Bayesian Analysis (2006) **1**, Number 2, pp. 237–240

Comment on article by van Dyk et al.

Ji Meng Loh* and Andrew Gelman†

We congratulate the authors on a clear and well-written paper. They used highly structured complex models that were nevertheless flexible to analyze large, complex datasets. We offer several comments.

1. The Poisson model used throughout the paper is sensible for the physical aspect of the problem. However, the Poisson distribution lacks a variance parameter. Overdispersion might arise from, say, inaccurate modeling of the point spread function; similar issues arose from applying these models to tomography data (Gelman 1990; Gelman et al. 1996). If overdispersion is present, the posterior uncertainties may be understated, and so cast doubt on the interpretations of the significance maps in Figure 13, for example.

   It will be reassuring to have a model that allows for overdispersion, or a test to show that overdispersion is not a problem for the data.

2. Since the models used are so complex, it will be helpful to have posterior simulations of replicated data sets alongside the actual data. This will be useful for both the reconstruction of NGC 6240 (Figure 13) and the spectrum of Capella (Figure 16). One can then check that the general patterns in the actual data are also present in the replicated data sets. This will help in finding problems with or building confidence in the model.

3. We have a question about the multiscale model shown in Figure 7. The quadrant divisions in the model should produce boundary effects, but are not present in the reconstructions. Perhaps it would be helpful to see some images simulated from the prior distribution, to get a sense of what this model is doing.

4. In describing kernel smoothing methods, the authors write, "Although such ad hoc smoothing routines can produce beautiful images, it is difficult to identify their inherent model assumptions, to quantify their fitting errors, or to assess their reliability." We would like to note that there has been some work studying the theoretical properties of smoothed estimates (see Silverman et al. 1990; Gelman 1996, section 4).

5. In comparing the reconstruction of NGC 6240 using spatial smoothing to the Bayesian reconstruction, the authors note that the smoothed reconstruction missed a loop in the upper right of the image that the Bayesian reconstruction captured. On the other hand, we find three bright, but separate point sources near the center

*Department of Statistics, Columbia University, New York, NY, http://www.stat.columbia.edu/~meng/
†Department of Statistics, Columbia University, New York, NY, http://www.stat.columbia.edu/~gelman/

 ba0002

of the smoothed image that are not apparent in the Bayesian reconstruction. It is not clear what to believe.

This is not to suggest that the smoothing method is superior, but rather than choosing one method over the one, we wonder if the Bayesian reconstruction method can be further improved to include the desirable and attractive features of the smoothing method. Perhaps this can be achieved by reconstructing at a resolution higher than that provided by the data, and using a spatial prior distribution to capture local smoothness (see Geman and McClure (1987) for a model that allows jumps).

6. In the DEM images shown on pages 41, various values of α were used. Is it possible to treat α as a hyperparameter in the model and estimate it from the data?

7. We did some simple image reconstruction of NGC 6240 ourselves. Treating the 65-by-65 image as observations on (1,1) to (65,65), we used kriging with the logarithm transformation to estimate the values (1.5, 1.5) to (64.5, 64.5). We obtained the images shown in Figure 1 (plotted on the log scale).

   We do not pretend that what we did achieves the aims of the authors in their analysis. We include it here to suggest the possibility of using geostatistical or spatial point process approaches.

   Diggle et al. (1998) introduced a generalized version of kriging, allowing for observations to follow distributions other than the Gaussian distribution (much like generalized linear models versus linear regression models). Let $Y(\mathbf{x})$ denote the observation at position $\mathbf{x}$. A model that might be applicable to the van Dyk et al. data would be

$$\begin{aligned} Y(\mathbf{x}) &\sim \mathrm{Poi}(\lambda(\mathbf{x})) \\ \lambda(\mathbf{x}) &= \mu(\mathbf{x}) + S(\mathbf{x}), \end{aligned}$$

   where λ is the link function, $\mu(\mathbf{x})$ the mean function and $S(\mathbf{x})$ a zero-mean Gaussian process. Further refinements might allow for non-stationarity of the Gaussian process.

   The authors mentioned that the analyses of spatial images, energy spectrum and light curves are often done separately and that there are reasons for joint analysis. Perhaps joint modeling can be pursued by treating the arrival of photons as a three-dimensional marked point process (two spatial dimensions and time as the third dimension) with the energy of the photon as the mark. Analysis of the unmarked process allows investigation into the clustering of photons in time, space or both. Analysis of the marks may yield information about how the energies of incoming photons may be related and so on.

   In making the images in Figure 1, we found that the color scheme used made a big difference in how the images looked to us. For example, the images at the top and bottom of Figure 1 show more structure than the image in the middle. Also, for the top image, there appears to be more material to the right of the main object than is apparent from the other two images. Since the images are X-ray

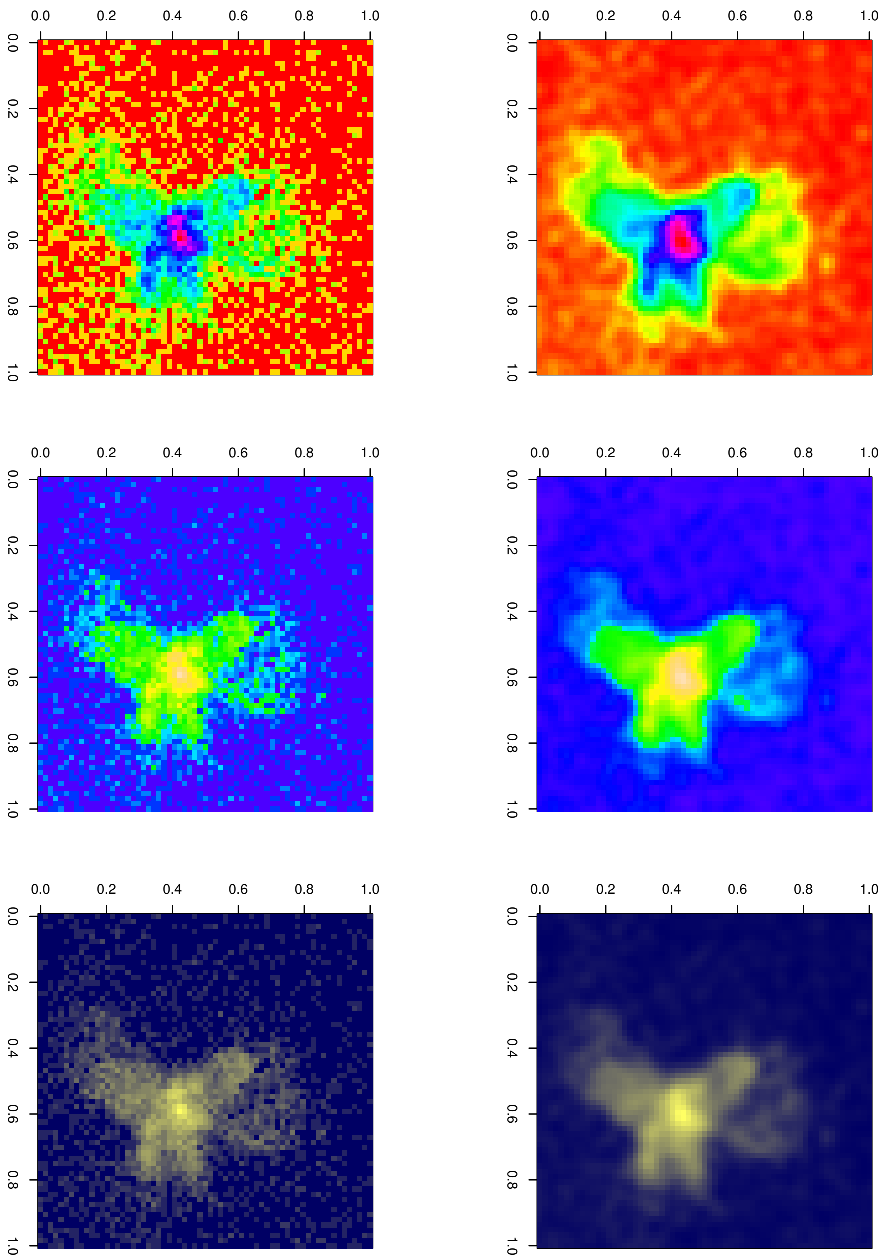

Figure 1: Reconstruction of NGC 6240. Shown here are images using different color schemes. The images on the left are the raw images while those on the right are reconstructed images.

images, and so have no "correct" colors to use, perhaps the authors would like to comment on how the color scheme was chosen and what impact it had on their images.

References

Diggle, P. J., Tawn, J. A., and Moyeed, R. A. (1998). "Model-Based Geostatistics." *Applied Statistics*, 47: 299–350. 238

Gelman, A. (1990). "Topics in image reconstruction from emission tomography." *Ph.D. thesis, Department of Statistics, Harvard University*. 237

— (1996). "Bayesian model-building by pure thought: some principles and examples." *Statistica Sinica*, 6: 215–232. 237

Gelman, A., Meng, X. L., and Stern, H. S. (1996). "Posterior predictive assessment of model fitness via realized discrepancies (with discussion)." *Statistica Sinica*, 6: 733–807. 237

Geman, S. and McClure, D. E. (1987). "Statistical methods for tomographic image reconstruction." In *Proceedings of the ISI Meetings*. Tokyo, Japan. 238

Silverman, B. W., Jones, M. C., Nychka, D. W., and Wilson, J. D. (1990). "A smoothed EM approach to indirect estimation problems, with particular reference to stereology and emission tomography (with discussion)." *Journal of the Royal Statistical Society B*, 52: 271–324. 237