



POLITÉCNICA

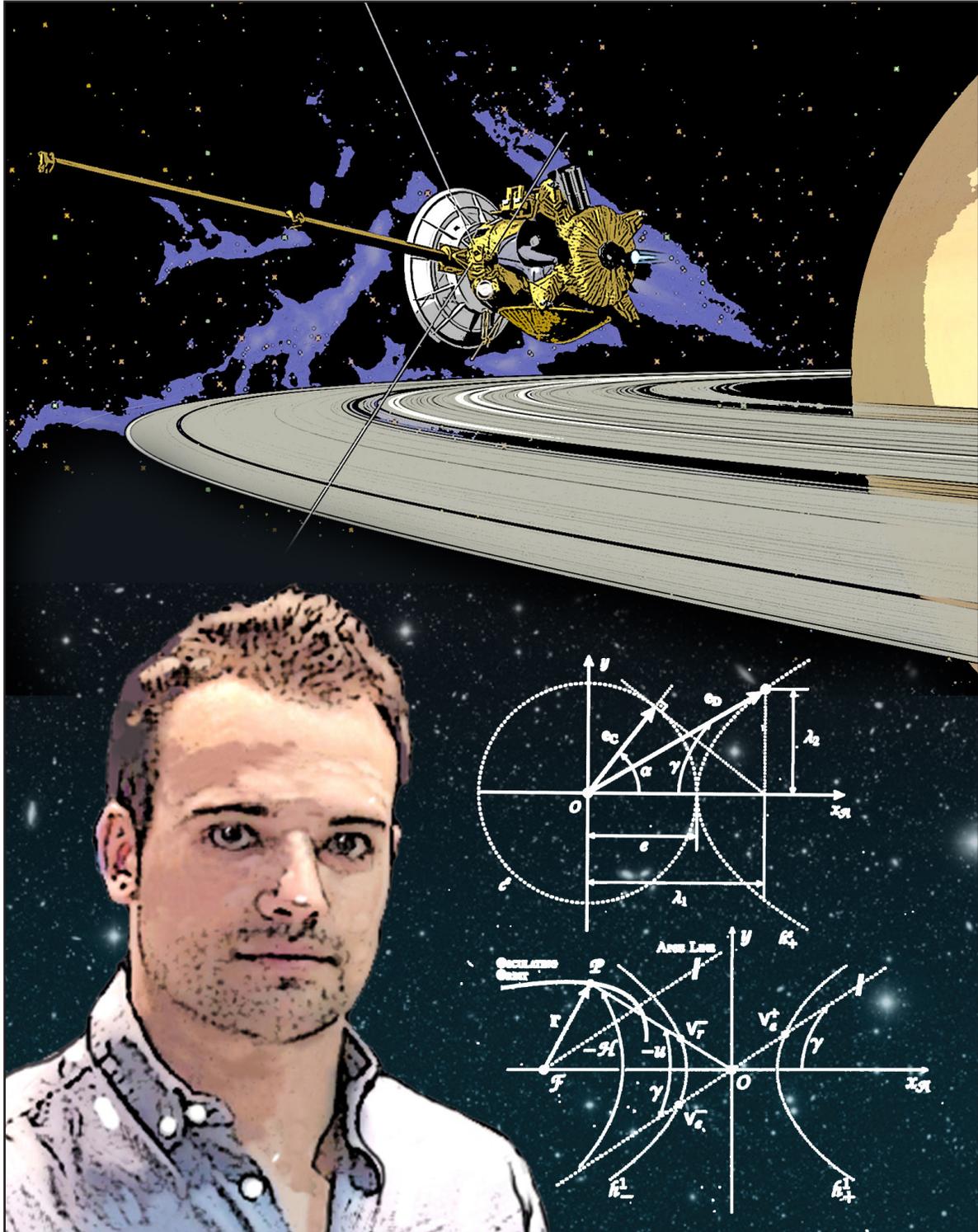
"Engineering the future"

INTERNATIONAL  
CAMPUS OF  
EXCELLENCE

UPMCOMIC  
THE HIGHER EDUCATION ADVENTURE

REAL UPM PROJECTS

12  
2015



# A new method for calculating interplanetary orbits

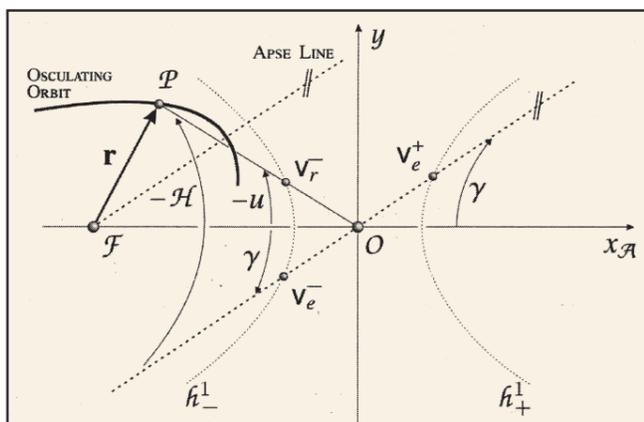
Space Dynamics Group (SDG) - School of Aeronautical and Space Engineering



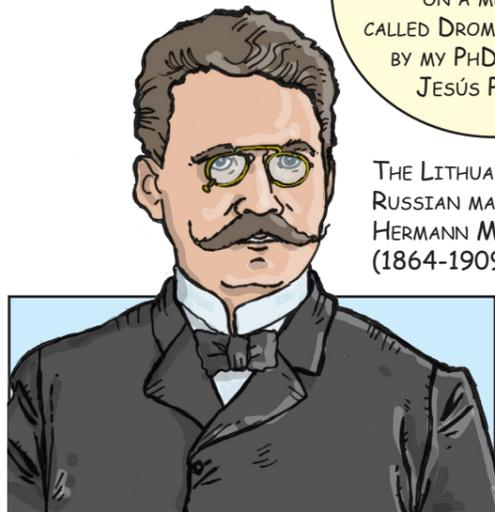
THE JET PROPULSION LABORATORY (JPL) IS THE NASA FIELD CENTRE WHICH PIONEERED TRAJECTORY CALCULATIONS AND IS RESPONSIBLE FOR DESIGNING UNMANNED SOLAR SYSTEM EXPLORATION MISSIONS. THE PASADENA-BASED JPL INVITED 25-YEAR-OLD JAVIER ROA FROM MADRID FOR A FIVE-MONTH STAY. AS A PHD STUDENT ATTACHED TO THE SPACE DYNAMICS GROUP AT THE UPM'S SCHOOL OF AERONAUTICAL AND SPACE ENGINEERING, JAVIER HAD DEVISED A METHOD FOR CALCULATING ORBITS THAT IS CLOSELY RELATED TO RESEARCH BEING DEVELOPED AT JPL.

OUR LINE OF RESEARCH ADDRESSES REGULARIZED FORMULATIONS FOR DESCRIBING ORBITAL MOTION. IN ORDER TO STUDY THE MOTION OF A BODY IN SPACE, WE HAVE TO USE SOFTWARE PROGRAMS THAT, GIVEN A STARTING POSITION AND SPEED, ARE CAPABLE OF PREDICTING WHERE THAT BODY WILL BE WITHIN A SPECIFIED TIME. AS A RESULT, WE REALIZED THAT THE MATHEMATICS USED TO DESCRIBE MINKOWSKI SPACETIME ARE BETTER ABLE TO DESCRIBE THE MOTION OF A SPACECRAFT IN A HYPERBOLIC ORBIT.

WE USED ALL THESE CONCEPTS TO DERIVE NEW FORMULAS BASED ON A METHOD CALLED DROME, DESIGNED BY MY PHD ADVISOR JESÚS PELÁEZ.



DEFINITION OF THE ORBIT ON THE MINKOWSKI PLANE, DRAWN BY THE TEAM TO ILLUSTRATE HOW TO APPLY THE RUSSIAN MATHEMATICIAN'S CONCEPTS TO HYPERBOLIC ORBITS.



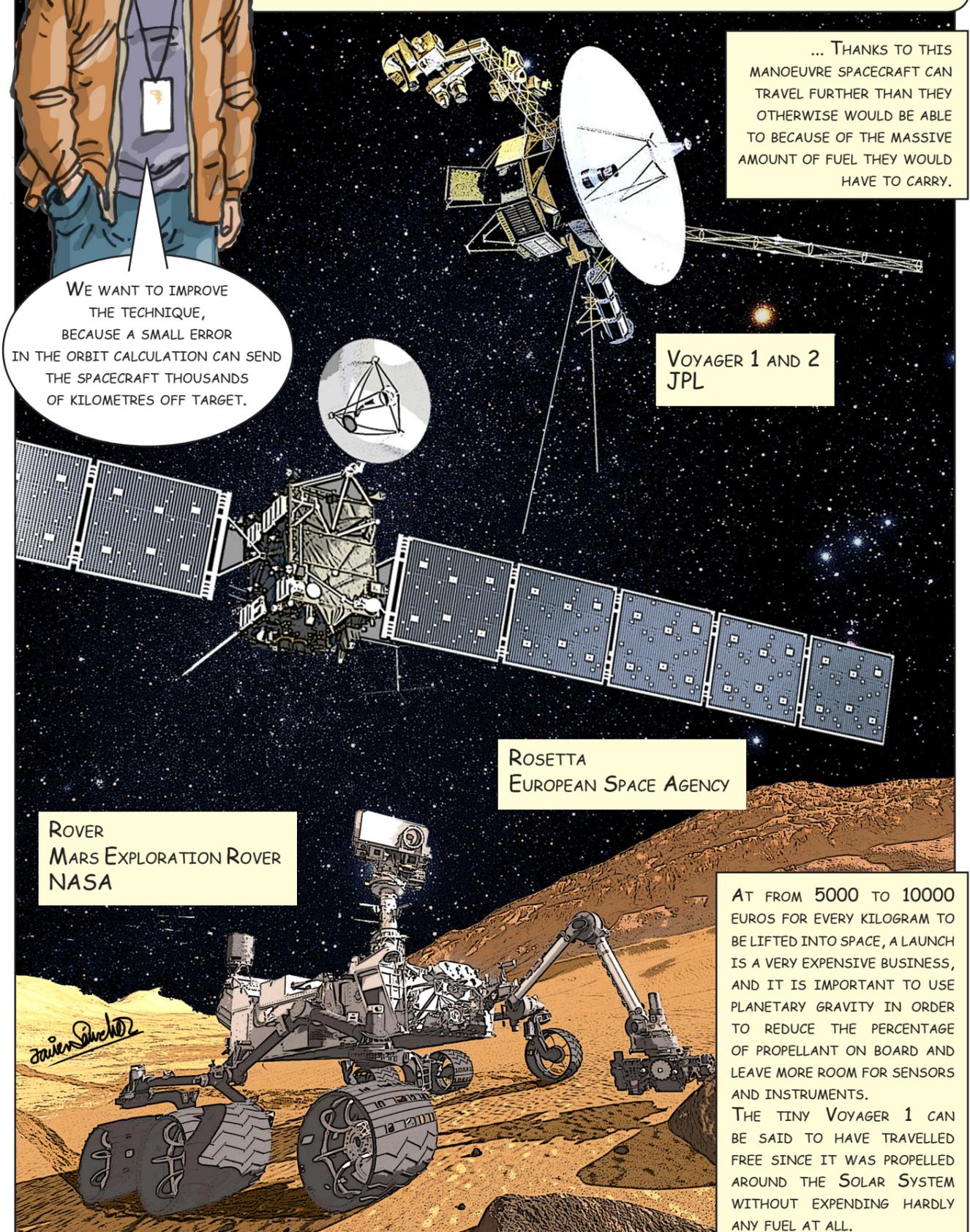
THE LITHUANIAN-BORN RUSSIAN MATHEMATICIAN HERMANN MINKOWSKI (1864-1909).



WE WANT TO IMPROVE THE TECHNIQUE, BECAUSE A SMALL ERROR IN THE ORBIT CALCULATION CAN SEND THE SPACECRAFT THOUSANDS OF KILOMETRES OFF TARGET.

WHEN A SPACECRAFT IS LAUNCHED TOWARDS A FAR-OFF PLANET, IT USES THE GRAVITY OF OTHER PLANETS IN ITS PATH LIKE A CATAPULT TO GAIN PROPULSION AND ACCELERATION. THIS IS KNOWN AS A GRAVITATIONAL ASSIST MANOEUVRE. ALL SPACECRAFT TRAVELLING AROUND THE SOLAR SYSTEM USE GRAVITATIONAL ASSISTS. THE MOST FAMOUS EXAMPLES ARE THE JUPITER AND SATURN FLYBYS BY VOYAGER 1 AND URANUS AND NEPTUNE APPROACHES BY VOYAGER 2, BOTH OF WHICH WERE LAUNCHED BY THE JPL. THE MARS EXPLORATION ROVER MISSIONS ALSO TOOK ADVANTAGE OF THE MOON'S GRAVITY, AND THE VERY LATEST EXAMPLE IS ROSETTA...

... THANKS TO THIS MANOEUVRE SPACECRAFT CAN TRAVEL FURTHER THAN THEY OTHERWISE WOULD BE ABLE TO BECAUSE OF THE MASSIVE AMOUNT OF FUEL THEY WOULD HAVE TO CARRY.



VOYAGER 1 AND 2 JPL

ROSETTA EUROPEAN SPACE AGENCY

ROVER MARS EXPLORATION ROVER NASA

AT FROM 5000 TO 10000 EUROS FOR EVERY KILOGRAM TO BE LIFTED INTO SPACE, A LAUNCH IS A VERY EXPENSIVE BUSINESS, AND IT IS IMPORTANT TO USE PLANETARY GRAVITY IN ORDER TO REDUCE THE PERCENTAGE OF PROPELLANT ON BOARD AND LEAVE MORE ROOM FOR SENSORS AND INSTRUMENTS. THE TINY VOYAGER 1 CAN BE SAID TO HAVE TRAVELLED FREE SINCE IT WAS PROPELLED AROUND THE SOLAR SYSTEM WITHOUT EXPENDING HARDLY ANY FUEL AT ALL.

WHILE ATTENDING A CONGRESS IN THE USA LAST SUMMER, JESÚS PELÁEZ WAS CHATTING TO AN AMERICAN PROFESSOR FRIEND OF HIS. THEY WERE DISCUSSING WHAT THEY WERE EACH WORKING ON WITH THEIR STUDENTS WHEN A MEMBER OF THE JPL JOINED THE CONVERSATION AND THE ISSUE OF THE NEW FORMULAS THAT THEY HAD DEVELOPED CAME UP. FOLLOWING UPON THIS CONVERSATION, THEY PASSED ON A COPY OF THE RESPECTIVE ARTICLE, WHICH AFFORDED THE OPPORTUNITY FOR THE STAY.



JAVIER ROA WAS LATER INVITED TO THE CALIFORNIA-BASED JET PROPULSION LABORATORY WHERE HE WAS TO TRY TO INTRODUCE THE FORMULATION DEVELOPED BY THE UPM TEAM INTO THE ALGORITHMS USED BY NASA. IN VIEW OF THE MAGNIFICENT RESULTS OF JAVIER'S RESEARCH, HE WAS INVITED TO STAY ON IN THE USA UNTIL SEPTEMBER 2016.

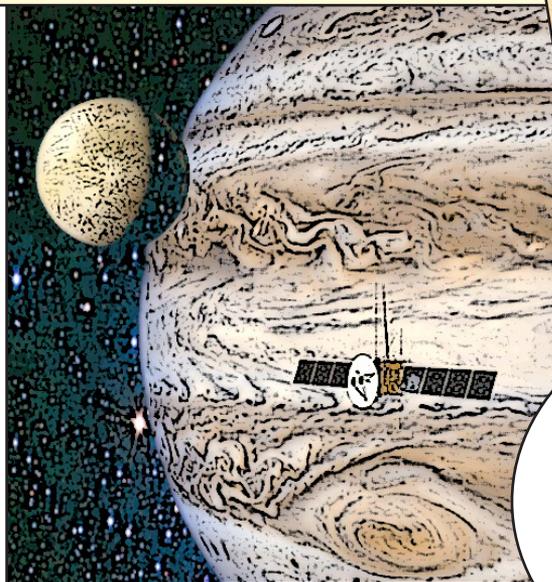


THE ORIGINALITY OF THE METHOD IS THAT IT CALCULATES THE HYPERBOLIC ORBIT DESCRIBED BY A SPACECRAFT AROUND A PLANET. ACCORDINGLY, WE STUDY THE PROBLEM'S GEOMETRY IN ORDER TO DEVELOP A NEW MATHEMATICAL FORMULATION TO IMPROVE ACCURACY. TO DO THIS, WE APPLY THE CONCEPTS OF THE THEORY OF RELATIVITY.

TO MAKE OUR CALCULATIONS, WE TAKE INTO ACCOUNT THE ATTRACTION BETWEEN ALL THE PLANETS IN THE SOLAR SYSTEM, WHETHER OR NOT THE PLANET WE ARE APPROACHING HAS AN ATMOSPHERE, SOLAR RADIATION PRESSURE, OUR POSITION WITH RESPECT TO THE PLANET BECAUSE, NOT BEING PERFECT SPHERES, THE FORCE OF ATTRACTION WILL VARY DEPENDING ON WHERE WE ARE, AND RELATIVISTIC CORRECTIONS.

IN THE FUTURE, JAVIER ROA'S RESEARCH MIGHT BE APPLIED TO MISSIONS LIKE THE EUROPEAN SPACE AGENCY'S JUICE WHICH IS TO EXPLORE JUPITER'S ICY MOONS: CALLISTO, EUROPA AND GANYMEDE. IT IS PLANNED FOR LAUNCH IN 2022 AND ARRIVAL AT JUPITER AROUND 2030. THE SPACECRAFT WILL MAKE 20 CALLISTO AND TWO EUROPA FLYBYS.

DURING HIS STAY IN PASADENA, CA, JAVIER ROA GOT THE CHANCE TO PARTICIPATE IN THE CALTECH SPACE CHALLENGE, A COMPETITION ORGANIZED BY CALIFORNIA INSTITUTE OF TECHNOLOGY, WHICH HE AND HIS OTHER 16 TEAM MATES WON.



GETTING TO KNOW JAVIER HAS TAUGHT ME A WONDERFUL THING: HE REALLY TAKES PLEASURE IN THE DEGREE HE IS STUDYING FOR AND IS TRULY DEVOTED TO THE RESEARCH HE IS DOING. HE SETS A PERFECT EXAMPLE FOR UPM STUDENTS TO FOLLOW IN ORDER ACHIEVE THEIR PRESENT AND FUTURE GOALS.



**SPECIAL PROGRAMME AND GRAPHIC DESIGN SERVICE**  
Script and illustrations: Javier Sánchez

