Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2018-59-RC2, 2018

Annales Geophysicae Discussions
Open Access

Interactive comment on "Beam tracking strategies for fast acquisition of solar wind velocity distribution functions with high energy and angular resolutions" *by* Johan De Keyser et al.

Anonymous Referee #2

Received and published: 23 July 2018

General Comments:

The presented manuscript presents and discusses a novel approach to employ electrostatic spacecraft analyzers fitted with angular deflectors. By evaluating beam parameters of the surrounding plasma, only energy- and directional bins relevant to resolving said beam need to be sampled, resulting in much faster signal acquisition and as a result, higher time resolution.

The presented method represents an instance of a sparse sampling approach, in which the sample points from a high-dimensional parameters space are deliberately constrained to certain subsets of that space in order to obtain a maximum amount of

Printer-friendly version

Discussion paper

information with minimal sampling requirements. Similar techniques have been employed with great success in Biophysics (Such as compressed sensing techniques in neurosciences [1]), Astronomy (in aperture synthesis for telescopes [2]). Likewise in the same field as this manuscript, kinetic simulation approaches in space physics employ similar techniques to reduce the computational load of high-dimensional simulation spaces [3,4].

References to similar approaches from those fields, as well as overview papers of compressed sensing methods should be added, since a large body of general theoretical background work from other fields can be applied for this approach.

Specifically, the presented manuscript discusses a method to sparsely sample space plasma velocity distributions, with the intention of tracking a "beam" and sampling it with a minimum number of required samples, to obtain an extraordinarily high temporal resolution.

The model assumptions going into the example analysis performed in this manuscript are a) that the "interesting" part of the particle distribution is quite compact in shape, more precisely, in this analysis it is assumed to be maxwellian b) that it's overall shape stays the same, and only it's parameters change. These assumptions preclude the possibility of multiple mixed plasma distributions, such as a core and beam setup in a foreshock, rings or loss cones in a fermi-type acceleration region or any other non thermally-relaxed particle distribution.

I assume that the authors only focus on the solar wind distributions' core is motivated by their specific research interests. However, the study of kinetic physics of the solar wind, including the effects of turbulence, shocks and magnetic reconnection depends strongly on the ability to study and understand nonthermal distribution functions, that is, precisely those distribution functions that do not fulfill the assumptions going into the manuscript at hand.

While a much more thorough analysis and quantification of the detector behaviour for realistic distribution functions will be required before the presented method can be employed in an actual instrument, it is probably not within the scope of this paper to perform them – the central subject and conclusion being the presentation and motivation of a sparse sampling scheme in the first place. Still, some more reflection on the limitations of the presented analysis, and avenues to further refine the analysis should be included.

In conclusion, this manuscript presents a thoroughly novel idea that merits publication and discussion in the wider scientific community, but suffers from being too narrow in it's goals and scope. After some major revisions, in which the presented method is evaluated with a focus on more general kinetic-physics processes, I consider it suitable for publication.

Specific Comments:

The prediction method presented in section 3.2 and it's discussion of polynomial extrapolation overshoots is very similar in nature to the problem of flux limiters in finite volume simulation methods, such as MHD simulation. There, too, the extrapolation of a reconstruction polynomial is clamped to remain within physically realistic boundaries. This similarity could be discussed and referenced (such as [5]).

The same section claims that "All in all, one can expect such techniques to work reasonably well only if the energy does not change rapidly", and I agree with that statement. However, especially in shocks, discontinuities and reconnection regions, where this assumption does not hold true, is where the most interesting kinetic plasma physics effects occur.

Note that the sudden changes of distribution function in these events are not simply a parameter change of a maxwellian: the shape of the distribution function departs *significantly* from a maxwellian whenever kinetic physics comes into play. If the spacecraft changes it's magnetic connection to a shock, beam distributions of highly nonthermal shape can suddenly "appear" outside of the thermal velocity radius of the previous maxwellian. In reconnection regions, spitzer orbits and crescent-shaped velocity distributions additionally appear on top of any thermal background that might still be present. Additionally, nonisotropic superthermal tails can deform the solar wind distribution away from a maxwell-boltzmann shape.

The discussion in section 4.4, comparing internal and external beam tracking, is thus incomplete, as the asumption of a continuous change of maxwell distribution parameters won't represent reality in many interesting kinetic physics scenarios.

As for the beam loss criterion itself (sections 3.3 and 3.4), it is based on the assumption that the "beam" encompasses the entire interesting part of the distribution function at time of tracking, and that the only noteworthy change at a plasma discontinuity would be a sudden loss of the beam at one spot, with reappearance at another. This is a rough oversimplification of the wide variety of foreshock distribution functions (compare [6]): in many cases, additional beam distributions will occur far outside the thermal velocity extents of the solar wind beam, thus remaining untracked by the restricted sampling process presented here. "Beam Loss" as defined in this paper is neither an appropriate, nor a sufficient criterion for re-scanning of the complete velocity space.

The presented tests inadequately asses the response of the method to these kind of scenarios. While it is good and correct to assess the ability of this method to re-acquire the beam after a beam loss scenario with realistic dynamic timescales, this is, by far, not the only relevant measurement quantity to optimize for. I would suggest expanding section 4 with a discussion of the applicability of the presented method for the study of nonthermal kinetic effects in the distribution function. This can be rather open-ended, to initiate constructive discussion about the proposed method: estimates of dynamic timescales, angular extents and energy ranges would already allow the method to be scrutinized by experts specializing on specific phenomena.

Technical Corrections:

Simulated measurement plots (figures 1, 3, 5, 7, 8 and 9) are missing an axis label on their (presumably) time axis.

References:

[1] Oñativia, J. & Dragotti, P. L. (2015). Sparse sampling: theory, methods and an application in neuroscience. Biological Cybernetics, 109, 125–139. doi: 10.1007/s00422-014-0639-x

[2] Greenaway, A. H. (1991). Optical aperture synthesis. Measurement Science and Technology, 2, 1.

[3] Kormann, K. & Sonnendrücker, E. (2016). Sparse Grids for the Vlasov–Poisson Equation. In J. Garcke & D. Pflüger (eds.), Sparse Grids and Applications - Stuttgart 2014 (p./pp. 163–190), Cham: Springer International Publishing. ISBN: 978-3-319-28262-6

[4] Pfau-Kempf, Y. P.-K., Battarbee, M., Ganse, U., Hoilijoki, S., Turc, L., von Alfthan, S., Vainio, R. & Palmroth, M. (2018). On the importance of spatial and velocity resolution in the hybrid-Vlasov modeling of collisionless shocks. Frontiers in Physics, . doi: 10.3389/fphy.2018.00044

[5] Leveque, R. (2002). Finite Volume Methods for Hyperbolic Problems. Cambridge, MA: Cambridge University Press. ISBN: 9780521009249

[6] Kajdič, P., Hietala, H. & Blanco-Cano, X. (2017). Different Types of Ion Populations Upstream of the 2013 October 8 Interplanetary Shock. The Astrophysical Journal Letters, 849, L27.

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2018-59, 2018.