CHOPPING TECHNIQUES TO DETECT GEOSYNCHRONOUS SPACE DEBRIS

S. Isobe

National Astronomical Observatory, Mitaka, Tokyo, Japan

and

T. Tajama

National Aeronautic and Space Development Agency, Tsukuba, Ibaraki, Japan

ABSTRACT

A trial of geosynchronous object observations has been carried out. There are two ways to determine an azimuth and elevation position of a geosynchronous object: one is an absoute measurement refering to its telescope coordinate system, and the other is a relative measurement refering to star positions. The former one needs a telescope with good mechanical system and encorder system which bring its expensive cost. For the latter one, an inexpensive telescope can be used. However, because of relative motion between the object and its reference stars, the star images become long streaks, and it is hard to determine those precise positions. We introduced a chopping system and divided each stellar image into pieces. Then, we get the quite higher position accuracy. We will show some results of observations carried out in these years.

1.INTRODUCTION

As discussed in this book, it becomes one of important activities for future safety space missions to observe and identify space debris at LEO and also GEO. There are radar observations mostly deticated for the LEO debris and optical observations for the higher orbit debris including the GEO debris. Using radar technique, we measure range and range rate of each object, and it is not necessary to have a radio telescope with accurate pointing since its radar beam can extend in a wide field (from 1 minute of are to 10 degree). For optical observations, we need high azimuth and elevation position accuracy of 1 to 10 second of arc, because the position of debris in a observered field is determined refering to absolute position of its telescope, and then such a telescope is expensive. There is a way to use a telescope with a low position accuracy but to refer star positions in a field, which make it possible to use existing cheap telescopes but need many reduction processes.

Currently, we are able to use a telescope at Kita-Karuizawa in Gumma prefecture belonging to the Sundai senior high school. Figure 1 shows the telescope. It is located at longitude of 138° 35' 18" east, latitude of 36° 27'18" north, and altitude of about 1123m. The telescope has an alt-azimuth mounting with a computer control system. Its aperture is 75cm in diameter and a focal length of the primary focus is 225cm. An ST-6 CCD camera with 375×242 pixels is set at the Newtonian focus, and then a field size of 11'×8' and a pixel field of 2"×2" are given. Two stage peltier cooling system is introduced. and produce a detector temperature of -45° K from its environmental temperature. Therefore, it is hard to observe in summer because of high detector noise level.

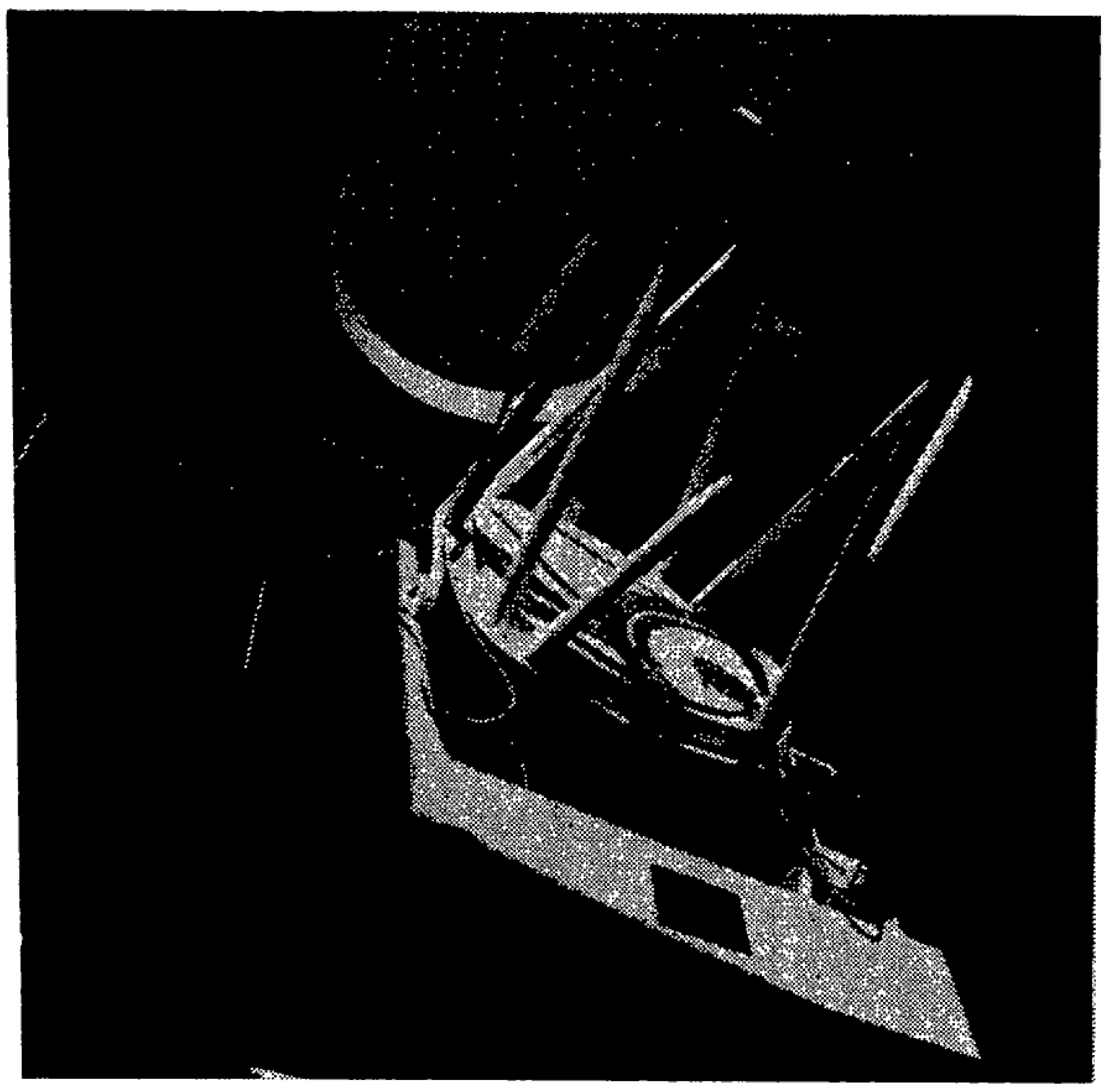

Figure 1 A 75 cm alt-azimuth mounting telescope of the Sundai senior high school.

Using this telescope system, we tried to make observations of GEO. satellites. A GEO satellite had a point-like image but star images were long streak images which result in poor position determinations. Therefore, we introduced a chopping system to have divided dotted images for each star. Here, we will show its performance and some results.

2.CHOPPING IMAGES

The chopping system consists of a GPS receiver, a control computer, and a mechanical shutter. Taking the GPS time signal, the shutter is opened and closed at every exact second with an accuracy of 1/500 seconds one by one as shown in Figure 2. An example of observed images is shown in Figure 3, and intensity distributions of a star and the ETS-VI satellite are shown in Figures 4 and 5, respectively. The star images chopped by our system are nearly equal each other although the 6-th images is one with a 2 second exposure. The ETS-VI satellite is not one of the GEOs and move with a certain speed. Therefore, it has not a point-like one but 6 chopped images. Looking at Figure 4, we can find the satellite motion in the field was an opposite direction to the star because of a position of the 2 second exposure image.

From Figure 4, we also find a brightness variation of the ETS-VI in an order of 10 second of time.

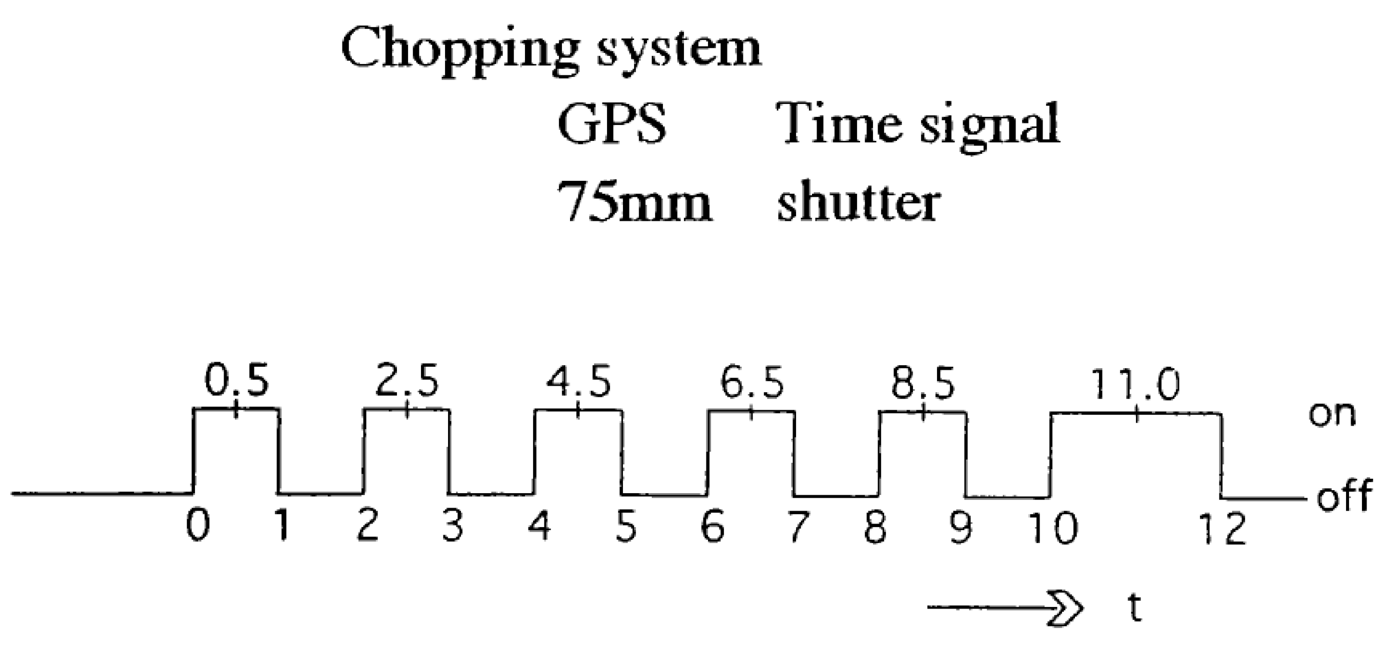

Figure 2 A shematic diagram of time schedule of chopping by a shutter.

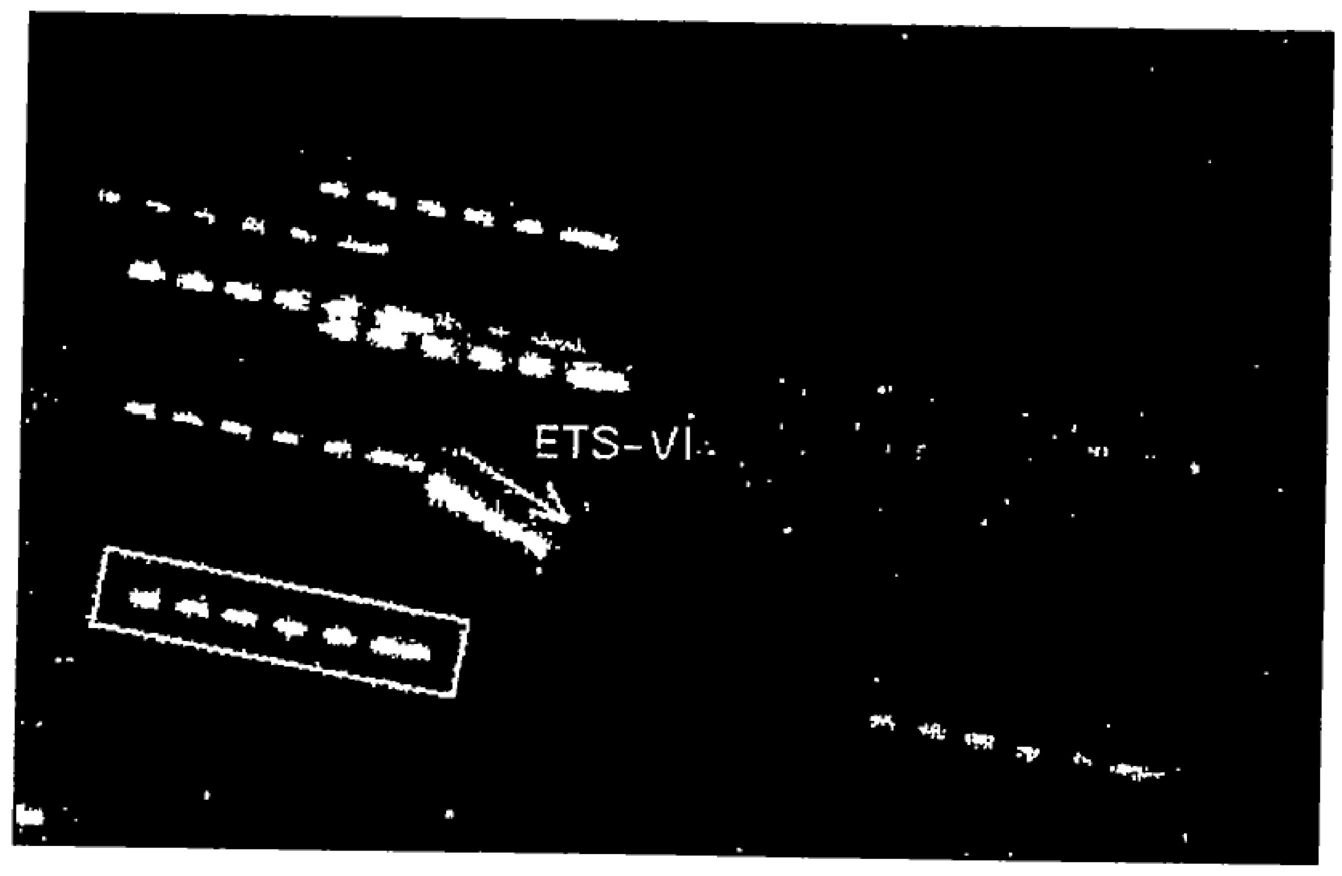

Figure 3 An image of the ETS-VI satellite obtained at 20h 00m UTC on January 11, 1997. Each chopped image of each star is at 0.5s, 2.5s, 4.5s, 6.5s, 8.5s, and 11s, respectively. A position of the brightest star is 12h 00m 49.7s in right ascension and +2° 06' 36" in declination at a epoch of 2000.0.

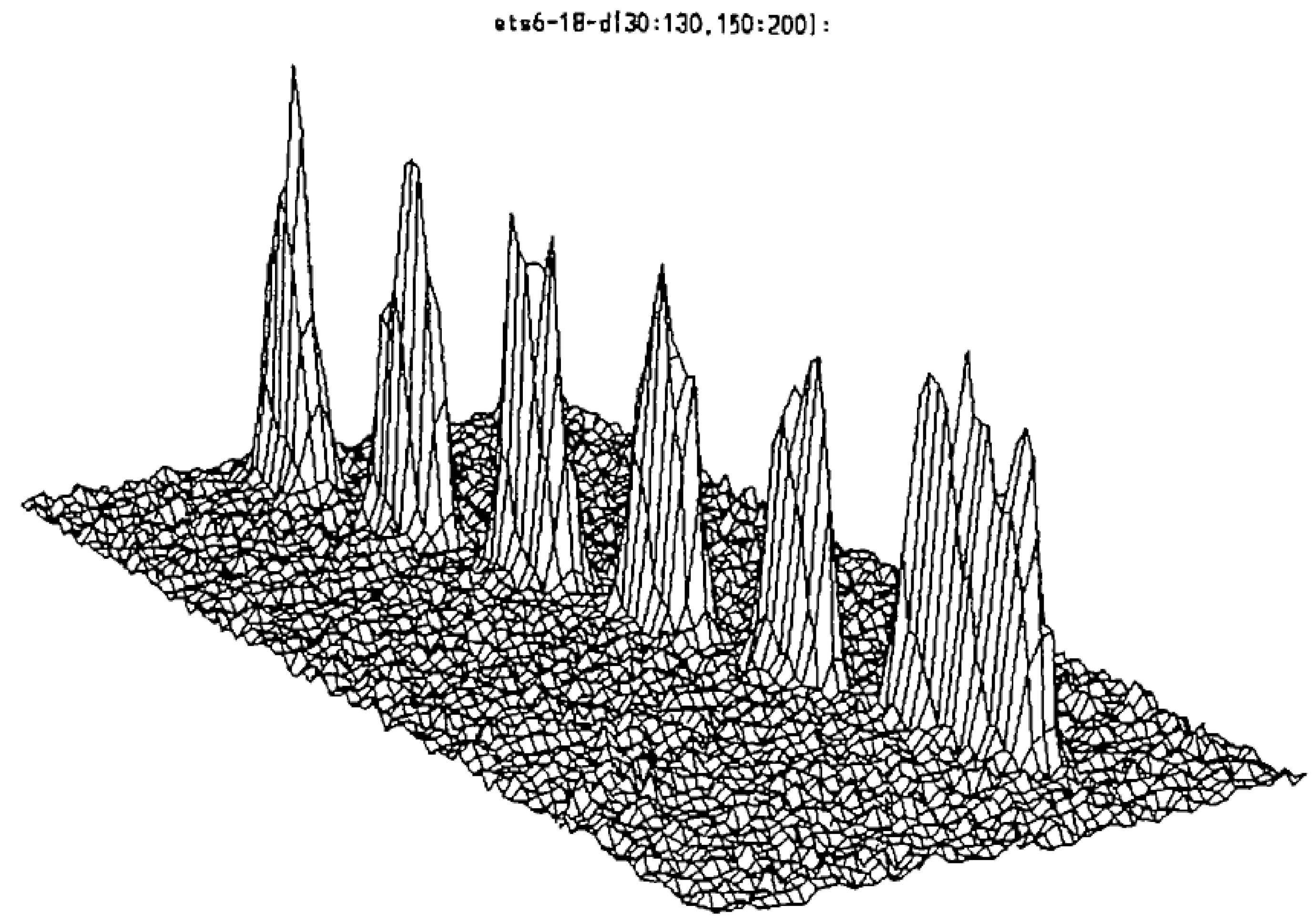

Figure 4 Intensity distribution of a star within a box in Figure 3.

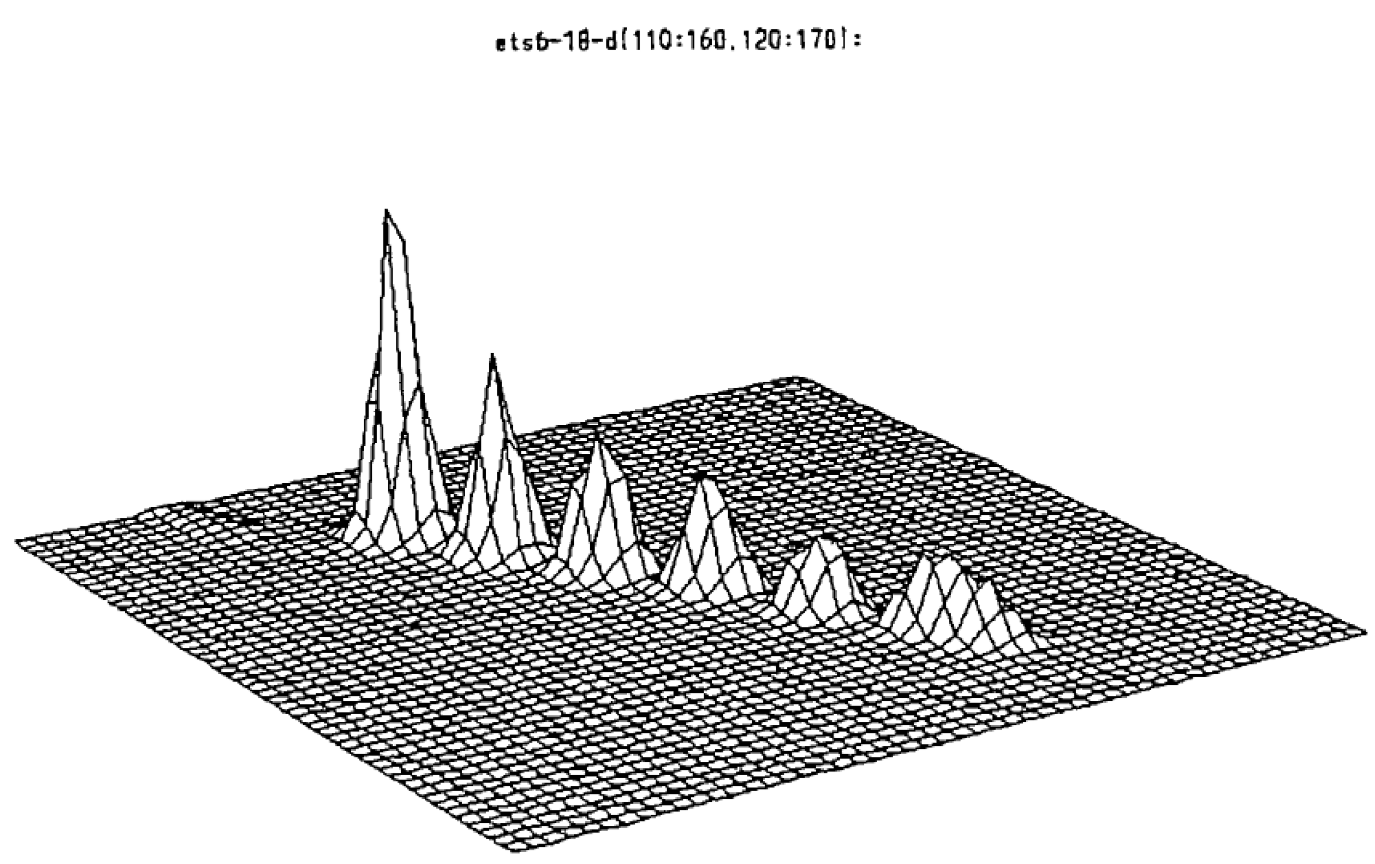

Figure 5 Intensity distribution of the ETS-VI satellite in Figure 3.

3.POSITION ACCURACY

To reduce each image, we first identify some number of stars in each field with the GSC stars for the Hubble Space Telescope as shown in Figure 6. Table 1 shows internal differences of each chopped stellar images. In this example cases, we have an internal accuracy of 0.5" in rms except the 5-th image for each GSC star. The telescope motion is controlled by its velocity changed at every 10 seconds and its position is adjusted at the same time. Since there is a drift motion of the telescope even when we try to fix its position, we may suffer a jump of telescope position as shown in Figure 7. Now, except this kind of telescope defect which can be easily solved by introducing a high speed computer for the telescope control, we are able to say our internal position determination accuracy is about 0.5" at 5" seeing condition.

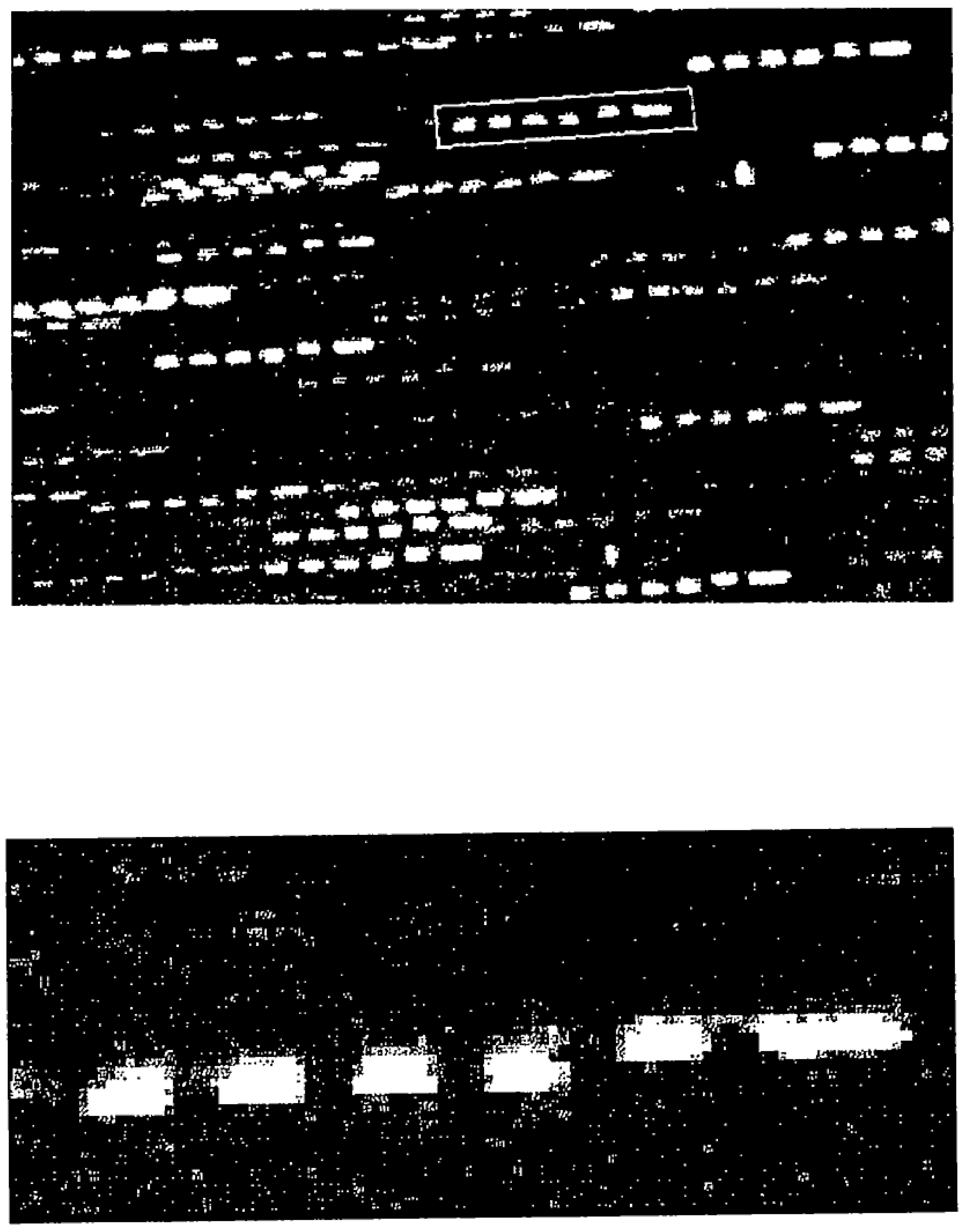

Figure 7 A field shows chopped star image (upper) and on enlarged image of a star have a image jump between the 4-th and 5-th images.

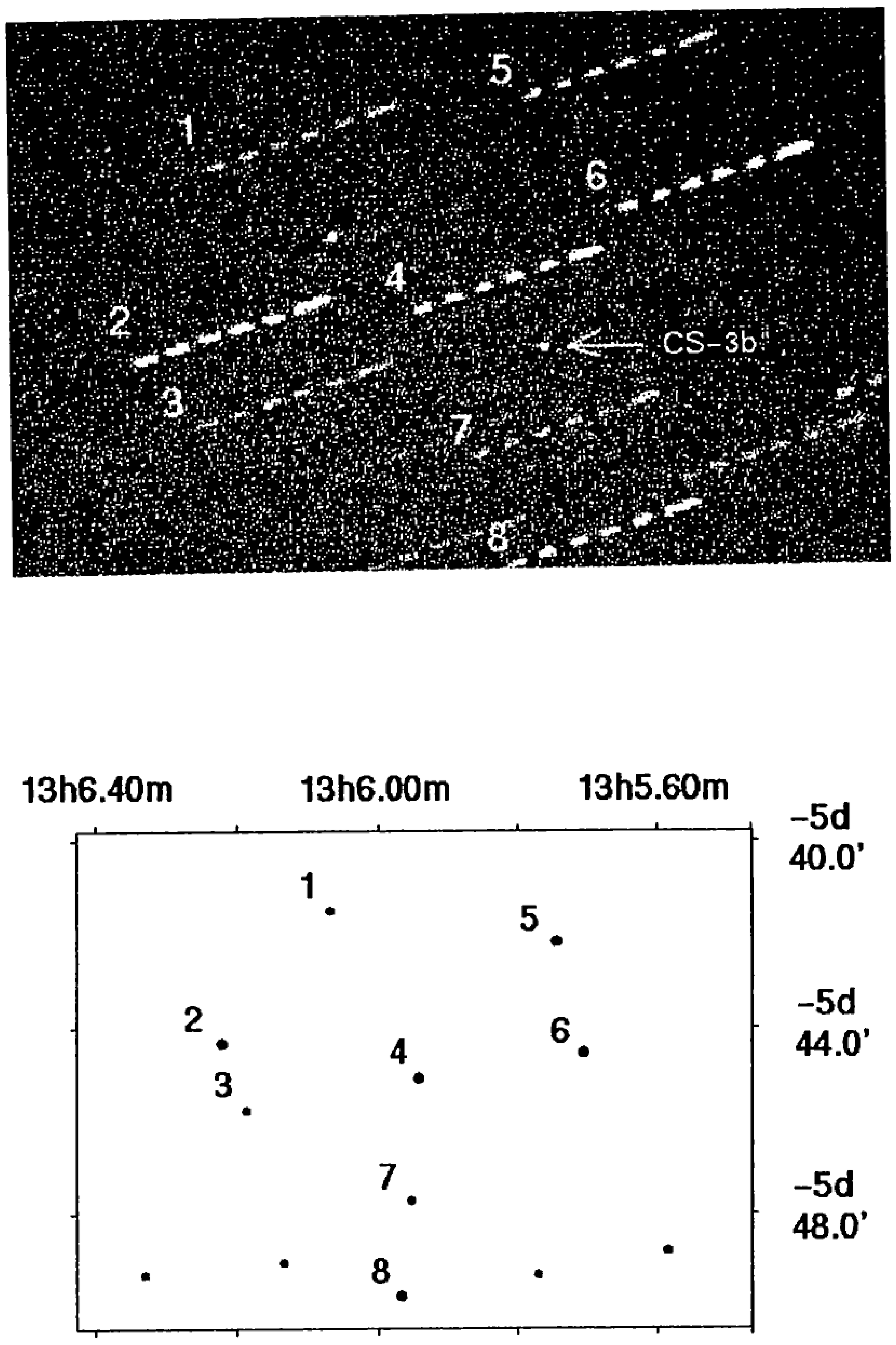

Figure 6 An observed field (upper) and a distribution of the GSC stars (lower) with numbers to identify common stars.

4.DEBRIS OBSERVATION

Till this observational season, we did not try to detect real GEO space debris, which is expected to be carried out next winter. However, we accidentally detected a space debris in a field targeted to the GMS-5 as shown in Figure 8. As a test, we observed the ETS-V satellite every two minutes within 30 minutes, during which the telescope position was fixed. An image superposed all 14 images top to top is shown in Figure 9. These results suggest that we are able to determine each position of space debris and also its orbit, and then the detected one can be identified with catalogued space debris or a new space debris.

In conclusion, we developed a system with an internal position determination accuracy of about 0.5" using an existing cheap telescope. and found that this system is useful for a detection of space debris.

```
GMS5-25 1997/01/13 14:06[UTC] A=177.4656 h=48.2474

ra[ 4]= 6h59m54.330s dc[ 4]=-5d12'25.80"  radiff[ 4]=-1.23 dcdiff[ 4]=-1.09
ra[ 4]= 6h59m54.334s dc[ 4]=-5d12'24.92"  radiff[ 4]=-1.16 dcdiff[ 4]=-0.22
ra[ 4]= 6h59m54.445s dc[ 4]=-5d12'24.96"  radiff[ 4]=+0.49 dcdiff[ 4]=-0.25
ra[ 4]= 6h59m54.467s dc[ 4]=-5d12'25.53"  radiff[ 4]=+0.82 dcdiff[ 4]=-0.82
ra[ 4]= 6h59m54.330s dc[ 4]=-5d12'20.31"  radiff[ 4]=-1.23 dcdiff[ 4]=+4.40

ra[ 5]= 6h59m58.708s dc[ 5]=-5d14'46.55"  radiff[ 5]=+1.84 dcdiff[ 5]=-1.66
ra[ 5]= 6h59m58.586s dc[ 5]=-5d14'45.41"  radiff[ 5]=+0.02 dcdiff[ 5]=-0.52
ra[ 5]= 6h59m58.541s dc[ 5]=-5d14'45.77"  radiff[ 5]=-0.65 dcdiff[ 5]=-0.88
ra[ 5]= 6h59m58.680s dc[ 5]=-5d14'46.05"  radiff[ 5]=+1.42 dcdiff[ 5]=-1.16
ra[ 5]= 6h59m58.706s dc[ 5]=-5d14'40.15"  radiff[ 5]=+1.82 dcdiff[ 5]=+4.74

ra[ 6]= 6h59m36.721s dc[ 6]=-5d 8'49.19"  radiff[ 6]=+1.09 dcdiff[ 6]=-2.21
ra[ 6]= 6h59m36.552s dc[ 6]=-5d 8'47.64"  radiff[ 6]=-1.44 dcdiff[ 6]=-0.66
ra[ 6]= 6h59m36.665s dc[ 6]=-5d 8'47.82"  radiff[ 6]=+0.24 dcdiff[ 6]=-0.84
ra[ 6]= 6h59m36.796s dc[ 6]=-5d 8'48.35"  radiff[ 6]=+2.21 dcdiff[ 6]=-1.37
ra[ 6]= 6h59m36.666s dc[ 6]=-5d 8'44.06"  radiff[ 6]=+0.26 dcdiff[ 6]=+2.92

ra[ 7]= 6h59m44.733s dc[ 7]=-5d15'05.14"  radiff[ 7]=-1.08 dcdiff[ 7]=-1.39
ra[ 7]= 6h59m44.777s dc[ 7]=-5d15'04.52"  radiff[ 7]=-0.43 dcdiff[ 7]=-0.77
ra[ 7]= 6h59m44.794s dc[ 7]=-5d15'04.05"  radiff[ 7]=-0.17 dcdiff[ 7]=-0.31
ra[ 7]= 6h59m44.854s dc[ 7]=-5d15'04.56"  radiff[ 7]=+0.73 dcdiff[ 7]=-0.81
ra[ 7]= 6h59m44.826s dc[ 7]=-5d14'59.48"  radiff[ 7]=+0.31 dcdiff[ 7]=+4.27
```

Table 1 An example of (O-C) in right ascention (radiff) and declination (dcdiff) for each chopped images of stars with numbers of 4,5,6, and 7. (O-C) is less than 1" except the 5-th images.

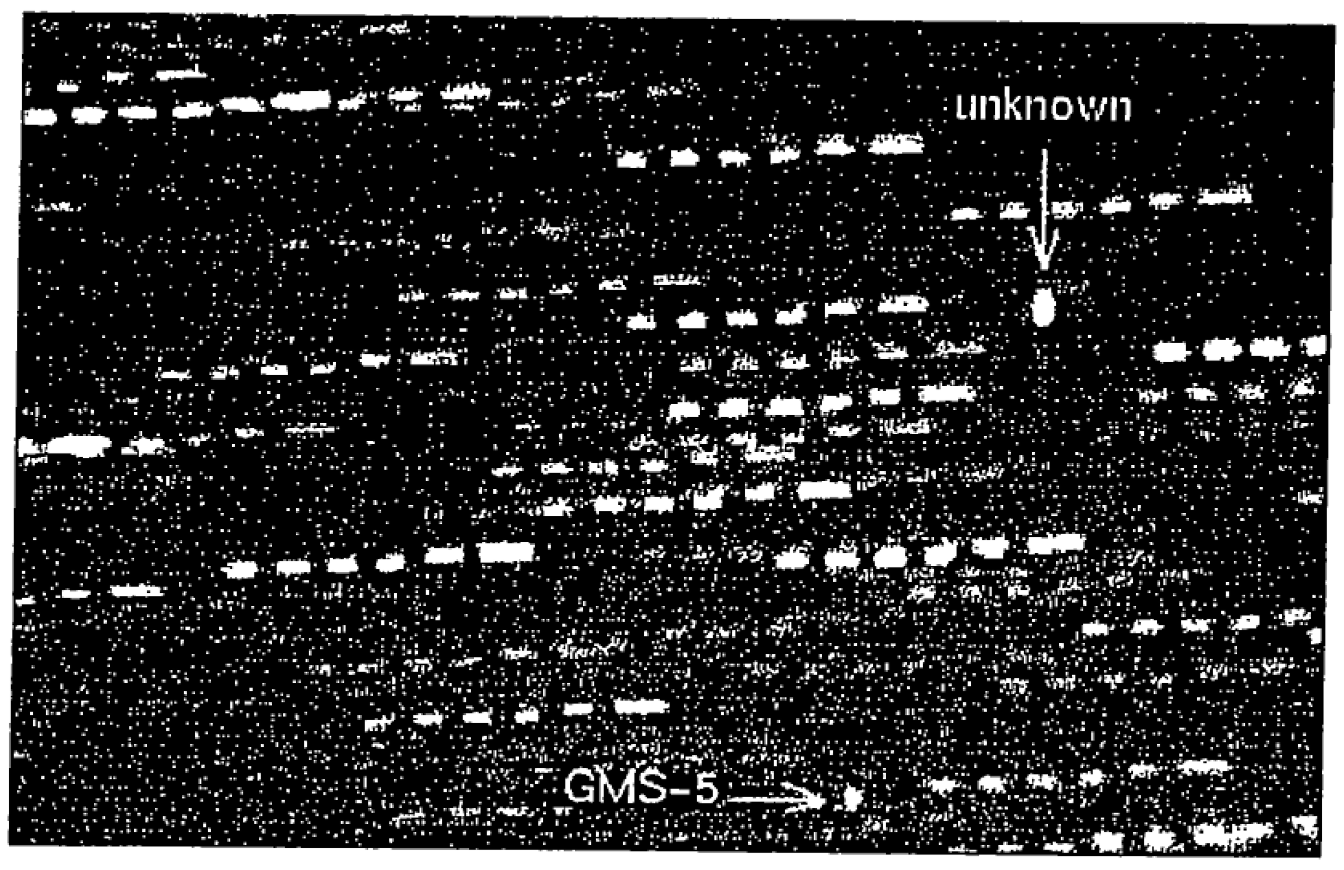

Figure 8 An image includes an unknown geosynchronous object (a dot at the upper part of the image).

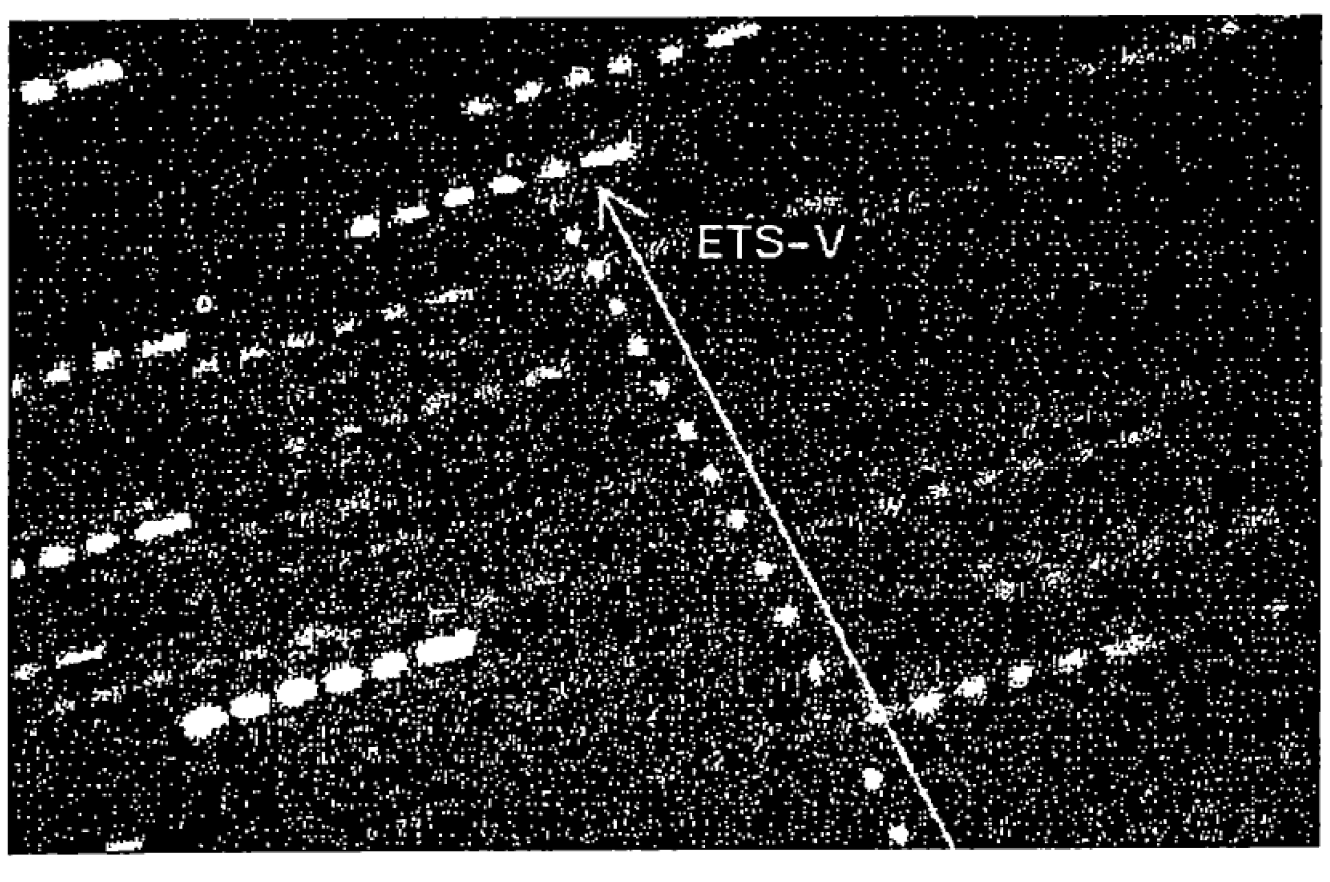

Figure 9 An image combined with 14 image for the ETS-V, from 15h 32m UTC to 16h 00m UTC on January 13, 1997.