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ARIELSim - the dedicated time domain simulator for the ARIEL mission.

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Abstract

With the selection of ARIEL for the ESA Cosmic Vision M4 mission a dedicated simulation tool that provides high accuracy time domain simulations of ARIEL observations will be necessary. Among various applications, this tool will provide a complete assessment of astrophysical and instrumental noise sources impacting ARIEL, and permit the verification of ARIEL's performance against requirements at all stages of development. Numerous other applications include the cross-validation of semi-analytical radiometric simulators and detailed studies of the impact of complex noise and systematics such stellar variability from pulsation and granulation, star spots, pointing jitter and detector systematics. By incorporating the time domain, correlated noise and time-dependent systematics can be modeled and their impact assessed. The simulator provides the nucleus for future observational planning, as well as the testing of data reduction pipelines and noise decorrelation and mitigation strategies. We build on the Phase A simulator for ARIEL, ExoSim, to develop ExoSim v2.0, and its dedicated version for this mission, ARIELSim.

1. ExoSim vs ARIELSim

During Phase A, the generic simulator ExoSim [1], was developed and was applied to the successfully to the design phase of the ARIEL mission. In Phase B, we will develop ExoSim v2.0 and a dedicated version for the ARIEL mission, ARIELSim.

ExoSim v2.0 will improve on ExoSim v1.0 with improved astrophysical and instrumental simulations, a future-proof architecture and and will utilize the same ARIEL pipeline that will be developed for the actual ARIEL data products. In ExoSim v2.0 we will address the issue of capturing widely differing time scales of time-dependent processes ranging from high frequency detector 1/f noise, to that of the planet phase curve or long-term thermo-elastic deformations. We will tackle this through a combination of recoding the way the time domain effects are simulated and more sophisticated memory management.

1.1. Astrophysical

We will expand the astrophysical component of the simulator with fully integrated models of stellar and planet time-dependent processes beyond the effects of the planet light curve. These will primary involve integrating stellar pulsation, granulation and spot/faculae models (already developed in Phase A) into ExoSim's astrophysics simulation as options for the user. It may also involve novel astrophysical simulations to assess ARIEL's sensitivity to detect phenomena such as exomoons, planet rotational effects, debris discs etc. The scientific expertise of the ARIEL consortium will be essential for selecting and implementing the required simulated scenarios.

1.2. Instrumental

We intend ARIELSim to be current at all stages of design, development and implementation of the mission, and to give the most accurate assessment of ARIEL's performance at all stages. As such ARIELSim's architecture will be modified to from that in ExoSim v1.0 to make it more 'future-proof'. This involves increased modularity so that as instrument components are developed and their characteristics become known, the model can be updated easily by recoding individual modular elements in isolation. It also involves a shift from complete generic capability to tailor-made modules for each instrument channel, that will capture any idiosyncrasies as they become known. The detector model will be greatly augmented to account for the readout architecture and will incorporate characteristics of the final detectors chosen for the mission, including non-linearlity, cross-talk, persistence etc, as well a model to capture cosmic ray impacts.

The ExoSim team will work in close collaboration with engineers and instrumental scientists to maintain

the most accurate model of ARIEL's integrated optical description, as well as the detector chain (pixel array, ROIC, CFEE and DPU) and all sources of noise and systematics. This will involve descriptions of noise power spectral density (PSD) and correlation matrices provided by other groups.

1.3. Data pipeline

As ExoSim becomes more sophisticated, so does the pipeline that is used to reduce and process ExoSim data products. As a result in Phase B, ARIELSim products will be processed using the working version of the ARIEL data reduction pipeline. ExoSim thus provides a test-bed for this pipeline, as well as for the testing of noise decorrelation and mitigation strategies, and systematics corrections.

2. Summary

ExoSim v2.0 is now under development, and will be the most complete and accurate end-to-end model of transit spectroscopy so far developed. Although dedicated to the ARIEL mission, many of its elements will be appropriate for simulation of transit spectroscopic observations from other platforms and with some modifications, dedicated versions can be produces for other key instruments.

References

[1] Sarkar, S., Papageorgiou, A., and Pascale, E.: Exploring the potential of the ExoSim simulator for transit spectroscopy noise estimation, Proc. SPIE 9904, 99043R.