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On aurora australis research

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Abstract This paper consists of two parts. The first part gives an account of reviewing the work already done for the aurora borealis, dealing with arctic explorers and observing station, since International Geophysical Year (IGY) in Antarctic, together with aurora height, brightness, forms and structures, colors and spectroscopy. The second part enumerates six modern problems of aurora australis to be undertaken for Chinese scientific workers during forthcoming years; these are aurora conjugacy, aurora ovals, aurora substorms, methods of treating large amount of data, study of shock-aurora and comparative planetology.
Key words aurora, Antarctica, key problems.

1 Introduction

China has established Changcheng Station in February 1985, and Zhongshan Station in February 1989, located respectively in Antarctica of geographical coordinate (62°13′S, 58°58′W) and (69°22′S, 76°23′E). These two stations will benefit Antarctic research, especially Zhongshan Station will be very useful for some problems of aurora australis research. As well known nowdays, the formation of aurora australis is just same as that of aurora borealis, primarily due to interactions among geomagnetic field, solar wind charged particles and upper atmosphere in the polar region. For the purpose of applying some experiences and lessons in the study of aurora borealis to southern auroral investigations, recently we have made extensive readings to several monographs concerned (Akasofu 1979; Eather 1980; Akasofu and Chapman 1972); this short paper is the outcome of the results. Part 2 of this paper gives historical review on work already done for the aurora borealis. Part 3 list six top problems of aurora australis research to be undertaken for Chinese scientific workers during forthcoming years.

2 Historical review

The aurora borealis is one of the most spectacular natural phenomena. Its beauty and splendor are often beyond description. The aurora borealis has intrigued mankind since ancient times. Early descriptions of the aurora are contained in the Old Testament, in the mythology of the Lapps, the Eskimos and the American Indians as well as Medieval European literature. On many occasions in historical times the aurora has reached as far south as the middle latitudes, and a typical Chinese description of the red aurora is of a "red cloud spreading all over the sky, among the red cloud there were ten-odd bands of white vapour like glossed silk penetrating it". Modern knowledge of aurora borealis has begun a long way. Chiefly from countless polar expeditions and several international coorperative programs. Among polar explorers and famous scientists, we may mention French A. Angot (1848 - 1924), Norwegian scholars F. Nason (1861 - 1930), K. Birkeland (1867 - 1917), C. Störmer (1874 - 1957), and L. Vegard from Oslo, Norway, also S.-I. Akasofu from Alaska, USA. First polar year (1881 - 1882) and second polar year (1930 - 1931) are two international coorperative programs. As regards the study of aurora australis, its history is much later than that of aurora borealis, though southern lights have danced in antarctic skies for just as long as their northern counterpart has in the Arctic. This is because the region of the southern auroral zone is located over the least traveled ocean of the earth and over the only uninhabited continent. Concerning antarctic explorers the following should be mentioned, Russian antarctic explorer T. Bellinghauser (1779 - 1852), English captain navigator and explorer J. Cook (1728 - 1779), another English antarctic explorer R. F. Scott (1868 - 1912, having an ill-fated trip to the south pole), Australian antarctic explorer Sir. D. Mawson(1882 - 1958), and the recently scholar R. H. Eather.

Since the beginning of the IGY of 1957 - 1958 the great increase in antarctic observing stations by different countries led to more auroral research (Liu 1996). Altogether there are 29 stations within 60°S to South pole, among which 17 stations are located between 60° - 70°S, 11 stations within 70° - 80°S, and one station at the South Pole, again nearly half of 29 stations in each western and eastern hemisphere. Referring to Fig. 1 (Liu 1996), the location of different stations for observing aurora australis is shown: station MIR, MOL and VOS from Russia, station SPL and SPA from USA,

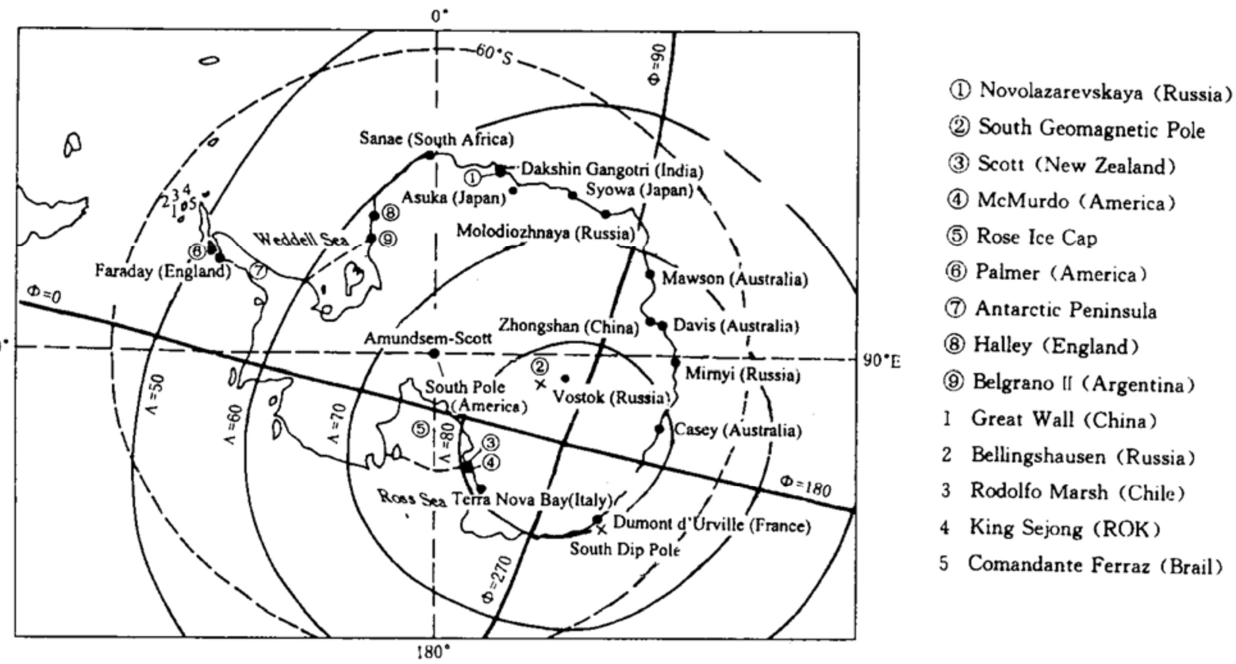

Fig. 1. Stations relevant to the observations of solar-terrestrial physics in Antarctica (Liu 1996).

station CSY and MAW from Australia, station DRV from France, station SNA from South Africa, station SYO from Japan, and station Changcheng and Zhongshan from People's Republic of China.

The height of aurora may be determined by triangulation, i. e. by measuring its elevation from two points a known distance apart. Störmer aslo became a great auroral observer(Egeland and Omholt 1966) , and from 1910 onward he took more than 40000 auroral photographs, more than 9000 sets being taken simultaneously from two stations. Triangulation on these photographs clearly established the range of auroral heights, which he showed averaged 105 - 130 km but could extend as low as 64 km and as high as 965 km. As regards aurora forms, it may be classified into five fundamental ones, i. e. arcs, bands, patches, veils and rays. These five forms commonly exhibit one of three types of structures: homogeneous, or the lack of internal structure, so that the brightness is uniform; striated, where irregular fine striations, filaments, are seen; or rays, where rays appear within forms, such as rayed arcs or bands. When the band exhibits long rays and has an overall folded structures, such auroras are often referred as draperies or curtains. Also when a rayed form is overhead and all rays appear to converge to a point, this is called corona. Finally auroras are also classified according to their temporal behavior into quiet and pulsating, the latter may still subdivided into flickering and flaming types.

Any auroral type may have a large range of brightness, classified between 0 (subvisual) and 4 (very bright) according to the International Brightness Coefficient (IBC). IBC 0 is subvisual, IBC 1 is comparable with Milky Way, IBC 2 is comparable with moonlit cirrus clouds, IBC 3 comparable with moonlit cumulus clouds and IBC 4 is much brighter than 3, casts discernible shadows. There are two rules of thumb: (1) If any color is distinguishable in the aurora, then it must be at least an IBC 2 aurora. (2) If bright stars can no longer be seen through the aurora, it is probably IBC 3 or greater. As to colors of aurora, through the spectroscopic works earlier by A. J. Angstrom (1814 - 1874) and later by L. Vegard, it was found that aurora light is nothing like that of a rainbow. The solar spectrum shows the familiar rainbow colors, a continuous transition red to violet, while the aurora spectrum consists of many lines and bands of different colors with dark space among them. The real cause is due to the interaction of solar wind precipitating particles with upper atmosphere. The lines are emitted by oxygen atoms, yielding green 5577 Å and red 6300 Å lines; the bands are emitted by ionized nitrogen molecules, forming N_2^+ blue and red bands. Aurora colors vary with height; below 96. 5 km of height due to higher density resulting blue and red band of nitrogen molecules; between the height of 96. 5 - 241 km, primary is the green line 5577 Å of oxygen atom; and higher than the height of 241 km, the red line 6300 Å being significant. Thus there are strong emissions in the blue, yellow-green and red regions; these are effectively the primary colors, and mixtures in varying ratios result in the wide variety of hue and color of the aurora.

In all, the variety of shapes, colors, structures, and movements of the aurora are infinite. Like snowflakes, no two are ever quite the same. Early in the 1930s Störmer published his "photographic Atlas of auroral Forms"; it became revised into a new "International Aurora Atlas" edited by F. Jacka and published in 1963 by Edinburgh University Press.

3 Key topics of aurora australis research

Here we enumerate six modern problems of aurora australis to be undertaken for Chinese scientific workers during forthcoming years; these are aurora conjugacy, aurora ovals, aurora substorms, methods of treating large amount of data, study of shock-aurora and comparative planetology.

3. 1 Aurora conjugacy

The remoteness and harsh environment of Antarctica has forced southern hemisphere research on aurora to take back seat to the ongoing vigorous investigations of the northern lights. One problem is the question of auroral conjugacy, i. e. if auroral displays occurred simultaneously at both ends of the geomagnetic field line. With the 1970's came the "Space age" for auroral photography. In 1967 scientists from USA took all-sky photographs simultaneously aboard two jet aircrafts, one flying over Alaska, and one well south of New Zealand. Their results proved (Belon *et al.* 1969) that the aurora borealis and the aurora australis are essentially the same. As stated above, two Chinese antarctic stations Changcheng Station and Zhongshan Station have been established. The conjugate point to the latter station is near Svalbard Island, where installed famous EISCAT Radar. Therefore Zhongshan Station in the south and EISCAT in the north polar regions will be very useful to study the problem of aurora conjugacy.

3. 2 Aurora ovals

Russian scientist Feldstein (1963) discovered in 1963 that auroras are distributed along a narrow band encircling the pole, called the auroral oval which is quite different from the auroral zone. The earth has two auroral ovals, one in each hemisphere. The ovals are not centred on the dipole poles, their centres appreciably shifted toward the dark hemisphere along the midnight meridian. As the auroral ovals fixed with respect to sun, the earth rotates under it once a day. Thus, the geographic pattern under the oval changes as the earth rotates. Thus, unlike the auroral zone, the auroral oval is not fixed at a particular geographic location at all times. The auroral zone is the locus of the midnight part of the auroral oval on the earth as it rotates once a day. The first chart showing the average annual frequency of aurora occurrence are made by E. Loomis in 1860, later revised by E. H. Vestine in 1944. On the contrary the same statistics for southern lights was made later in 1939 (White and Geddes 1939). Note also that the character of the aurora varies with local time, in the evening hours well defined arcs and bands are common, usually green in color; after midnight in the early morning hours the aurora is often patchy, and during the daytime hours the auroras are less bright and usually red in color.

Again the size of the auroral oval is not fixed. During very quiet periods the oval shrinks, contracting toward the poles. During a great magnetospheric storm, both the inner and outer limits of the oval shift equatorward. In concluding this topic it may point out that by the use of the data from Zhongshan Station and South Pole Station (SPA) one may study problem on southern auroral oval.

3. 3 *Aurora substorms*

Based on large amount of all-sky imaging data during IGY, S. -I. Akasofu proposed the developing pattern of the auroral substorm (Akasofu 1964). The auroral substorm not only has close relations to solar disturbance and magnetospheric substorm, but also is associated with magnetic storm in mid-low latitude, and it is a key problem in space physics. Regarding the energy source and triger mechanism of substorm, the common point of view is that substorm includes two processes, i. e. direct driven and loading-unloading. In direct driven process, the solar wind energy directly enter to magnetosphere and upper atmosphere in polar region along magnetic field lines; in loading-unloading process, solar wind energy at first deposit in magnetotail as magnetic energy, then release suddenly to the upper atmosphere in polar region, and lead to a series of strong auroral activities (e. g. auroral bulge, west travelling surge, and so on). So far, various substorm expansion models have been proposed, different model responds for different mechanism, the viewpoint still does not reach consistence. Hence, the triger mechanism and energy transport in processes of auroral substorm is still unsolved problem.

3. 4 *Methods of treating large amount of data*

Earlier mentioned 29 stations have been established since IGY (1957 - 1958) between 60°S circle to South Pole, among which 11 stations making all-sky camera photography, 3 - 6 stations having aurora TV recorders and aurora photometers to make study. Also, several satellites carry instruments for photographing the aurora from high above the polar region. Thus, more than a hundred of these cameras or other devices were installed in the Arctic and Antarctic wideness during the IGY in order to photograph auroras simultaneously once per minute. Now the question arises: how to manage effectively such large amount of data? Methods of processing and analyzing the huge observation data should be undertaken, together with different techniques of time-series and dynamic spectra analysis. In these aspects scanner and computer of very good quality must be used, also taking the advantage of using modern algorithm and model experiments with sound basis in physics.

3. 5 *Study of shock-aurora*

Recently Zhou and Tsurutani (1999) analyzed many interplanetary events where there are both WIND interplanetary data and POLAR UV imaging data. Auroral brightenings (at both day and night sides) being associated with shock arrivals at the magnetosphere have been discussed by few articles. What she found is that not only dayside auroral brightenings occur just after shocks impacting on the magnetopause, but also propagate towards both dawn and dusk flanks at the very fast speed (5 - 15 km/s or higher) as the shocks propagate down tail. This auroral propagation speeds are match with the shock down tail travel speeds. But this fast propagated shock-aurora have never been reported by ground observations. Indeed, this needs further space and ground observations. Perhaps the visible auroral observation for the shock-aurora have to be at right places with both high geographic and magnetic latitude. Svalbard and some portions of Greenland are good for the dayside shock-aurora. Also some high latitude antarctic stations such as Zhongshan Station and others may contribute a bit in the forthcoming years.

3. 6 Comparative planetology

Studies of Earth's auroras of two polar regions may be extended to other planets of our solar system. The existence, location, and colors of auroras on other planets would depend on the strength of the magnetic field and the solar wind charged particles, the density and composition of the atmosphere. Mercury has a relatively strong magnetic field but thin helium atmosphere. The Mariner 10 spacecraft has investigated Mercury and found that auroras should exist between 50° and 57° of latitude on the dayside and between 25° and 35° on the nightside, being very near the planet's surface and being visible in the characteristic spectral emissions of helium. On Venus it is the dense ionosphere and the weak magnetic field, giving widespread diffuse auroras over much of the planet. The light would be familiar oxygen and nitrogen emissions of auroras on earth with the addition of strong CO and CO_2 emissions. Mars has little in the way of either CO_2 atmosphere or magnetic field, leading one to expect little in the way of auroral phenomena above the red planet. On the contrary Jupiter has both a dense atmosphere and a strong magnetic field, it may well host the most spectacular auroras of the solar system. Jupiter's atmosphere is primarily hydrogen and helium, with some methane and ammonia, so the aurora would be expected to be seen in the spectral emissions of these gases. The magnetosphere of Jupiter is some 10 times larger than that of the earth; thus Jupiter's nightside will exhibit fantastic shapes of shimmering auroras, later being confirmed by Voyager mission taking a photograph of an aurora around its north pole in March 9, 1979.

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References

Akasofu S-I(1979): Aurora Borealis. Alaska Geographic, 6(2): 1 - 95.

Akosofu S-I, Chapman S(1972): Solar-Terrestrial Physics. Oxford: Oxford University Press, 655 - 716.

Akasofu S-I(1964): The development of the auroral substorm. Planet. Space Sci., 12: 273 - 282.

Belon AE, Maggs JE, Davis TN, Mather KB, Glass NW, Hughes GF(1969): Conjugacy of visual auroras during magnetically quiet periods. J. Geophys. Res., 74: 1 - 28.

Eather RH(1980): Majestic Lights. Washington D. C.: American Geophysical Union.

Egeland A, Omholt A(1966): Störmer's height measurements of aurora. Oslo: Geophys., 26(6).

Liu RY(1996): Advances in China in the study of solar-terrestrial physics in Antarctica. In: Xu Wenyao, ed. Geomagnetism Atmosphere Space Researches and Applications, Beijing: Seismological Press, 125 - 136

Feldstein YI(1963): Some problems concerning the morphology of auroras and magnetic disturbances at high latitudes. Geomagn. Aeron, 3:183 - 185.

Zhou XY, Tsurutani BT(1999): Rapid intensification and propagation of the dayside aurora: large scale interplanetary pressure pulse (fast shocks). Geophys. Res. Lett., 26: 1097.

White FWG, Geddes M(1939): The Antarctic zone of maximum auroral frequency. Terr. Magn. Atmos. Elec., 44: 367 - 370.