



# The Art of Doing Science

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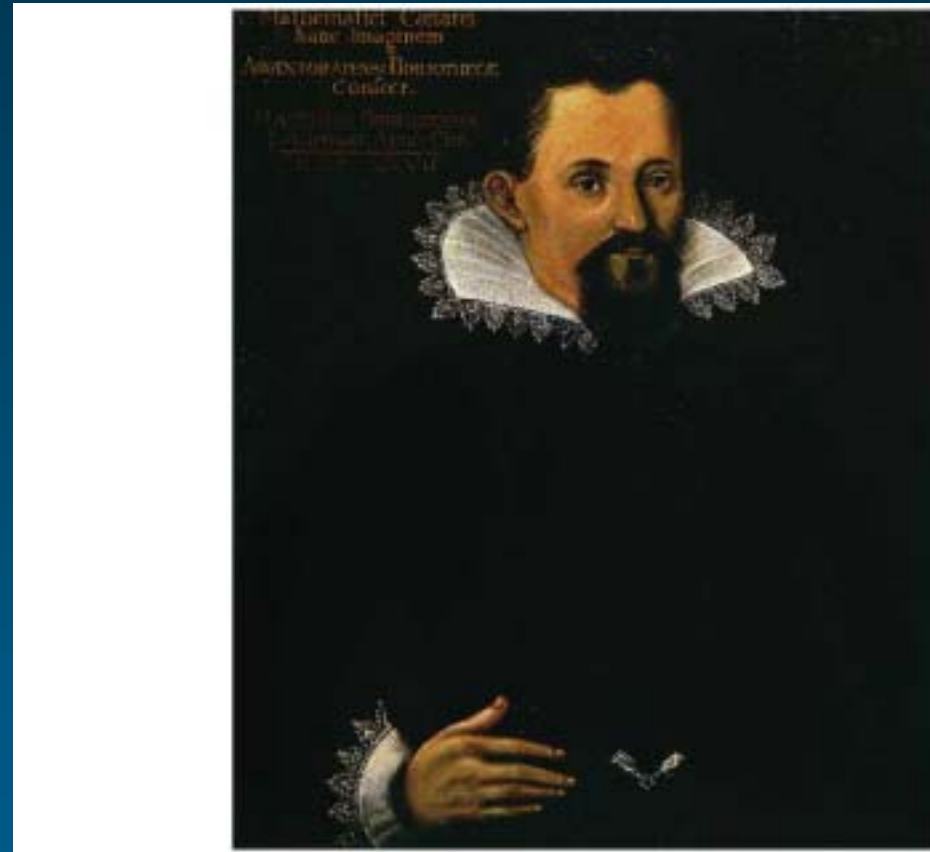
Talk given in McMaster Astrophysics Grad  
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# Johannes Kepler (1571 – 1630)

- His original motivating idea – 5 intervals between planetary orbits could be inscribed inside set of 5 “perfect” solids!
- Passion, diligence, mathematical prowess, use of data in totally new way, discovers new cosmology.

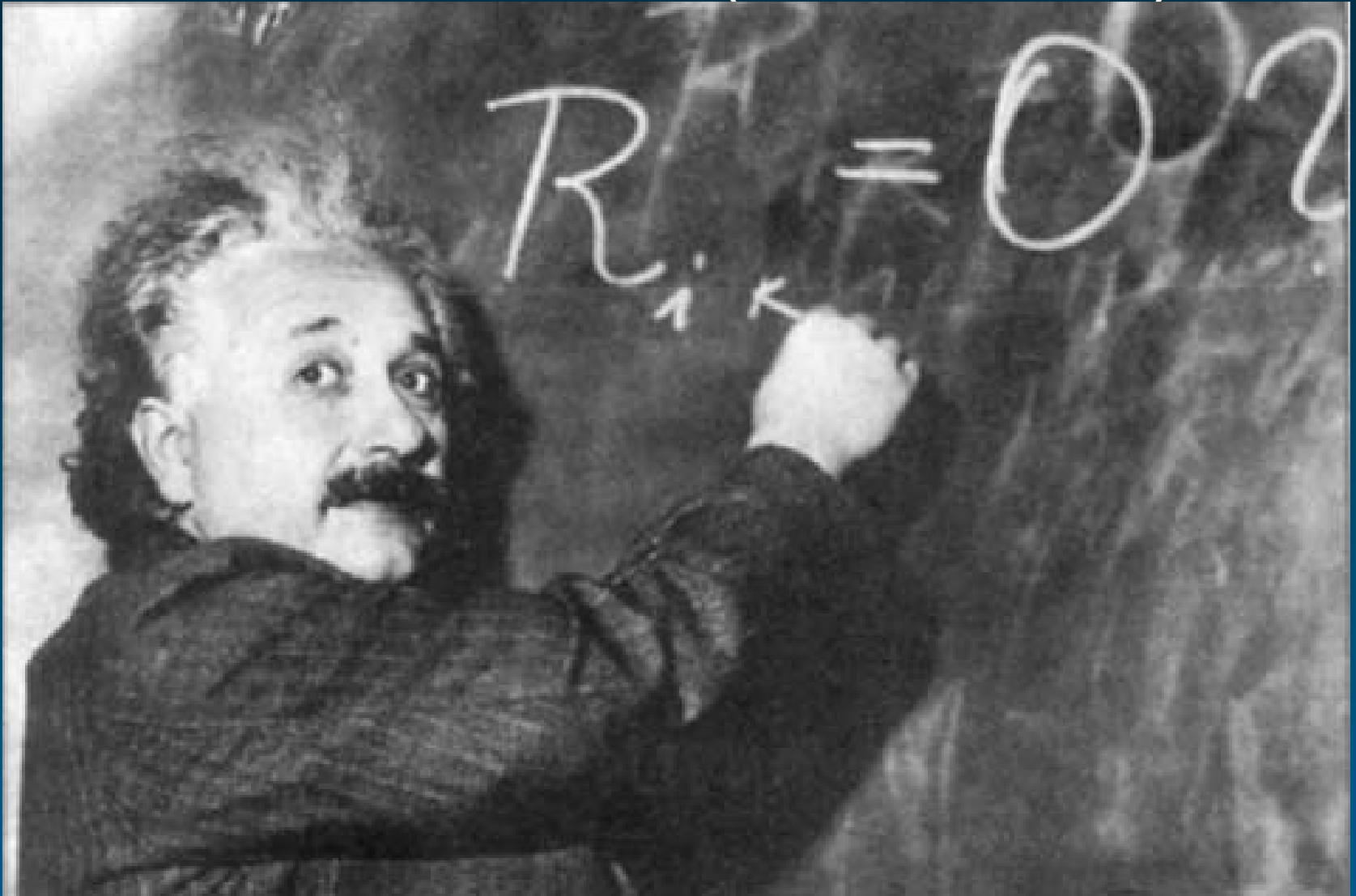
On not yet realizing that his empirical formula fit Mars data:

“ I thought and searched, until I nearly went mad, for a reason why the planet preferred an elliptical orbit (to mine)... “



Science as a voyage of exploration... and a difficult one.

# Albert Einstein (1879-1955)



Theorist's poster child – cosmic exploration driven by the power of pure thought and mathematics; also helps develop quantum mechanics against his own “better” instincts...

# THE EXPANDING UNIVERSE

■ Edwin Hubble:  
(1889 – 1953)

-No guide to “what is out there” – prime discoverer of extragalactic astronomy and cosmology.

As late as 1937... states:

“ Well, perhaps the nebulae are all receding in this peculiar manner. But the notion is rather startling.”



# Richard Feynman – precision physics; working out QED

“..the way I think of what we’re doing is we’re exploring, we’re trying to find out as much as we can about the world.”

“I think the theory is simply a way to sweep difficulties under the rug. I am, or course, not sure of that.” (interview about QED).



Feynman on choosing a problem:

“ ... I had this notion that you could take the importance of a problem and multiply by your chance of solving it. ... if you can get the right combination of those factors, you don't spend your life getting nowhere with a profound problem, or solving lots of small problems that others could do just as well.”

Feynman on the delight of doing science:

“ I learned how to live without knowing. I don't have to be sure that I am succeeding, and as I said before about science, I think my life is fuller because I realize that I don't know what I am doing. I'm delighted with the width of the world!”

# [ Chandrasekhar (1910- 1995) ]

On motivation and work:

“... when one is young, one has ideas and motives that become refined later. ...

I am certain that the primary motivation was the attraction in some way of becoming well known.”

“However, one has to put an enormous amount of labor and hard work into it. One has to persist in a positive way.”



On the role of luck:

“ If you are moderately lucky, or let us say not unduly unlucky, you are sure to do something in the long run.”

On beauty – final words of his 1983 Nobel lecture:

“ The simple is the seal of the true. And beauty is the splendour of truth.”



# Vera Rubin – exploration of dark matter

Astronomy as fun:

“Every day is fun. Observing is spectacularly lovely.”

“There’s also this incredible hope that somehow we can learn how the universe works.”



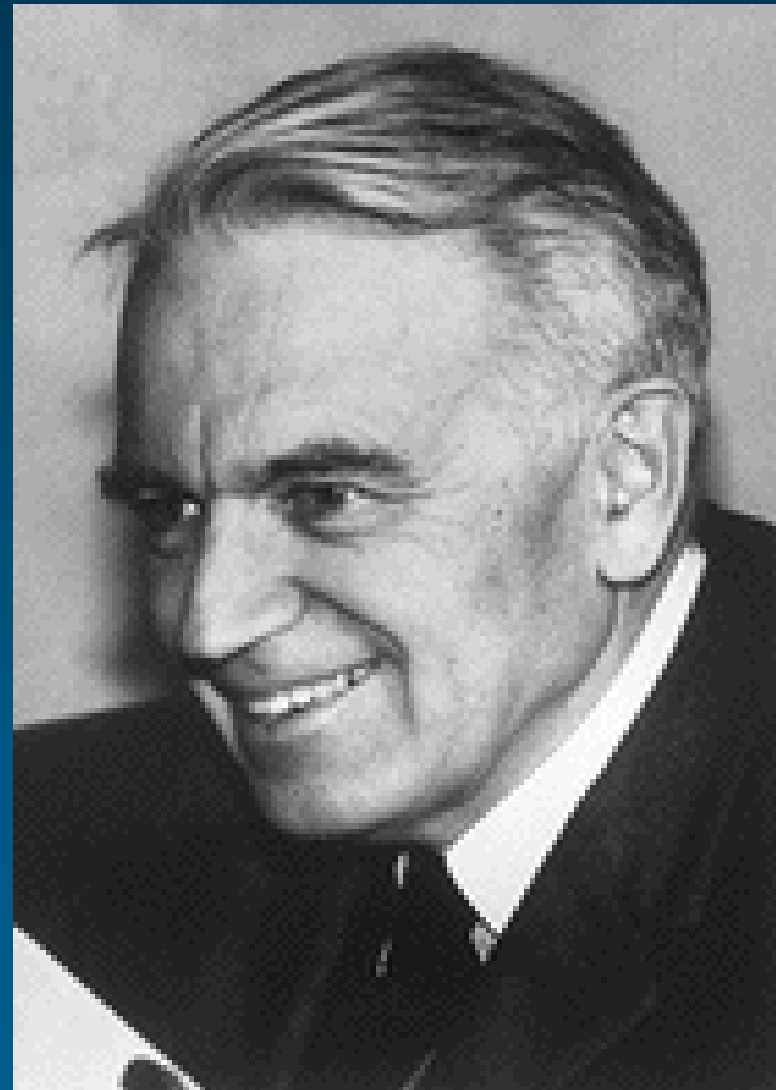
“Many days I really don’t have a very clear idea of what I’m going to be doing. I just sort of continue where the work seems to lead.”

Gerhard Herzberg (Nobel prize in chemistry 1971)...

One of my favourite viewpoints about doing science:

“The sole aim of science is the glory of the human spirit.”

(Very close to how an artist would see their work)



# A guide to doing science...

- Science is the exploration of the cosmos... think of the skills you need to be the successful explorer of a new world:

## 1. Explore something important:

- eg. the source of the Nile, not creeks along the Winnipeg river.
- Scientific reputations are not built on trivial pursuits. Astronomy is unusually rich in unsolved important problems... good field to be in.
- problem could be new – or an important chestnut that is amenable to a new attack

## 2. Ask the right question – develop the right attack:

- eg. if goal is to climb highest mountain in the Rockies, first learn how to scale a few cliffs...
- the art of what is doable with resources and techniques at hand – critical for success.
- no credit for working on something hard for which no progress is ultimately made.
- the right approach comes from many patrols and probes of the landscape... curiosity and common sense required. Try stuff!
- for theorists; beauty and simplicity are key signals that one is onto something possibly important.

### 3. 10% inspiration, 90% perspiration:

- inspiration and creativity needed to plot the course and to learn from the voyage,
- energy, dedication, hard work, intense curiosity, real enjoyment, flexibility to learn from dead ends needed to carry through.
- resilience; a positive attitude needed at all times on any successful journey.
- self-confidence; grows with experience and “trying things”. Exploration depends on it.

The solution is always obscured... don't be dismayed by the fog. Work through it.

## 4. The tool is not the solution... it's just a tool.

- progress comes from developing physical ideas - which directs how you use the tools.
- eg. of non-starters: "... more data is needed" (isn't it always?)
  - " I'm writing a code" (computers don't think, and won't necessarily save you),
  - " ...for simplicity, consider a spherical cow"  
(math models that are too naïve can be very misleading).
- don't re-invent the wheel... use existing tools cleverly
- if you need to build a new one... build one that does the job efficiently.

## 5. Lady Luck - every expedition depends on it.

- take advantage of new opportunities as they arise... not necessarily too early, but definitely not too late!

(there are other explorers out there,  
seeking to stake claims...)

- luck favours the prepared – hard work, alertness, sharp tools and methods, and timely flexible response all needed.

- most scientific careers involve “being at the right place at the right time”.

## 6. Quality, productivity, and impact:

- the most valued explorers leave clear trails and markers along which the rest can readily follow.
- learn to do highest quality work first, then learn how to do more of it.
- most influential authors write a steady flow of outstanding papers in a career, but not the most! Impact, not numbers essential.
- variety: the spice of life and research. Go deep, but also be broad.

**WRITE WELL & GIVE GOOD TALKS!** How else will people learn about what you are trying to do, and what you have achieved?



# Astronomy in your generation - mind-blowing:

The cosmos is richer than any mind will ever be, so further exploration will **always** be needed.

Why are we able to understand anything at all about the cosmos?

- It seems incredible that such simple intelligent beings as ourselves have already gleaned size, and fate of the universe....
- Within next generation, astronomers will probe beyond “first light”...