Strehl-constrained blind deconvolution of post-adaptive optics data & the Software Package AIRY, v. 6.1

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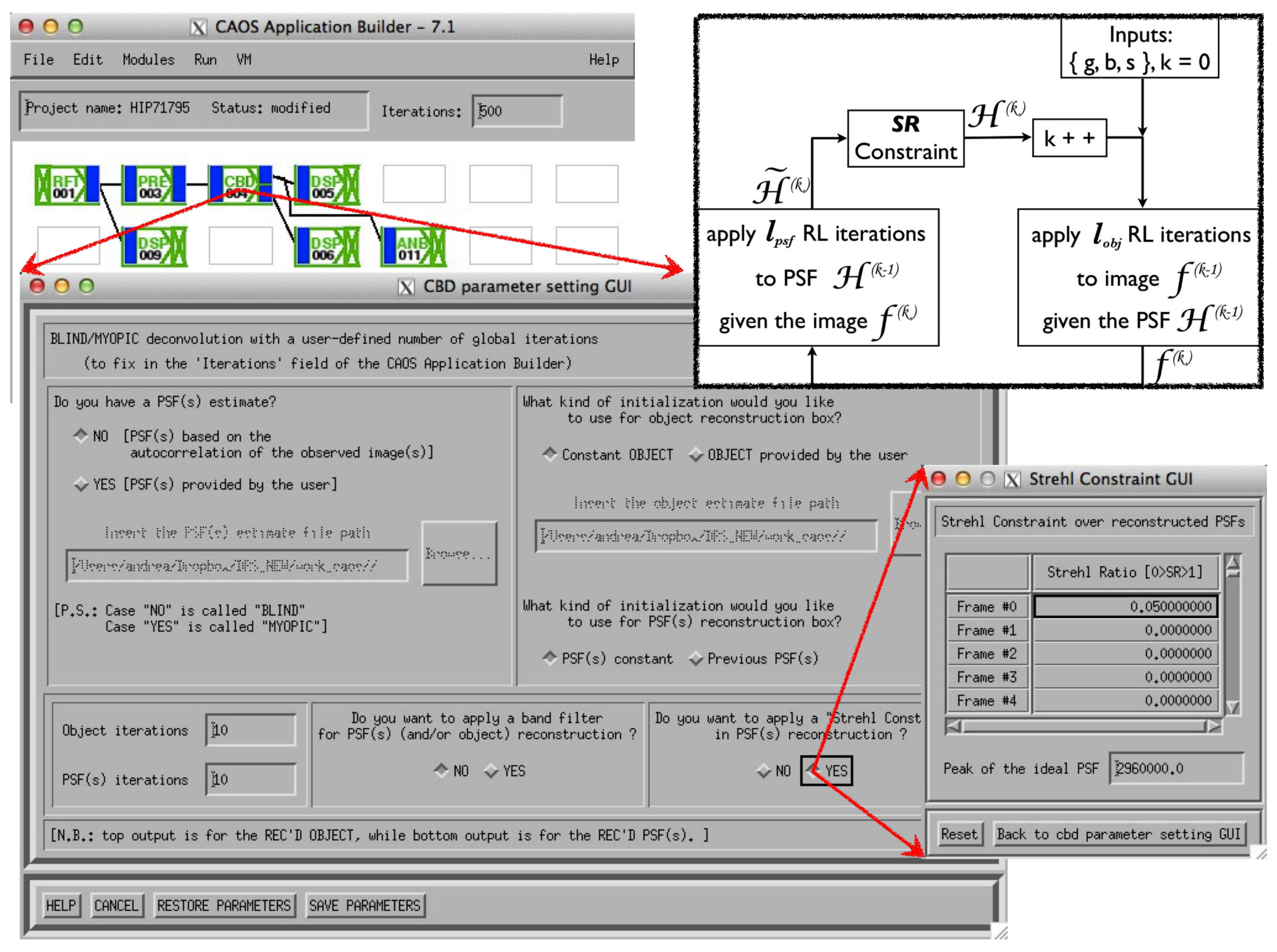
Abstract We first briefly present the last version of the `Software Package AIRY`, version 6.1, a `CAOS`-based tool which includes various deconvolution methods, accelerations, regularizations, super-resolution, boundary effects reduction, PSF extraction/extrapolation, stopping rules, and constraints in the case of iterative blind deconvolution (IBD). Then, we focus on a new formulation of our Strehl-constrained (SC) IBD, here quantitatively compared to the original formulation for simulated data of FLAO/LBT in the near-infrared domain, showing their equivalence. Next, we extend the application of the original method to the visible domain with simulated data of ODISSEE/MéO, testing also the robustness of the method with respect to the Strehl ratio (SR) estimation.

The `Software Package AIRY`, version 6.1

The `Software Package AIRY` [1, 7, 10] is a software tool designed to perform the simulation and/or deconvolution of astronomical images, a priori post-AO ones, and coming from monolythic or even binocular telescopes. It is written in IDL and it is part of the `CAOS Problem Solving Environment` (`CAOS PSE`) [2, 6, 9]. The `Software Package AIRY`, v. 6.1, summarizes 14 years of developments and includes various deconvolution methods (Richardson-Lucy (RL), Ordered Subset - Expectation Maximization (OS-EM), Image Space Reconstruction Algorithm (ISRA), OS-ISRA, Scaled Gradient Projection (SGP) [5]), accelerations (Biggs & Andrews), regularizations (Tikhonov, Laplacian, entropy, edge-preserving, high-dynamic range), special methods (super-resolution, boundary effects reduction, PSF extraction/extrapolation), stopping rules, IBD (including constraints on the SR and the bandpass). The main latest enhancements are the implementation of the SGP method and a new formulation of our method of SCIBD.

The Strehl-constrained blind deconvolution algorithm(s)

Original vs. new formulation



Project name: HIP71795 Status: modified Iterations: 500

BLIND/MYOPIC deconvolution with a user-defined number of global iterations
(to fix in the 'Iterations' field of the CAOS Application Builder)

Do you have a PSF(s) estimate?
◇ NO [PSF(s) based on the autocorrelation of the observed image(s)]
◇ YES [PSF(s) provided by the user]
Insert the PSF(s) estimate file path
/Users/andrea/Dropbox/IDL_NEW/work_caos//
[P.S.: Case "NO" is called "BLIND"
Case "YES" is called "MYOPIC"]

What kind of initialization would you like to use for object reconstruction box?
◇ Constant OBJECT ◇ OBJECT provided by the user
Insert the object estimate file path
/Users/andrea/Dropbox/IDL_NEW/work_caos//

What kind of initialization would you like to use for PSF(s) reconstruction box?
◇ PSF(s) constant ◇ Previous PSF(s)

Object iterations 10
PSF(s) iterations 10

Do you want to apply a band filter for PSF(s) (and/or object) reconstruction ? ◇ NO ◇ YES

Do you want to apply a Strehl Const in PSF(s) reconstruction ? ◇ NO ◆ YES

[N.B.: top output is for the REC'D OBJECT, while bottom output is for the REC'D PSF(s).]

Strehl Constraint over reconstructed PSFs

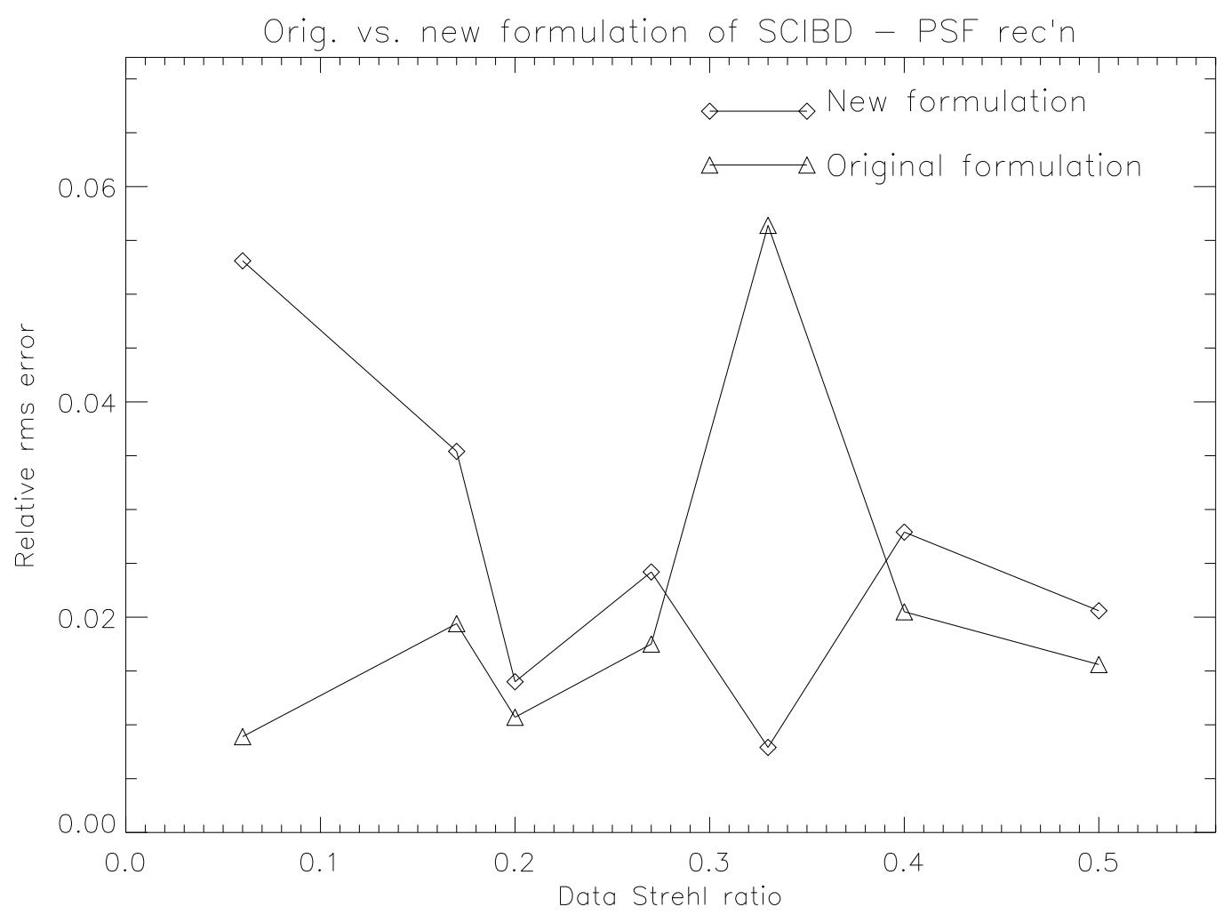
	Strehl Ratio [0>SR>1]
Frame #0	0.050000000
Frame #1	0.0000000
Frame #2	0.0000000
Frame #3	0.0000000
Frame #4	0.0000000

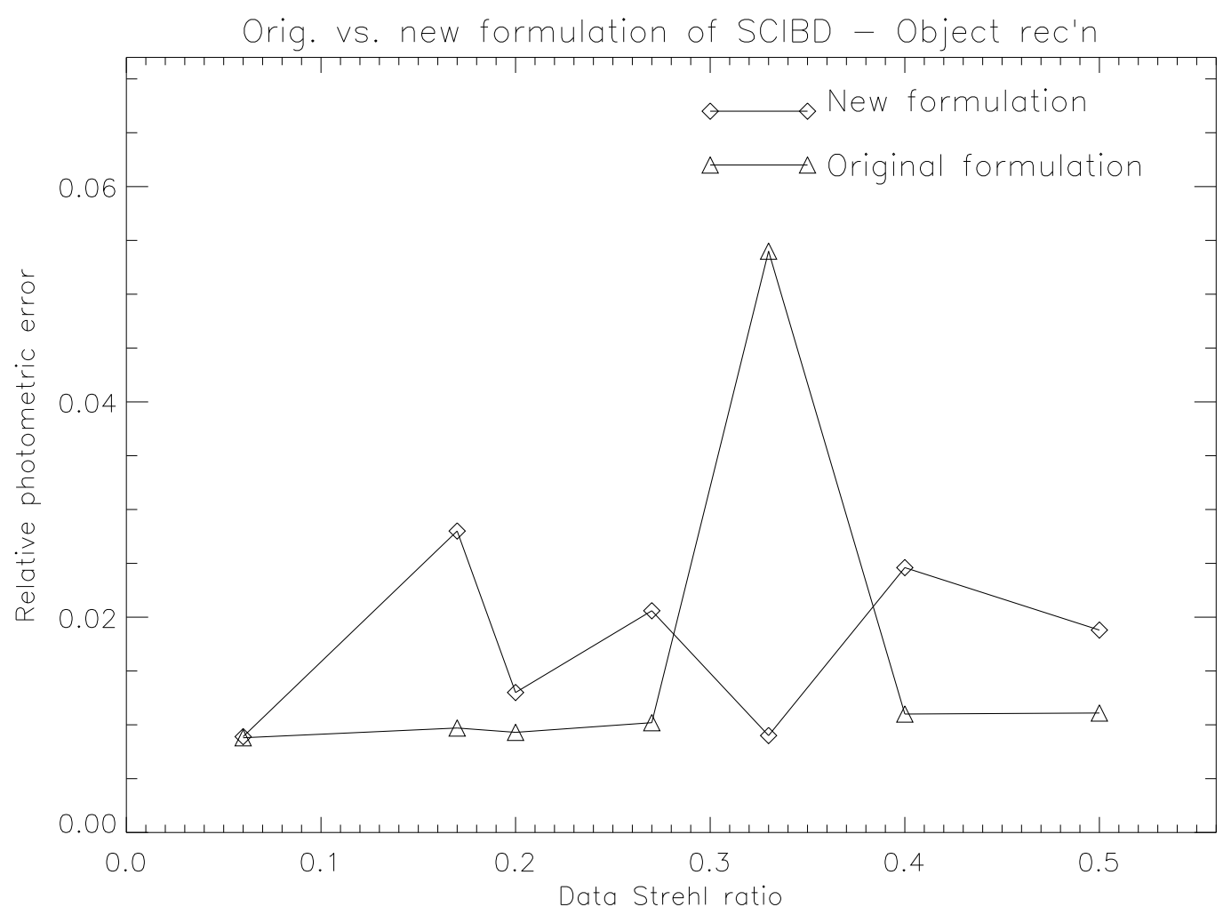
Peak of the ideal PSF 2960000.0

The original SCIBD algorithm, proposed by Desiderà & Carbillet [4], consists in constraining the SR of the reconstructed PSF, by slightly blurring the latter at the exit of the PSF reconstruction box and at each global iteration of the algorithm (see block diagram), with a small Gaussian untill its SR lowers down to the estimated data SR.

The new formulation [8] includes the Strehl constraint within the PSF box by substituting the RL algorithm with SGP, whose iterates automatically satisfy all the constraints (SR, non-negativity and normalization) thanks to the projection performed within the descent direction. The same substitution is also performed in the image box, imposing non-negativity and flux conservation within the inner SGP iterations themselves. The presence of an adaptive steplength parameter could also allow to speed-up the convergence of the algorithm.

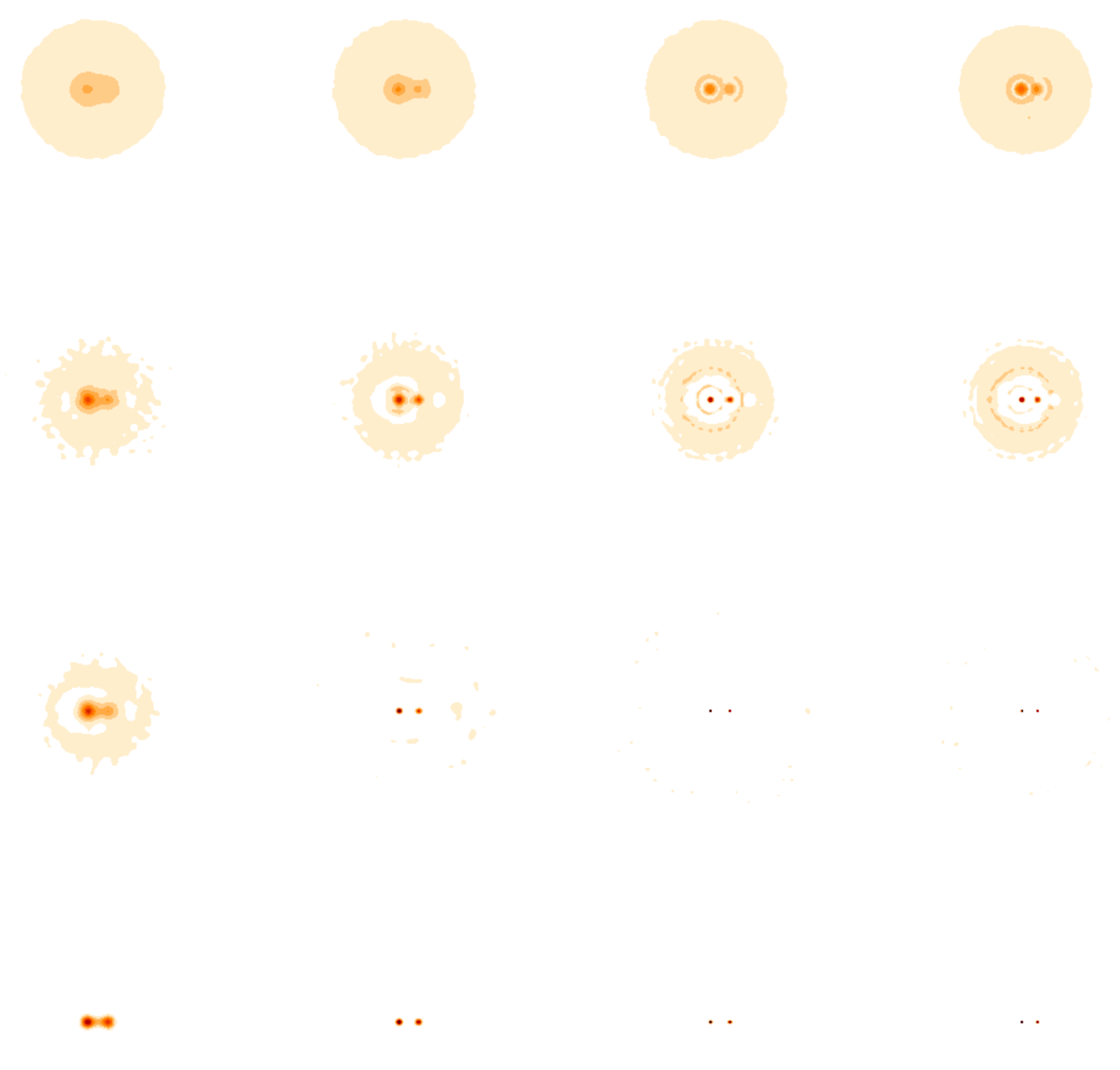
From the same case study as for the original paper (LBT/FLAO in band H), with expansion of the original test range of SR towards lower values (down to 0.06), we find a rather good agreement between the two approaches for both the PSF reconstructions (next left figure) and the object reconstruction (next right figure).



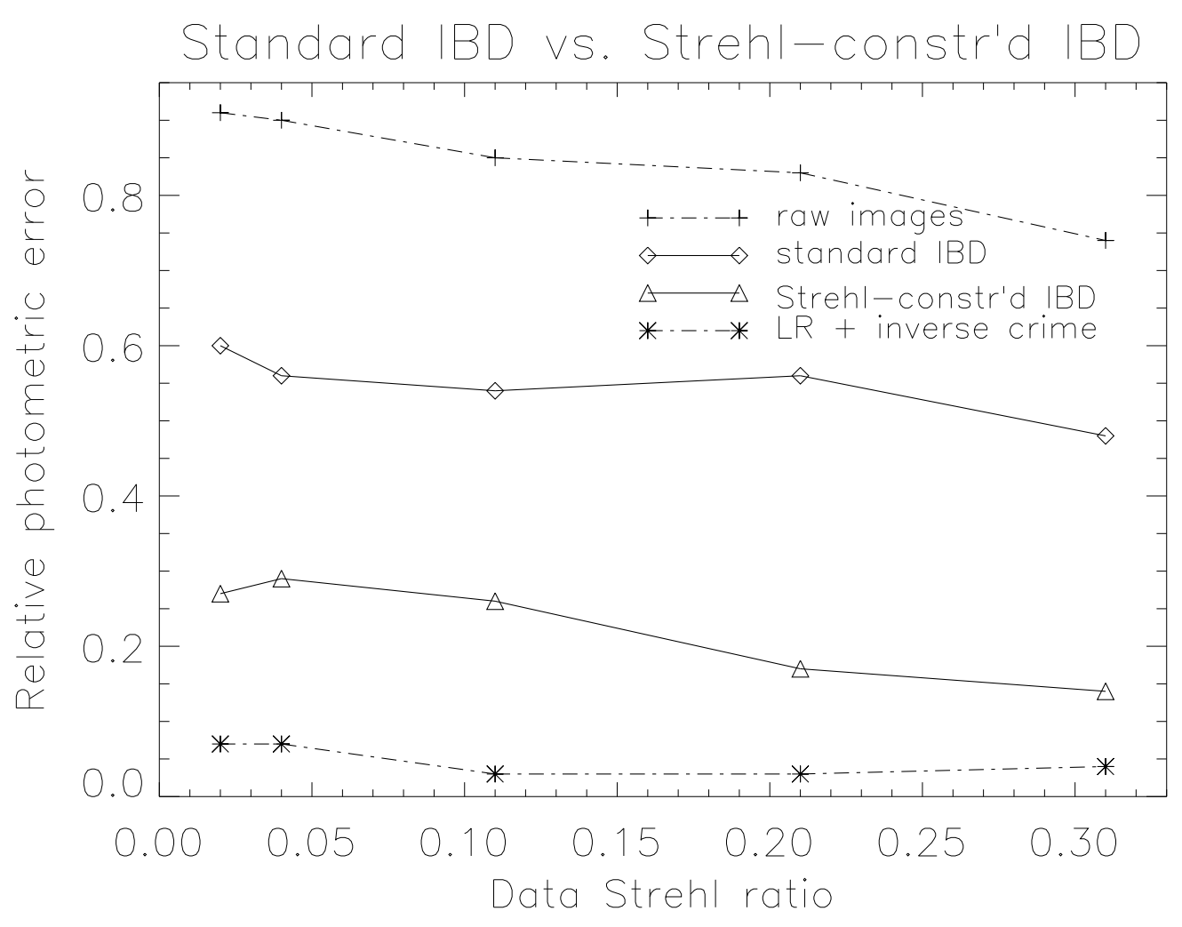


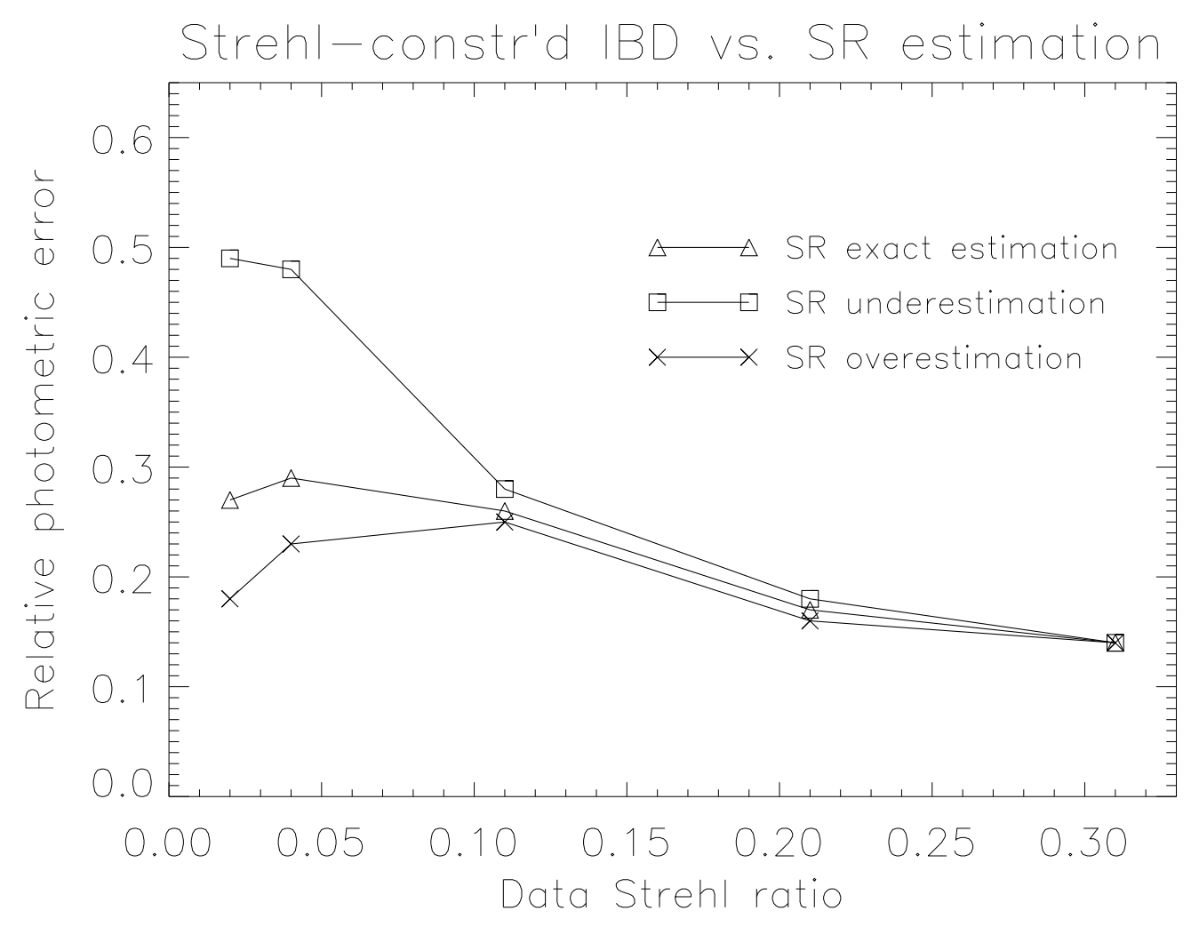
Towards visible wavelength

Next figure shows another test on binary star data simulated by means of the `Software Package CAOS` [3] for the case-study of the 1.52-m telescope MéO (plateau de Calern, France), equipped with the AO system ODISSEE, in the visible domain (R band), with SR of 0.04, 0.11, 0.21, 0.31. First row is for the raw images, second row for the reconstructed objects with IBD, third row with SCIBD, and, for sake of comparison with a somehow ideal deconvolution case, last row with an inverse-crime RL (PSF perfectly known).



Next left figure shows a quantitative comparison of the four cases considered (raw images, standard IBD, SCIBD, RL with inverse crime). Next right figure shows the robustness of the SCIBD algorithm with respect to SR evaluation, considering both underestimation and overestimation, with a slight preference for overestimation (limiting in practice the PSF blurring at the exit of the PSF box).





Conclusion, perspectives, and a last remark

We have presented the last results concerning the development of our SCIBD method. Its two flavors presented, both implemented within the `Software Package AIRY`, v. 6.1, are shown to give similar results on the case-study of simulated H-band FLAO/LBT data, with SR down to 0.06. An extension towards visible wavelenghts, namely for the case-study of ODISSEE/MéO in band R, confirms the gain obtained by SCIBD with respect to standard IBD. It also permits to test the robustness of our method with respect to SR estimation, showing a slight preference for overestimation for the lower SR considered (down to 0.02).

Perspectives concerning this work include: (1) application of the method to real data, and (2) comparison with short-exposure approaches (Lucky imaging, advanced speckle techniques), in particular for very low SR.

The `Software Package AIRY`, as well as the whole `CAOS PSE`, can be freely downloaded from `lagrange.oca.eu/caos` and `www.airyproject.eu` .

References

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[10] `http://www.airyproject.eu` (as on June 2014).