# The Planeterrella

http://planeterrella.osug.fr/?lang=en

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You all know (or heard of) this amazing wonderfull natural show…
Crédit: P. Volke, LPG
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So tiny, so fragile. One sees the stars through.
Crédit: P. Volke, LPG
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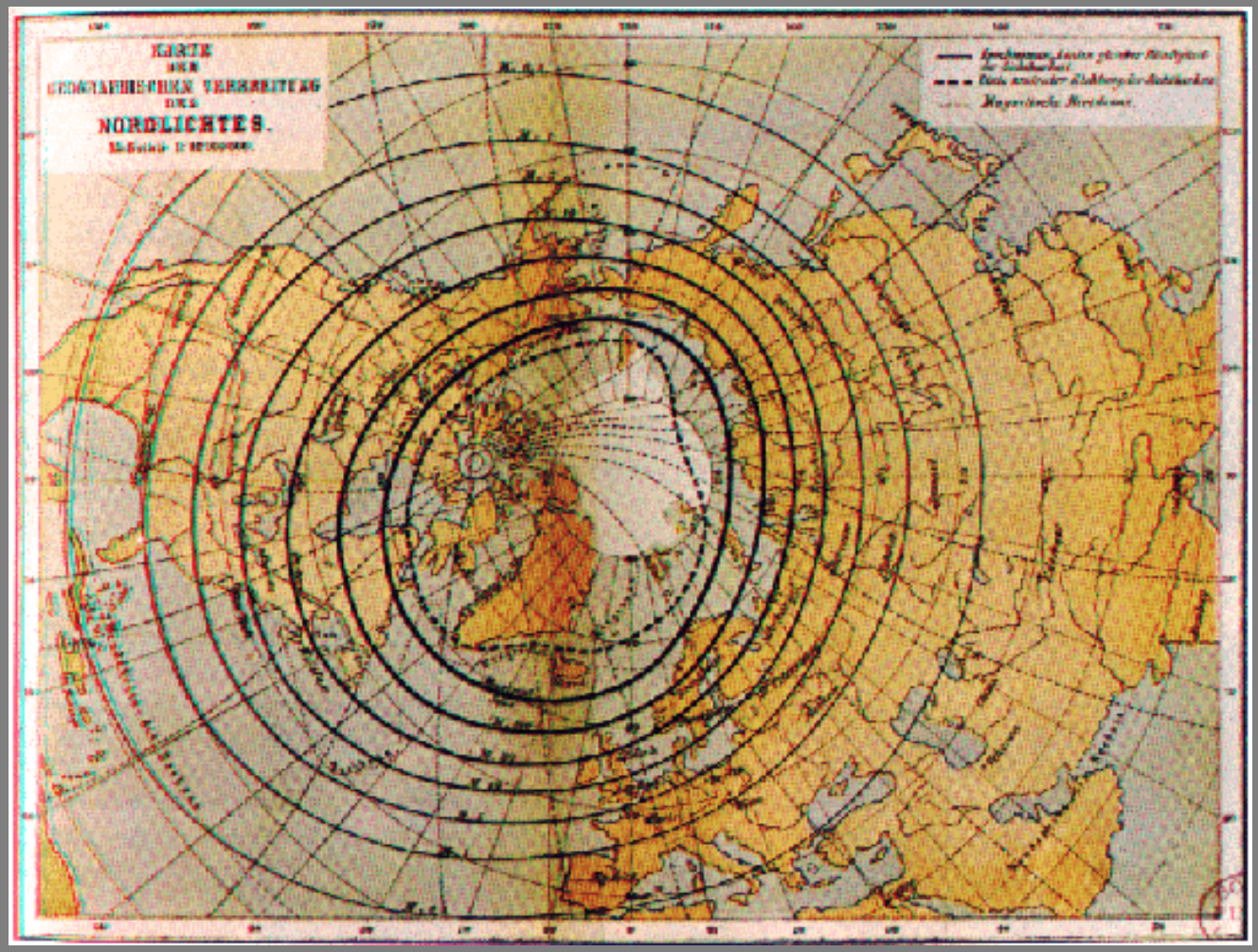
# Green red, yellow, purple, white …

Crédit: club d'astronomes amateurs de Gretz-Armainvillier

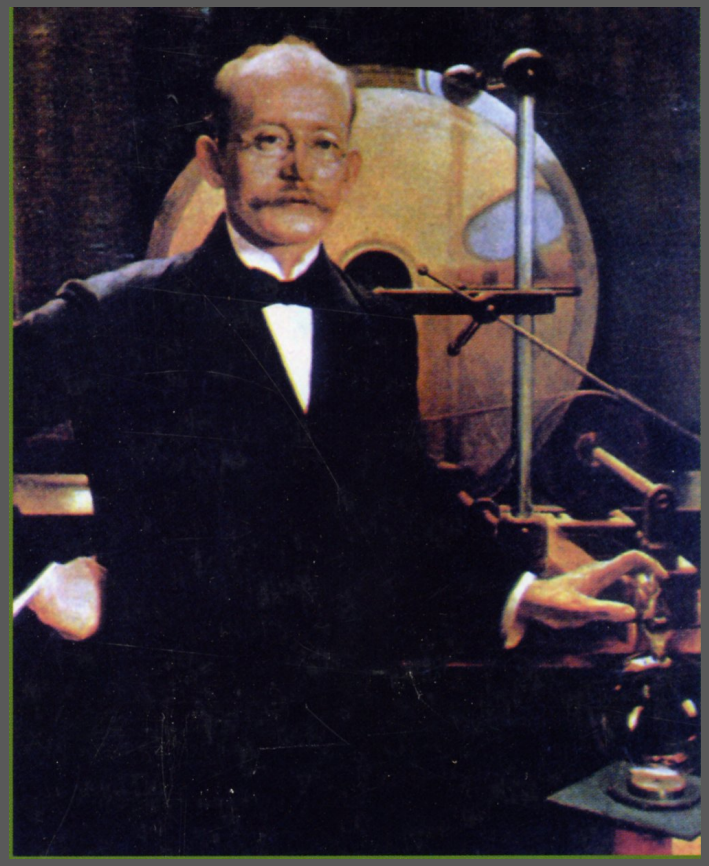

A long time a deep mystery for mankind

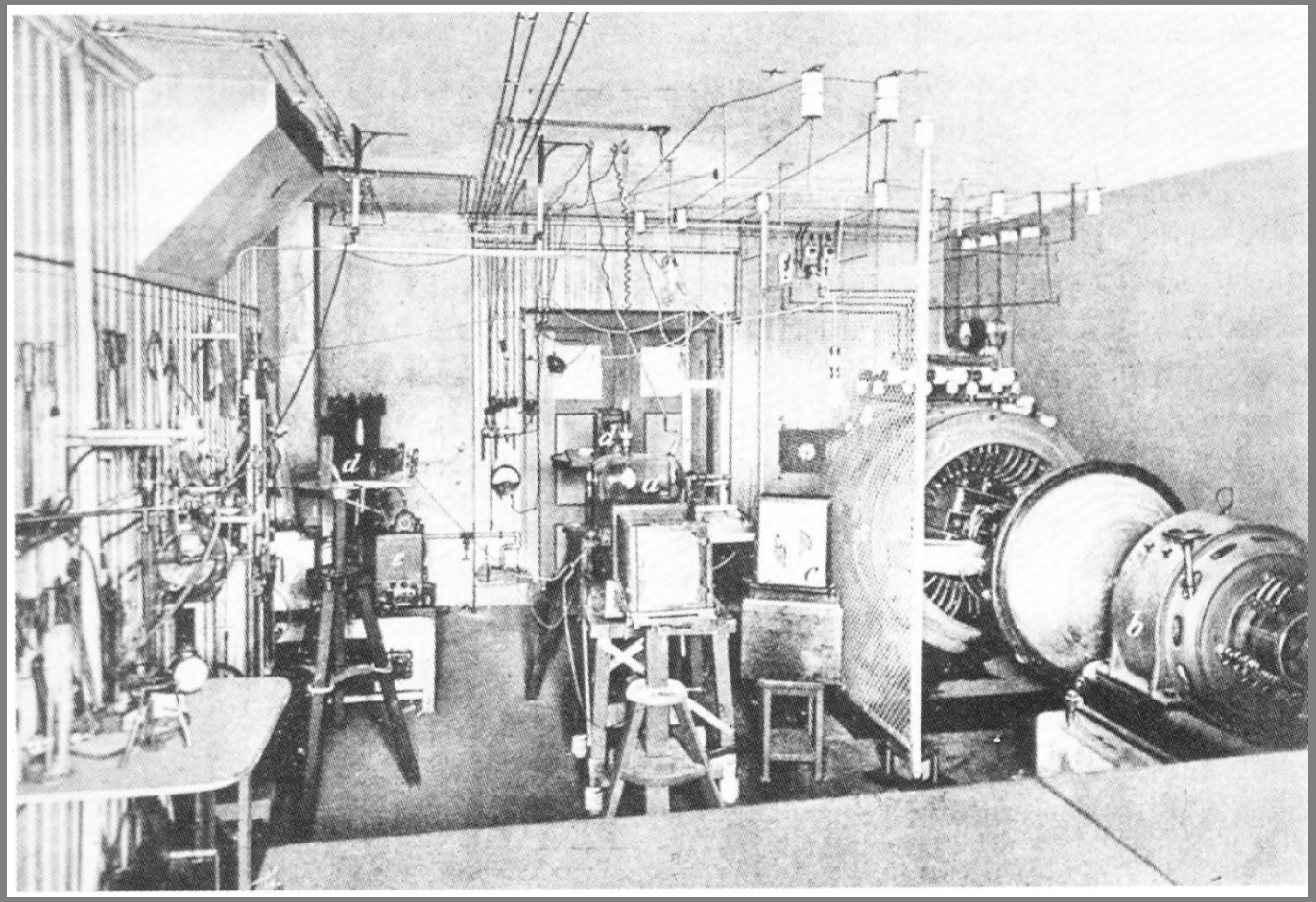



Mid 19th century: localisation of the auroral oval

At the end of the 19th century, Thomson discovers the electrons, first called « cathode rays »

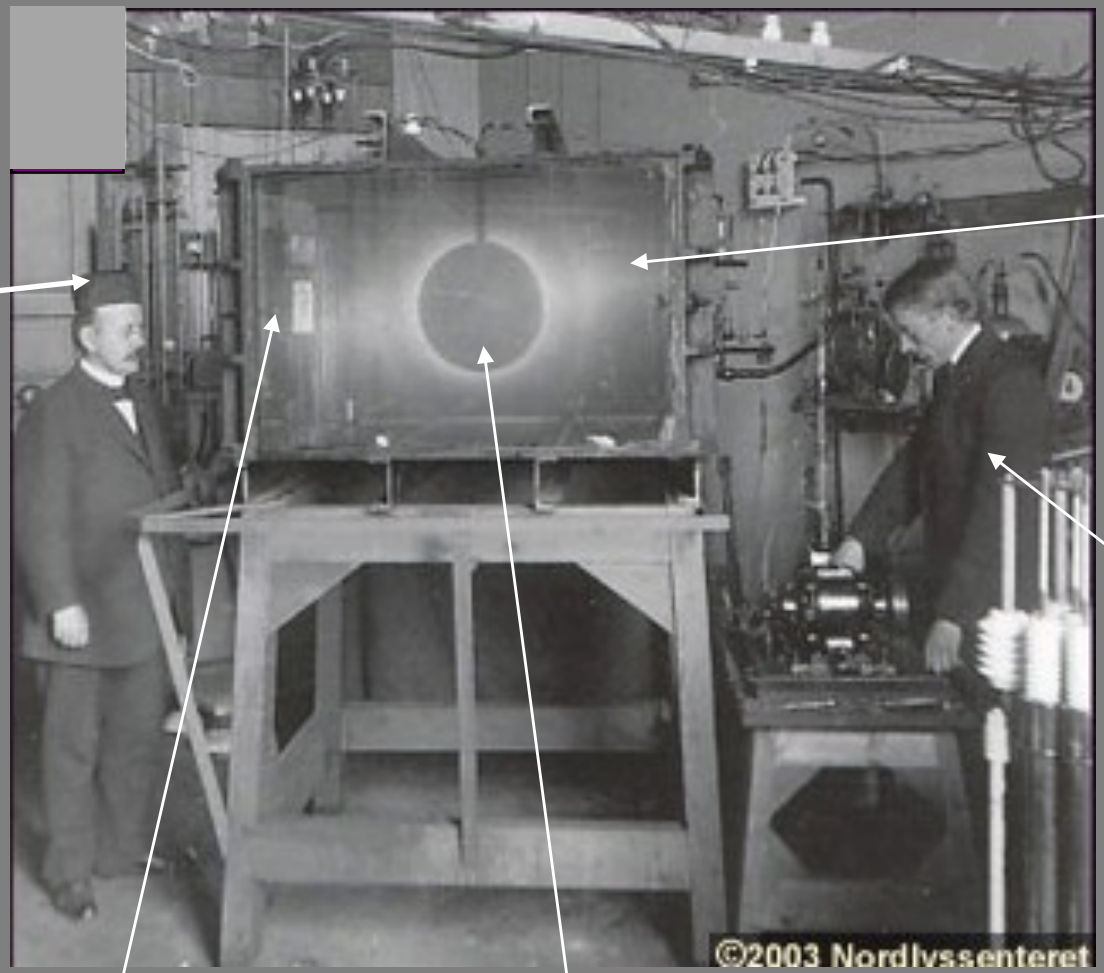
The great Norvegian scientist Kristian Birkeland (1876 – 1917) was already working on these cathode rays





Birkeland then had this extraordinary idea, while about nothing was known about the space environment

His hat: he got really sick at the end of his life, due to the experiment

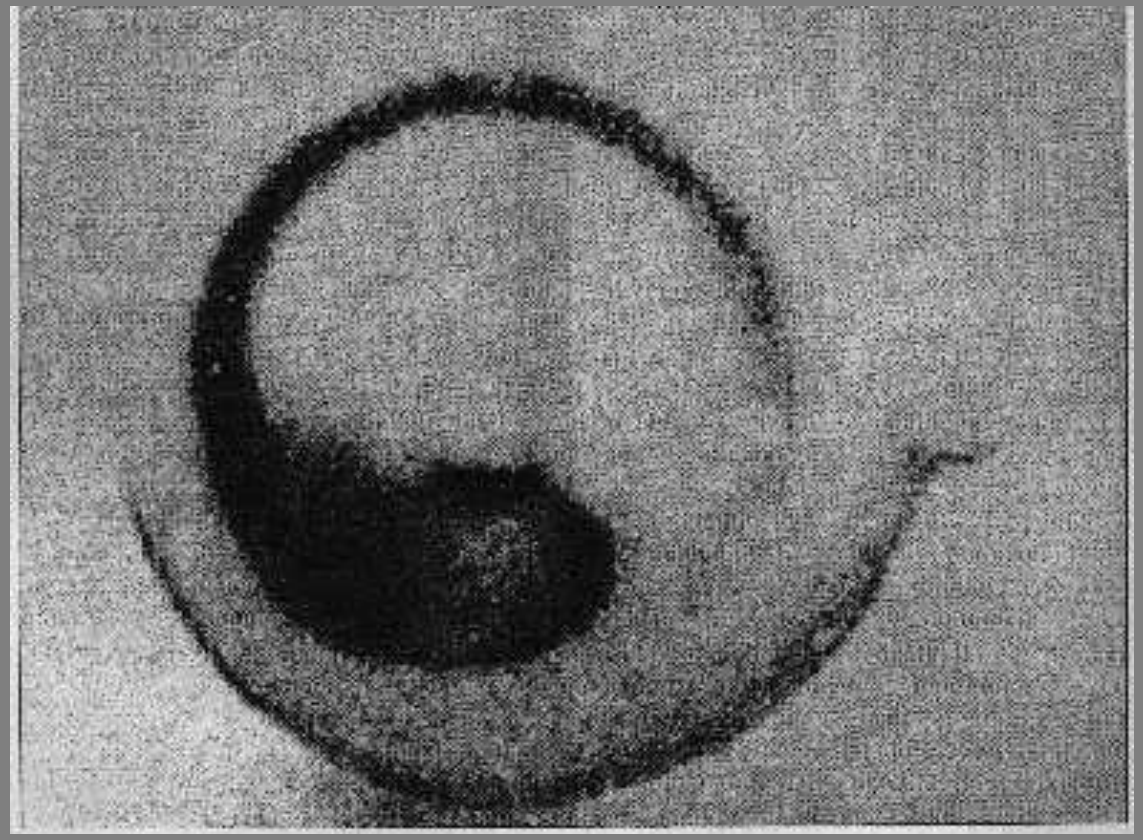



Vacuum (about 50 Pascal)

Evik, Birkeland's PhD student

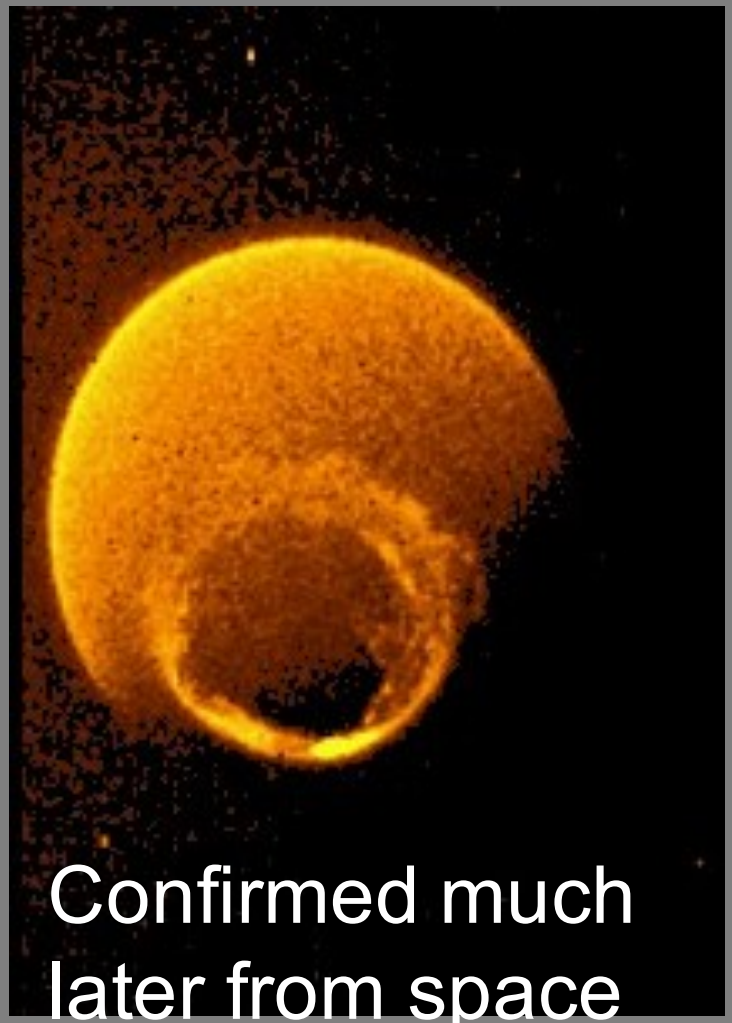
Electron gun (cathode)

Magnetized sphere (+ anode)



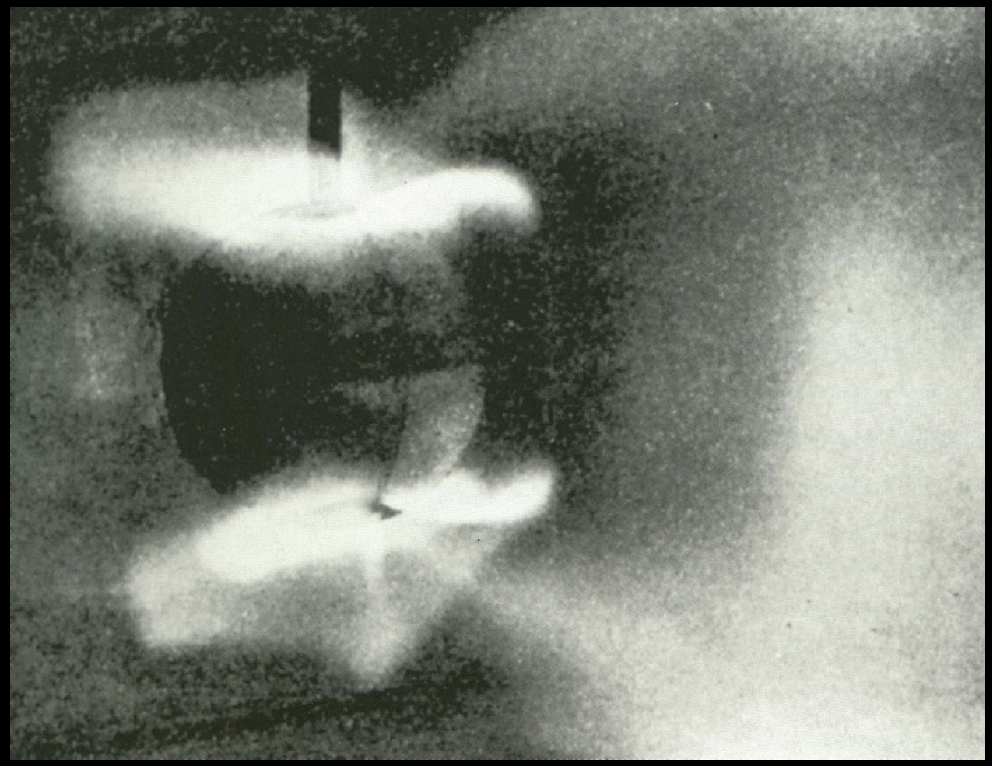
1895

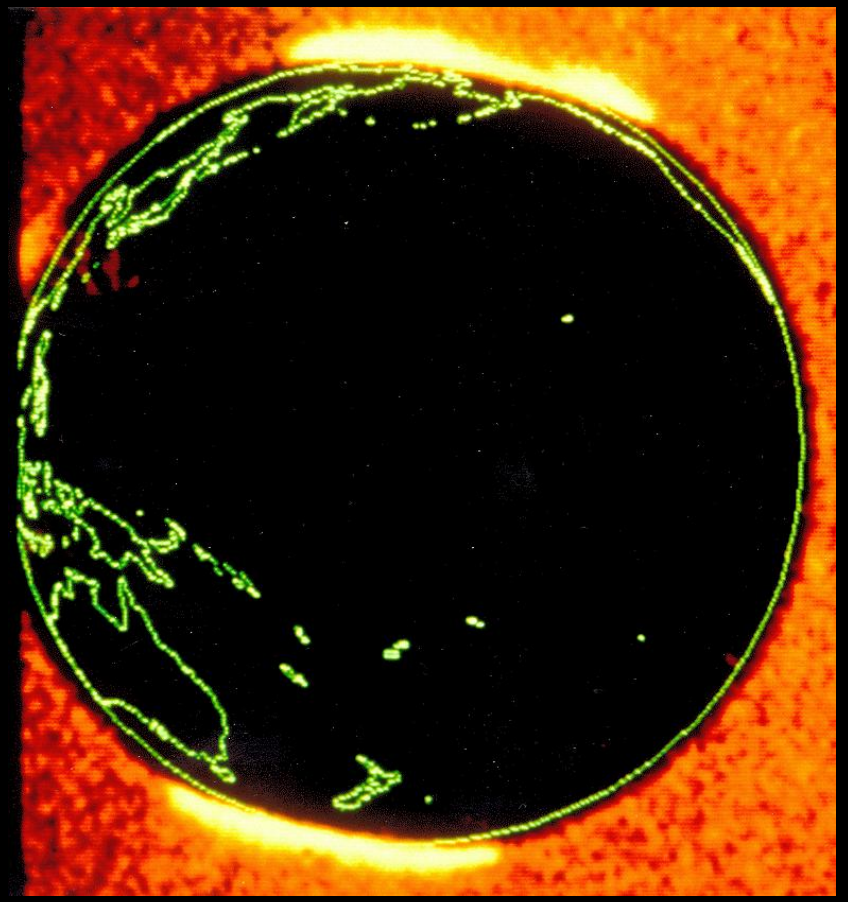
This is what he saw

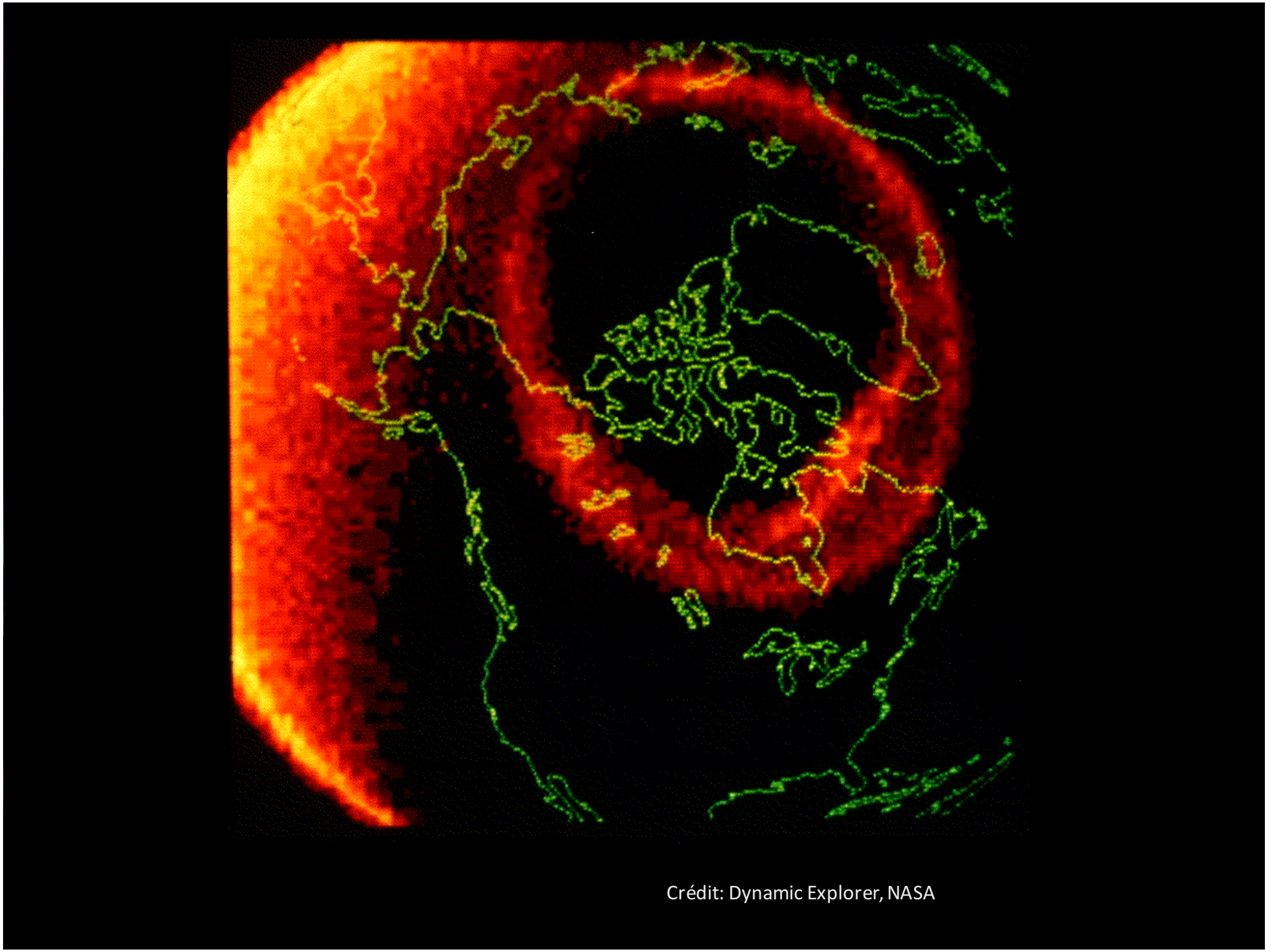


Confirmed much later from space (here in 1985)

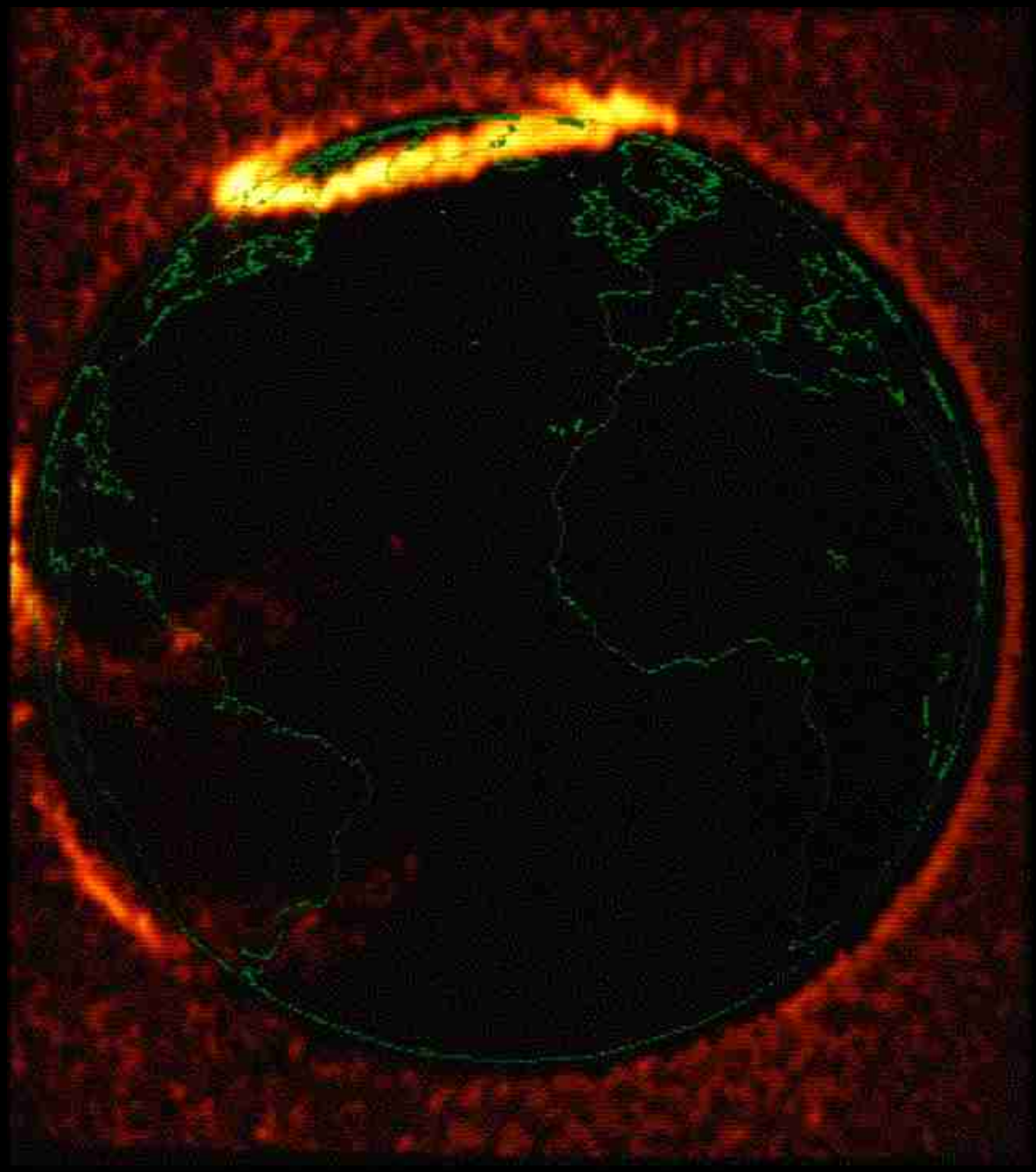
Crédit: Dynamic Explorer, NASA







Crédit: Dynamic Explorer, NASA



Crédit: Dynamic Explorer, NASA

# From the ground

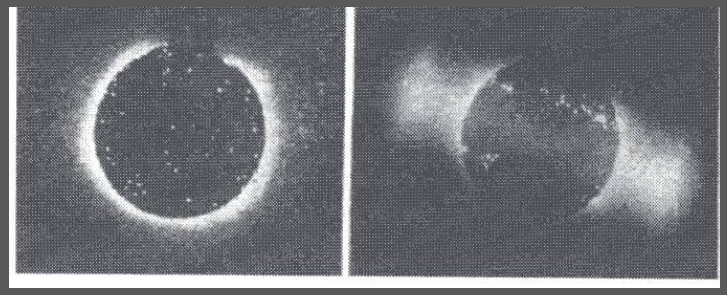
Crédit: G. Gronoff, NASA

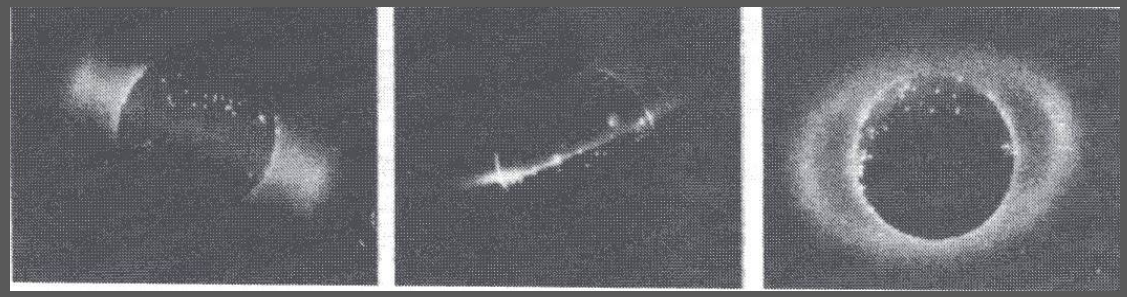

Crédit: C. Simon, BIRA

Crédit: C. Simon, BIRA

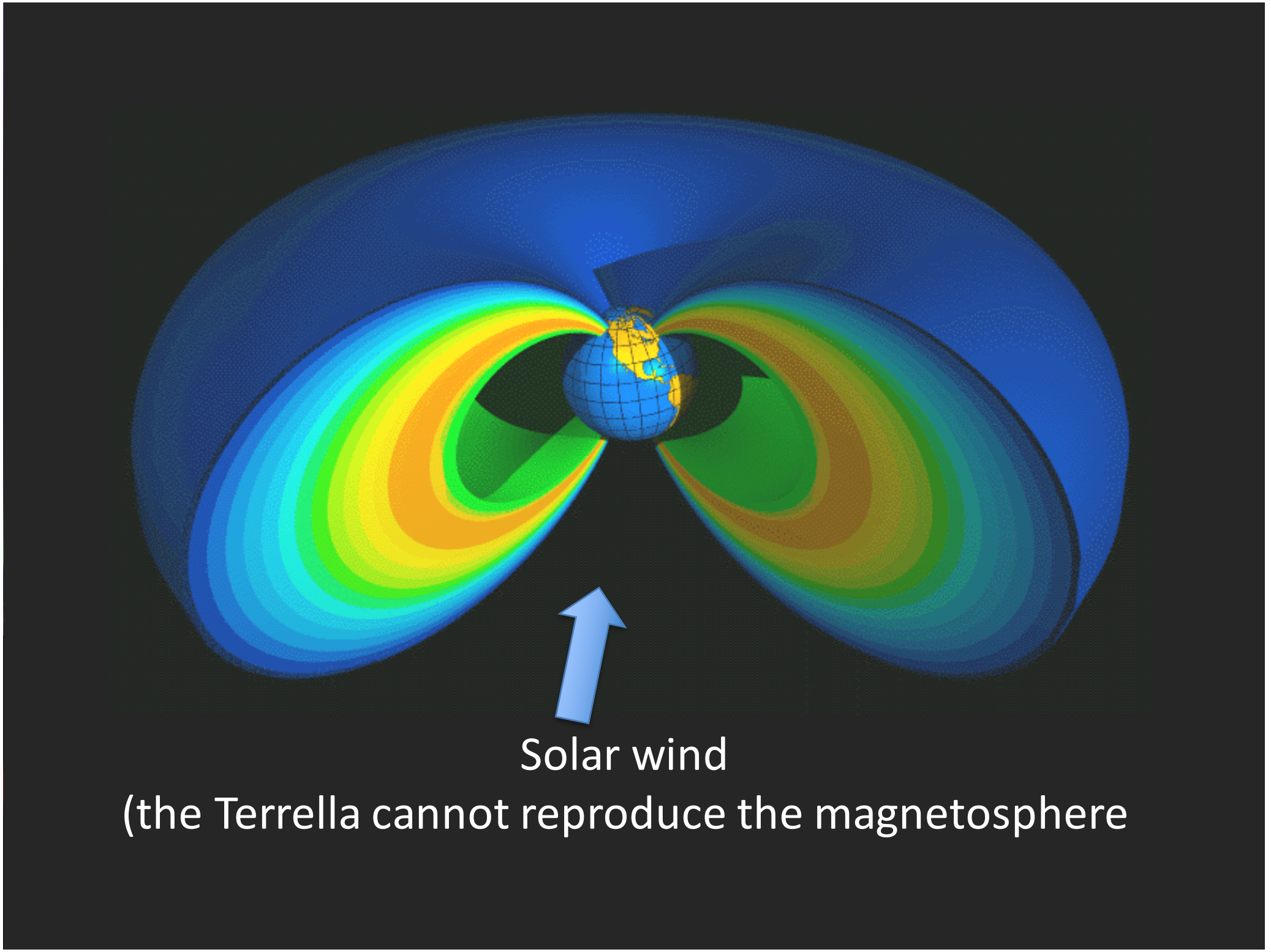
Crédit: O. Grünewald

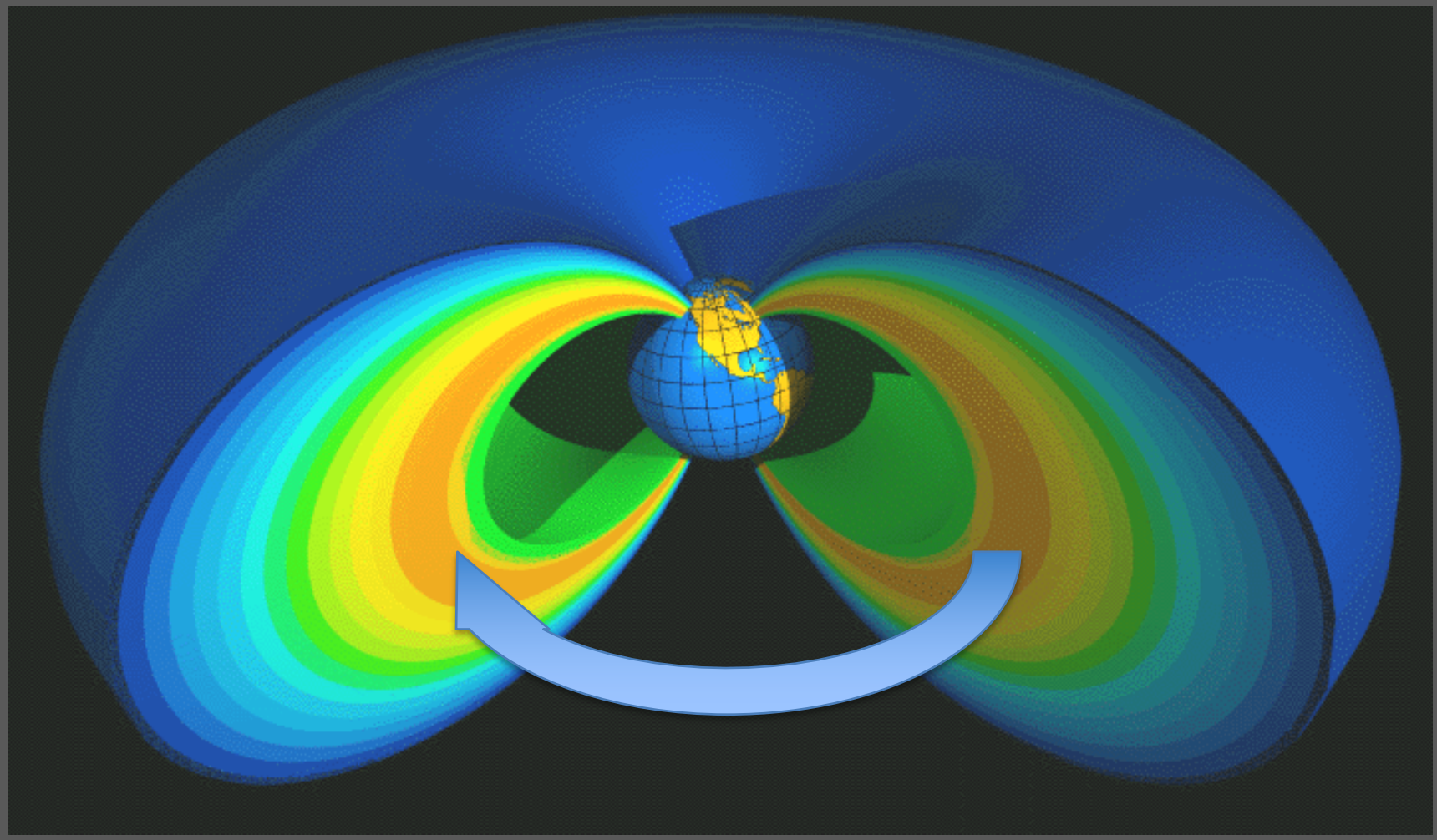
Birkeland built 14 Terrellas, with increasing volumes and different magnetic / electric configurations
In his enthusiasm, he thought to have modeled the sun, the ring of Saturn…



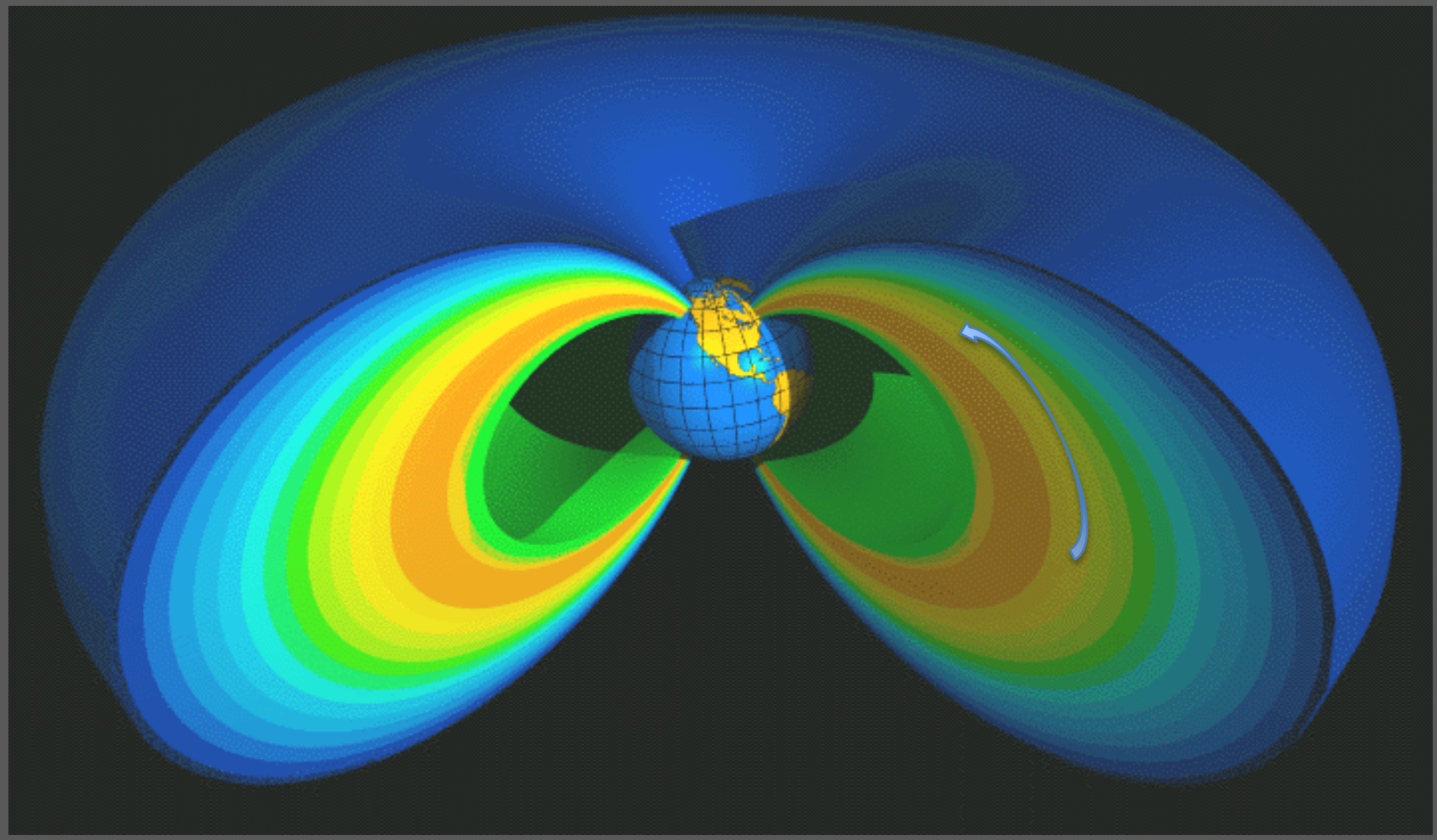


What goes on?
The mechanisms are a little bit more complicated in the case of the Earth than in the Terrella. But still, several things are correctly reproduced.

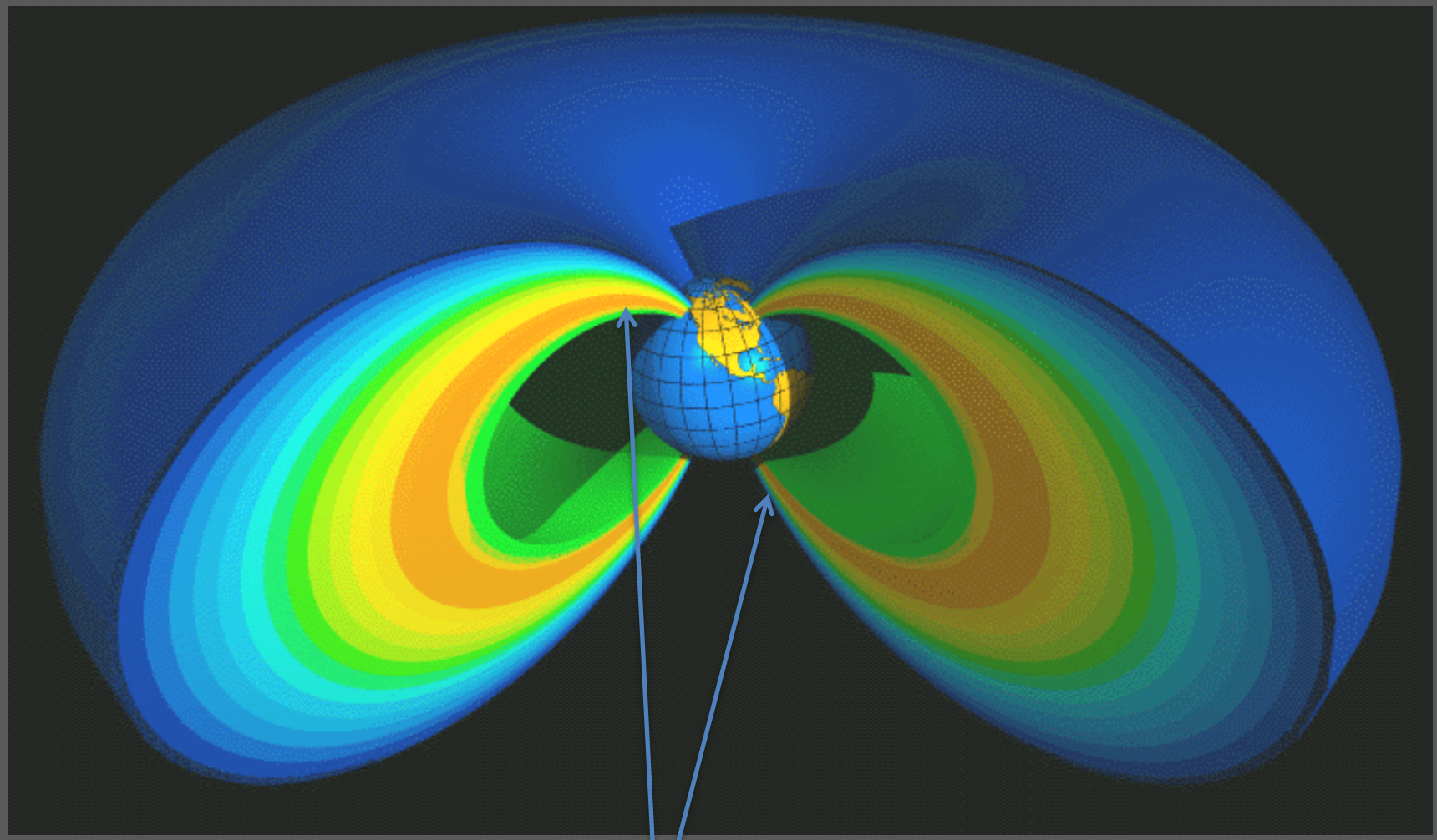

Solar wind
(the Terrella cannot reproduce the magnetosphere



Rotation around the Earth and making of the radiation belt (5 to 7 Earth radii from the surface)

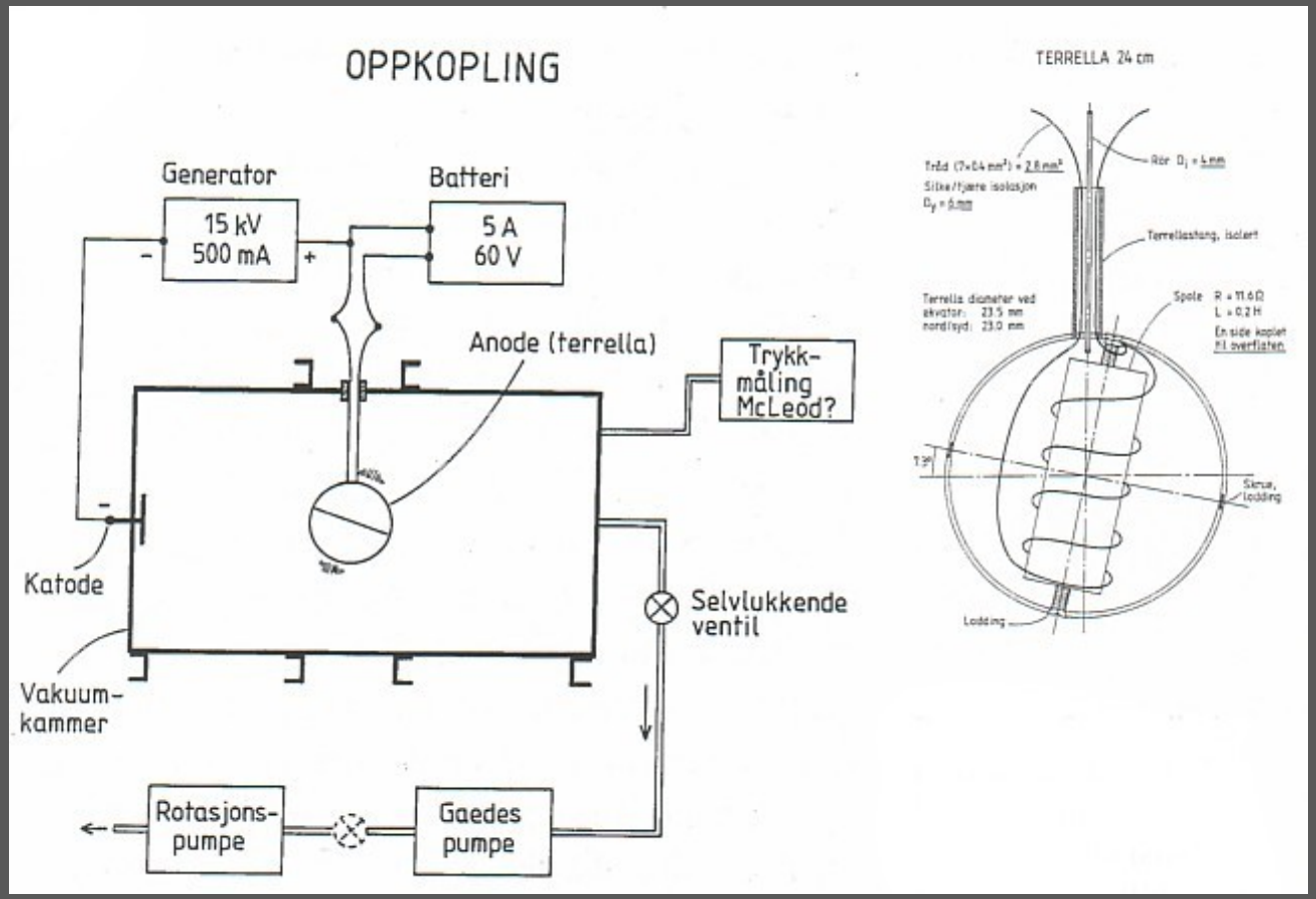


Collisions and making of the auroral ovals.



Excitation, heating, ionization, dissociation

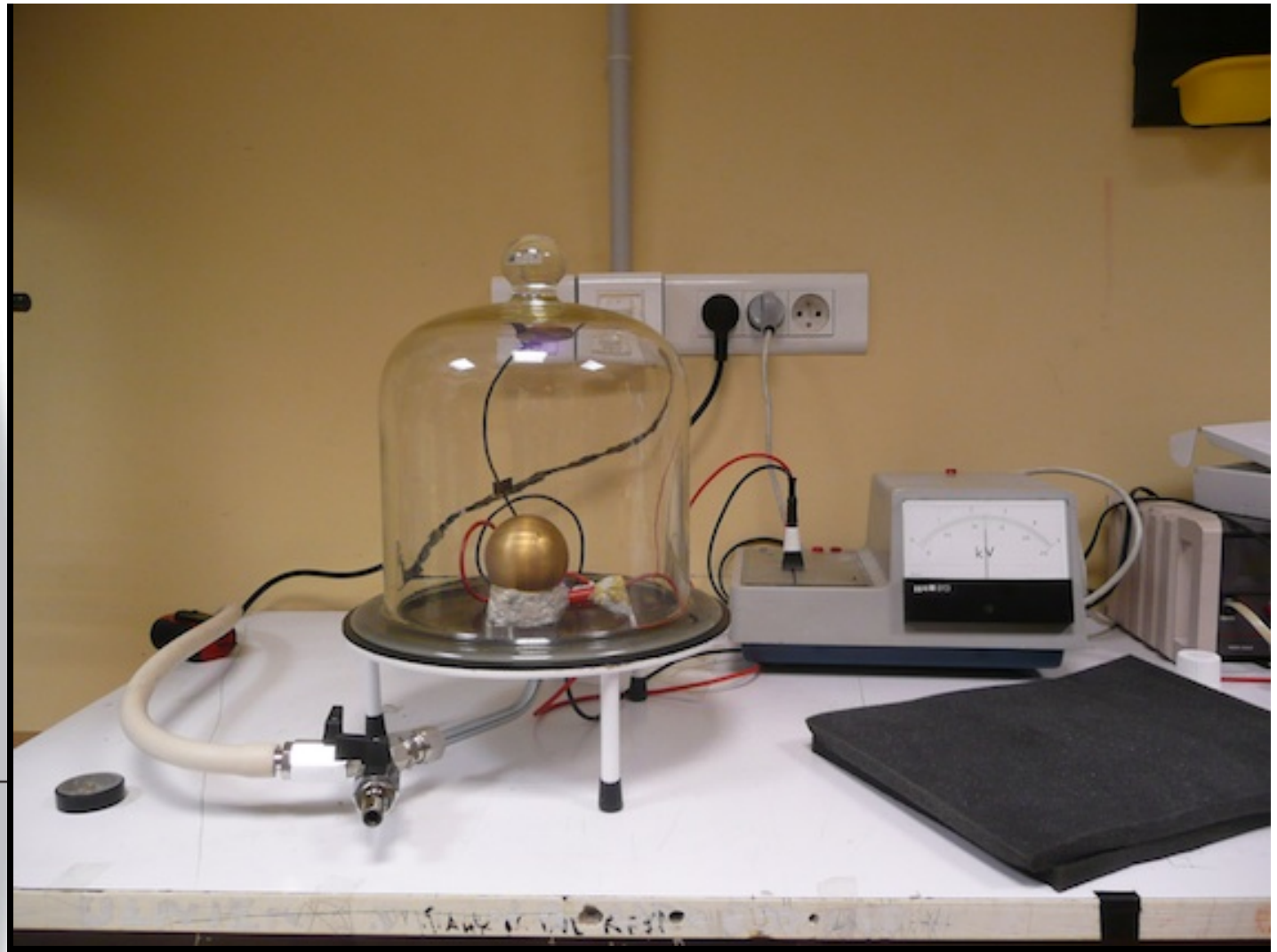
Unfortunately, Birkeland did not leave many notes on the parametrization of his experiments.



In the 90’s, Ingenior Terje Brundtland (Tromso University) rebuilt one of the Birkeland’s Terrella from the original « Universe ». I had a chance to visit him.

Now in a museum in Oslo

Inspired by Birkeland and by Terje, I then built several Terrellas



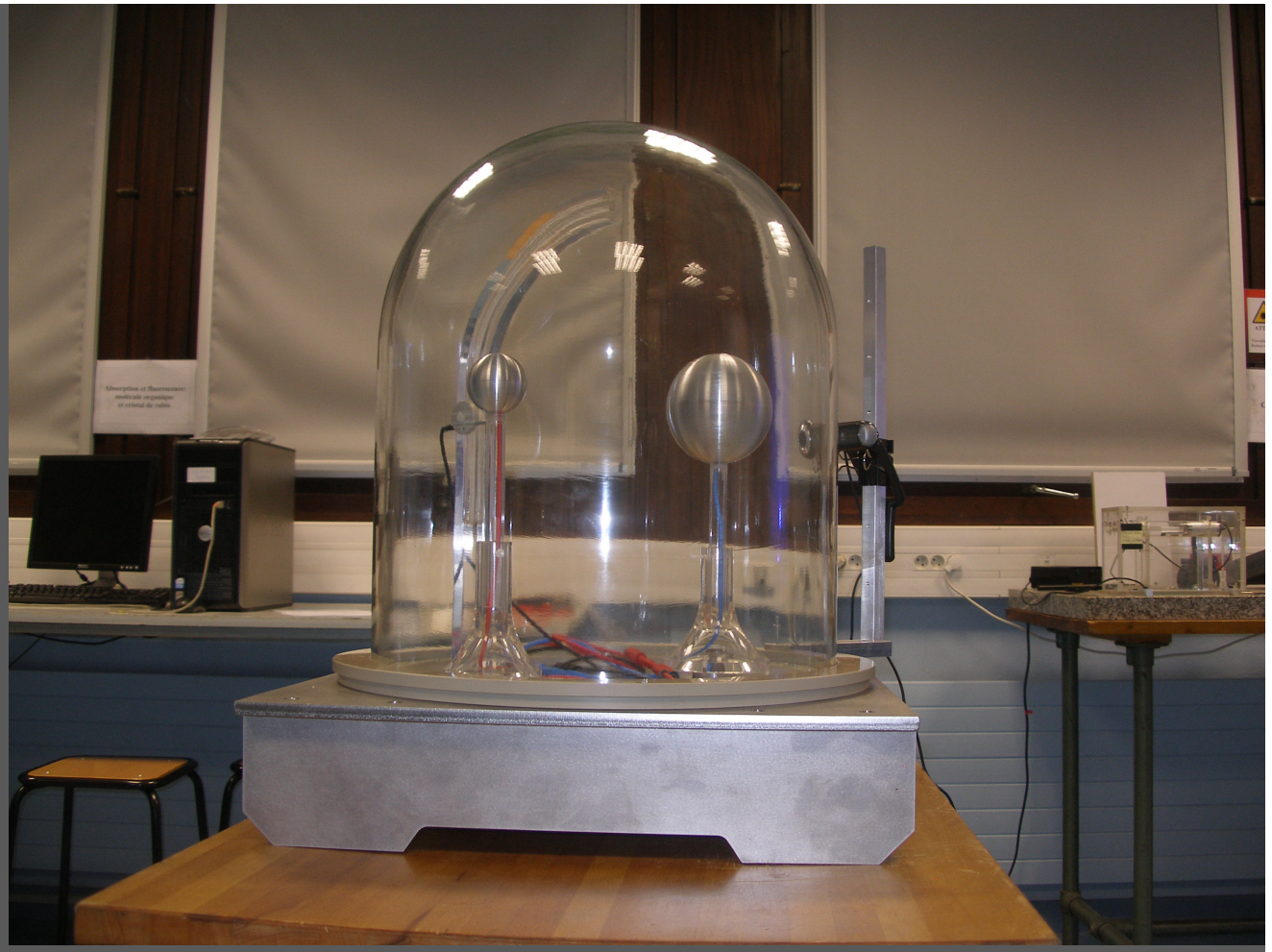
The first one for the Olympics of Physics in 1996 (with a physics professor near Lyon and his 16 years old pupils). We were ranked silver medal. I made 2 more in high schools.


This is the COST 724 - ICTP-UNESCO – NSF. It was used for practical work


Actually, it is not so different from these instruments in the science museum in Coimbra!

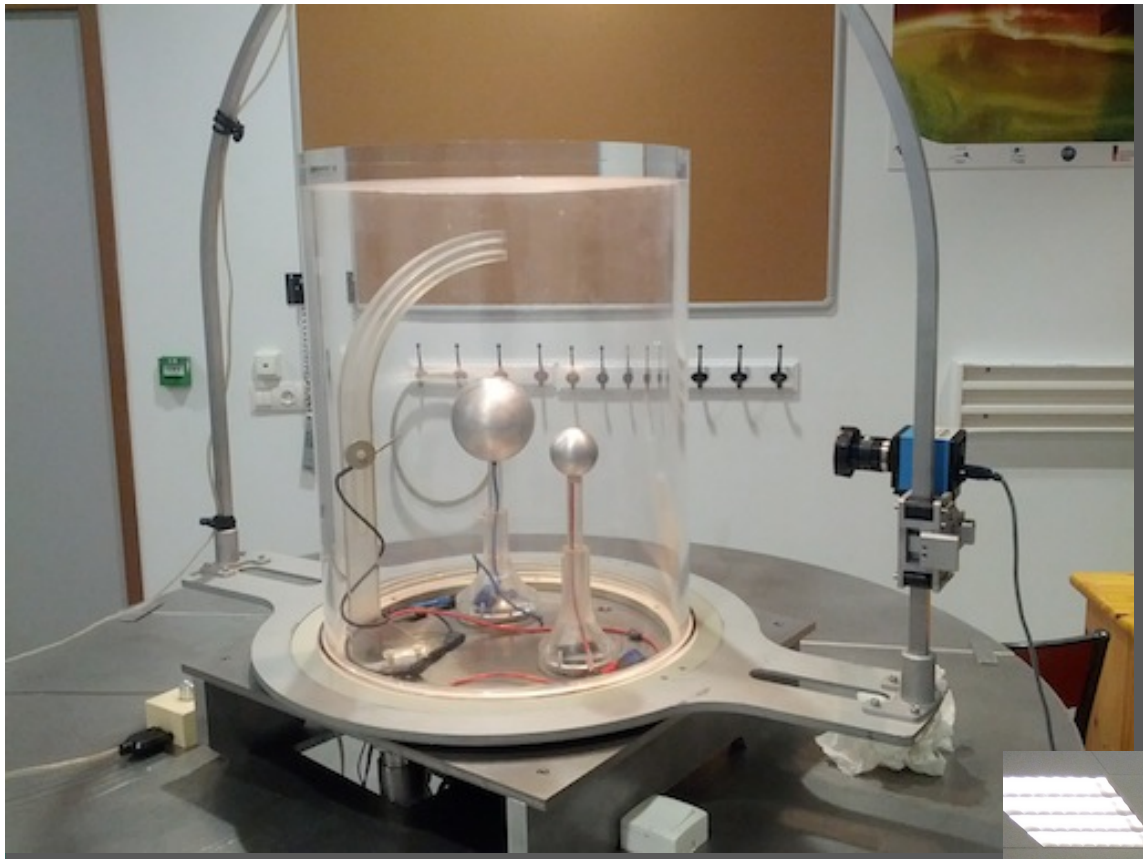
Then I realized that one could considerably improve it: The Planeterrella

# Planeterrella I (2008)



Planeterrella II (2011)

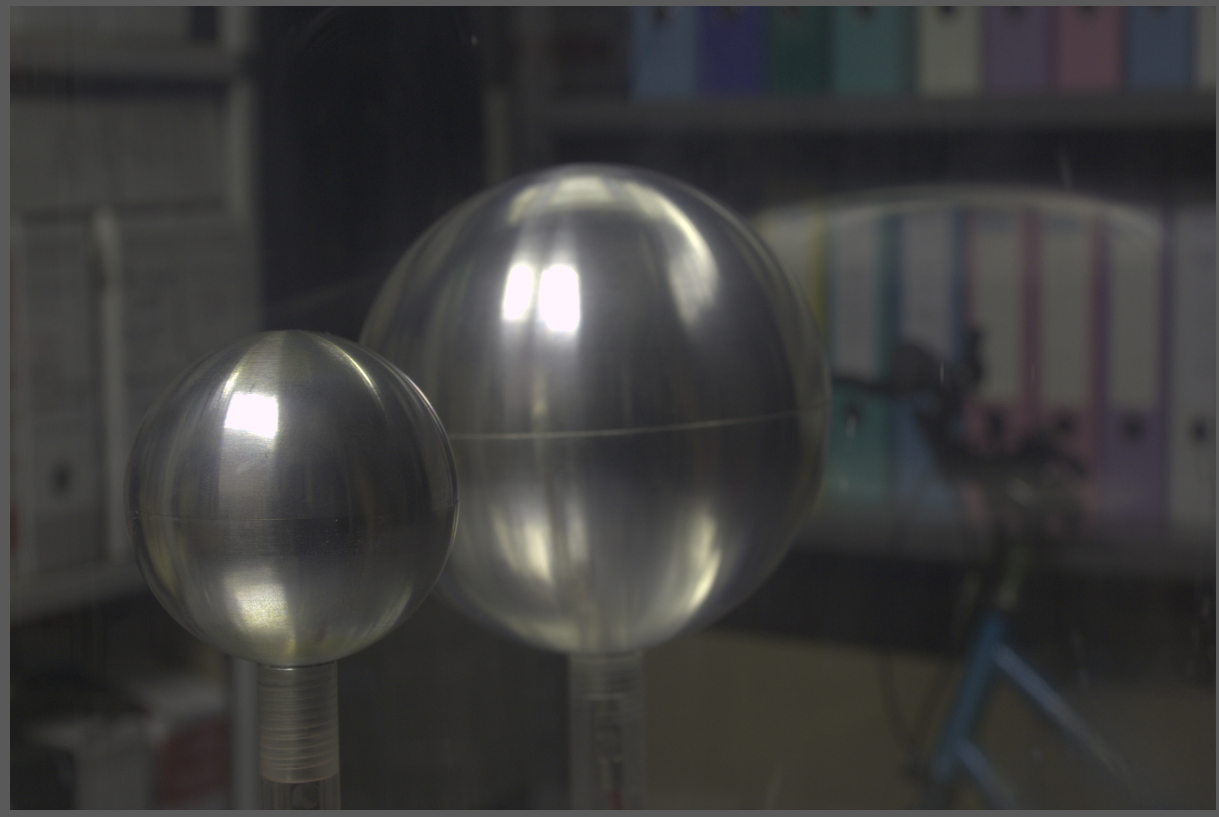
Mobile spheres, different gases, new electric plugs…



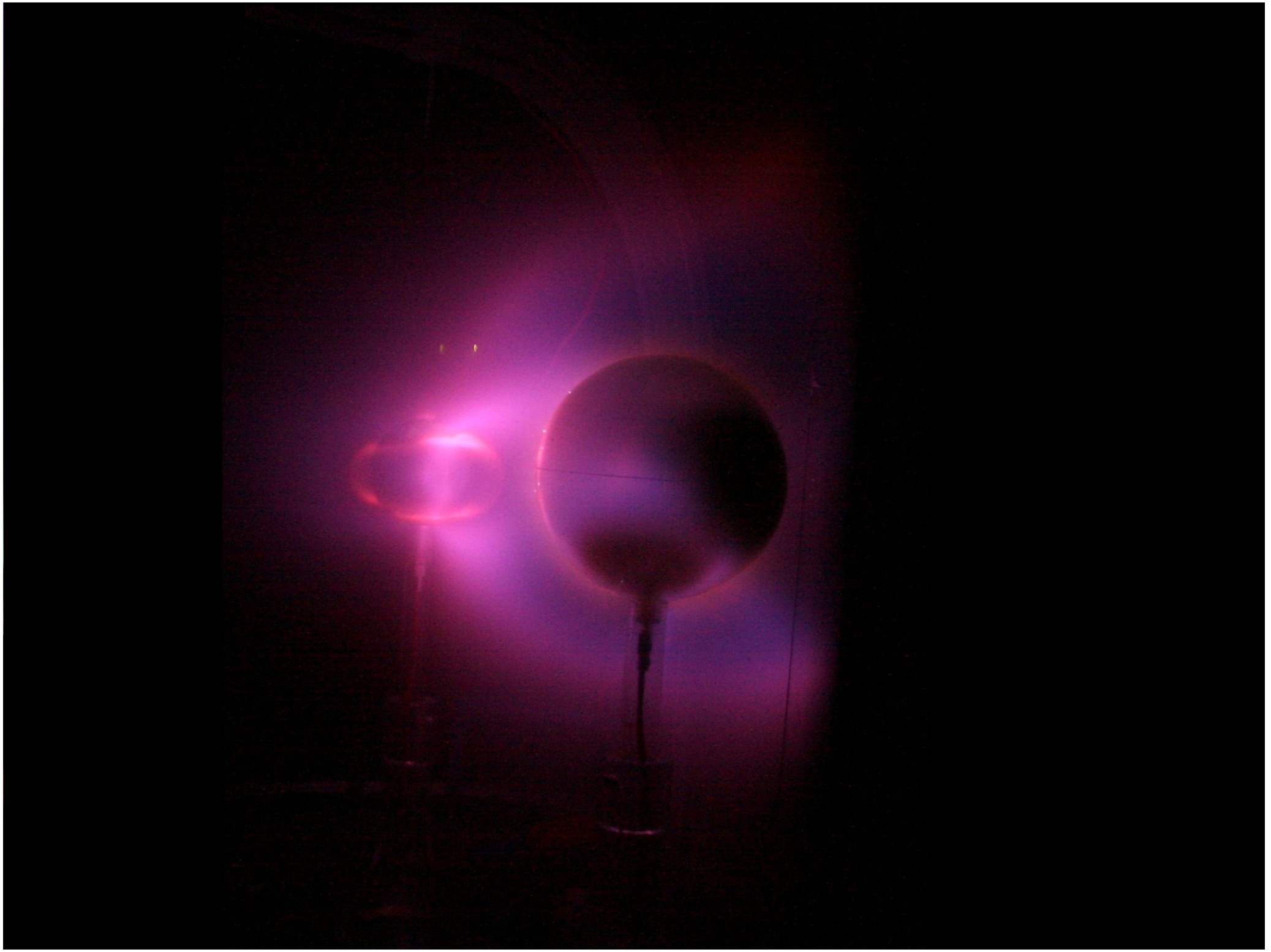
Camera, preparing the spheres to rotate (next month!) and electromagnet, glass or plexi

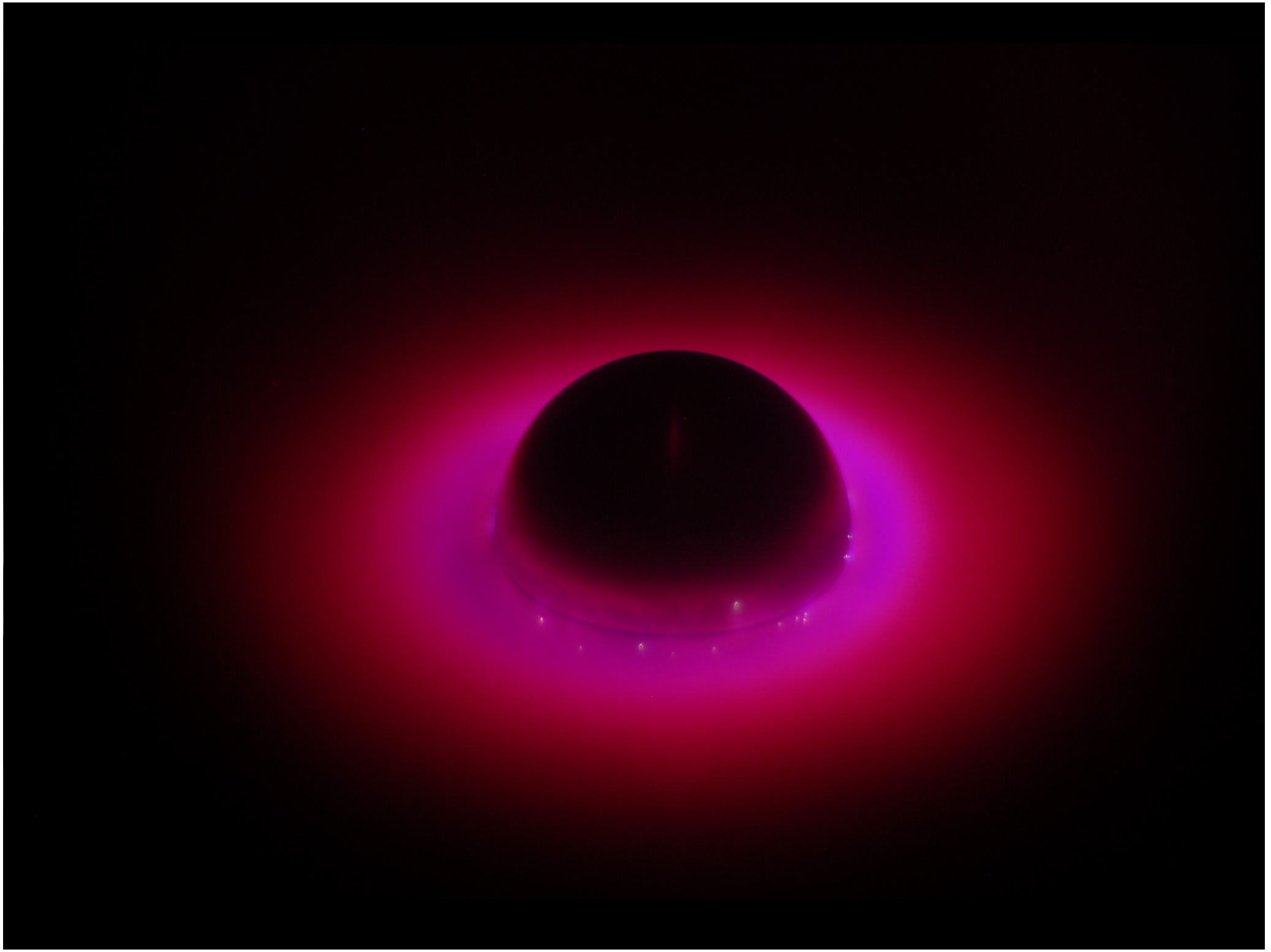
Planeterrella III

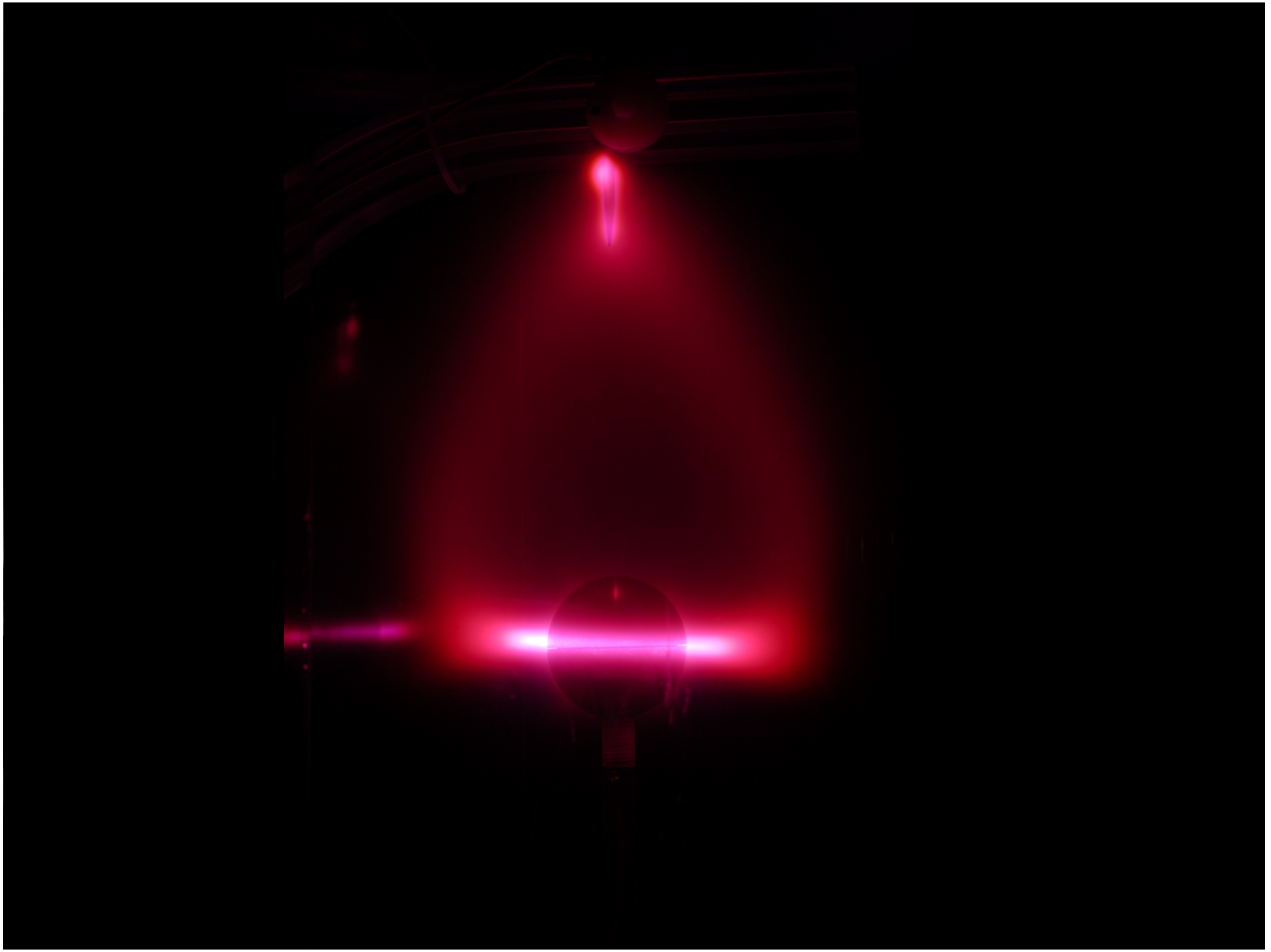
# Some wonders…

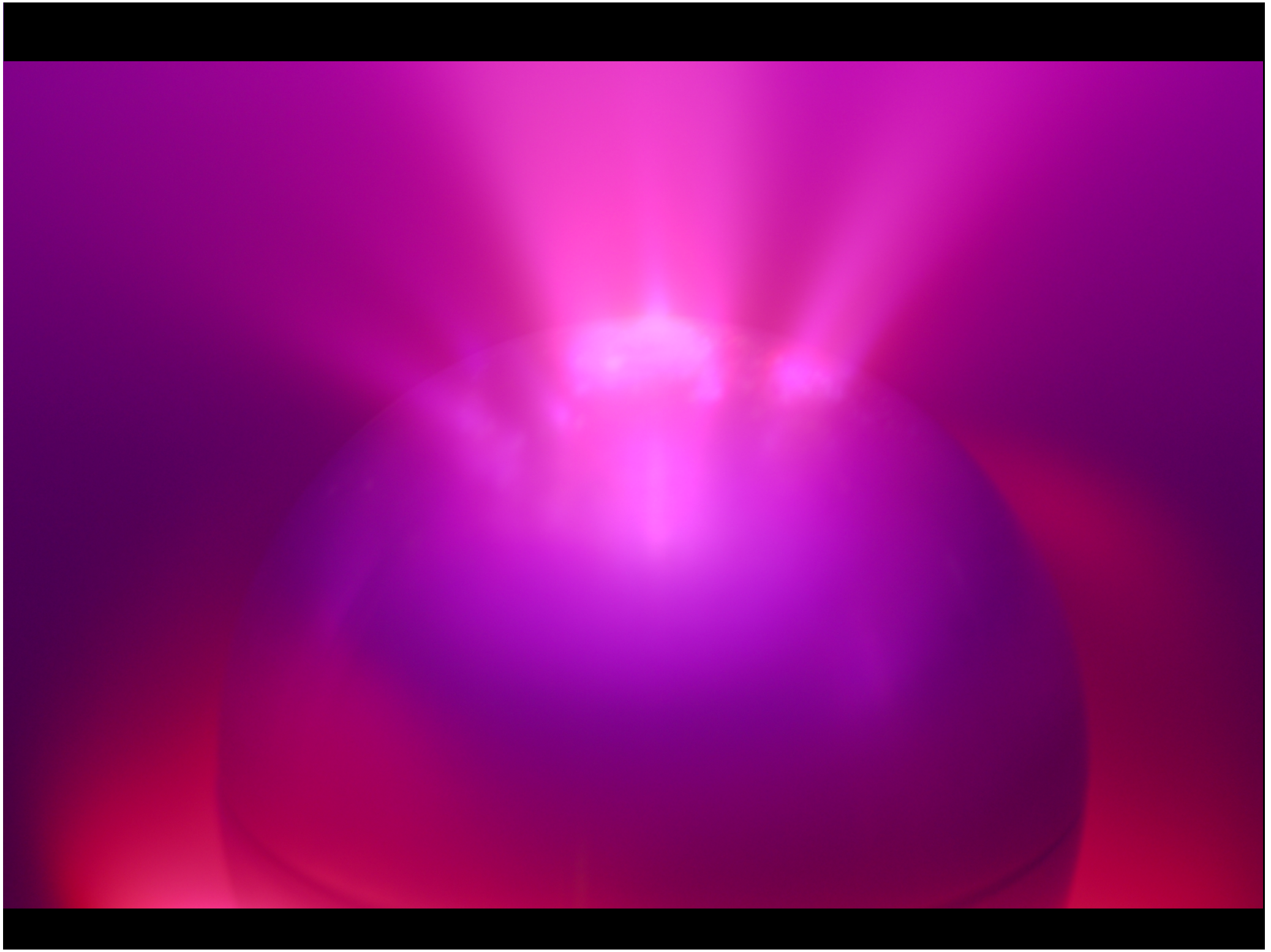


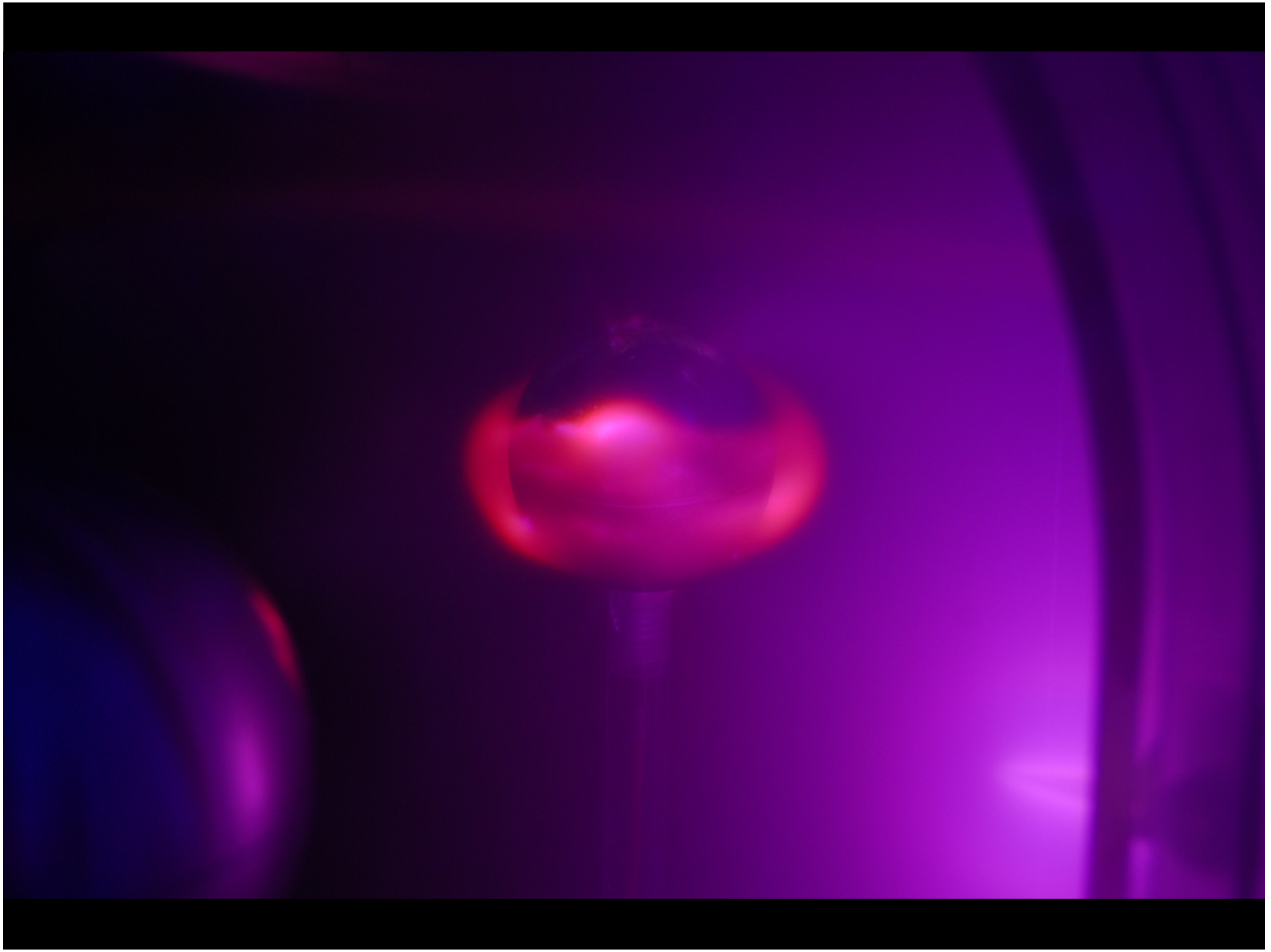
Credit: C. Simon, G. Gronoff, F. Toporenko, P. Jeanjacquot

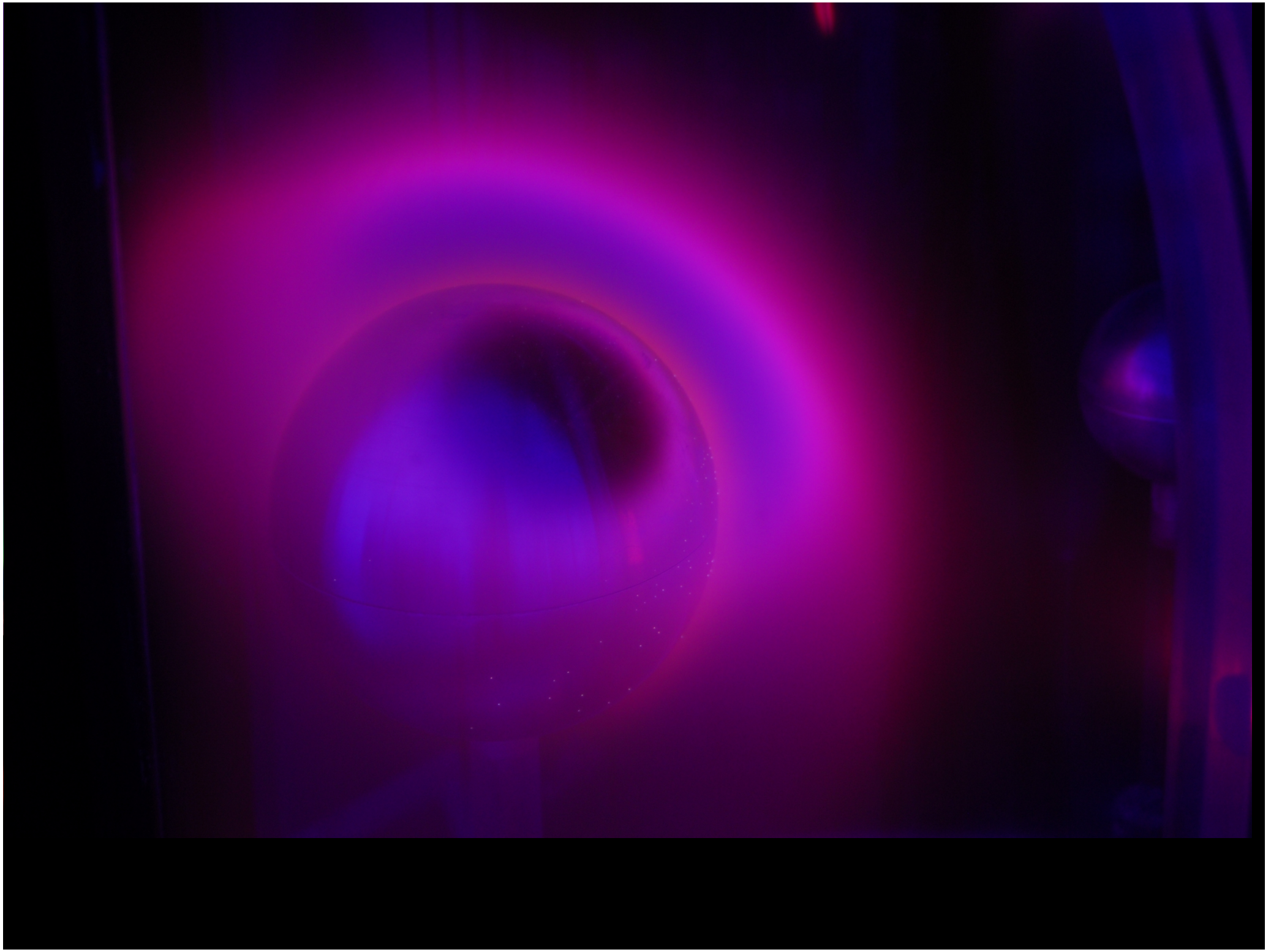


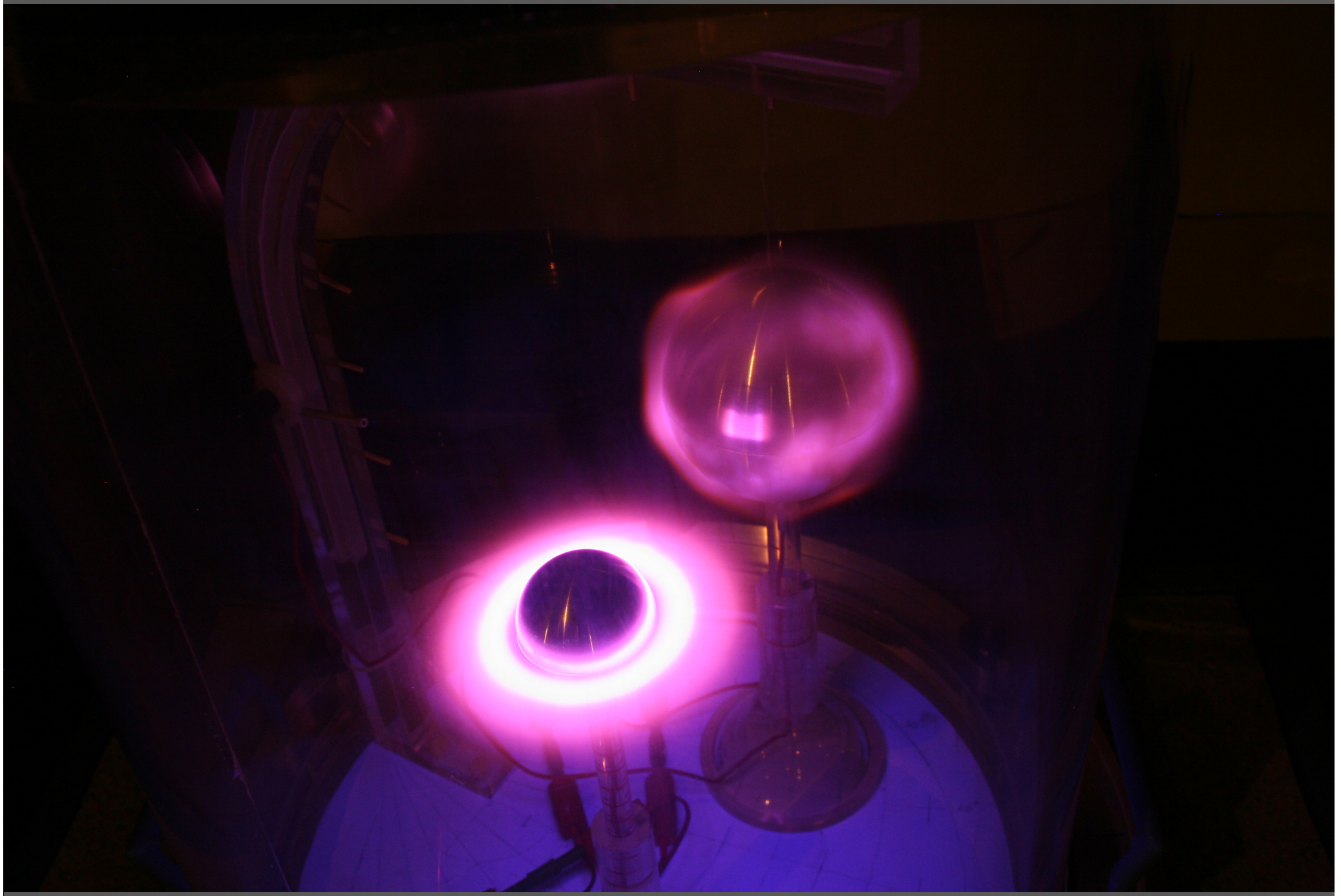


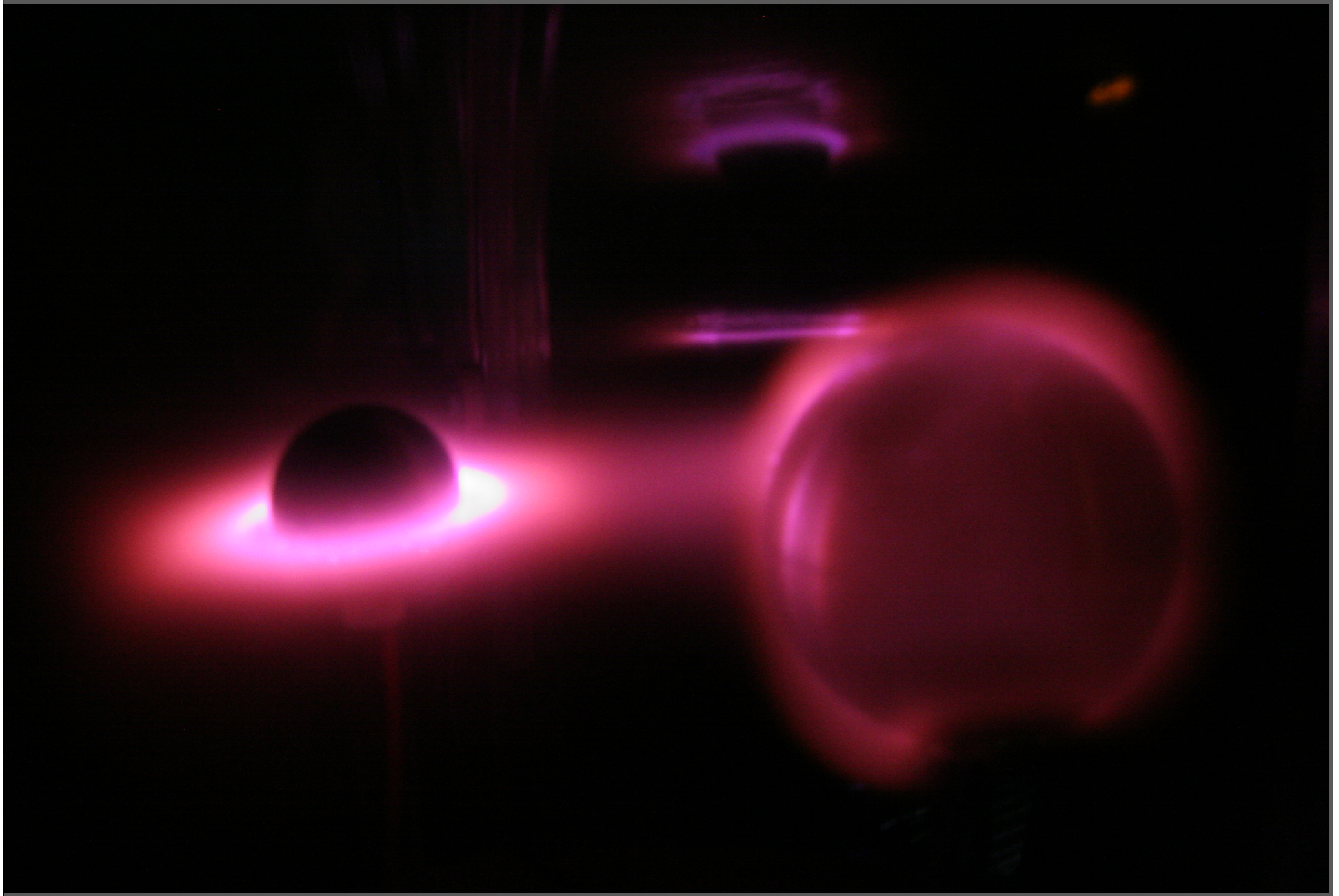


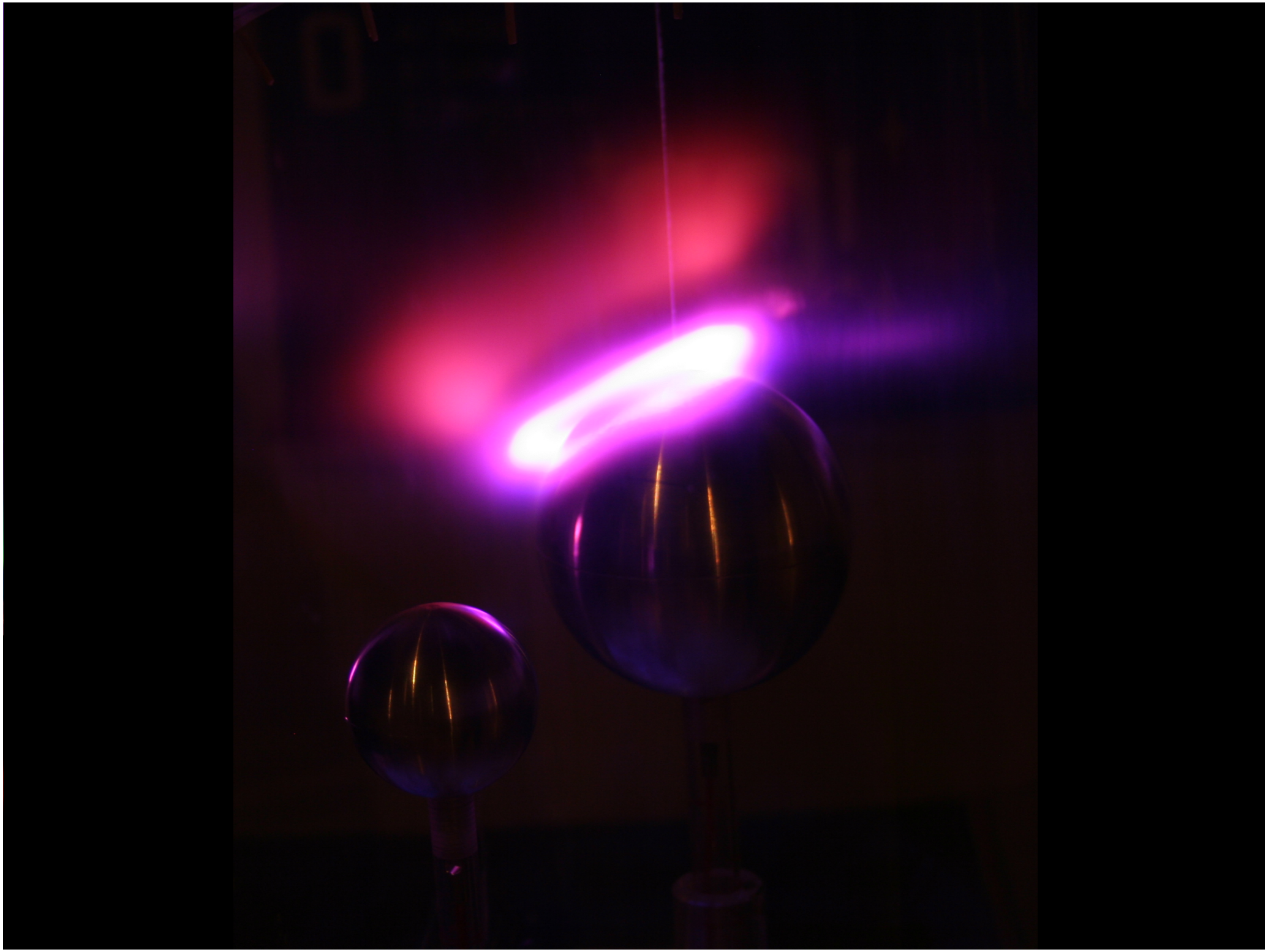


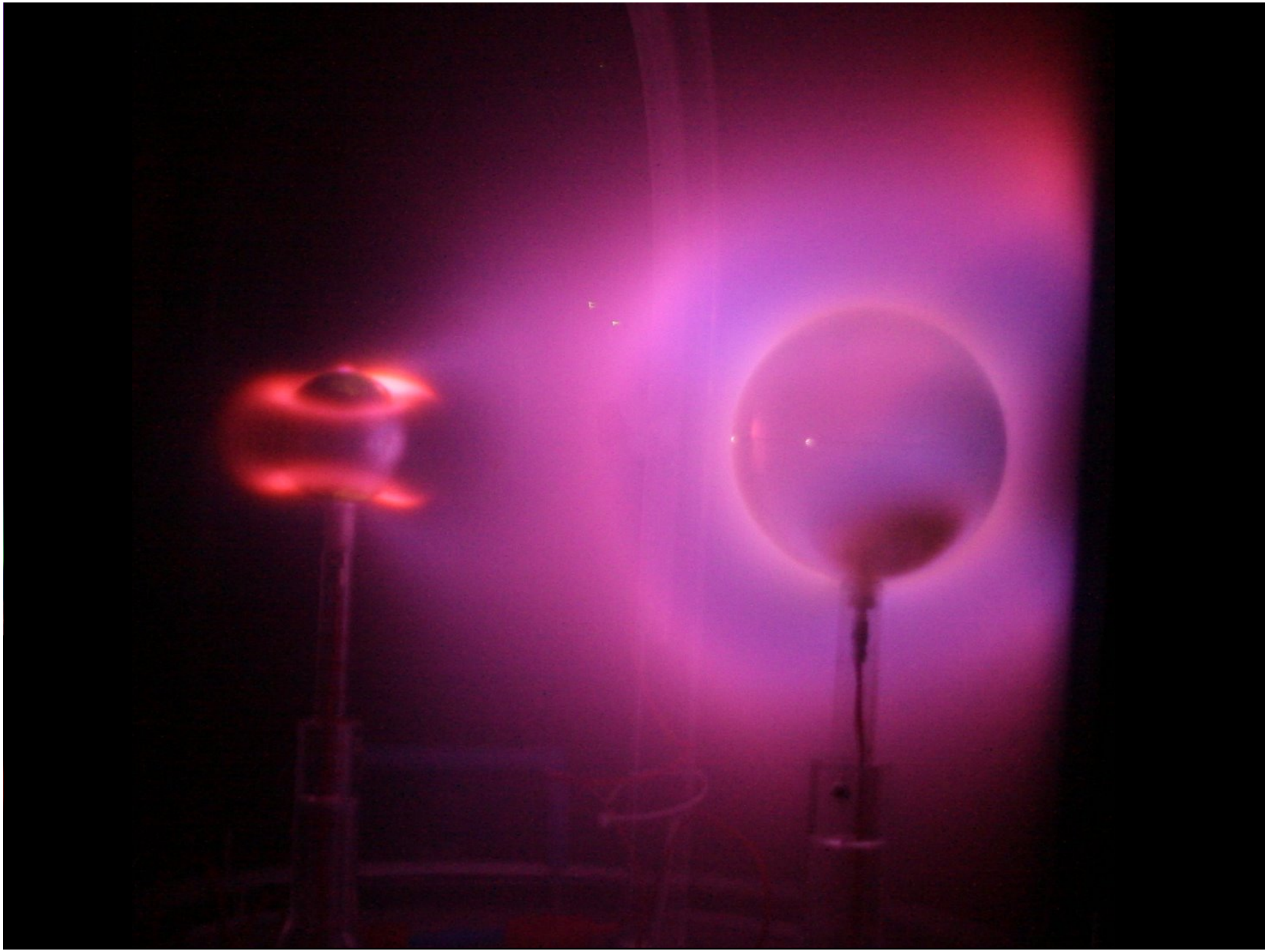


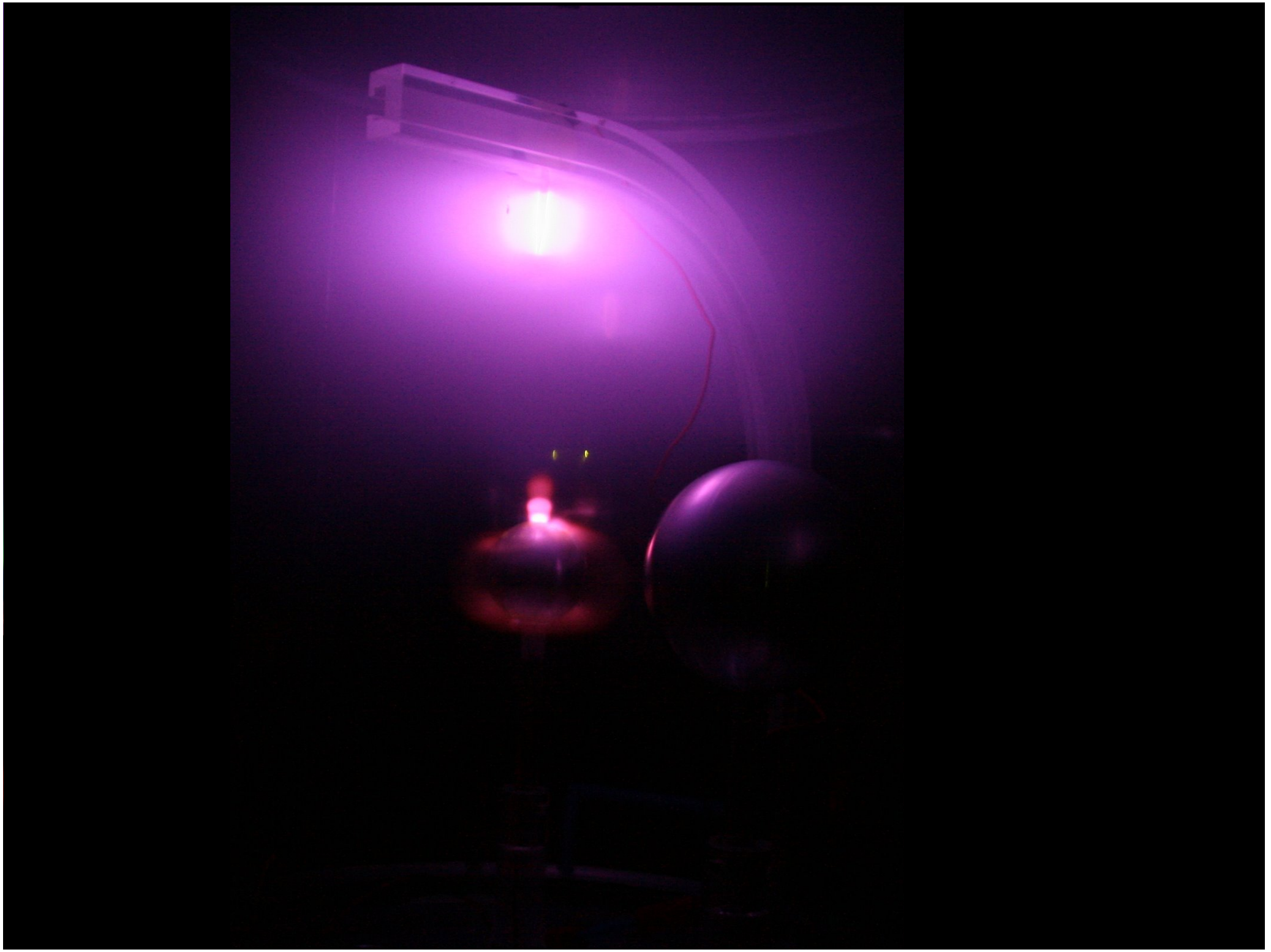












I imagined this experiment with different constraints.
Surprisingly, security was not the most difficult.

Flexibility was the main!!!

# No tool, easy to mount and unmount

50 cents coins

# Must fit in my Peugeot 206 (a small car…)

# Fundings:

- Main cost is time ≈ 400 h conception; ≈ 250 h technical work
- experimental equipment ≈ 12000 € (but…)
- In France, possibility to take money from research budget and reporting afterwhile.

# Small or big?

- Closeness to the public turned out to be important
- Feeling of being a giant
- Constrained costs and difficulty to build a large vacuum chamber
- Easy to move → easy to show (scholars, astronomical festivals, elderly houses…)

# Automated or operated?

- Security becomes much stronger if automated
- Most important and somehow surprising: looks very new and modern to the visitors used to numerical and robotic demonstrations rather than physical and manually operated experiments

# Patent or Gentleman Aggreement?

- Birkeland did not patent the Terrella…
- Public science is expensive, but the outcome of public science should remain free for the public (who funds it through taxes)

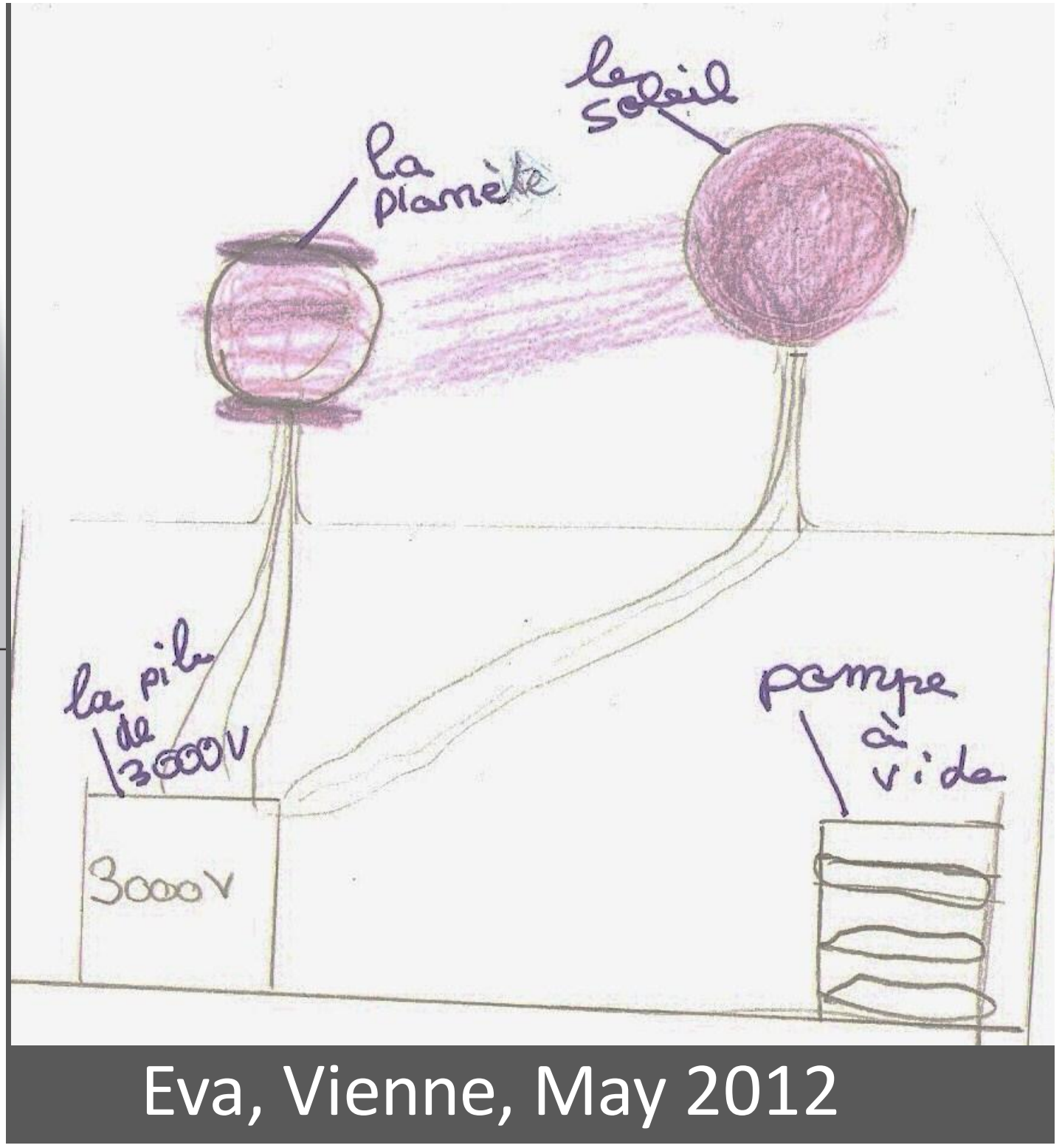
Already existing Planeterrellas: France, Belgium, UK, Ireland, Finland, Holland, Switzerland, USA-UCLA, Spain, USA (NASA, UCLA Princeton Univ.), Norway, Danmark … : 30 copies

More than 20 ongoing. An aggreement sent on Monday this week to Canada

- Several 100 thouthand of visitors
- Several millions on public TV channels in France, Spain, Germany, USA (I may not be aware of others)


# Awarded once in France, once in Switzerland (not me by the way), a European prize

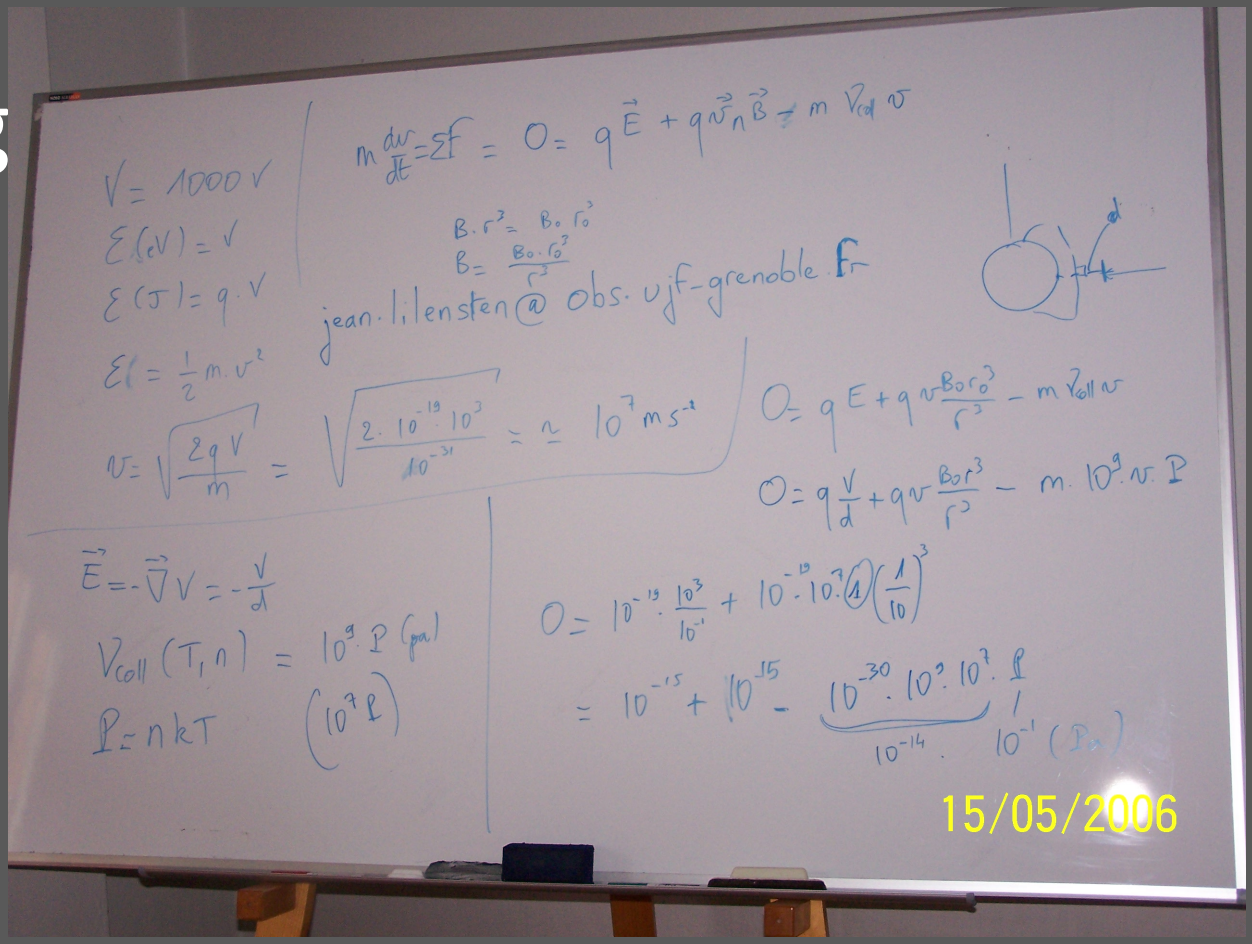
I created the Planeterrella to show auroras to people. I turned out to have many unexpected other uses…



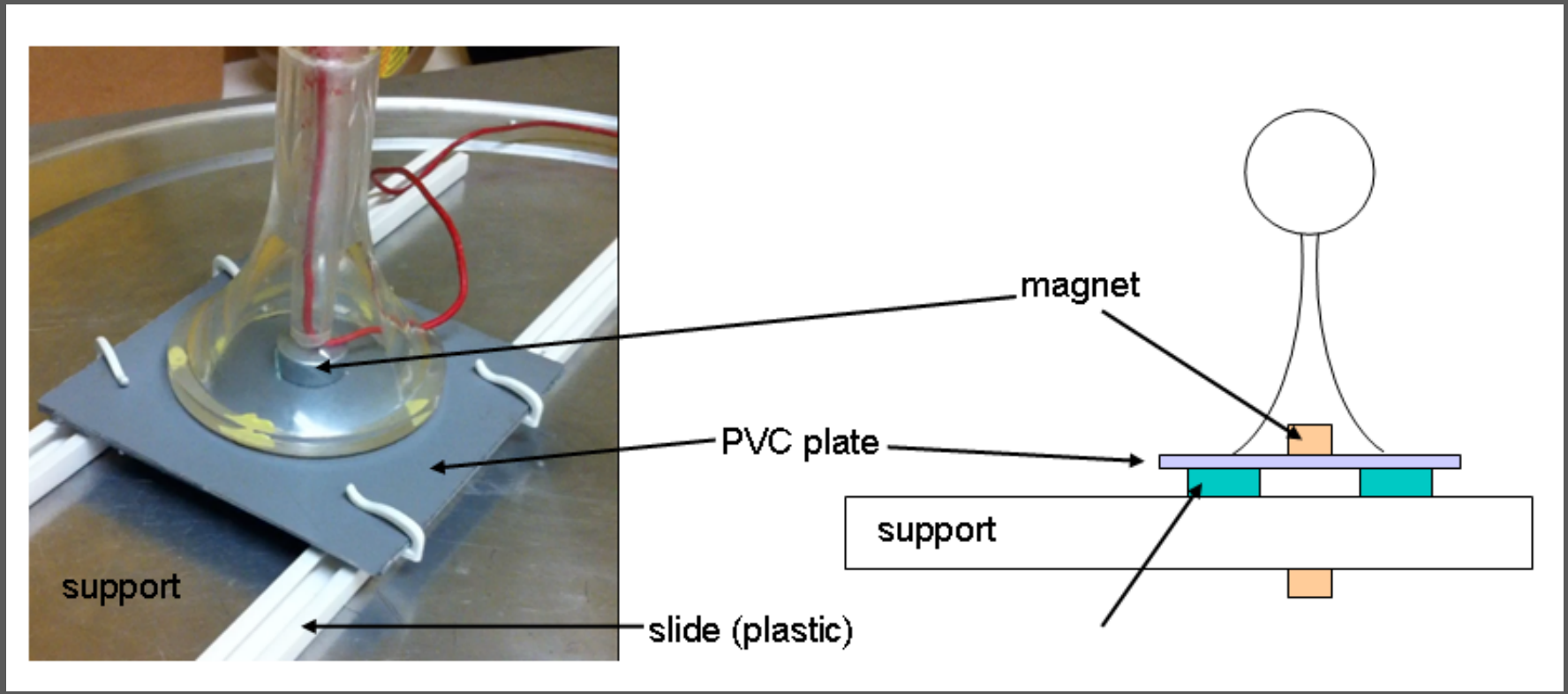

Eva, Vienne, May 2012

Pedagogy:

- Internships from highschools
- University theoretical developments
- University practical work (spectro, plasma physics…)
- Physics modeling

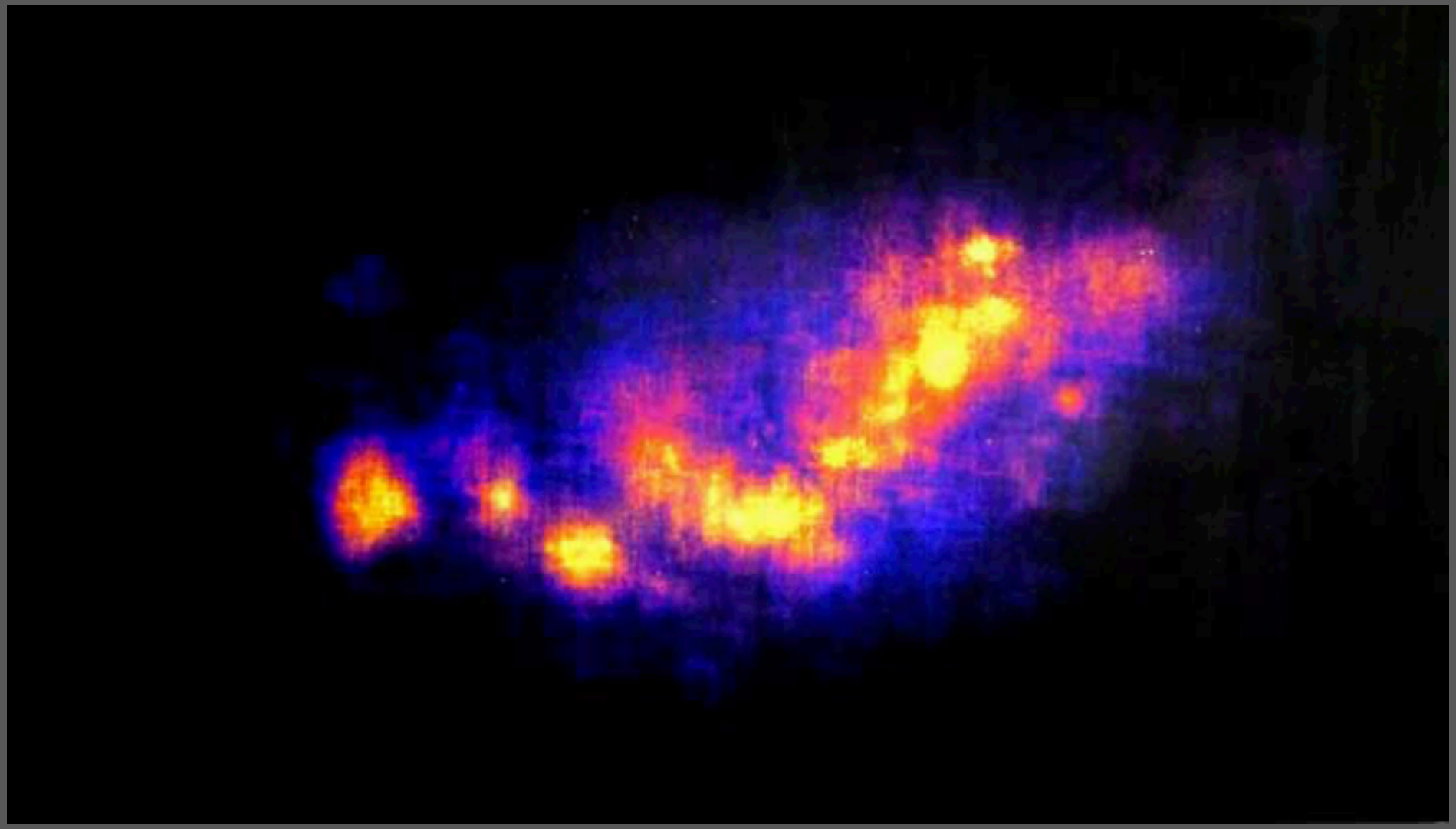


- Technological student projects (Toulouse, Grenoble, Danmark…)



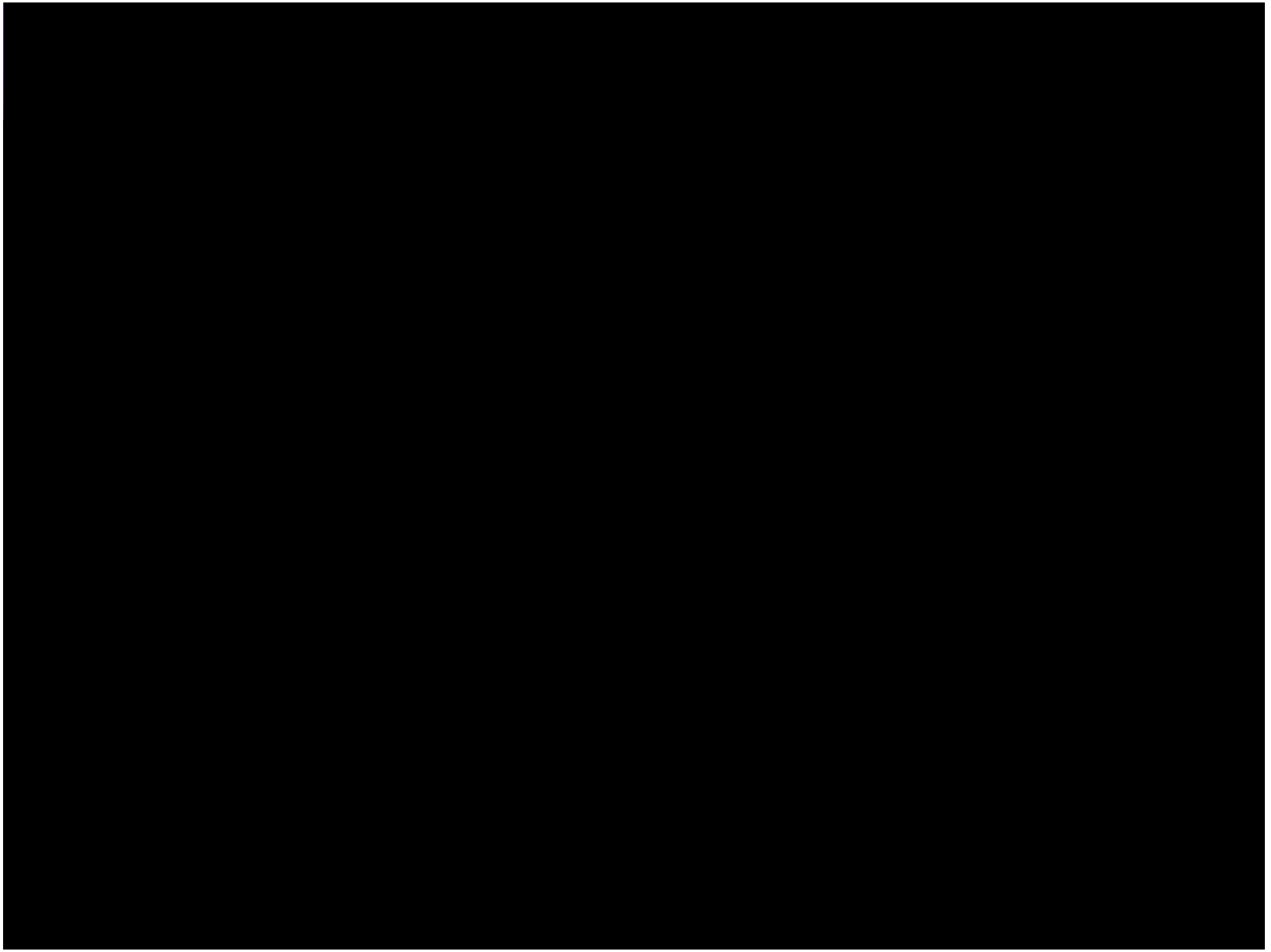
Art:

Several artists visit to get inpiration. From France, Belgium, Italy: painters, sculptors, novelists…



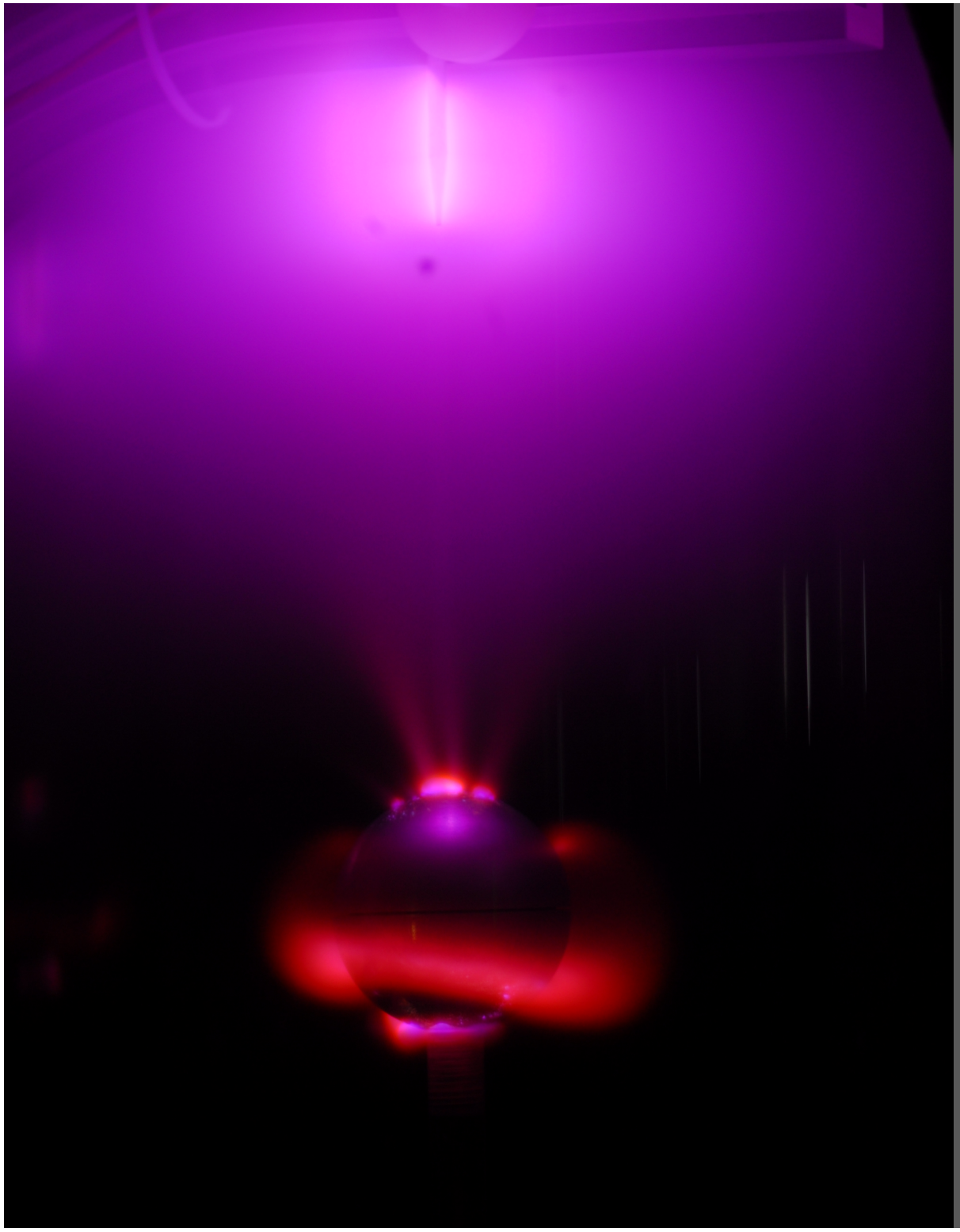
E. Régent, Nice

Played in Lyon, Caen, Geneva, Paris, Grenoble …



# Publics are enlarging:

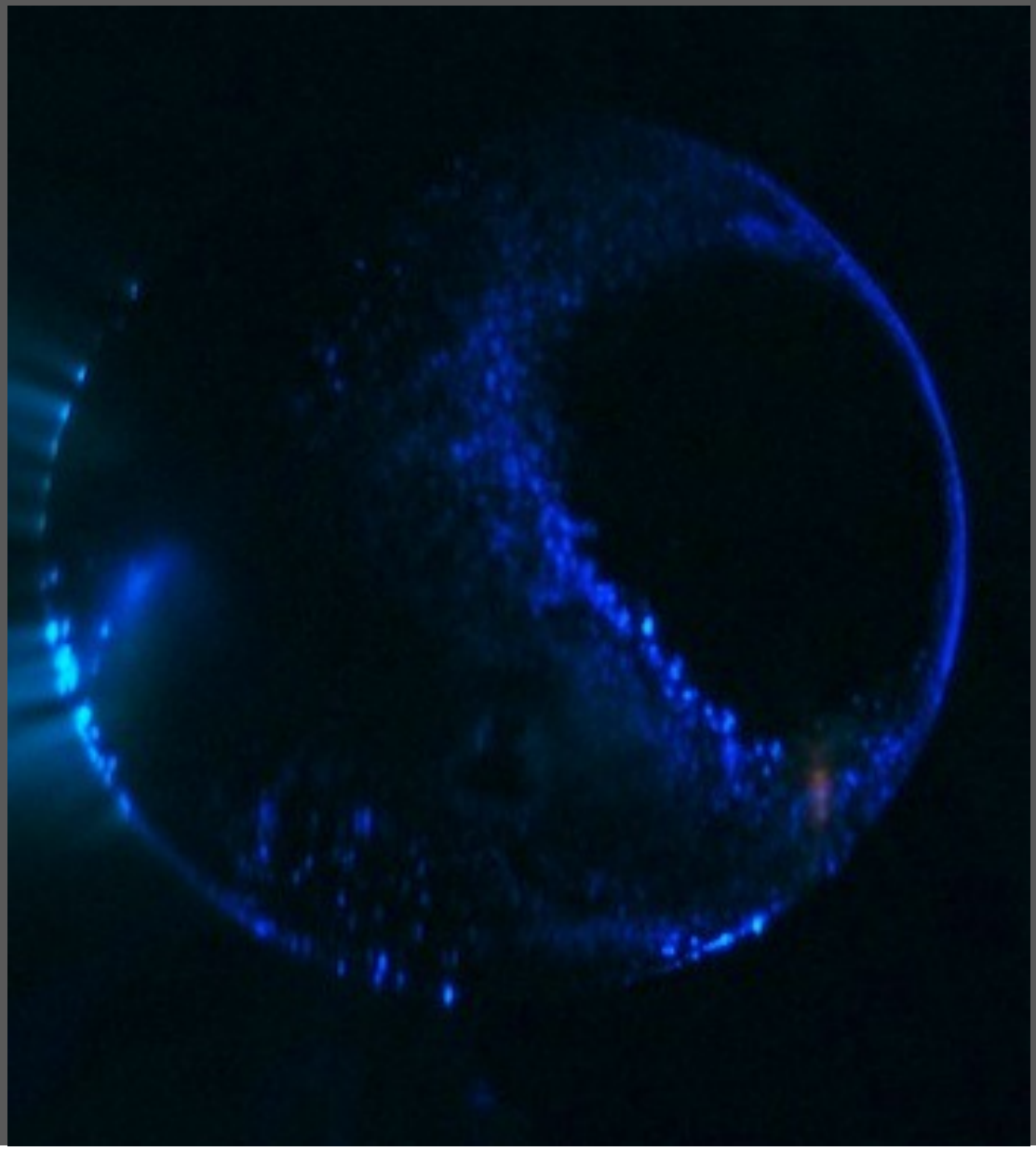
- Outreach: festivals, planetaria, teatchers, scholars…
- Artists
- Politicians !
- Journalists, photographs



And science of course!!!

-Uranus: predicting auroral ovals
- Exoplanets : 2 PhD thesis

# Discovery of the blue aurora at Mars



Blue (N2+) and green (O) at 140 km
- Red (O) at 160 km

Planetary and Space Science ∎ (∎∎∎∎) ∎∎∎–∎∎∎

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# Prediction of blue, red and green aurorae at Mars☆

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ABSTRACT

The upper atmosphere of Mars is a laboratory for better understanding the planetary atmosphere evolution, and is an example of the interaction of the solar wind with an unmagnetized planet that has only patches of crustal magnetic field. In that context, several space missions were launched to study the Martian environment and its aurorae, notably ESA's Mars Express discovered the first aurora-like structures, and more recently NASA's MAVEN, which is dedicated to understand the atmospheric escape. However, none of the existing missions have spectrometers in the visible spectral range for the observation of the upper atmosphere and the aurorae, but there are UV spectrometer which can be used to infer visible aurora emission.

The UV aurorae on Mars have a counterpart in the visible spectral range which should be detectable under the right conditions. We discuss what are the most favorable conditions to observe these aurorae discernible with the naked eye. In this paper, we simulate the Martian aurora in the visible spectral range both with an experimental setup (the Planeterrella, which we use to measure intensity with respect to the naked eye) and with a numerical ionosphere simulation model (Trans*/Aeroplanets). We show that the electron impact on $CO_2$ produces strong emissions at 412 nm and 434 nm, i.e., in the blue part of the visible spectrum which are due to the $CO_2^+$(A) Fox–Duffendack–Barker bands. The modeling of the electron transport at Mars shows that these blue emissions as well as the emissions of the 630 nm (red) and 557.7 nm (green) lines of atomic oxygen may be observable several times during a solar cycle during strong solar events.

The absence of visible spectrometers dedicated to these observations onboard existing space missions and the location of the different Martian rovers, far from the vertically aligned crustal magnetic field lines of Mars, have prevented so far the observations of such an aurora. In the foreseeable future, two missions may help observing these aurorae: the exo-Mars/Trace Gas Orbiter mission will carry a visible spectrometer which could be used to detect these events in the visible spectral range. NOMAD (Nadir and Occultation for Mars Discovery) will carry a UV–visible spectrometer in the 200–650 nm range.



## 1. Introduction

The aurora at Mars was discovered in 2005 by Mars Express (MEX). The detection (Bertaux et al., 2005a) was made by the UV channel of the SPICAM instrument. These aurorae are located close

references therein). However, these aurorae have only been studied in the UV, mainly due to lack of instrumentation able to observe the counterpart in the visible spectral range (Section 2.2). At Venus, continuous and highly variable emissions at 130.4 nm have been observed on the nightside by the Pioneer Venus Orbiter ultraviolet

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## Kék aurórák a Mars egén?

2015.05.28 07:15 *A Nap- és bolygókutatásról*

**Az emberi szem számára láthatatlan ultraibolya tartományban nemrég felfedezett marsi „sarki fények" mellett talán kék színű égi jelenségeket láthatnak majd egykor a Mars-utazók.**

Legalábbis erre az eredményre jutott szimulációk és laboratóriumi kísérletek alapján egy francia vezetésű nemzetközi kutatócsoport, közülük Opitz Andrea, aki jelenleg az MTA Wigner Fizikai Kutatóközpontjának munkatársa. Cikkük (http://dx.doi.org/10.1016/j.pss.2015.04.015) a *Planetary and Space Science* című folyóiratban jelent meg.

Ez lenne az első eset, hogy a látható fény tartományban aurórákat figyelnének meg egy a Földtől különböző bolygón. A Mars-utazásra persze még egy darabig várni kell, de a számítások azt mutatják, hogy külső bolygószomszédunk ritka légkörének felső régióiban jellemzően kék színben pompázna a jelenség, a Nap aktivitásának mértékétől függően. (Mielőtt emberek jutnának a Marsra, valószínűleg automata űrsz… ha azokra a látható tartományban is érzéke…

Ahogy a Földön, úgy a Marson is a sarki fén… űrből, a világűrből érkező nagyenergiájú ré… Mars között, hogy a mi bolygónknak van glo… Ehelyett lokálisan, egy-egy régióban mérhet… részecskék pályáját, és így a sarki fény létre… határozzák meg. Igazából a Mars esetén ne… globális mágneses tér és így a pólusok hiá…



(/sites/default/files/thumbnails/image/aurores_bleues.jpg)

May 20, 2015

## Blue Aurorae in Mars' Sky Visible to the Naked Eye

For the first time, an international team of scientists from NASA, the Institute of Planetology and Astrophysics of Grenoble Agency and Aalto University in Finland, have predicted that colorful, glowing aurorae can be seen by the naked eye on a Mars.

Visible Martian aurorae seemed possible after the SPICAM imaging instrument on-board the ESA satellite Mars Express o… Those observations were confirmed in March 2015 by the NASA-led MAVEN mission, which completed 1,000 orbits aroun… visible range. The most intense color is deep blue. As on Earth, green and red colors are also present. Several times during… eruptions, these lights are bright enough to be seen with the naked eye.

Aurorae occur when charged solar particles reach local magnetic field lines, where they enter the planetary atmosphere and excite its atoms and molecules. As they deactivate, the particles produce light …

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## Marsin ja Maan revontulet muistuttavat toisiaan

27.06.2015 Suosittele 0

*Kansainvälinen tutkijaryhmä on ensimmäistä kertaa ennustanut muualla kuin Maa-planeetalla paljain silmin nähtävien revontulien esiintymisen.*



Blue aurorae on Mars: an artist interpretation of what aurorae may look like as seen by the NASA Curiosity rover, were it close to magnetic anomalies on Mars. Photomontage (c) NASA/JPL-Caltech/MSSS and (c) CSW/DB

Marsin ylempi kaasukehä saattaakin muistuttaa Maan ilmakehää enemmän kuin tähän asti on luultu. Tutkijat osoittivat, että Marsin ylempi kaasukehä hehkuu sinisenä riippuen auringon aktiivisuudesta. Valoilmiöt ovat paljain silmin nähtävissä voimakkaiden auringonpurkausten jälkeen. Tulos saatiin aikaan numeeristen simulaatioiden ja revontulisimulaattorina toimivan Planeterella-laboratoriokokeen avulla. Tutkimus julkaistiin johtavassa planetologia-alan julkaisussa Planetary and Space Sciencessa 26. toukokuuta.

– Tutkimus osoittaa, että revontulien voimakkain väri on syvänsininen. Myös vihreää ja punaista väriä esiintyy, kuten Maassa. Mars-planeetan punaisella magnetiltä kävelevä astronautti voisi yläpuolellaan

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Université Joseph Fourier GRENOBLE

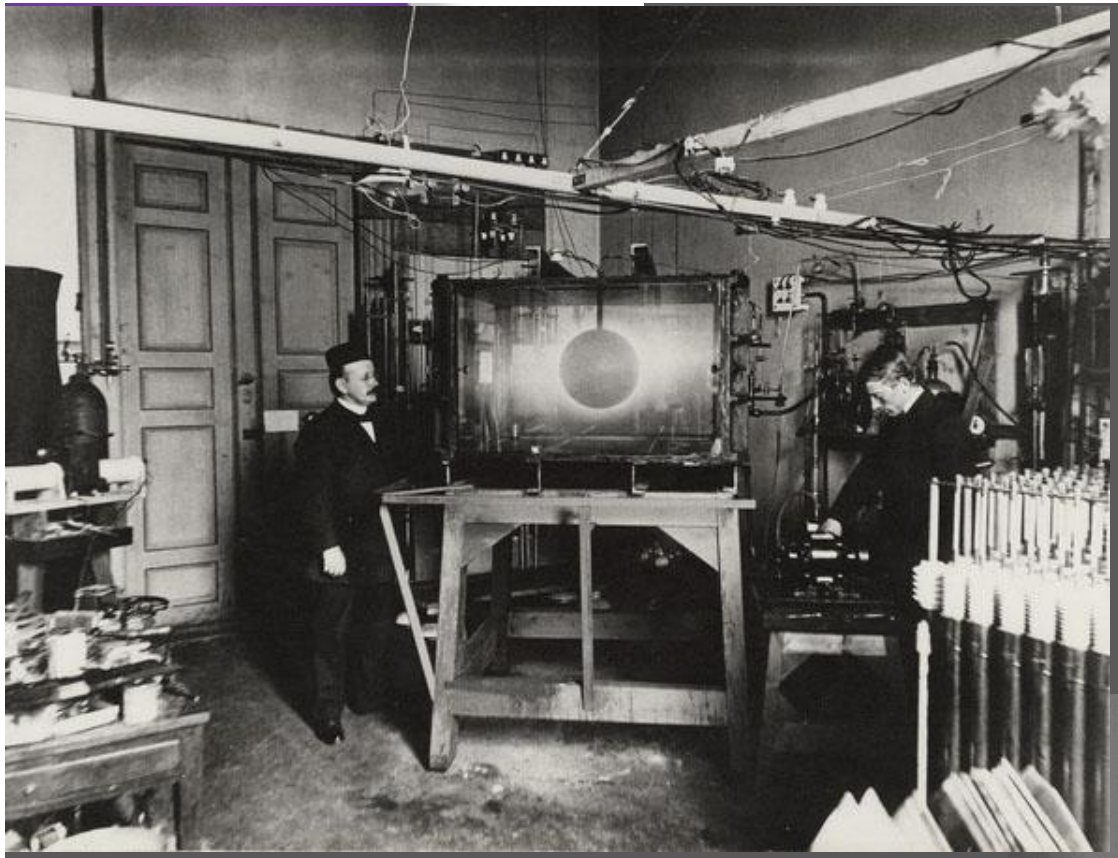
COMMUNIQUÉ DE PRESSE I GRENOBLE I 26 mai 2015

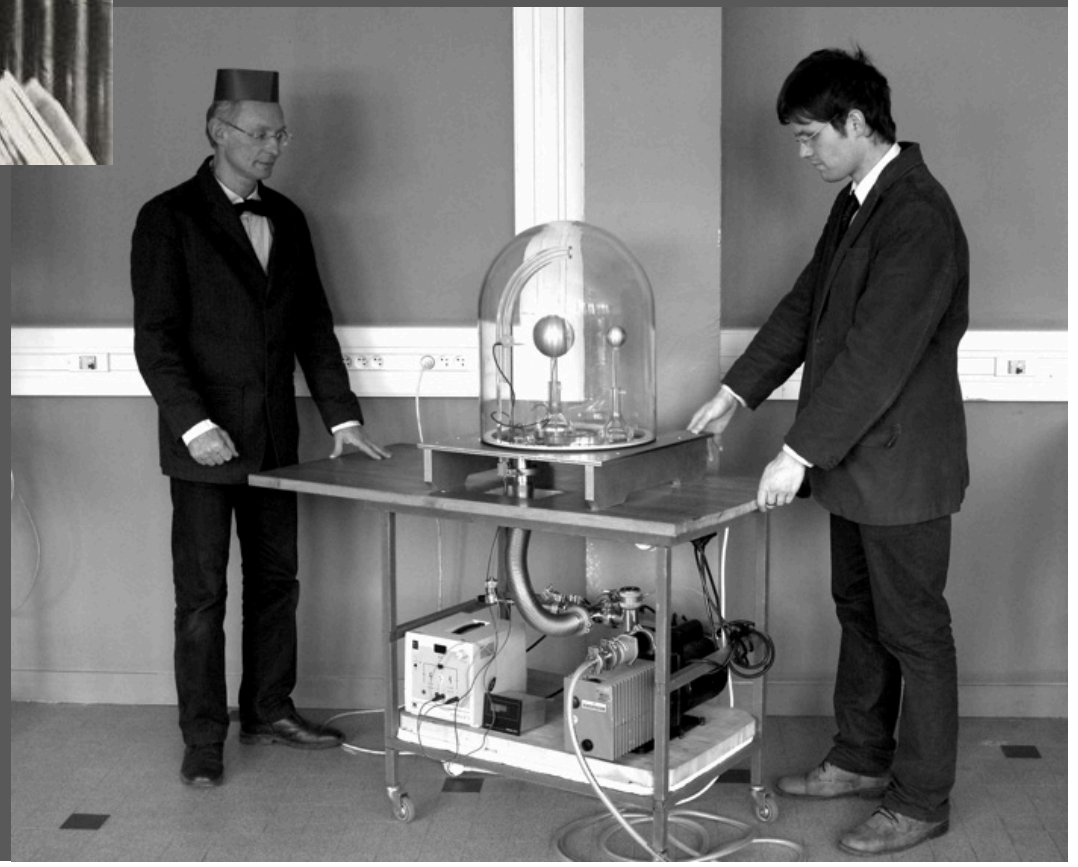
## Des aurores bleues dans le ciel de Mars

**Une équipe composée de scientifiques de l'Institut de planétologie et d'astrophysiq… Grenoble[1] (IPAG - CNRS/Université Joseph Fourier), de la NASA, de l'ESA … l'Université d'Aalto en Finlande, a prédit pour la première fois l'existence d'au… visibles à l'œil nu sur une autre planète tellurique que la Terre : Mars. Ce résultat … obtenu grâce à des simulations numériques et à un simulateur d'aurores : la Planete… Il est publié dans la revue *Planetary and Space Science* du 26 mai 2015.**

Les aurores polaires se produisent lorsque des particules chargées d'origine solaire, conduites … champ magnétique local, pénètrent dans une atmosphère planétaire et excitent les atomes … molécules de l'atmosphère. Lorsque la désexcitation s'accompagne d'émission lumineuse, il se … une aurore. Sur Terre, les aurores sont essentiellement vertes ou rouges (excitation de l'ox… atomique), mais aussi mauves (excitation de l'azote moléculaire).

# Um dia uma Planeterrella em Coimbra?





Obrigado! Muito obrigado pelo seu convite e sua escuta!