Welcome Back to
Physics 1010

2019 Spring SMU
Honors Physics

Physics of Sports

Dr. Neil deGrasse Tyson
October 5, 1958 - present

Announcements

- **March 11th** - No class - Spring Break
- **March 18th** - Egg Drop Contest
- **March 25th** - Collaboration Meeting #2
    - Presentation of status of the solutions to the Grand Challenge Problem. Should include equations, mathematical solutions, etc.
    - Rough outline of poster.

Poster Basics

- Size: 36” x 48”
  - Can choose either a portrait or a landscape orientation
- Boiler-Plate Material
  - Title of Poster
  - Authors of Poster
  - Name of the Class (“SMU Honors Physics PHYS 4049 – Spring 2016”)
  - Logo of the Class
  - Acknowledgements

A Good Poster …

- Has an introduction, explaining the aims of the poster
- Supporting material to explain how the aims were met
- A conclusion at the end, summarizing findings
- Just like a research paper!

A Good Poster

- Unlike a research paper...
  - A poster uses as few words as possible to convey information
  - A poster utilizes appropriate graphics that allow the poster presenters to point to things and walk their audience through their story
- Visually...
  - Fonts are large and easily readable from many feet away
  - Pictures are large and crisp and clear (high-quality graphics)
  - Use of color is tasteful – appropriate to the design of the poster without being cluttering or distracting. Recall that color blindness affects 5-10% of males and about 1% of females. Don't rely only on color to make a point.

The Importance of Being Neutral

Stephen Sekula and Eric Godat
"Team Dynamic Duo"

sekula@physics.smu.edu egodat@smu.edu

Introduction

We have been asked to assess the possible physical outcomes of the following scenario: what if all of the electrons in the Solar System suddenly were transferred to the Sun? In order to answer this question, we first had to define the "Solar System." Then we had to estimate the number of electrons in the Solar System, excluding those already present in the Sun. We also had to consider the change in the masses of the Sun and the planets in order to use those as inputs to our various solutions. We then had to apply principles learned in PHYS 1307 and PHYS 1308 to predict three distinct outcomes of this event. We decided to consider the following questions as guidance to our solutions. (1) What is the new orbital force between a planet (e.g. the Earth) and the Sun, and how does this change the orbit of the Earth? (2) Since the planets now represent loops of current, what is the magnetic field created by planetary motion about the Sun? (3) What happens to newly charged particles in the Earth's atmosphere, and will the atmosphere be able to hang onto the Earth via gravity? We will detail our calculations. We will conclude with further implications of this work.

Attraction and New Orbits

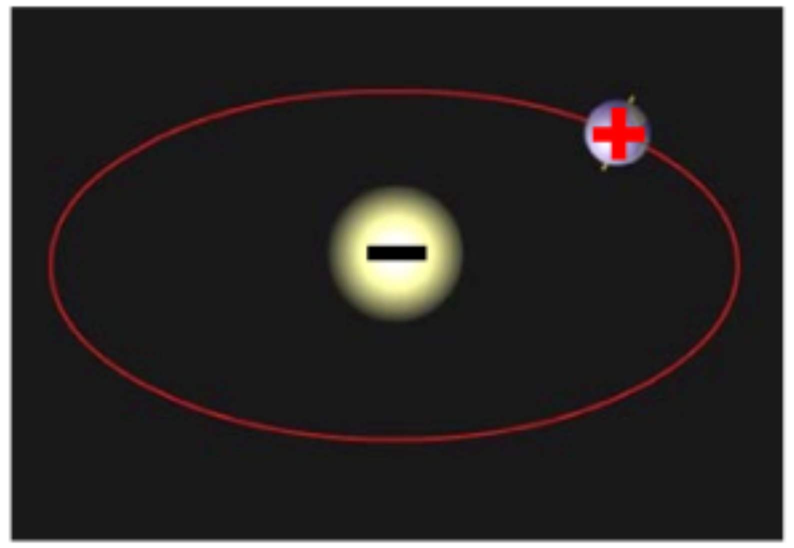
Due to the movement of the electrons to the Sun, the Earth and Sun now experience a large attractive force described by Coulomb's Law:

$$F_{coulomb}=\frac{k q_{earth} q_{sun}}{r^2}=3.9\times10^{52}N$$

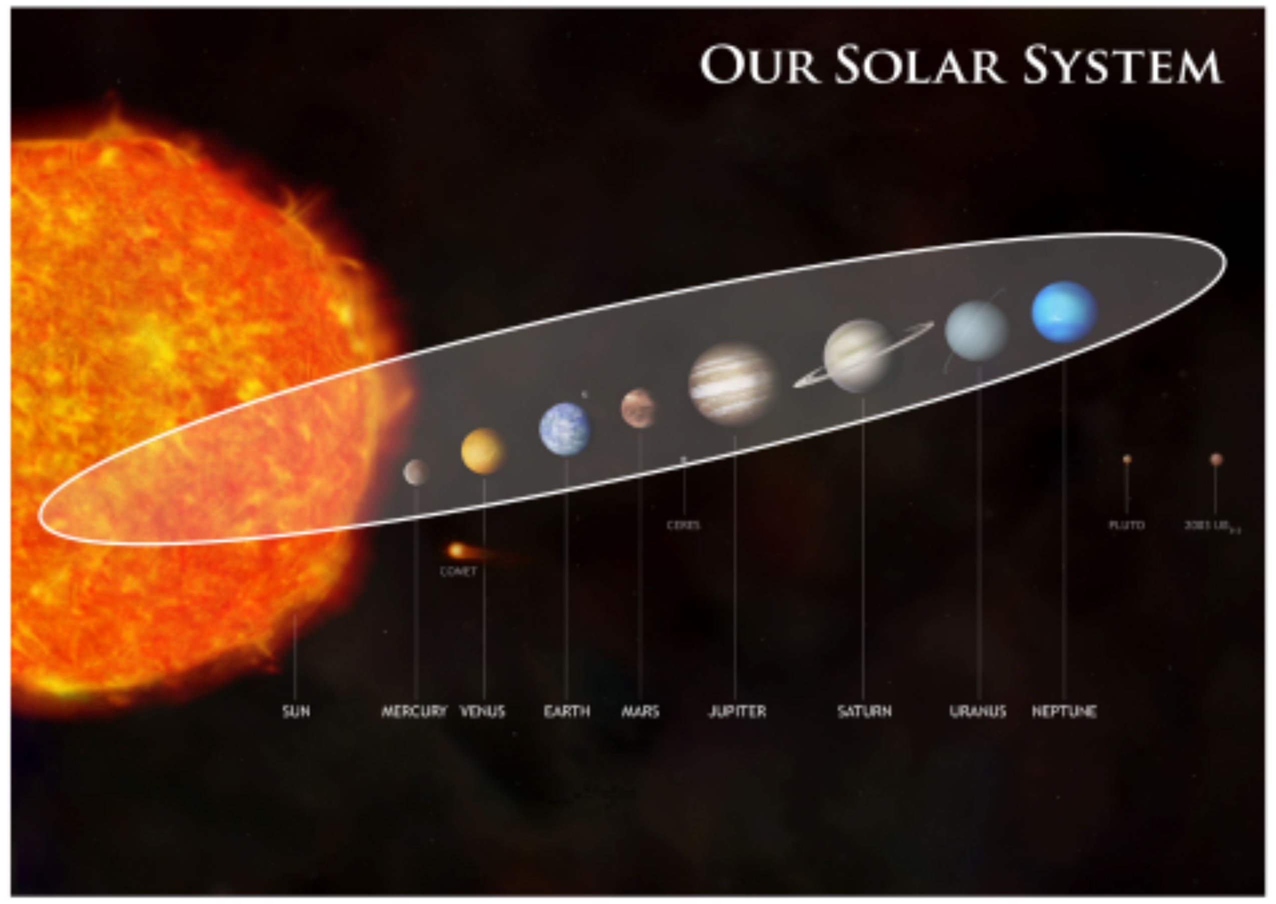
This force is significantly larger than the gravitational attraction therefore the Earth will spiral towards the Sun until it reaches a stable orbit. This orbit can be calculated using conservation of angular momentum:

$$r=\frac{M_{earth} v_i^2 r_i^2}{k q_{earth} q_{sun}}=1.4\times10^{-19}m$$

This is smaller than the radius of a proton, thus would have catastrophic effects on the Earth.



A Solar System's Worth of Electrons



Planet	Crust/Mantle Components (% by weight)	Core Components (% by weight)	Crust/Mantle / Core Mass Fractions	Total Mass (kg)
Mercury	SiO_2 (45%) MgO(55%)	Fe (95%) Ni (5%)	35% / 65%	3.3002×10^{23}
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Jupiter		H (77%) He (23%)		1.8986×10^{27}
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Planet	Number of Electrons
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Uranus	4.1×10^{50}
Neptune	4.9×10^{50}
Total	1.3×10^{51}

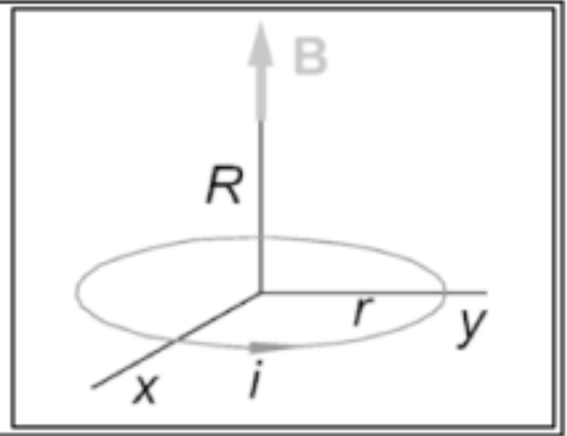
Top: Our definition of the Solar System
Left: Table containing calculations of planetary masses
Above: Table containing calculation of numbers of electrons for each planet and the total number of electrons transported into the Sun

Earth as a Current

Upon having its electrons stripped, the Earth becomes a charged particle in an orbit. Since moving charges create magnetic fields, it is possible to calculate the strength of this field on a distant object such as a comet in the Oort cloud.

$$B_{central\,axis}=\frac{\mu_0 i r^2}{2R^3}=6.2\times10^{-11}T$$

This field is fairly small and would unlikely have much effect considering the fields of all other planets.



Atmospheric Repulsion

Since the Earth is entirely composed of positive charges. We can examine how an oxygen molecule in the upper atmosphere would be accelerated by the new repulsive force. This acceleration can be found to be:

$$a=\frac{k q_{oxygen} q_{earth}}{m R^2}=1.5\times10^{33}\frac{m}{s}$$

At this acceleration, the planet would blow itself apart. For reference, the shockwave at the front of a nuclear explosion has an acceleration of:

$$a=10^{20}\frac{m}{s}$$

Conclusions

If all the electrons in the Solar System were suddenly transported into the Sun, terrible things would happen. We see that the Coulomb attraction between planets and the Sun itself would overwhelm all other forces and crush the Earth into the Sun. We also see that the atmosphere of Earth, and likely the whole Earth itself, would blow apart under the new and overwhelming Coulomb repulsion. We see that even if Earth survived, the magnetic fields created by this new current encircling the Sun has the potential to affect other charged bodies in the Solar System – maybe not the Oort Cloud, but certainly closer bodies with new big charges like Mars. Such a phenomenon would completely alter the structure of the Solar System, and reveals the weakness of gravity in comparison to the electromagnetic force

References

1: NASA, Solar System Dynamics, 2015, http://ssd.jpl.nasa.gov/?body_count
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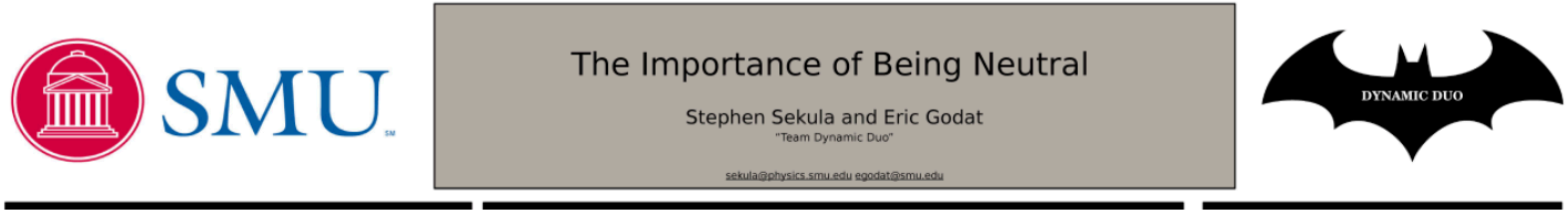
Acknowledgement

This work was done as a sample for Honors Physics at Southern Methodist University. Special thanks to the Physics Department for supporting this work.



Notice that there is a clear title, a list of authors/contributors and contact information. There is even a little logo for the team! This helps to “brand” your work for reference later, when the poster is just hanging on a wall some place...

Introduction

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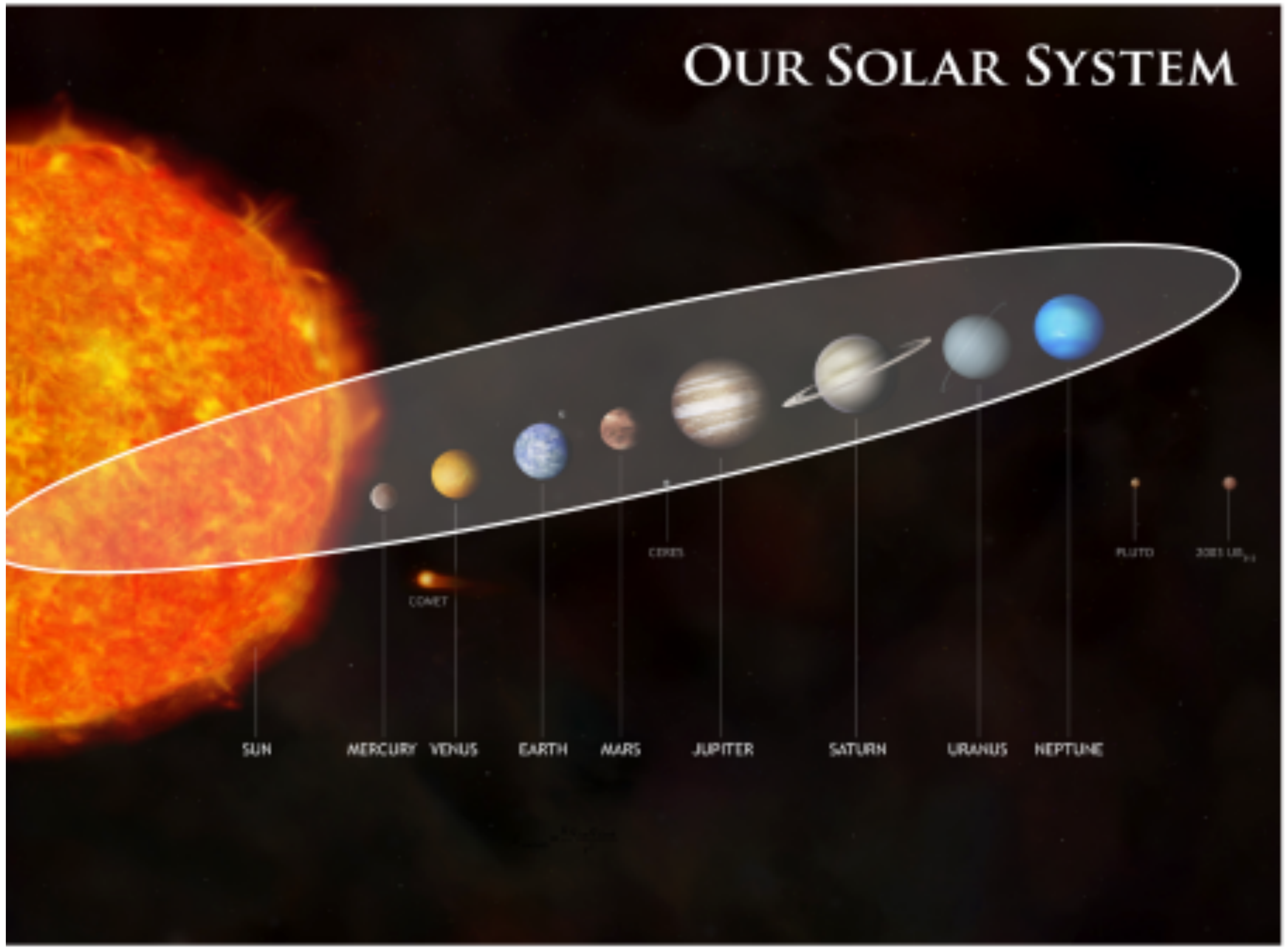
There is an introduction. Rather wordy, but not the worst thing ever seen! Clearly explains the problem and aims of the research.

A Solar System's Worth of Electrons



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Top: Our definition of the Solar System
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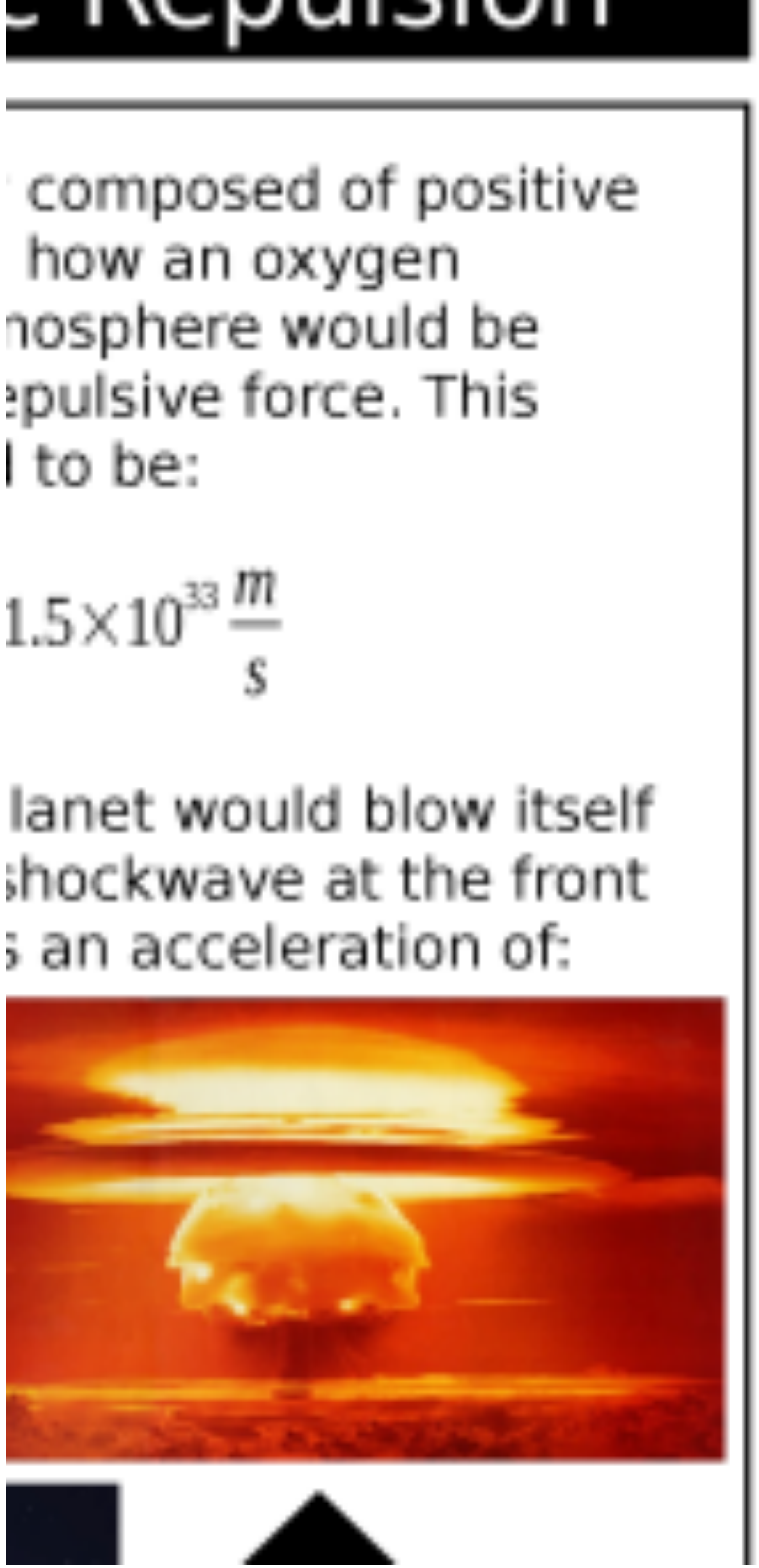
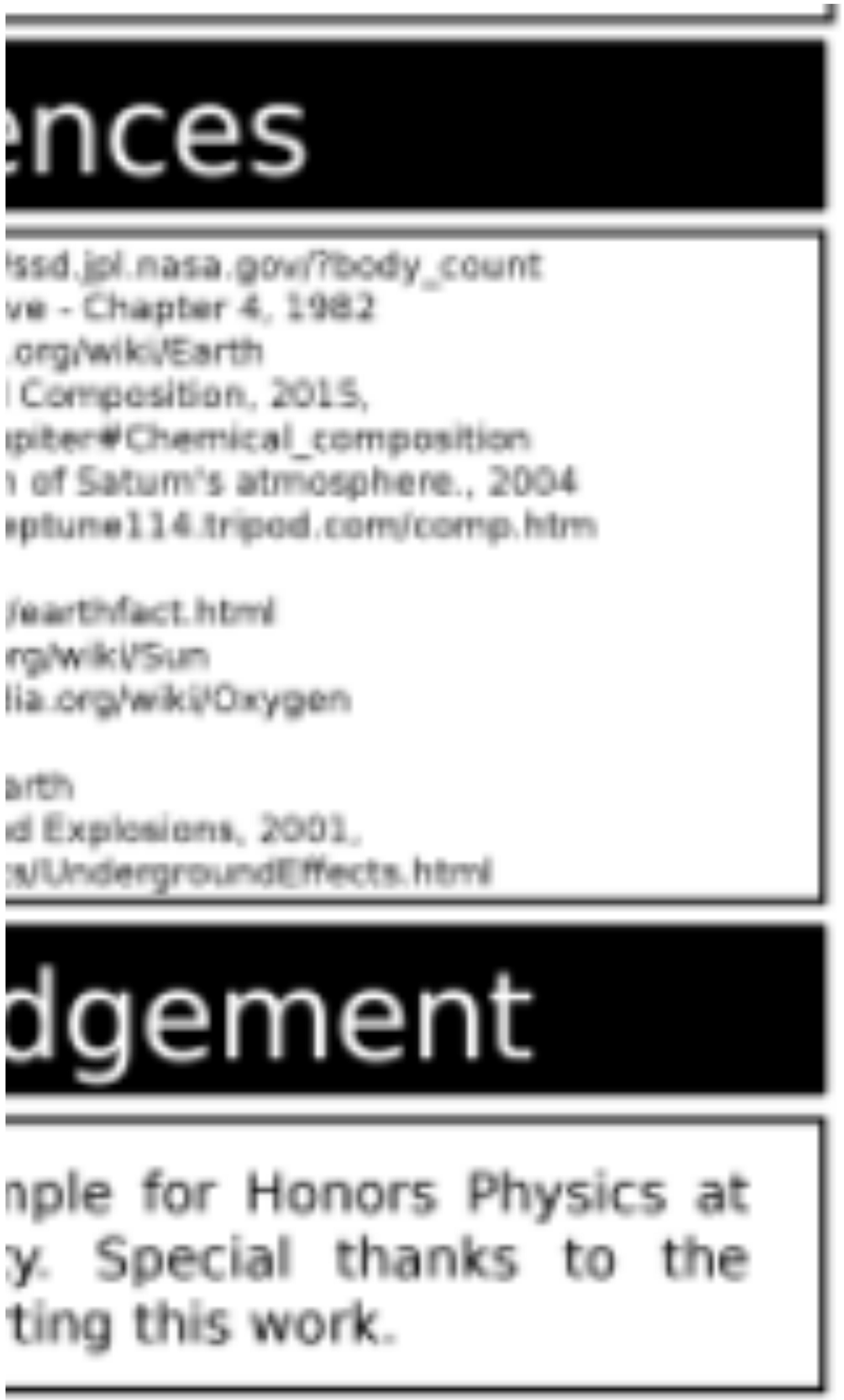
masses
Above: Table containing calculation of n
of electrons for each planet and th

A large eye-catching graphic can be used to explain how we defined "The Solar System" (just the 8 planets), with supporting calculations/ numbers below.



You can even have a little fun with your graphics – just make sure that it helps support a real point that you are making. Humor is like salt – used appropriately, it improves the flavor of the dish. Used in excess, somebody is going to vomit or have a heart attack.



Finally, remind the audience what you wanted them to know, what you figured out, and what its implications would be. Cite references and thank supporting organization(s).

We have a boiler-plate acknowledgement that you can start from and add to as appropriate

Examples of Posters (Discussion)

SMU

What happens when the electrons are pulled from the solar system into the sun?

Group

Department of Physics, Southern Methodist University

Introduction

We have been asked to assess the possible physical outcomes of the following scenario: what if all of the electrons in the Solar System suddenly were transferred to the Sun? In order to answer this question, we first had to define the "Solar System." Then we had to estimate the number of electrons in the Solar System, excluding those already present in the Sun. We also had to consider the change in the masses of the Sun and the planets in order to use those as inputs to our various solutions. We then had to apply principles learned in PHYS 1307 and PHYS 1308 to predict three distinct outcomes of this event. We decided to consider the following questions as guidance to our solutions. (1) What is the new orbital force between a planet (e.g. the Earth) and the Sun, and how does this change the orbit of the Earth? (2) Since the planets now represent loops of current, what is the magnetic field created by planetary motion about the Sun? (3) What happens to newly charged particles in the Earth's atmosphere, and will the atmosphere be able to hang onto the Earth via gravity? In the rest of this document, we will detail our calculations. We will conclude the document with further implications of this work.

Solar System

The Solar System is quite a complex system. According to information available from the NASA website[1], we are still learning about exactly how many bodies make up the Solar System. The Sun is the most obvious part of the system besides Earth. In addition to Earth, there are seven other planets. There are also smaller bodies, called planetoids, of which Pluto is a member. Smaller than planetoids are asteroids, such as the ones that make up the belt between 3 Mars and Jupiter. The outermost objects that are still directly gravitationally bound to the Sun make up the "Oort Cloud," from which we get comets. Given the variety of objects, and the observational fact that we have not yet classified well the number of bodies – large and small – in the Solar System, we will choose to define "Solar System" as merely the Sun and the eight planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. We will ignore planetoids and smaller bodies. We need to estimate the number of electrons in the eight planets. In order to do this, we need to estimate the elemental composition of the planets and then use those abundances (and known chemical structure) to estimate the number of electrons. Our primary source for elemental composition of the planets is Ref. [2]

, and the results are summarized in Table 1. By studying the moon and earth chemical composition, and using spectroscopy to study the composition of other planets (such as Mercury, Mars, and Venus), the data suggests the following dominant components of planets. Since the source only bounds the possible range of chemical components (e.g. for Mercury, the SiO2 component is estimated to lie between 43.6-47.1), we choose a number in that range that is round and easy to handle (e.g. 47%, in the case just given) and make sure our sums add to 100%. The mass of a planet, M, is the sum of the product of the molecule masses and their total Numbers:

M=∑imi−Ni where mi (−Ni) is the mass (number) of molecule type i. Table 1 contains fractions by weight, which we will use as fractions by mass, of the most abundant molecules in each planet. We want 4 to find the number of each type of molecule present in a planet. To do this, we merely need to compute the total mass represented by that fraction of the planet and use the molecular mass to solve for the number of each type, i:−Ni=fiMmi To determine the total number of electrons due to molecular species, i, we need only know that the number of electrons is equal to the number of protons, assuming that all atoms are electrically neutral:Nje=Njp where Nje(Njp) is the number of either electrons (protons) for atom type j. For a molecule, like SiO2, one has to take into account the fact that silicon and oxygen have different numbers of electrons and there are two oxygen atoms for every silicon atom. Thus the number of electrons for a molecule is given by:Nie=∑jnjNi, jp−Ni where j labels the type of atom in molecule i and nj is the number of atoms of type j in molecule i. Thus, in terms of numbers we either have or can look up, the total number of electrons in a planet of mass M is given by: Ne=∑ifiMmi(∑jnji,jp)

Thus, the total number of electrons in each planet, and the defined solar system used for this writeup, are computed (using a spreadsheet to automate the calculations) as detailed above and given in Table 2 We find that a vast 1.3 10×54 electrons are transported from the planets in the solar system and deposited suddenly in the sun. We anticipate that this will have many effects on the structure or behavior of the solar system. In the following sections, we explore three possible effects. The first will be the effect of a new component on the orbital forces on a planet such as the Earth. The second will be magnetic field generated by the "loops of current" represented by a planet or planets. The third will be the acceleration of Oxygen ions in the upper atmosphere and speculation about what would happen overall to a body like Earth

Tables

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Total	**1.3×10^{54}**

First Possibility

Normally, when the Solar System is electrically neutral, we only have to consider the orbital force due to gravity on each planet. In general, the Solar System's gravitational interactions are complicated and orbits are the result of a variety of forces. For instance, the Earth experiences the gravitational attraction of the sun as its primary force, but the gravitational attractions of other bodies like the Moon, Mars, Jupiter, etc. cannot be neglected in a more general treatment. For this exercise, we will consider only the new electrical force between the Earth and the Sun, in addition to the preexisting gravitational force. First, we need to consider how the masses of bodies have changed. Since in each stable atom the number of electrons is equal to the number of protons, and the number of neutrons is approximately equal to the number of protons, we can assume that for each atom the number of electrons is half the number of nucleons (neutrons + protons). The mass of all electrons in a single stable atom accounts for less than 0.03% of the total mass of the atom. We consider this to be a negligible contribution to the mass of each atom, and thus the sum of all electron masses in a planet a negligible contribution to the mass of the planet. Therefore, we will NOT treat the masses of the planets or the sun as having been meaningfully changed by the removal or addition of even this many electrons. The masses of all planets therefore remains approximately the same. We can calculate the magnitude of the force exerted by the sun on the Earth when Earth is at its nominal orbital radius of 149 10×9 m [7]. The mass of the sun [8] is 1.99 10×30 kg, while the mass of the Earth is as given in Table 1. Thus the force due to gravity between the Earth and the Sun has magnitude:

Fgravity=GMsunMearthr2=3.6×1022N.

What about this new Coulomb Force between the Sun and the Earth due to the imbalance of charge now present in the solar system? We already know the number of electrons present in the sun and we know the number that departed the Earth. We can thus calculate the charge of the sun:

qsun=nesun·(−e)=−2.1×1035C

and then the charge of the Earth:qearth=neearth·e=4.6×1029C.

Therefore the magnitude of the Coulomb Force, which is attractive like the gravitational force due to the dissimilar charges of the Sun and Earth, at the original orbital radius of the Earth is:

FCoulomb=kqsunqearthr2=3.9×1052N.

We see just how powerful the electric force is in comparison to the gravitational force. Although shifting the entire Solar System's worth of electrons to the Sun will have essentially no effect on the mass of the Sun or the Earth (due to the small mass of the electron) and thus no effect on the gravitational force, this imbalance of charge creates a HUGE new force in the Solar System that will overpower gravity.We can then determine what would be the new, stable orbital radius of Earth around the Sun. Let us assume that Earth, now very attracted to the Sun by a new force, closes its orbit until it moves in a new orbital position that keeps its centripetal and Coulomb forces completely balanced. That is, we want to find the new orbital radius such that:

Mearthv2r=kqearthqsunr2.

We know everything here except the new orbital radius, which we want to find, and the speed of the Earth at its new orbital position. We have to relate velocity to something we can know or something we want to solve for. If we consider the new orbit to be circular, then we can relate velocity to time and position via:v=dsdt

where s is the arclength; thus linear velocity of a planet is a small change in arclength over a small change in time. Arclength can be related to the angle subtended by the motion and the radius of the orbit:v=dsdt=rdθdt=rω and we now only have to relate linear velocity to angular velocity and the orbital radius. We can employ conservation of angular momentum between the old orbital radius and the new orbital radius to figure out the new angular velocity. Angular momentum is given by L=Iω and since it is conserved we know that Li=Lf→Iiωi=Ifωf. We can compute the initial and final moments of inertia, and we can compute the initial angular velocity. From that, we can calculate the final angular velocity in terms of the new orbital radius and known quantities:

Ii=Mearthri2If=Mearthr2ωi=vi/ri

Therefore:ωf=IiIfωi=ri2r2viri=virir2

Inserting this into our force-balancing equation:

Mearthv2r=kqearthqsunr2Mearthrr2ωf2=kqearthqsunr2Mearthrr2(virir2)2=kqearthqsunr2Mearthr3vi2ri2=kqearthqsunr2Mearthvi2ri2kqearthqsun=r

We have the mass of the Earth and can lookup from external sources the speed of the Earth at its original orbital radius. We obtain the following solution:

r=1.4×10−19m.

This new stable orbit is smaller than the radius of a proton! We see that putting all that charge in the center of the sun has catastrophic effects for the solar system. Earth, and likely all other planets, would be quickly pulled down into the sun and the solar system as we know it would be destroyed. Clearly, Earth would never survive to reach this stable orbital radius, as it would be absorbed into the sun along with all other planets until the Solar System became electrically neutral again.

Second Solution

Although we have just seen how terribly unstable the Solar System will become under these conditions, we can imagine for a moment that Earth remains in its original orbit. This now represents a current traveling in a nearly circular orbit around the Sun. We know the charge possessed by the Earth, and we know its original linear velocity (29.78 km/s) [7] and from this we can compute the electric current that this represents. The goal here is to then determine the magnetic field created by the motion of the Earth around the sun, now that the Earth carries a huge net charge. The charge of the Earth is given in Table 2. We know the velocity of the Earth, and we know that it makes one revolution in one year at its current orbit. This means that the time required to make this charge complete one revolution is t=365d/orbit×24h/d×3600s/h=3.154×107s/orbit. So the current isi=(2.9×1048)e3.154×107s=1.5×1022A. We know from studying moving charge and magnetic fields that such motion of charge (current) creates magnetic field. We can, for instance, look at the magnetic field created by the Earth's motion on the axis that points through the center of the Earth's orbit and it perpendicular to its orbital plane. This is given by Bcentral axis=μ0iR22D3 where D is the distance along the axis measured relative to the center of the orbital circle (e.g. the location of the Sun) and R is the orbital radius of the Earth, whose semi-major orbital axis is 149.6 10×9m. It would be interesting, for instance, to look at the strength of the magnetic field along this axis at a distance corresponding to where the "Oort Cloud" is located. What is the strength of the charged Earth's magnetic field at that kind of distance? The distance, D, is about 100,000 AU (astronomical units), where 1 AU is the typical distance between the Earth and the Sun, 149,597,870,700 m (we determined this by using Google to convert 1 AU to meters). Using this for D, and using the computed Earth electric current and the present orbital radius of the Earth, we find:

Bcentral axis(R=100,000AU)=6.2×10−11T.

This is a small magnetic field. Likely, the effect of such magnetic fields on the other charged planets in the Solar System would be a far larger effect, causing the orbits of planets (now carrying huge electric charges) to bend and twist like charged particles in an external magnetic field.

Third Solution

The final consequence we will consider in this paper is the acceleration of an oxygen ion that originally begins near the top of the atmosphere due to all the charge in the Earth below it. The Coulomb repulsion of all the newly ionized matter in the Earth, including its atmosphere, will have explosive effects on the Earth itself. Given the incredible force that the Sun now exerts on the Earth, we would expect the Coulomb repulsion of all the positive charge on Earth to blow us apart. We can consider the acceleration on an Oxygen ion [9]

that would be felt at the moment all the electrons move to the Sun. Consider an Oxygen ion sitting right at the top of the atmosphere. Oxygen molecules are pairs of Oxygen atoms; an Oxygen ion would have a net charge of q=2 q×O = 16 e =2.56 10××-18C. We know the net charge of the Earth, which has the same sign as the Oxygen ion. We can compute the force that entire rest of the Earth exerts on this ion at the moment all electrons are moved to the Sun. The top of the atmosphere is at around 6200 miles [10], or 9.98 10×6m. We can treat all the charge in the Earth as being arranged in a uniformly charge sphere. When we're outside the radius of that sphere (which is where we are when we are right at the top of the atmosphere), the Coulomb Force has the SAME form as that between two point charges. Let Q be the charge of the Earth and q be the charge of the Oxygen ion. The radius we have to put in Coulomb's Law is the sum of the radius of the Earth and the height of the atmosphere above the surface of the Earth, R = 6357km + 9,980km = 16,247km = 1.62 10×7m. Thus F=kQqR2=4.1×107N.

We can then compute the acceleration of the Oxygen ion using: F=ma→a=F/m=1.5×1033m/s2.This is a huge acceleration, far in excess of the 1g present at the surface of the Earth. By comparison, the acceleration of particles at the front of a shockwave from a nuclear explosion, two seconds after the explosion, are just 20 m/s2 [11] - this Coulomb repulsion represents an unprecedented force of destruction that would tear the atmosphere away from the Earth, and dissolve the Earth as well since the acceleration due to gravity cannot compete with such Coulomb force-induced accelerations.

Conclusions

If all the electrons in the Solar System were suddenly transported into the Sun, terrible things could happen. We see that the Coulomb attraction between planets, like the Earth, and the Sun itself would overwhelm all other forces and crush the Earth into the Sun. We also see that the atmosphere of Earth, and likely the whole Earth itself, would blow apart under the new and overwhelming Coulomb repulsion. We see that even if Earth survived, the magnetic fields created by this new current encircling the Sun has the potential to affect other charged bodies in the Solar System – maybe not the Oort Cloud, but certainly closer bodies with new big charges like Mars, Venus, or Jupiter. Such a phenomenon would completely alter the structure of the Solar System, and reveals the weakness of gravity in comparison to the electromagnetic force.

Acknowlegments

This work was done to meet the requiremens of Honors physics at Southern Methodist University. Thanks to the SMU Physics Departmetn for funding this work.

Reference

1: NASA, Solar System Dynamics, 2015, http://ssd.jpl.nasa.gov/?body_count
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8: Wikipedia, Sun, 2015, https://en.wikipedia.org/wiki/Sun
9: Wikipedia, Oxygen, 2015, https://en.wikipedia.org/wiki/Oxygen
10: Wikipedia, Atmosphere of the Earth, 2015, https://en.wikipedia.org/wiki/Atmosphere_of_Earth
11: Sublette, Carey, The Effects of Underground Explosions, 2001, http://nuclearweaponarchive.org/Library/Effects/UndergroundEffects.html

Tables

Planet	Crust/Mantle Components (% by weight)	Core Components (% by weight)	Crust/Mantle / Core Mass Fractions	Total Mass
Mercury	SiO_2 (45%) MgO(55%)	Fe (95%) Ni (5%)	35% / 65%	3.3002×10^{23}
Venus	SiO_2 (50%) MgO (40%) FeO (10%)	Fe (90%) Ni (5%) S (5%)	70% / 30%	4.8676×10^{24}
Earth	SiO_2 (45%) MgO (40%) FeO (10%) Al_2O_3 (5%)	Fe (85%) Ni (5%) S (10%)	69% / 31%	5.97219×10^{24}
Mars	SiO_2 (50%) MgO (30%) FeO (20%)	Fe (90%) Ni (5%) S (5%)	81% / 19%	6.4185×10^{23}
Jupiter	H (77%) He (23%)			1.8986×10^{27}
Saturn	H (77%) He (23%)			5.6846×10^{26}
Uranus	H (77%) He (23%)			8.6810×10^{25}
Neptune	H (77%) He (23%)			1.0243×10^{26}

Planet	Number
Mercury	1.55×10^{47}
Venus	2.3×10^{48}
Earth	2.9×10^{48}
Mars	2.8×10^{47}
Jupiter	9.1×10^{53}
Saturn	2.7×10^{53}
Uranus	4.1×10^{52}
Neptune	4.9×10^{52}
Total	$\mathbf{1.3 \times 10^{54}}$

Normally, when the Solar System is electrically neutral, we only hav
complicated and orbits are the result of a variety of forces. For insta
bodies like the Moon, Mars, Jupiter, etc. cannot be neglected in a m
to the preexisting gravitational force. First, we need to consider how
the number of neutrons is approximately equal to the number of pro
all electrons in a single stable atom accounts for less than 0.03% of
electron masses in a planet a negligible contribution to the mass of
removal or addition of even this many electrons. The masses of all
when Earth is at its nominal orbital radius of 149 10×9 m [7]. The m
Earth and the Sun has magnitude:
Fgravity=GMsunMearthr2=3.6×1022N.
What about this new Coulomb Force between the Sun and the Eart
sun and we know the number that departed the Earth. We can thus
qsun=nesun·(−e)=−2.1×1035C
and then the charge of the Earth:qearth=neearth·e=4.6×1029C.
Therefore the magnitude of the Coulomb Force, which is attractive
FCoulomb=kqsunqearthr2=3.9×1052N.

Typeset your math formulas, or hand-write them as graphics, so that the notation is crisp and clear to the reader. The above is unreadable gibberish.

ManeParse

PDF Reader and Interface Mathematica Package

Abstract

Parton Distribution Functions (PDFs) are essential components to making predictions at hadron colliders. These PDFs are determined by fitting several parameters to data from a number of experiments. PDFs are universal inputs for hadronic interactions, however, due to differences in fitting procedures between collaborations, variations in PDFs can arise. We have written a custom Mathematica package capable of reading several different collaboration's proprietary formats. This software gives the user the ability to perform calculations involving PDFs within the Mathematica framework and compare results from different PDF collaborations. Physics calculations made using the tools available in the package will be demonstrated along with some additional applications and future improvements.

Parton Distribution Functions

At electron-positron colliders, point particles are accelerated to relativistic speeds before being smashed together, annihilating, and leaving a shower of particles and energy in the detectors. Since these are both point particles, we are able to use a mathematical theory to understand what occurs in these interactions. These experiments, however, have their limitations so hadron-hadron colliders have been constructed to further probe the structure of matter. Hadrons, a class of particles including protons and neutrons, pose their own set of problems. They are composite objects, not point particles. As a composite object, hadrons can no longer be described using corrections to the Standard Model so we are forced to look inside these objects at the point-like components known as partons. Partons can be described this way but we lose the ability to know exactly how much of the original particle's momentum is shared by each of the several partons. Parton Distribution Functions, which are able to describe the momentum fraction, x, and the energy of the collision, Q, provide a solution to this problem. These PDFs are generated from fitting data from scattering experiments, such as Deep Inelastic Scattering and a few other methods. In DIS, a proton and a lepton are scattered causing a parton and the lepton to interact and exchange energy. The final state hadrons and lepton can then be measured to better understand the hadronic structure.

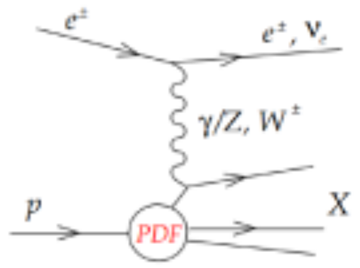


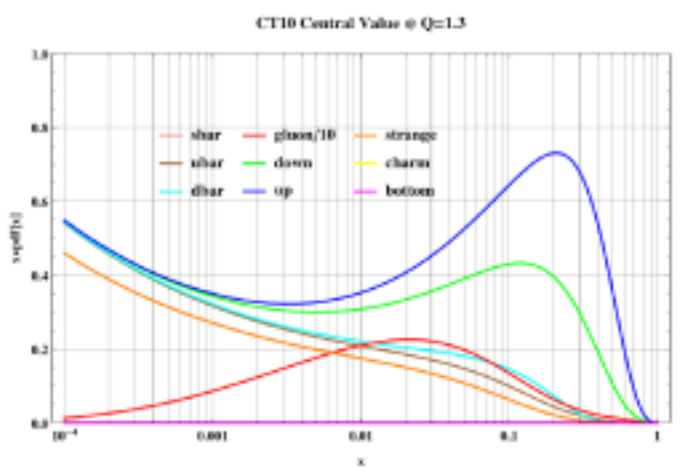
Figure 1: Fully inclusive DIS process, here X represents final state hadrons.

In a collider environment, the likelihood of a particle interaction occurring is governed by a value called a cross section, which roughly equates to the area of a particle. Point particles have cross sections that can be calculated directly but the total cross sections for hadronic processes cannot be. However, we can use the fact that PDFs are at a lower energy scale than the processes, to use a technique known as Factorization, to convolute the parton cross sections with the PDFs to produce the total cross section of the hadron.

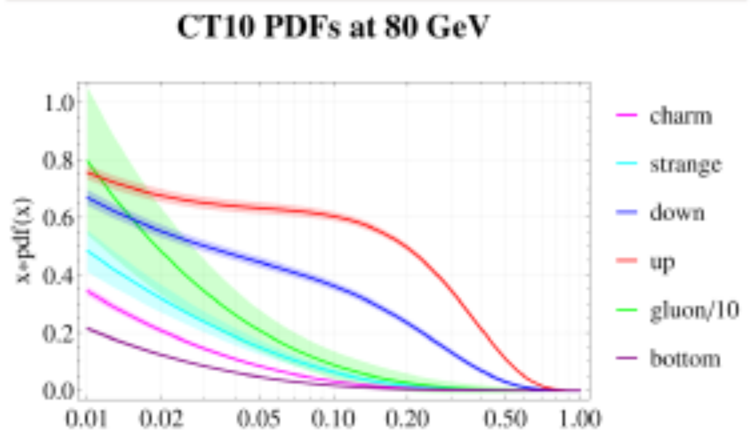
Purpose

ManeParse is a lightweight package that is capable of very quickly loading a large number of PDFs into memory and uses a custom four-point Lagrange interpolation routine in a way that is fast, reliable and transparent. The data reader contained in the package handles multiple collaborations' data formats and converts them into a uniform style. The package avoids using built-in Mathematica interpolation routines in favor of a more efficient and straight-forward custom routine. The interpolater provides immediate access to the PDF at any value of momentum fraction x and hard scattering energy Q within the bounds of the PDF set. The user then has access to the powerful computational and plotting tools available in Mathematica to perform calculations of hadronic interactions.

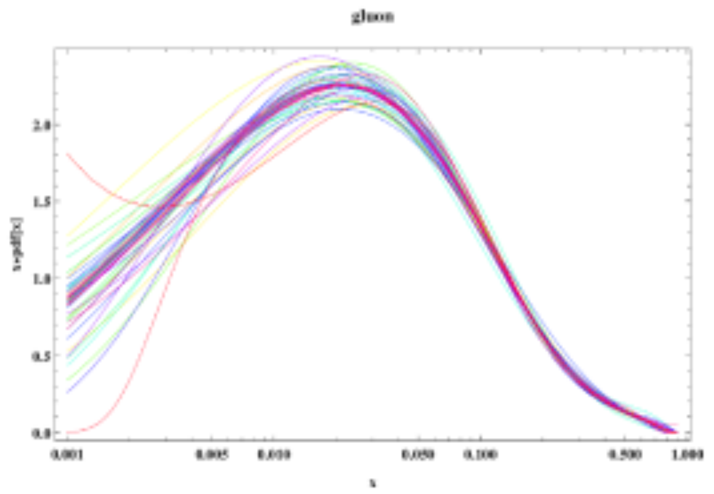
Sample Plots



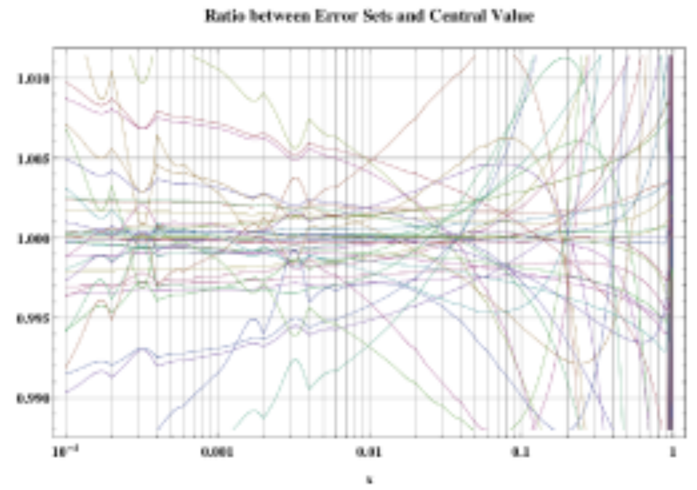
Plot 1: CT10 Central Value PDF.



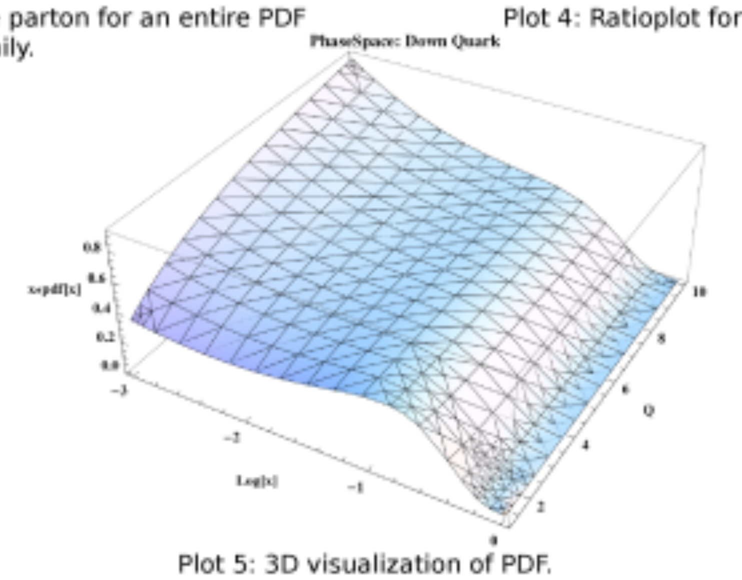
Plot 2: CT10 from PDS with errors added.



Plot 3: Bandplot of single parton for an entire PDF family.



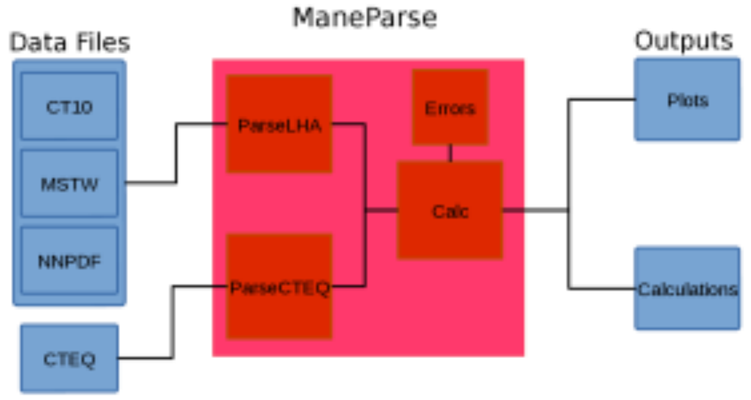
Plot 4: Ratioplot for MSTW PDF family.



Plot 5: 3D visualization of PDF. (as a function of x and Q)

Computation

Currently CTEQ and LHAPDF files are read and interpolated using Fortran and C++ interfaces. These programs are difficult to use and require installing separate and proprietary software. However, the data files that are inputs into these programs are available from HepForge, an open software resource for high-energy physics. This allows us to use ManeParse to replicate the functionality of the proprietary programs within the easier to use Mathematica interface. This saves a potential user time and effort when attempting to manipulate and compare data from multiple collaborations, make plots and do calculations.



	Files	File Parsed	pdfFunction Call
PDS	228	0.01489242	0.00015975
CT10	53	0.0358849	0.0006904
MSTW	41	0.0317307	0.0007548
CT10nlo	53	0.0372413	0.0007889
NNPDF	100	0.04349748	0.00066572

Table 1: Time, in seconds, to read a file from several sample PDF sets. Time, in seconds, to run an interpolation. The speed for the interpolation is critical to allow for feasible integrations containing the PDFs.

Future Work

We are looking forward to computing cross sections of DIS processes using the utilities provided by the package. Additional functions, including full error implementation, are in preliminary testing and will be able to be simply plugged into the existing package.

References

R. Placakyte [H1 and ZEUS Collaborations], Physics in Collision XXXI, 2011 arXiv:1111.5452v4.
J. Owens, CTEQ Summer School, 2007, "Parton Distribution Functions and Global Fitting".
K.A. Olive *et al.* (Particle Data Group), Chin. Phys. C, **38**, 090001 (2014)
LHAPDF http://lhapdf.hepforge.org/
CTEQ http://users.phys.psu.edu/~cteq/
http://ncteq.hepforge.org/code/pdf.html

Thanks to:
SMU Physics Department and Dr. Olness for supporting this work.

Measuring Neutrino Magnetic Moment in NOνA Near Detector

Introduction to NOνA experiment

Figure: The sizes of NOνA detectors

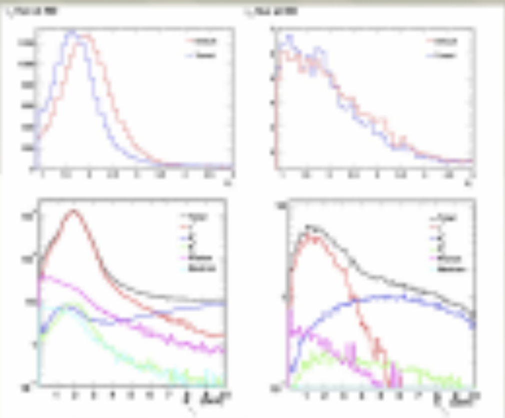
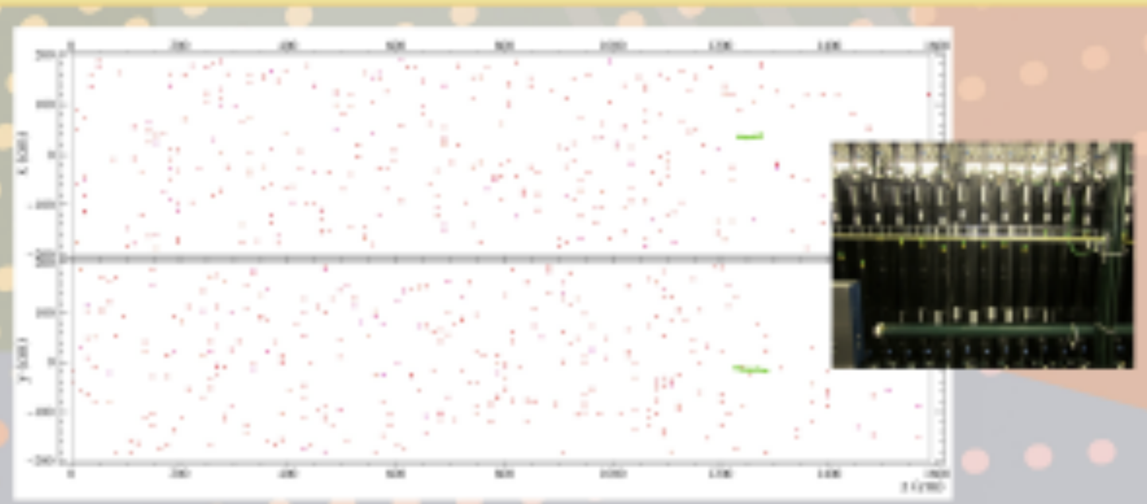


Figure: Comparison of neutrino flux in Neardet with 2.7e19 POT

NOνA experiment is using the NuMI neutrino beams from Fermilab, aiming at Ash River in Minnesota with a 14 mrad off-axis angle so that the energy spectrum of ν_μ is peaked at about 2 GeV. The Near detector is made of PVC extrusion and 220 ton liquid scintillator and located 2 km from the beam source. The far detector has the same structure but with a bigger size in scale. The NOνA experiment will measure the keen parameters of neutrino oscillation including mass hierarchy, CP phase and octant of θ_{23}. While being benefited from the large far detector, we can also give support to the astro particle topics such as supernova, east west effects and so on. Since the Near Detector is so close to the NuMI target, we will have enough flux to accumulate significant statistics for Deep Inelastic Scattering, Quasi-elastic interactions, Kaon decay and magnetic moment of neutrino from $\nu - e$ elastic scattering.

Event Gallery



Selection method on the scattered angle

$$\cos\theta = \frac{E_\nu + m_e}{E_\nu}\sqrt{\frac{T}{T+2m_e}} > 0.95 \quad (1)$$

$$T\theta^2 = 2(1-\frac{T}{E_\nu})m_e < 2m_e \quad (2)$$

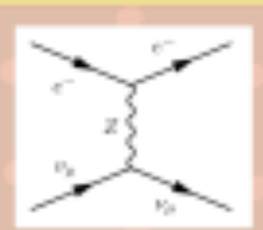
This significant feature distinguish our signal events from most ν_e or ν_μ charged current, Michel electrons and other backgrounds.

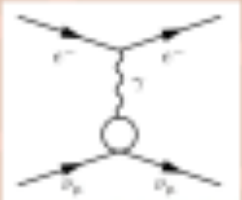
Dirac Neutrino or Majorana Neutrino ?

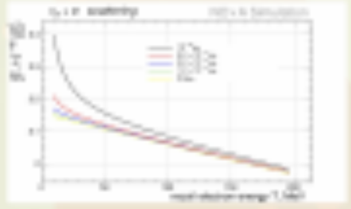
- Dirac neutrino, NMM no larger than $10^{-12}\mu_B$ in plasmon decay, upper limit $10^{-14}\mu_B$ from theory. Impact the final abundance of Big Bang and supernova nucleosynthesis.
- Majorana neutrino, $\bar{\nu} = \nu$. Double beta decay becomes possible and CP invariance might differ. NMM could be at the level of $10^{12} - 10^{-10}\mu_B$.

Therefore, the experimental results of neutrino magnetic moment will be an important evidence for whether neutrino has Dirac or Majorana mass term and thus become the window to new physics.

Theoretical Approach







The cross section of ν_μ electron elastic scattering can be written into two parts. Where T represents the recoil electron energy and g_r is the shifting parts of coupling constant due to squared charge radius of neutrinos.

$$\left(\frac{d\sigma}{dT}\right)_{MSM} = \frac{G_F^2 m_e}{2\pi}\{(g_V + g_r + g_A)^2 + (g_V + g_r - g_A)^2(1-\frac{T}{E_\nu})^2 + [g_A^2 - (g_V + g_r)^2]\frac{m_e T}{E_\nu^2}\} \quad (3)$$

$$\left(\frac{d\sigma}{dT}\right)_{EM} = \frac{\pi\alpha^2}{m_e^2}(\frac{1}{T} - \frac{1}{E_\nu})(\frac{\mu_\nu}{\mu_B})^2 \quad (4)$$

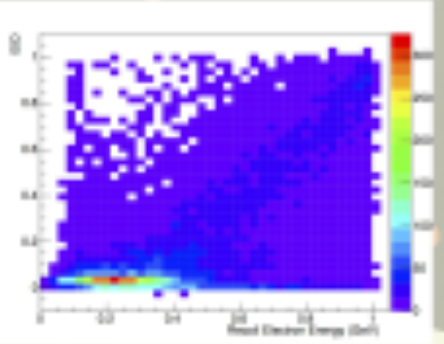
For recoiled electron energy T larger than 100 MeV, the cross sections is dominated by the events from Z boson exchange. However the charge radius may have some effects on the coupling constant and change the base line of simulation results. Grifols and Masso obtained the $< r_\nu^2 > < 2 \times 10^{-33} cm^2$ from SN 1987A data, which is within the range that g_r is much smaller than the excess events from EM process, but we will give a limit of $< r_\nu^2 >$ based on our results.

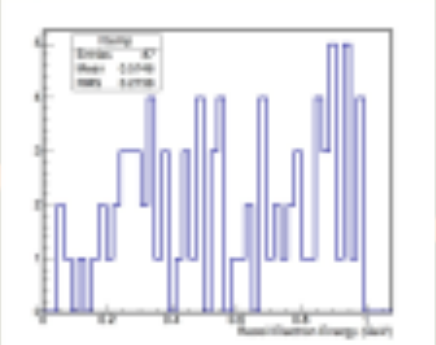
$$R(T, \frac{\mu_\nu}{\mu_B}) = \left(\frac{d\sigma}{dT}\right)_{EM} / \left(\frac{d\sigma}{dT}\right)_{MSM} \quad (5)$$

We derived the predicted NC events within $16MeV < T < 100MeV$ from $100MeV < T < 300MeV$ and then calculate the ratio R as a function of $\frac{\mu_\nu}{\mu_B}$ above. By making a cut on a certain confidence level. we get the limit of neutrino magnetic moment.

The Algorithm and Low Energy Electron Selector

By evaluating several conditions, such as the minimum number of cell hits and allowed gap to make a cluster, the energy & position to form the vertex, the center of cluster with cell memberships and so on, we give a parameter(EID) that describe whether and event is more close to real electron(1.0) or pure noise(0.0).





The plots above showed the performance of electron selector and the preliminary candidate events from ND data.

Further Plans

- Accumulate more candidates events and make proper cuts on the NuE selection. Then give the estimation of squared charge radius of ν_μ.
- Run over the Neardet data when the NuMI beam is shut down in order to estimate background events and retune slicer4D.
- Previously, the candidates events for antineutrino-electron scattering is much smaller than the theory predicted. We hope that we can give an better explanation and unveil the mystery of this phenomenon.
  - The CHARM collaboration announced $44 \pm 9 \pm 4$ for neutrino-electron scattering and $4 \pm 10 \pm 4$ for antineutrino.
  - The LSND observed 6 events for ν_μ electron scattering and 1 event for $\bar{\nu}_\mu$ electron elastic scattering.
- Statistical error and Systematic error will be analyzed due to the total data events.

Reference and QR codes

[1] P. Vogel and J. Engel, Phys. Rev. D 39, 3378 (1989).

[2] N. Bell, M. Gorchtein, et al, Phys. Lett. B 642 (2006)377.

[3] LSND Collaboration, Phys. Rev. D 63, 112001(2001).

[4] N. Bell, V. Cirigliano, et al, PRL 95, 151802(2005).

http://www-nova.fnal.gov/ biaow@smu.edu

Real-Time Flavor Tagging Algorithms in ATLAS

Physics Motivation

Identifying and tagging jets originating from b-quarks (flavor tagging) at the trigger level is a necessary aspect for many physics analyses, such as: fully hadronic tt, single top, Higgs bosons decaying to a b-quark pair (H→bb), fully hadronic ttH, 2HDM CP-odd Higgs bosons produced in association with a b-quark (bA→bbb), exotic signatures decaying to multi b-jet final states, e.g. G→hh→bbbb, and supersymmetric signatures such as 3rd generation squarks. B-jet tagging at the trigger level in the ATLAS detector during Run 2 offers unique opportunities for improvements in boosting the rate of valuable, heavy-flavor events while suppressing light quark jets.

The ATLAS Detector

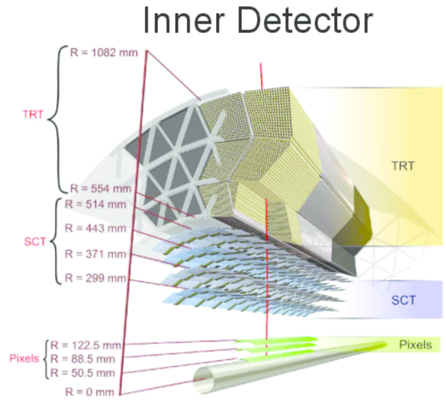
Inner Detector: portion of the ATLAS detector designed for charged particle tracking with excellent momentum resolution and primary and secondary vertex reconstruction; consists of three main subsystems

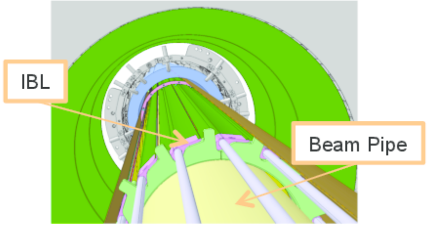
- Pixel Detector: 3 + 1 (IBL) layers and 3 disks of silicon-based pixel detectors
- Semi-Conductor Tracker (SCT): 4 layers and 9 disks of stereo silicon strips
- Transition Radiation Tracker (TRT): Straw drift tubes (tube diameter 30 μm)

Calorimeters: an electromagnetic (liquid argon (LAr)) and hadronic calorimeter (both LAr and steel/scintillator tile) are used to measure energy deposition

Muon detector: forms the outermost detector layer, used for triggering events with muons and well as precise measurement of muon trajectories

Magnet system: 1 solenoidal and 3 toroidal superconducting magnets provide essential support for momentum measurements



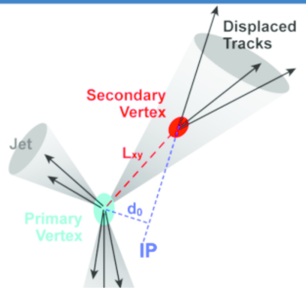


IBL = Insertable B-Layer
R_{IBL} = ~33mm
Description: New pixel layer designed to assist in tracking which is vital to accurately identifying a b-jet

Characteristics of a b-Jet

A jet originating from a b-hadron has several distinct properties:

- τ = ~1.5ps
- L_{xy} (γ = 100) = ~5cm
- Primary vertex (PV) with displaced secondary vertex (SV)
- Positive transverse impact parameter (d_0)
  - Due to relatively long B-hadron lifetime
- Non-isolated associated lepton (~10% BR)



The ATLAS Trigger System

The ATLAS trigger system decides which collision events are saved to disk for offline reconstruction and analysis. It consists of two levels:

Level 1 (L1):
- Hardware based using custom made electronics
- Uses reduced detector granularity for calorimeters and fast muon detectors

High Level Trigger (HLT):
- Software based using custom algorithms to find and cut on physics objects
- Uses regions of interest (RoIs) from L1 decision as input

Total Event Rate Reduction: 400MHz → L1 → 100kHz → HLT → 1kHz → disk

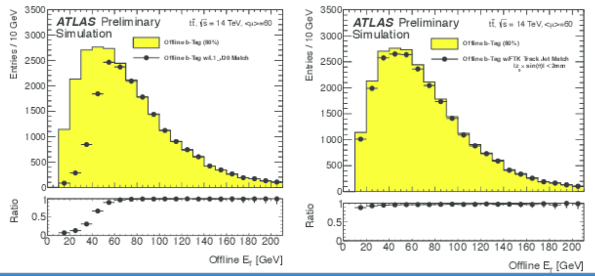
Run 2 b-Jet Related Trigger Hardware Upgrades

L1 Topological Triggers (L1 Topo)

- No functionality for selecting events based on topology at L1 trigger in Run 1
- L1 Topo added for Run 2
  - New hardware component
  - The topological processor performs real-time event selection based on the geometric and kinematic relationships between trigger objects
- Trigger decision can be based on different topologies:
  - Angular separation (ΔR, Δφ, Δη)
  - Invariant mass (M, M_T)
  - Interaction hardness (H_T, M_{eff})
- L1 Topo allows geometric matching between a muon and jet at L1. This muon-in-jet trigger can then be used by the b-jet trigger to select semi-leptonic b-decays.

Fast TracKer (FTK)

- Receives all data from the SCT components at each L1 accept signal, with up to 100kHz rate
- Hardware finds and reconstructs charged tracks candidates using pattern matching on specially pre-processed data in an associative memory:
  - Tracking information for whole detector provided immediately after L1 without any HLT processing
  - Track quality can be further improved at the HLT by just refitting pre-existing patterns
  - Track reconstruction at full L1 output rate will aid in SV tagging



Offline-based Algorithms

- Online b-jet trigger needed to implement tagging algorithms during Run 1
  - These were similar algorithms to the ones used in offline reconstruction
  - Advances made in offline performance had no direct way of affecting trigger
- For Run 2 the b-jet trigger now calls the same algorithms as the offline reconstruction
  - Separate tuning allows algorithms to adapt to online environment
  - Less code maintenance translates to more time to focus on physics performance
  - Specifically, the trigger will use IP3D, SV1, JetFitter, and MV2c20

- **IP3D:** Likelihood ratio technique that uses the longitudinal and transverse impact parameter significances of charged tracks within the jet cone to discriminate b- and light-jets
- **SV1:** likelihood ratio technique to find a secondary vertex
- **JetFitter:** likelihood technique that exploits the topology of weak b- and c-decays
- **MV2c20:** BDT that uses the outputs of IP3D, SV1, and JetFitter; specialized for additional c-jet rejection
- Run 1 b-jet trigger used a combination of IP3D and SV1
- Run 2 will see the use of MV2c20 at the trigger level
  - This same algorithm will be used in physics reconstruction

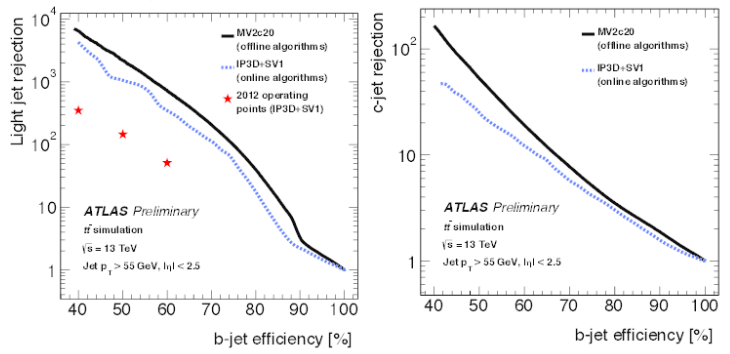
Offline-based Algorithms: Tuning and Performance

The offline algorithms used in the trigger have been tuned using online track and jet objects. The process of tuning is as following:

1. Run the offline tuning framework using the online tracks and jets to obtain reference histograms for the IP3D and SV1 taggers.
2. Rerun the tuning using the new reference histograms to obtain input for the MVA-based training (JetFitter and MV2c20)
3. Optimize both JetFitter and MV2c20
4. Feed desired b-tagging efficiency operating point to offline optimization framework to obtain an optimal MV2c20 working point (WP)
5. Create new database from these components

This newly created database contains:

- IP3D/SV1 reference histograms (for each flavor) of impact parameters/ vertex masses, etc.
- JetFitter/MV2c20 neural net layers information/BDT weights and variables



More Run 2 Improvements

A new approach to eliminate track overlap removal and constrain the track finding by the PV can lead to improved performance in the higher pileup scenarios envisioned during Run 2. The b-jet trigger must process each RoI individually (an RoI corresponds to a jet object in the context of b-jet tagging in the HLT). Tracking and PV finding must be performed on each jet for tagging purposes. A comparison of the Run 1 and Run 2 approaches is given below:

Run 1	Run 2
A pseudorapidity cut is applied to eliminate very forward jets where tracking isn't available	All RoIs merged into a single, topologically unique "super RoI"
Track finding performed on a per RoI basis	Fast tracking and PV finding performed on super RoI
All tracks are then used to find the PV	Precision tracking performed on single RoIs, but now constrained by the PV
Jets not pointing to the PV are then removed	

The Run 1 approach lead to some inefficiencies as some tracks would be double counted because of overlapping RoIs. Thus, an improvement is envisioned in the new, "split" configuration.

EPS Poster Session – Vienna, 22 July 2015

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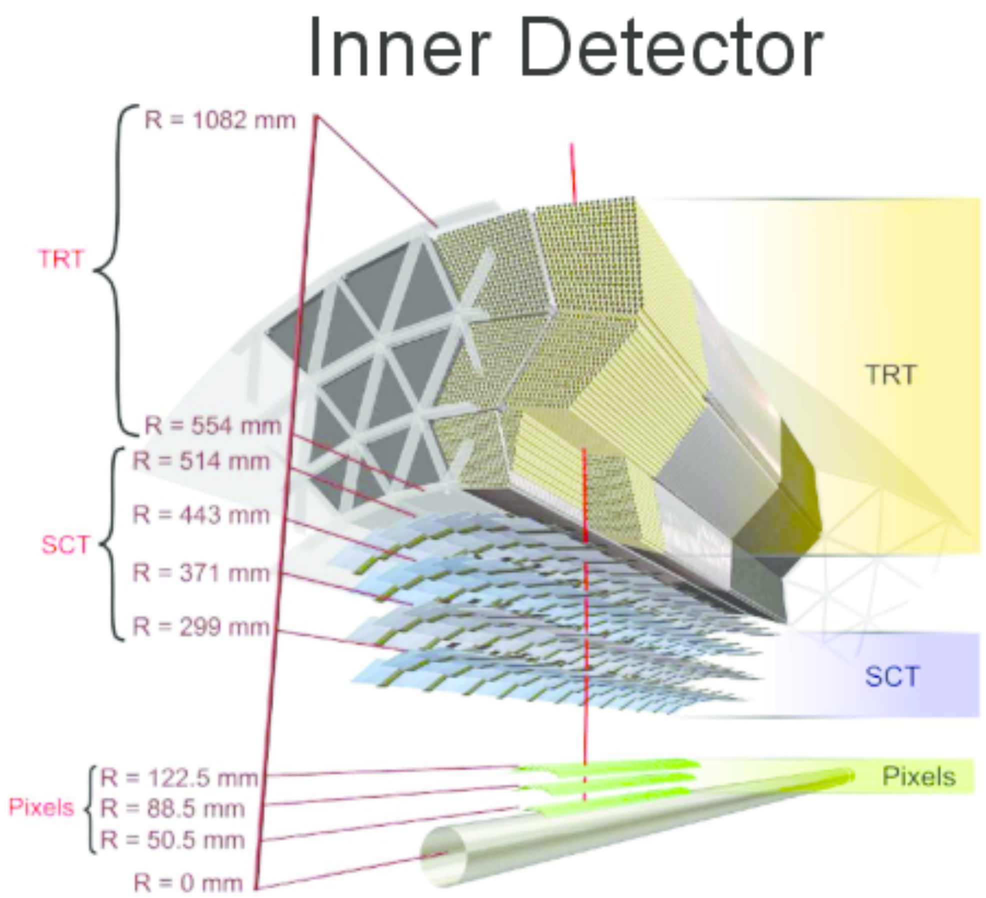

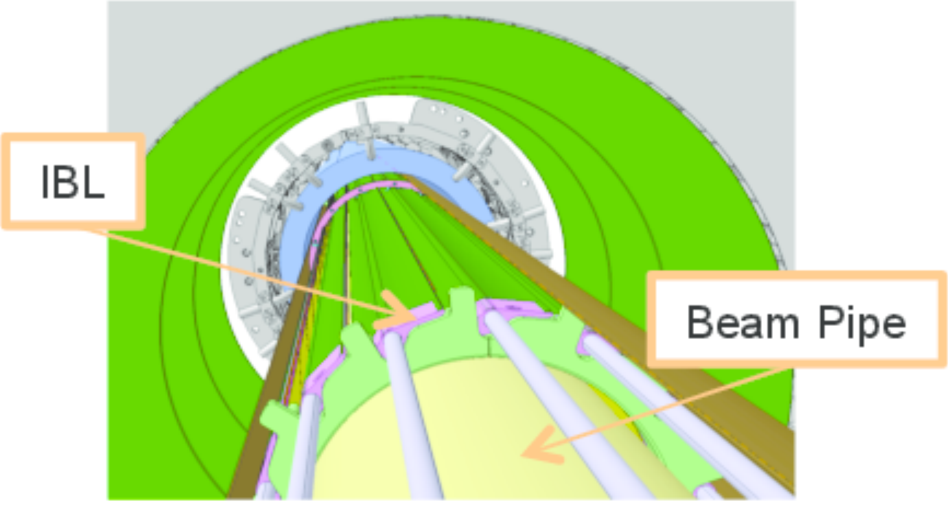

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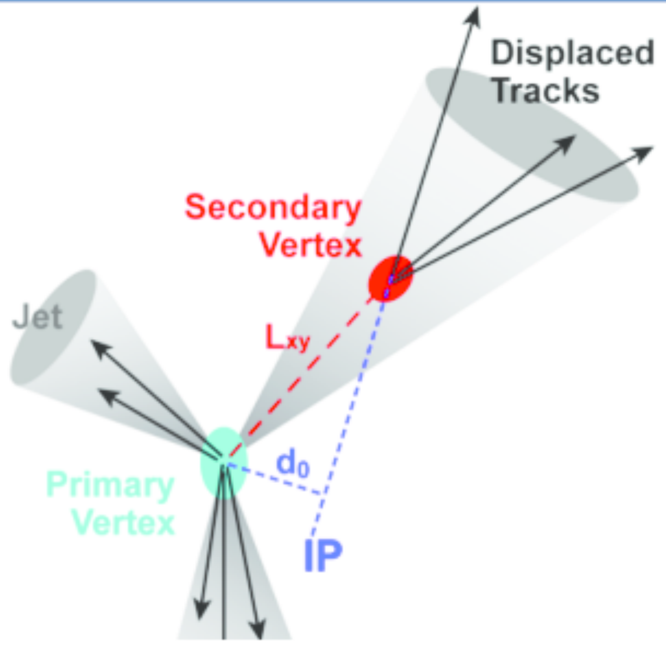
  - Due to relatively long B-hadron lifetime
- Non-isolated associated lepton (~10% BR)



The ATLAS Trigger System

The ATLAS trigger system decides which collision events are saved to disk for offline reconstruction and analysis. It consists of two levels:

Level 1 (L1):

- Hardware based using custom made electronics
- Uses reduced detector granularity for calorimeters and fast muon detectors

High Level Trigger (HLT):

- Software based using custom algorithms to find and cut on physics objects
- Uses regions of interest (RoIs) from L1 decision as input

Total Event Rate Reduction: 400MHz → L1 → 100kHz → HLT → 1kHz → disk

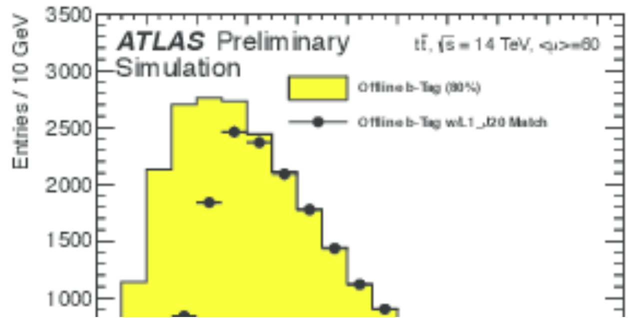
Run 2 b-Jet Related Trigger Hardware Upgrades

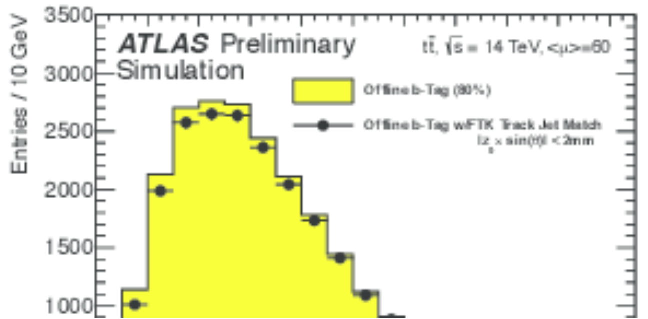
L1 Topological Triggers (L1 Topo)

- No functionality for selecting events based on topology at L1 trigger in Run 1
- L1 Topo added for Run 2
  - New hardware component
  - The topological processor performs real-time event selection based on the geometric and kinematic relationships between trigger objects
- Trigger decision can be based on different topologies:
  - Angular separation (ΔR, Δφ, Δη)
  - Invariant mass (M, M$_T$)

Fast TracKer (FTK)

- Receives all data from the SCT components at each L1 accept signal, with up to 100kHz rate
- Hardware finds and reconstructs charged tracks candidates using pattern matching on specially pre-processed data in an associative memory:
  - Tracking information for whole detector provided immediately after L1 without any HLT processing
  - Track quality can be further improved at the HLT by just





Field Trip
(To the Wall of Honors!)

Last Items

Boiler Plate Stuff

- **Course Logo**

- **Minimum acknowledgement:**
  “We thank the SMU Honors Program for its support of academic excellence and creativity. We also thank the SMU Physics Department for funding our activities.”