

# Philippine Journal of Astronomy

The journal of the Astronomical League of the Philippines

**On Double Star System, Parallel Universe,  
Quantum Duality and Super Symmetry:**

## BINARIES

In this issue:

- The Hunt for a Binary Star System
- Parallel Universe: Life opposite our own
- Super Symmetry: Where are we in physics
- Quantum Duality: Some sensible absurdities of nature



# Philippine Journal of Astronomy

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The *Philippine Journal of Astronomy (PJA)* is published by the Astronomical League of the Philippines (ALP), the eminent astronomical organization in the country. The *Society* is the major scientific and educational organization for astronomy in the Philippines. It is a general society with membership from the professional and amateur astronomy community.

The journal is the first astronomical journal published in the Philippines, signifying the continued evolution of Philippine Astronomy.

The *Journal* publishes refereed manuscripts, popular astronomy articles, proceedings of astronomical conference, letters, image submissions and reviews from amateur and professional astronomers, as well as news and announcements from the organization.

For inquiries, comments, or suggestions, please send an electronic mail to the editor at

[pjastro@astroleaguephils.org](mailto:pjastro@astroleaguephils.org)  
[john.cabrera@physicist.net](mailto:john.cabrera@physicist.net)

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## Philippine Journal of Astronomy

### EDITORIAL STAFF

#### Editor-in-Chief

John Ray Cabrera

#### Contributing Editor

John Ray Cabrera

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#### Scientific Advisers:

Thijs Kouwenhoven, PhD

*Kavli Institute for Astronomy and Astrophysics  
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*Peking University  
Beijing, China*

Jelly Grace Nonesa, PhD

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*Natural Science Research Institute*

*Korea Advanced Institute of Science and  
Technology*

Reinabelle Reyes, PhD (Astrophysics)

*Department of Astrophysical Sciences*

*Princeton University, USA*

---

#### Contributors:

James Kevin Ty

Christopher Louie Lu

Norman Marigza

Custer Deocaris

Peter Benedict Tubinal

Jett Aguilar

Armand Lee

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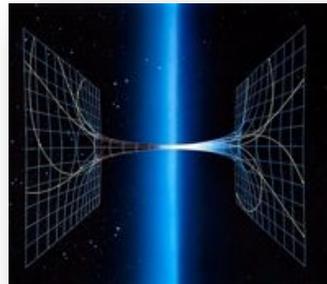
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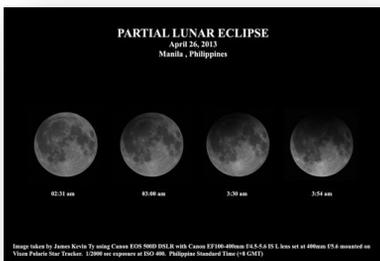
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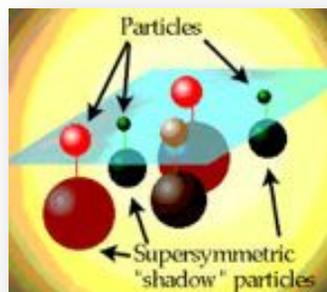
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# The Hunt for a Binary Star System

By John Ray Cabrera



Much like the life's polar partners, some objects (or perhaps most) of the universe come in pairs.

A black hole, a moon, a star system— all these can come in a binary formation. In fact, more than 80% of the single points of light we see in the night sky are actually double star system orbiting each other. These pairs of celestial waltz come in an array of configuration.

These stars orbit in a common center of mass with the brighter star classified as a Primordial Star and the others are just tagged as A or B, depending on the quantity with the dimmer one being the least letter. But in cases where all of them exudes the same luminosity, the designation is up to the discretion of the discover.

Going back into the graduate astronomy class, here are the stratifications of the binary star system:

Wide Binary - stars that have orbits which keep them spread apart from one another. These stars evolve separately, with very little impact from their companions. They may have once contained another star in their lifetime, which muzzled out the other one outward while eventually ejecting themselves.

Close Binary - evolve nearby, able to transfer their mass from one to the other. The primaries of some close binaries consume the material from their companion, sometimes exerting a gravitational force strong enough to pull the smaller star in completely. The pairs can also be classified based on how they are observed, a system which has overlapping categories

Visual Binary - two stars with a wide enough separation that both can be viewed through a telescope, or even with a pair of binoculars. Five to 10 percent of visible stars are visual binaries.

Spectroscopic Binary - appear close even when viewed through a telescope. Scientists must measure the wavelengths of the light the stars emit and determine their binary nature based on features of those measurements.

Eclipsing Binary - two stars whose orbits are at an angle so that, from Earth, one passes in front of the other, causing an eclipse. This feature is based on the line of sight rather than any particular feature of the pair

Astrometric Binary - tars that seem to dance around an empty space; that is, their companions cannot be identified but only inferred. Such a companion may be too dim to be seen, or could be hidden in the glare from the primary star.

The maiden quest for the binary star hunt started way back 16<sup>th</sup> century when Galileo discovered another star in the far end of the Big Dipper handle, saying that there were actually two stars orbiting each other. It

turned out to be six and not two.

Following in the 18<sup>th</sup> century, William Herschel catalogued 700 pairs of stars and was the first person who uses the term “binary” to mean double stars.

A question poses in the middle of the 19<sup>th</sup> century asking whether a Sun belonged to a binary star. It was hypothesized that there was once either a brown dwarf, dim red dwarf or a white dwarf in the neighborhood, ancestors call Nemesis, that has been the Sun’s sky partner but was eventually slung out because of gravitational instability. Accordingly, the Nemesis is the one culprit of the periodic mass extinctions that occurred multiple times in the Earth’s history, which some paleontologists suggested to be an occurrence in a 26million year cycle.

Not so long ago, in 2010, NASA’s Wide-field Infrared Survey Explorer (WISE) began searching for brown dwarfs not only in our Solar System but outside as well to account for this claim. This small-scale space telescope was designed to perform a survey of the entire expanse of space in near- to mid-infrared wavelengths ranging from 3.4 to 22 microns. Same way does the Two Micron All Sky Survey does.

The result? Nothing was found out to be any signs (even tantalizing clues) of Sun’s companion star.

Our Sun, much like a life in our planet, is then coined by many as a freak of nature because of its solitary existence.

If a Sun’s lonely world is a peculiar sight, how common then is the binary star at least in our neighboring star system?

Around March of this year, a recent report of WISE discovering a binary star just around 6.5light years away swept the newsrooms by storm. The pair, called WISE J1049-5319 A and B, are brown dwarf stars and only two star systems – the triple star Alpha Centauri, and Barnard's Star – which is rather residing close to our Sun.

WISE J1049-5319 has a low galactic latitude which means that it appears against the bright background of the Milky way, eluding its detection from long ago.

The object is actually a binary star system composed of two brown dwarfs currently separated by 1.5 seconds of arc. Their period of rotation around each other is about 25 years, which corresponds to a separation of about three astronomical units (approximately 449 million km). The spectrum revealed that the surface temperature of the stars is in the neighborhood of 1300 K (1850 F).

The impact it would bring is that it might be a viable hunting ground to find a carbon-based life since it is very close to the Earth.

But if it doesn’t so, maybe a future endeavor will. The we are closing to a thousand exoplanets just to find a goldilocks planet to harbor life, but maybe the life we are looking for might be really close to our backyard.

***“In the deepest sense the search for extraterrestrial intelligence is a search for ourselves.”***

-- Carl Sagan



# Global Astronomy Month (GAM) SUNday

By James Kevin Ty



Last April 7, members of the Astronomical League of the Philippines went to Rajah Sulayman Park at Baywalk after their monthly meeting to conduct a free public solar viewing session to celebrate the Global Astronomy Month SUNday. ALP is also coordinating with Vietnam Ho Chi Minh Astronomy Society to conduct this events as both countries are under segment 2 of 30 nights of StarPeace Project. Members who were present to help were ALP President James Kevin Ty, wife Charito and son Kendrick Cole KC Ty; ALP Secretary Christopher Louie Lu, Gary Andreassen with wife Irma Andreassen; Ronald Sison, Per Edman with son Oliver; Mark Vornhusen and wife Arlene Vornhusen ; Bel Pabunan & Liza Quitlong; guests Canadian amateur astronomer Nolan Smith and German amateur astronomer Patrick Schmeer. James brought along Coronado PST-Ha on Vixen Polarie Mount; Per with Orion XT6 dobsonian reflector ; Louie with Celestron Powerseeker 80 refractor with EQ-1 mount and Mark with Coronado PST-Ha on sturdy tripod and Ronald Sison with Celestron C90 Mak on sturdy tripod. They started out at around 4:30pm and pointed their telescopes to our solar system's closest star, the Sun. They let the viewers look at the Sun through white light as well as

Hydrogen Alpha wavelength . NOTE: DO NOT LOOK AT THE SUN WITHOUT THE USE OF SAFE SOLAR FILTERS OR EYE DAMAGE WILL OCCUR!!!



The viewers were able to see huge sunspot AR11711 Sunspot Group in white light wavelength as well as several smaller sunspot groups and 2 huge eruptive prominences, AR11711 Sunspot Group and numerous flares and long twisting dark filaments!!! More than 150+ people were able to get their chance to view the Sun up close and personal that late afternoon. They were also able to see a good clear view of sunset as well as seeing International Space Station(ISS) flyby! At around 6:30pm, they had their traditional group shot taken before packing up their telescopes and went to Aristocrat restaurant for dinner before heading home.

A perfect SUNday indeed !!!

*All images featured in the article are owned by the Astronomical league of the Philippines, Inc.*



Astro Kid KC take a peek at the Coronado PST-Ha.



ALPer Per Edman had a great time showing the Sun to the public with his XT6 reflector.



German amateur astronomer Patrick Schmeer also join ALPers in conducting free solar observation to the public.



ALPer Gary Andreassen posed beside the Coronado PST-Ha on Vixen Polarie Mount.”



ALPer James Kevin Ty beside his Coronado PST-Ha on Vixen Polarie Mount.



ALPers had a power dinner after a successful SUNDAY free solar observation!!!



Group shot

## Caliraya Stargazing Part 1

By James Kevin Ty



Last April 13, members of the Astronomical League of the Philippines went to Caliraya , Laguna for their monthly dark skies stargazing session. Members who were present were ALP President James Kevin Ty, wife Charito and son Kendrick Cole KC Ty; VP Jett Aguilar, Treasurer Andrew Ian Chan and Iah Serna; Mike Enage, Ronald Sison with sons Adrian & Aldrin Sison, Mark Vornhusen, Per Edman & son Oliver Edman ; guests German amateur astronomer Patrick Schmeer and Sky Wei.

They departed after lunch individually and most of them arrive late at around 8:00pm more or less because of heavy traffic along Calamba , Laguna! James brought along his Canon EF100-400mm IS L lens mounted on Vixen GPDXmount & Vixen Polarie Star Tracker. Jett brought along his MicroTech 6" RC & William Optics Megrez 90 refractor on Vixen GPDX mount. Andrew with his Skywatcher 80ED refractor on Vixen GP mount; Mike with his ETX125 Mak OTA mounted on Vixen GPDX mount; Mark with his Nikon 180mm lens on Polarie Star Tracker, Ronald with his Nikon lenses mounted on Vixen Polarie Star Tracker.

The sky was mostly clear the whole night although some passing clouds did interfere once

in a while. They were able to image the Milky Way as well as some deep sky objects such as Orion Nebula, Omega Centauri globular star cluster, Lagoon & Triffid Nebula & M101 Pinwheel Galaxy. They attempted to image Comet 2011 L4 PanSTARRS but was foiled by low NE horizon clouds.

At around 8:00am, they packed up their stuffs and had their customary group shot taken before going to Jollibee Pagsanjan to have their breakfast before going home.



Breakfast before going home



Group shot

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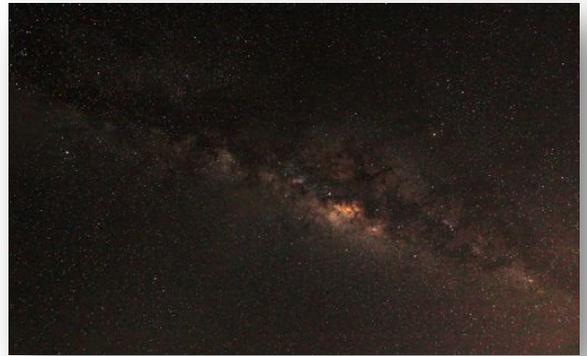
Summer Milky Way by ALPer Mark Vornhusen



Eta Carina Nebula by ALPer Mike Enage.



M101 Pinwheel Galaxy by ALPer Jett Aguilar



Summer Milky Way by ALPer James Kevin Ty



M42 Orion Nebula by ALPer Mark Vornhusen



M8  
Lagoon  
& M20  
Trifid  
Nebula  
by  
ALPer  
James  
Kevin  
Ty

## Caliraya Stargazing Part 2

By James Kevin Ty



Last April 20, members of the Astronomical League of the Philippines went to Caliraya, Laguna for their monthly dark skies stargazing session. Members who were present were ALP President James Kevin Ty wife Charito and son Kendrick Cole KC Ty; VP Jett Aguilar, Treasurer Andrew Ian Chan, director Arnel Campos, Gary Andreassen with wife Irma Andreassen; Mike Enage, Mark Vornhusen and wife Arlene Vornhusen, Manuel Goseco and son, and guest Canadian amateur astronomer Nolan Smith.

They departed after lunch individually and all arrived at the site at around 8:00pm more or less. James brought along his Canon EF100-400mm IS L lens mounted on Kenko Sky Memo tracker mount & Vixen Polarie Star Tracker. Jett brought along his Takahashi TSA102 refractor mounted on Vixen GPDX mount. Arnel with his Explore Scientific 103 refractor mounted on Skywatcher HEQ-5 mount; Gary with his GSO 8" f/4 Newtonian reflector on Orion SVD mount; Andrew with his Skywatcher 80ED refractor on Vixen GP mount; Mike with his ETX125 Mak OTA mounted on Vixen GPDX mount; Mark with his Nikon 180mm lens on Polarie Star Tracker, Nolan brought along his Canon Image Stabilizer 40mm binoculars.

The Moon was still high in the western horizon and shows a very nice Moon Halo together with some scattered clouds. James then refer to the Moon Halo as a bad sign for not that good weather to come that evening session but nevertheless, they were still hoping there will still be some clearing from time to time.

After the bright Moon sets at around 1:40am, they were able to image some parts of the Summer Milky Way as well as Lagoon & Triffid Nebula through passing clouds. They attempted to image Comet 2011 L4 PanSTARRS once again but was again foiled by low NE horizon clouds.

At around 8:00am, they pack up their stuffs and had their customary group shot taken before going to McDonald's in Los Banos to have their breakfast before going home.



ALPer Arnel Campos posed beside Gandalf, his Explore Scientific 102 refractor on Skywatcher HEQ5 mount system.

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Wide field shot of Triffid and Lagoon Nebula by ALPer Mike Enage



Beautiful Nebula Like Sunrise Clouds by ALPer James Kevin Ty



Moon Halo by ALPer James Kevin Ty



Milky Way Star Cloud & Scorpio Stinger by ALPer Gary Andreassen



Group shot. See next event!!!



M8 Lagoon and M20 Triffid Nebula by ALPer James Kevin Ty

# PARTIAL LUNAR ECLIPSE

On the early morning of April 26, 2013, there was a very subtle partial lunar eclipse that was visible here in the Philippines as well as whole of Europe, Africa and Asia. The Earth's umbral (dark) shadow only cover less than 1.5% of the Moon's northern surface area but it was totally immersed on the penumbral (light) shadow nevertheless. Penumbral eclipse will start at around 2:04am with umbral eclipse starting at around 3:54am. Maximum eclipse will occur at around 4:09am with about 1.5% obscuration. Then umbral eclipse ended at around 4:21am. Penumbral eclipse ends at around 6:11am but Moonset occurred at around 5:40am thus ending the eclipse before penumbral eclipse ends. Below are 2 composite parts of the eclipse taken by ALP President James Kevin Ty & VP Jett Aguilar.



02:31 am



03:00 am



3:30 am



3:54 am

Image taken by James Kevin Ty using Canon EOS 500D DSLR with Canon EF100-400mm f/4.5-5.6 IS L lens set at 400mm f/5.6 mounted on Vixen Polaris Star Tracker. 1/2000 sec exposure at ISO 400. Philippine Standard Time (+8 GMT)



19:38 UT



19:51 UT



19:58 UT



20:02 UT



20:08 UT



20:12 UT



20:18 UT



20:36 UT

# StarPeace with Global Astronomy Month (GAM) Jupiter and Saturn Watch

By James Kevin Ty



Last April 6, members of the Astronomical League of the Philippines went to Rajah Sulayman Park at Baywalk to conduct a free public viewing session to celebrate the StarPeace with Global Astronomy Month Jupiter and Saturn Watch. ALP is also coordinating with Vietnam Ho Chi Minh Astronomy Society to conduct this events as both countries are under segment 2 of 30 nights of StarPeace Project. Members who were present to help were ALP President James Kevin Ty, wife Charito and son Kendrick Cole KC Ty; ALP Secretary Christopher Louie Lu, wife Karren and daughter Frances; ALP Treasurer Andrew Ian Chan, Gary Andreassen with wife Irma Andreassen; Mike Enage, Per Edman with son Oliver; Mark Vornhusen and wife Arlene Vornhusen.

James brought along Meade 8" f/10 SCT on Vixen GPDx mount ; Per with Orion XT6 dobsonian reflector ; Louie with Celestron Powerseeker 80 refractor with EQ-1 mount and Mark with WO 66SD refractor on sturdy tripod. They started out at around 7:30pm and initially pointed their telescopes to planet Jupiter and its 4 Jovian moons. They later pointed some of the telescopes to the beautiful ring planet Saturn with was rising from the eastern horizon. James was

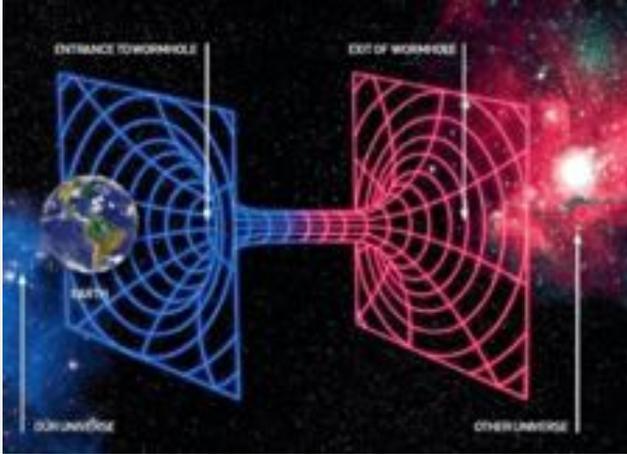
able to let the viewers get a good view of Saturn at 510x under fair seeing for free and most of them got blown away with the beauty of Saturn as it looks very 3D and like floating in space!!!

Mark was able to show the viewers some low power views of M42 Orion Nebula as well! More than 250+ people were able to get their chance to view the 2 gas giant up close and personal that evening. AT around 10:00pm. They had their traditional group shot taken before packing up their telescopes and went to Jollibee for late dinner while also using the time to discuss preparations for next day's GAM SUNDAY solar observations at the same site.



# Parallel Universe: A World Opposite Our Own

By John Ray Cabrera



The beautiful thing about science is that whatever baffles us is the very same thing that fascinates us.

The idea of parallel universe is never new to our perspective. In fact, even Hollywood industry is banking on this concept with movies like *The One* by Jet Li, and lately a TV series *Fringe* by Joshua Jackson.

But does it really exist? Have you ever thought what will happen in your life, if sometime three years ago, you decided to pursue a different careers? In my case, will I be the chartbuster rockstar? If these things (foolish aspirations) didn't happen in our universe, maybe it does in another? If so, would I be able to cross in another universe to watch my own self in a rock concierto?

For me, I ponder the possibilities all the time. Not only me, in 1954, a young Princeton University doctoral candidate named Hugh Everett III came up with a radical idea: That there exist parallel universes, exactly like our universe.

In a parallel universe, things may look like just a

replica of our own, perhaps we are of the same DNA as us and so does everybody. The only difference is the branching off of each other's chartered course to which I fondly call the Trajectory of Time.

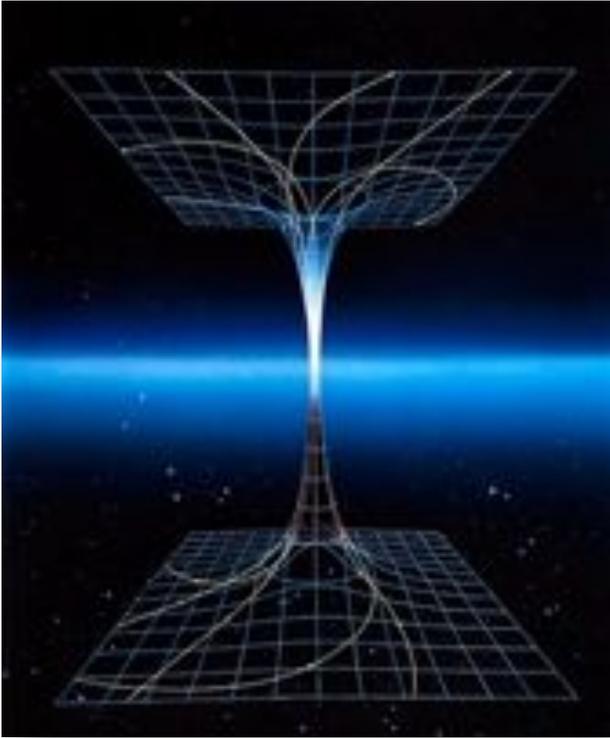
In this universe, we may exist, or may have already been dead already, or may never have existed at all. If we exist, we might not have the same jobs, or family. World War II might not ever happen, instead a World War Z. And more radically, dinosaurs might still exist, only they have evolved, adapted and coexisted with us. Every different decision we take, every different action we do, create a whole new reflex in the parallel universe so in reality if a parallel universe does exist, then there are countless parallel universes out there and this fact isn't just all Hollywood, it maybe a fact stranger than fiction.

The idea of parallel universes that mirrors like our very own have been used as explanations for metaphysics. This is particularly useful in explaining time travel machine, even way beyond a flux capacitor technology can do.

So in the future, if a doomsday machine able to travel back in time is successfully created and we traveled back in time and accidentally killed our ancestors, will we then cease to exist? If yes, this is a very strange reality we live in as we may suddenly vanished into thin air if any person from the future traveled to the past and killed our grandparents. And if so, then parallel universes we created out of the remnants of the left over destiny was take will not

therefore exist.

Let's study and take account of this possibly happening by taking a Black Hole travel.



Albert Einstein first predicted this cosmic phenomenon rising from the death of a huge star, around three to several tens of solar masses or more, and collapses in itself from itself under the force of its own gravity, thus forming a dark region in the sky we now call Black Hole.

Einstein along with another renowned physicist, Nathan Rosen, suggested that a black hole is symmetrically pointed to another gravitational well called White Hole. Although this is purely conceptual as we speak, so does Black Hole in the past, but now it has been substantially proven by science.

This Black Hole / White Hole tandem creates a vortex, or wormhole, or in physics "Einstein Rosen Bridge" (this has been mentioned numerous times by the movie Thor to mean a channel from Asgard to Earth).

Hypothetically, this would mean that anything

Gobbled up by a Black Hole will be spitted somewhere through a White Hole into an unknown location, hence a shortcut of space and time. Alternatively, this could be a passageway to a parallel universe, in any case, acting as a cosmic tunnel between two dimensions.

The second hypothesis may explain the total absence of anti-matter in our midst. According to the universe's governing principle of symmetry, there must be equal amounts of matter and anti-matter, but we know how largely scarce the anti-matters are. Indeed, we have failed to locate the traces of anti-matter in our neighborhood that would account the equality of numbers.

The only way we would be able to produce it would be from particle accelerators, particularly the Large Hadron Collider in the CERN laboratory in Geneva Switzerland.

The existence of the parallel universe may explain the lack of anti-matter in our world. And perhaps, in the parallel universe, there could be a world a lot like our own, but is constructed out of anti-matter, following the principles of dissymmetry and annihilation frontier.

Unlike before when a scientist talks about anything shrouded in mystery, it consequently follows an electrocution of his career. Today the scientific community is bravely facing a new frontier, the possibility of a parallel universe has become widely accepted, and perhaps in a not so distant future, it will soon be proven true by science, just as how it is mathematically plausible.

Sadly to be able to cross from this cosmic shortcut, it would require tremendous amount of energy, perhaps that same total energy as our Sun. And not only are we hamstrung by the energy requirement, the wormhole is gravitationally unstable too.

# QUANTUM DUALITY:

## Wave? Or particle. Compiled by John Ray Cabrera

### Was light really made of corpuscles?

Newton wasn't the only person at the time that had a theory about the nature of light. Huygen put forward his **wave theory of light** which could explain **reflection and refraction**. Huygen said that when light passed into a transparent object (such as glass) the **speed of the light waves decreased**. Huygen's wave theory of light was rejected by most scientists in favour of Newton's corpuscular theory. An exam question might ask why. The reasons are:

- The speed of light could not be measured at the time so what happened to the speed when it entered a transparent object was not known for sure
- Newton had a better scientific reputation than Huygen
- Wave theory of light was thought to be made of longitudinal waves which couldn't explain the polarisation of light

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### Why are there dark and bright fringes?

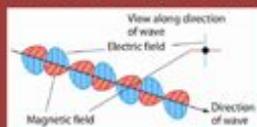
Young's double slit experiment produces dark and bright fringes on the screen because:

- **Bright fringes** are formed when light waves from each slit arrive in phase so they reinforce each other (**constructively interfere**)
- **Dark fringes** are formed when light waves from each slit arrive **180° out of phase** and so they cancel each other out (**destructively interfere**)

You can use these two points in a lot of wave particle duality exam questions so make sure you can quote them both!

### MAXWELL'S DISCOVERY OF ELECTROMAGNETIC WAVES

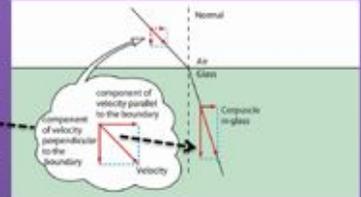
Huygen's wave theory of light developed into the **theory of electromagnetic waves** by James Clark Maxwell. He was able to prove mathematically that changing a current in a wire leads to radiation of waves which have changing electric and magnetic fields. He showed the waves are **transverse** and that the electric waves are **in phase with** and **perpendicular** to the magnetic waves.



### CORPUSCULAR THEORY CONTINUED...

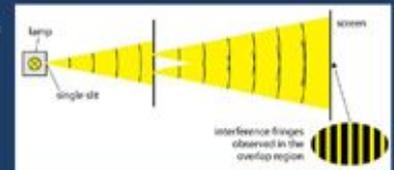
Newton also had to describe how the path of light changed when it entered a transparent object (such as glass). He stated "*the component of velocity perpendicular to the boundary of each corpuscle is increased as the corpuscle crosses the boundary into the substance and the component of velocity parallel to the boundary is unchanged*".

Basically in simple terms this means the force acting parallel to the normal (see figure) increases, the force acting perpendicular to it remains the same, hence it gets faster.



### THEN CAME YOUNG'S DOUBLE SLITS

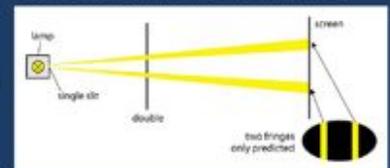
In 1803 Thomas Young set up an experiment where he passed light through double slits and observed the pattern that was formed on a screen (see diagram below). He could see **interference fringes** (dark and bright) which confirms the wave-like nature of light. The experiment shows that the light diffracts at the slits which makes them spread out. The double slits act as **coherent sources of waves** so the wave fronts from each of the slits produce an interference pattern where they overlap (producing parallel equally spaced fringes).



### Why didn't Newton's theory support Young's Double Slits?

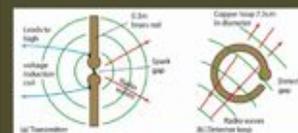
Newton's corpuscular theory doesn't support Young's double slits experiment because the particle nature of light would suggest the corpuscles would travel straight through the slits and produce two fringes (i.e. no diffraction occurs at the slits).

Despite Young's findings the wave theory of light was still not accepted until it was later proved experimentally that light travelled slower in water than in air



### HERTZ'S DISCOVERY OF RADIO WAVES

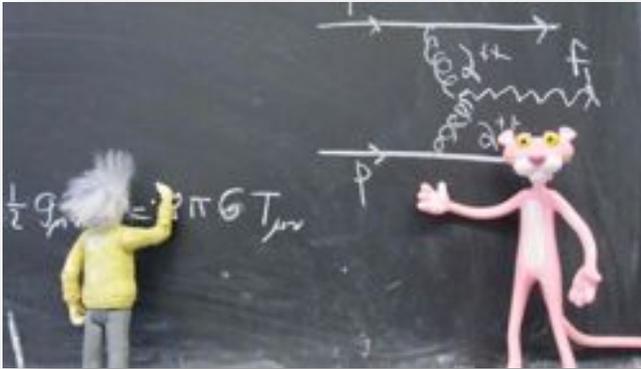
More than 20 years after Maxwell's discovery of electromagnetic waves Hertz was able to **produce** and **detect** radio waves. These radio waves could be produced when a **high voltage spark** jumps across an air gap. They could be detected using a **wire loop** with a small gap in it (shown in the diagram).



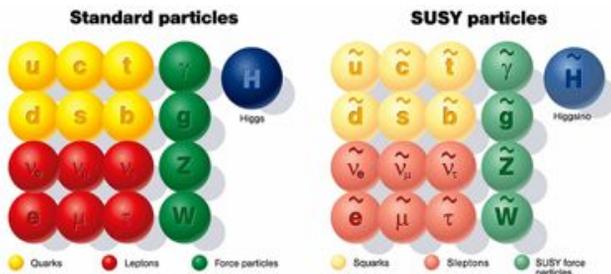
Sparks generated from the spark gap spread out and pass through the detector loop. This induces a voltage in the loop which makes a spark jump across the gap in the loop.

# SuperSymmetry: Where are we in particle physics

By John Ray Cabrera



Modern physics sent two relatively paradoxical concept in the world of physics, a kind of paradigm shift that baffles many physicists. One is Quantum Mechanics and the other is the Theory of Relativity. The interaction between the two is aptly described in the Quantum Field Theory and a new matter, which is technically not a particle, was born in the form of anti-matter. As a result, the number of elementary particles doubled



There is a great hurdle in between the interaction between the two, they don't interact. In short, marrying the two brings about marital incompatibility. The couple has not been getting along very well, resulting in mathematical inconsistencies, meaningless infinities and negative probabilities. The key to success may be in *supersymmetry*.

But what is SuperSymmetry and why was anti-matter needed? One reason was to solve a crisis

in the 19th century physics of classical electromagnetism. An electron is, to the best of our knowledge, a point particle. Conversely, it has no size, yet an electric charge. A charged particle inevitably produces an electric potential around it, and it also obtains the potential created by itself. This leads to an infinite loop of "self-energy" of the electron. In other words, it takes substantial energy to "pack" all the charge of an electron into small size.

Einstein's states that the mass of a particle determines the energy of the particle at rest. For an electron, its rest energy is known to be 0.511 MeV. For this given amount of energy, it cannot afford to "pack" itself into a size smaller than the size of a nucleus. Classical theory of electromagnetism is not a consistent theory below this distance. However, it is known that the electron is at least ten thousand times smaller than that.

Accordingly, supersymmetry is a conjectured symmetry of space and time. A consequence of having this symmetry in nature is that every type of particle has one or more superpartners — other types of particles that share many of the same properties, but differ in a crucial way. If a particle is a fermion, its super-partner is a boson. If a particle is a boson, its super-partner is a fermion.

Our world has many fermions — all the matter particles — and many bosons — all the force carriers. But none of them have the right properties to be super-partners of one other. So therefore, if supersymmetry were a symmetry of nature, every type of

elementary particle that we know of in nature would have to have partners we have not discovered yet.

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However it is also a symmetry that relates space and time themselves to superpartner directions of space and time — in other words, space-time itself has extra dimensions quite unlike the ones we know. In a bosonic world, you can move as far as you want, taking step after step to the left. Moving in a fermionic dimension, it is as though you can only take one step. Take a second step in the same direction, and you're nowhere. The only thing you can do is go back.

Einstein's theory of relativity does a really awesome job in describing and predicting many aspects of our world. It consists of a set of equations that obey a certain set of symmetries. It was proven mathematically in the 1960s that SuperSymmetry is the only symmetry that can be added to the symmetries of Einstein's theory without making the resulting equations inconsistent with the world we live in. So SuperSymmetry is, in this sense, one of a kind.

So what are these superpartner particles?

The theory states that if the world were exactly supersymmetric, every particle known would have superpartners with the same interactions and the same mass. But fermions have boson superpartners, and vice versa.

For each matter fermion, such as the electron or the strange quark, you see that there are two new particles, both bosons, Selectrons and Squarks. For the force carrier bosons, they instead have a partner fermion. The photon has a Photino, the Gluons have Gluinos, etc.

The massive W bosons are a little more confusing. They have a partner wino and also a partner Higgs, called the H<sup>+</sup>.

All of these particles have exactly the same mass, in this imaginary exactly-SuperSymmetric world.

There are two Higgs particles h<sub>0</sub> and H<sub>0</sub> in this model, and each has a partner Higgsino. One is massless and the other has a mass. Why two? Turns out that in a supersymmetric world you need two to allow both the UP type quarks and its Down quarks to obtain their masses. Another argument is that you need the Higgsinos to avoid mathematical absurdities.

But why can't we see these SuperSymmetry in a real world scenario. It is a common notion in physics that symmetries may be hidden from view. Physicists often say that it is *spontaneously broken* but this is not a good argument intuitively since the symmetry is still there, it has just been made difficult to recognize.

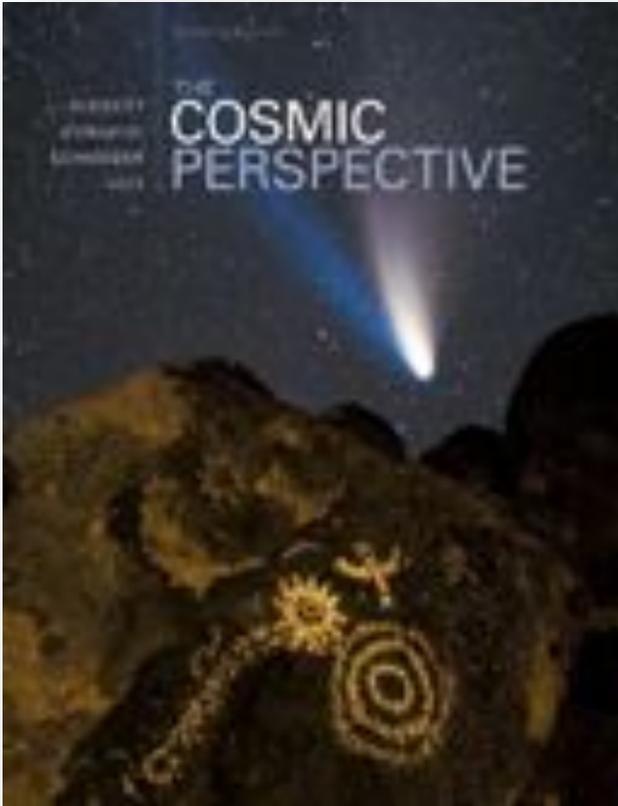
The laws of physics are rotationally symmetric. But on Earth, the rotational symmetry is hidden; right-side up, up-side down and sideways take on meaning. This hiding or rather "spontaneous breaking" of a symmetry happens commonly in physics.

The question is, then, what if some aspect of our world, not similar to the Earth, but something subtle similar to a Higgs field comprises the universe and changing its properties, hides SuperSymmetry from view everywhere throughout the universe. What would happen then? It turns out that it is quite easy to get a world that looks just like ours, in which the superpartners of the known particles exist but have become heavy... too heavy for us yet to have produced them in experiments..

## The Cosmic Perspective (7th Ed)

By John Ray Cabrera

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Astronomy has always been a daunting task and is probably one of the most mentally grinding when it comes to graduate and post-graduate course. That is why to have tools that will make life easier has always been a welcoming addition. A good book, comprehensive, well-arrayed, easy to understand, is of no exception.

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