TESELA: A New Virtual Observatory Tool to Determine Blank Fields

N. Cardiel,[1] F.M. Jiménez-Esteban,[2,3,4] J.M. Alacid,[2,3] E. Solano[2,3] and M. Aberasturi[2,3]

[1]*Departamento de Astrofísica y CC. de la Atmósfera, Facultad de CC. Físicas, Avenida Complutense s/n, E-28040 Madrid, Spain*

[2]*Centro de Astrobiología (INTA-CSIC), Departamento de Astrofísica, PO Box 78, E-28691, Villanueva de la Cañada, Madrid, Spain*

[3]*Spanish Virtual Observatory, Spain*

[4]*Saint Louis University, Madrid Campus, Division of Science and Engineering, Avenida del Valle 34, E-28003 Madrid, Spain*

Abstract. To point a telescope to a sky region devoid of bright stars is a typical procedure when obtaining calibration images for astronomical observations. To date, no systematic catalogue is available providing the location in the sky of blank fields for varying limiting magnitudes. In this work we describe a method that helps to determine the availability of blank fields in any region of the celestial sphere, based on the use of the Delaunay triangulation. In addition, we present TESELA, a Virtual Observatory tool which provides a simple interface that allows the user to retrieve the list of blank fields available near a given position in the sky.

1. The Need of Observing Blank Fields

Many times astronomical observations demands the pointing of the telescope to *blank fields*, sky regions devoid of bright objects, in particular bright stars down to a given magnitude. This is particularly true when one tries to obtain calibration frames for flatfielding, or when the sky subtraction requires the observation of auxiliary images nearby the science targets because the objects are extended. With the advent of instruments with increasing field of view, the problem of avoiding bright objects in the images is getting more difficult. The situation is also starting to be important in spectroscopic observations, since integral field units with high multiplexing capabilities (and thus, increasingly larger field of view) are expected to be the most common instrumentation in ground-based observatories.

The work presented in this paper describes a method that helps to determine the availability of blank fields in any region of the celestial sphere. The method is based on the use of the Delaunay triangulation, and generates blank field catalogues to varying limiting magnitudes. In order to facilitate the use of these catalogues, we have created TESELA, a new Virtual Observatory tool accessible through the WEB, which provides a simple interface that allows the user to retrieve the list of blank fields available near
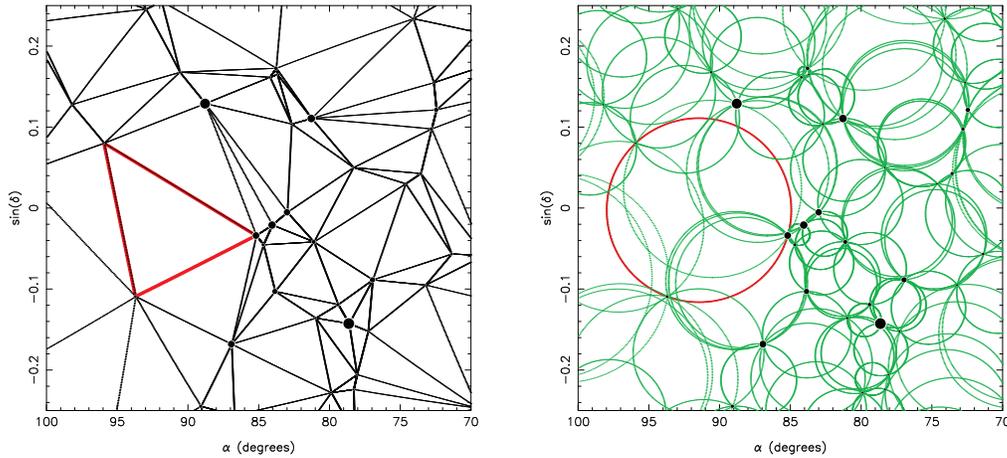
Figure 1. *Left:* Sky region centered at the Orion constellation, considering all the stars brighter than $m_V = 4.5$ mag. The triangulation is carried out considering all the stars as nodes for the triangles, independently of their magnitude. A particular triangle is highlighted in red colour. *Right:* Circumcircles corresponding to all the triangles derived in the previous triangulation. The red circle indicates the circumcircle associated to the previously highlighted triangle. Note that the *empty circumcircle interior property* guarantees that there are no stars inside any of the displayed circumcircles.

a given location in the celestial sphere. Interested readers can find a full description of this work in Cardiel et al. (2011).

2.   Using the Delaunay Triangulation to Tessellate the Sky

The Delaunay triangulation (Delaunay 1934) lies in the subdivision of a geometric object into a set of simplices (the *n*-dimensional analogue of a triangle). In particular, for the Euclidean planar (2-dimensional) case, given a set of points, also called nodes, the Delaunay triangulation becomes a subdivision of the plane into triangles whose vertexes are nodes.

There is a particular property of the Delaunay triangulation, known as the *empty circumcircle interior property*, that, for our purposes, becomes extremely useful. This property indicates that all the circumcircles that can be drawn passing exactly through the three vertexes of all the triangles are empty, i.e., there are no nodes inside any of the computed circumcircles.

Since the Delaunay triangulation can be applied to the 2-dimensional surface of a 3-dimensional sphere, if one computes such triangulation using the coordinates of stars on the celestial sphere (down to a given threshold magnitude) as nodes, the above property will guarantee that there are no stars within the circumcircles associated to the derived triangles. In this way, the circumdiameter of every circumcircle determines the maximum field of view that can be employed in that region of the sky as blank field (see Fig. 1 for a graphical example).

In this work we have applied the Delaunay triangulation to the Tycho-2 stellar catalogue. In order to proceed with the triangulation, we have made use of STRIPACK (Renka 1997), a Fortran 77 software package that employs an incremental algorithm to
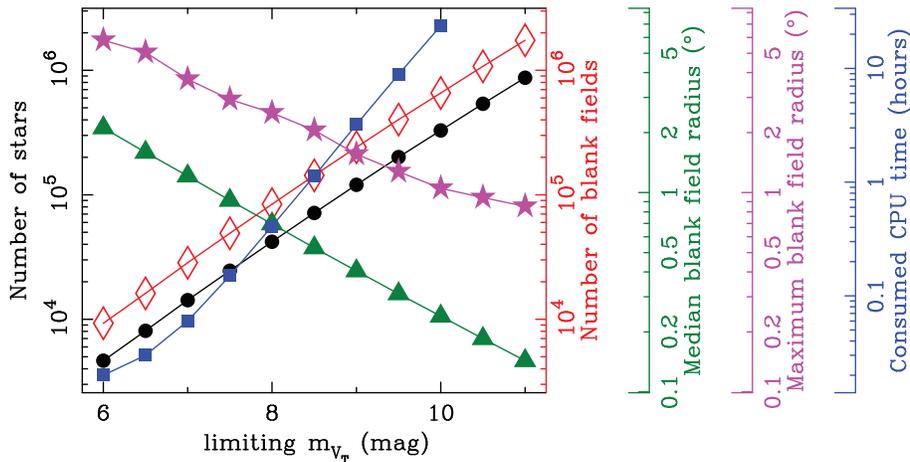
Figure 2.   Variation of relevant parameters during the tessellation as a function of the limiting magnitude of the considered stellar catalogue. Not surprisingly, these parameters exhibit a linear behavior in logarithmic scale, resulting from the exponential increase of the number of stars with m_{V_T}. Note also the decreasing blank field radius (both the median and the maximum) with m_{V_T}.

build the Delaunay triangulation of a set of points on the surface of the unit sphere. For the work presented here, we have modified the code in order to use double-precision floating arithmetic, which guarantees the proper computation of the triangulation when working with star separations approaching a few arcseconds.

In principle it is straightforward to obtain a list of blank fields for the whole celestial sphere by using as input a stellar catalogue including stars down to a given magnitude. In Fig. 2 we represent several relevant parameters derived from the tessellation of the Tycho-2 catalogue as a function of the limiting m_{V_T}, for values between 6.0 mag and 11.0 mag. Although, in particular, the consumed CPU time depends on the characteristics of the machine used for the tessellation, the most important aspect is the exponential increase of the required time with m_{V_T} (blue filled squares), mainly due to the exponential growth of the number of stars (black filled circles). In addition, since the tessellation of the whole celestial sphere demands memory storage (for stellar coordinates plus auxiliary variables) that scales with the number of stars, this method requires excessively large memory capacity for faint magnitudes. For those reasons our approach for the tessellation down to m_{V_T} = 10.5 and 11.0 mag was to subdivide the whole celestial sphere in many smaller subregions (with some overlap among them), in order to individually compute the Delaunay triangulation in each of these smaller patches and, finally, merge the separate blank field lists.

3.   TESELA

In order to provide an easy way to access the blank field catalogues, we have created TESELA, a tool developed by the Spanish Virtual Observatory and publicly available via WEB: `http://sdc.cab.inta-csic.es/tesela` and ConeSearch: `http://sdc.cab.inta-csic.es/tesela/ConeSearch/VOTableTESELA.jsp`.
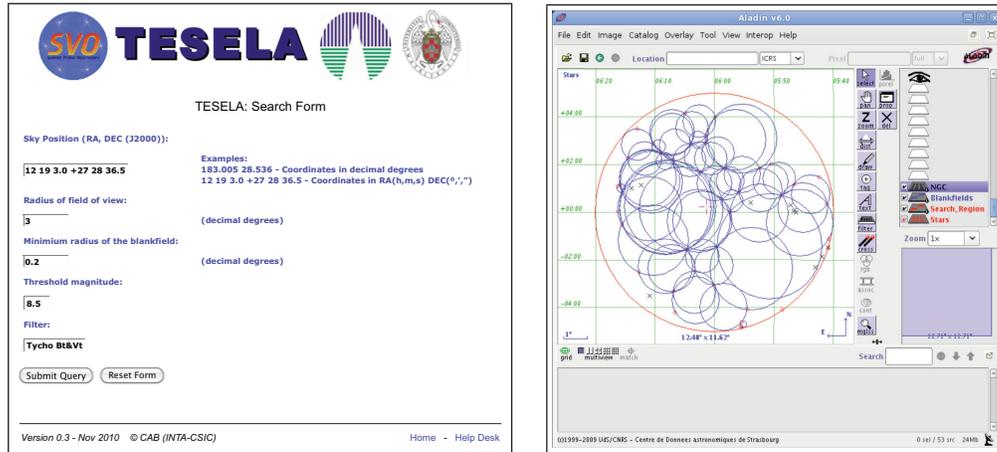
Figure 3.   *Left:* TESELA's search form, that can be used to define the parameters of the cone-search of blank fields. *Right:* Example of visualization of the blank fields with Aladin. The large red circle defines the searching area; Tycho-2 stars are shown by red diamonds; the blue circles depict the blank fields; the black sails are the objects from the NGC 2000.0 in the region.

The tool consists of a database containing the Tycho-2 stars, the already computed blank fields regions, and an user-friendly interface for accessing the data. TESELA allows the users to perform a cone-search around any position in the sky. Through its search form (see Fig.3, left panel), users can select the threshold magnitude, the Tycho-2 filter to be used (B_T, V_T, or the combination of both), and define a minimum radius for the blank field regions. TESELA also provides users with the possibility of visualizing the data, making use of the excellent VO tool Aladin (Bonnarel et al. 2000) (Fig. 3, right panel). In this way it is trivial to superimpose entries from astronomical catalogues or databases to the results provided by TESELA.

The current version of TESELA allows users to access the collection of blank fields obtained from the optical Tycho-2 catalogue. But TESELA has been conceived as a dynamic tool, which will be improved in the future with both deeper optical catalogues and catalogues in others wavelength ranges.

References

Bonnarel, F., Fernique, P., Bienaymé, O., Egret, D., Genova, F., Louys, M., Ochsenbein, F., Wenger, M., & Bartlett, J. G. 2000, A&AS, 143, 33
Cardiel, N., Jiménez-Esteban, F. M., Alacid, J. M., Solano, E., & Aberasturi, M. 2011, MNRAS, 417, 3061. `1107.3949`
Delaunay, B. 1934, Bull. Acad. Sci. USSR, 793
Renka, R. J. 1997, ACM Transactions on Mathematical Software, 23, 416