

National Aeronautics and Space Administration

Operator STP, AFRL, SMC/WM
Mission type Technology Demonstrator
Satellite of Earth
Launch date 16 April 2008
Carrier rocket Pegasus-XL
Launch site Kwajalein Atoll, Marshall Islands
COSPAR ID 2008-017A

Mass 395 kg (870 lb)

Regime	Low Earth orbit
Eccentricity	0.032
Inclination	13.0°
Apogee	853 km (530 mi)
Perigee	405 km (252 mi)
Orbital period	97.3 min



CINDI

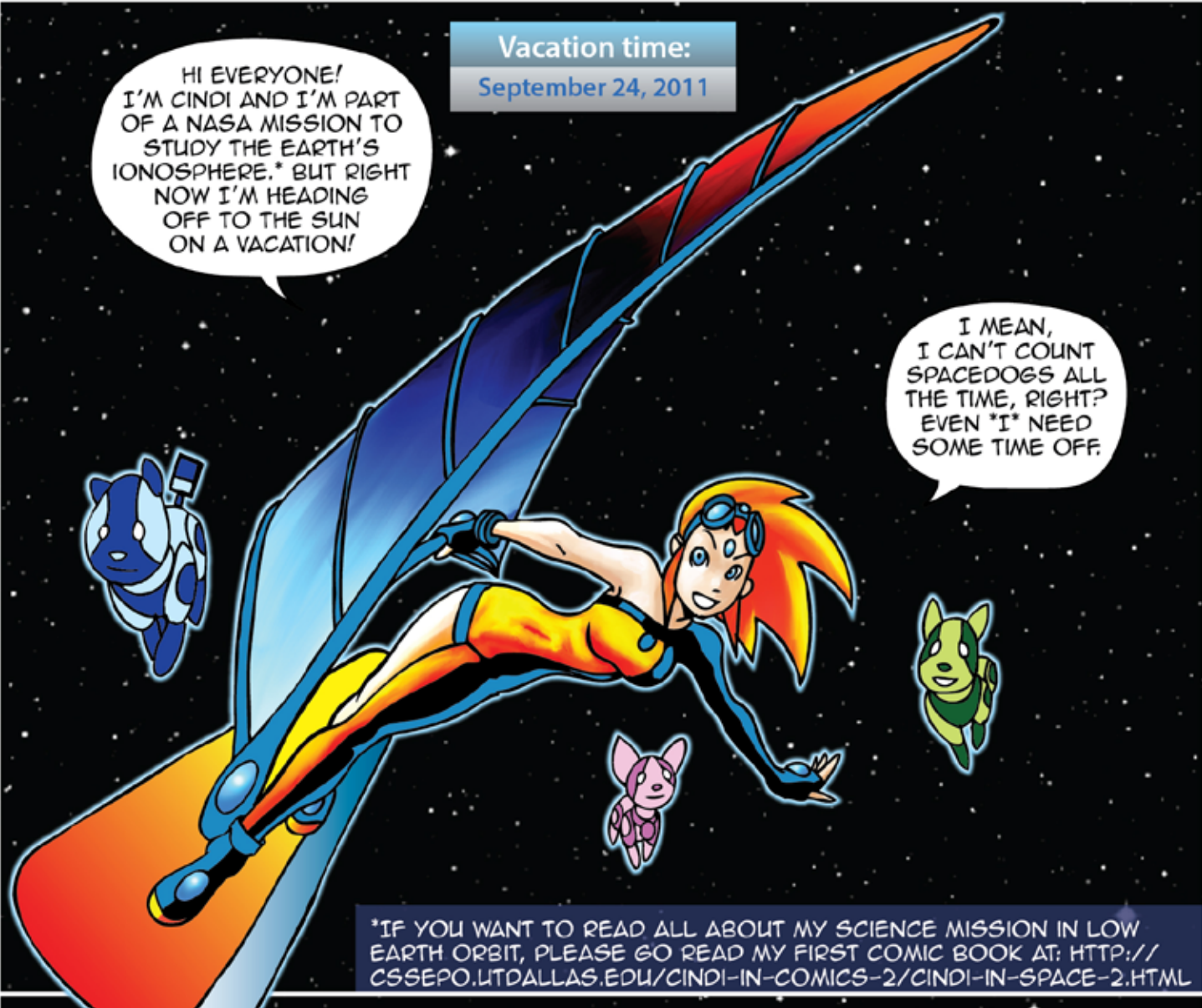
in the

SOLAR WIND

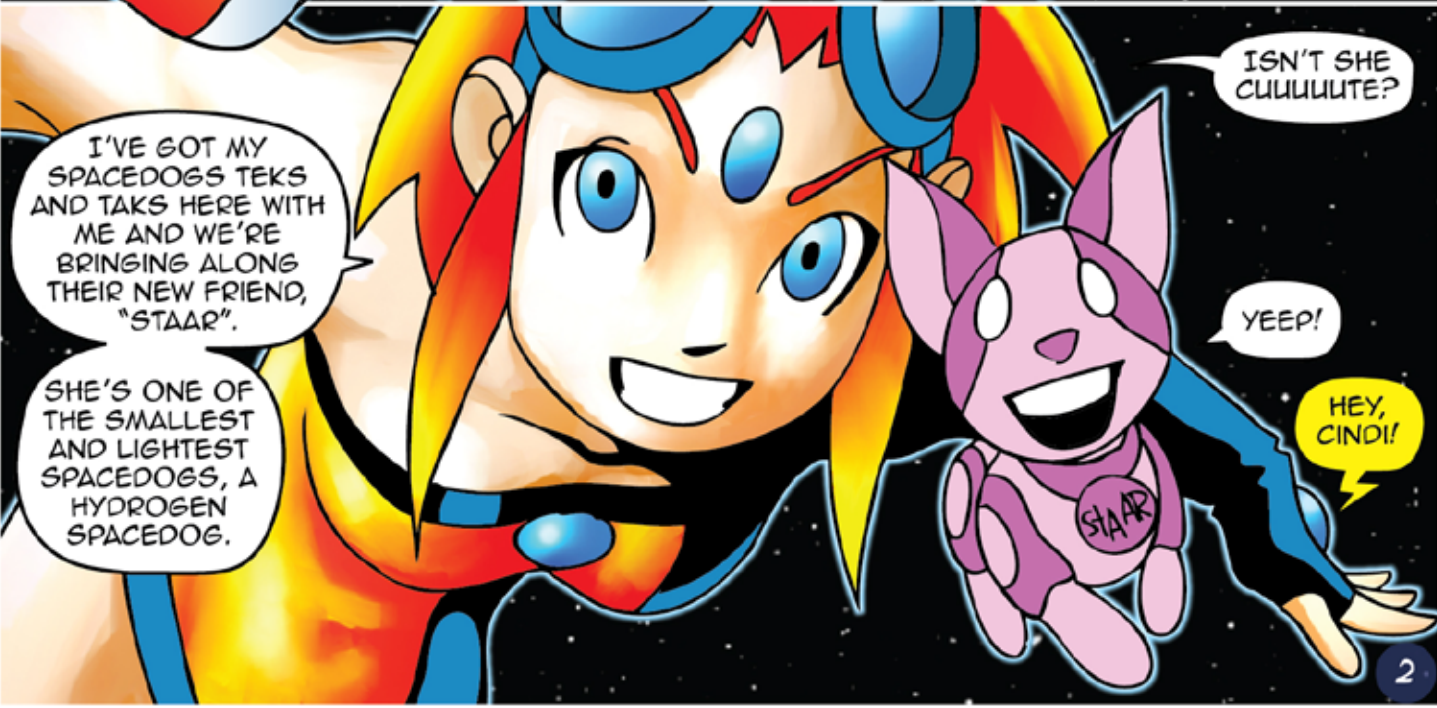
Vacation time:
September 24, 2011

HI EVERYONE!
I'M CINDI AND I'M PART
OF A NASA MISSION TO
STUDY THE EARTH'S
IONOSPHERE.* BUT RIGHT
NOW I'M HEADING
OFF TO THE SUN
ON A VACATION!

I MEAN,
I CAN'T COUNT
SPACEDOGS ALL
THE TIME, RIGHT?
EVEN "I" NEED
SOME TIME OFF.



*IF YOU WANT TO READ ALL ABOUT MY SCIENCE MISSION IN LOW EARTH ORBIT, PLEASE GO READ MY FIRST COMIC BOOK AT: [HTTP://CSSEPO.UTDALLAS.EDU/CINDI-IN-COMICS-2/CINDI-IN-SPACE-2.HTML](http://CSSEPO.UTDALLAS.EDU/CINDI-IN-COMICS-2/CINDI-IN-SPACE-2.HTML)



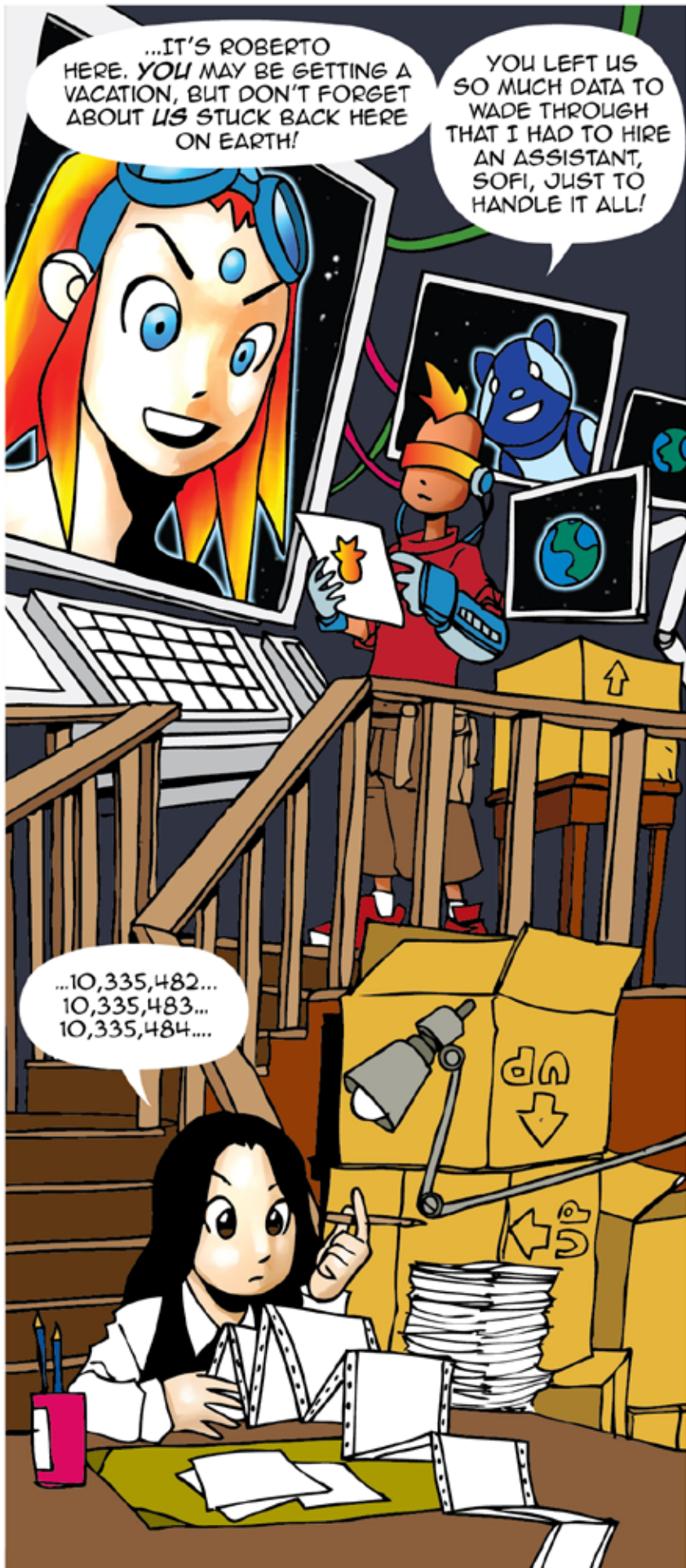
I'VE GOT MY
SPACEDOGS TEKS
AND TAKS HERE WITH
ME AND WE'RE
BRINGING ALONG
THEIR NEW FRIEND,
"STAAR".

SHE'S ONE OF
THE SMALLEST
AND LIGHTEST
SPACEDOGS, A
HYDROGEN
SPACEDOG.

ISN'T SHE
CUUUUUUTE?

YEEP!

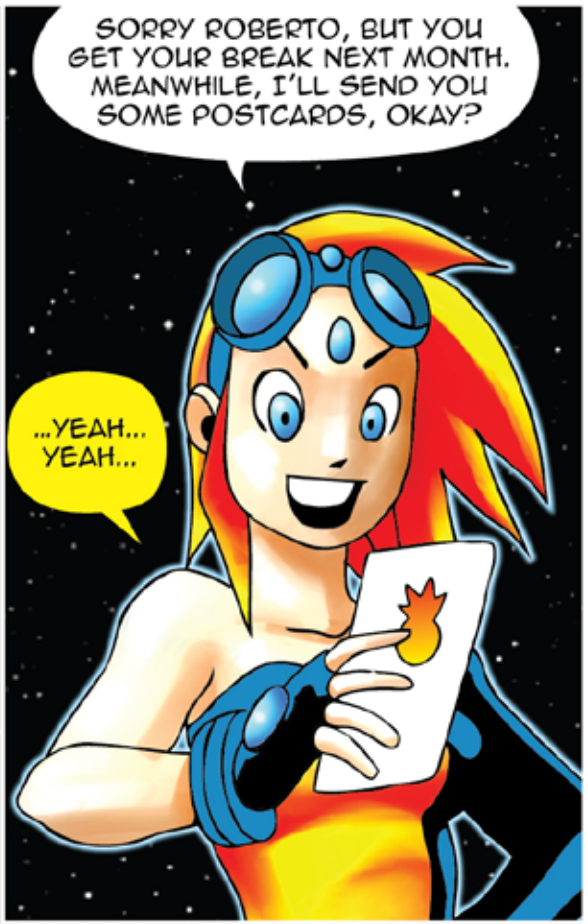
HEY,
CINDI!



...IT'S ROBERTO HERE. YOU MAY BE GETTING A VACATION, BUT DON'T FORGET ABOUT US STUCK BACK HERE ON EARTH!

YOU LEFT US SO MUCH DATA TO WADE THROUGH THAT I HAD TO HIRE AN ASSISTANT, SOFI, JUST TO HANDLE IT ALL!

...10,335,482...
10,335,483...
10,335,484...




SORRY ROBERTO, BUT YOU GET YOUR BREAK NEXT MONTH. MEANWHILE, I'LL SEND YOU SOME POSTCARDS, OKAY?

...YEAH...
YEAH...



SO WE'RE TAKING SOME TIME OFF TO VISIT THE SUN CLOSE UP! THERE'S SOME REALLY EXCITING STUFF GOING ON HERE. LET ME TELL YOU ABOUT IT.



AS YOU KNOW, THE SUN IS OUR NEAREST STAR. AND YOU'VE PROBABLY LEARNED THAT IT'S MADE UP OF A HOT GAS, BUT THAT'S NOT EXACTLY TRUE.

IF YOU SAW MY SECOND COMIC BOOK* YOU ALREADY KNOW THAT THERE ARE FOUR COMMON STATES OF MATTER: GAS, LIQUID, SOLID, AND PLASMA.



*AND IF YOU HAVEN'T READ MY SECOND COMIC BOOK, YOU NEED TO GO DOWNLOAD A COPY AT [HTTP://CSSEPO.UTDALLAS.EDU/CINDI-IN-COMICS-2/CINDI-IN-THE-ELECTRIC-ATMOS.HTML](http://CSSEPO.UTDALLAS.EDU/CINDI-IN-COMICS-2/CINDI-IN-THE-ELECTRIC-ATMOS.HTML)



PLASMA IS A GAS WHERE MOST (OR ALL) OF THE ATOMS ARE IONIZED. SO YOU HAVE A MATERIAL MADE UP OF FREELY MOVING ELECTRONS (WHICH ARE NEGATIVELY CHARGED) AND IONS (WHICH ARE POSITIVELY CHARGED).



SO SAYING THE SUN IS "A BALL OF VERY HOT GAS" IS NOT CORRECT. IT'S REALLY A BALL OF VERY HOT MATERIAL MADE OF IONS AND FREE-ROAMING ELECTRONS. IN OTHER WORDS, IT'S MADE OF **PLASMA!**



THE MAIN THING TO KNOW ABOUT A PLASMA IS THAT SINCE IT IS COMPOSED OF CHARGED PARTICLES, IT IS AFFECTED BY ELECTRIC AND MAGNETIC FIELDS.



SEE THE TENDRILS ABOVE THE SUN'S SURFACE? THEY'RE STREAMS OF PLASMA COMING OFF THE SUN AND FOLLOWING THE MAGNETIC FIELD LINES OUT INTO SPACE. THEY'RE CALLED ACTIVE REGIONS. SOMETIMES YOU WILL SEE A BRIGHT FLASH IN AN ACTIVE REGION. THOSE ARE CALLED FLARES.



FACT CHECK



HI FOLKS, ROBERTO HERE. I WANTED TO CHECK IN AND TRY AND KEEP THE FACTS STRAIGHT. IN REAL LIFE WE CAN'T SEND EVEN A ROBOT PROBE, MUCH LESS A HUMAN, THIS CLOSE TO THE SUN. ALL THE METAL AND ELECTRONICS WOULD MELT! BUT THIS IS A COMIC BOOK AND CINDI IS AN ANDROID, SO WE'RE LETTING HER GET THIS CLOSE TO THE SUN SO SHE CAN EXPLAIN THINGS.



SEE THAT FAINTER GLOW ALL AROUND THE SUN? THAT'S WHAT WE CALL THE CORONA.



WE'VE KNOWN ABOUT THE CORONA FOR THOUSANDS OF YEARS, BUT BECAUSE THE SUN'S BRIGHT DISC WASHES THE CORONA'S FAINT LIGHT OUT WE COULD ONLY SEE IT DURING SOLAR ECLIPSES.

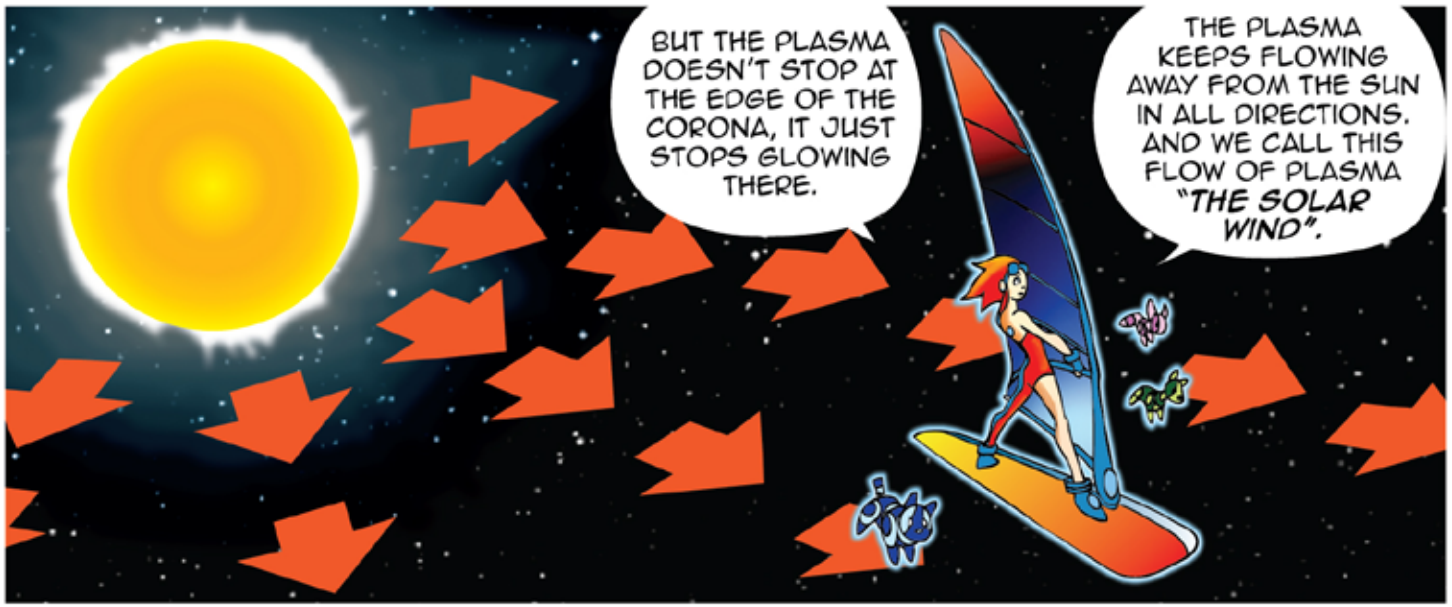


IT WASN'T UNTIL WE LAUNCHED SPACECRAFT AWAY FROM THE EARTH THAT WE DEFINITELY FIGURED OUT WHAT THE CORONA WAS.



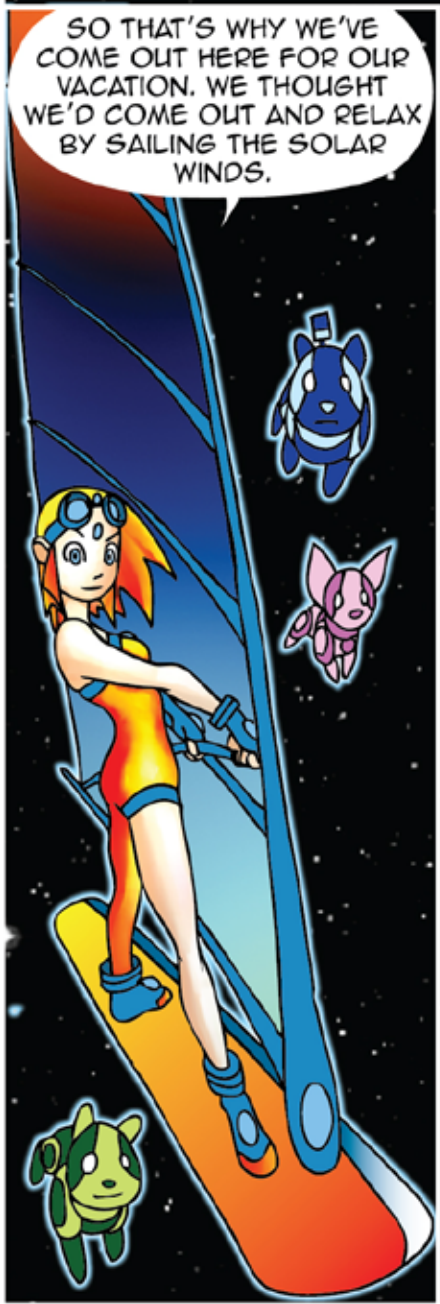
IT'S FORMED BY VERY LOW-DENSITY PLASMA THAT IS CONTINUALLY STREAMING OFF OF THE SURFACE OF THE SUN.





BUT THE PLASMA DOESN'T STOP AT THE EDGE OF THE CORONA, IT JUST STOPS GLOWING THERE.

THE PLASMA KEEPS FLOWING AWAY FROM THE SUN IN ALL DIRECTIONS. AND WE CALL THIS FLOW OF PLASMA "THE SOLAR WIND".



SO THAT'S WHY WE'VE COME OUT HERE FOR OUR VACATION. WE THOUGHT WE'D COME OUT AND RELAX BY SAILING THE SOLAR WINDS.

FACT CHECK

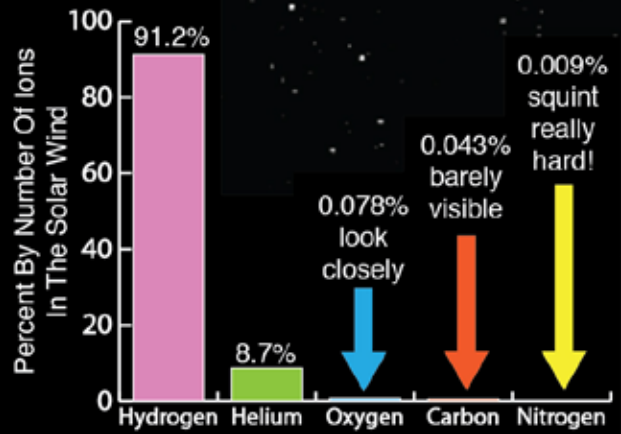
ANOTHER QUICK "FACT CHECK" HERE. WHILE CINDI'S SOLAR WINDSURFING BOARD IS FICTITIOUS, THERE ARE SPACE PROBES WITH REAL SOLAR SAILS. BUT THEY USE THE PRESSURE FROM SUNLIGHT, NOT THE PRESSURE FROM THE SOLAR WIND, TO MOVE. THAT'S RIGHT, SUNLIGHT PRODUCES MORE PRESSURE ON A SURFACE THAN THE FLOWING PLASMA IN THE SOLAR WIND! THESE REAL SAILS DON'T MOVE AS FAST AS CINDI'S SAILBOARD DOES, BUT OVER TIME THEY CAN GET UP A PRETTY GOOD SPEED. CHECK OUT [HTTP://SCIENCE.NASA.GOV/SCIENCE-NEWS/SCIENCE-AT-NASA/2008/31JUL_SOLARSAILS/](http://science.nasa.gov/science-news/science-at-nasa/2008/31jul_solarsails/).



I KEEP GOING ON ABOUT THE SUN AND THE CORONA AND THE SOLAR WIND ALL BEING PLASMA, BUT YOU'RE PROBABLY WONDERING "SO WHAT ARE THEY MADE OF?" THAT'S EASY, IT'S MADE UP OF THE SAME STUFF THE SUN IS MADE OF!



BY MASS THE SUN IS ABOUT 71% HYDROGEN, BUT SINCE HYDROGEN IS THE LIGHTEST ELEMENT, THAT MEANS THAT IF YOU COUNT THEM BY THE NUMBER OF IONS IN THE SUN THEN OVER 91% OF THE IONS ARE HYDROGEN IONS.



AND SINCE A HYDROGEN ATOM IS THE SIMPLEST ATOM THERE IS, THEN A HYDROGEN ION IS JUST A SINGLE BARE PROTON, ALONG WITH THE FREE ELECTRON IT RELEASED.



SO SINCE THE SUN IS MADE UP OF MOSTLY HYDROGEN IONS, THEN THE PLASMA COMING OFF THE SUN THAT MAKES THE SOLAR WIND IS ALSO MOSTLY HYDROGEN IONS, JUST LIKE STAAR HERE!



STAAR HERE IS A HYDROGEN SPACE-DOG, JUST LIKE TAKS IS A HELIUM SPACEDOG, AND TEKS IS AN OXYGEN SPACEDOG.



SO FOR EVERY 100 IONS IN THE SOLAR WIND, ABOUT 91 WILL BE HYDROGEN IONS, ALMOST 9 WILL BE HELIUM IONS, AND LESS THAN ONE IN A HUNDRED WILL BE ANY OTHER ELEMENT LIKE OXYGEN OR CARBON OR SILICON OR SUCH. OF COURSE THERE WILL BE AN EQUAL NUMBER OF ELECTRONS (OR TAILS HERE) IN THE SOLAR WIND TOO.





Fun Facts said:

Typical speed of the solar wind: usually 400 to 500 km/s (generally takes a little over 4 days to reach Earth's orbit), but can range from less than 200 to over 1000 km/s.

Typical density of the solar wind: about 5 to 10 ions/cm³ by the time it reaches the Earth.

Typical temperature of the the solar wind: between 100,000 and 200,000 degrees (Kelvin).

Typical composition of the solar wind (by percentage of the number of ions):

Hydrogen	91.2 %
Helium	8.7 %
Oxygen	0.078 %
Carbon	0.043 %
Nitrogen	0.0088 %
Silicon	0.0045 %
Magnesium	0.0038 %
Neon	0.0035 %
Iron	0.0030 %
Sulfur	0.0015 %

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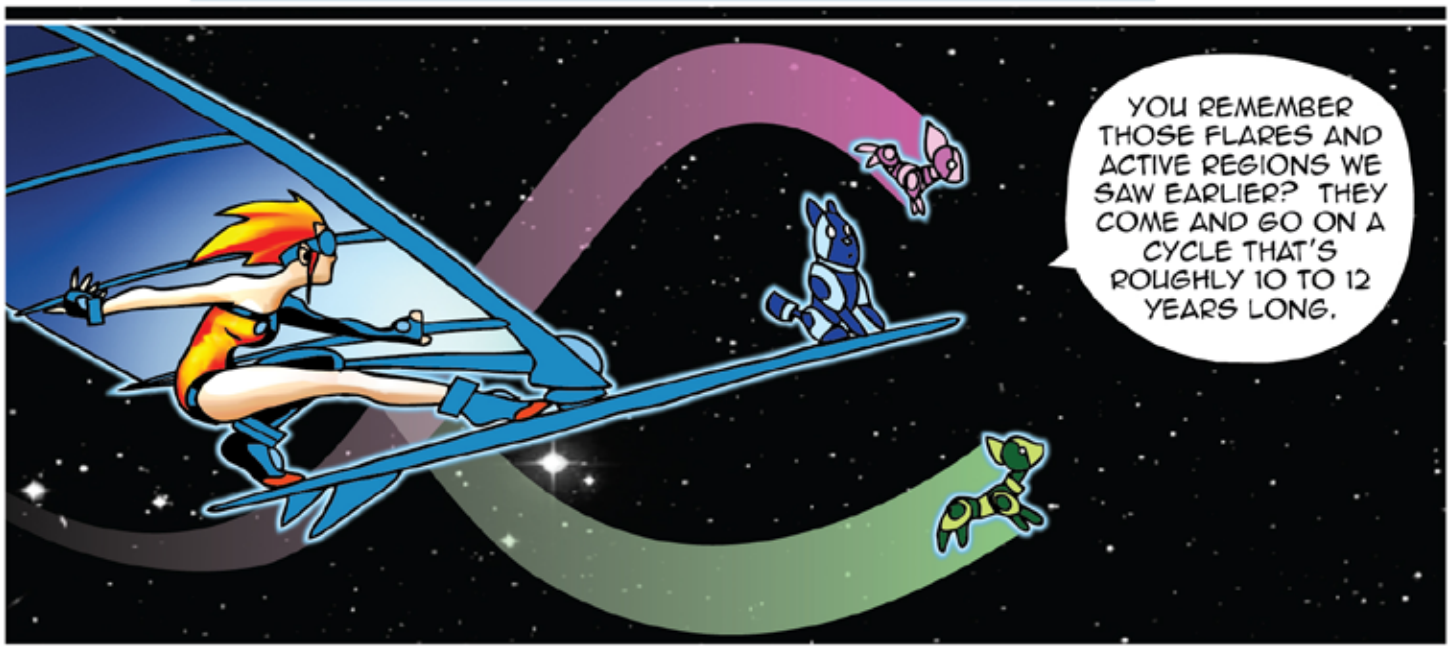


PRIME REAL ESTATE



Tired of never having space to roam? Love vast expanses of red rocky land? Great Real Estate Bargains on Mars! Click here for details.

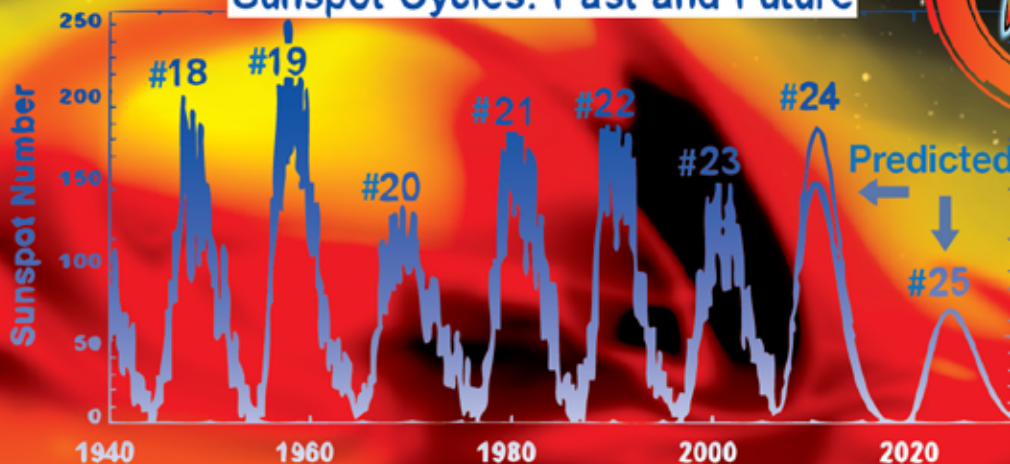
The Sun and Proxima Centauri like this



WE CALL THIS THE SOLAR CYCLE. AT SOLAR MAXIMUM WE HAVE HIGH ACTIVITY ON THE SUN WITH LOTS OF SUNSPOTS, FLARES, AND ACTIVE REGIONS APPEARING. THEN ABOUT 5 OR 6 YEARS LATER THERE IS VERY LITTLE ACTIVITY AND WE CALL THAT THE SOLAR MINIMUM.



Sunspot Cycles: Past and Future





THE PAST FEW YEARS WE'VE BEEN IN A DEEP SOLAR MINIMUM, SO THINGS HAVE BEEN VERY QUIET IN THE EARTH'S IONOSPHERE.



I REALLY WANTED MY MISSION TO OCCUR DURING A SOLAR MAXIMUM. THAT'S WHEN THE SUN'S ACTIVITIES CAUSE ALL KINDS OF EXCITING AND INTERESTING THINGS TO HAPPEN TO THE EARTH'S IONOSPHERE.



SO HERE IN SEPTEMBER 2011 WE'RE JUST STARTING ON THE UPSWING INTO THE SOLAR MAXIMUM, SO I'M EXPECTING THINGS WILL GET MORE EXCITING VERY SOON.



I SURE HOPE SO. THINGS HAVE BEEN SO ROUTINE FOR THE PAST SEVERAL YEARS SINCE I WAS LAUNCHED THAT FRANKLY I WAS STARTING TO GET JUST A LITTLE BORED.



THAT'S WHY I'M SOOO HAPPY TO TAKE THIS VACATION. THIS WILL GIVE ME A CHANCE TO RECHARGE MY BATTERIES FOR A BIT...

WHAT?!

YEEEEEEPPP!!!

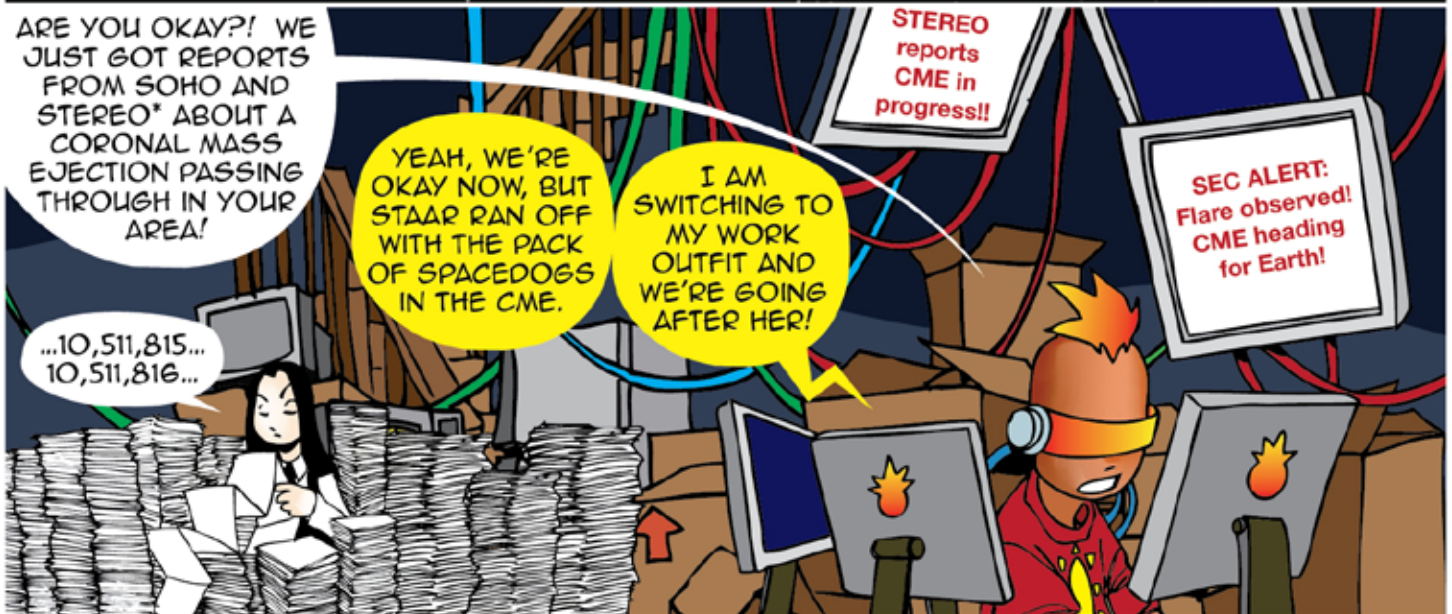


NOOOOOO!!!!



STAAR!
COME
BACK!

CINDI!



ARE YOU OKAY?! WE JUST GOT REPORTS FROM SOHO AND STEREO* ABOUT A CORONAL MASS EJECTION PASSING THROUGH IN YOUR AREA!

YEAH, WE'RE OKAY NOW, BUT STAAR RAN OFF WITH THE PACK OF SPACE DOGS IN THE CME.

I AM SWITCHING TO MY WORK OUTFIT AND WE'RE GOING AFTER HER!

STEREO reports CME in progress!!

SEC ALERT: Flare observed! CME heading for Earth!

...10,511,815...
10,511,816...

*SOHO AND STEREO ARE SPACECRAFT THAT MONITOR THE SUN AND THE SOLAR WIND. FOR REALLY COOL IMAGES AND MOVIES OF REAL CME BLASTS CHECK OUT: SOHO.WWW.NASCOM.NASA.GOV AND STEREO.GFSC.NASA.GOV



GOOD LUCK, CINDI! WE'LL TRACK THE CME AND GIVE YOU DIRECTIONS.

THANKS!



SIGH
SO MUCH FOR OUR VACATION.
SORRY GUYS.

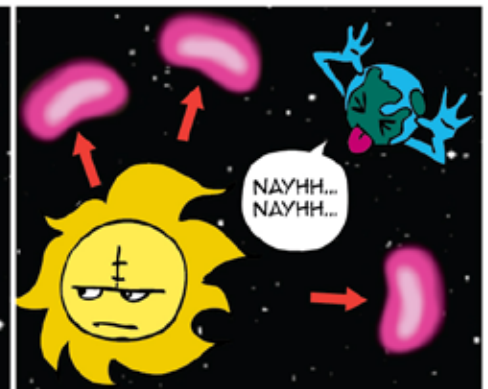


SO YOU'RE PROBABLY WONDERING ABOUT WHAT HIT US. THAT WAS A CORONAL MASS EJECTION OR A "CME", AND IT'S A HUGE BLOB OF HIGH-SPEED PLASMA IN THE SOLAR WIND.

WE STILL DON'T KNOW EXACTLY WHAT TRIGGERS THESE EJECTIONS, BUT SOMETIMES A CHANGE IN THE CORONA'S MAGNETIC FIELD LEADS TO AN EXPLOSIVE RELEASE OF ENERGY, BLASTING A HUGE BLOB OF PLASMA AWAY FROM THE SUN.



SINCE THE PLASMA IN THE CME IS MORE DENSE AND MOVING FASTER THAN THE REGULAR SOLAR WIND PLASMA, THE CME RUNS INTO SLOWER PLASMA IN FRONT OF IT. THIS CAUSES THE CME TO "SNOWPLOW" THE PLASMA IN FRONT INTO A BOWED-BACK PANCAKE-SHAPED SHOCK WAVE.



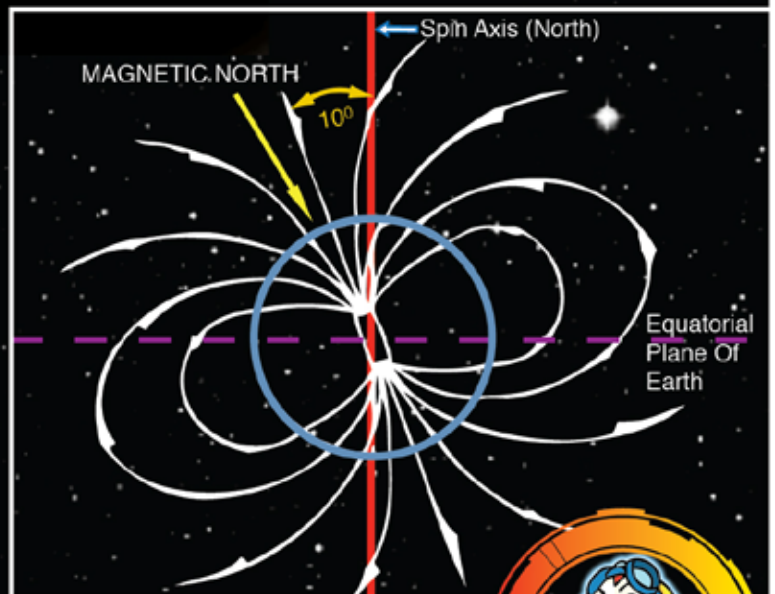
ALTHOUGH CMES ARE BIG, THEY GO STRAIGHT OUT FROM DIFFERENT PARTS OF THE SURFACE OF THE SUN, SO MOST OF THEM MISS THE EARTH.



BUT **THIS** ONE IS HEADING STRAIGHT FOR THE EARTH!



SO WHAT HAPPENS TO THE EARTH WHEN THE SOLAR WIND PLASMA REACHES IT?

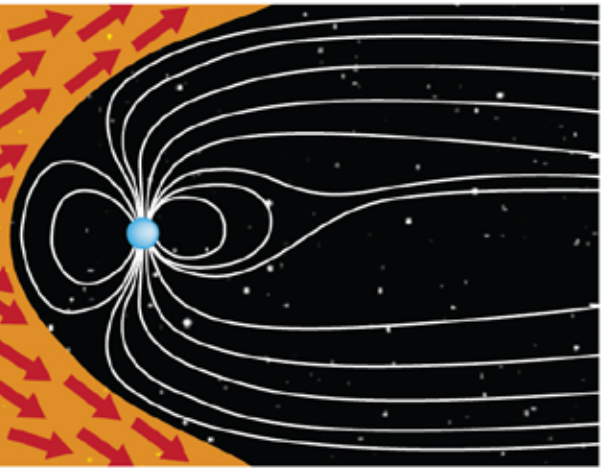


ACTUALLY THE SOLAR WIND NEVER REACHES THE EARTH BECAUSE WE'RE PROTECTED BY THE EARTH'S MAGNETIC FIELD. SINCE THE SOLAR WIND IS MADE UP OF PLASMA, THE CHARGED IONS AND FREE ELECTRONS CAN'T EASILY MOVE ACROSS THE MAGNETIC FIELD LINES. SO THEY GET PUSHED ASIDE AND GO AROUND THE EARTH. THIS IS THE SIMPLE PICTURE OF THE EARTH'S MAGNETIC FIELD YOU'VE PROBABLY SEEN IN BOOKS...





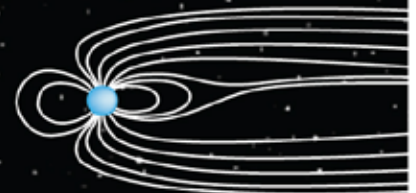
...BUT THIS IS WHAT THE EARTH'S MAGNETIC FIELD REALLY LOOKS LIKE. THE SOLAR WIND COMPRESSES IT ON THE DAYSIDE AND STRETCHES IT WAAAYY OUT ON THE NIGHTSIDE. WE CALL THIS REGION OF SPACE FROM THE EARTH'S UPPER ATMOSPHERE TO THE SOLAR WIND THE "MAGNETOSPHERE." AND THE SURFACE OF THE MAGNETOSPHERE THAT TOUCHES THE SOLAR WIND IS CALLED THE "MAGNETOPAUSE."



FUN FACT: IF THE MAGNETOSPHERE IS SHAPED LIKE A COMET AND NOT A BALL, WHY DO THEY CALL IT THE MAGNETOSPHERE? AS WITH MANY THINGS IT WAS A HISTORICAL ACCIDENT. THE NAME "MAGNETOSPHERE" WAS FIRST COINED IN THE LATE 1950S DURING THE EARLY DAYS OF THE SPACE PROGRAM. THE SCIENTISTS STUDYING THE LAYERS OF THE ATMOSPHERE AT THE TIME GAVE THEM NAMES WITH "SPHERE" IN IT ("MESOSPHERE," "THERMOSPHERE," "IONOSPHERE," ETC.) SINCE EACH LAYER FORMED A CONCENTRIC SPHERICAL SHELL ABOVE THE LAYER BELOW IT. WHEN THE FIRST SATELLITES GOT UP INTO ORBIT THE MAGNETIC FIELD PLAYED A MAJOR ROLE IN EXPLAINING THE PHENOMENON UP THERE (LIKE THE VAN ALLEN RADIATION BELTS) SO THEY CALLED THAT REGION THE "MAGNETOSPHERE." A FEW YEARS LATER SATELLITES GOT OUT FAR ENOUGH TO DISCOVER THAT THE MAGNETOSPHERE WAS "BLOWN BACK" BY THE SOLAR WIND AND NOT A SPHERE. BUT IT WAS TOO LATE AND THE NAME HAD STUCK.

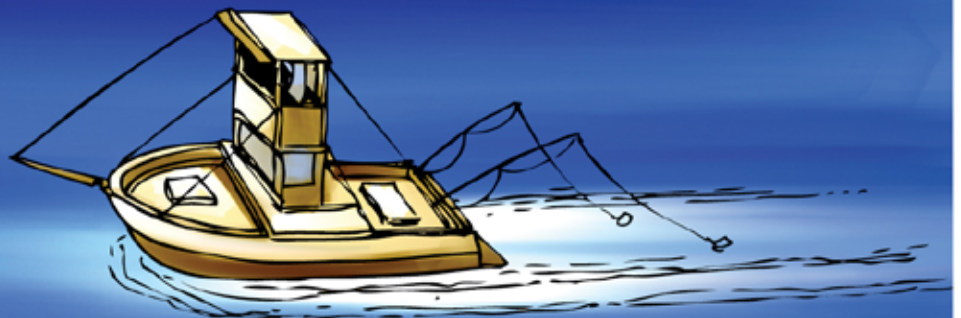


SHAPED LIKE A SPHERE

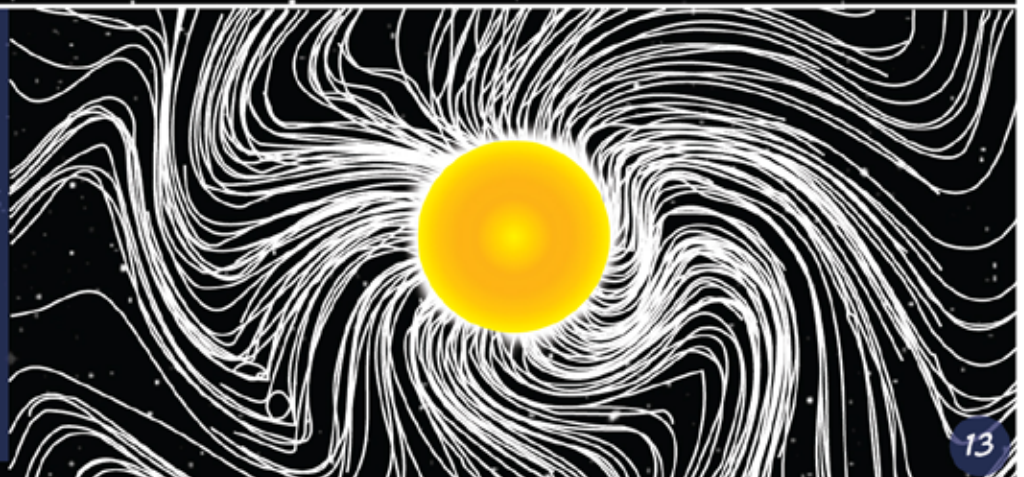


NOT SHAPED LIKE A SPHERE

THE YELLOW LINE IN THE TOP PANEL PICTURE IS WHAT WE CALL THE BOW SHOCK HERE IN FRONT OF THE MAGNETOSPHERE. THAT'S THE PLACE WHERE THE SOLAR WIND PLASMA STARTS TO SLOW DOWN BEFORE IT GOES AROUND THE MAGNETOSPHERE. IT'S SIMILAR TO THE BOW WAVE YOU SEE IN THE WATER IN FRONT OF A MOVING BOAT. IN A LOT OF WAYS YOU CAN THINK OF THE SOLAR WIND AS SOMETIMES ACTING LIKE A VERY, VERY LOW DENSITY FLUID.

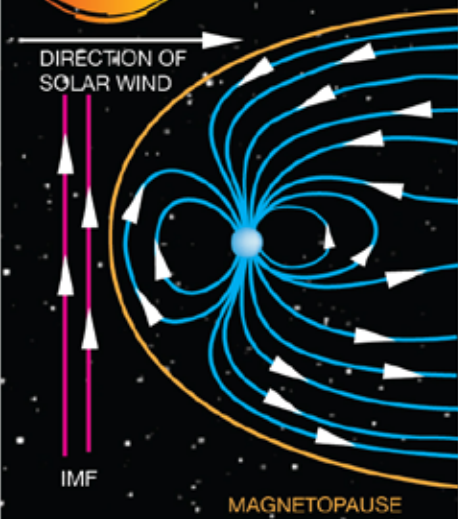


WHEN THE SOLAR WIND PLASMA COMES OFF THE SUN IT HAS THE SUN'S MAGNETIC FIELD EMBEDDED IN IT, SO AS IT FLOWS OUTWARD THE PLASMA DRAGS THE MAGNETIC FIELD LINES WITH IT. AWAY FROM THE SUN WE CALL THIS THE INTERPLANETARY MAGNETIC FIELD (IMF) AND OUT THERE THE FIELD LINES CAN BEND AND END UP POINTING IN ALL DIFFERENT DIRECTIONS.

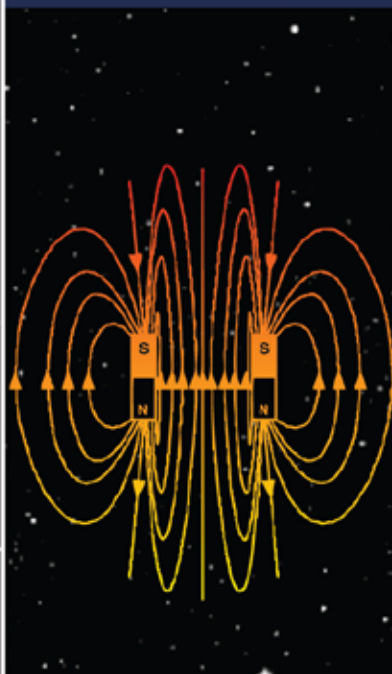


BUT THE ORIENTATION OF THE SOLAR WIND'S MAGNETIC FIELD AFFECTS THE EARTH'S MAGNETOSPHERE. SUPPOSE THE IMF WAS POINTED NORTHWARD SO THE IMF'S FIELD LINES POINT IN THE SAME DIRECTION AS THE

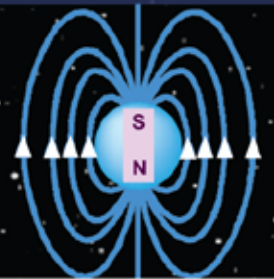
EARTH'S MAGNETIC FIELD LINES ON THE DAY SIDE. WHAT WOULD HAPPEN?



IN THAT CASE IT'S LIKE WHAT HAPPENS IF YOU TRY TO PUSH TWO BAR MAGNETS TOGETHER WHEN THE POLES ARE POINTED THE SAME DIRECTION. THE LINES CAN'T CROSS EACH OTHER AND THE MAGNETS RESIST EACH OTHER.

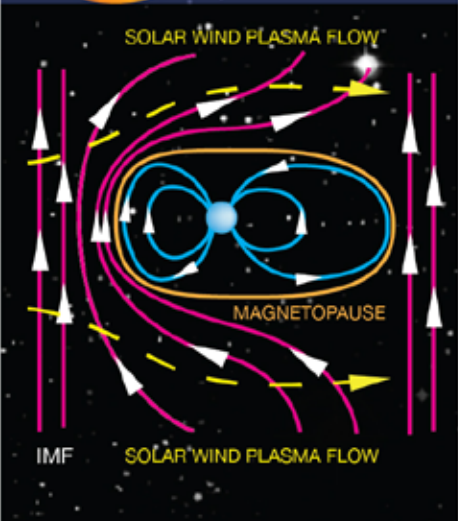


SOME OF YOU MAY HAVE NOTICED THAT MAGNETIC FIELD LINES GO FROM THE NORTH TO THE SOUTH POLE OF THE MAGNET, BUT THE ARROWS ON THE EARTH'S MAGNETIC FIELD LINES TWO PANELS AGO POINT TO THE EARTH'S NORTH GEOGRAPHIC POLE. WHAT'S GOING ON HERE? WE DEFINE THE NORTH AND SOUTH MAGNETIC POLES OF COMPASS OR MAGNET BASED ON WHICH WAY IT POINTS. BUT FOR THE NORTH MAGNETIC POLE OF A COMPASS TO POINT NORTH, THAT MEANS THE MAGNETIC POLE NEAR THE EARTH'S GEOGRAPHIC NORTH POLE THAT ATTRACTS THE NORTH END OF THE COMPASS HAS TO BE A **MAGNETIC SOUTH POLE!** THIS TENDS TO CONFUSE FOLKS, SO MOST SCHOOLBOOKS DON'T BOTHER MENTIONING THIS UNTIL HIGH SCHOOL OR SO.



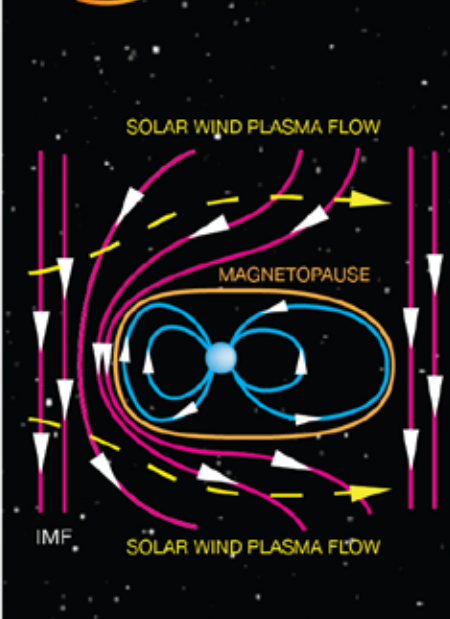
THE SOLAR WIND'S MAGNETIC FIELD AND THE EARTH'S MAGNETIC FIELD DON'T EXACTLY REPEL EACH OTHER THE WAY THE BAR MAGNETS DO, BUT THEIR FIELD LINES DON'T CONNECT. SO

THE SOLAR WIND PLASMA FLOWS AROUND THE EARTH AND LITTLE OR NONE OF THE PLASMA GETS INTO THE MAGNETOSPHERE.



NOW SUPPOSE THE IMF WAS POINTED **SOUTHWARD** SO THE IMF'S FIELD LINES POINT IN THE **OPPOSITE** DIRECTION

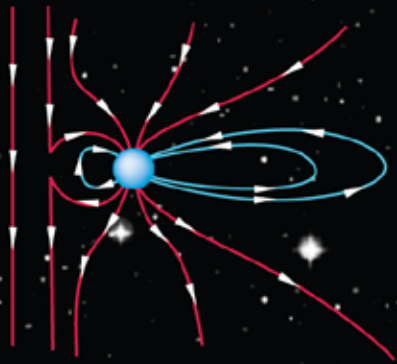
COMPARED TO THE EARTH'S MAGNETIC FIELD LINES ON THE DAY SIDE. WHAT HAPPENS THEN?



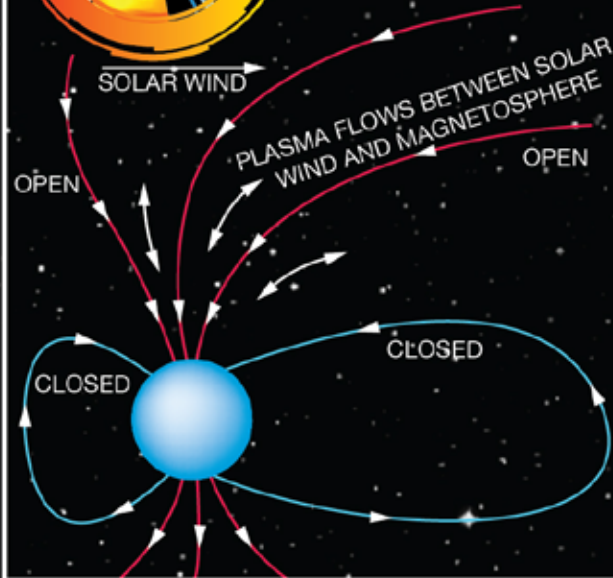
IN THIS CASE THE MAGNETIC FIELD LINES **DO** CONNECT BETWEEN THE TWO MAGNETS AND THEY ATTRACT EACH OTHER.



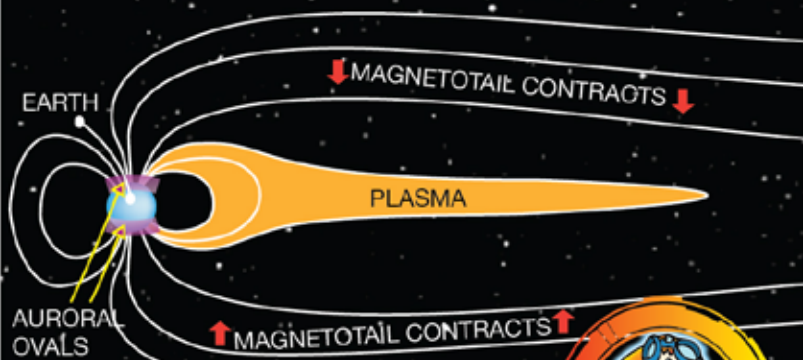
LIKE BEFORE, IT'S A MISTAKE TO THINK THAT THE SOLAR WIND'S MAGNETIC FIELD AND THE EARTH'S MAGNETIC FIELD ATTRACT EACH OTHER LIKE THE BAR MAGNETS DID, BUT THIS TIME SOME OF THE SOLAR WIND FIELD LINES **DO CONNECT** TO THE EARTH'S MAGNETIC FIELD LINES. THAT MEANS SOME OF THE SOLAR WIND PLASMA AND THE EARTH'S MAGNETOSPHERIC PLASMA GET MIXED IN THE POLAR REGIONS.



SO AT CERTAIN TIMES SOME OF THE EARTH'S MAGNETIC FIELD LINES IN THE HIGHEST LATITUDE POLAR REGIONS WILL BE CONNECTED DIRECTLY TO THE SOLAR WIND'S MAGNETIC FIELD LINES. WE CALL THESE "OPEN FIELD LINES" BECAUSE ONLY ONE END OF THEM IS CONNECTED TO THE EARTH. SOLAR WIND PLASMA ON THESE LINES CAN GET INTO THE MAGNETOSPHERE AND MAGNETOSPHERIC PLASMA CAN LEAK OUT INTO THE SOLAR WIND. ANY FIELD LINE WITH ITS ENDPOINT A BIT CLOSER TOWARDS THE EQUATOR HAS BOTH ENDS CONNECTED TO THE EARTH AND WE CALL THOSE "CLOSED FIELD LINES".



YOU CAN THINK OF THE MAGNETOSPHERE AS SORT OF LIKE A WATER BALLOON. AS THE SOLAR WIND BLOWS AROUND IT AND PUSHES ON IT, IT CHANGES SHAPE AND PULSES. AND JUST LIKE THE WATER IN A WATER BALLOON DOES, THE PLASMA INSIDE THE MAGNETOSPHERE SLOSHES AROUND!



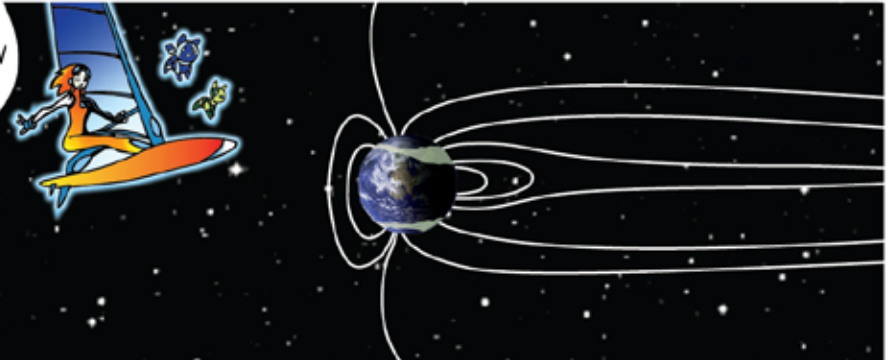
DURING THE "SLOSHING" WHEN THE MAGNETOTAIL CONTRACTS AND ITS PLASMA GETS PUSHED EARTHWARD THE PLASMA FOLLOWS THE FIELD LINES AND HITS THE ATOMS IN EARTH'S UPPER ATMOSPHERE CREATING THE GLOWING LIGHTS WE CALL THE AURORA. SINCE THE FIELD LINES IN THE DISTANT MAGNETOTAIL HAVE THEIR ENDPOINTS AT HIGH LATITUDES THE AURORA ONLY OCCURS IN A RING IN THE POLAR REGIONS CALLED THE "AURORAL OVAL". THAT'S WHY YOU USUALLY ONLY SEE THE AURORA WHEN YOU'RE CLOSE TO THE NORTHERN OR SOUTHERN POLAR REGIONS OF THE EARTH.



THE CME IS ALREADY PAST THE EARTH, LET'S SEE WHAT IT DID TO THE MAGNETOSPHERE.



WOW! THAT CME REALLY DID A NUMBER ON THE MAGNETOSPHERE! LOOK AT HOW COMPRESSED THE MAGNETOSPHERE IS, AND AT THOSE REALLY STUPENDOUS AURORAL DISPLAYS



IF YOU WANT TO KEEP TRACK OF CURRENT SOLAR WIND CONDITIONS, GET ALERTS ABOUT CMES, AND SEE BEAUTIFUL PICTURES OF THE AURORA, CHECK OUT SPACEWEATHER.COM.

SPACE STORMS LIKE THAT CAN AFFECT OR DAMAGE SPACECRAFT. FORTUNATELY THAT WASN'T A MAJOR STORM SO IT LOOKS LIKE ALL MY FELLOW NASA MISSIONS ARE OKAY.

HI FOLKS!



THEMIS-P4

THEMIS-P3

ARTEMIS-P2

ARTEMIS-P1

THEMIS-P5

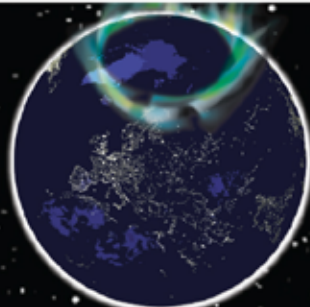
HUBBLE

IBEX

HINODE (SOLAR-B)

SOHO

SDO (CAMILLA)



I'D LOVE TO STAY AND TELL YOU MORE ABOUT THE EARTH'S MAGNETOSPHERE, BUT WE'VE GOT TO KEEP GOING AND GET STAAAR BACK. I HOPE SHE'S OKAY.



GOOD LUCK CINDI! WE'RE TRACKING THE CME AND WILL KEEP UPDATING ITS POSITION TO YOU. AND YOU'RE RIGHT. WHILE THIS WAS A BIG CME, IT WASN'T BIG ENOUGH TO CAUSE WHAT SPACE SCIENTISTS CALL A "SUPERSTORM."

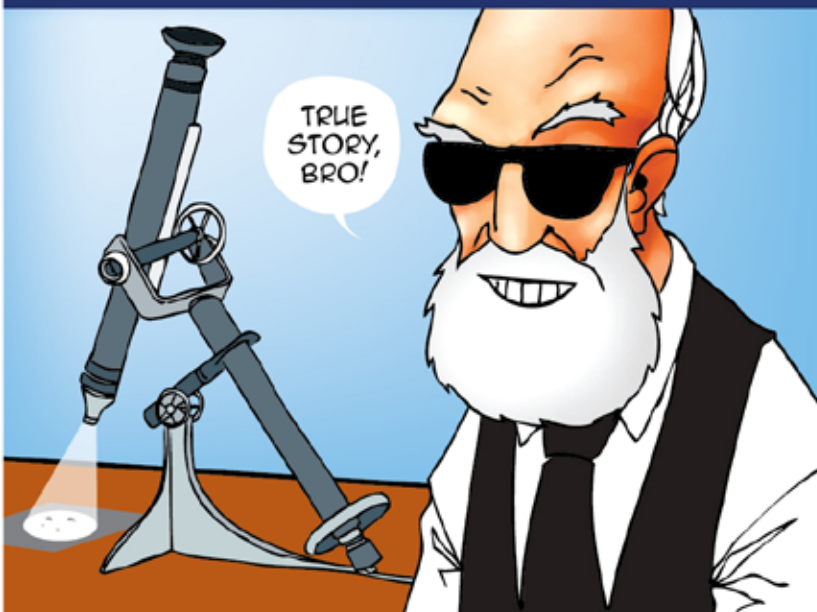
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A FEW TIMES DURING EACH SOLAR MAXIMUM PERIOD THE EARTH GETS HIT BY A **REALLY BIG** CME. IN 1989 WE HAD A SUPERSTORM SO BIG THAT ITS CHANGING MAGNETIC FIELDS GENERATED CURRENTS IN LONG-DISTANCE HIGH POWER LINES IN QUEBEC LARGE ENOUGH TO KNOCK OUT THE POWER SYSTEM FOR THE WHOLE PROVINCE! AND THE HALLOWEEN 2003 SUPERSTORM LITERALLY FRIED THE ELECTRONICS ON INSTRUMENTS ON ABOUT A DOZEN SPACECRAFT AND THE AURORAL OVAL EXPANDED SO MUCH THAT AURORAS WERE SEEN IN TEXAS AND FLORIDA

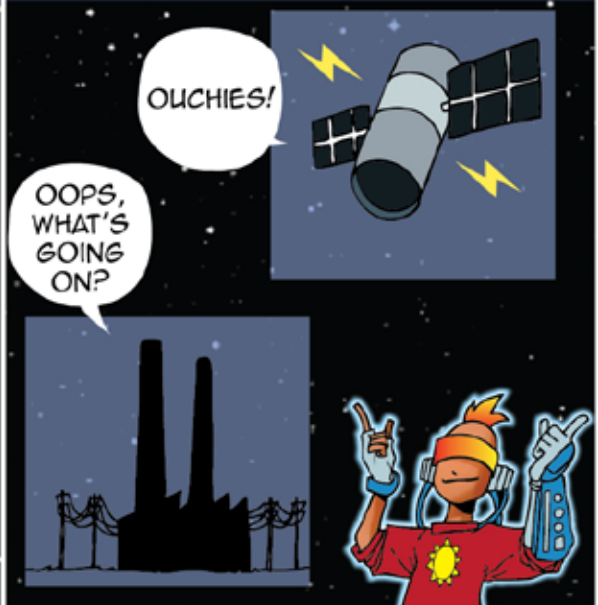


ON SEPTEMBER 1, 1859, BRITISH ASTRONOMER RICHARD CARRINGTON OBSERVED AN UNUSUALLY BRIGHT SOLAR FLARE ON THE SUN'S SURFACE WITH HIS SOLAR PROJECTOR TELESCOPE. EIGHTEEN HOURS LATER THE EARTH WAS HIT BY A CME SO LARGE THAT AURORA WERE SEEN IN HAWAII AND TELEGRAPH WIRES IN NEW ENGLAND SPONTANEOUSLY BURST INTO FLAMES BECAUSE OF THE LARGE INDUCED CURRENTS. THE MAGNETOMETER AT KEW OBSERVATORY IN LONDON SHOWED CHANGES IN THE EARTH'S MAGNETIC FIELD FAR LARGER THAN ANY WE HAVE SEEN IN THE 150 YEARS SINCE.



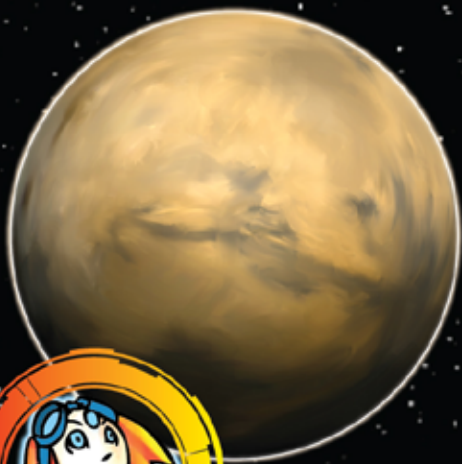
[HTTP://NGM.NATIONALGEOGRAPHIC.COM/2012/06/SOLAR-STORMS/FERRIS-TEXT](http://ngm.nationalgeographic.com/2012/06/solar-storms/ferris-text)

BACK IN 1859 THERE WERE NO ELECTRONICS OTHER THAN TELEGRAPHS, BUT WHAT IF A SUPERSTORM AS BIG AS THE CARRINGTON STORM HIT TODAY? WE HAVE TO WORRY ABOUT WHAT IT WOULD DO TO OUR SATELLITES, OUR COMMUNICATIONS, AND OUR POWER GRIDS. THAT'S WHY CINDI AND ALL THE OTHER SPACE PROBES KEEP TABS ON THE SPACE WEATHER ENVIRONMENT.



SEE [HTTP://SCIENCE.NASA.GOV/SCIENCE-NEWS/SCIENCE-AT-NASA/2009/21JAN_SEVERESPACEWEATHER/](http://science.nasa.gov/science-news/science-at-nasa/2009/21jan_severespaceweather/) FOR MORE INFORMATION.

THIS CME WILL MISS MARS, BUT I WANTED TO POINT OUT THAT MARS DOESN'T HAVE A STRONG ENOUGH MAGNETIC FIELD TO FORM A MAGNETOSPHERE, SO THE SOLAR WIND DIRECTLY HITS THE MARTIAN UPPER ATMOSPHERE.



SCIENTISTS WONDER WHY MARS' ATMOSPHERE IS SO THIN COMPARED TO THE EARTH'S. EVEN THOUGH ITS GRAVITY IS WEAKER THAN THE EARTH'S GRAVITY, MARS SHOULD STILL HAVE A MUCH MORE MASSIVE ATMOSPHERE THAN IT DOES. SOME SCIENTISTS THINK THE SOLAR WIND IS ACTUALLY PULLING OFF THE ATOMS AND IONS OF MARS' UPPER ATMOSPHERE SO THAT OVER SEVERAL BILLION YEARS THE SOLAR WIND HAS ERODED AWAY MOST OF MARS' AIR.



FOR MORE INFORMATION ABOUT THIS, SEE THIS STORY: [HTTP://SCIENCE.NASA.GOV/SCIENCE-NEWS/SCIENCE-AT-NASA/2008/21NOV_PLASMOIDS/](http://science.nasa.gov/science-news/science-at-nasa/2008/21NOV_PLASMOIDS/)



FUN FACT: SO IF THE SUN IS BLOWING OFF SO MUCH PLASMA ALL THE TIME, IS IT GOING TO ULTIMATELY EVAPORATE AWAY?

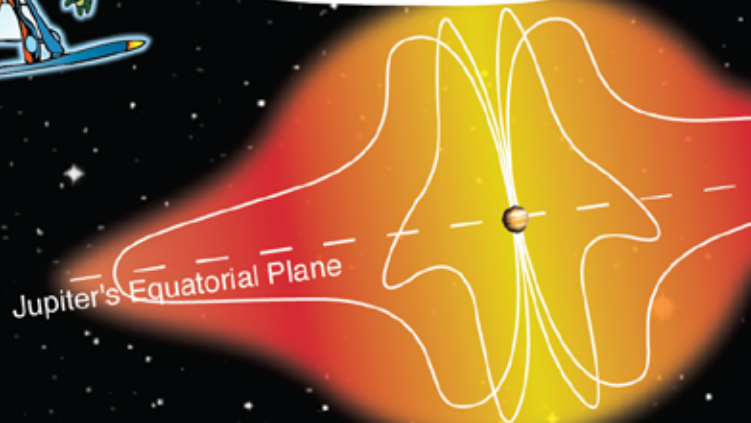
LET'S LOOK AT THE NUMBERS. ON AVERAGE THE SUN IS LOSING ABOUT 3×10^{10} KG/SECOND TO THE SOLAR WIND. (THAT'S ABOUT 33 MILLION TONS A SECOND.) ASSUMING THAT RATE HAS BEEN MORE OR LESS CONSTANT FOR THE 4.5 BILLION YEARS AFTER THE SUN FINISHED FORMING AND SETTLED DOWN, THAT MEANS THE SUN HAS LOST A TOTAL OF $(3 \times 10^{10} \text{ KILOGRAM/SECOND}) (3600 \text{ SECOND/HOUR}) (24 \text{ HOURS/DAY}) (365.24 \text{ DAYS/YEAR}) (4.5 \times 10^9 \text{ YEARS}) = 4.26 \times 10^{27}$ KILOGRAMS OF PLASMA. BUT THE CURRENT MASS OF THE SUN IS 1.989×10^{30} KILOGRAMS. SO THAT MEANS THE SUN HAS SO FAR ONLY LOST

$$\frac{4.26 \times 10^{27} \text{ KG}}{1.989 \times 10^{30} \text{ KG}} = 0.00214$$

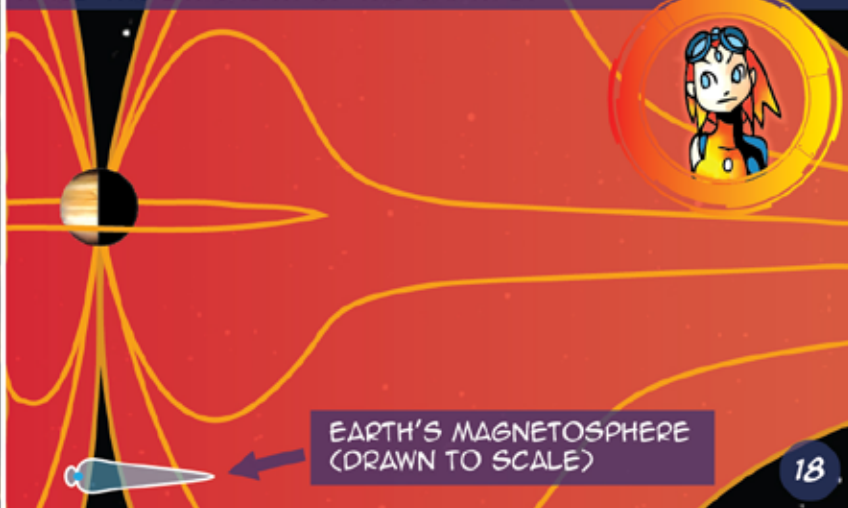
OR ABOUT 0.2% OF ITS TOTAL MASS. SO WE DON'T HAVE TO WORRY ABOUT THE SUN EVAPORATING AWAY ANYTIME SOON.

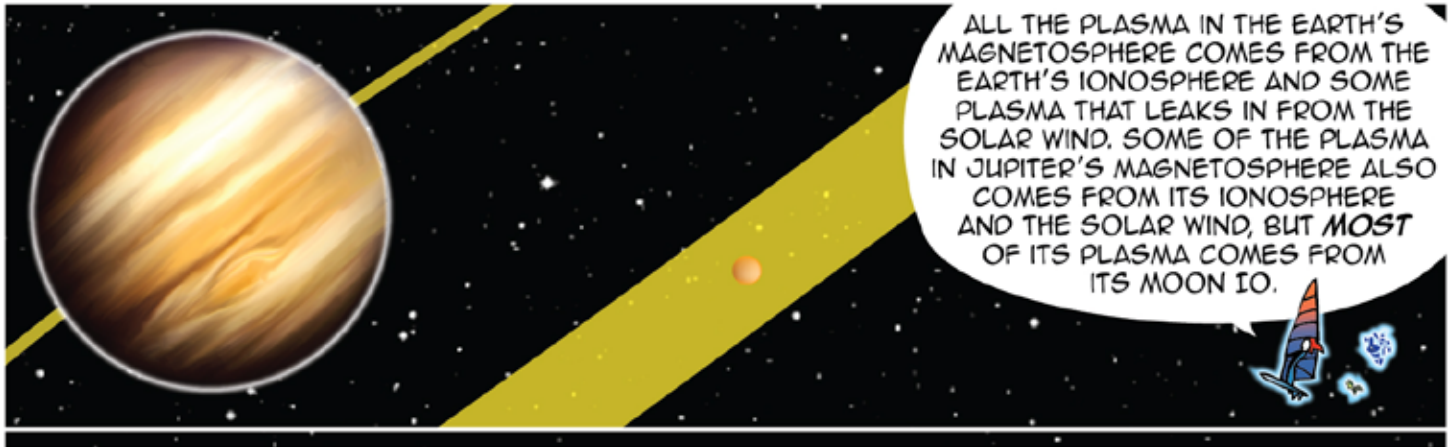


NEXT UP IS JUPITER! NOT ONLY IS IT THE BIGGEST PLANET IN THE SOLAR SYSTEM, IT ALSO HAS THE BIGGEST MAGNETOSPHERE.



IF YOU COULD PUT THE TWO MAGNETOSPHERES SIDE BY SIDE, THE EARTH'S MAGNETOSPHERE IS TINY! THIS IS BECAUSE JUPITER'S MAGNETIC FIELD IS ABOUT 20,000 TIMES THE STRENGTH OF THE EARTH'S.





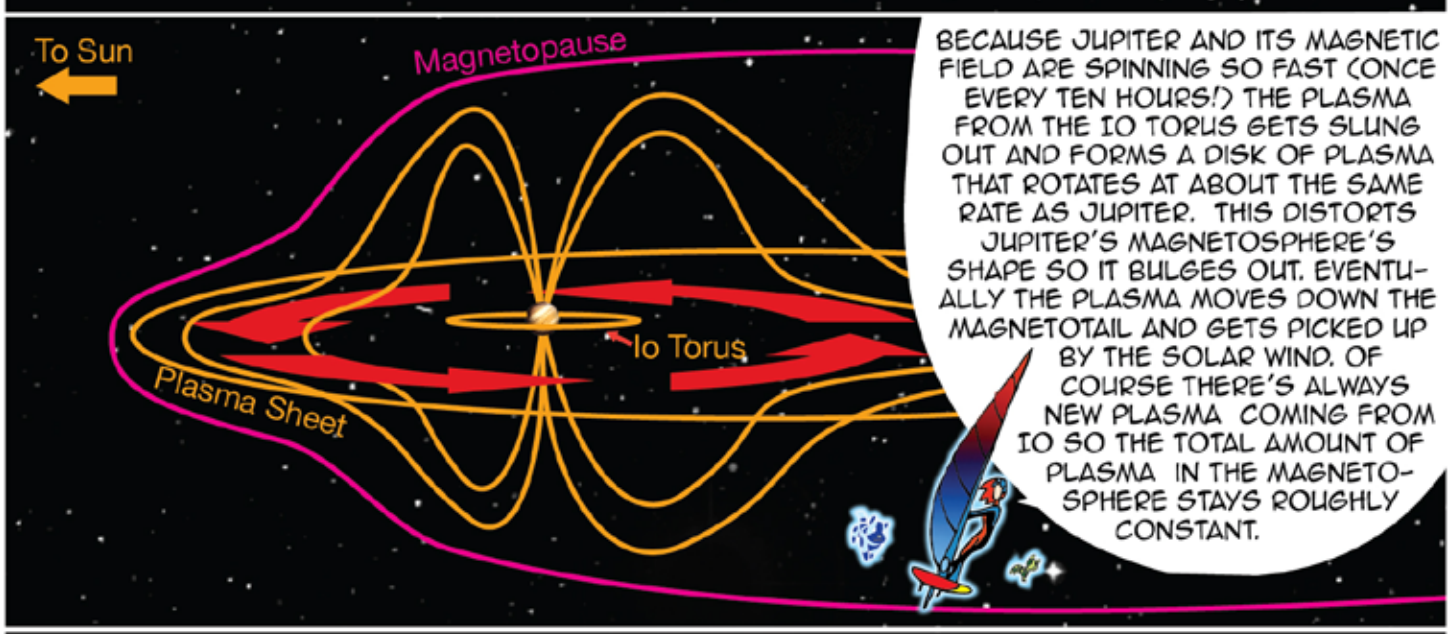
ALL THE PLASMA IN THE EARTH'S MAGNETOSPHERE COMES FROM THE EARTH'S IONOSPHERE AND SOME PLASMA THAT LEAKS IN FROM THE SOLAR WIND. SOME OF THE PLASMA IN JUPITER'S MAGNETOSPHERE ALSO COMES FROM ITS IONOSPHERE AND THE SOLAR WIND, BUT **MOST** OF ITS PLASMA COMES FROM ITS MOON IO.



IO HAS ONLY A THIN ATMOSPHERE, AND ITS VOLCANOES ARE SO POWERFUL THAT SOME OF THE SULFUR AND SODIUM GASES REACH ESCAPE VELOCITY AND FLY OUT INTO SPACE. ONCE THOSE GAS ATOMS GET OUT THERE, THE SUN'S ULTRAVIOLET LIGHT IONIZES THEM*. ONCE THEY'RE IONIZED, JUPITER'S RAPIDLY SPINNING MAGNETIC FIELD CATCHES THEM AND THEY FORM A BIG PLASMA DONUT WE CALL THE "IO TORUS."



*WE TALKED ABOUT IONIZING ATOMS BACK IN MY LAST COMIC BOOK. SEE [HTTP://CINDISPACE.UTDALLAS.EDU/EDUCATION/CINEA_COMIC.HTML](http://cindispace.utdallas.edu/education/cinea_comic.html)



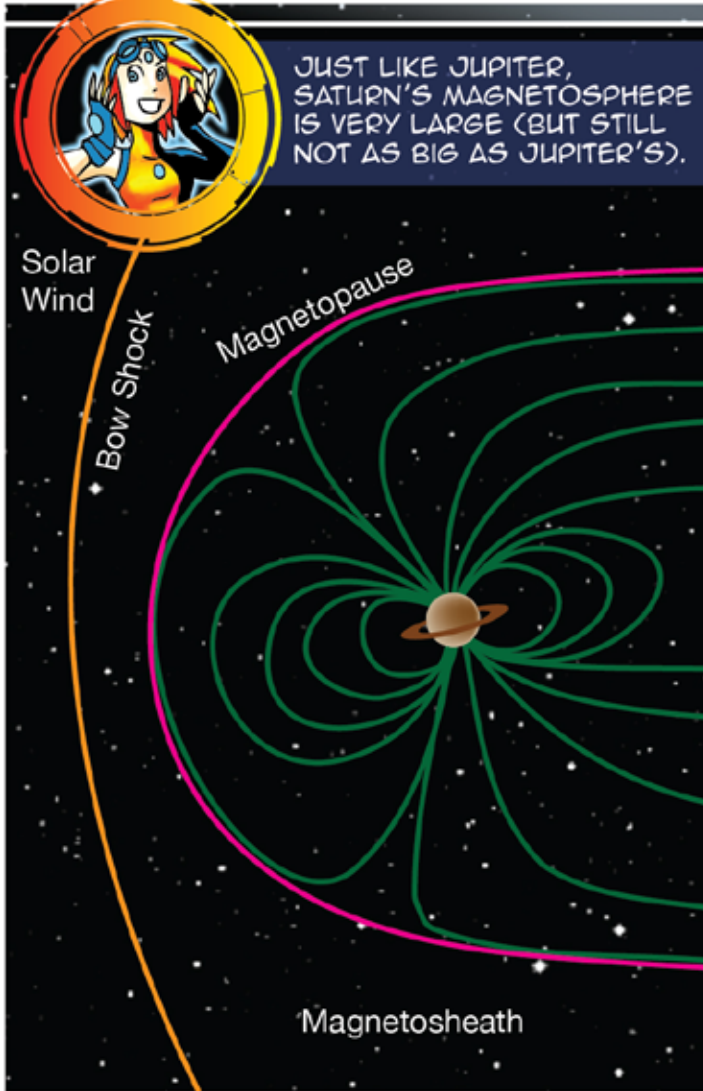
BECAUSE JUPITER AND ITS MAGNETIC FIELD ARE SPINNING SO FAST (ONCE EVERY TEN HOURS!) THE PLASMA FROM THE IO TORUS GETS SLUNG OUT AND FORMS A DISK OF PLASMA THAT ROTATES AT ABOUT THE SAME RATE AS JUPITER. THIS DISTORTS JUPITER'S MAGNETOSPHERE'S SHAPE SO IT BULGES OUT. EVENTUALLY THE PLASMA MOVES DOWN THE MAGNETOTAIL AND GETS PICKED UP BY THE SOLAR WIND. OF COURSE THERE'S ALWAYS NEW PLASMA COMING FROM IO SO THE TOTAL AMOUNT OF PLASMA IN THE MAGNETOSPHERE STAYS ROUGHLY CONSTANT.



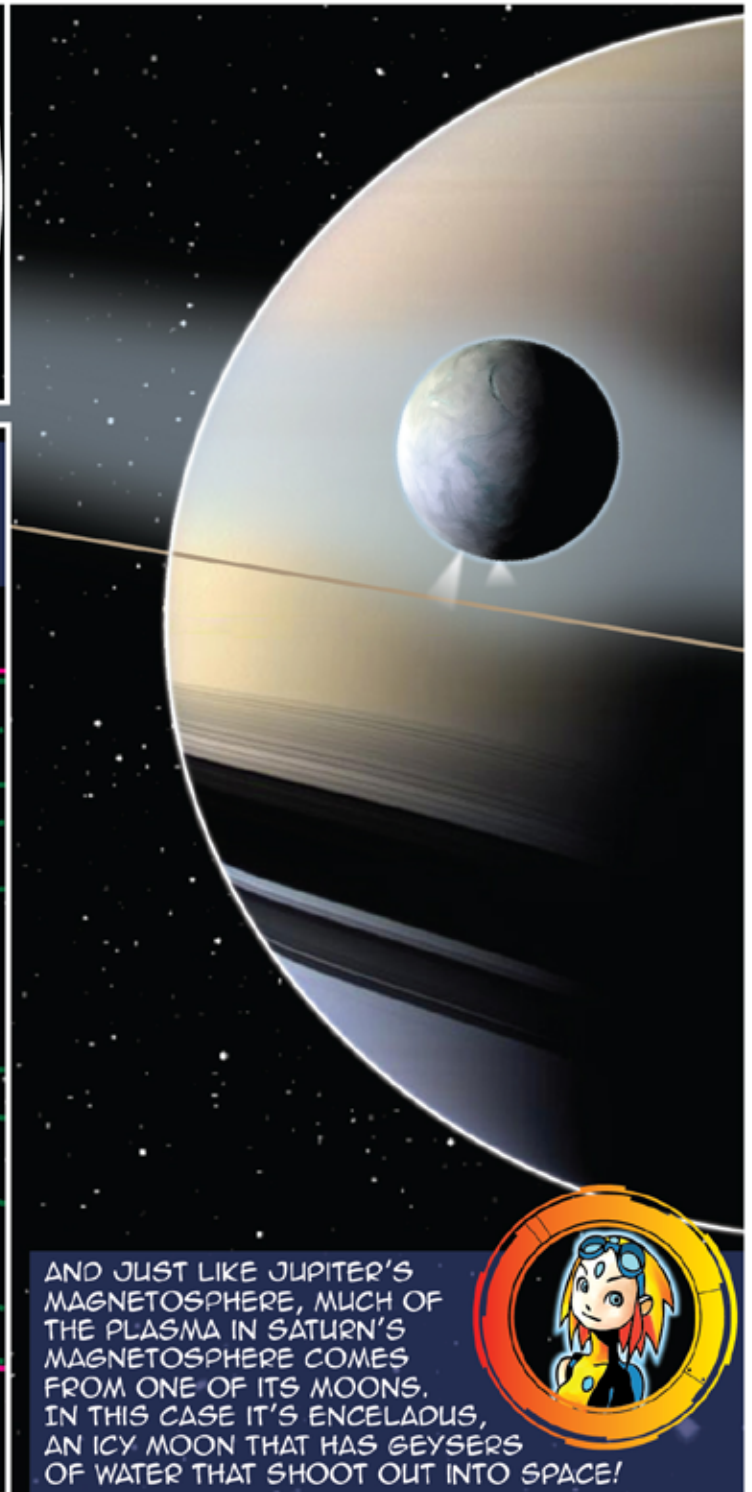
BUT WE'VE STILL GOT TO FIND STAAR. I HOPE SHE'S OKAY.



WE'RE GOING TO MISS SATURN ON THIS TRIP BECAUSE IT'S WAAAY BACK OVER THERE ON THE OTHER SIDE OF THE SUN IN THE OPPOSITE DIRECTION OF THIS CME'S PATH. BUT I DON'T WANT TO IGNORE IT.



JUST LIKE JUPITER, SATURN'S MAGNETOSPHERE IS VERY LARGE (BUT STILL NOT AS BIG AS JUPITER'S).



AND JUST LIKE JUPITER'S MAGNETOSPHERE, MUCH OF THE PLASMA IN SATURN'S MAGNETOSPHERE COMES FROM ONE OF ITS MOONS. IN THIS CASE IT'S ENCELAEDUS, AN ICY MOON THAT HAS GEYSERS OF WATER THAT SHOOT OUT INTO SPACE!

COMPOSITION OF THE PRIMARY IONS IN DIFFERENT MAGNETOSPHERES

EARTH: HYDROGEN, HELIUM, OXYGEN (IONIZED ATOMS); N₂, NO, O₂ (IONIZED MOLECULES)

JUPITER: HYDROGEN, HELIUM, OXYGEN, SULFUR, SODIUM (IONIZED ATOMS);
O₂, S₂, SO, SO₂ (IONIZED MOLECULES)

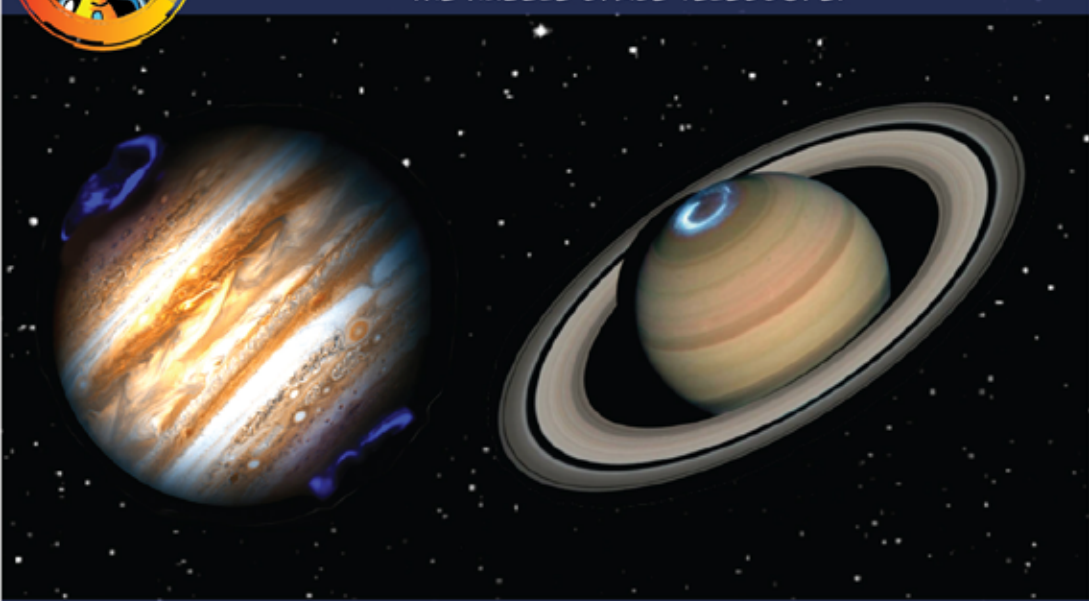
SATURN: HYDROGEN, HELIUM, OXYGEN, NITROGEN (IONIZED ATOMS);
H₂, O₂, OH, H₂O, H₃O (IONIZED MOLECULES)



SO WHILE MOST OF THE PLASMA IN THE SOLAR WIND AS WELL AS THE EARTH'S AND JUPITER'S MAGNETOSPHERES ARE MADE UP OF IONS OF SINGLE **ATOMS**, MOST OF THE PLASMA IN SATURN'S MAGNETOSPHERE IS MADE UP OF IONS OF **MOLECULES** THAT CAME FROM WATER (H₂O+, OH+, AND H₃O+).



AND JUST LIKE THE PLASMA IN THE EARTH'S MAGNETOSPHERE CAUSES THE AURORAS AROUND OUR MAGNETIC POLES, BOTH JUPITER AND SATURN HAVE AURORAS AROUND THEIR MAGNETIC POLES TOO! THESE ARE IMAGES OF THEIR AURORAS TAKEN BY THE HUBBLE SPACE TELESCOPE.



FOR MORE INFORMATION AND PICTURES OF JUPITER'S AND SATURN'S AURORAS GO TO [HTTP://HUBBLESITE.ORG/NEWSCENTER/ARCHIVE/RELEASES/2007/11/](http://hubblesite.org/newscenter/archive/releases/2007/11/) [HTTP://HUBBLESITE.ORG/NEWSCENTER/ARCHIVE/RELEASES/2005/06/](http://hubblesite.org/newscenter/archive/releases/2005/06/)

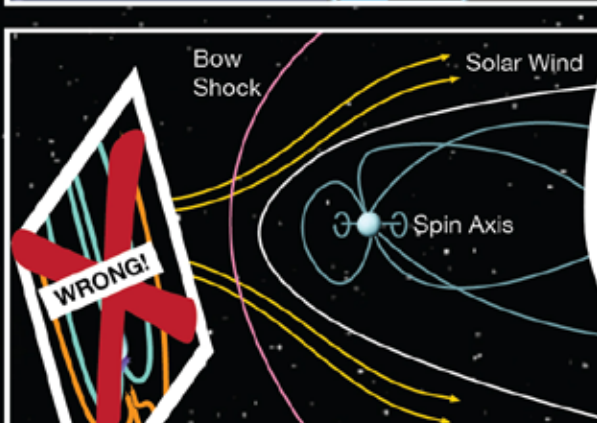
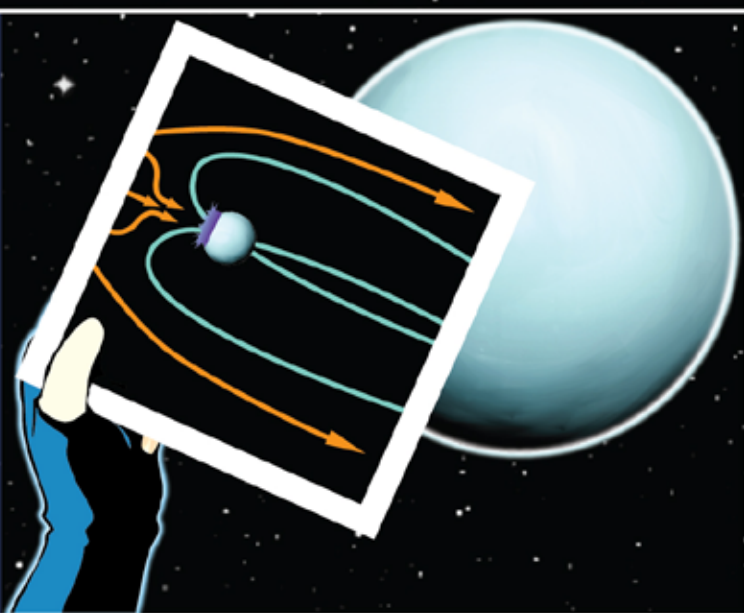
NEXT STOP IS URANUS AND IT LOOKS LIKE THE CME IS ALREADY PAST IT.



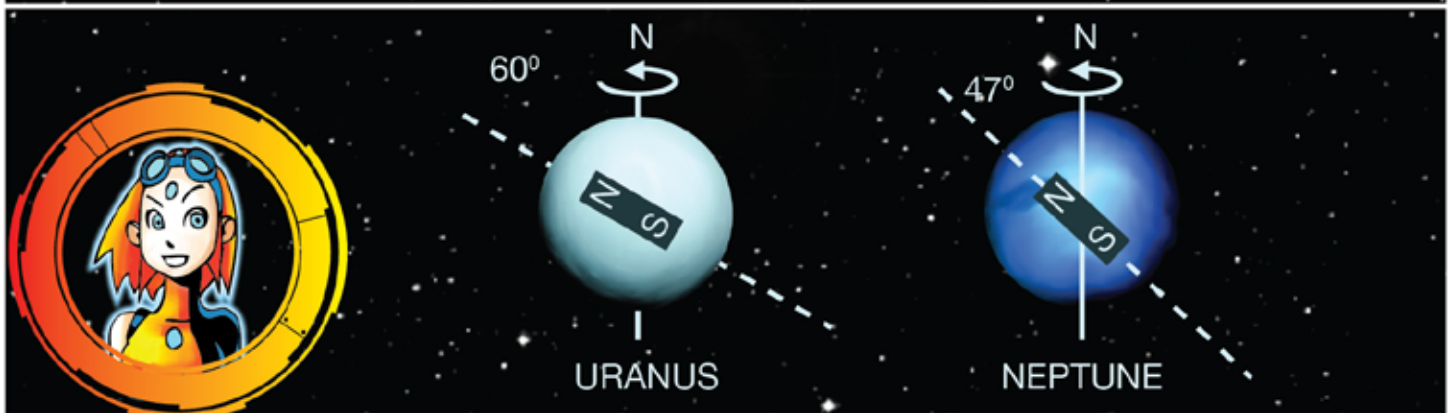
NOW URANUS HAS THE WEIRDEST MAGNETOSPHERE IN THE SOLAR SYSTEM. YOU SEE, ITS SPIN AXIS IS TILTED ALMOST 90 DEGREES, SO AT THE TIME THAT THE VOYAGER 2 SPACECRAFT FLEW BY IT IN 1986 THE SPIN AXIS WAS POINTED ALMOST DIRECTLY AT THE SUN.



SINCE THE MAGNETIC FIELDS OF THE OTHER PLANETS LINE UP ROUGHLY PARALLEL TO THE PLANET'S SPIN AXIS, WE FIGURED THE URANIAN MAGNETOSPHERE WOULD LOOK SOMETHING LIKE THIS WITH THE SOLAR WIND BEING FUNNELED STRAIGHT INTO THE POLAR REGION. WE EXPECTED TO SEE SPECTACULAR AURORA THERE.



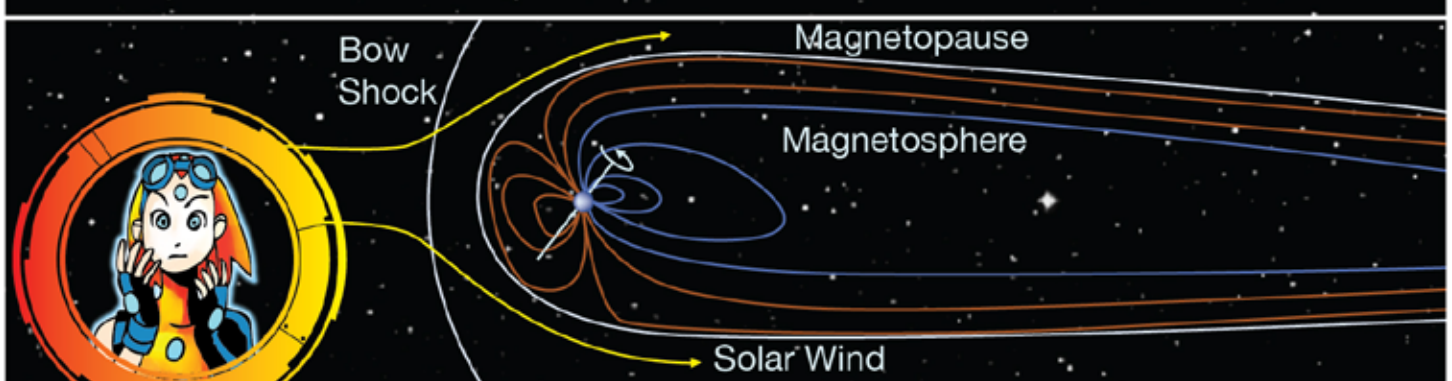
INSTEAD, IT TURNED OUT THAT THE MAGNETIC FIELD WAS TIPPED OVER 60 DEGREES RELATIVE TO URANUS' SPIN AXIS. THIS MEANT THE URANIAN MAGNETOSPHERE WAS FLIPPING END-OVER-END AS THE PLANET ROTATED.



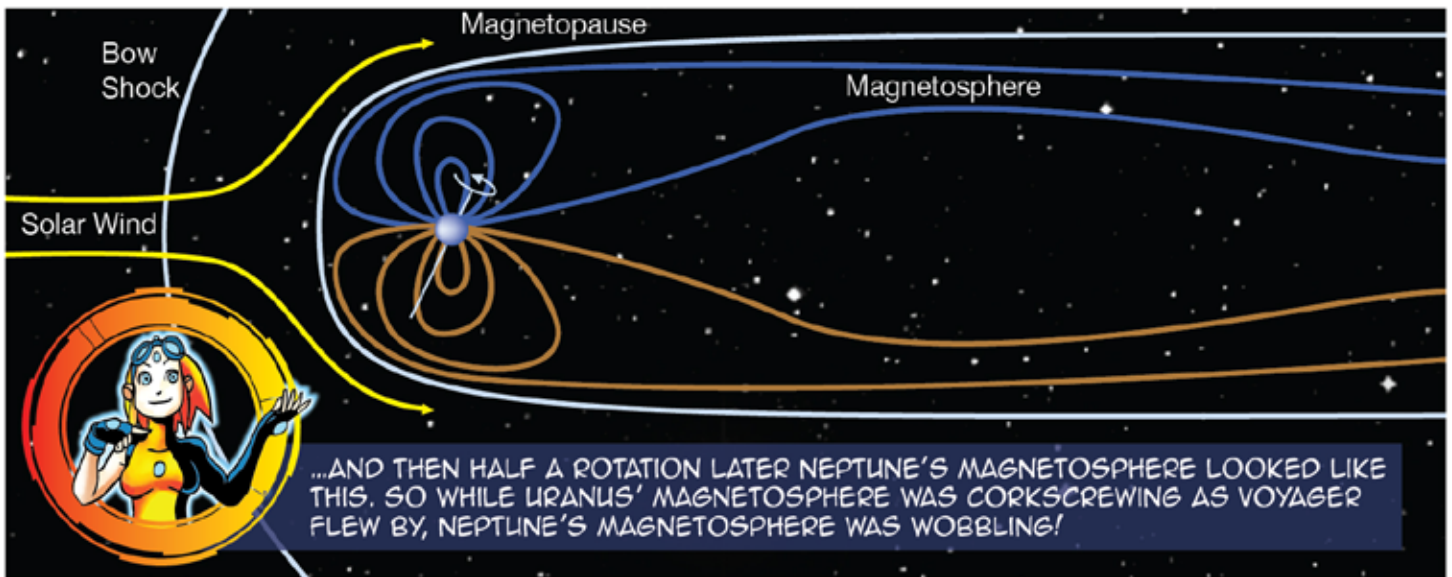
URANUS AND NEPTUNE ARE ALMOST TWIN PLANETS IN A LOT OF WAYS. AND JUST LIKE URANUS, NEPTUNE'S MAGNETIC FIELD IS NOT PARALLEL TO ITS SPIN AXIS, BUT IS TILTED AT ONLY 47 DEGREES.



AND WHILE NEPTUNE'S SPIN AXIS ISN'T TILTED ON ITS SIDE LIKE URANUS, IT IS TILTED ALMOST 30 DEGREES FROM VERTICAL (A BIT MORE THAN EARTH'S 23 DEGREE TILT). AND THE NORTHERN HEMISPHERE WAS TILTED AWAY FROM THE SUN WHEN VOYAGER FLEW PAST NEPTUNE IN 1989.



SO COMBINING THE SPIN AXIS TILT AND THE MAGNETIC FIELD'S TILT IT TURNS OUT THAT AT A CERTAIN TIME OF THE DAY NEPTUNE'S MAGNETOSPHERE LOOKED LIKE THIS....



AND THE DWARF PLANET PLUTO IS EVEN FURTHER OVER THERE AWAY FROM THE PATH OF THE CME. SO WE'LL MISS IT TOO.

PLUTO OR BUST!

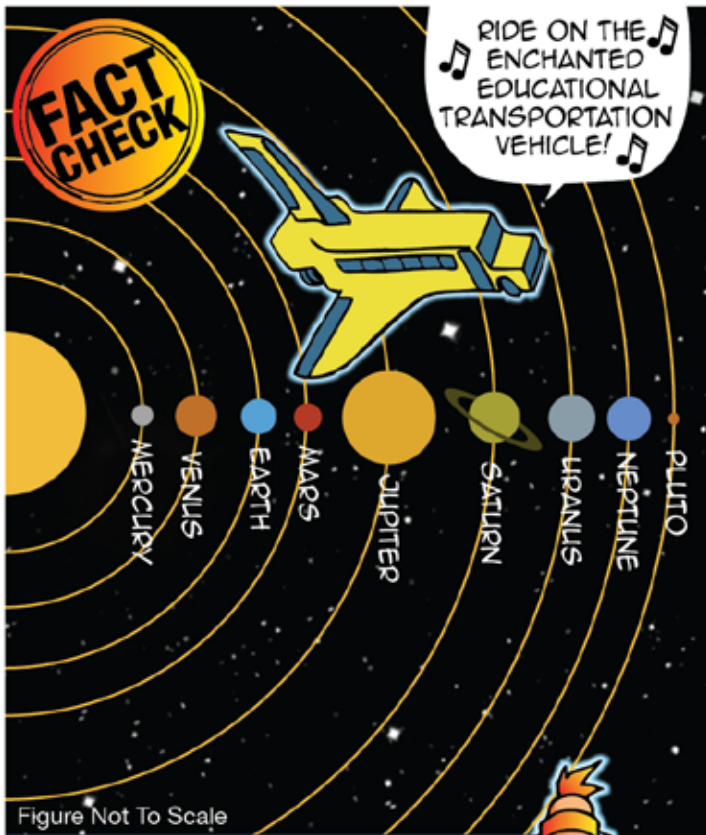
I DON'T CARE WHETHER YOU CALL ME A PLANET OR NOT, I'M STILL OUT HERE!

SINCE NONE OF OUR SPACE PROBES HAVE REACHED PLUTO YET, WE DON'T EVEN KNOW IF IT HAS A MAGNETIC FIELD OR NOT. MOST PLANETARY SCIENTISTS THINK IT PROBABLY DOESN'T, BUT WE'VE BEEN SURPRISED BEFORE. CHECK BACK IN JULY 2015 AFTER THE NEW HORIZONS SPACECRAFT FLIES PAST PLUTO.

FOR MORE ABOUT THE NEW HORIZONS MISSION, GO TO: [HTTP://PLUTO.JHUAPL.EDU/](http://pluto.jhuapl.edu/)

TIME FOR ANOTHER FACT CHECK. YOU'RE PROBABLY WONDERING WHY CINDI DIDN'T GO DIRECTLY BY EACH OF THE PLANETS, RIGHT?

23

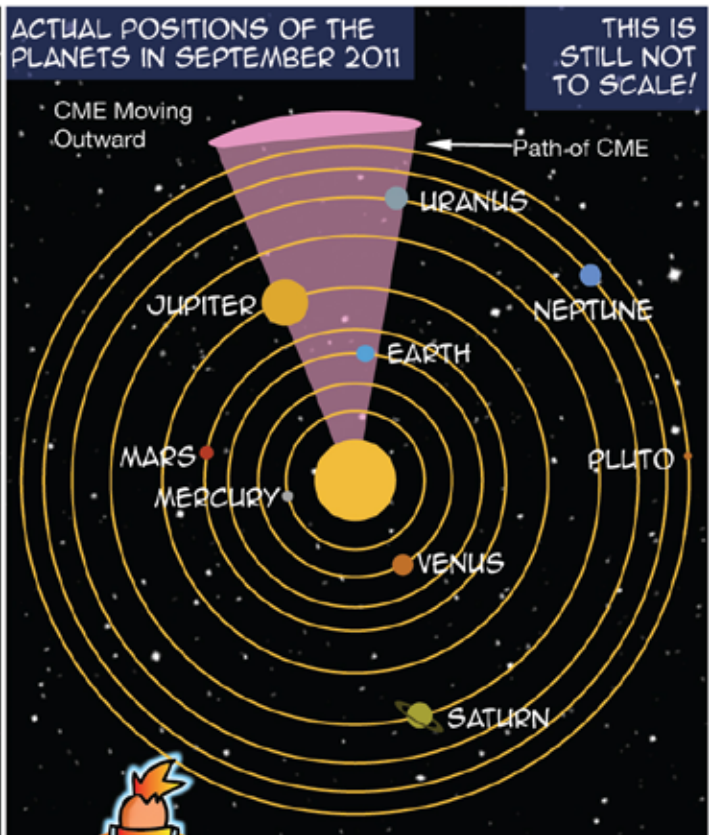


FACT CHECK

♪ RIDE ON THE ENCHANTED EDUCATIONAL TRANSPORTATION VEHICLE! ♪

Figure Not To Scale

IN MOST OF THE STORIES WHERE SOMEONE GOES THROUGH THE SOLAR SYSTEM, THE CHARACTER GOES IN A STRAIGHT LINE FROM MERCURY TO PLUTO, AND IT MAKES PEOPLE THINK THE PLANETS ARE ALWAYS LINED UP IN A NICE, NEAT ROW LIKE THIS.

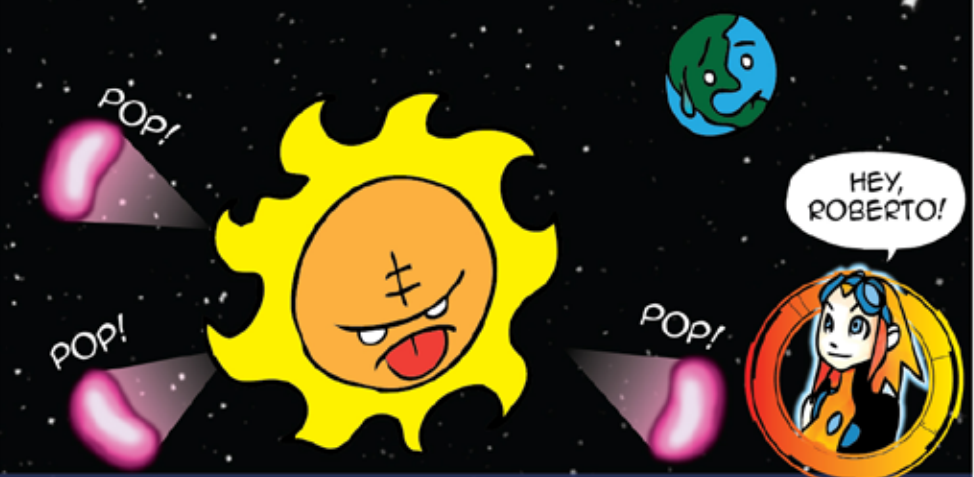


THIS IS STILL NOT TO SCALE!

BUT HERE IN SEPTEMBER 2011, THESE ARE THE *REAL* POSITIONS OF ALL THE PLANETS, AND AS YOU CAN SEE ONLY EARTH, JUPITER AND URANUS WERE IN THE PATH OF THE CME. SO THOSE WERE THE ONLY THREE PLANETS CINDI ACTUALLY FLEW PAST.



YOU SEE, CMES ARE BIG, BUT THEY AREN'T VERY WIDE COMPARED TO THE SIZE OF THE ORBITS OF THE PLANETS. SO LIKE CINDI SAID EARLIER, EVEN THOUGH THE SUN IS FREQUENTLY KICKING OFF CMES, MOST OF THEM MISS THE EARTH AND THE OTHER PLANETS COMPLETELY.



YOU CAN SEE MOVIES OF CMES THAT DO NOT HIT THE EARTH AT THIS WEBSITE:
[HTTP://SOHOWWW.NASCOM.NASA.GOV/GALLERY/MOVIES/FLARES.HTM](http://sohowww.nascom.nasa.gov/gallery/movies/flares.htm)

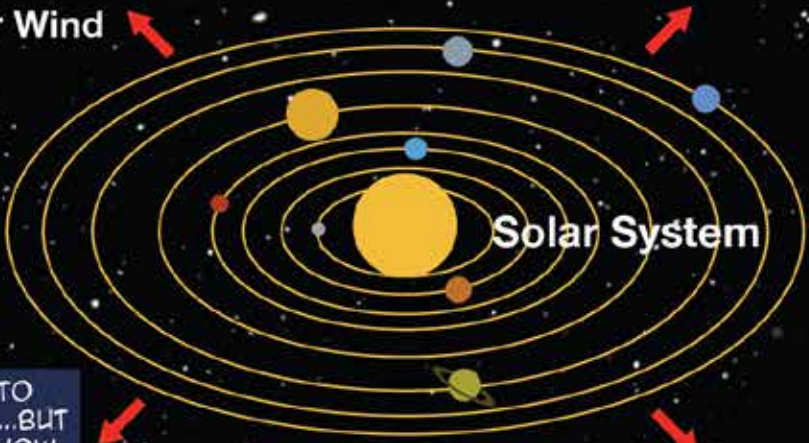
WE'RE WAY PAST THE ORBIT OF PLUTO NOW AND IT LOOKS LIKE THE CME HAS SLOWED DOWN AND WE'RE FINALLY CATCHING UP WITH IT.



SO YOU'RE WONDERING WHAT A "HELIOPAUSE" IS AND WHY THE CME SHOULD SLOW DOWN, RIGHT? OKAY, I'LL EXPLAIN IT.



Solar Wind



NOT TO SCALE.... BUT YOU KNOW THAT BY NOW.

← Nearest Star This Way
(Several Thousand Times The Width Of This Panel)



AS THE SOLAR WIND SPREADS OUT FARTHER FROM THE SUN, THE DENSITY OF ITS PLASMA DECREASES, AND IN GENERAL THE SPEED STAYS ABOUT THE SAME. NOW IF THE SPACE BETWEEN THE EDGE OF THE SOLAR SYSTEM AND THE NEAREST STARS WAS A COMPLETE VACUUM THEN THE SOLAR WIND WOULD KEEP GOING LIKE THAT ALL THE WAY TO THE STARS.



BUT THAT'S NOT HOW THINGS ARE. THERE IS ACTUALLY A VERY LOW-DENSITY GAS AND PLASMA WITH A MAGNETIC FIELD BETWEEN THE STARS IN OUR GALAXY. ASTRONOMERS CALL THIS THE "INTERSTELLAR MEDIUM" OR "ISM".

SUN

ALPHA CENTAURI

Interstellar Gas
(Look Closely, It's Really Low Density)

No Solar Wind

SUN

ISM

With Solar Wind

SUN

ISM

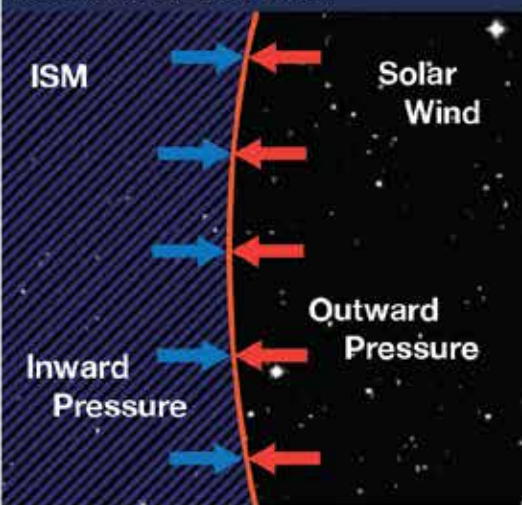


SUPPOSE THE SUN DIDN'T EMIT ANY SOLAR WIND SO THAT THE ISM REACHED ALL THE WAY TO THE SUN. (THAT WOULD NEVER ACTUALLY HAPPEN OF COURSE, BUT WE CAN IMAGINE IT.) IF YOU TURNED THE SOLAR WIND ON THEN THE SOLAR WIND PLASMA WITH ITS MUCH HIGHER DENSITY WOULD PUSH THE LOWER DENSITY ISM OUTWARD AND WOULD FORM A BUBBLE IN THE ISM.



BUT SINCE THE SOLAR WIND'S PLASMA DENSITY DECREASES AS IT MOVES OUTWARD, EVENTUALLY IT GETS TO A PLACE WHERE ITS OUTWARD PRESSURE FROM ITS MOVING

PLASMA AND MAGNETIC FIELD IS ABOUT EQUAL TO THE INWARD PRESSURE FROM PLASMA AND MAGNETIC PRESSURE OF THE ISM. AT THAT POINT THE SOLAR WIND BUBBLE WOULD STOP GROWING.



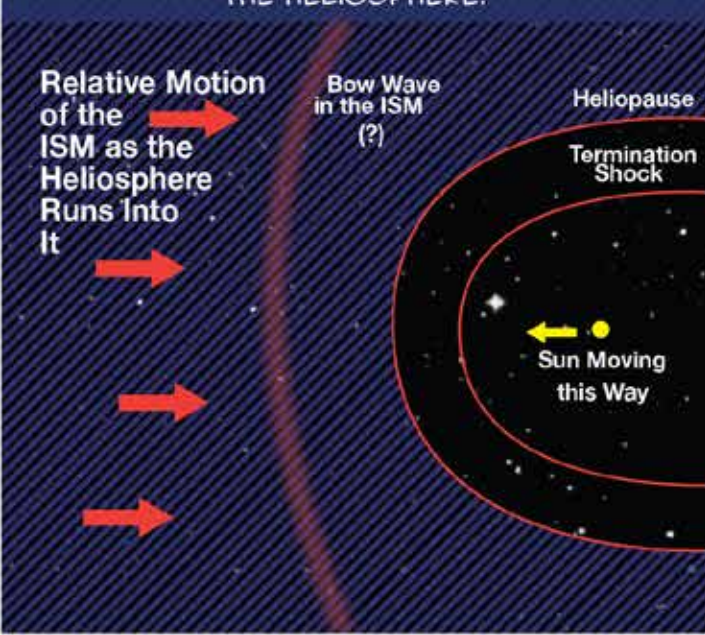
THIS BOUNDARY WHERE THE SOLAR WIND STOPS FLOWING OUTWARD AS IT REACHES THE ISM IS CALLED THE "HELIOPAUSE" AND THE ENTIRE BUBBLE CREATED BY THE SOLAR WIND IS CALLED THE "HELIOSPHERE." BUT BEFORE WE REACH THE HELIOPAUSE, WE GET TO A BOUNDARY WHERE THE SOLAR WIND SPEED SLOWS DOWN. SCIENTISTS CALL THIS THE "TERMINATION SHOCK." THE TWO VOYAGER SPACECRAFT DETECTED THEIR PASSES THROUGH THE TERMINATION SHOCK BACK IN 2004 AND 2007, BUT THEY STILL HAVEN'T REACHED THE HELIOPAUSE.



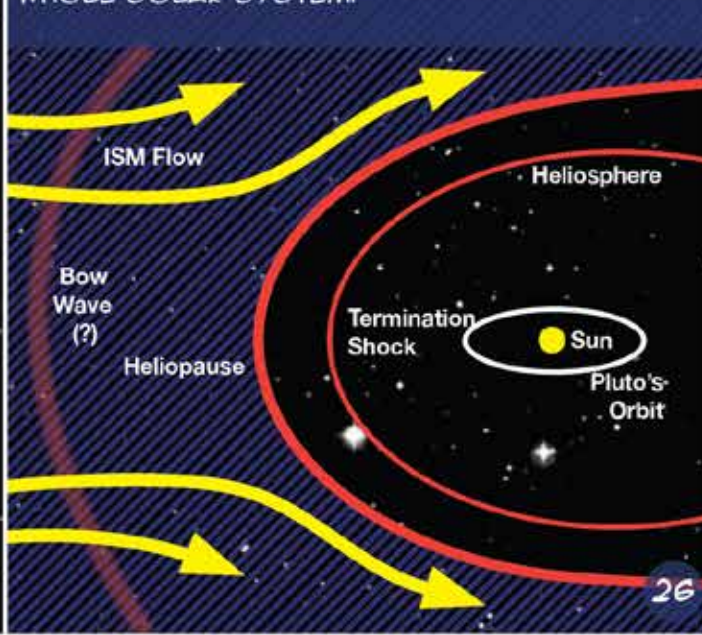
SINCE WE DON'T KNOW EXACTLY WHAT THE EDGE OF THE HELIOPAUSE WILL LOOK LIKE, THERE HAVE BEEN SEVERAL TIMES WHEN SCIENTISTS THOUGHT VOYAGER 1 HAD REACHED THE EDGE, BUT SO FAR THEY WERE ALL FALSE ALARMS. CHECK OUT THE VOYAGER HOMEPAGE TO SEE WHAT'S HAPPENED SINCE 2011: [HTTP://VOYAGER.JPL.NASA.GOV/](http://voyager.jpl.nasa.gov/)



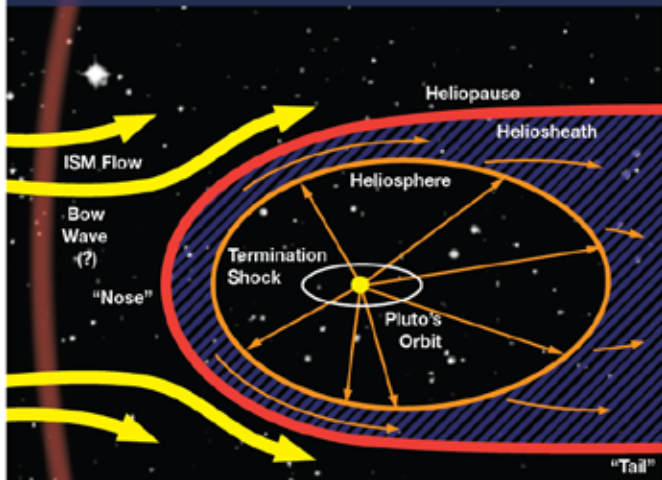
HERE IT GETS A BIT COMPLICATED. THE SUN AND SOLAR SYSTEM ARE MOVING THROUGH THE INTERSTELLAR GAS AND PLASMA, SO THIS MEANS THE ISM PLASMA IS RUNNING INTO THE SOLAR WIND ON ONE SIDE AND THAT CREATES A BOW WAVE (SIMILAR TO THE BOW SHOCK) ON THAT SIDE. THIS IS WHERE THE ISM PLASMA SLOWS DOWN AND BEGINS TO MOVE AROUND THE HELIOSPHERE.



AND THE OTHER SIDE OF THE HELIOSPHERE WHERE THE SOLAR WIND ISN'T RUNNING INTO THE ISM, THE SOLAR WIND FLOW EXTENDS MUCH FURTHER OUT MAKING A TAIL. SO THE WHOLE HELIOSPHERE IS SHAPED LIKE (SURPRISE!) A GIANT MAGNETOSPHERE! IN A SENSE THE HELIOSPHERE IS THE BIGGEST MAGNETOSPHERE IN THE SOLAR SYSTEM BECAUSE IT CONTAINS THE WHOLE SOLAR SYSTEM!

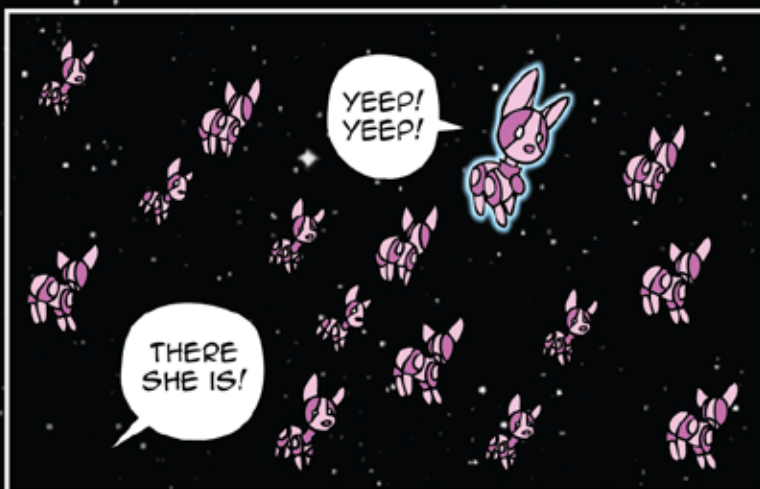


BETWEEN THE TERMINATION SHOCK AND THE HELIOPAUSE IS THE REGION WHERE THE SOLAR WIND PLASMA SLOWS DOWN AND THIS IS CALLED THE "HELIOSEATH." ULTIMATELY ALL THE SOLAR WIND PLASMA ENDS UP FAR DOWN IN THE TAIL OF THE HELIOSPHERE AND GETS MIXED INTO THE ISM AND EVENTUALLY DRIFTS OUT INTO INTERSTELLAR SPACE.



IN OCTOBER 2008 NASA LAUNCHED A SMALL SATELLITE CALLED IBEX (INTERSTELLAR BOUNDARY EXPLORER) INTO EARTH ORBIT WHERE IT USES SPECIAL DETECTORS TO STUDY THE INTERACTION BETWEEN THE ISM AND THE SOLAR WIND. TO FIND OUT MORE ABOUT THE IBEX MISSION, GO TO: [HTTP://WWW.IBEX.SWRI.EDU/STUDENTS/INDEX.SHTML](http://www.ibex.swri.edu/students/index.shtml)

FORTUNATELY FOR US, THE CME THAT SWEEP STAAR AWAY HEADED ALMOST DIRECTLY FOR THE NOSE OF THE HELIOSPHERE. SO NOW WE'RE IN THE HELIOSEATH WHERE ALL THE CME PARTICLES HAVE SLOWED DOWN AND ARE STARTING TO FLOW BACK AROUND TOWARDS THE TAIL, SO WE CAN START LOOKING FOR STAAR HERE.





OKAY, IN ORDER TO COMPRESS THIS INTO THE LENGTH OF A COMIC BOOK WE MADE IT APPEAR THAT CINDI ONLY SPENT ABOUT A DAY CHASING THE CME FROM THE SUN AND BACK, BUT THAT'S COMPLETELY UNREALISTIC! IN REALITY THE REGULAR SOLAR WIND PLASMA TAKES NEARLY **TWO YEARS** TO GET OUT CLOSE TO THE NOSE OF THE HELIOPAUSE! SO HERE IS A TABLE SHOWING HOW LONG LIGHT (WHICH HAS THE FASTEST SPEED IN THE UNIVERSE), A FAST CME, THE AVERAGE SOLAR WIND, AND THE VOYAGER 1 SPACECRAFT (THE FASTEST SPACECRAFT WE EVER BUILT) EACH TAKE TO GET TO THESE BOUNDARIES. DISTANCES ARE GIVEN IN ASTRONOMICAL UNITS (AU) WHERE 1 AU IS THE AVERAGE DISTANCE FROM THE SUN TO THE EARTH.

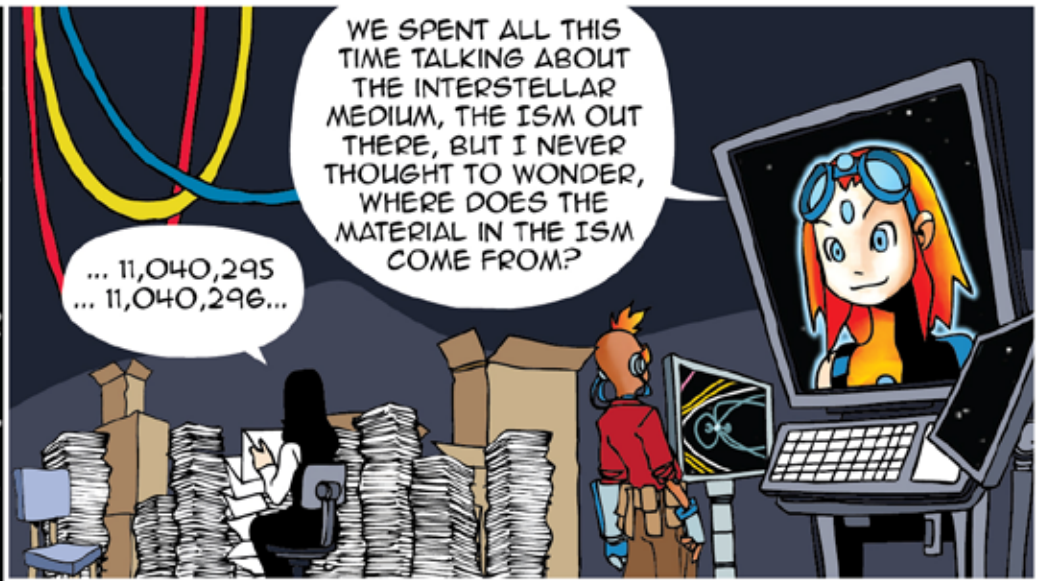
From Sun to	Earth's Orbit	Jupiter's Orbit	Pluto's Orbit	Termination Shock (at most distant point)	Near Edge of Heliopause
	1 AU	5.2 AU	48.8 AU	94 AU	>116 AU*
Light	8min 22s	43min 30s	6hours 48m	13hours 6m	>16hours 10m
Fast CME 2000 km/s	~21 hours	4.5 days	42 days	81 days	>119 days
Regular Solar Wind at 400 km/s	4 days 8h	22.5 days	211 days	1 year 42d	>1yr 232d
Voyager Spacecraft	---	1.5 years	14 years	27 years	>33.5 years

* We're using the 116 AU distance since that was Voyager 1's distance from the sun in mid-2011 and we know the heliopause is even further out. So the actual times to the heliopause will be longer than these times for 116 AU, we just don't know yet how much larger.



HEY, ROBERTO!
I'VE GOT A
QUESTION
FOR YOU.

SURE
CINDI.
WHAT
IS IT?



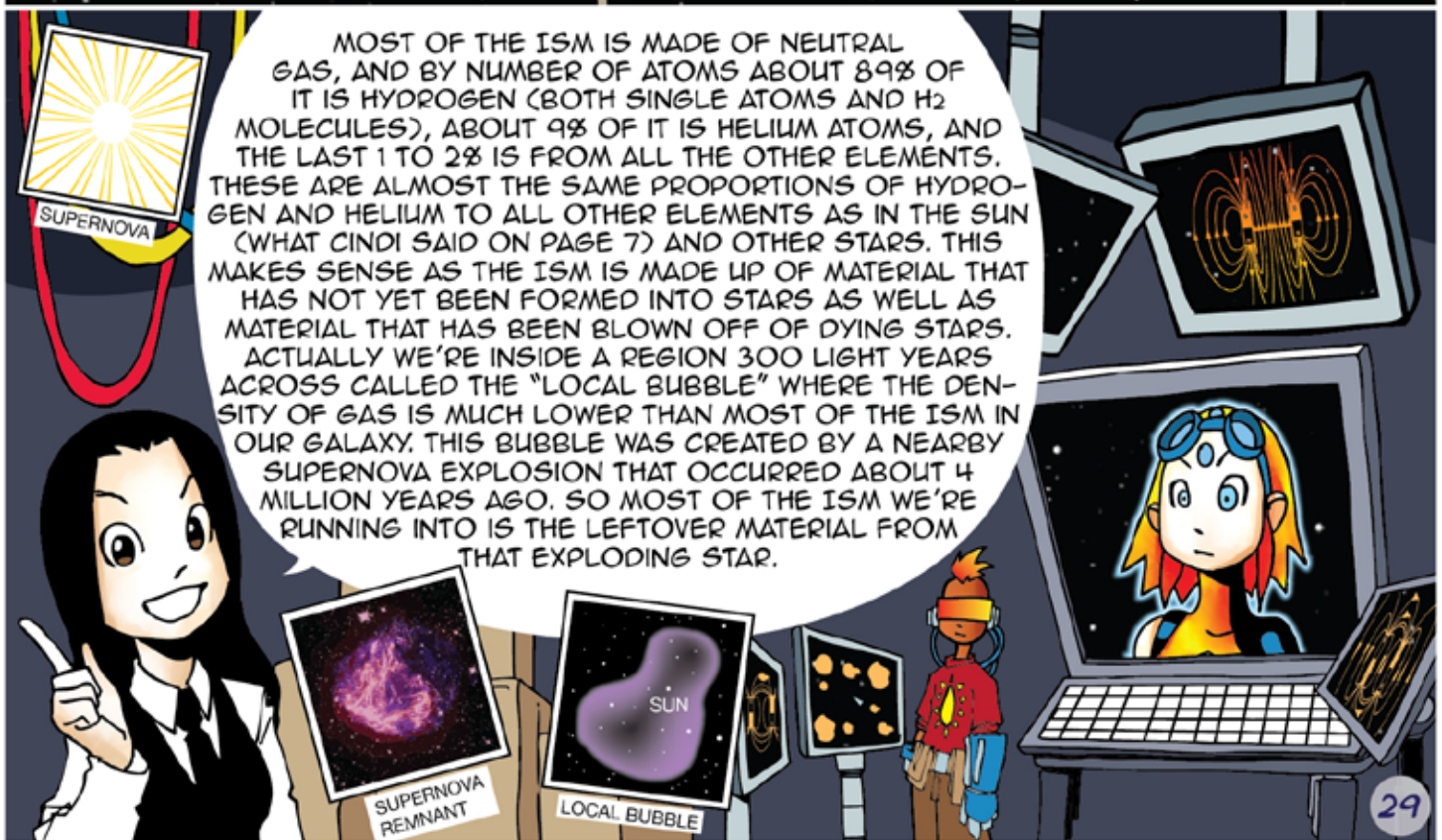
... 11,040,295
... 11,040,296...

WE SPENT ALL THIS
TIME TALKING ABOUT
THE INTERSTELLAR
MEDIUM, THE ISM OUT
THERE, BUT I NEVER
THOUGHT TO WONDER,
WHERE DOES THE
MATERIAL IN THE ISM
COME FROM?



WOW,
THAT'S A
REALLY GOOD
QUESTION,
CINDI. I DON'T
KNOW THE
ANSWER. I
GUESS I
COULD LOOK
IT UP...

OH
THAT'S
EASY.

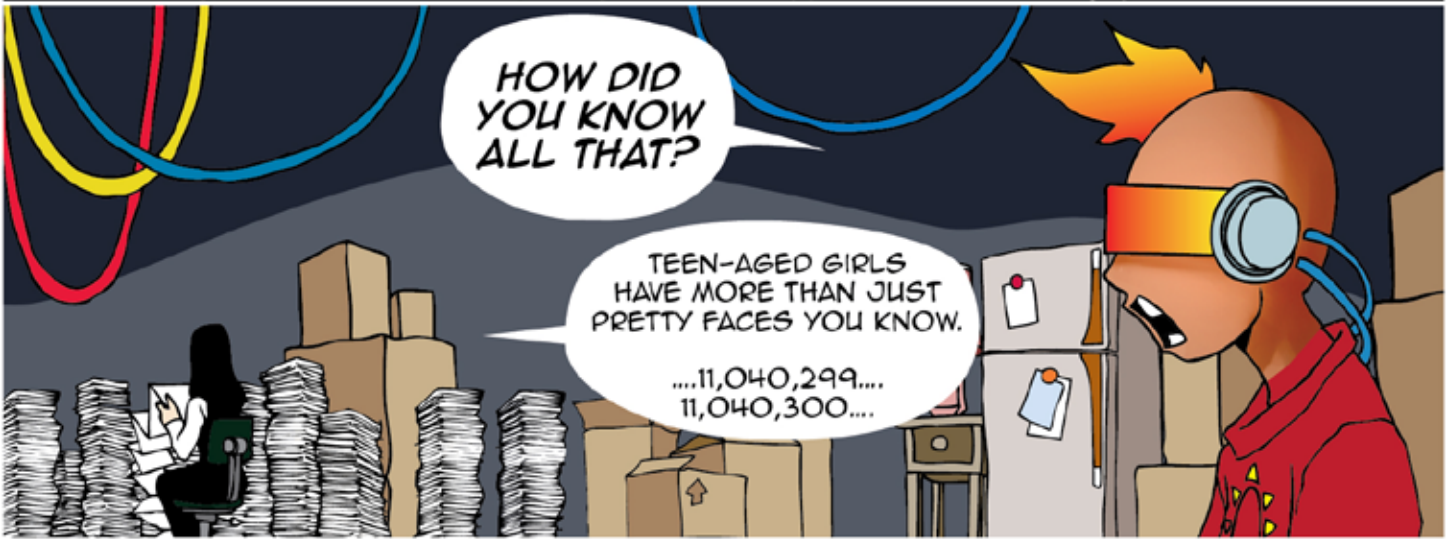


MOST OF THE ISM IS MADE OF NEUTRAL GAS, AND BY NUMBER OF ATOMS ABOUT 89% OF IT IS HYDROGEN (BOTH SINGLE ATOMS AND H₂ MOLECULES), ABOUT 9% OF IT IS HELIUM ATOMS, AND THE LAST 1 TO 2% IS FROM ALL THE OTHER ELEMENTS. THESE ARE ALMOST THE SAME PROPORTIONS OF HYDROGEN AND HELIUM TO ALL OTHER ELEMENTS AS IN THE SUN (WHAT CINDI SAID ON PAGE 7) AND OTHER STARS. THIS MAKES SENSE AS THE ISM IS MADE UP OF MATERIAL THAT HAS NOT YET BEEN FORMED INTO STARS AS WELL AS MATERIAL THAT HAS BEEN BLOWN OFF OF DYING STARS. ACTUALLY WE'RE INSIDE A REGION 300 LIGHT YEARS ACROSS CALLED THE "LOCAL BUBBLE" WHERE THE DENSITY OF GAS IS MUCH LOWER THAN MOST OF THE ISM IN OUR GALAXY. THIS BUBBLE WAS CREATED BY A NEARBY SUPERNOVA EXPLOSION THAT OCCURRED ABOUT 4 MILLION YEARS AGO. SO MOST OF THE ISM WE'RE RUNNING INTO IS THE LEFTOVER STAR MATERIAL FROM THAT EXPLODING STAR.

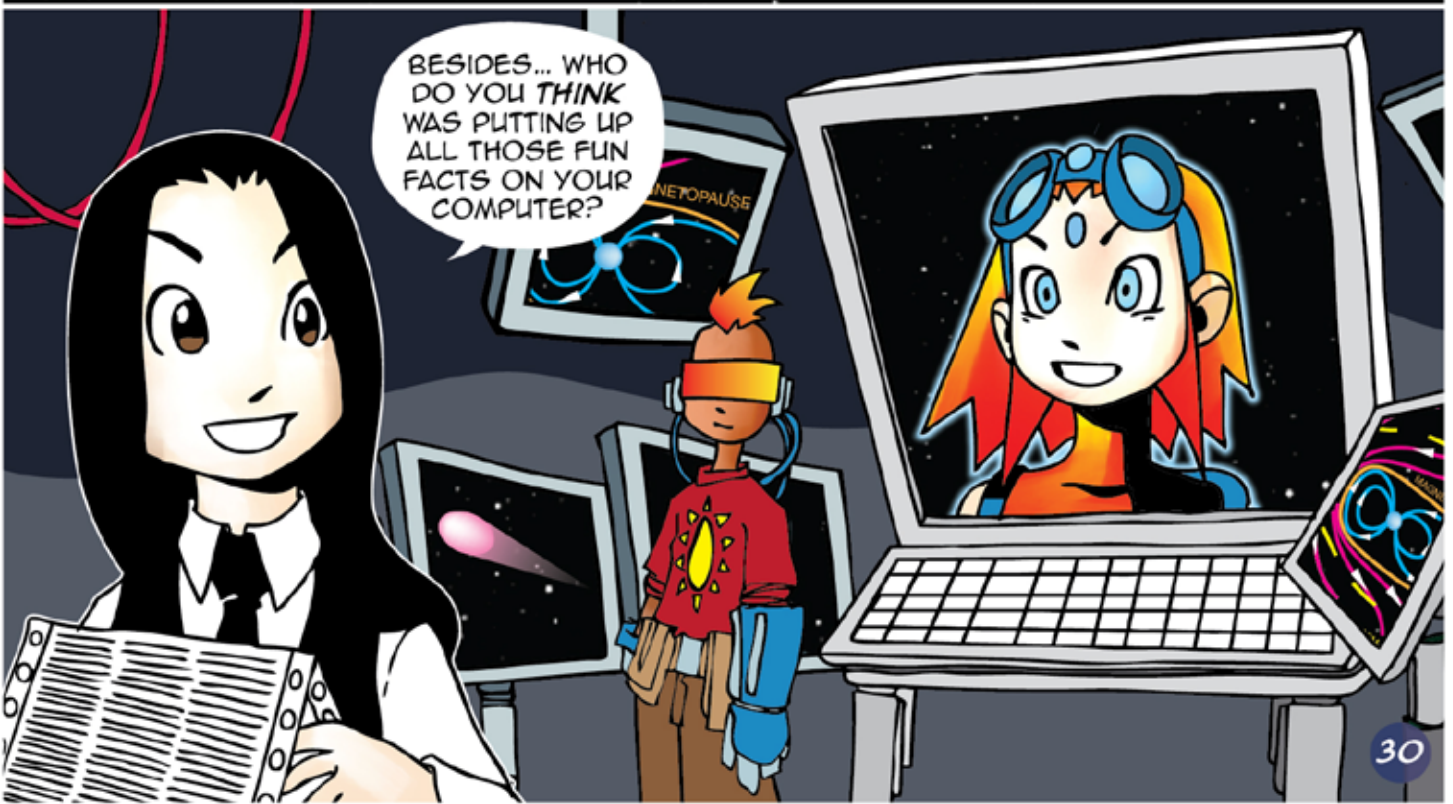


HOW DID YOU KNOW ALL THAT?

TEEN-AGED GIRLS HAVE MORE THAN JUST PRETTY FACES YOU KNOW.
...11,040,299...
11,040,300...



BESIDES... WHO DO YOU THINK WAS PUTTING UP ALL THOSE FUN FACTS ON YOUR COMPUTER?



WELL, THAT WASN'T THE VACATION I WAS PLANNING, BUT IT WAS STILL PRETTY EXCITING. WE GOT ALL THE WAY TO THE EDGE OF THE SOLAR SYSTEM AND BACK. THANKS FOR COMING ALONG WITH US. SEE YOU AGAIN IN OUR NEXT COMIC BOOK!





Would you like to know more about the Earth's ionosphere, the CINDI mission, the C/NOFS satellite, and download this comic book and copies of my other two comic books? Then come to our really cool website:

<http://cssepo.utdallas.edu/>

On our website we have more information about the CINDI mission, classroom projects, videos about space science and the CINDI mission, and even real data from CINDI! You can even follow me on Facebook! Search for "Cindi InSpace". And here are all the folks who created this comic book:

Cindi character created and developed by:
**Dr. Mary Urquhart and
Dr. Marc Hairston**

Script and storyboarding by:
Dr. Marc Hairston

Educational content oversight by:
Dr. Mary Urquhart

Incredible character designs; dazzling artwork, magnificent layouts, and precision lettering by:

Erik Lervold

Special Artistic Help and Great Guys:

Kevin Kosmo and Eric Winkelmann

Cindi Comics Ultra Director and Head Cheerleader:

Dr. Marc Hairston

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OKAY, ONE LAST QUESTION: WHY DOES STAAR HAVE A COLLAR AND NONE OF THE OTHER DOGS IN THE SOLAR WIND DO?

STAAR IS A METAPHOR FOR A HYDROGEN ION JUST LIKE IN THE SOLAR WIND. SINCE HYDROGEN IS THE SIMPLEST ATOM, A SINGLE PROTON WITH A SINGLE ELECTRON, THEN A HYDROGEN ION IS JUST A BARE PROTON. BUT ALL THE PROTONS IN THE UNIVERSE ARE IDENTICAL! IF CINDI LOST A REAL PROTON IN THE SOLAR WIND, SHE'D NEVER BE ABLE FIND EXACTLY WHICH ONE SHE LOST IN ALL THE OTHER SOLAR WIND PROTONS. SO WE GAVE STAAR A COLLAR TO MAKE IT EASY TO DISTINGUISH HER FROM ALL THE OTHER DOGS. SO IT'S NOT REALITY, BUT THIS IS A COMIC BOOK. IT'S ARTISTIC LICENSE, OKAY?

