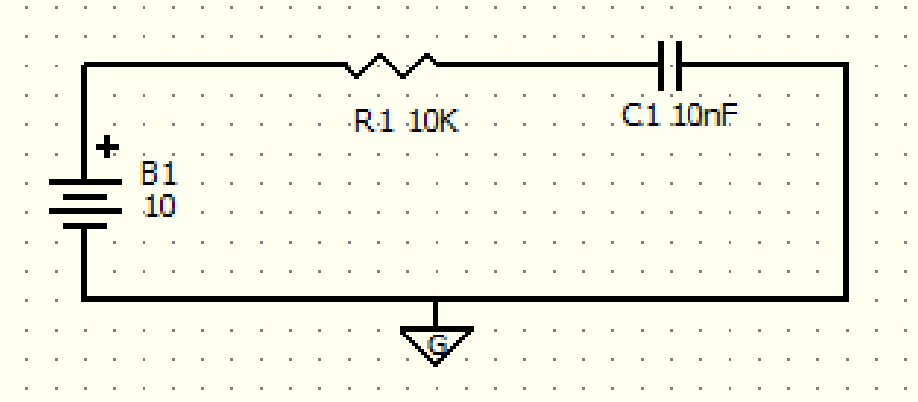
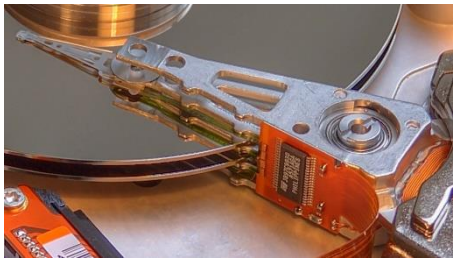
Physics 401: Electricity & Magnetism I

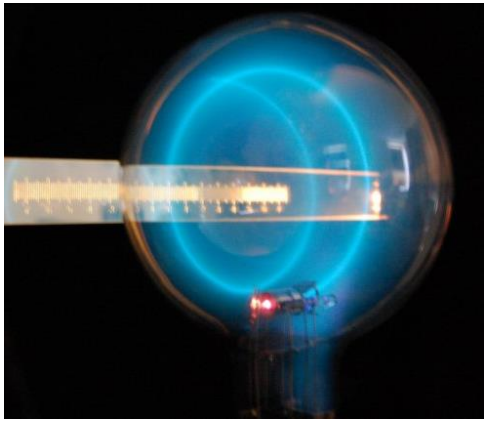
[i.e. electrostatics, magnetostatics, vector calculus]





[wikipedia.org]

[nanotechetc.com]



[ixnovi.people.wm.edu]

[Thywissen group, U. of Toronto]

[J-lab accelerator]

Instructors

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Aubin: Tuesday 3-4 pm

Course Objectives

- Review & explore **vector calculus.**
- Theory of **electrostatics** and **magnetostatics**.
- Briefly introduce **electrodynamics.**

The course will cover the following topics:

- Vector calculus, divergence, curl, Laplacian.
- Boundary value problems.

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- Magnetization, bound currents, the auxiliary field.
- Basic electrodynamics, Faraday's law, inductance.

Applications

- Calculate electric fields of **complex charge and conductor arrangements** (capacitors, electrostatic lenses, beam steerers).

[Wikimedia commons]

[J-lab accelerator]

[nanotechetc.com]

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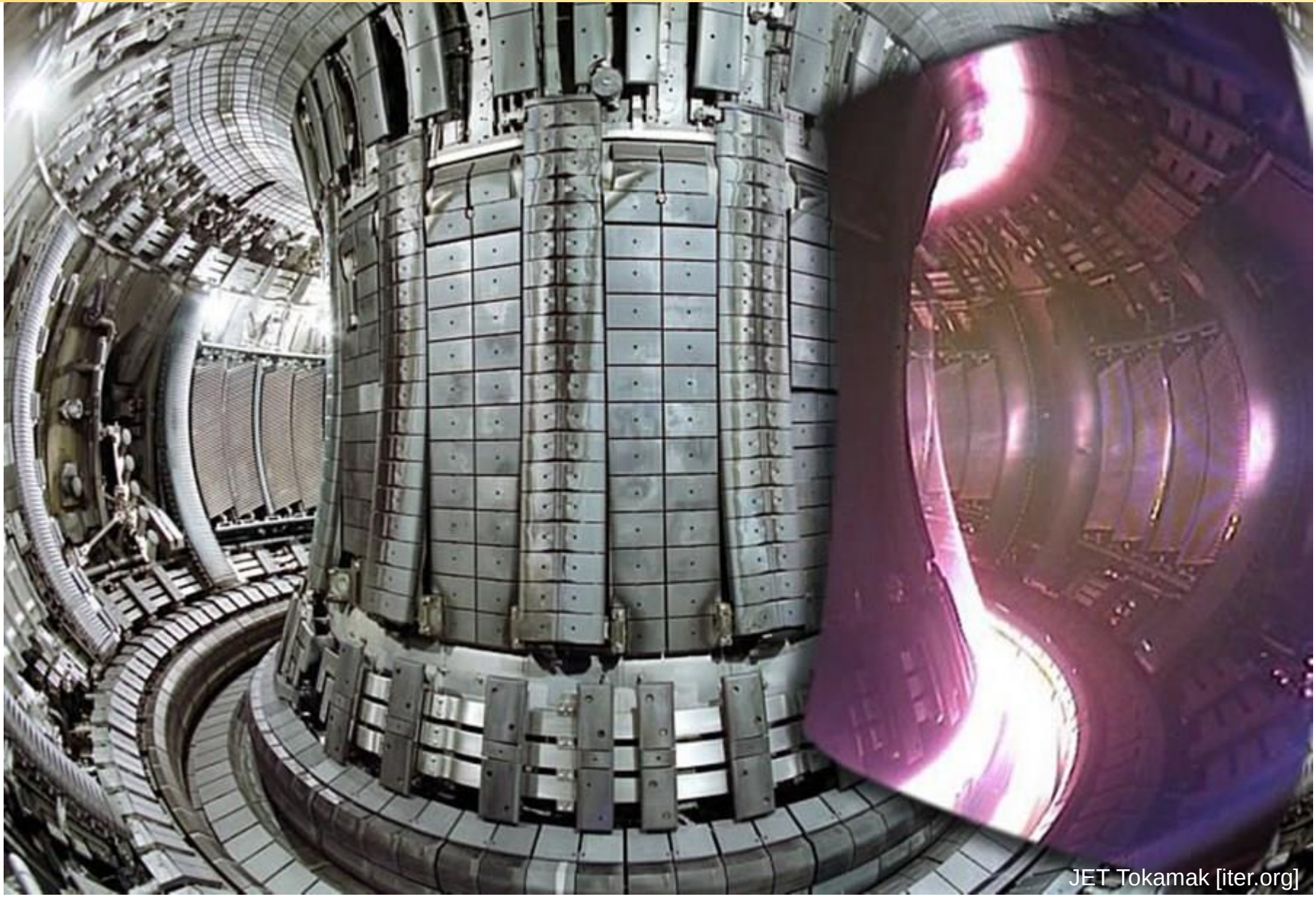
- Calculate magnetic fields and inductance for various **current distributions** (i.e. **coils**, dipoles).

- Calculate behavior of quasi-DC **circuits**
  … and some RF circuits !!!

[Thywissen group, U. of Toronto]

Fusion: Tokamak



JET Tokamak [iter.org]

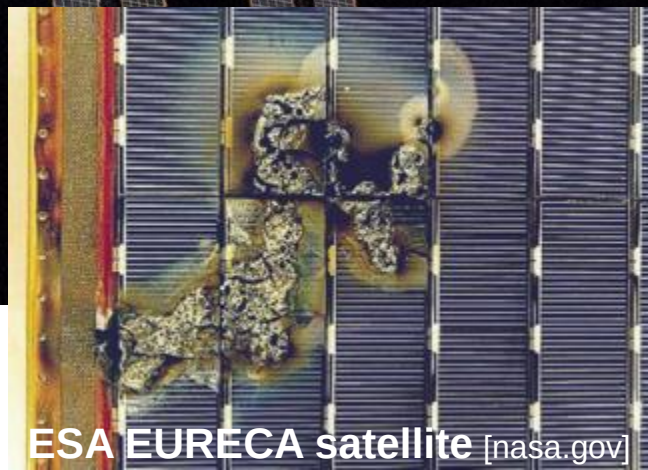
Weather: Lightning

[https://www.distancecme.com/lightning-strike/]

Weather: Lightning

Satellites: Static Electricity

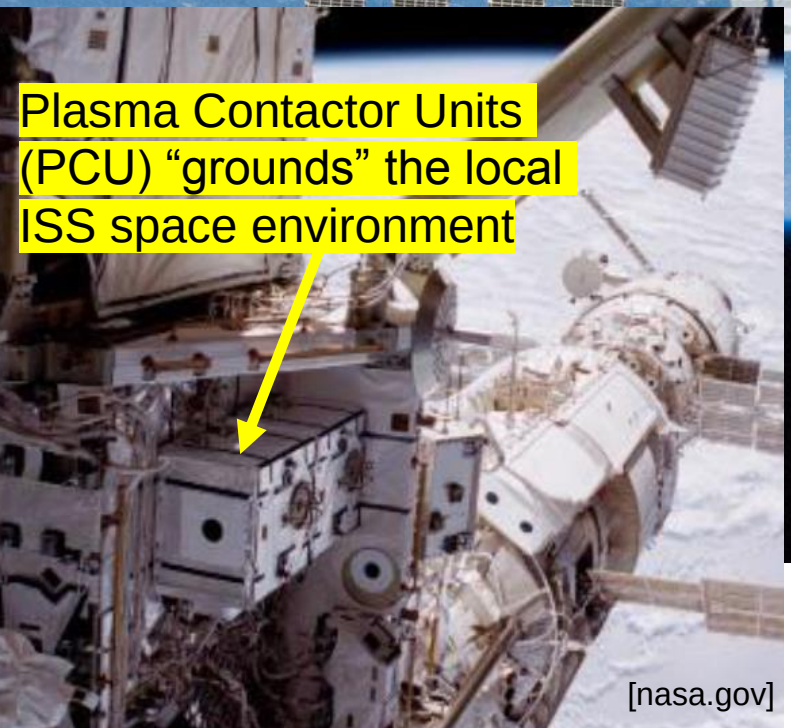
International Space Station [nasa.gov]

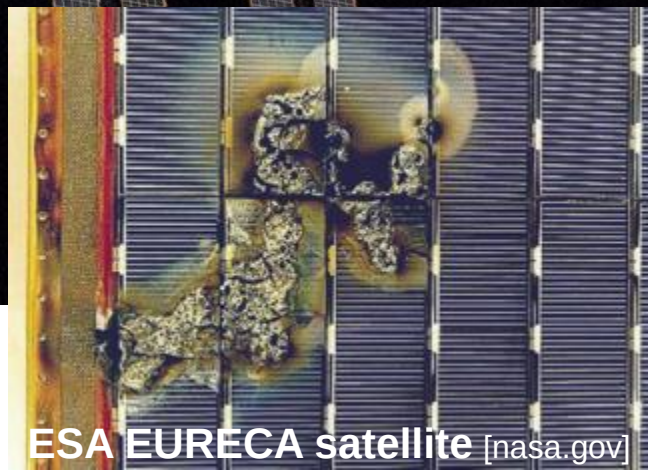


ESA EURECA satellite [nasa.gov]

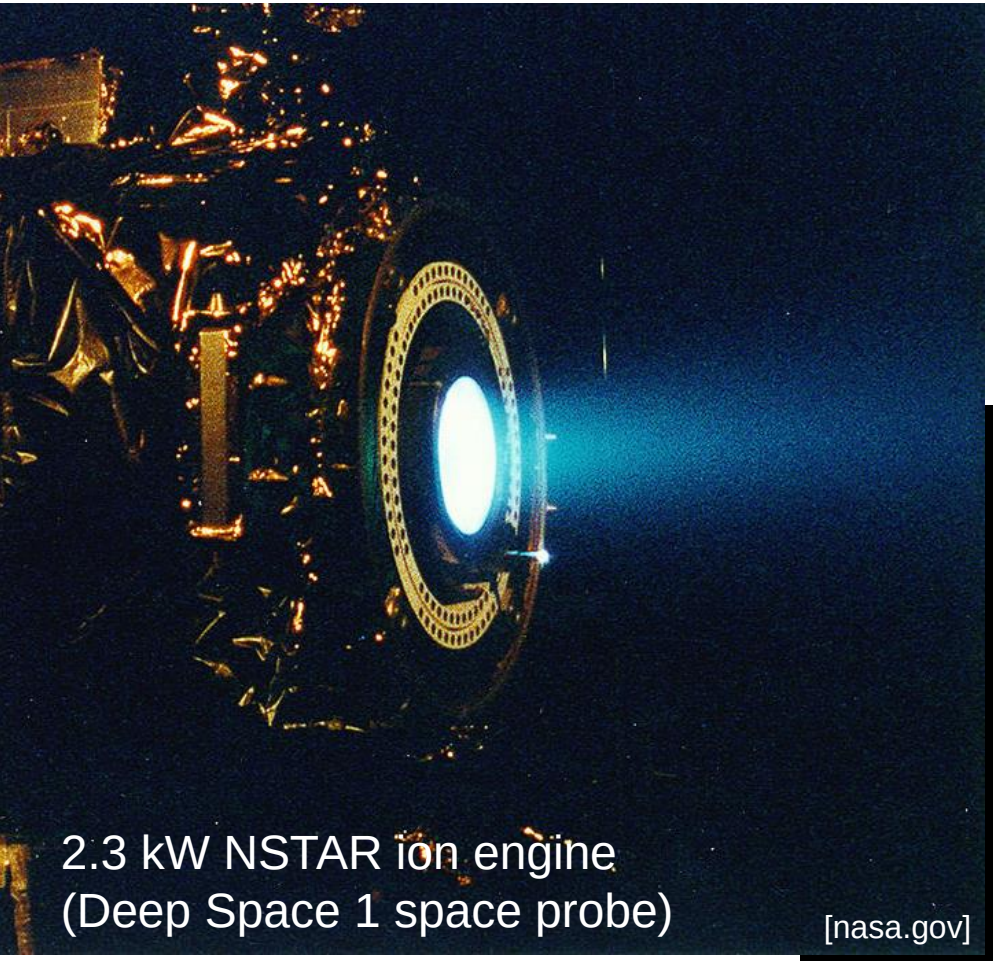
Satellites: Static Electricity

International Space Station [nasa.gov]



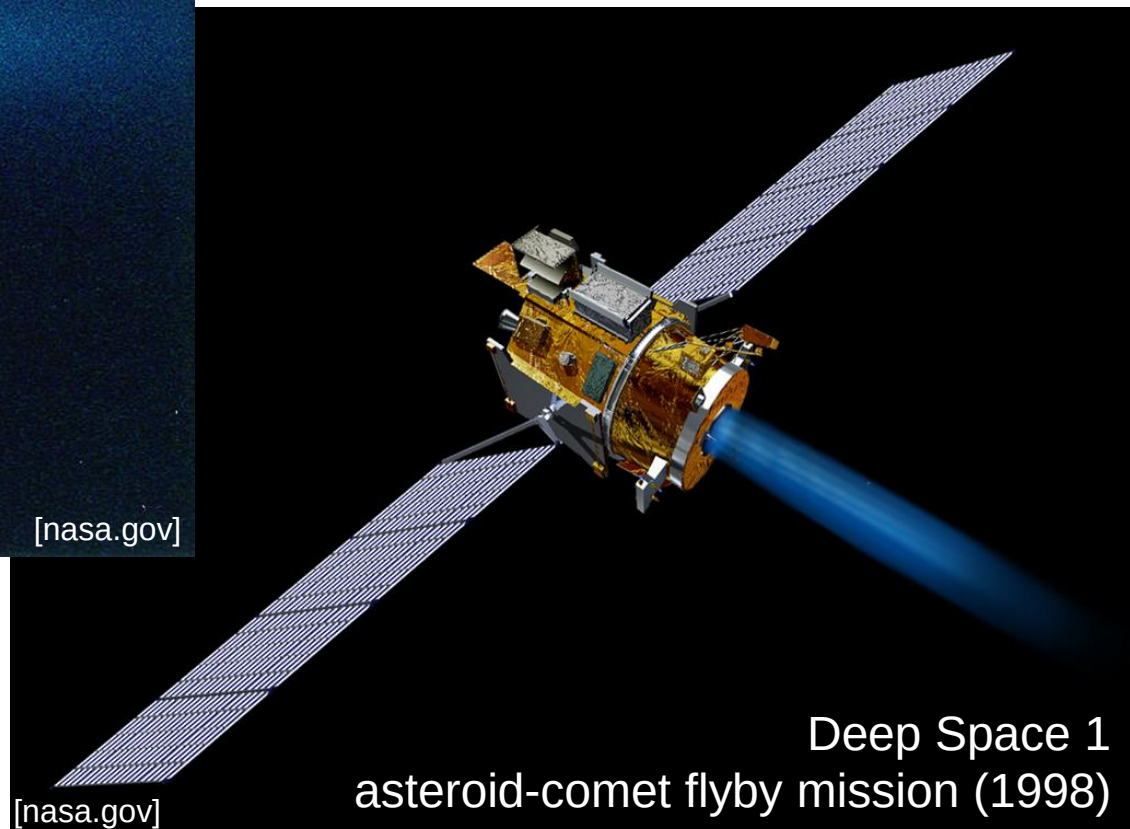


Space Propulsion: Ion Engine



2.3 kW NSTAR ion engine
(Deep Space 1 space probe)

[nasa.gov]



[nasa.gov]

Deep Space 1
asteroid-comet flyby mission (1998)

… a few more things about E&M

- E&M is the most mathematically sophisticated theory in Physics.

  … except for quantum field theory and general relativity.

- Standard E&M theory can solve very hard/complex problems.

- E&M is generally the hardest part of graduate qualifying exams.

Course Work

- **Problem sets:** weekly.
- **Participation:** class attendance, classroom discussion, quizzes.
- **Midterm** (mid march).
- **Final** covers all course material with emphasis on 2nd half of course.

Weighting:

Problem sets:	45%
Participation:	10%
Midterm:	15%
Final Exam:	30%
Total =	100%

Textbooks

Text: Almost all of the course materials and problem sets will be taken from the following required texts for the course:

Introduction to Electrodynamics, by D. J. Griffiths [4th Ed., 2013]

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Some course materials will be taken from the following texts:

The Feynman Lecture on Physics, by R. Feynman, R. Leighton, M. Sands.

Modern Electrodynamics, by A. Zangwill [1st Ed., 2013].

Tentative Schedule (I)

Week 0: 1/25 **Review of Vector Calculus, part 1**
Vector fields, scalar and vector products, gradient, divergence, curl, Laplacian.

Week 1: 1/30-2/1 **Review of Vector Calculus, part 2**
Gauss's theorem, Stokes's theorem, curvilinear coordinates, Dirac delta function.

Week 2: 2/6-8 **Electrostatics, part 1**
Coulomb's law, charge distributions, Gauss's law, electric potential, Earnshaw th.

Week 3: 2/13-15 **Electrostatics, part 2**
Poisson's equation, electrostatic energy, perfect conductors, capacitors.

Week 4: 2/20-22 **Method Images & Separation of Variables**
Laplace's equation, uniqueness theorem, method of images, separation of variables.

Week 5: 2/27-3/1 **Separation of Variables**
Cartesian symmetry, series solutions, spherical symmetry, Legendre polynomials.

Week 6: 3/6-8 **Multipole Expansion & Dipoles -- Midterm**
Multipole expansion, dipole fields.

----- Midterm on March 8 -----

Week 7: 3/13-15 **Spring Break !!!**

Tentative Schedule (II)

Week 8: 3/20-22 **Electric Fields in Matter, part 1**
Dipole forces, dielectrics, bound charges, polarizability, electric displacement field.

Week 9: 3/27-29 **Electric Fields in Matter, part 2**
Linear dielectrics, dielectric constant, capacitors, energy, separation of variables.

Week 10: 4/3-5 **Magnetostatics, part 1**
Magnetic fields, Lorentz force law, current density, Biot-Savart law, Ampère's law.

Week 11: 4/10-12 **Magnetostatics, part 2**
Ampère's law, vector potential, multipole expansion, magnetic dipoles, dipole forces.

Week 12: 4/17-19 **Magnetic Fields in Matter**
Diamagnets, paramagnets, bound currents, auxiliary field, magnetic susceptibility.

Week 13: 4/24-26 **Faradays' Law**
Ohm's law, electromotive force, induced electric field, inductance, magnetic energy.

Week 14: 5/1-3 **Maxwell's Equations**
Ampère's improved law, electromagnetic waves.

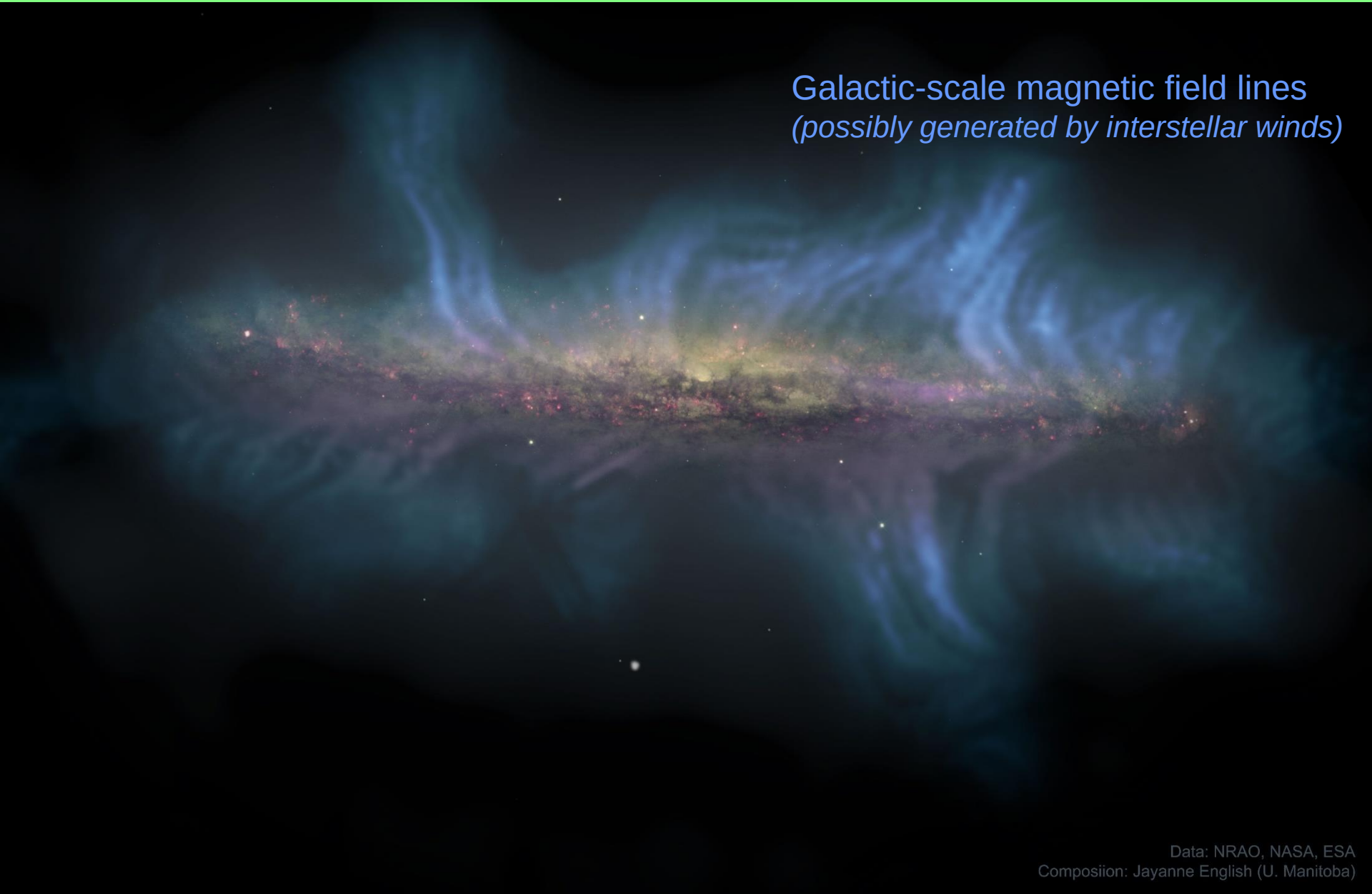
May 9, 2023, 7-10 pm **Final Exam**

Macro E&M: Galactic Magnetism

NGC 5775 galaxy, Virgo cluster

[Source: NASA/Hubble/ESA]

Macro E&M: Galactic Magnetism



Micro E&M: Electron's Magnetism

Electron's g-factor (relates spin to magnetic moment)

Classical EM / Schrodinger: $g_e = 1.0$

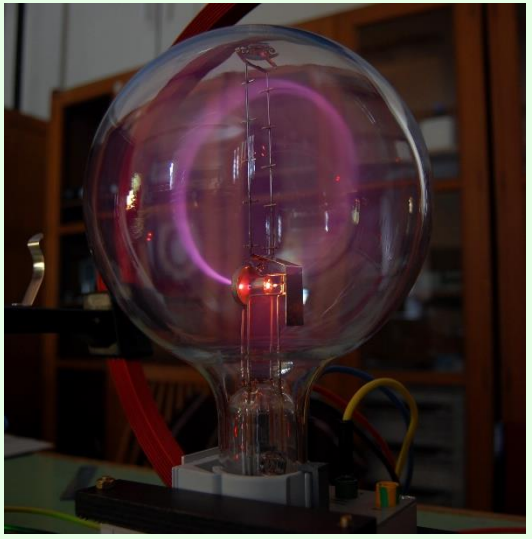
Relativistic electrodynamics + spin-1/2: $g_e = 2.0$

Dirac: $g_e = 2.0$

QED: $g_e = 2.002\ 319\ 304\ 362$

12-digits

Theory and experiment agree to 9 digits.



[Wikipedia, 2009]