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POWER SPECTRUM EXTENDED: PRELIMINARY RESULTS

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Abstract. We propose, in the framework of short-exposure high-angular-resolution imaging (Lucky Imaging, speckle techniques), a simple improvement of the original Labeyrie's speckle interferometry technique. This new method, denoted as Power Spectrum Extended, allows to perform direct imaging of extended objects in the case of post-adaptive optics images and/or small diameter telescopes. The algorithm works in the Fourier domain. It combines informations from the average power spectrum of an ensemble of images with phase information estimated from an ad hoc shift-and-add process. It can be used together with a Lucky Imaging selection process. Preliminary results are presented, with application to images of both an astronomical object and an artificial satellite.

Keywords: high angular resolution imaging, speckle techniques, lucky imaging

1 Introduction

Atmospheric turbulence degrades the angular resolution of astronomical images. Labeyrie's speckle technique (Labeyrie 1970) was a first attempt to give a solution, but does not allow direct imaging. A lot of powerful but somewhat cumbersome techniques were developed during the 80's and the 90's (see Aime (2001) for a review).

In the case of small diameter telescopes (indeed small D/r_0) we observed that the high angular resolution information contained in images is present even in the case of long exposure times (several seconds). In particular, the phase of the Fourier transform of long-exposure images is not totally destroyed by the turbulence and can be used for imaging, providing that a tip-tilt correction is applied.

In this communication we present a new technique, denoted as Power Spectrum Extended (PSE), which is quite simple. It combines information from Labeyrie's speckle technique and from the phase of the sum of re-centered short-exposure images. We successfully applied the technique to images of a binary star in the near infrared with a 1-m telescope, as well as to images of the International Space Station in the visible with a 50-cm telescope.

2 Power Spectrum Extended

The PSE algorithm is a combination of a tip-tilt correction (shift and add) and a speckle method (well adapted to post adaptive optics short exposure images and/or small D/r_0). It takes for input a sequence of short exposure (a few milliseconds) images of an astronomical object. With these images we can reconstruct the Fourier transform of the object. The algorithm proceeds in two steps: the first for the modulus of the Fourier transform, and the second for the phase. To compute the modulus, we make use of the Labeyrie's original speckle technique: computation of the ensemble average of the square of the modulus of the Fourier transform of short-exposure frame . For the phase, we apply a shift-and-add processing (Cady & Bates 1980) to individual frames, which is equivalent to compensate from the atmospheric tip-tilt. We then take the phase of the Fourier transform of the resulting image. With the modulus and the phase, we can then reconstruct the objet by applying an inverse Fourier transform.

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3 Preliminary results

We have tested PSE on the double star 16 Vul, observed with the 1-m telescope of the Plateau de Calern C2PU facility (Bendjoya et al. 2012), in H band (1.6 microns), with a very good seeing with respect to the diffraction limit (0.3 ″). This is a double star with a separation of 0.8 ″ and a magnitude difference of 0.4. The reconstruction seems definitely better than a simple shift-and-add reconstruction (see Fig. 1). These data were obtained with an exposure time of 50 ms.

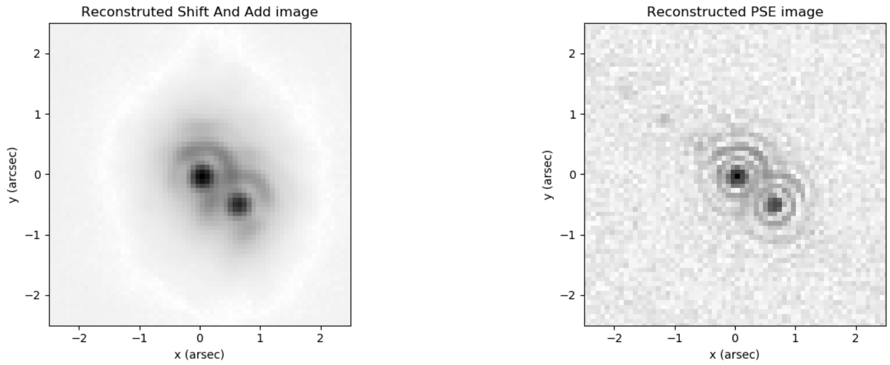

Fig. 1. Left: Shift-and-add reconstruction of 16 Vul. **Right:** PSE reconstruction of 16 Vul.

The PSE technique gives a better resolution than a simple tip-tilt correction, and it still works for an extended object. We tested it on images of the ISS (see Fig. 2), whose angular diameter of 30″ is larger than the isoplanatic angle. These images were taken with a 50-cm telescope at 650 nm (Ariane-Group facility).

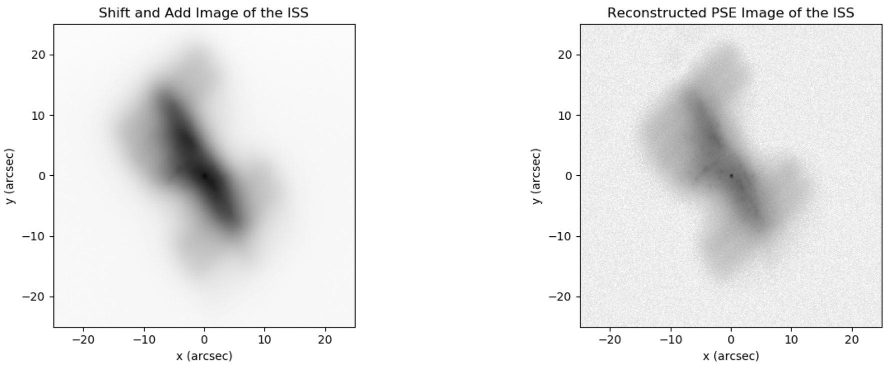

Fig. 2. Left: Shift-and-add reconstruction of the ISS. **Right:** PSE reconstruction of the ISS.

4 Conclusions

This new simple technique seems very promising. It gives better results than a mere tip-tilt compensation for weak turbulence: we tested it successfully with $D/r_0 \sim 10$. It may be combined with a Lucky Imaging process to increase image quality. Further investigations are currently performed in order to quantify the gain and limits of the method, and to compare it with other existing techniques.

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