



TRANSIT OF VENUS

6TH JUNE
2012



CONCEPT AND TEXT :
NIRUJ MOHAN RAMANUJAM
ILLUSTRATIONS :
RESHMA BARVE



THE TRANSIT OF VENUS



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NOTE !

If you are living in the Americas,
the Transit of Venus will occur on the
evening of June 5th instead !

RESOURCES

Websites

<http://www.daytimeastronomy.com> - *General information and how to perform experiments in the daytime using the Sun, including Transit observations*

<http://www.sunderstanding.net/index.html> - *Navnirmity site on how to observe & measure the Transit*

<http://www.transitofvenus.org/> - *General Information*

<http://transitofvenus.nl/wp/where-when/local-transit-times/> - *times, tracks and more, for your town*

<http://www.sunderstanding.net/filterindia.htm> – *to obtain solar filters in India*

http://mutha.ncra.tifr.res.in/ncra/for-public/transit-of-venus_ - *to download this book in more than 10 languages !*

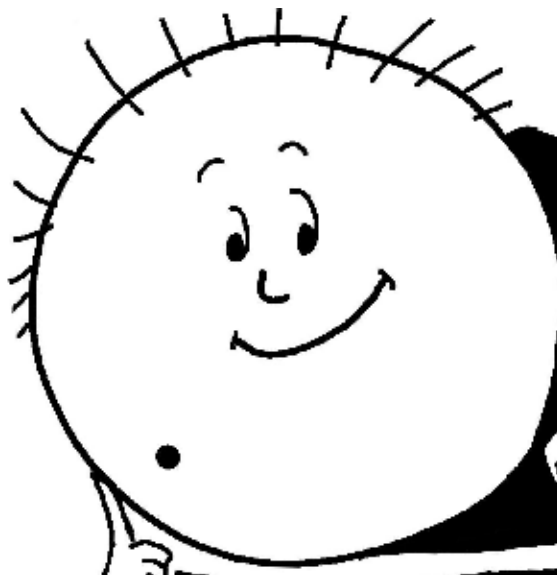
Books

Measuring the Universe with a string and a stone – Transit of Venus experiment, by Dr. Vivek Monteiro, Navnirmity (<http://www.sunderstanding.net>)

Transit of Venus, by Dr. B.S. Shylaja, Navakarnataka Publications

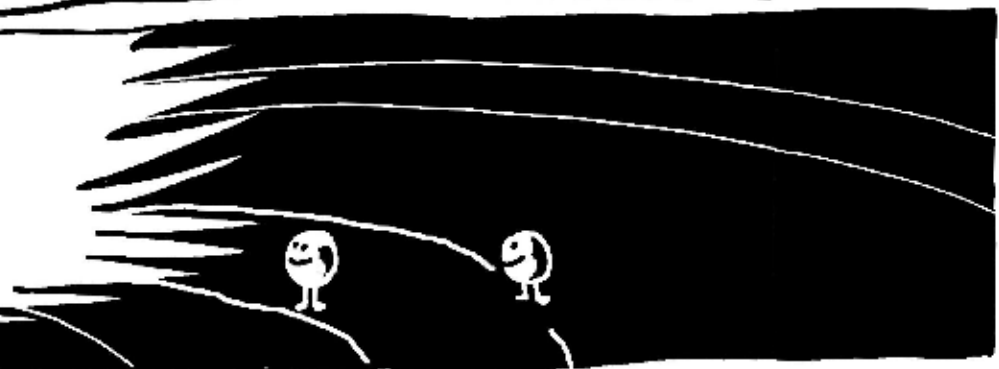
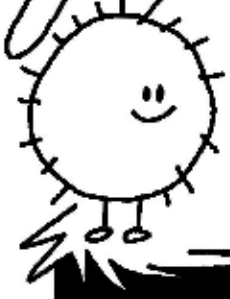
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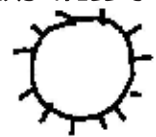
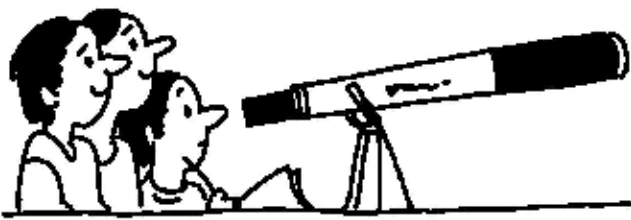


A VERY DIFFERENT KIND OF SOLAR ECLIPSE WILL OCCUR ON JUNE 6TH, 2012 - THE PLANET VENUS WILL COME BETWEEN US AND THE SUN. ASTRONOMERS CALL THIS ...

THE TRANSIT OF VENUS.



MANY PEOPLE WILL BE GETTING UP VERY EARLY INDEED, ON THAT DAY, TO SEE VENUS, A SMALL BLACK DOT, MOVE SLOWLY ACROSS THE SUN'S DISK IN THE SKY. WHY BOTHER, THOUGH? VENUS WILL ONLY BE 1/30 AS BIG AS THE SUN AND WILL 8 HOURS TO CROSS IT.



BUT PEOPLE DID BOTHER. FOR OVER 250 YEARS, THE MOST POWERFUL NATIONS HAVE BEEN SENDING THEIR BEST ASTRONOMERS...

...TO SAIL ACROSS OCEANS AND CLIMB OVER MOUNTAINS, JUST TO GLIMPSE SUCH AN EVENT. WHY DID THEY THINK IT WAS SO IMPORTANT?



JOHANNES KEPLER

OUR STORY STARTS WAY BACK IN 1631, WHEN JOHANNES KEPLER (THE GUY WHO GAVE US HIS THREE LAWS OF PLANETARY MOTION) PREDICTED THAT VENUS WOULD COME IN BETWEEN THE EARTH AND THE SUN ON DEC 6TH 1631. IT WASN'T VISIBLE IN EUROPE UNFORTUNATELY, SINCE IT OCCURRED AT NIGHT. SOON AFTER...



...A CLEVER YOUNG MAN, JEREMIAH HORROCKS, CALCULATED THAT THESE TRANSITS ACTUALLY OCCUR IN PAIRS AND THE NEXT ONE WOULD OCCUR ON NOV 24TH 1639,



JEREMIAH HORROCKS

HE WAS THE FIRST, ALONG WITH HIS FRIEND, TO OBSERVE THE TRANSIT OF VENUS. HOWEVER HE MADE A WRONG ASSUMPTION IN HIS CALCULATIONS. HE DEDUCED A VALUE OF 96 MILLION KM FOR THE EARTH-SUN DISTANCE, FROM HIS OBSERVATIONS. BUT MORE ON THIS LATER. HORROCKS WAS A BRILLIANT SCIENTIST, COULD EVEN CALCULATE PLANET ORBITS WHEN HE WAS JUST 17, AND WAS A BRIDGE BETWEEN KEPLER AND NEWTON, BUT TRAGICALLY DIED AT THE AGE OF 22.



IT WAS HALLEY (OF HALLEY'S COMET FAME) WHO, IN 1678, ASKED ALL COUNTRIES TO SEND THEIR SCIENTISTS AROUND THE WORLD TO TIME THE TRANSIT.

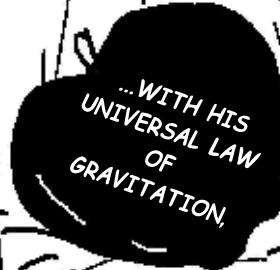


REMEMBER, KEPLER HAD ALREADY TOLD US HOW THE PLANETS MOVE - WHAT KIND OF ORBITS, AND HOW FAST.

"... I recommend it therefore, again and again, to those curious Astronomers, who ... diligently apply themselves with all their might to the making of this observation."

THEY HAD NO CLUE ! WHAT THEY DID KNOW WERE THE RELATIVE DISTANCES BETWEEN VARIOUS OBJECTS - THAT IS, THEY KNEW THE DISTANCES BETWEEN VARIOUS PLANETS AND THE SUN AS A FRACTION OF THE EARTH-SUN DISTANCE. IF ONLY THEY COULD FIND OUT WHAT THE EARTH-SUN DISTANCE ACTUALLY WAS...

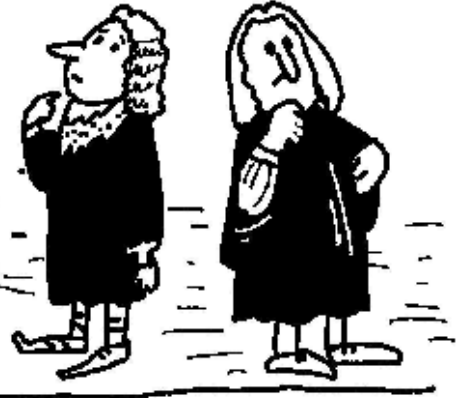
NEWTON THEN CAME ALONG...



WHICH NEATLY EXPLAINED WHY KEPLER'S LAWS WORK. USING HIS LAWS, ASTRONOMERS WANTED TO KNOW...

...HOW BIG IS THE SOLAR SYSTEM ?

IS IT A FEW 1000 KMS BIG, A MILLION KM BIG, OR MUCH MUCH MORE ?

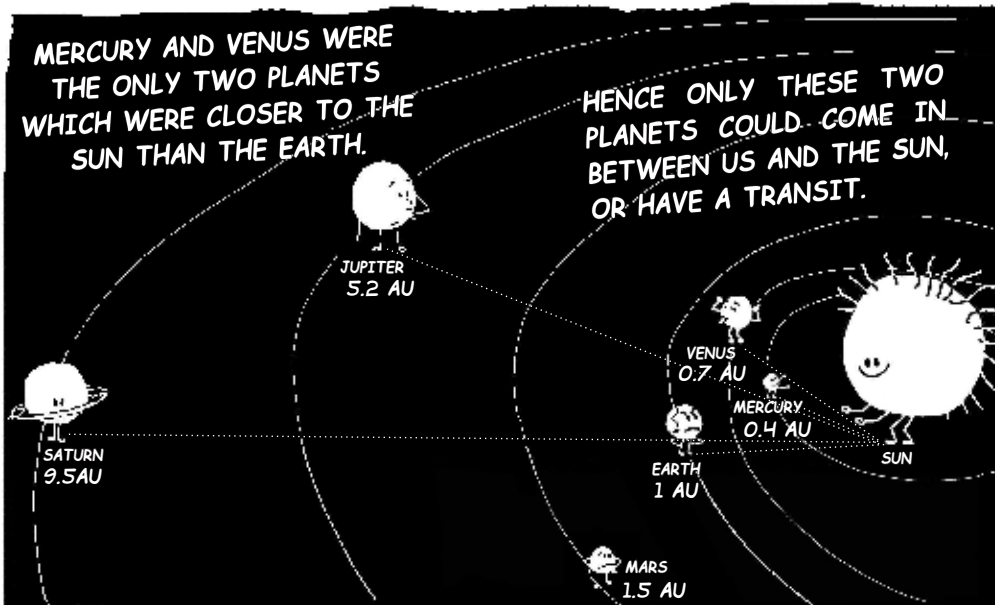


...THEY WOULD BE ABLE TO MEASURE THE UNIVERSE.



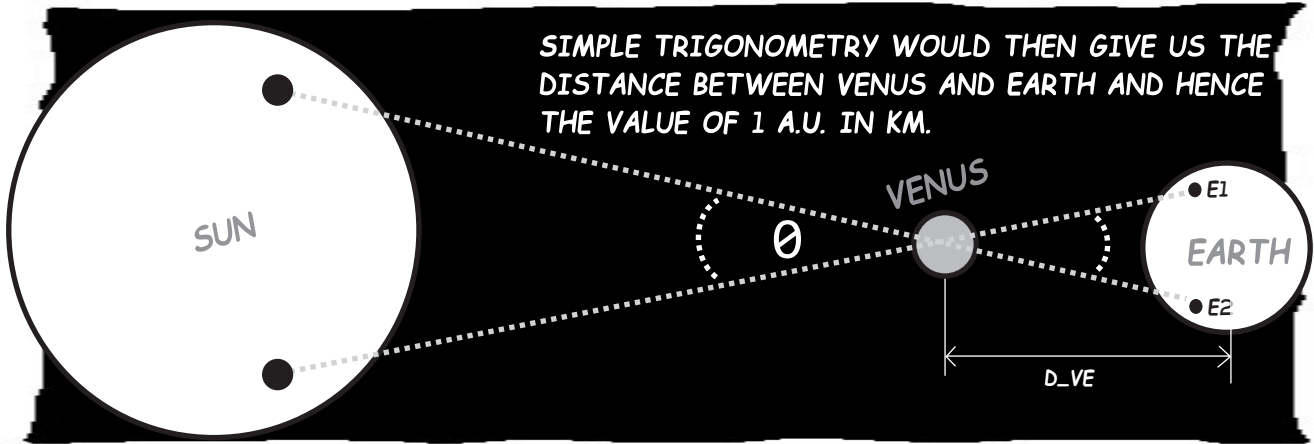
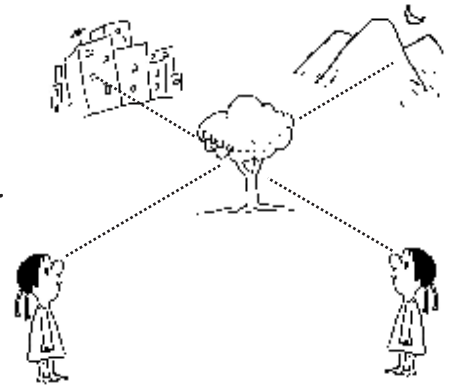
IN FACT, A COUPLE OF CENTURIES LATER, EVEN THE DISTANCES TO THE STARS, AND THE SIZE OF OUR GALAXY WAS TIED TO THE EARTH-SUN DISTANCE -NOW YOU KNOW WHY IT WAS SO IMPORTANT. BY THE MID-1600S, SCIENTISTS ALREADY KNEW THAT...

...THE PLANETS WENT AROUND THE SUN,



PLANETS	DISTANCE FROM THE SUN (A.U.)
MERCURY	0.4
VENUS	0.7
EARTH	1
MARS	1.5
JUPITER	5.2
SATURN	9.5

HALLEY'S IDEA WAS SIMPLE. IMAGINE YOU ARE TRAVELLING BY TRAIN AND YOU NOTICE A NEARBY OBJECT LIKE A HUT OR AN ELECTRIC POLE.. AS THE TRAIN MOVES, YOUR POSITION CHANGES, AND THIS OBJECT APPEARS TO BE IN FRONT OF DIFFERENT PARTS OF THE DISTANT LANDSCAPE. SIMILARLY, ASTRONOMERS SEEING THE TRANSIT FROM TWO DIFFERENT PLACES ON EARTH WOULD SEE VENUS AGAINST DIFFERENT PARTS OF THE SUN'S DISK. HALLEY WANTED ALL THESE ASTRONOMERS TO NOTE DOWN, AT THE SAME TIME, WHERE ON THE SUN'S DISK THEY SAW VENUS.



SIMPLE TRIGONOMETRY WOULD THEN GIVE US THE DISTANCE BETWEEN VENUS AND EARTH AND HENCE THE VALUE OF 1 A.U. IN KM.

WE CAN MEASURE THIS TOO !!

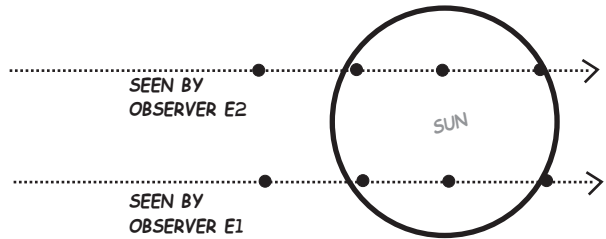
DISTANCE BETWEEN E1 AND E2 ON EARTH

DISTANCE BETWEEN VENUS AND EARTH D_{VE}

$\theta =$

WE MEASURE THIS !

THE ANGULAR DISTANCE BETWEEN THE POSITION OF VENUS ON THE SUN AS SEEN FROM E1 AND E2 AT THE SAME TIME



WE CAN NOW COMPUTE THIS.

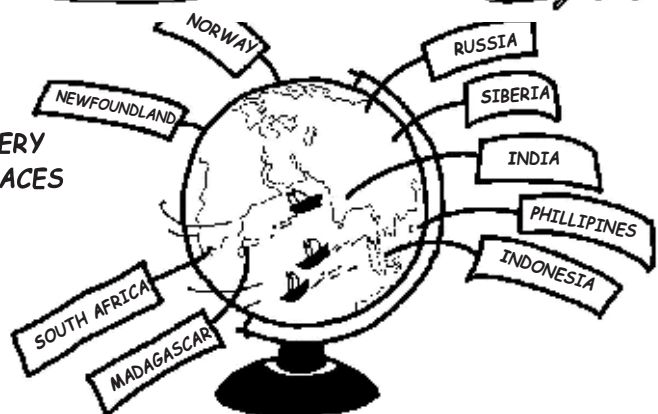
$$\text{EARTH-SUN DISTANCE} = \frac{(\text{EARTH-SUN}) / (\text{EARTH-VENUS})}{3.4} \times \text{EARTH/VENUS}$$

MAKING MEASUREMENTS AT THE EXACT SAME TIME, FROM DIFFERENT PARTS OF THE EARTH, WAS INCREDIBLY DIFFICULT 300 YEARS AGO. HENCE HE ALSO THOUGHT OF ANOTHER CLEVER METHOD WHICH DIDN'T NEED THEM ALL TO OBSERVE THE TRANSIT SIMULTANEOUSLY . HOWEVER, ALL THESE METHODS NEEDED TIMING OF THE TRANSIT TO BE MADE WITH AN ACCURACY OF A SECOND.



MEASURING THE TRANSIT WAS DIFFICULT FOR OTHER REASONS TOO - THEY OCCUR IN PAIRS, EVERY 110 YEARS OR SO, AND EACH PAIR OCCURS EVERY 8 YEARS. THEY ALSO NEED NOT BE VISIBLE FROM PLACES WHICH WERE EASILY ACCESSIBLE IN THOSE DAYS. AFTER HALLEY'S ANNOUNCEMENT,

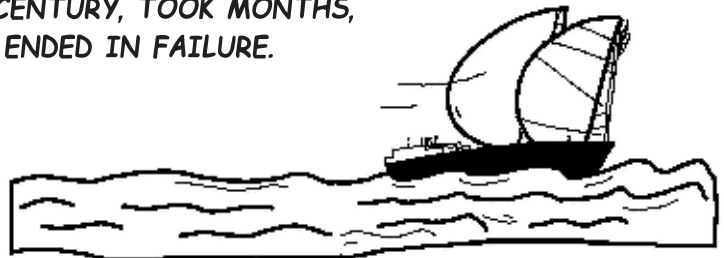
IT WAS KNOWN THAT FUTURE TRANSITS WOULD OCCUR IN 1761, 1769, 1874, 1882, 2004 AND, OF COURSE JUNE 6TH 2012.



FOR EVERY ONE OF THE FIRST FOUR TRANSITS, MANY COUNTRIES - PRIMARILY ENGLAND, FRANCE, UNITED STATES AND RUSSIA - MOUNTED HUGE EXPEDITIONS.



SCIENTISTS WENT TO MANY COUNTRIES. THESE VOYAGES, ESPECIALLY IN THE 18TH CENTURY, TOOK MONTHS, AND MANY ENDED IN FAILURE.



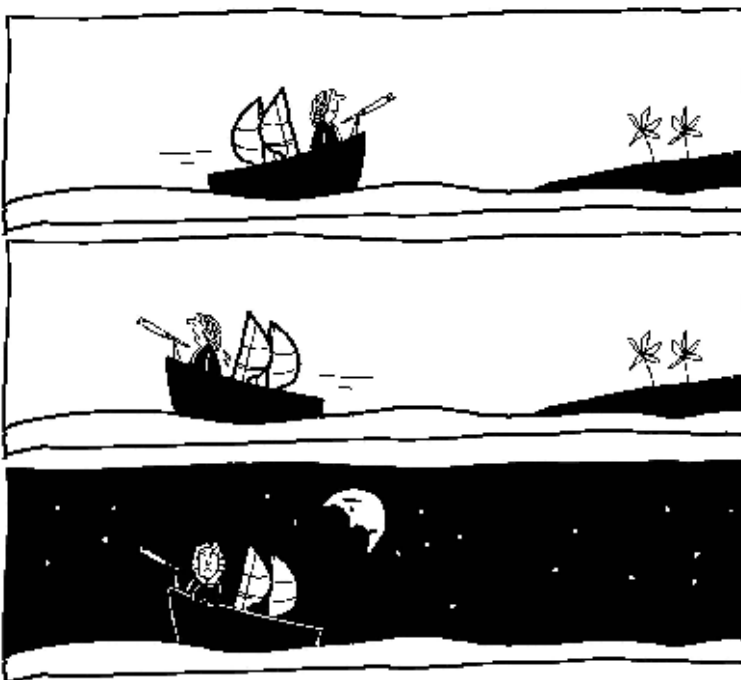
FOR INSTANCE, WHEN THE ENGLISHMEN MASON AND DIXON, SAILED TO SUMATRA IN 1761, THE FRENCH KILLED ELEVEN OF THEIR SHIPMATES.....



..... AND HAD ALSO CAPTURED SUMATRA BEFORE THEY COULD REACH IT.

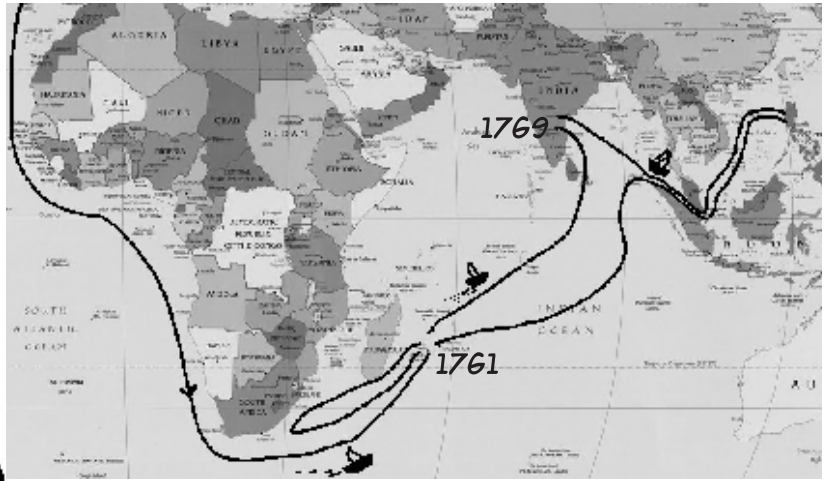
THE MOST TRAGIC STORY, IS OF GUILLAME JOSEPH HYACINTH JEAN-BAPTISTE LE GENTIL DE LA GALAISIERE (YES, THATS JUST ONE GUY!), A FRENCH ASTRONOMER.

HE SET SAIL FOR PONDICHERRY TO MEASURE THE 1761 TRANSIT. BEFORE HE COULD ARRIVE IN INDIA, HE LEARNT THAT THE BRITISH HAD CAPTURED THE CITY.....

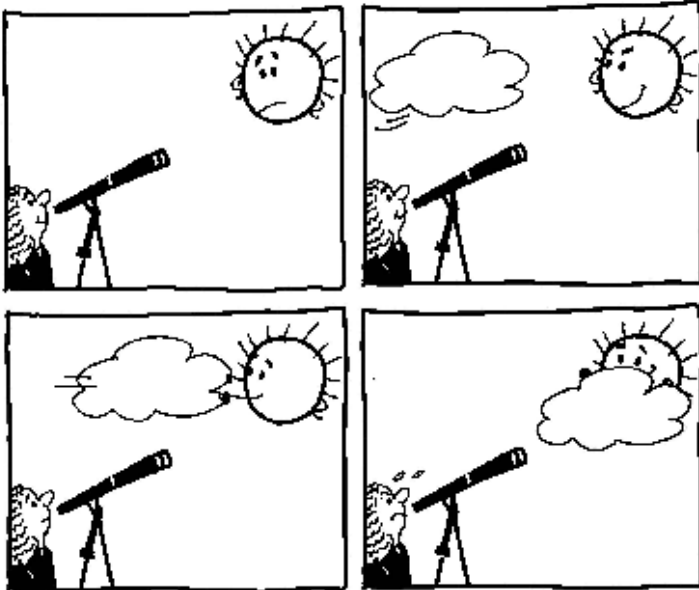


...DURING THE TRANSIT ITSELF, HE WAS STUCK ON HIS SHIP IN THE MIDDLE OF THE INDIAN OCEAN. HE COULDN'T REALLY MEASURE ANYTHING PROPERLY FROM A SHIP BOUNCING ON TOP OF THE WAVES ! HE WAS A STUBBORN AND DEDICATED MAN, AND HENCE DECIDED TO JUST WAIT AROUND THE INDIAN OCEAN TILL THE NEXT TRANSIT IN 1769 - HE HAD A GOOD TIME SAILING TO VARIOUS ISLANDS.....

THEN HE STARTED TOWARDS PHILLIPINES. THE SPANISH, HOWEVER, WERE IN CONTROL IN PHILLIPINES BY THEN, AND SENT HIM BACK. SO OFF HE WENT TO PONDICHERRY.



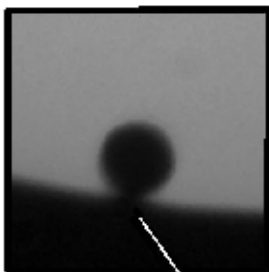
HE ARRIVED IN TIME FOR THE TRANSIT, BUILT A SMALL OBSERVATORY, SET UP HIS TELESCOPE AND HIS CLOCK AND WAITED. ON THE DAY OF THE TRANSIT, THOUGH, THE SKY WAS CLOUDY!



HAVING WASTED 11 YEARS OF HIS LIFE, HE WENT BACK HOME TO FRANCE, WHERE HE DISCOVERED THAT HE HAD BEEN LEGALLY DECLARED DEAD, HIS WIFE HAD REMARRIED AND HIS RELATIVES HAD ENTHUSIASTICALLY PLUNDERED ALL HIS PROPERTY ! BEING AN ASTRONOMER IN THOSE DAYS WAS SOMETIMES FRUSTRATING.

OTHERS, HOWEVER, HAD MORE LUCK. COMBINING ALL THE AVAILABLE OBSERVATIONS IN 1761 AND 1769, THE EARTH-SUN DISTANCE WAS CALCULATED TO BE 153 +/- 1 MILLION KMS - A FAST AIRPLANE, TRAVELLING AT 1000 KM/HR, WOULD TAKE 17 YEARS TO REACH THE SUN ! HOWEVER, THIS ESTIMATE WAS STILL NOT ACCURATE ENOUGH.

THE CAUSE OF SUCH A LARGE UNCERTAINTY WAS A STRANGE PHENOMENON. ASTRONOMERS NEEDED TO TIME THE EXACT MOMENT THE DISK OF VENUS TOUCHED THE DISK OF THE SUN.



HOWEVER, THEY DISCOVERED THAT WHEN THE TWO DISKS ALMOST EXACTLY TOUCHED, A BLACK EXTENSION WOULD APPEAR, WHICH WOULD TAKE A MINUTE TO GO AWAY - HENCE, THEIR TIMINGS WERE ACCURATE TO ONLY A MINUTE, RATHER THAN A SECOND. THIS WAS INCREDIBLY FRUSTRATING.



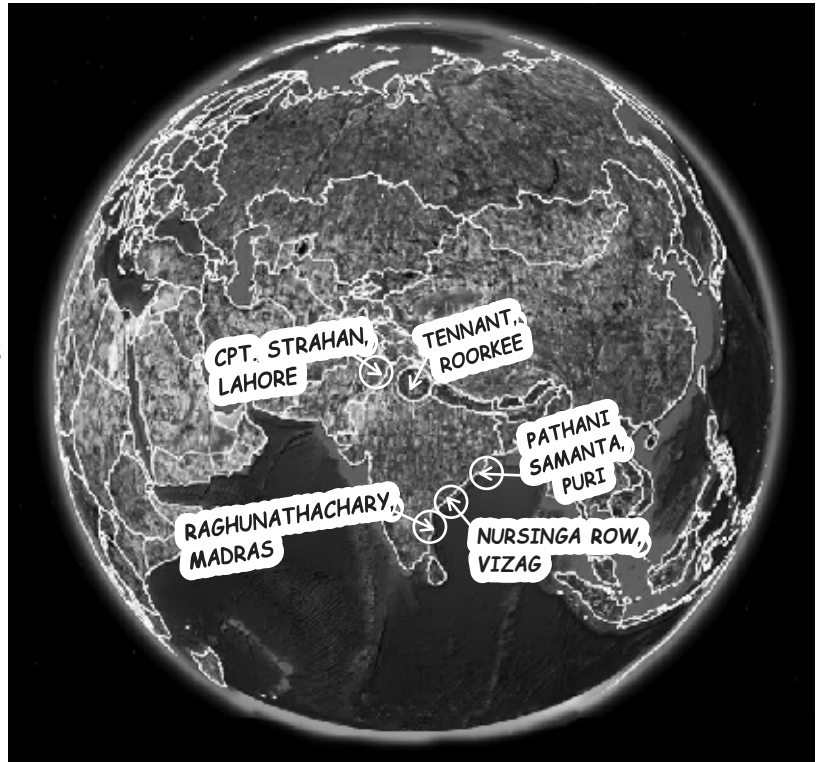


MANY THEORIES WERE ADVANCED TO EXPLAIN THIS 'BLACK DROP EFFECT', BUT IT WAS SATISFACTORILY EXPLAINED ONLY IN 2005 AS DUE TO A COMBINATION OF OPTICAL BLURRING AND THE DARKER LIMB OF THE SUN.

HOLD YOUR FINGERS AGAINST A BRIGHT LIGHT AND BRING THEM CLOSE TOGETHER. JUST BEFORE THEY TOUCH, A BRIDGE SEEMS TO APPEAR, CONNECTING THE TWO FINGERS. THIS IS SIMILAR TO THE BLACK DROP EFFECT DURING VENUS TRANSITS.



THE 1874 TRANSIT WAS EAGERLY AWAITED BY THE NEXT GENERATION OF ASTRONOMERS. THIS LED TO ONE OF THE EARLIEST EXAMPLES OF INTERNATIONAL SCIENTIFIC COLLABORATION. INDIA WAS ONE OF THE PLACES IT COULD BE SEEN FROM, AND THERE WERE A NUMBER OF EUROPEAN ASTRONOMERS WHO DID MEASURE THE TRANSIT TIMES FROM INDIA -



PIETRO TACCHINI FROM ITALY MEASURED IT FROM MUDDAPUR IN BENGAL, JAMES FRANCIS TENNANT FROM ROORKEE, NORMAL POGSON FROM MADRAS OBSERVATORY, AND SO ON.

THERE WERE, NOTABLY, INDIAN ASTRONOMERS WHO MADE MEASUREMENTS INDEPENDENTLY - RAGHUNATHACHARY EVEN WROTE A POPULAR PAMPHLET ABOUT IT FOR THE PEOPLE, AND GOT IT TRANSLATED INTO MANY LANGUAGES.

HISTORICAL ESTIMATES OF 1 AU IN UNITS OF THE RADIUS OF EARTH

300 BC	10000
200 BC	490
180 BC	1210
1635	14000
1639	14000
1659	24000
1672	21700
1771	24000
1895	23440
1909	23420
1941	23466
MODERN	23455

PAMPHLET TRANSLATED IN URDU BY RAGUNATHACHARY



MUDDAPUR OBSERVATORY





FROM THE OBSERVATIONS IN 1874 AND 1882, ASTRONOMERS NOW KNEW THAT THE EARTH WAS 149.59 ± 0.31 MILLION KM AWAY FROM THE SUN.

IN THE LAST 50 YEARS THOUGH, TECHNOLOGY HAS ADVANCED SO MUCH THAT WE NO LONGER NEED THE TRANSIT OF VENUS TO MEASURE THE EARTH-SUN DISTANCE. SCIENTISTS CAN TRANSMIT A STRONG RADAR SIGNAL TOWARDS VENUS, WHICH REFLECTS SOME OF THIS BACK TO US.



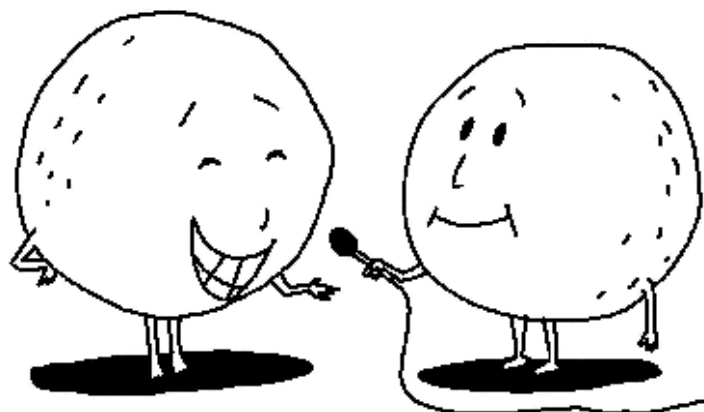
WE THEN MEASURE HOW LONG IT TAKES BEFORE WE RECEIVE THIS BOUNCED-BACK SIGNAL. SINCE WE KNOW THE SPEED OF LIGHT, WE CAN CALCULATE THE EARTH-VENUS DISTANCE FROM WHICH THE EARTH-SUN DISTANCE IS CALCULATED TO BE 149.597870700 MILLION KILOMETERS, WITH AN ACCURACY OF 3 METRES !



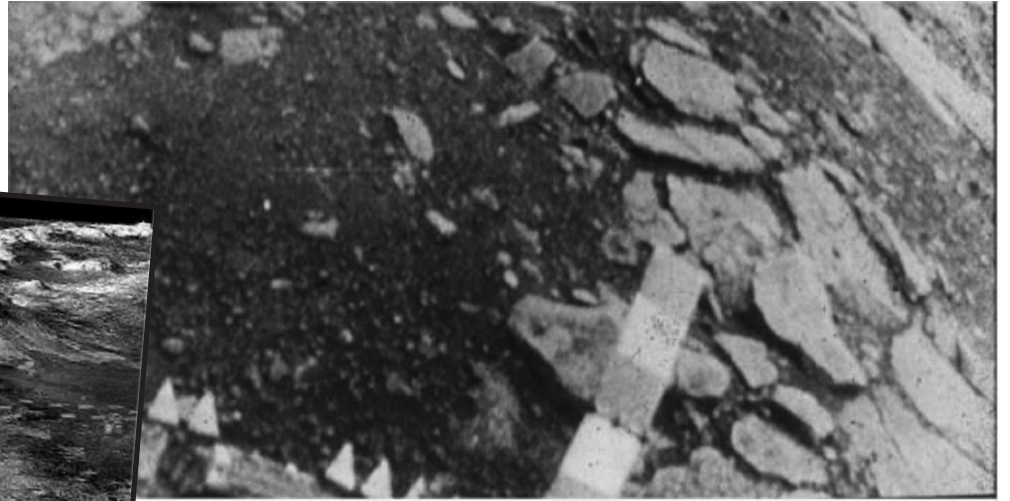
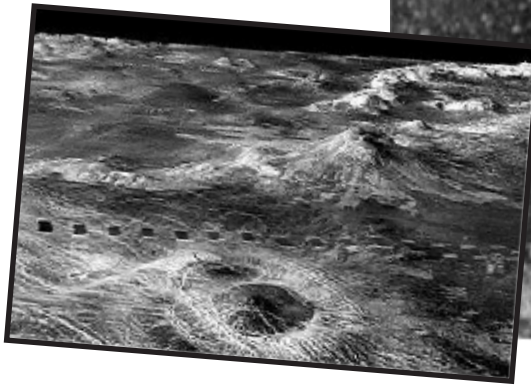
WE HAVE EVEN SENT SPACECRAFTS TO VENUS !!



STARTING IN 1961, THE USA AND USSR SENT A NUMBER OF SPACECRAFTS, THE MARINERS AND THE VENERAS. THESE ORBITED VENUS, AND SOME LANDED ON IT AS WELL.

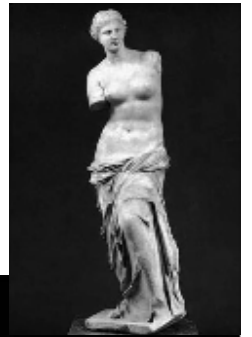


LATELY, EUROPE AND JAPAN HAVE SENT SPACECRAFTS TOO. WE NOW KNOW A LOT ABOUT VENUS - ITS ATMOSPHERE AND WEATHER, ITS TERRAIN, ITS SOIL AND SO ON.

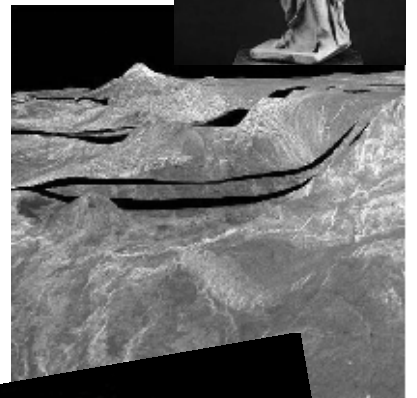


IT WAS NAMED ISHTAR BY THE BABYLONIANS, INANNA BY THE SUMERIANS, TIOUMOUTIRI AND OUAITI BY THE EGYPTIANS, APHRODITE BY THE GREEKS, VENUS BY THE ROMANS, NOH EK BY THE MAYANS, ANAHITA BY THE PERSIANS, BARNUMBIRR BY THE ABORIGINES, AND OF COURSE, SHUKRA BY THE INDIANS.

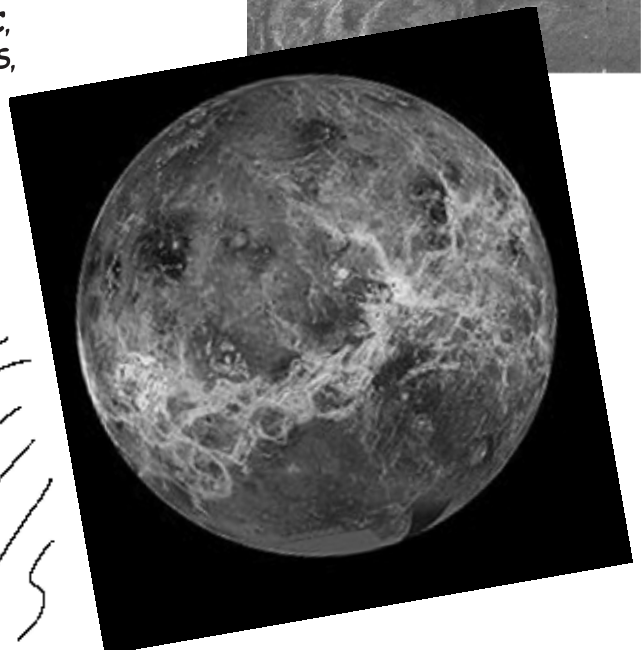
THE PLANET VENUS HAS ALWAYS BEEN PORTRAYED IN MYTHOLOGY AS THE GODDESS OF LOVE, BEAUTY OR PLEASURE.



APHRODITE



VENUS IS AN EXTREMELY HOSTILE PLANET. DUE TO A RUNAWAY GREENHOUSE EFFECT. VENUS HAS SULPHURIC ACID RAINS, TEMPERATURE OF 460 DEGREES C, A NUMBER OF ACTIVE VOLCANOES, 300 KM/H WINDS IN THE UPPER ATMOSPHERE, AND ALMOST CONTINUOUS LIGHTNING. NOT A NICE PLACE TO LIVE IN, FOR SURE !



SHUKRA



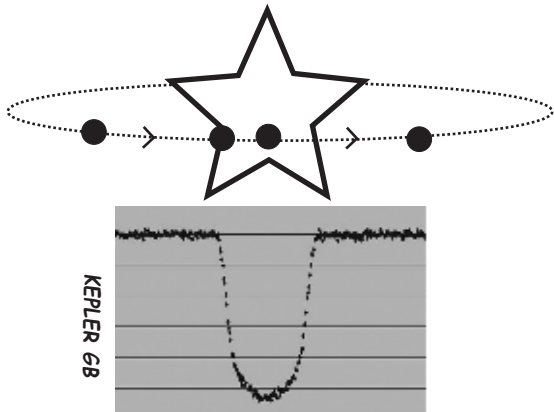


SINCE WE KNOW THE DISTANCES BETWEEN THE PLANETS AND THE SUN SO ACCURATELY THESE DAYS, WHY IS THE 2012 TRANSIT OF VENUS IMPORTANT ?

IT IS A BEAUTIFUL SIGHT. OVER A FEW HOURS, WE CAN ACTUALLY SEE OUR SISTER PLANET MOVE MAJESTICALLY THROUGH SPACE, IN ITS ORBIT AROUND OUR SUN. THE HISTORIC IMPORTANCE OF THE EVENT INVOLVING SO MANY ADVENTURES MAKES IT EVEN MORE INTERESTING. SCIENTISTS, HOWEVER, STILL WANT TO STUDY THE TRANSIT OF VENUS, BUT FOR A COMPLETELY DIFFERENT REASON.



SINCE THE LAST FEW YEARS, WE HAVE DISCOVERED MORE THAN 763 PLANETS GOING AROUND NEARBY STARS.

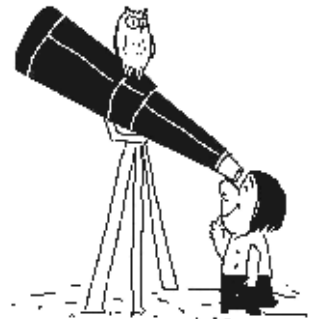


THIS PLANET TOOK 2.5 HRS TO CROSS ITS PARENT STAR

ABOUT 230 OF THESE WERE DISCOVERED BY THE TRANSIT METHOD - THE STAR DIMS SLIGHTLY (BY $< 1\%$) OVER A FEW HOURS WHEN ITS PLANET COMES BETWEEN US AND THE STAR. DETECTING THIS DIMMING IS DIFFICULT AND ASTRONOMERS ARE HOPING TO REFINE THEIR EXPERIMENTS BY STUDYING THE VENUS TRANSIT.

... PRETEND THAT THEY DO NOT KNOW ABOUT THE VENUS TRANSIT, AND TRY AND DETECT VENUS PURELY FROM THEIR DATA.

ON JUNE 6TH, THEY WILL CAREFULLY MEASURE THE LIGHT FROM THE SUN, ...



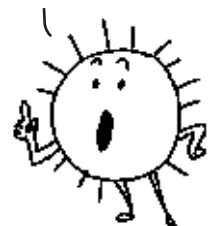
WE HOPE THAT THEY INDEED 'DISCOVER' VENUS ONCE AGAIN !

THE NEXT TRANSIT OF VENUS IS ON JUNE 6TH 2012. UNFORTUNATELY, FROM INDIA, THE SUN RISES ONLY WHEN VENUS IS ALREADY HALFWAY ACROSS THE SUN. STILL, WE WILL HAVE ABOUT 4 FULL HOURS OR OBSERVING TO DO. VENUS WILL BE IN THE MIDDLE OF ITS TRANSIT AT 07:02 AM IST.

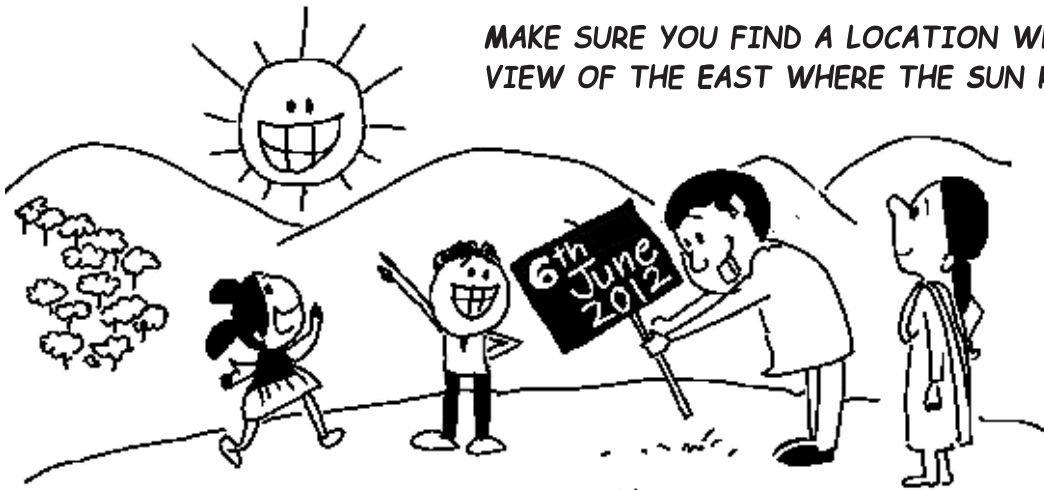
ITS DISK WILL TOUCH THE SUN INTERNALLY AT 10:05 AM

AND WILL BE COMPLETELY OUTSIDE THE SUN'S DISK AT 10:22 AM.

DONT MISS THIS - THE NEXT TRANSIT OF VENUS WILL OCCUR 105 YEARS FROM NOW !



MAKE SURE YOU FIND A LOCATION WHICH HAS A CLEAR VIEW OF THE EAST WHERE THE SUN RISES.



THE SUNRISE TIMINGS ARE
4:30 AM FOR
GUWAHATI,

5:30 AM FOR
NAGPUR,

5:52 AM FOR
VADODARA.

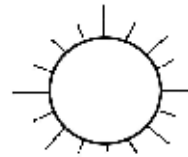
DO NOT STARE AT THE SUN
DIRECTLY, OR LOOK AT THE SUN
WITH ANY KIND OF LENS OR MIRROR..

..YOU WILL PERMANENTLY
DAMAGE YOUR EYES OR
EVEN GO BLIND.



CONTACT YOUR NEAREST
PLANETARIUM, AMATEUR
ASTRONOMY CLUB, OR
COLLEGE TO ASK IF THEY
ARE ORGANISING A SKY
VIEWING SESSION.

YOU CAN SEE THE TRANSIT OF VENUS BY A
VARIETY OF WAYS....



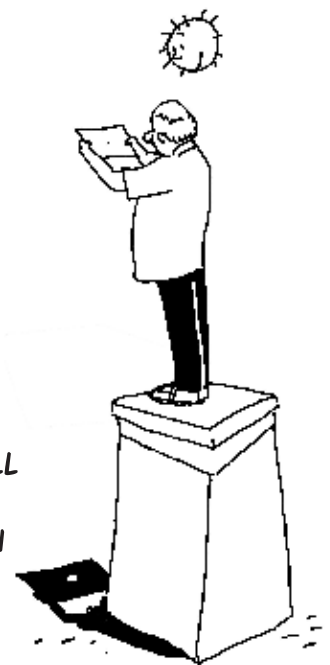
A SAFE WAY TO OBSERVE THE
TRANSIT IS TO PROJECT THE
IMAGE OF THE SUN FROM A
TELESCOPE OF BINOCULARS ONTO
A PIECE OF PAPER AND LOOK AT
THE PAPER. BE CAREFUL NOT TO
EVEN ACCIDENTALLY LOOK AT
THE LIGHT FROM THE TELESCOPE
DIRECTLY.



GET A RELIABLE
SOLAR FILTER
(ASK YOUR
PLANETARIUM
WHERE TO GET
THEM FROM)
TO LOOK THROUGH.



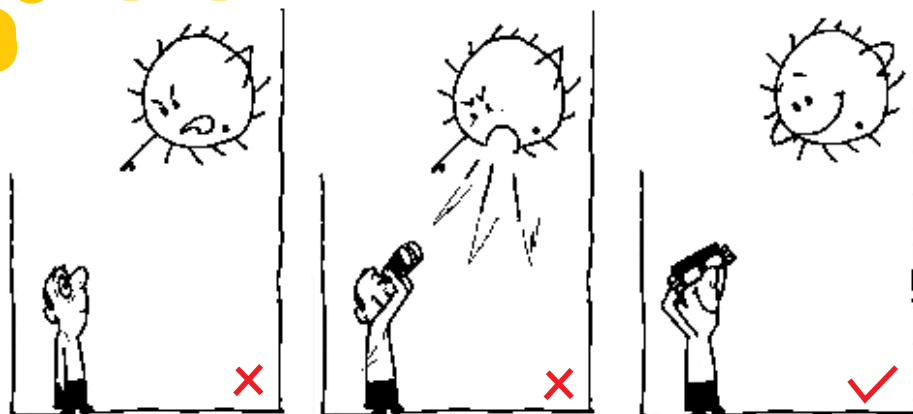
TAKE A PLASTIC BALL, SAY 20 CM BIG
AND CUT A 1 INCH SIZE HOLE IN IT.
POUR IN SOME SAND TO MAKE IT HEAVY.
PLACE A FLAT MIRROR ON THE HOLE AND STICK
IT TO THE BALL USING CELLOTAPE. PLACE THE BALL
ON A CELLOTAPE RING, OR A VESSEL FROM THE
KITCHEN. ADJUST THE BALL TO REFLECT THE SUN
INTO A DARKENED ROOM. FOR A BETTER IMAGE,
HOLD A SHEET OF PAPER WITH A SMALL HOLE
(4-5 MM) IN FRONT OF THE MIRROR.



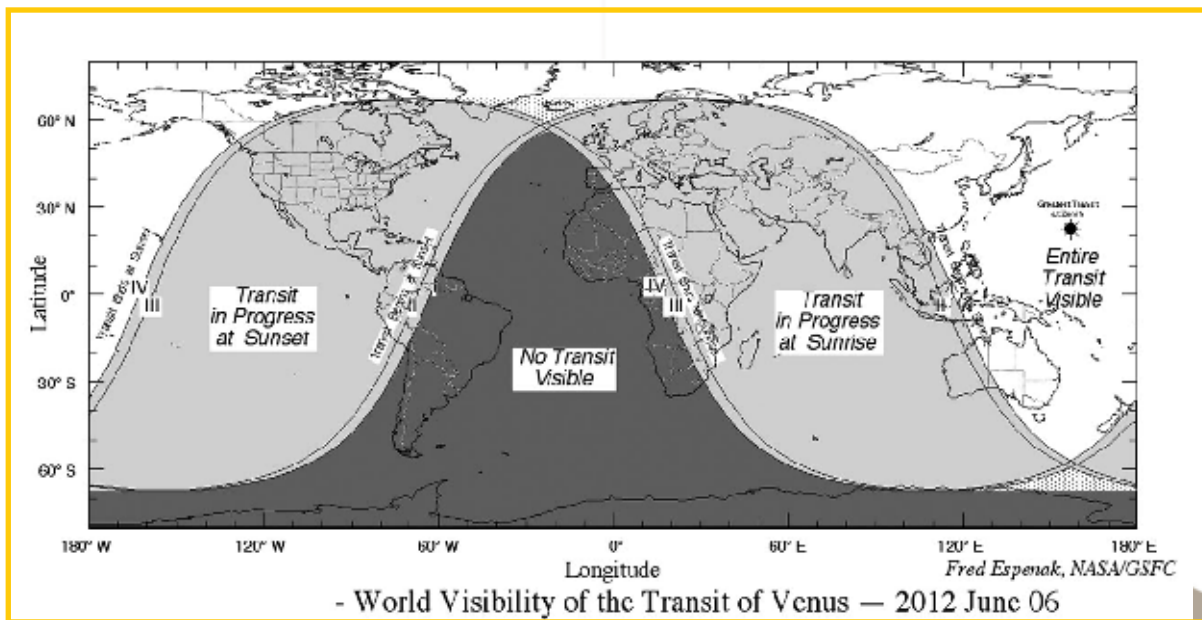
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