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DEVELOPMENT OF ASYMMETRIC MAGNETIC DISTURBANCE FIELDS IN MIDDLE LATITUDES DURING FEBRUARY 1986 STORM

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Abstract

The longitudinally asymmetric geomagnetic disturbances during the February 1986 storm are analyzed using the data from 10 middle latitude stations. Both H and D components are used to derive the asymmetry indices. The amplitude of the asymmetry in H and D is found to be on the same order of magnitude indicating that the field-aligned currents mainly contribute to the mid-latitude asymmetric disturbances rather than the partial ring current. The temporal variation of the asymmetry indices suggests a drastic switching of the large scale magnetospheric current system during the storm after the IMF northward turning.

1. Introduction

The asymmetry of the ring current has been studied using ground geomagnetic data and the partial ring current systems have been proposed (e.g., Fukushima and Kamide, 1973a and references therein). The asymmetry index (ASY) which uses H component only has been proposed and used to monitor the asymmetry of the ring current (Kawasaki and Akasofu, 1971). However, it has been suggested that the field-aligned currents mainly contribute to the asymmetry (e.g., Fukushima and Kamide, 1973b) and the ASY index does not necessarily indicate the development of partial ring current quantitatively. In this study, both H and D components are used to calculate the ASY indices, because the effect of partial ring current should be smaller in D component than in H component, and the comparison of the ASY indices for H and D gives the independent information on the current system.

2. Derivation of ASY Indices

The hourly value data from 10 stations, listed in Table 1, are used to derive the ASY indices. Firstly, the Sq variation is subtracted using the data of five quiet days of the month. The base line for the H–component is determined using the Dst index (Sugiura and Poros, 1971) derived at WDC-C2 for Geomagnetism using the data from 4 stations (i.e. Kakioka, Honolulu, San Juan and Hermanus). Next, the perturbed components (ΔH and ΔD) are calculated for both components and rotated to the dipole direction (ΔH' and ΔD') because the declination (D_0) does not necessarily correspond to the direction of the dipole axis, and a large decrease in H, which is caused by the ring current flowing on the dipole equatorial plane, contaminates the D component. The angle between these two directions is shown in Table 1. To avoid the effects of the latitudinal dependence of the amplitude, a set of coefficients that are multiplied to the level of the disturbance is determined for each station empirically. The difference between maximum and minimum ΔH'(ΔD') is defined as the H–ASY (D–ASY) index. The magnetic local time (MLT) is also calculated for the stations that give the maximum and minimum ΔH' (ΔD'). The symmetric component is also calculated for both components.

Table 1. Stations used for the derivation of the ASY indices. Angle between declination and dipole direction is shown.

Station name	G.M. Lat.	Long.	D_0-dipole D
San Juan (SJG)	29.36	5.21	–8.85
Tucson (TUG)	40.37	314.57	2.74
Papeete (PPT)	–15.09	284.44	0.04
Honolulu (HON)	21.46	268.57	–0.44
Kakioka (KAK)	26.62	207.77	–12.97
Lunping (LNP)	14.21	191.28	–5.33
Tashkent (TKT)	32.51	145.52	12.89
L'Aquila (AQU)	42.52	94.35	15.02
Hermanus (HER)	–33.73	82.67	–10.07
M'Bour (MBO)	20.68	56.80	–2.18

3. Data

Figure 1 (a) and (b) show the ASY indices, the symmetric components, MLTs and Dst indices. Each frame covers 10 days. D–SYM and H–SYM mean the symmetric component for ΔH' and ΔD', and the symbol "+" and "–" mean the MLT of the stations that give maximum and minimum perturbation, respectively. The H–SYM correspond to the Dst index and the Dst index derived from 4 stations is shown by a dotted line for comparison. The dotted line between H–ASY and D–ASY traces indicates the middle point between these indices. The ring current starts to develop around 0900 UT on February 7 and reaches minimum around 0000 UT on February 9. The ASY indices develop roughly 4 times during the main phase, and the last development shows extremely large amplitude (~450 nT for H and 300 nT for D). The asymmetry, however, decreases within a day to the quiet level. The amplitude of the H-ASY and D-ASY is on the same order of magnitude, indicating that the field-aligned currents are the main source of asymmetric disturbances.

There is a tendency that the H–ASY is greater than D–ASY at the early stage of each sharp ASY development. When the asymmetry is large, the MLT of the minimum ΔH' is in the dusk sector and the maximum is near the midnight or the early morning sector. On the other hand, the MLT of the minimum ΔD' is in the morning sector or around noon, and that of the maximum is around midnight. In the early recovery phase (i.e., 0000–1000 UT on February 9), the MLTs of the maximum and the minimum ΔD' (and ΔH') suddenly move, indicating a drastic variation of the current system. The MLT for D–component switches the sign at 0300 UT on February 9. If we assume that the MLT of minimum ΔD' indicates the position of the net field-aligned current flowing into the ionosphere and that the MLT of the maximum ΔD' indicates the position of outward flow, the switching means that the large-scale current system changed its flow direction.

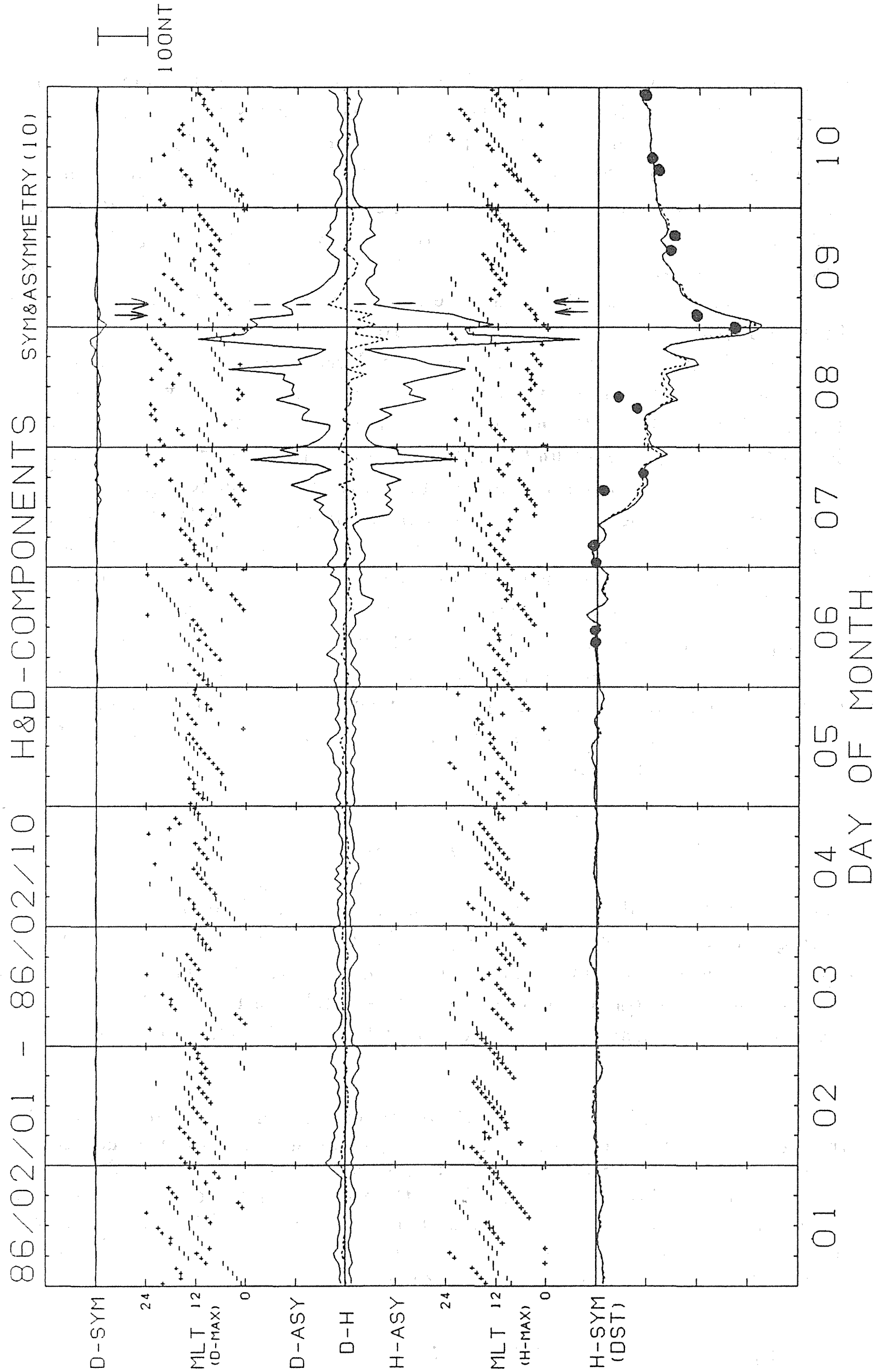
In the late recovery phase (i.e., February 11–14 in Figure 1 (b)), the weak asymmetry continuously exists, suggesting weak particle injection to the ring current region. The distribution of MLT of ΔD' indicates that the net field-aligned currents mainly flow in and out on the dayside in this stage.

4. Discussion

The proposed partial ring current system is constructed from three parts, i.e., the partial ring current which flows on the equatorial plane, the ionospheric current and the field-aligned currents that connect the partial ring current. The ionospheric current, and the center of the partial ring current system has been believed to be in the afternoon sector (e.g., Kamide and Fukushima, 1971; Crooker and Siscoe, 1971). The distribution of the

Fig. 1(a). ASY indices for H and D components (D–ASY and H–ASY), MLTs that give maximum (+) and minimum (−) of asymmetric disturbance components, and symmetric parts (D–SYM and H–SYM). Dst derived at WDC–C2 is shown by dotted line. Solid circle shows the particle energy density observed by AMPTE/CCE satellite (reproduced from Hamilton et al., 1988). The first arrow indicates the time of switching of MLTs of maximum and minimum D and the second indicates the switching in H component. (p. 86)

Fig. 1(b). Same as Figure 1 (a). (p. 87)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100NT
D-SYM
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MLT 12
(D-MAX)
0
D-ASY
D-H
H-ASY
24
MLT 12
(H-MAX)
0
H-SYM
(DST)
01
02
03
04
05
06
07
08
09
10
DAY OF MONTH

Fig. 1(a)

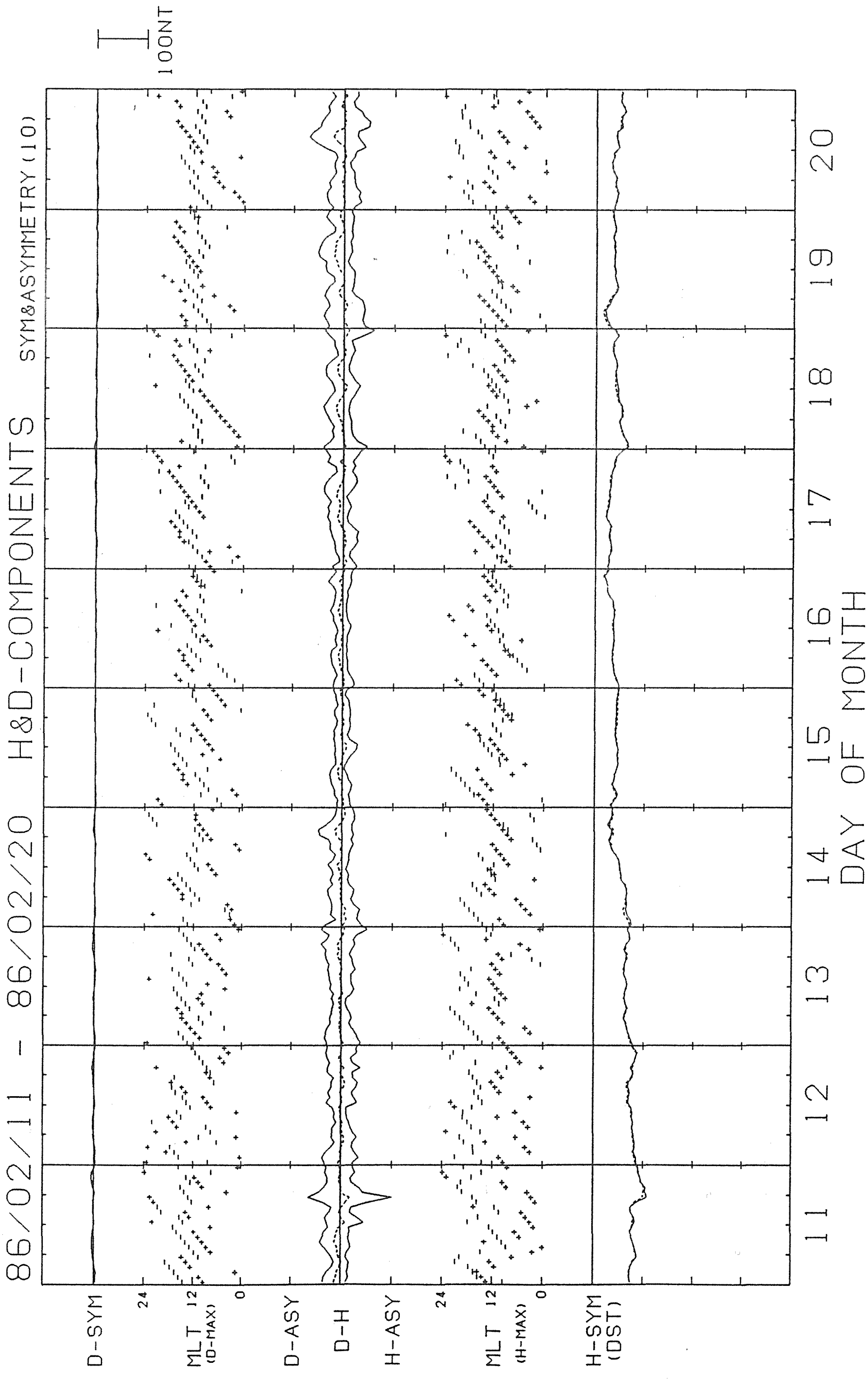
86/02/11 - 86/02/20
H&D-COMPONENTS
SYM&ASYMMETRY(10)
100NT
D-SYM
MLT (D-MAX)
D-ASY
D-H
H-ASY
MLT (H-MAX)
H-SYM (DST)
DAY OF MONTH
11 12 13 14 15 16 17 18 19 20

Fig. 1(b)

minimum ΔH' (i.e., in the dusk sector) supports this idea if we take into account the effect from the enhanced tail current. The distribution of the minimum ΔD' is in the morning sector rather than in the early afternoon sector or around noon during the main phase except the early stage (i.e., 0900–1500 UT on February 7). If the ΔD' indicate the net field-aligned current, this result shows that the net current flows into the ionosphere from the dawn-side and flows out from the evening or the early morning sector. This tendency is sometimes observed in other storm events though not shown here.

After the switching in ΔD' at 0300UT on February 9, the sense of asymmetry in ΔH' remains the same for two hours, though the amplitude of H–ASY rapidly decreases. The amplitude of D–ASY remains at a high level for 3-4 hours. This difference in temporal variation between H and D components indicates that different current systems contribute to mid-latitude asymmetric disturbances and these ASY indices give independent information.

Two hours after the switching, the asymmetry in ΔH' also changes its topology and the maximum shift to the noon from early morning sector. The topology in this stage is consistent with the net current flow from dusk to dawn. The interplanetary magnetic field has a strong northward component in at least some intervals of this stage (i.e., 0600-0700 and 0900-1100UT) when the interplanetary data are available.

The solid circles in Figure 1 (a) show the particle energy density near the noon sector observed by AMPTE/CCE satellite with adjusted scale to the Dst index (reproduced from Figure 3 in Hamilton et al., 1988). When the ASY indices are large, the difference between the plot of adjusted energy density and the Dst index is large, and it is small in the recovery phase when the ASY indices are small. This result means that the ring current is weaker near the noon sector than the average (i.e., Dst) when the ASY indices develop. Thus, the ASY indices do indicate qualitatively the development of partial ring current to a certain extent.

From H–ASY and maximum and minimum ΔH' distribution only, we cannot separate the effect of the field-aligned current from that of the partial ring current. However, using D–ASY and maximum and minimum ΔD' distribution, we can see that the ΔH' distribution is strongly affected by the net field-aligned current and that the maximum of partial ring current is not necessarily in the afternoon sector.

A computer simulation of high-energy (100 keV proton) particle motion in a realistic model of the magnetosphere (Takahashi and Iyemori, 1989) suggests that the particles injected from the tail flow out from the dusk-side of the magnetosphere. Figure 2 shows the particle trajectories of 30 keV energy with the 90^0 pitch angle in the Tsyganenko (1987) model (long version, $Kp = 4$ case). Even with this energy range, protons escape from the dusk-side magnetopause. In this energy range, the particles around 20 MLT contribute most to the observed H decrease on the ground. To understand the complex relationship between ΔH' and ΔD', the effect of such partial ring current, which is not linked to the ionosphere but closed in the magnetosphere and interplanetary space, may be important.

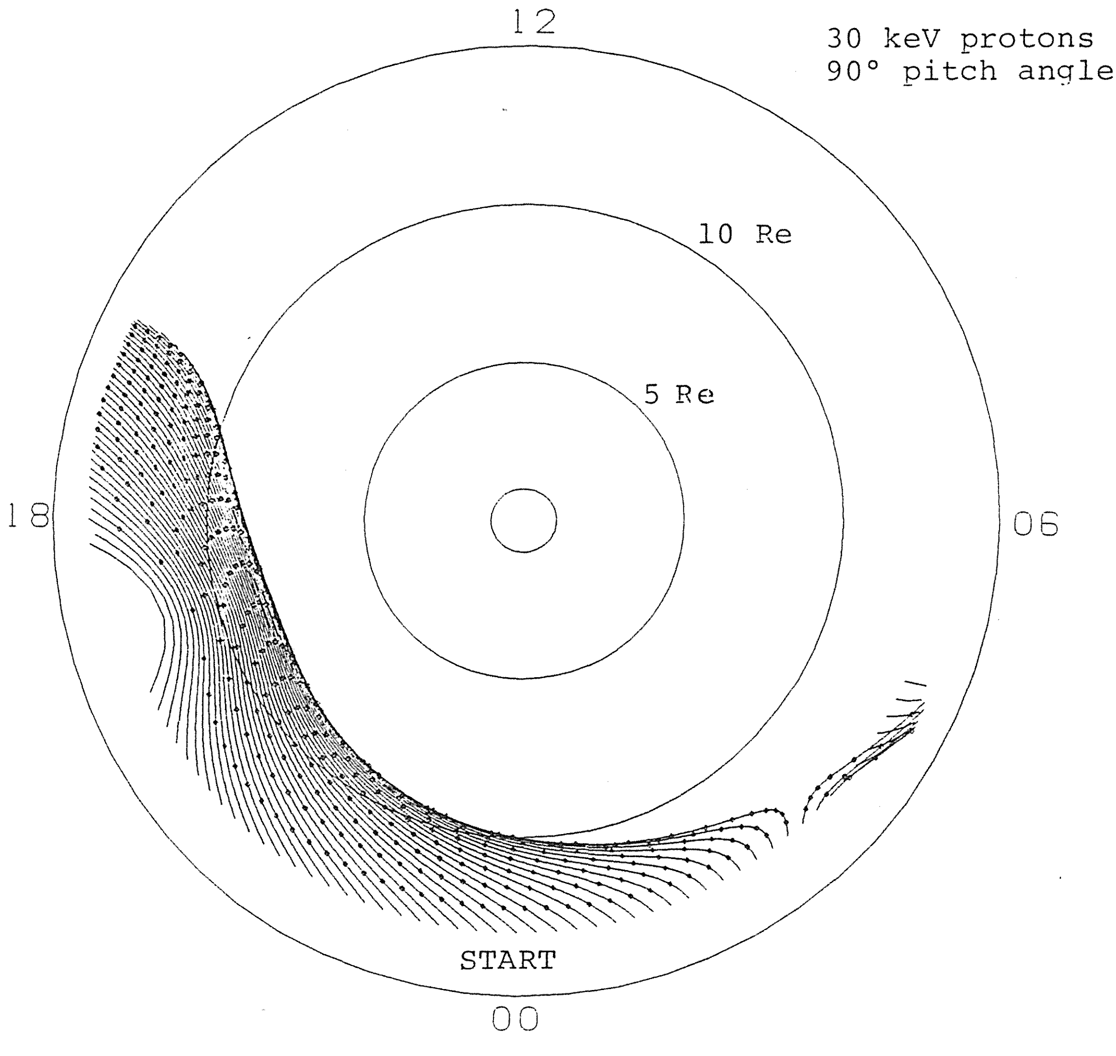

Fig. 2. Proton trajectories of 30 keV, 90° pitch angle particles injected at 13 Re. Tsyganenko (1987) model for $K_p = 4$ is used. The dots indicate the position of the particles every 100 seconds.

Acknowledgments

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