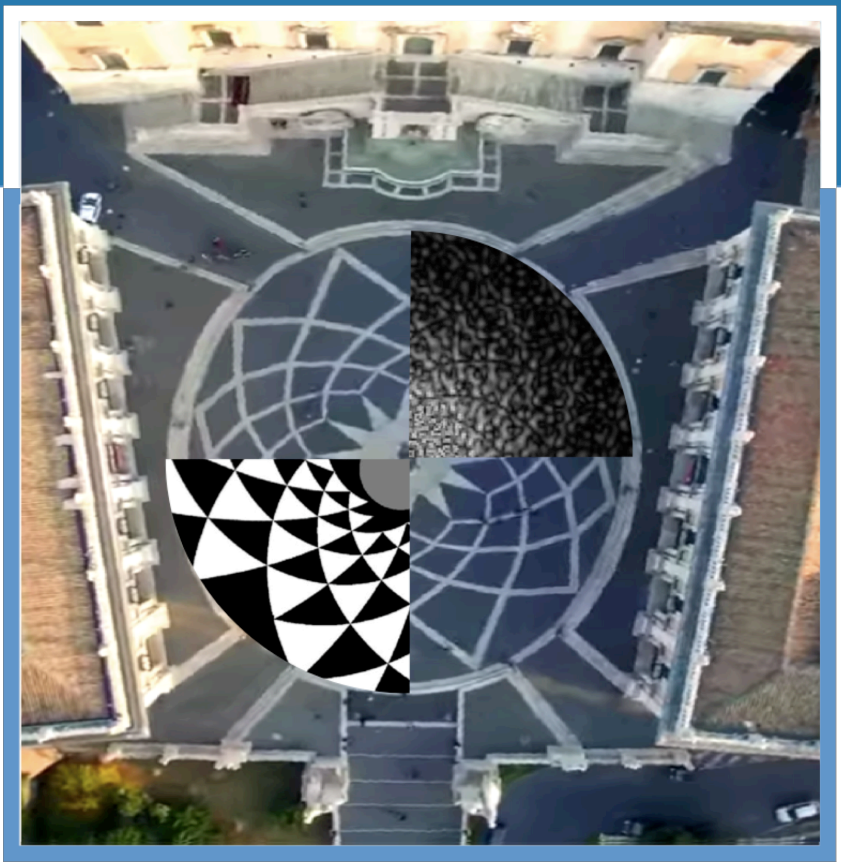

19 – 20 NOVEMBER 18

FINDING EARTH TWINS WITHIN 10PC

A conference devoted to developing the Italian involvement in TOLIMAN

Book of Abstracts

BREAKTHROUGH INITIATIVES

agenzia spaziale italiana

INAF ISTITUTO NAZIONALE DI ASTROFISICA

FRONTIERA

ASI Headquarters I Via del Politecnico snc, Rome I Sala Cassini

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Session 1

1.1 The Breakthrough Initiatives — The Search for Life in the Universe

Autor:
• Pete Worden (Breaktrough Foundation)

On July 20, 2015 Yuri Milner and Stephen Hawking announced the Breakthrough Initiatives at the Royal Society in London. The Initiatives now consist of several hundred million dollars devoted to addressing three big questions: 1) Is there life beyond earth, 2) Can we detect evidence of an extra-terrestrial technological civilization and 3) Is it possible to send a probe to the nearest star systems within the next few decades to study these questions. The Initiatives are dedicated to working closely with space and science agencies around the world. S. Pete Worden is the Executive Director for the Initiatives. In this presentation he will present the current scope and status on them and how the proposed Toliman mission fits within this framework.

1.2 The TOLIMAN space telescope

Autor:
• Peter Tuthill (University of Sidney)

TOLIMAN is a low-cost, agile mission concept dedicated to astrometric detection of exoplanets in the near-solar environment, and particularly targeting the Alpha Cen system. Although successful discovery technologies are now populating exoplanetary catalogs into the thousands, contemporary astronomy is still poorly equipped to answer the basic question of whether there are any rocky planets orbiting any particular star system. Toliman will make a first study of stars within 10 PC of the sun by deploying an innovative optical and signal encoding architecture that leverages the most promising technology to deliver data on this critical stellar sample: high precision astrometric monitoring. Here we present results from the Foundational Mission Study, jointly funded by the Breakthrough Prize Foundation and the University of Sydney which has translated innovative underlying design principles into error budgets and potential spacecraft systems designs.

1.3 Possible mission design

Autor:
• Peter Klupar (Breakthrough Foundation)

NA

Session 2

2.1 Precision astrometry mission for exoplanet detection around binary stars

Autor:
• Eduardo Bendek (NASA Ames)

We propose a relative stellar astrometry mission capable of achieving sub-micro arcsecond astrometry precision, thus revealing potentially habitable planets around a sample of solar-type stars near the sun. For our primary targets Alpha Centauri A & B, objects below one Earth mass will be accessible. This paper describes the optical and mechanical architecture of the mission and first order instrument design. We also explain the trades used to define the instrument stability requirements imposed by the diffractive pupil post-processing calibration capabilities.

2.2 A panoramic view of concepts under discussion for future space astrometry

Autor:
• Alberto Krone-Martins (Universidade de Lisboa - Portugal)

Astrometry stands among the most fundamental and transversal branches of Astronomy, and its developments present far-reaching consequences for Science and the overall human life. With a few notable exceptions, most of high-precision and high-accuracy astrometry is made nowadays from space, reaching the micro-arcsecond levels. This is exclusively the case for the optical wavelengths. In this talk I will comment on the exciting present of space-Astrometry, with the ESA/Gaia mission, discuss a few lessons learnt so far from it, and present a panoramic overview of a few space concepts currently under discussion, as Gaia/NIR, Theia and the JASMINE series, together with some of their challenges.

2.3 NEAT/THEIA/STARE

Autor:
• Celine Boehm (Durham University)

NA

2.4 Gaia-inspired suggestions to TOLIMAN

Autors:
- *Mario Gai (INAF - Astrophysical Observatory of Turin)*
- *Alberto Riva (INAF - Astrophysical Observatory of Turin)*
- *Deborah Busonero (INAF - Astrophysical Observatory of Turin)*
- *Carlo Paolo Sasso (INRIM)*
- *Giovanni Mana (INRIM)*

Based on the lessons learned from Gaia and other studies, we review the TOLIMAN science requirements and proposed implementations, identifying potential contributions to the project.

Among the areas of interest, we list:
- Forward analysis on instrument and operation design;
- Calibration, data reduction and analysis packages;
- Metrology aspects analysis and possible solutions.

We also propose alternative experimental options, which may be evaluated in the evolution of the current measurement and instrument concept.

Session 3

3.1 Stellar magnetic activity and how it can limit astrometry

Autor:
- *Antonino F. LANZA (INAF - Astrophysical Observatory of Catania)*

Magnetic fields in the atmospheres of late-type stars produce brightness inhomogeneities such as dark spots and bright faculae that can affect the astrometric measurements in the case of the closest targets. The expected periodicities of the perturbations are at the stellar rotation period and its harmonics. Using the Sun as a template for magnetic activity and some simulations, I briefly review these effects and discuss the ways we can follow to reduce their impact in the astrometric detection of planets around close stars.

3.2 Detection and characterization of giant planets combining astrometry, radial velocities and transits: the GAIA potential

Autors:
- *Paolo Giacobbe (INAF - Astrophysical Observatory of Turin)*
- *Alessandro Sozzetti (INAF - Astrophysical Observatory of Turin)*

The global impact of Gaia micro-arcsecond level astrometric measurements in the astrophysics of planetary systems has been addressed in the past (e.g. Sozzetti 2011). However, those studies only provided general metrics for gauging detectability thresholds. We revisit the topics of planet detection and characterization with Gaia focusing on the sample of nearby low-mass stars.
The main thrust of this work is three-fold.

First, we gauge the Gaia potential precision astrometry of exoplanets orbiting an actual sample of thousands of known dM stars. We then express Gaia sensitivity thresholds as a function of system parameters and in view of the latest mission profile.
The analysis of the simulations results will also provide insight into the capability of high precision astrometry to reconstruct the underlying orbital element distributions and occurrence rates of the planetary companions. These results will help in evaluating the expected Gaia recovery rate of actual planet populations around late-type stars.

Second, we investigate some elements of the synergy between the Gaia data on nearby M-dwarfs and other ground-based and space-borne programs for planet detection and characterization, with a particular focus on a) the potential for Gaia to precisely determine the orbital inclination, which might indicate the existence of transiting long period planets; b) the ability of Gaia to accurately predict the ephemerides of (transiting and non-transiting) planets around M stars, and c) its potential to help in the precise determination of the emergent flux, for direct imaging and systematic spectroscopic characterization of their atmospheres with dedicated observatories from the ground and in space.
Third, we test a Hybrid Markov Chain Monte Carlo Differential Evolution approach with the aim of tackling the challenge of combining astrometry and radial velocities of single planetary systems.

3.3 Proxima re-reloaded: updates about our closest stellar neighbour from the analysis of an enlarged radial velocity dataset

Autors:
- Mario Damasso (INAF - Astrophysical Observatory of Turin)
- Fabio Del Sordo (Department of Physics, University of Crete)
- Guillem Anglada-Escud (School of Physics and Astronomy, Queen Mary University of London)

The discovery of a temperate planet around Proxima Centauri (Anglada-Escudé et al. 2016) represented an important breakthrough along the pathway toward the detection of low-mass planets with the radial velocity (RV) technique. Therefore, Proxima represents a benchmark in the quest for exoplanets in the immediate vicinity of our Solar System and, even though Proxima b is not a true Earth-analog, the lessons we are learning from the present investigation have great relevance for the objectives of TOLIMAN.
We present results from an analysis of RV time series of Proxima alternative to that of Anglada-Escudé et al. (discussed in Damasso & Del Sordo 2017) to show the impact of the stellar activity on the detection of low-mass exoplanets in this system and the ways we have now to get rid of it. We also present fresh results obtained by analyzing an enlarged sample of RVs, which includes data collected during 2017 with HARPS by the RedDots campaign, in synergy with contemporary follow-up photometry. Our main goals are the search for additional signals due to possible outer companions to Proxima b, as well as a reliable characterization of the stellar activity contribution to the variability of the radial velocities.

3.4 Climate and radiative properties of a tidally-locked planet around Proxima Centauri

Autors:
- *Luca Giovannelli (University of Rome "Tor Vergata")*
- *Francesco Berrilli (University of Rome "Tor Vergata")*
- *Daniele Galuzzo (University of Rome "Tor Vergata")*

Three dimensional General Circulation Models (GCMs) are at the moment, the best available tools for investigating and predict the properties of the exo-atmospheres of Earth-like planets orbiting nearby stars. As a case study, we investigate the climate of the tidally locked Earth-like planet orbiting around Proxima Centauri via the 3-D GCM PlaSim and the 1-D radiative transfer model uvspec. A planetary preindustrial atmosphere, circular orbit and null axial tilt are assumed. The model output include the atmospheric dynamics, surface temperature and the presence of liquid water, as well as reflective and emission spectra of the planet at high resolution. Our tool can effectively retrieve atmospheric fingerprints of Earth-like planets of nearby systems, giving clues on the habitability of such planets, and has been used to set observational limits with space-born (e.g., JWST) and ground-based telescopes.

3.5 The Breakthrough Watch Initiative: Identifying and Characterizing nearby Habitable Exoplanets

Autor:
- *Olivier Guyon (University of Arizona)*

The Breakthrough Watch (BTW) Initiative goals are to find and characterize nearby habitable planets. BTW's first phase is focused on the Alpha Cen system, which provides unique short-term opportunities with astrometry and thermal imaging. BTW will then expand its search to habitable planets within 5pc. Future large ground-based telescopes (ELT, TMT, GMT) will play a key role in spectroscopic identification of biomarkers. I will, on behalf of the BTW advisory committee, outline the BTW vision and discuss related ongoing technology development efforts and future scientific opportunities.

Session 4

4.1 Push Technogical Development for Exoplanet Search in Italy

Autor:
- *Roberto Ragazzoni (INAF - Astronomical Observatory of Padua)*

NA

4.2 Exoplanets in Italy

Autor:
- *Isabella Pagano (INAF - Astrophysical Observatory of Catania)*

The main scientific projects involving the Italian exoplanets community will be presented with review of specific results and highlight of competences and expertises.
The aim is giving an overview from the current to future space and ground based programs.

4.3 Lessons from the Sun for precision Alpha Centauri astrometry experiments

Autor:
• *Jeff Kuhn (Institute for Astronomy – University of Hawaii)*

From near-Earth orbit satellites, like the Solar Dynamics Observer (SDO) and a generation of orbiting precise bolometric solar observatories, it is possible to deduce the magnitude and form of the stellar astrometric "noise" Alpha Cen A or B may generate in an experiment like Toliboy. Understanding and predicting this signal in the presence of the stellar wobble due to an exoplanet, can provide a calibrator and test of the sensitivity of the astrometry measurements. This talk will describe possible stellar signals and how they might be used to advantage for the Toliboy mission.

4.4 Leonardo electro-optical capabilities for astronomical and exploration missions

Autor:
- *Marco MOLINA (Leonardo SpA)*

Leonardo activities in space instruments development are presented. In particular, focus if given to electro-optical payloads for Earth Observation and Scientific Missions.Cheops and PLATO achievements are presented, with a discussion on the technical and organization challenges.
GAIA success in precise attitude control thanks to micropropulsion Leonardo technology completes the overview of Leonardo capabilities for TOLIMAN mission.

Session 5

5.1 Astrometry in Italy

Autor:
- *Alessandro Sozzetti (INAF - Astrophysical Observatory of Turin)*

I will provide an overview of the Italian contributions to the field of high-precision astrometry, both in terms of technological advances as well as successful astrophysical applications of the technique. I will focus in particular on the important involvement of the Italian community in Gaia, the state-of-the-art machine for space astrometry. I will next briefly discuss the potential for Gaia astrometry to revolutionize several areas of exoplanetary science, and its initial contributions based on the early exploitation of the contents of Gaia Data Release 2. I will conclude by outlining some of the relevant synergy aspects between Gaia and other ongoing and planned programs (both from the ground and in space) that have the detection and characterization of extrasolar planets in their primary science focus and that fit in the landscape of strategic involvements of the Italian astronomical community.

5.2 Recent history and thoughts on Narrow angle astrometry Error sources at the uas level.

Autor:
- *Michael Shao (JPL - NASA)*

NA

5.2 Spacecraft Capability for Astrometry Mission

Autor:
- *Giuseppe SISINNI (EnduroSat)*

NA

5.3 Astrometric Gravitation Probe

Autors:
- *Alberto Riva (INAF - Astrophysical Observatory of Turin)*
- *Mario Gai (INAF - Astrophysical Observatory of Turin)*
- *Deborah Busonero (INAF - Astrophysical Observatory of Turin)*
- *Alberto Vecchiato (INAF - Astrophysical Observatory of Turin)*
- *Federico Landini (INAF - Astrophysical Observatory of Arcetri)*
- *Mario Gilberto Lattanzi (INAF - Astrophysical Observatory of Turin)*
- *Mariateresa Crosta (INAF - Astrophysical Observatory of Turin)*
- *Alessandro Sozzetti (INAF - Astrophysical Observatory of Turin)*
- *Marco Pisani (INRIM)*
- *Agnes Fienga (Cote Azur Observatory)*

The Astrometric Gravitation Probe (AGP) is the concept of a space mission for Fundamental Physics tests in the Solar system, based on high precision differential astrometry, in a modern rendition of the 1919 Dyson-Eddington-Davidson experiment.The key innovation is a space-borne telescope with built-in permanent eclipse provided by a coronagraphic system.The precision goal on the "γ" and "β" parameters of the Parametrised Post-Newtonian formulations of General Relativity and competing models is respectively in the 10−8 and 10−7 range, improving by one or two orders of magnitude with respect to the expectations on current or near future experiments.
The instrument concept is based on multiple field, multiple aperture Fizeau interferometry, observing simultaneously regions close to the Solar limb, embedding coronagraphic techniques, and other fields in opposition to the Sun.

5.4 Hunting Earth-like planets: a long roadmap supported by ThalesAlenia Space

Autors:
- *Andrea Martelli (Thales Alenia Space Italia)*
- *Sergio Mottini (Thales Alenia Space Italia)*

Hunting the planets around stars beyond the Sun has gathered fast growing interest from different science communities. The goal of identifying such small and not bright objects in the universe has been made possible by means of new technology and space missions that are able to bring telescopes and instruments above the earth atmosphere allowing in such a way to observe faint fenomena from which information about the presence and the characteristics celestial bodies orbiting round stars can be deduced. The characterization of such objects is a further step to identify a planet with the environmental conditions that can sustain life.

The observation of these fenomena requires to rely on satellite challenging capabilities designed since the beginning to take into account all the constraints, from the optical to the power, from the cleanliness to the radiation and implementing very accurate pointing, stringent thermal control, mechanical stability,
In the European roadmap for the discovery and characterizations of Planets outside the Solar system, Thales Alenia Space is playing a relevant role in the current missions under development, as well as in the future candidate missions, developing specific solutions and enabling technologies.

Session 6

6.1 Kayser Italia potential contribution to Toliman

Autor:
- *Alessandro Donati (Kayser Italia)*

Kayser Italia is a private Italian medium enterprise whose core business is the development of instruments and equipment for scientific applications in space. Operating with success in the aerospace context for nearly 30 years, Kayser Italia has contributed and played a significant role in the completion of 68 space missions with over 100 payloads, always providing high quality products and services and delivering great levels of performance, leading to scientific, economic and programmatic accomplishments.
The presentation shows the main completed or ongoing projects from which significant contribution in terms of competences, know-how or technology could be handed over to the Toliman mission.

6.2 Italian space optics manufacturing, an industrial perspective

Autor:
- *Giovanni Bianucci (Media Lario)*

For many years, low-thermal expansion glass mirrors have been the preferred architectural choice for most space missions. CHEOPS adopts light-weighted ZERODUR ® mirrors realized by Leonardo (substrate) and Media Lario (figuring and polishing). However, the market is turning towards Aluminium-based optics, which can competitively be scaled in size with high-precision diamond turning and can integrate interface features, thus simplifying system integration. New Aluminium alloys CTE-matched to Nickel based hard coatings or optimized for optical finishing processes respond to the satellite constellations needs. Aluminium remains a competitive proposition also for scientific IR missions at cryogenic operating temperatures, such as ARIEL.

At Media Lario, we’ve responded to these optics manufacturing needs with an industrial mindset, using deterministic and repeatable processes for predictive allocation of resources and facilities. CNC figuring and polishing techniques allow iterative and converging optics finishing processes for aspheric, off-axis and also freeform mirrors. These processes allow high-end finish in an industrial setup that is scalable to volume production with unattended processes.

But it’s the replication paradigm that really enables industrial optics manufacturing processes. Over 25 years, Media Lario has pioneered the manufacturing of high-performance highly-replicable optical components and systems with unique patented processes. Electroforming is an industrial replication technology that Media Lario has adopted for the optics of the renown X-ray observatories Beppo-SAX, XMM-Newton, SWIFT and eROSITA. Media Lario has recently been selected by ESA and CAS for the Chinese mission Einstein Probe. With Repli-formed Optics™ we’ve gone one step further to enable industrial optics manufacturing with 1 mirror-per-day production throughput, or greater, thus responding to high-volume and cost-sensitive applications.

6.3 OHB Italia capabilities for TOLIMAN mission

Autor:
- *Paolo Sarra (OHB Italia SpA)*

OHB Italia S.p.A. is a leading company in Italy in the field of space systems design, development and integration. Satellites for scientific missions and scientific Payloads are part of the core business of the company. The company works in close cooperation with space agencies, research institutes and largeindustrial groups. Consolidated technical expertise at system, instrument and equipment level has been demonstrated in several missions operated in the past and currently under operation or in the development phase.
The TOLIMAN mission can take advantage of the engineering capabilities available at OHB Italia, in particular, but not limited to, in the structural, thermal, optical, mechanical and mechanisms areas. For instance these competences can be effectively implemented for the TOLIMAN space telescope temperature control and thermal stability to limit the impact of various forms of systematic noise.

6.4 Launch Opportunities with VEGA and advanced space propulsion concepts

Autor:
- *Rocco Pellegrini (ASI Italian Space Agency)*

NA

6.5 Technosignatures

Autor:
- *Amedeo Balbi (Dep. of Physics - University of Rome "Tor Vergata")*

Technosignatures are sign or signals that would allow us to infer the existence of technological life elsewhere in the universe. They can be thought of as an extension of the concept of biosignatures: while the latter are the product of metabolism of living organisms, technosignatures are the result of deliberate intervention of a species in its environment. As such, they are a promising target when observing and characterizing habitable exoplanets. In this talk I will give a review of the concept, some possible examples, and prospects for future searches.

Session 7

7.1 Exoplanet occurrences statistics

Autor:
• Ruslan Belikov (NASA Ames Research Center

NA

7.2 EDEN: The Search for Nearby Transiting Earths

Autor:
• Luigi Mancini (Department of Physics, University of Rome 2)

The Exo-Earth Discovery and Exploration Network (EDEN) aims to find habitable planets within fifty lightyears. The EDEN transit survey is utilizing existing 1-2m diameter telescopes to carry out the most sensitive transit survey in the northern hemisphere. Many of the planets discovered by our EDEN transit survey will be ideal for follow-up spectroscopy for atmospheric characterization.

7.3 Monitoring stellar optical centroid variations due to magnetic activity for astrometric detection of exoplanets: Lessons from the Gravity Probe B mission

Autor:
• Svetlana Berdyugina (Leibniz Institut fuer Sonennphysik - KIS, Freiburg, Germany)

NASA/Stanford Gravity Probe B space mission (GP-B, 2004-2005, PI Francis Everett) was designed to verify two predictions of Einstein's general relativity (GR) theory: the geodetic and frame-dragging effects. It was based on measurements of a mean drift of gyroscopes on a polar orbit with respect to the optical centroid of a guide star. Hence, the guide star had to be both optically and radio bright, so that it could be observed with a small optical space telescope and ground-based radio antennas to provide an astrometric reference with respect to distant quasars. These observational constraints narrowed down the choice to a few nearby, luminous, magnetically active red giants –members of RS CVn-type binary systems, out of which IM Peg was finally selected because of its favorable coordinates. The required standard errors of 0.7 and 0.4 mas/year for the two GR effects, respectively, implied that contributions to the IM Peg optical centroid shift due to its magnetic activity must have been determined with the accuracy of 1 to 1/2 R_star. In support of the GP-B mission, I was contracted to undertake a thorough magnetic activity survey of the IM Peg K2 III primary componentto determine its optical centroid shifts due to starspot evolution, using high-resolution spectroscopy and spectropolarimetry (Zeeman- and Doppler Imaging) as well as broad-band photometry and polarimetry. Results of this survey include: first direct detection of the secondary star identified as a Sun-like G2V dwarf, time series of stellar surface maps with starspots, detection of the stellardifferential rotation, strong photometric variability in all bands and marginal polarimetric variability in the blue. Resulting time-series of the optical centroid shifts were found to be systematically smaller than 1/2 R_star. Therefore, the effect of starspots on the GP-B results was excluded.

The experience gained with the GP-B mission and the techniques developed to determine stellar optical centroid of IM Peg can be employed for supporting the TOLIMAN space mission. Time series of high-resolution spectroscopy andspectropolarimery, broad-band photometry and polarimetry can be used to determine spot distribution and evolution and, hence, centroid shifts on Alpha Cen stars. By simulating and analyzing these kinds of data, one can validate observational requirements (spectral resolution, signal-to-noise ratio, frequency of measurements, etc.) and estimate the minimum centroid shift that is possible to determine from such measurements. Even though starspots on Alpha Cen stars are smaller than on IM Peg, the required astrometric accuracy of the TOLIMAN mission of 0.2 micro-arcseconds is three orders of the magnitude smaller than that of the GP-B mission. Therefore, even sunspot-like activity could affect the mission results.

7.4 SHARK-VIS at LBT: pushing the limits of visible AO-assisted imaging for exoplanets

Autor:
• Fernando Pedichini (INAF - Astronomical Observatory of Rome)

Co-autor:
• Fernando Pedichini (Institute for Astronomy University of Hawaii)
• Simone Antoniucci (INAF - OAR)
• Gianluca Li Causi (Istituto Nazionale di Astrofisica (INAF))
• Massimiliano Mattioli (Istituto Nazionale di Astrofisica (INAF))
• Roberto Piazzesi (INAF)
• Marco Stangalini (Istituto Nazionale di Astrofisica (INAF))
• Vincenzo Testa (Istituto Nazionale di Astrofisica (INAF))

SHARK-VIS is the upcoming high-resolution high-contrast optical imager for the LBT, which will see the first light in 2019. This project is led by the INAF OAR ADONI team that since 2014 has begun investigating fast cadence imaging techniques at LBT to assess the performance of the XAO FLAO system. After 4 years of deep investigation and analysis, the team is now leading the construction of this instrument which will deliver the full potential of observing in the visible spectrum, trying to attain a contrast of 1e-6 at 100mas thanks to innovative post processing pipelines. Furthermore will be presented the future improvements envisaging the coupling of SHARK-VIS with a high-resolution IFU and an advanced detector that, according to the current guidelines, should improve the instrument's final performance shortening the gap between us and the detection and characterization of exoplanets in reflected light.

7.5 Recurrence Quantification Analysis as a Post-processing technique in Adaptive Optics High Contrast Imaging

Autor:
- *Marco Stangalini (INAF - Astronomical Observatory of Rome)*

In this presentation we will show results of an analysis aimed at exploring the possibility of using recurrence quantification analysis (RQA) in astronomical high-contrast imaging to statistically discriminate the signal of faint objects from speckle noise. To this end, we tested RQA on a sequence of high frame rate (1 kHz) images acquired with the SHARK-VIS forerunner at the Large Binocular Telescope. Our tests show promising results in terms of detection contrasts at angular separations as small as 50 mas, especially when RQA is applied to a very short sequence of data. These results are discussed in light of possible science applications and with respect to other techniques such as, for example, angular differential imaging and speckle-free imaging.

7.6 Fast-cadence high-contrast imaging: the Speckle-Free ADI (SFADI) method

Autor:
• Gianluca Li Causi (INAF - IAPS)

We present the R&D status of the Speckle-Free Angular Differential Imaging method (SFADI), which we developed for the SHARK-VIS high-contrast imager for the LBT telescope.

The technique bases on the acquisition of kHz frame-rate image sequences, which we combine in post-processing after speckle identification and suppression in each frame. With respect to the standard angular differential imaging (ADI), this method provides a much smoother residual background, especially closer to the star, thus providing higher detection contrast at a given signal-to-noise ratio. In its Speckle-Free Imaging (SFI) version, the method is able to provide high-contrast imaging on extended sources, as well as on very short observation sequences where field rotation is not present.

On sky, this technique reached a contrast of around 10^-5 on a 20 minutes 1ms exposures sequence at the Large Binocular Telescope (LBT) as close as 100 mas around a 5.7th magnitude star. We also developed a custom pipeline structure to process similar huge frame sequences, consisting in millions of frames, in a reasonable computation time.

7.7 The ASI SSDC infrastructure and expertise for exoplanetary sciences

Autor:
• *Angelo Zinzi (SSDC - ASI)*

NA