCE IS THEORY  
AND SCIENTIFIC THEORIES CAN NEVER BE PROVED**

# SCIENTIFIC THEORIES ARE ALWAYS PROVISIONAL

## NEWTON'S Theory - 1687

Space is empty and unchanging, but time is separate and flows at a constant rate.  
Gravity is an instantaneous attractive force between bodies that possess mass.





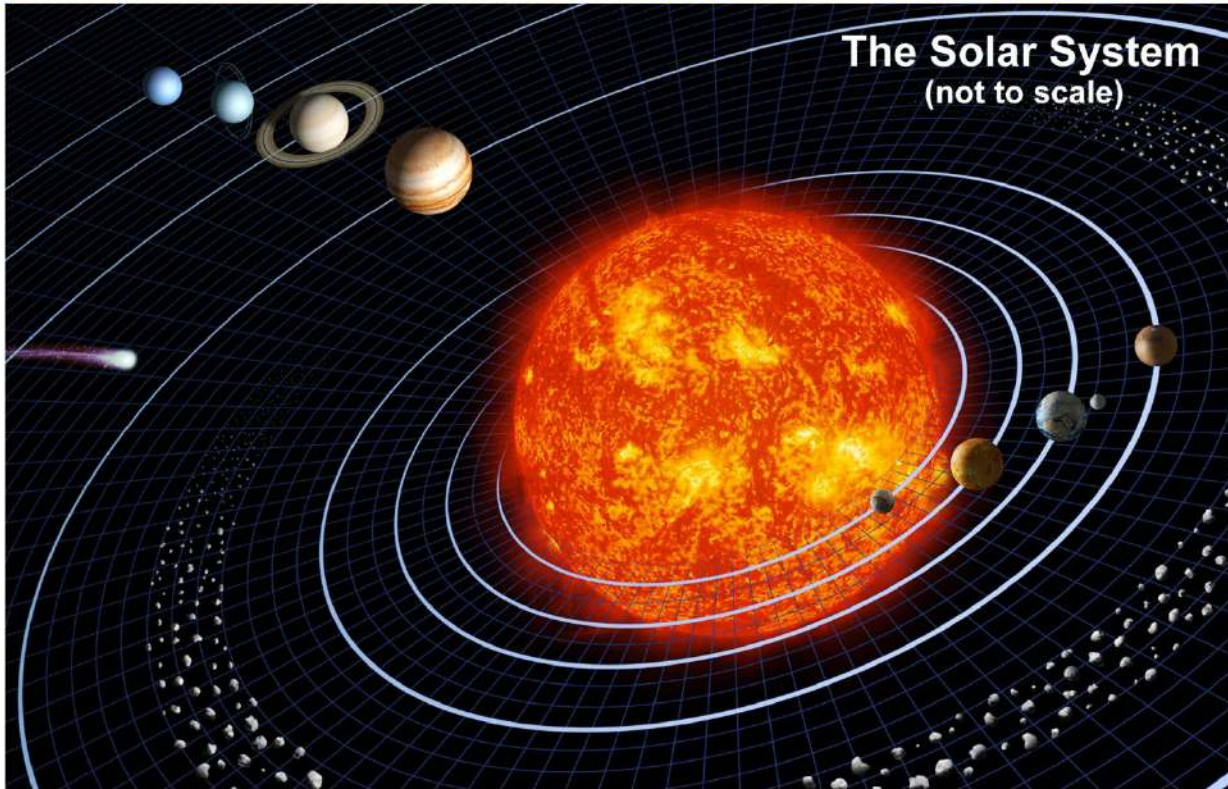
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Gravity is not a force, but the following of a curve in spacetime, that propagates at the speed of light.



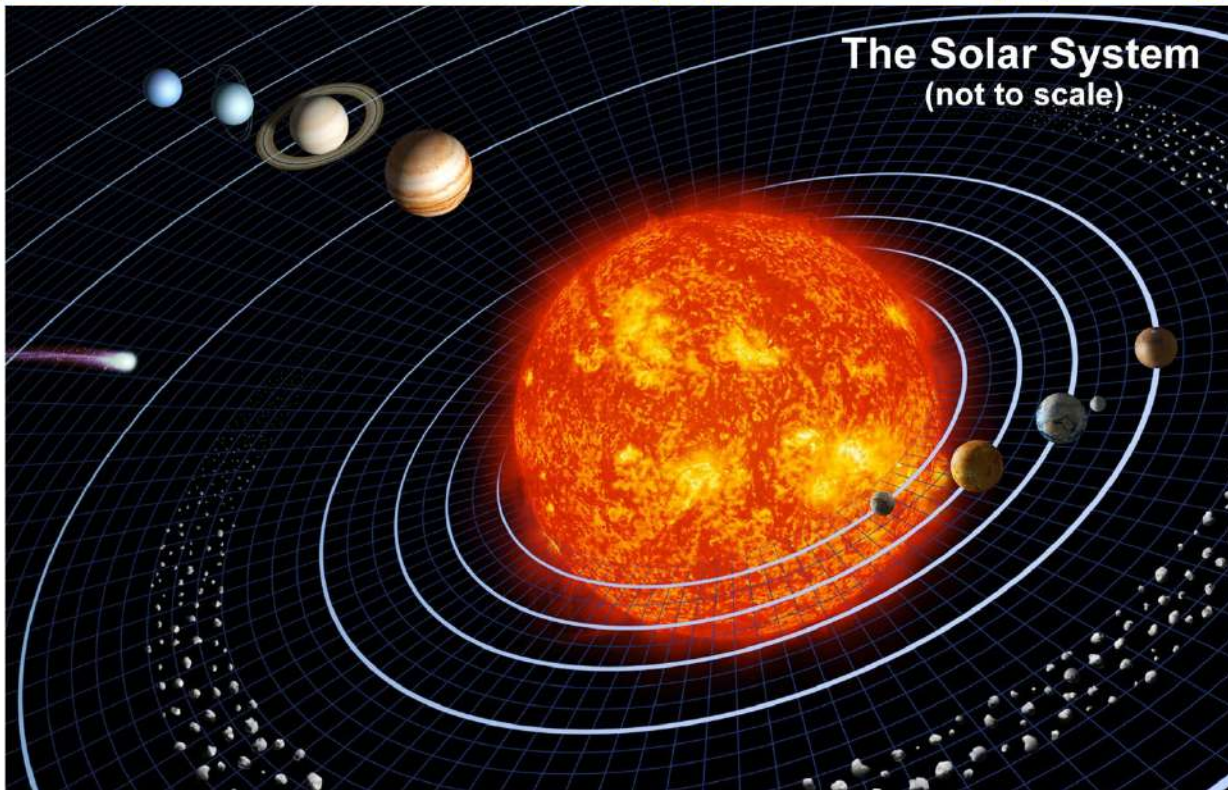
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## OBSERVATIONS THAT SUPPORT EINSTEIN

1. Gravity bends light
2. The speed of light is independent of the speed of the source of light
3. The faster an object moves, the heavier it becomes
4. The faster a clock moves, the slower it ticks

# HOW SCIENCE WORKS

## THE IMPORTANCE OF DEFINITIONS

**FACTS** in science are **empirical** observations available in principle to everyone. Facts can be inferred as well as direct.

**HYPOTHESES** are imaginary **but testable** speculations that might explain some facts.

**THEORIES** are coherent conceptual models that explain whole sets of facts and that **withstand falsifiable predictions**.

Good theories are quantitative, propose mechanisms, and lead to the discovery of new phenomena.

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**THUS TO BE A GOOD SCIENTIST YOU NEED  
CURIOSITY, IMAGINATION AND SKEPTICISM**

# HOW SCIENCE WORKS

## SUMMARY

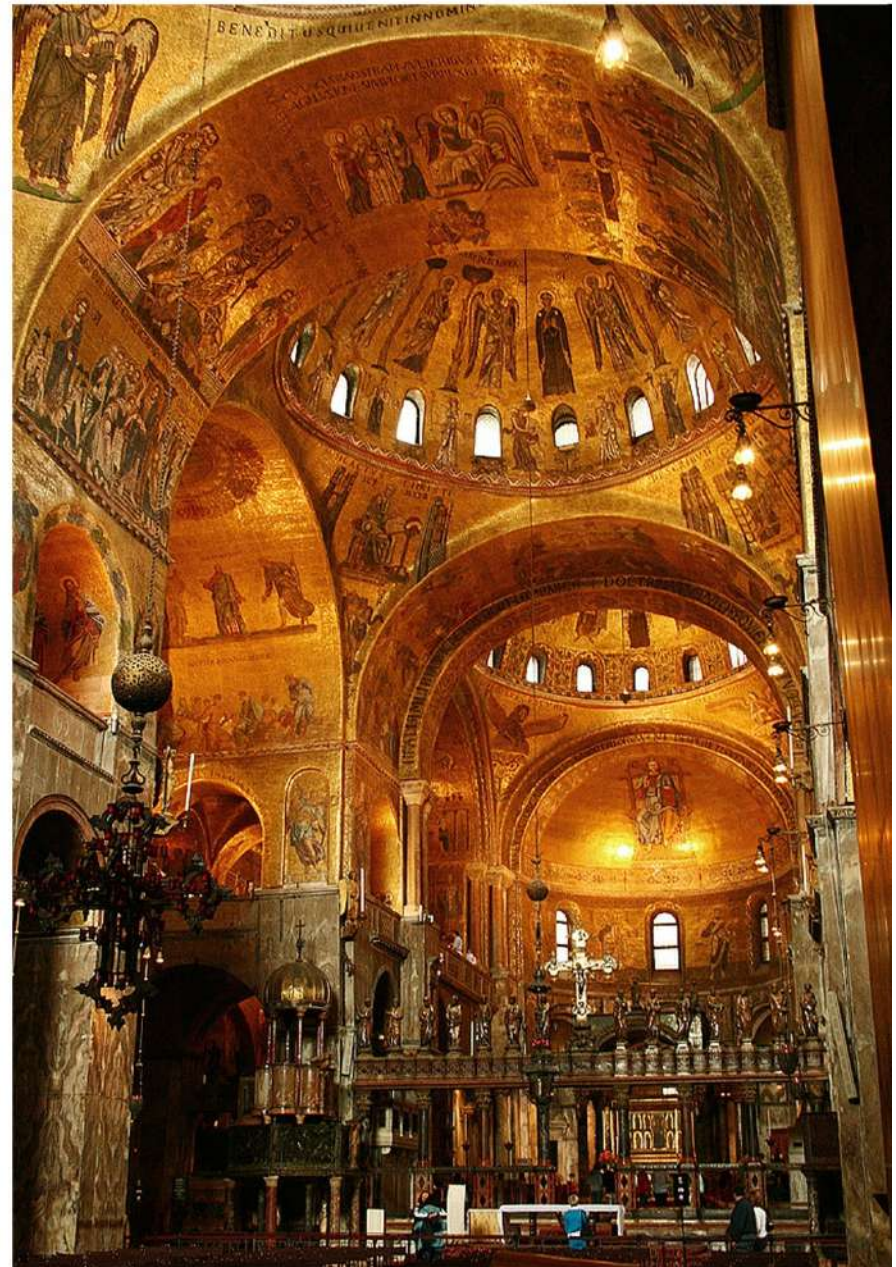
*Source: US National Academy of Sciences*

1. Scientists pose, test and revise multiple hypotheses to explain what they observe in the natural world.
2. Scientists use only natural causes to explain natural observations.
3. Science does not prove or conclude; science is always a work in progress.
4. Science is neither democratic nor dogmatic.
5. Scientific claims are subject to peer review and replication.
6. Science is a human endeavour but it cannot make moral or aesthetic decisions.

# RELIGIONS INSPIRE GREAT ART



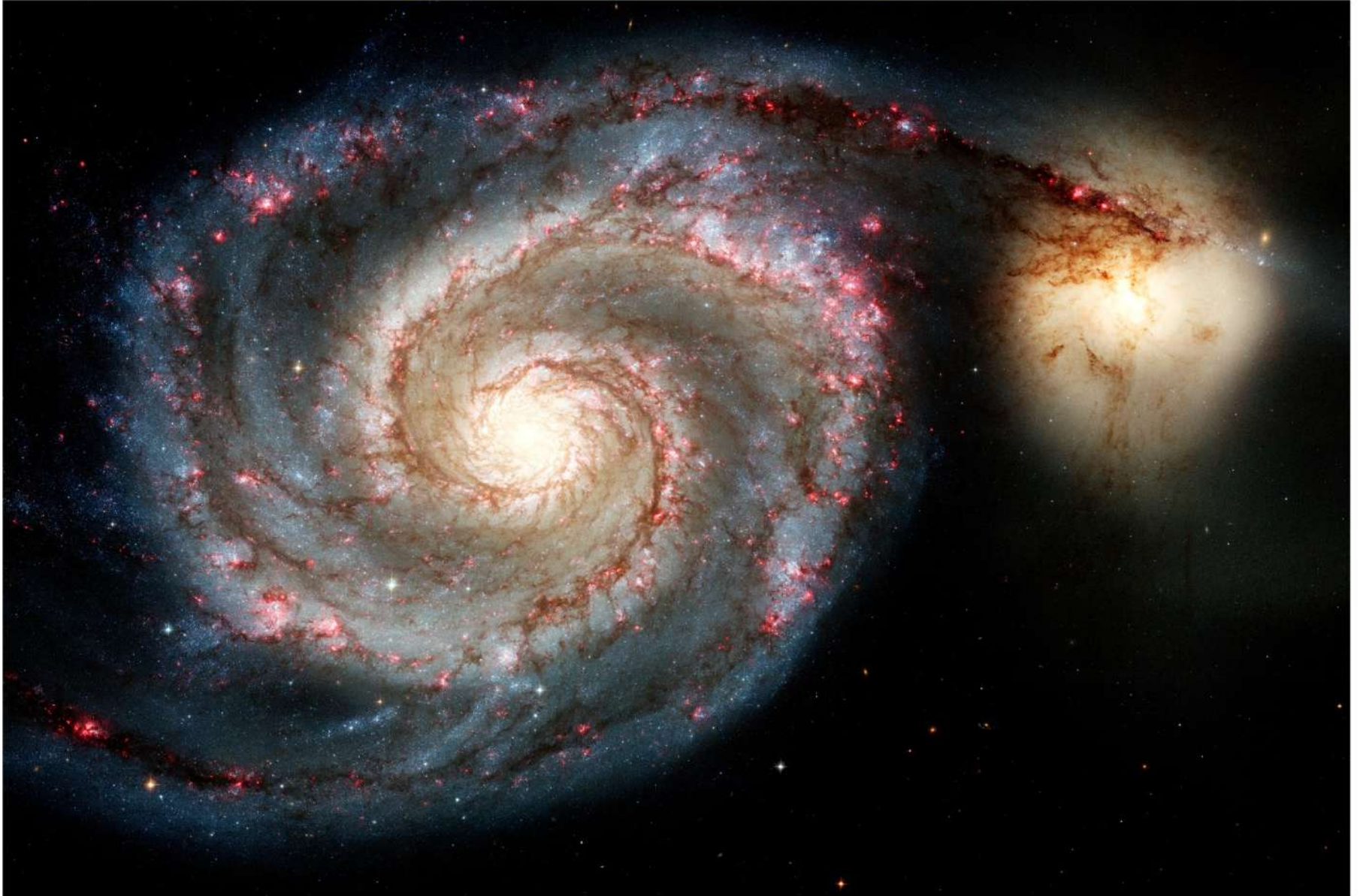
16th century painting in Siena Cathedral



Interior of St. Mark's Cathedral, Venice

# SCIENCE IS REVEALING AN AMAZING UNIVERSE

## The Whirlpool Galaxy



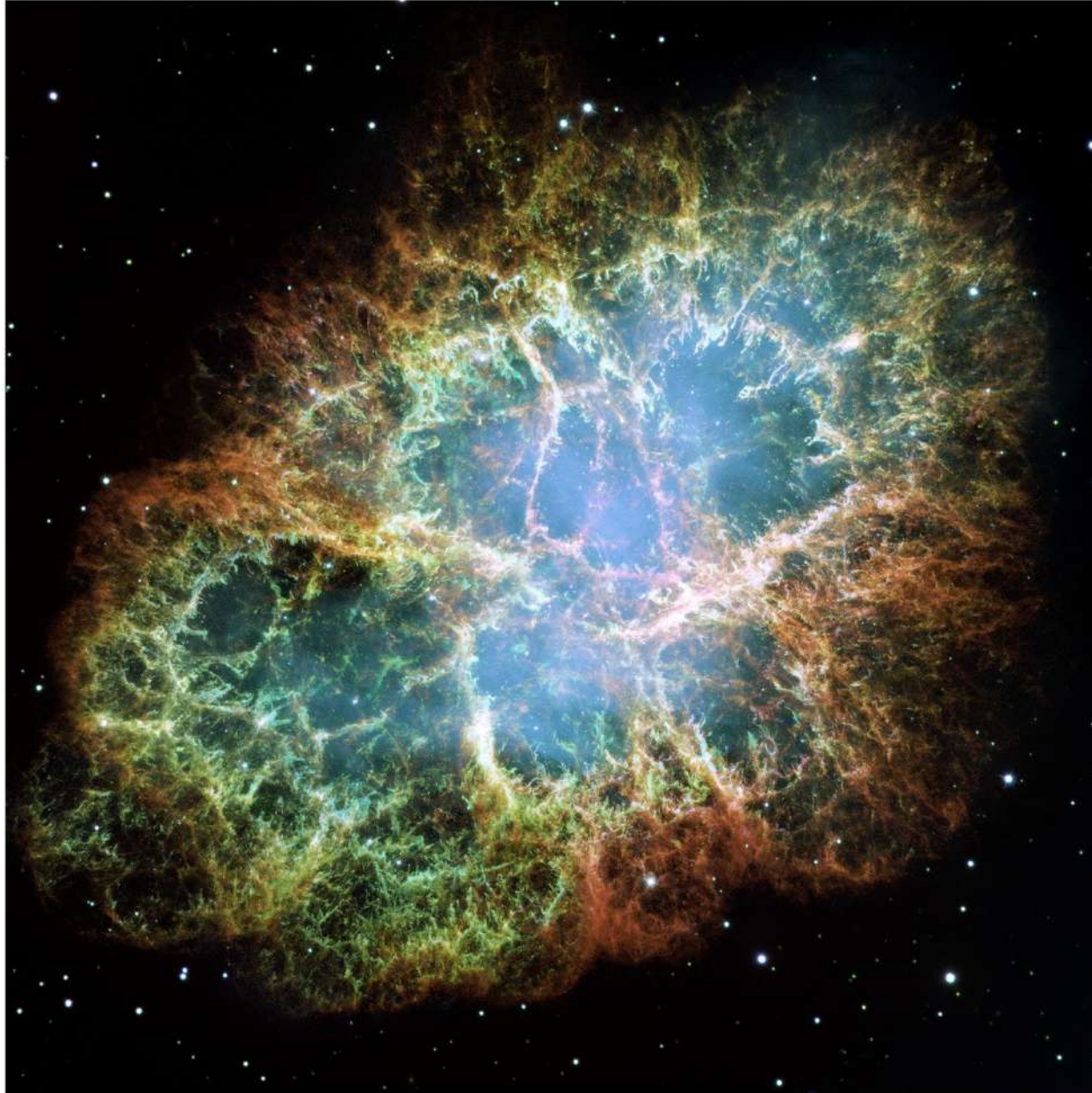
# SCIENCE IS REVEALING AN AMAZING UNIVERSE

THE MILKY WAY GALAXY CONTAINS AT LEAST 200 BILLION STARS





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## THE CRAB NEBULA SUPERNOVA

Stars more massive than the Sun explode into supernovae when their hydrogen fuel is exhausted.

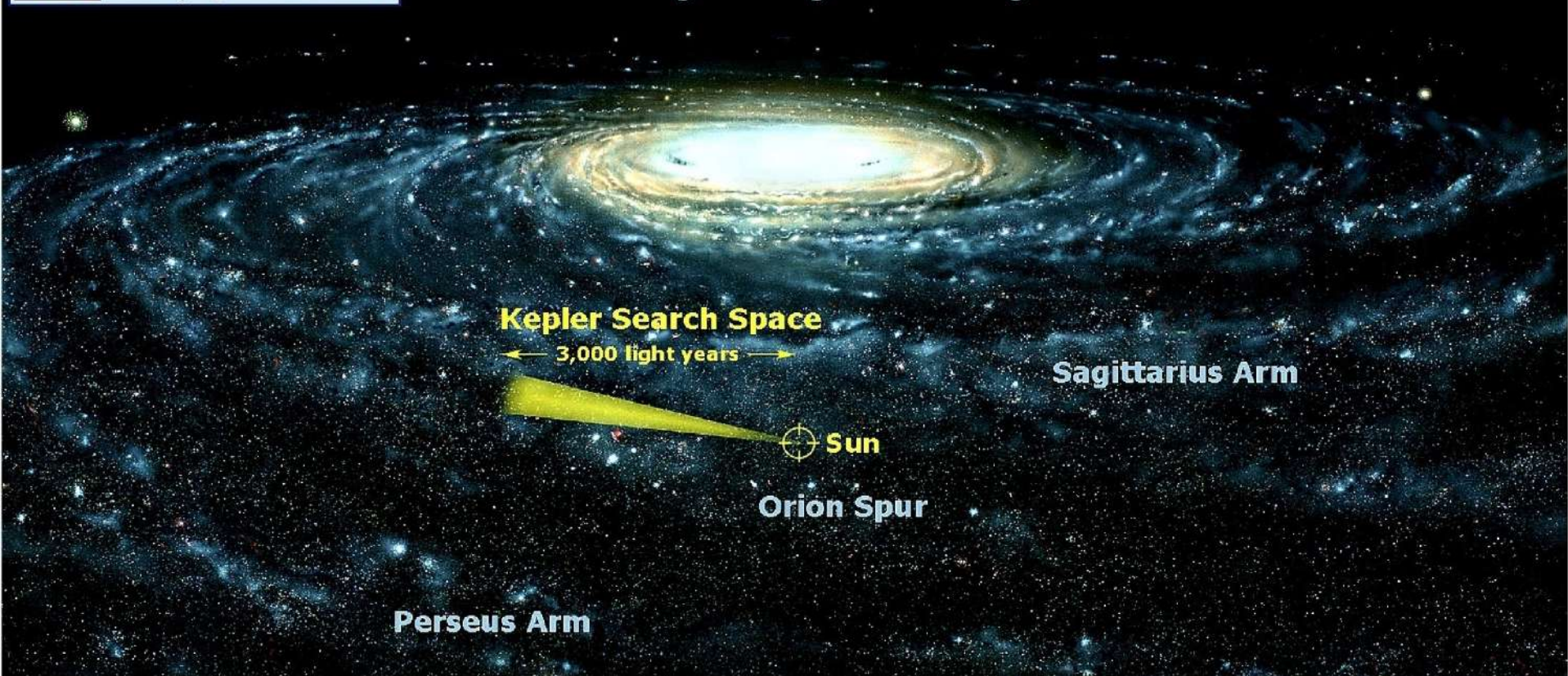
These explosions distribute elements essential for life into space, where they condense into dust from which planets form.

***WE ARE ALL MADE  
OF STARDUST!***

# THE SEARCH FOR EXTRASOLAR EARTH-LIKE PLANETS



## Milky Way Galaxy



### RESULTS RELEASED ON December 6th, 2011

Number of planetary candidates	=	2326
Candidates approx. Earth-size	=	207
Candidates in habitable temp. zone	=	48

