Why Does the Sun Shine?

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QuarkNet

Wattage of the Sun

- The Sun is big. Its diameter is 109$\times$ the earth's diameter.
- The Sun is hot.
  Surface is 2$\times$ hotter than a red hot electric stove element.
- The Sun emits 4×10^{24} watts.
  4,000,000,000,000,000,000,000,000 watts
- What would the Sun cost to run @ 10 cents/kilowatt-hour?
  Answer: $100 trillion per millisecond.
- How does the Sun produce this tremendous wattage?
  Hint: The Sun is mostly made of hydrogen and helium.
  Helium was not discovered on earth, but in the sun in 1868.
  A hydrogen nucleus has one proton.
  A helium nucleus has two protons and two neutrons.

Neutron Decay

- Neutron decay was observed in 1930. Chadwick, Pauli...
  A free neutron at rest lives for about 15 minutes.
  $n \longrightarrow p + e^- + \bar{\nu}$
  The neutron is neutral, the proton is positive, and the electron is negative. So electric charge is conserved.

- But who ordered the neutrino ($\bar{\nu}$)?
  Answer: The electron speed varies in the decay.
  So there must be a missing particle. Hence the neutrino.
  Neutrinos only interact weakly and
  can pass through miles of matter.

Running neutron decay backwards in the Sun

- Helium is 0.3% less massive than hydrogen per nucleon.
  A nucleon is a proton or neutron.
  1000 kg of hydrogen and 993 kg of helium have the same number of nucleons. Binding energy makes the difference.

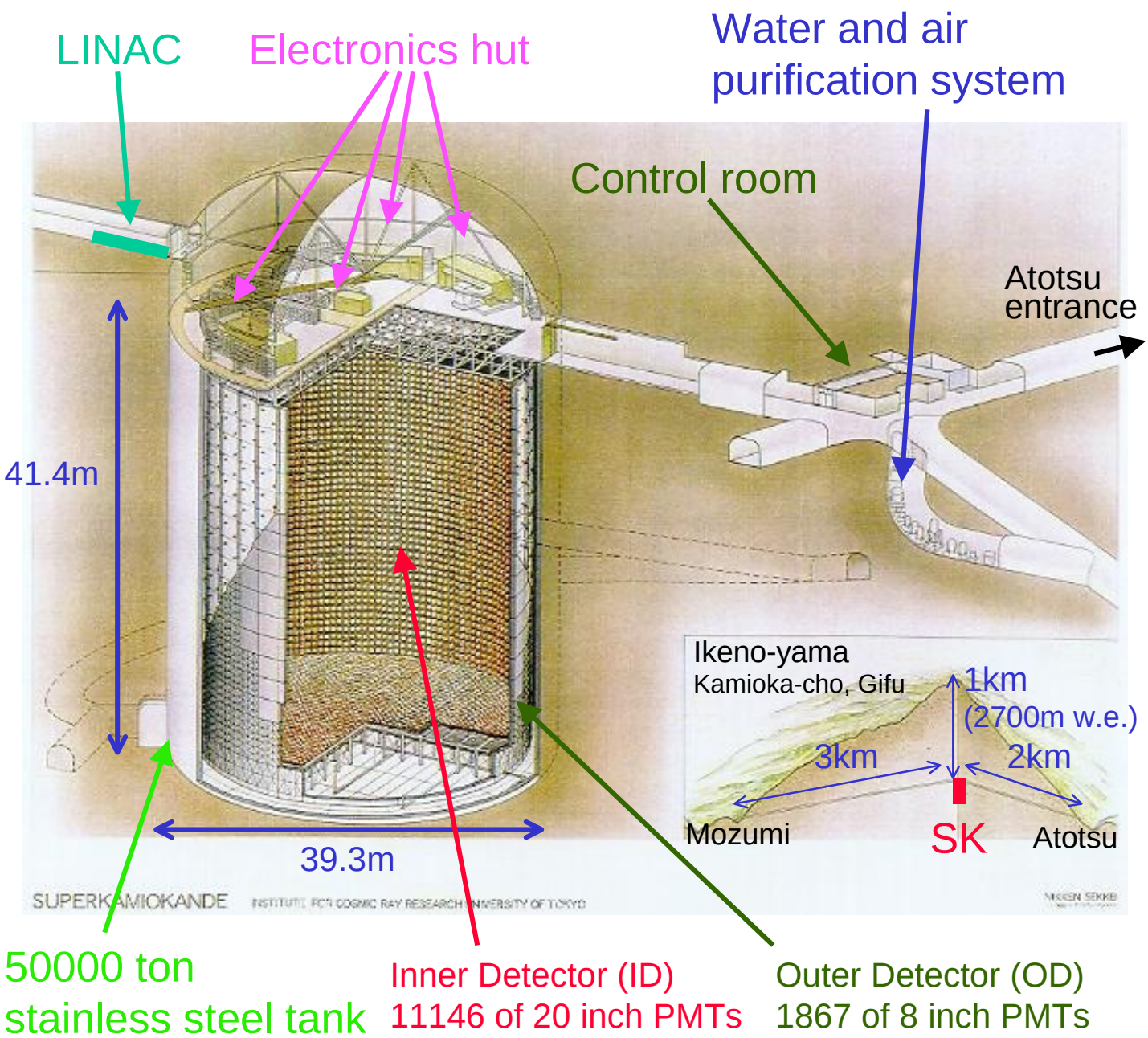
- 7 kg is a lot of energy. c is the speed of light in meters/s.
  $E = mc^2 = 7 \times (3 \times 10^8)^2 = 6.3 \times 10^{17}$ watt-seconds

- The mass of the Sun is large, 2×10^{30} kilograms.
  Like charges repel each other. K = degrees Kelvin.
  So use a hot solar core (15×10^6 K) to collide protons.

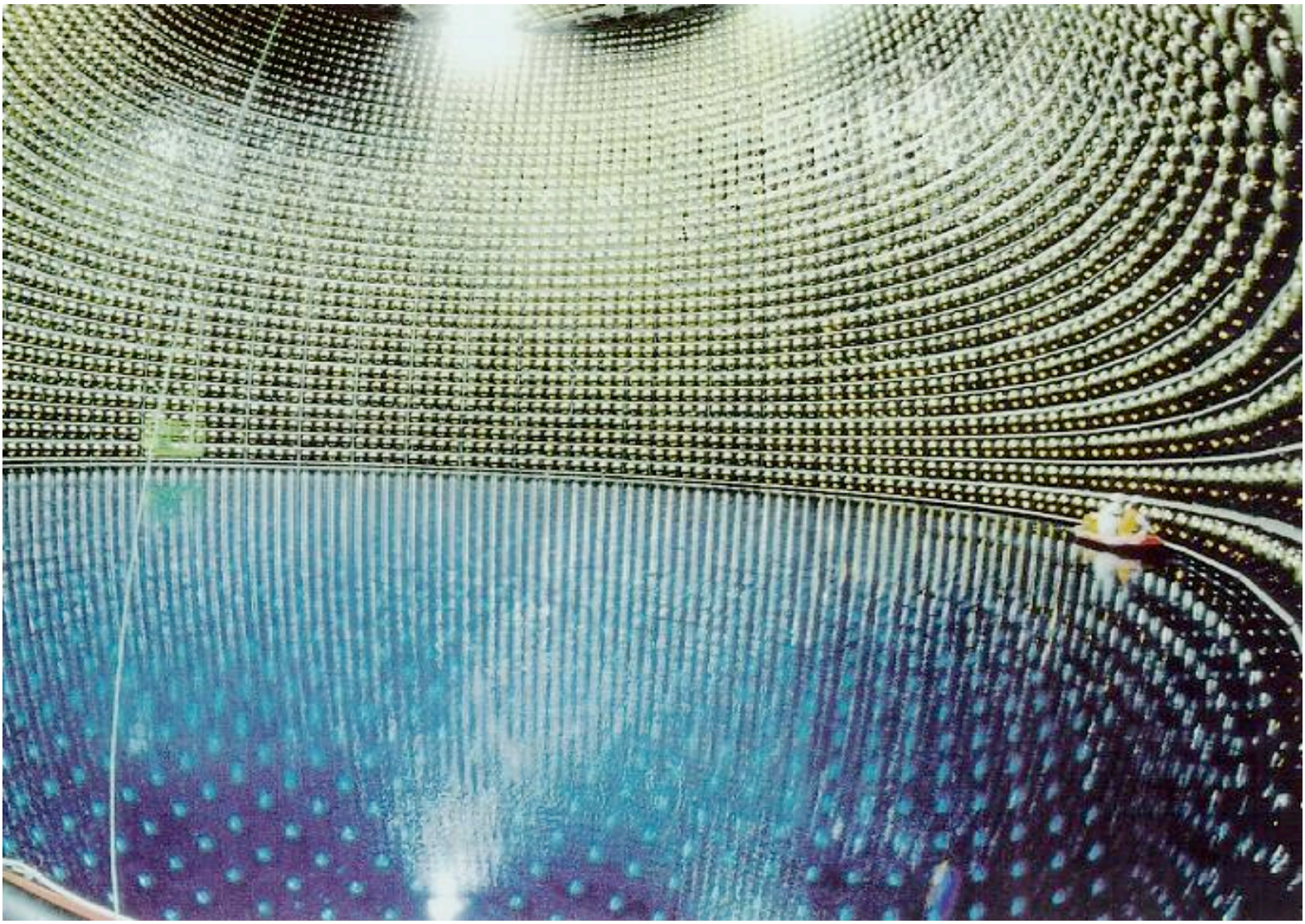
- Use $p \longrightarrow n + e^+ + \nu$, to turn protons into neutrons.
  This allows hydrogen (p) to fuse into helium (ppnn).
  p + p + p + p $\longrightarrow$ ppnn produces lots of fusion energy.

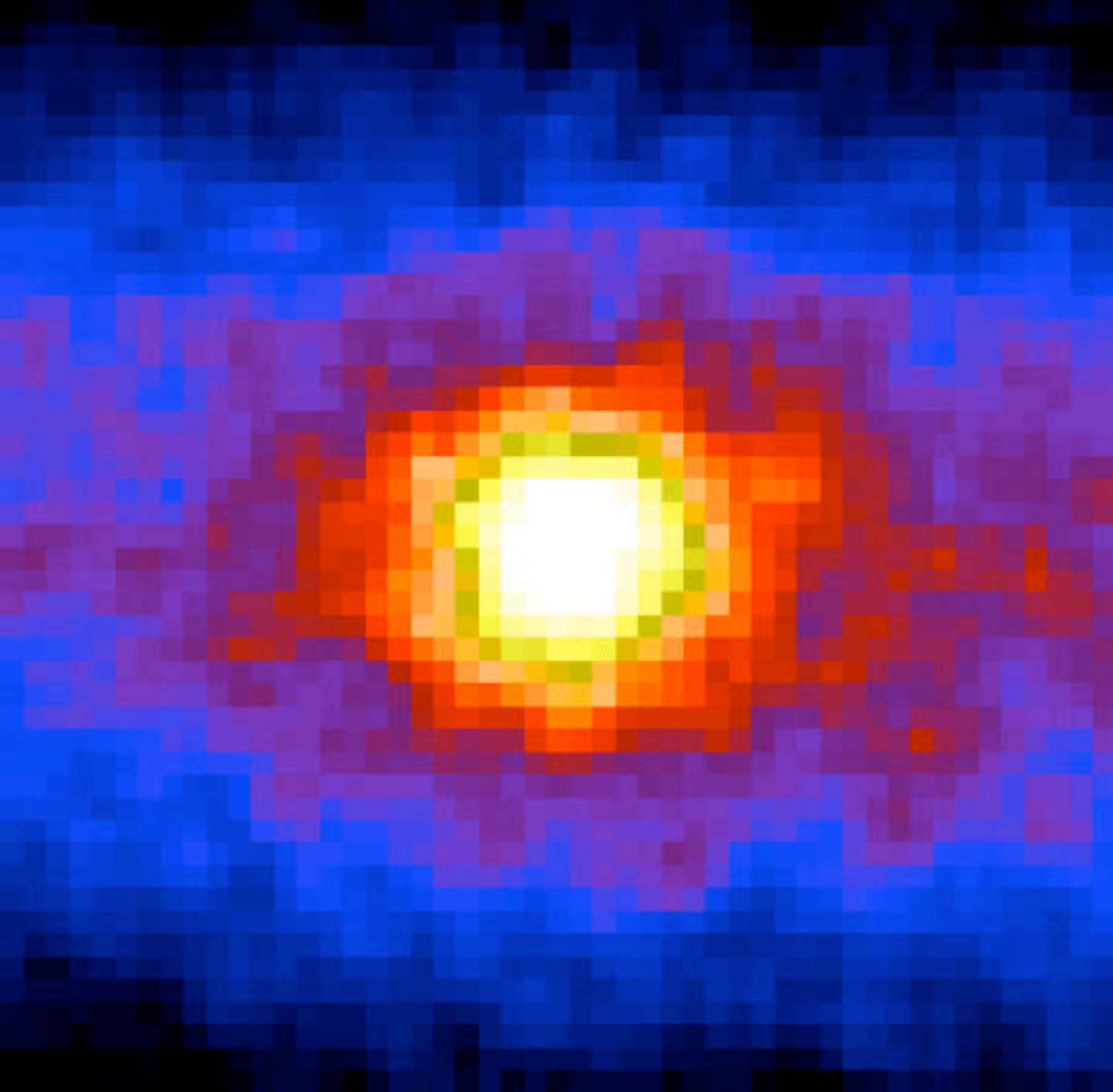
- Is this real? Can we see the solar neutrinos, needed to turn protons into neutrons and make fusion energy?

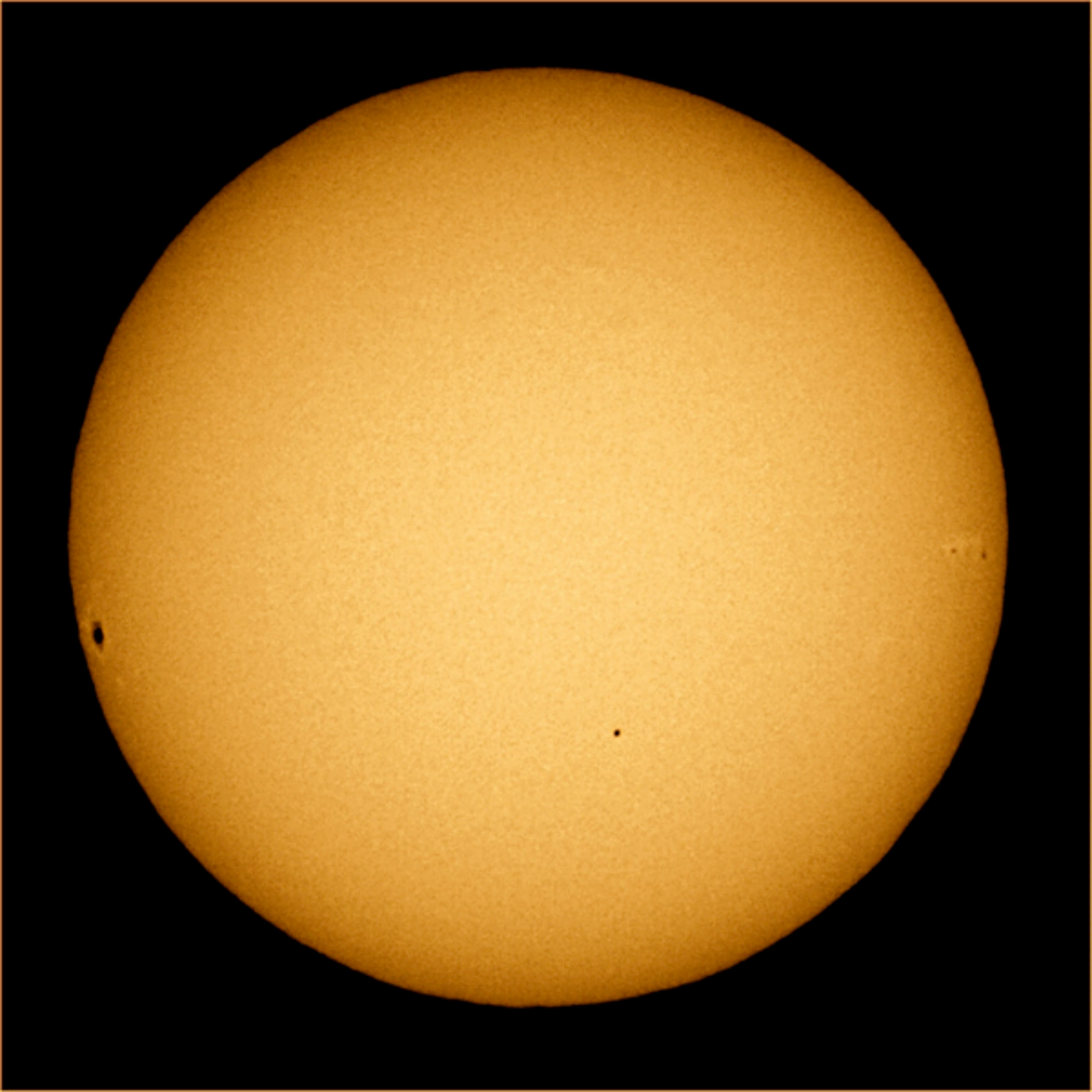
Super-Kamiokande

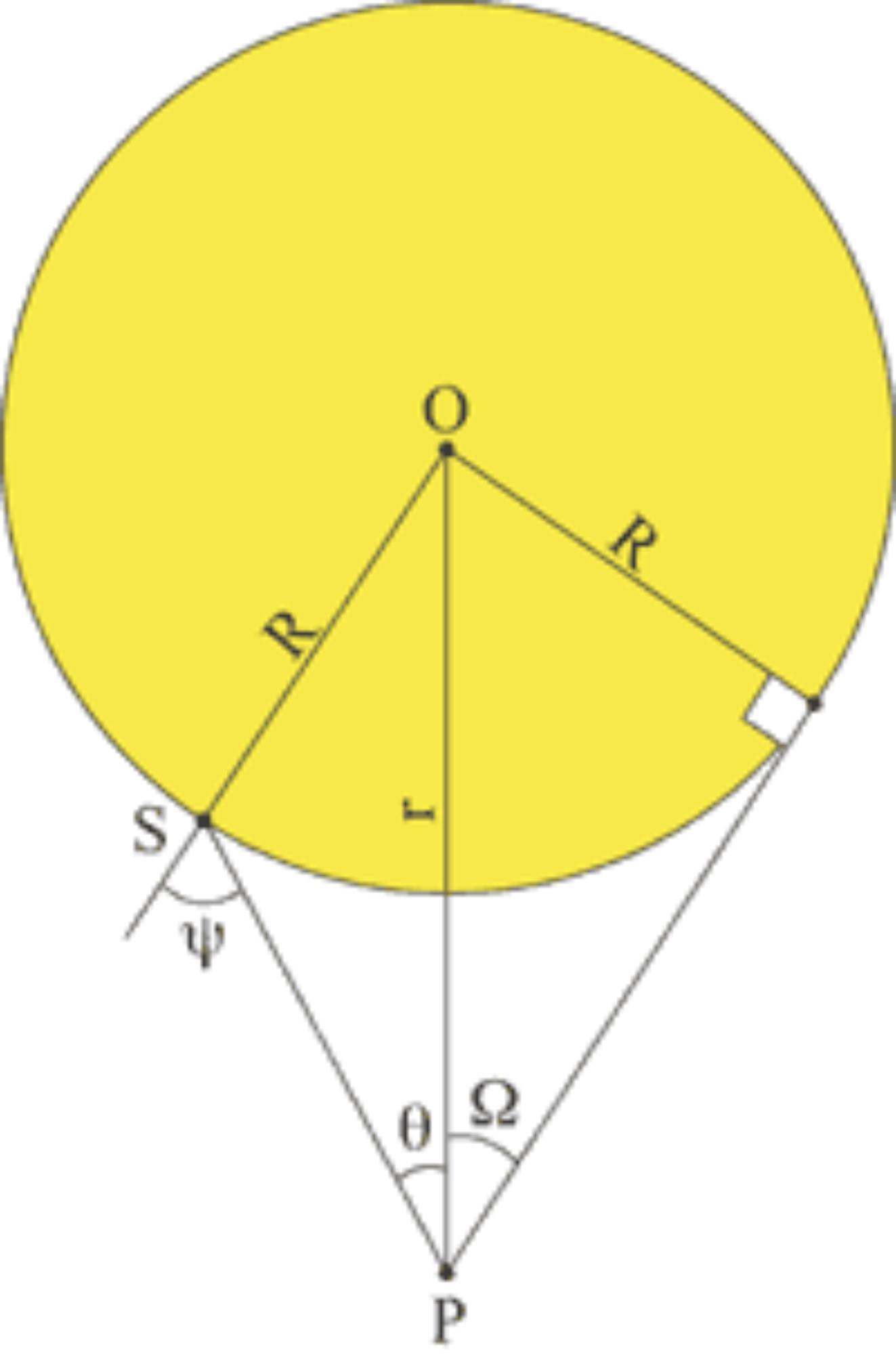


• photo coverage	40%
• outer detector	2.5m for all surfaces
• fid. vol. for ν_{solar}	22.5kt (2m from ID wall)
• for 10 MeV electron	
vertex resolution	87cm
energy resolution	14%
angular resolution	26^{o}





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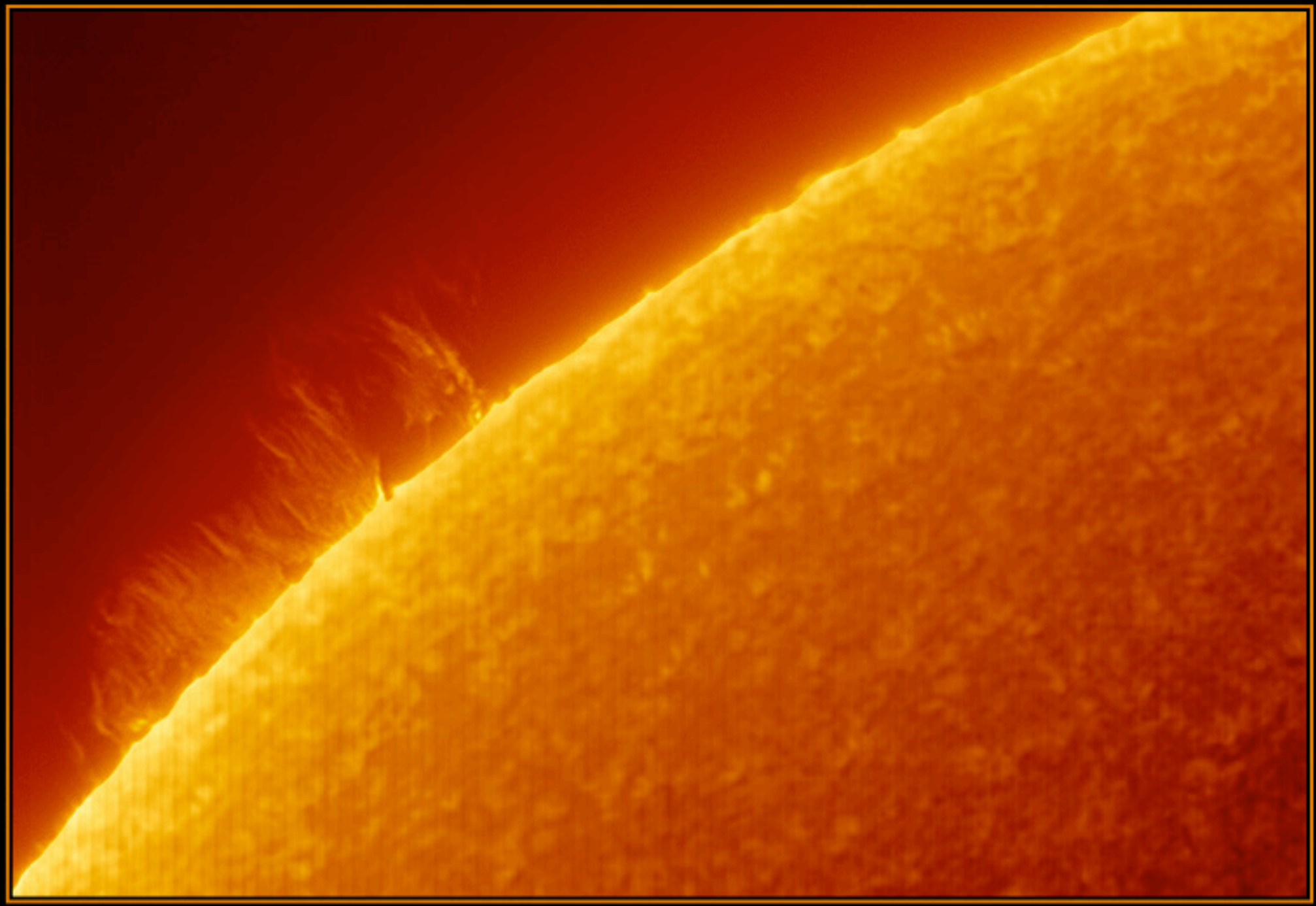

Following the Leader