

Dissertation Topic – Egemen Kolemen

My research objective is to provide the dynamical framework for the next generation of space interferometers. A combination of the need for more resolution and higher contrast is driving the astronomy community to consider multiple satellites forming a space based interferometer. Recently, our group at Princeton, working with colleagues at the University of Colorado, developed a concept for a planet finding mission using a conventional telescope and a distance star shade to block the interfering light from the star. By 2013, the James Webb Space Telescope (JWST) will be placed 1.5 million km away from Earth in the anti-sun direction. In this new approach to planet imaging, we suggest sending a mask satellite in an orbit approximately 50,000 km from this telescope. The mask satellite will fly in the line of sight between the planetary system to be imaged and JWST (or any other high resolution space telescope) and, in simple terms, block the light emitted by the star. Using coronagraphic mask designs developed by our group headed by Prof. N. Jeremy Kasdin, my principal advisor, and Prof. Robert J. Vanderbei in ORFE, the light coming from the planets will be isolated from the light that is emitted by the star, and the faint light coming from the planets will then be observable by the telescope. This approach does not require new telescope design or a great number of satellites; rather, the scientific challenge is moved to the area of precise dynamics and control, which is my dissertation topic.

Three main challenges of this mission will be the focus of my dissertation: trajectory design of the mask satellite, the integration of the spacecraft dynamics to the imaging process, and control of the formation. I will expound on these challenges in the following paragraphs.

Trajectory design is a pivotal challenge since it pertains to the cost and lifetime of the mission. The mission length, and thus the number of planetary systems observed, is directly a function of the amount of fuel on board. Thus, the trajectory of the satellite should be designed to require minimal control effort. Therefore, I first identified all the fuel-free trajectories that satisfy the mission constraints. Instead of using the thrusters, these trajectories employ the gravitational forces applied by the celestial bodies in our solar system to keep the satellite on the desired path. To this end, I developed new numerical algorithms to find the invariant structures around a given orbit in a generic system, and I applied these algorithms to the possible orbits of JWST. I found all the invariant tori and quasi-periodic orbits that keep approximately the same distance to JWST with maximum sky coverage, which gives the option of imaging a greater number of planetary systems. Next, taking into account the positions of the possible planetary systems to be observed, an optimization study will be conducted to select the order and timing of imaging sessions that will make the best use of the fuel-free trajectories.

One of the most interesting and novel aspect of this project is the analysis of the interaction between spacecraft dynamics and the images obtained by the telescope. The light that comes to the telescope is diffracted by the mask satellite, and the planet image is decoded from this diffracted pattern. Analyzing the effect of the dynamics on the diffraction patterns in the image, I will attempt to develop a control algorithm that utilizes this information and find image filtering methods that take the dynamics of the formation into consideration.

Control laws that have been developed for planet imaging missions until present have assumed full-state feedback i.e. knowledge of all the states of the spacecrafts. However, available onboard optical instruments on these spacecrafts do not provide range information, thereby invalidating this assumption. At present, I am developing realistic control laws, in collaboration with Dr. Pini Gurfil at Technion Institute of Technology, that use angle-only measurements. The initial results are promising, and I will be looking into the proof of stability and optimality in due course.