DETECTION AND DYNAMIC ANALYSIS OF SPACE DEBRIS IN THE GEO RING

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RESUMEN

En la zona geoestacionaria (GEO) existen diferentes poblaciones de escombros espaciales. Es de gran interés conocer con la mayor precisión posible su dinámica a fin de contribuir con los controles de alerta ante posibles colisiones para reposicionar satélites GEO y para posicionar aquellos que entran en servicio. En esta contribución presentamos un estudio sobre la detección y análisis dinámico de escombros espaciales ubicados en la zona GEO. Haciendo uso de los telescopios del Observatorio Astronómico Nacional (OAN) de Venezuela, se ha adquirido una gran cantidad de observaciones astrométricas, con las cuales se ha realizado un análisis dinámico preliminar que evidencia cómo es el movimiento relativo promedio de estos orbitadores, con un error absoluto promedio en las coordenadas de $\approx$ 0.09 pix.

ABSTRACT

There are different populations of space debris (SD) in the geostationary (GEO) region. It is of great interest to know their dynamics, in order to contribute to aspects such as alert against possible collisions, repositioning of GEO satellites or placing those satellites that come into service. In this contribution we present a study about the detection and dynamic analysis of SD located in the GEO ring. Using the telescopes of the Venezuelan Obseratory National (VON), a large amount of astrometric observations have been acquired. A preliminary dynamic analysis of them has been carried out, which evidences the average relative motion of these orbiters with a mean absolute error for coordinates $\approx$ 0.09 pix.

Key Words: astrometry — methods: data analysis — space vehicles

1. GEOSTATIONARY RING

In the last four decades the increase of orbiters in the GEO ring has been exponential. These objects have been generated by different sources such as the launch process, in-orbit explosions, hypervelocity collisions, operational debris separations, uncontrolled satellites, amoung others. These orbiters are classified by Flohrer (2012) in different groups, according to their osculating elements, and therefore the GEO ring limits are extended to $(736\times736\times400)$ km^3 at longitude, latitude and altitude, respectively (Anderson et al. 2013; McKnight et al. 2013). Accurate detection and initial orbit determination of these orbiters are of great importance in order to avoid collisions with operational satellites. A reliable data acquisition is necessary to support the development and validation of population models, in order to build catalogues SD including information such as: orbital elements, shape, size, etc. Unfortunately, there is no real knowledge of the number of small SD in the GEO ring. In this contribution we use optical telescopes and astrometric observations in order to provide a preliminary dynamical analysis of these orbiters.

2. ASTROMETRIC OBSERVATIONS AND DISTORTION PATTERN

Observations are being carried out with both ground-based and space-based instrumentation. Optical observations contribute in the detection and tracking of SD, since it is possible to obtain high precision in the geocentric coordinates with errors of the order of $0.1''$ (Lacruz et al. 2015) which is equivalent to 20 m for objects located at 42164 km from the barycenter of the Earth. Since February 2015 we use the telescopes at the VON and more than 20000 astrometric observations have been acquired until now.

In left panel of Fig. 1 is shown an astrometric observation. Two kinds of images can be distinguished: streaks representing the stars sources and point sources representing SD candidates and GEO satellites. The orientation of the CCD is such that the (x, y) axes are correspond to (α, δ). The astrometric reduction process requires for each observation at least three complete streaks. Therefore, the

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exposure time was of the 10 s, taking into account that the length of the streak is proportional to exposure time as well as the sensitivity limits of the instrument which determinate the number of reference stars that can be detected (Shildknecht et al. 2004).

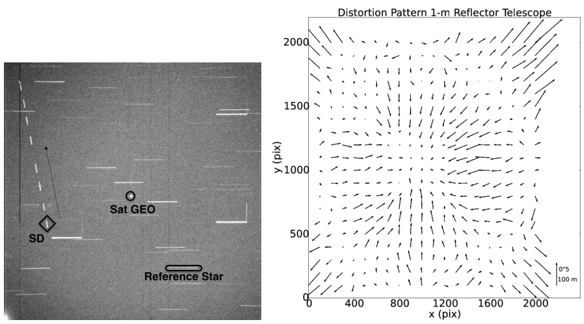

Fig. 1. Astrometric observations over the operation windows 76° W (left panel). Streaks represent stars sources (rectangle), point sources (circles) represent GEO satellites and SD candidates. The inclined streaks (diamond) represent the position of a LEO satellite; the direction of its relative orbital movement is indicated by the black arrow. Astrometric distortion pattern (right panel) for the 1-m reflector telescope in mode F/5 obtained by the reduction process using a block-adjustment method.

In right panel of Fig. 1 is shown the distortion pattern (DP) calculated for the 1-m reflector telescope and CCD $2\,k \times 2\,k$ pixels, where the field of view is $18.8^{'}$ square with a scale of $0.55''/pix$. The DP represents the systematic errors calulcated through the block-adjustment method shown in Stock (1981). The computation of the errors is based on the Sliding Weighted Polynomial (Abad 1993). The final average errors, as a function of magnitude for stars down to 13 V magnitude from the UCAC4 catalog, are $0.18^{''}$ and $0.15^{''}$ for α and δ, respectively. In this iterative reduction process we can obtain stars links between observations and the catalog, which will be those that contribute in the search of the solution of the systematic errors represented as the DP. The links with the catalog yield 11208 reference stars and the links between observations yield 35101 stars.

3. ORBITAL MOTION

On February, 8th 2016, 37 astrometric observations were taken over the slot $\lambda = 43°$ W. These observations are sufficient to appreciate the drift in position at the GEO ring. In Fig 2 the relative motion of the satellite is shown. It is evident that the orbit is non-stationary due to the effect of the joint action of disturbing forces, the most important being the solar radiation pressure, which is directly proportional to the area to mass ratio of the object (Früh et al. 2012).

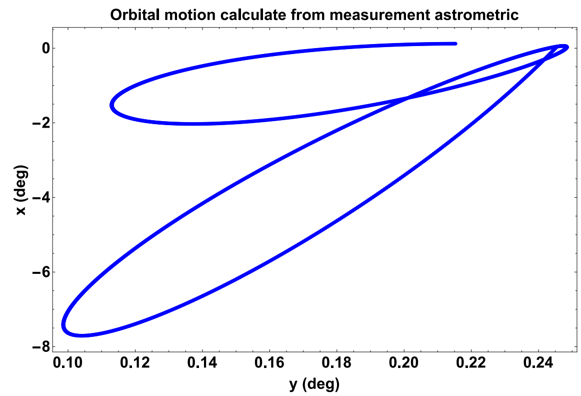

Fig. 2. Relative orbital motion.

The relative motion for other object in the GEO ring is very different because they are in different positions in the GEO ring, and therefore the action of different disturbing forces allows a greater or lesser drift. The relative orbital motion is calculated by means of least squares fit to circular trigonometric functions. The black points represent the coordinates (x, y), which has been determined through a fit of the point spread function (Gaussian) with a mean relative errors of the 8.8×10^{-2} and 9.9×10^{-2} pixels. In Fig 2 we show that relative motion is contained in an area of the $\approx\ 3° \times 0.14°$ in α and δ, respectively.

4. CONCLUSION

Ground-based optical tracking and many astrometric observations have been acquired in survey mode. We determined the systematic errors of the 1-m reflector telescope and the possibility to correct for these in the coordinates. We calculate the preliminary relative motion of the objects in the GEO ring with high precision. The average errors were of the order of 0.09 pix. This research allows the possibility of an exquisite analysis of the effects produced by the perturbations in the satellites in the GEO ring.

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