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SPECTRAL STUDIES OF THE K–F CORONA INTERFACE AT 5000–6000 Å

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Abstract. Studies of the inner regions of the Solar System remain limited, despite their importance for understanding interplanetary matter and the near-Sun environment. The region extending from the solar corona to Earth’s orbit, including the zodiacal light and the inner Zodiacal Cloud, has been studied only fragmentarily, although it hosts key processes transforming cometary—asteroidal material into dust and gas. The aim of this work is to investigate near-Sun dust by determining its line-of-sight velocities in the transition region between the solar corona and the zodiacal light at heliocentric distances from 3R to 16R, with emphasis on dust dynamics and its relation to the electron corona. The proposed method is spectroscopic observations using a small space telescope equipped with a spectrograph operating in the wavelength range $\lambda = 5000\text{--}6000\text{ \AA}$. This range enables analysis of key diagnostic lines: the Mg I triplet ($\lambda 5167\text{--}5184\text{ \AA}$) for dust velocity measurements; the Fe XIV green emission line ($\lambda 5303\text{ \AA}$) from the electron corona, also serving as a wavelength reference; and the Na I doublet ($\lambda 5890\text{--}5896\text{ \AA}$) for dust diagnostics and detection of atomic emissions from disrupted small bodies. The expected results include improved determination of dust particle sizes and the radial distribution of near-Sun dust concentration compared to the Parker Solar Probe experiment (Szalay et al., 2024). The practical significance lies in advancing remote spectral diagnostics of near-Sun dust and supporting future space experiments focused on the inner Solar System.

Keywords: F-corona, dust, Zodiacal Cloud, comets, radial velocities



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5000–6000 Å ДИАПАЗОНЫНДА К- ЖӘНЕ F-КОРОНАЛАР АРАСЫНДАҒЫ ӨТПЕЛІ АЙМАҚТЫ СПЕКТРЛІК ЗЕРТТЕУ

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Аннотация. Күн жүйесінің ішкі аймақтарын зерттеу олардың планетааралық зат эволюциясын және околосолнечтік ортаны қалыптастыратын процестерді түсінудегі маңызды рөліне қарамастан әлі де жеткіліксіз. Күн коронасынан Жер орбитасына дейінгі кеңістік, яғни зодиақтық жарық пен Зодиақтық бұлттың ішкі бөлігі, бүгінгі күнге дейін тек фрагментарлы түрде зерттелген. Дәл осы аймақта кометалық-астероидтық текті заттың шаң және газ фазаларына ауысуы сияқты іргелі процестер жүреді, алайда олар бақылауға нашар қолжетімді және тек жекелеген эксперименттер аясында ғана тіркелген. Бұл жұмыстың мақсаты — Күн коронасы мен зодиақтық жарық арасындағы өтпелі аймақта, Күннен 3R—16R аралығындағы гелиоцентрлік қашықтықтарда, околосолнечтік шаңның сәулелік жылдамдықтарын анықтау арқылы оның физикалық қасиеттерін зерттеу. Ерекше назар шаң компонентінің динамикасына және оның электрондық коронамен байланысына аударылады. Негізгі әдіс ретінде $\lambda = 5000\text{--}6000 \text{ \AA}$ толқын ұзындықтары диапазонында жұмыс істейтін спектрографпен жабдықталған шағын ғарыштық телескопты қолданатын спектроскопиялық зерттеу ұсынылады. Бұл спектрлік диапазон бірнеше маңызды диагностикалық сызықтарды бір мезгілде талдауға мүмкіндік береді: Mg I триплеті ($\lambda 5167\text{--}5184 \text{ \AA}$) шаң коронасының сәулелік жылдамдықтарын анықтау үшін, Fe XIV электрондық коронасының жасыл эмиссиялық сызығы ($\lambda 5303 \text{ \AA}$) толқын ұзындығының тірек сызығы ретінде, сондай-ақ Na I дублеті ($\lambda 5890\text{--}5896 \text{ \AA}$) шаңды диагностикалау және кіші денелердің ыдырауы нәтижесінде пайда болатын атомдық эмиссияларды іздеу үшін қолданылады. Күтілетін нәтижелерге Parker Solar Probe экспериментімен (Szalay et al., 2024) салыстырғанда шаң бөлшектерінің өлшемдерін және

околосолнечтік шаң концентрациясының радиалдық таралуын анағұрлым дәл анықтау жатады. Жұмыстың практикалық маңыздылығы околосолнечтік шаңды қашықтан спектрлік диагностикалау әдістерін дамытуда және Күн жүйесінің ішкі аймағын зерттеуге арналған болашақ ғарыштық эксперименттер үшін ғылыми негіз қалыптастыруда көрінеді.

Түйінді сөздер: F-тәж, шаң, Зодиактық бұлт, кометалар, сәулелік жылдамдықтар

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СПЕКТРАЛЬНЫЕ ИССЛЕДОВАНИЯ ОБЛАСТИ ПЕРЕХОДА МЕЖДУ К И F КОРОНОЙ В ДИАПАЗОНЕ 5000–6000 Å

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Аннотация. Исследования внутренних областей Солнечной системы остаются крайне ограниченными, несмотря на их ключевую роль в понимании эволюции межпланетного вещества и процессов, формирующих околосолнечную среду. Пространственная область от солнечной короны до орбиты Земли, включающая зодиакальный свет и внутреннюю часть Зодиакального облака, до настоящего времени изучена фрагментарно. Именно в этой зоне происходят фундаментальные процессы трансформации вещества кометно-астероидного происхождения в пылевые и газовые компоненты, которые слабо доступны для наблюдений и известны лишь по отдельным экспериментам. Целью данной работы является исследование физических свойств околосолнечной пыли на основе определения её лучевых скоростей в переходной области между солнечной короной и зодиакальным светом на гелиоцентрических расстояниях 3R–16R. Особое внимание уделено динамике пылевой компоненты и её связи с электронной короной. Основным методом исследования предлагается спектроскопия с использованием небольшого космического телескопа, оснащённого спектрографом, работающим в диапазоне $\lambda = 5000–6000$ Å. Этот диапазон позволяет одновременно анализировать несколько диагностически значимых линий: триплет Mg I ($\lambda 5167–5184$ Å) для определения лучевых скоростей пылевой короны, зелёную эмиссионную линию Fe XIV ($\lambda 5303$ Å), применяемую также как опорную линию, и дублет Na I ($\lambda 5890–5896$ Å), чувствительный к присутствию атомарных эмиссий, возникающих при разрушении малых тел. Ожидаемые результаты включают более точное

определение размеров частиц и радиального распределения концентрации околосолнечной пыли, чем в эксперименте Parker Solar Probe (Szalay et al., 2024). Практическая значимость работы заключается в развитии методов дистанционной спектральной диагностики околосолнечной пыли и создании научной основы для будущих космических миссий, направленных на изучение внутренней области Солнечной системы.

Ключевые слова: F- корона, пыль, Зодиакальное облако, кометы, лучевые скорости

Introduction. The dust or Fraunhofer corona (F-corona) was discovered long ago, during the total solar eclipse of December 12, 1871. Dark absorption lines, or Fraunhofer lines, were visually detected by Pierre Janssen (Janssen, 1883) in the spectrum of the solar corona. During the 1883 eclipse, he succeeded in photographing the spectrum of the F-corona. Based on his observations, he concluded that dust particles reflecting sunlight were present in the solar corona. Later, Grotrian (1934) proposed a common origin for the F-corona and the zodiacal light. It is evident that as zodiacal dust approaches the Sun, it must sublimate at some critical distance.

Observations of the radial velocities of dust in the F-corona remain scarce due to the experimental challenges involved. Attempts to measure Doppler shifts of absorption lines using spectrographs were largely unsuccessful because of insufficient measurement precision. The short duration of eclipses and the absence of sensitivity-enhancing equipment made it impossible to conduct such experiments in the first half of the 20th century.

1) The first successful observations of dust radial velocities in the F-corona were carried out during the solar eclipse of June 30, 1973, at an elongation of $7.5R_{\odot}$ west of the Sun (Kozlov, 1974). A Fabry–Pérot spectrometer with pneumatic spectral scanning was used in the observations near the strong absorption line of Mg I at $\lambda 5184 \text{ \AA}$. After accounting for the profile of the corresponding Fraunhofer line from the daylight sky, the measured radial velocity west of the Sun was found to be $+50 \text{ km/s}$. This result implies that the interplanetary dust along the line of sight is orbiting the Sun in the same direction as the planets.

2) Later, during the solar eclipse on February 26, 1979, radial velocities were measured at distances of $3.2R_{\odot}$ and $4.3R_{\odot}$ west of the Sun using a radial velocity correlation spectrometer (Beavers et al., 1980). The correlation spectrometer enables simultaneous scanning of the profiles of multiple spectral lines within a selected wavelength interval. In practice, this yields a composite velocity profile based on the sum of all lines, each of which may be indistinguishable individually. The resulting data revealed a common feature in both velocity profiles—a negative velocity of -50 km/s . At the $4.3R_{\odot}$ distance, the velocity profile also exhibited an additional peak of $+230 \text{ km/s}$. To interpret the findings, the authors proposed a simple two-component model of near-solar dust: one component consisting of dust moving along straight orbits beyond the region starting at $4R_{\odot}$, and a second component of dust falling toward the Sun with velocities ranging from -50 to -250 km/s .

Methods, materials and results. The task of observing not merely isolated points in the F-corona, but obtaining a two-dimensional map—i.e., a full field of radial velocities—was first formulated and implemented during the total solar eclipse of July 31, 1981 (Shcheglov et al., 1987). Observations of the dust radial velocity field in the outer solar corona at distances from 3 to $7.5R_{\odot}$, based on the Doppler shift of absorption lines, were carried out under the supervision of Professor P.V. Shcheglov (Moscow State University (MSU)). The expedition team, which included scientists from both MSU and FAI, was stationed in the village of Shortandy, Akmola region, in northern Kazakhstan. The experimental setup included a coronagraph with an artificial Moon blocking the inner corona up to $2.5R_{\odot}$, an interference filter (IF) with a half-width of 14 \AA tuned to the Mg I $\lambda 5184 \text{ \AA}$ line, a Fabry–Pérot etalon placed in the exit pupil, a fast ($f/1.5$) camera lens with an image intensifier (IIT), and 103aG photographic film for registration.

At the time, such an experiment seemed nearly impossible. Given the short duration of totality (only 75 seconds), achieving a spectral resolution of $\sim 0.5 \text{ \AA}$ for the dusty corona was considered unrealistic. The task required the development of a specialized spectral instrument—a spectrograph based on a Fabry–Pérot interferometer. The full field of view of the instrument reached 3.5 degrees. The results were obtained an interferogram as a concentric ring centered on the Sun, corresponding to Fraunhofer lines in the green region of the solar spectrum (around Mg I $\lambda 5184 \text{ \AA}$), which contained information on the Doppler velocities of near-Sun dust. For the first time, a full velocity field was obtained rather than a few point measurements in the F-corona at distances from 3 to $7 R_{\odot}$. Data analysis revealed that dust near the ecliptic plane was dominated by particles on direct Keplerian orbits. Additionally, retrograde-moving dust was detected—its origin was attributed to a retrograde comet that had fallen into the Sun about 10 days before the eclipse (Shcheglov et al., 1987). However, some features of the observed radial velocities remain unexplained, particularly the origin of the northern polar outflow with a radial velocity of approximately $+150 \text{ km/s}$.

A second successful attempt to observe the radial velocity field in the F-corona was made during the total solar eclipse on July 11, 1991 (Aimanov et al., 1995), in Mexico. For this campaign, FAI developed two identical coronagraphs for the green (around Mg I $\lambda 5184 \text{ \AA}$) and blue (around Ca II $\lambda 3933 \text{ \AA}$) spectral regions. The field of view was expanded to 5 degrees. Unfortunately, the exposure time was insufficient to fully implement the plan; data were obtained only in the inner region up to $6 R_{\odot}$ using the "blue" coronagraph. The new observations confirmed earlier results from the 1981 eclipse: the existence of a dust-free zone around the Sun at distances of $6\text{--}7 R_{\odot}$ and the finding that dust particles near the Sun were approximately $0.5 \mu\text{m}$ in size—nearly two orders of magnitude smaller than the "average" zodiacal cloud particles (Leinert, 1975).

In addition to the FAI group, similar research was conducted by colleagues from the United States, W.I. Beavers and J.J. Eitter, who happened to be at the same observing site in Mexico as the FAI team. As in 1979, they employed Griffin's mask correlation technique. In 1979, they obtained radial velocity profiles at only two locations. In 1991, they acquired a series of 12 radial velocity measurements of the solar corona in the 400–

440 nm spectral range, both west and east of the Sun, from $2.5R_{\odot}$ to $5 R_{\odot}$ along the celestial equator, and at three positions north of the Sun. Their findings were published only in 2009 (Beavers and Eitter, 2009). They concluded that the near-Sun component of the F-corona is relatively weak, contributing only 7–14% of the total volume. A stronger diffraction component from the near-Earth F-corona, with zero Doppler shift, dominated the line profiles. They also detected a high-velocity redshifted outflow at 330 km/s.

After a long break, successful observations of the dust radial velocity field in the F-corona were once again carried out in Kazakhstan under excellent weather conditions near the village of Mugalzhur, Aktobe region, during the total solar eclipse of March 29, 2006. These observations were repeated shortly thereafter due to the eclipse path on August 1, 2008, also passing close to the region. The second campaign was conducted near Barnaul, Russia, using nearly identical instrumentation. In both cases, interferometric observations of the radial velocity field of dust in the F-corona were conducted at distances from 3 to $11 R_{\odot}$ using a coronagraph with a Fabry–Pérot etalon and an interference filter placed in the exit pupil. The region within $2.5R_{\odot}$ was blocked by a mask placed on the field lens, whose flat surface was aligned with the primary image of the corona. The difference in the optical layout between the 2008 setup and the 2006 setup consisted solely of replacing the interference filter. In 2006, an interference filter with a half-width of 10 \AA tuned to the Mg I $\lambda 5172 \text{ \AA}$ line was used, while in 2008, an interference filter with a half-width of 20 \AA and maximum transmission at $\lambda 5202 \text{ \AA}$ was employed. An Apogee Alta-10 CCD camera with $14 \mu\text{m}$ pixel size was used for image capture. The Fabry–Pérot etalon produced concentric spectral rings, with the wavelength of each ring decreasing as its radius increased. By measuring the ring radius at each point in the field of view, one can determine the wavelength, and thus the integrated Doppler velocity of dust along the line of sight. A summary of the results from these two eclipses is presented in Shestakova and Demchenko (2016).

As an example, Figure 1 shows the original image of a working frame obtained during the 2006 eclipse, along with its transformations at two processing stages.

A comparison of the radial velocity observations of near-Sun dust up to $11R_{\odot}$ during the total eclipses of March 29, 2006, and August 1, 2008, revealed that the dust varies in composition and is dynamically inhomogeneous from year to year. During the 2006 eclipse, it was found that there was virtually no dynamical connection with the ZC (Figure 2). The dust motion on March 29, 2006, was directed opposite to planetary motion and had a significant inclination to the ecliptic plane. These results suggest a genetic link between the observed dust orbital motion and Kreutz-group comets observed near the Sun around the eclipse date. In contrast, the 2008 eclipse revealed classical zodiacal dust concentrated near the ecliptic plane (Figure 3).

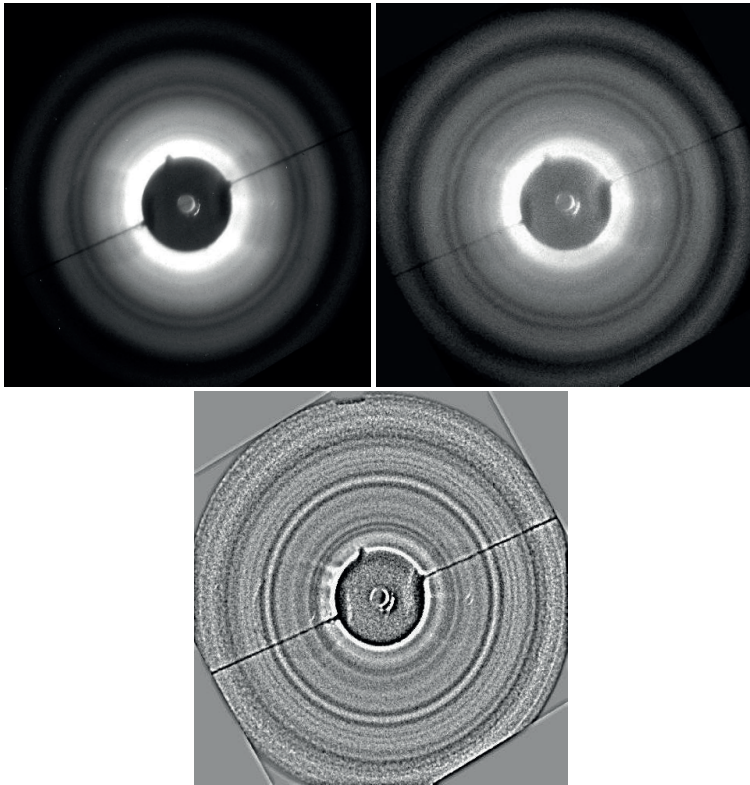


Figure 1. 130-second interferogram of the near-Sun region from March 29, 2006, shown at different processing stages: the raw frame, the frame corrected for the field function, and the fully corrected frame after mathematical processing.

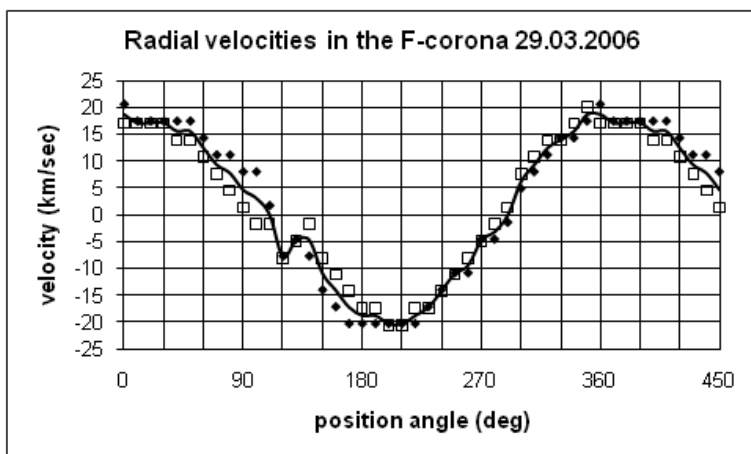


Figure 2. Radial velocities of dust in the F-corona on March 29, 2006. N corresponds to 0° , E to 90° , S to 180° , and W to 270° . The range from 360° to 450° represents a repetition of the initial 0° — 90° segment. Open squares and filled diamonds indicate two different processing methods using images of the daytime sky taken before and after the eclipse. The solid line represents the average between the two methods.

Zodiacal dust moving along classical orbits in the direction of planetary rotation is expected to exhibit positive radial velocities west of the Sun (270°) and negative velocities to the east (90°), as shown in the eclipse observations from August 1, 2008, in Figure 3. In contrast, Figure 2 presents the results from the March 29, 2006, eclipse, where cometary dust dominates the near-Sun region, moving across the ecliptic plane. The influence of zodiacal dust appears only as a slight negative deviation on the eastern side (around 120°) and a more pronounced rise on the western side between 270° and 300° . Bsol

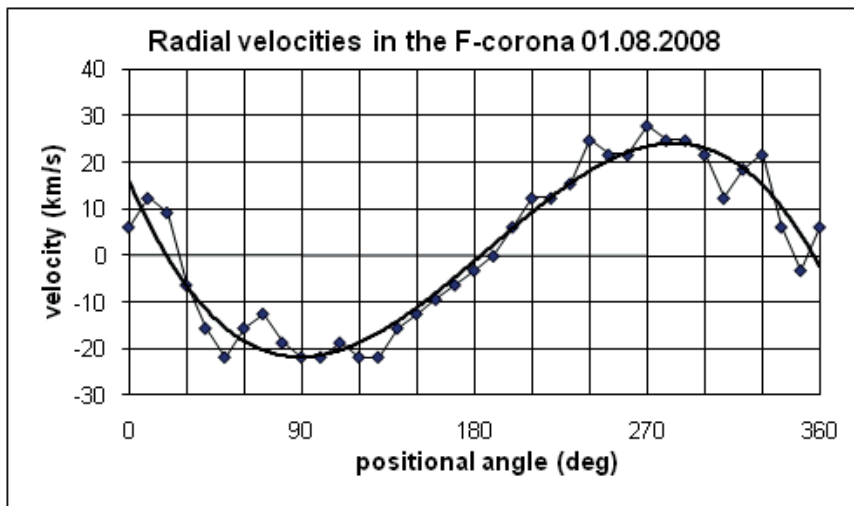


Figure 3. Radial velocities of dust in the F-corona on August 1, 2008. 0° corresponds to the north ecliptic pole; E = 90° , S = 180° , W = 270° . The bold curve represents a fourth-order polynomial fit to the data.

To date, due to the exceptional difficulty of such experiments, no new observational data on dust dynamics in the near-Sun region have been obtained. The most recent results worth mentioning come from the Parker Solar Probe space mission (Szalay et al., 2024), which traversed the innermost regions of the ZC. Contrary to previous expectations, the mission revealed that most of the dust mass is concentrated in very fine particles with radii of approximately $0.6\text{--}1.4\ \mu\text{m}$, rather than $10\text{--}100\ \mu\text{m}$ as previously assumed (Leinert, 1975). In our own eclipse experiments following the 1981 campaign, we determined particle radii of approximately $0.4\text{--}0.5\ \mu\text{m}$ and a power-law exponent of the dust concentration variation with distance of $\alpha = 1.1$ (Shcheglov et al., 1987). Based on the 2008 eclipse data, we derived an average particle radius of $1.15\ \mu\text{m}$ and an exponent of $\alpha = 1.08$ (Shestakova and Demchenko, 2016), which closely agrees with the Parker Solar Probe findings (Szalay et al., 2024). Only in 2006, when the near-Sun region was filled with cometary dust, did the power-law exponent α appear significantly steeper at $\alpha = 2.2$, while the particle radii remained in a similar range of about $0.9\ \mu\text{m}$.

Discussion. Existing knowledge of the dust corona brightness is largely based on observational syntheses and eclipse measurements. The study by Kimura and Mann

(1998) presents a composite graph of the brightness of the solar corona and the zodiacal light, compiled from observations by various authors (Figure 4), providing a unified view of brightness variations across the near-Sun region. Complementary results were obtained from observations of sky brightness conducted by specialists of the Fesenkov Astrophysical Institute during total solar eclipses, as well as in the periods immediately before and after the eclipses (Shestakova and Demchenko, 2010). These measurements offer valuable constraints on the spatial distribution and brightness of the dust corona and its contribution relative to other coronal components.

Table 1. Sky brightness during the total solar eclipse on March 29, 2006, and of the daytime sky before and after the eclipse.

| File/elongation | 4.0R _☉ | 4.4R _☉ | 10R _☉ | 10R _☉ |
|--------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Eclipse | $4.92 \times 10^{-9} B_{\odot}$ | $4.70 \times 10^{-9} B_{\odot}$ | $2.85 \times 10^{-9} B_{\odot}$ | $2.86 \times 10^{-9} B_{\odot}$ |
| Day sky 1 (before) | $4.58 \times 10^{-5} B_{\odot}$ | $3.62 \times 10^{-5} B_{\odot}$ | $3.41 \times 10^{-5} B_{\odot}$ | $2.61 \times 10^{-5} B_{\odot}$ |
| Day sky 2 (after) | $1.82 \times 10^{-5} B_{\odot}$ | $2.16 \times 10^{-5} B_{\odot}$ | $1.47 \times 10^{-5} B_{\odot}$ | $1.43 \times 10^{-5} B_{\odot}$ |
| Day sky 1/eclipse | 0.93×10^4 | 0.77×10^4 | 1.20×10^4 | 0.91×10^4 |
| Day sky 2/eclipse | 0.37×10^4 | 0.46×10^4 | 0.52×10^4 | 0.50×10^4 |

The observations of the March 29, 2006, eclipse were conducted under excellent weather conditions. The brightness measurement errors at the edge of the field of view (10R_☉) for the eclipse image reached up to 30%, while the errors for the remaining measurements remained within 5–10%.

As seen from Table 1, at a distance of approximately 4R_☉, the coronal brightness exceeds the background sky brightness far from the Sun (at 10 R_☉) by a factor of about 1.7. Moreover, at the field edges (10 R_☉), the background sky in both the western and eastern parts remains constant during the eclipse: $B(\text{eclipse}) \approx 2.9 \times 10^{-9} B_{\odot}$. This value closely matches the eclipse sky line in Figure 4, where $B(\text{eclipse}) \approx 1 \times 10^{-9} B_{\odot}$. The last two rows of Table 1 allow us to estimate the difference between daytime and eclipse sky brightness. The brightness ratios $B(\text{day sky} / \text{eclipse})$ are within the range 0.37×10^4 to 1.20×10^4 . These estimates may be valuable for ground-based testing of instruments intended for space-based observations. Also of interest are the data in Tables 2 and 3, which present the results of sky brightness measurements during the total solar eclipse of August 1, 2008 (Table 2), and comparative results from both eclipses on March 29, 2006, and August 1, 2008 (Table 3).

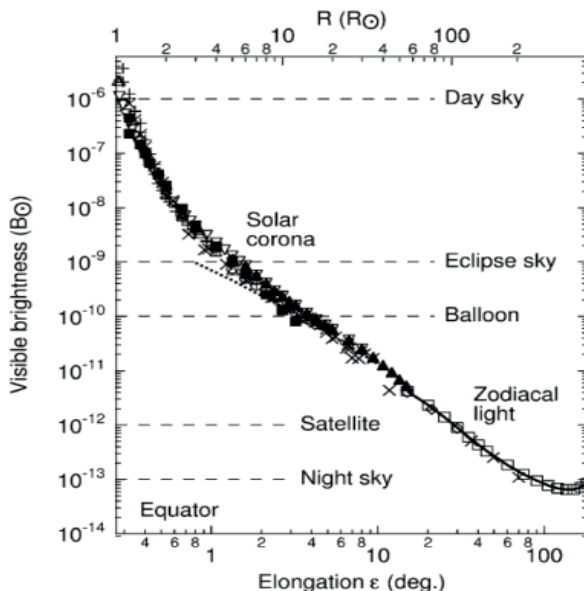


Figure 4. The visible brightness of the solar corona in the equatorial plane of the Sun as a function of elongation, expressed in units of the solar disk brightness.

Table 2. Sky brightness during the total solar eclipse on August 1, 2008, and of the daytime sky after the eclipse.

| | | | | |
|------------------|--|--|--|--|
| File/elongation | 4.9 R _☉ | 4.1 R _☉ | 10 R _☉ | 10 R _☉ |
| Eclipse | 1.32 · 10 ⁻⁸ B _☉ | 1.26 · 10 ⁻⁸ B _☉ | 0.90 · 10 ⁻⁸ B _☉ | 1.24 · 10 ⁻⁸ B _☉ |
| Day sky | 6.54 · 10 ⁻⁵ B _☉ | 5.70 · 10 ⁻⁵ B _☉ | 4.60 · 10 ⁻⁵ B _☉ | 5.21 · 10 ⁻⁵ B _☉ |
| Day sky /eclipse | 0.50 · 10 ⁴ | 0.45 · 10 ⁴ | 0.51 · 10 ⁴ | 0.42 · 10 ⁴ |

Table 3. Ratio of sky brightness values for the solar eclipses: B_☉ (2008) / B_☉ (2006)

| | | | | |
|---|----------------|--------------------|-------------------|------------------|
| File/elongation | 4.9 R/4.0 R(E) | 4.1 R _☉ | 10 R _☉ | 10R _☉ |
| Eclipse2008/eclipse2006 | 2.68 | 2.68 | 3.16 | 4.33 |
| Sky(2008)/ Sky2 (2006) | 3.59 | 2.64 | 3.13 | 3.64 |
| (Day sky /eclipse)2008/ (Day sky /eclipse)2006 | 1.34 | 0.99 | 0.99 | 0.84 |

The observation of the August 1, 2008, eclipse was carried out about an hour after cloud cover had passed. The sky was noticeably brighter than during the 2006 eclipse. As seen in Table 3, the sky brightness during the 2008 eclipse was approximately B(eclipse) ≈ 10⁻⁸ B_☉, which is about five times higher than during the 2006 eclipse and an order of magnitude greater than the eclipse sky brightness shown in Figure 4. Particular attention should be given to the Day sky / Eclipse ratio in the last row of Table 3. Despite the differences in weather conditions between the two eclipse events, the ratio B (Day sky / eclipse)2008/ B (Day sky /eclipse)2006 ≈ 1. This result is important, for example, when planning and preparing future total solar eclipse observations. *Auxiliary Tasks:*

1) *Observation of the Green Coronal Line Fe XIV at $\lambda 5303 \text{ \AA}$.*

In addition to the above-discussed observations of radial velocities during solar eclipses using the Mg I absorption triplet ($\lambda 5167\text{--}5184 \text{ \AA}$), it is worth noting an emission line that appeared in the final frame taken 20 seconds before the end of totality. In both 2006 and 2008, a bright emission line was observed in the form of three rings corresponding to three interference orders. This bright line, seen in the scattered light of the eclipse sky, is likely associated with the strongest emission line of thirteen-times-ionized iron, Fe XIV, from the electron corona at $\lambda 5303 \text{ \AA}$. This emission was used as a reference line for radial velocity measurements. Thus, the green coronal line, in addition to being an indicator of coronal activity, can serve as a wavelength reference line.

2) *Observation of the Sodium Doublet Na I, $\lambda 5890\text{--}5896 \text{ \AA}$.*

As for the Na I doublet at $\lambda 5890\text{--}5896 \text{ \AA}$, FAI specialists have experience observing its emission during the NASA experiment known as the DART mission (Shestakova et al., 2023). At the moment of impact between the spacecraft and the asteroid Dimorphos, spectral observations of the Didymos—Dimorphos asteroid pair were conducted using the AZT-20 telescope at the Assy-Turgen Observatory. During and immediately after the collision, emission lines of alkali metals—Na, K, and Li—were detected in the spectra. Thus, observations of the sodium doublet can be used both for determining dust radial velocities and for detecting atomic emissions resulting from the disruption of small bodies.

3) *Search for Oxygen Emission at $\lambda 5577 \text{ \AA}$ in Earth's Atmosphere as Earthquake Precursors.*

Solving the problem of earthquake forecasting is of paramount importance and requires no justification of its significance. Observing the Earth's nighttime hemisphere from space in the oxygen O I emission line at a wavelength of $\lambda 5577 \text{ \AA}$ offers a way to test the hypothesis that fluctuations in the nightglow of Earth's atmosphere at this wavelength may serve as precursors to earthquakes. To carry out such observations, a small-aperture telescope equipped with a spectrograph capable of recording the $\lambda 5000\text{--}6000 \text{ \AA}$ range in a single frame can be used to scan the nighttime hemisphere of Earth. A spectrograph slit length of 20—30 arcminutes would be sufficient to cover the entire visible disk of the Earth. *Capabilities of Space-Based Observations and Instrument Selection.* Based on the observational experience described above in the $\lambda 5000\text{--}6000 \text{ \AA}$ spectral region, we propose a program of comprehensive spectral studies at the interface between the electron and dust components of the corona (the K- and F-corona).

The background zodiacal light brightness in the ecliptic plane at a distance of $50 R_{\odot}$ (12.5° elongation) from the Sun is about $10^{-11} B_{\odot}$ (see Figure 1), which is two orders of magnitude fainter than the sky brightness during a solar eclipse. Ideally, spectral observations in the $\lambda 5000\text{--}6000 \text{ \AA}$ range should be conducted starting from $4R_{\odot}$ and extending as far as the instrument sensitivity allows. The region up to $16 R_{\odot}$ corresponds to the sublimation zone for dust of various chemical compositions. Using slit-based observations with a spectrograph, the entire radial range from $4 R_{\odot}$ to $16 R_{\odot}$ can be covered with a field of view of approximately 30 arcminutes when the slit is oriented radially with respect to the Sun. Since zodiacal dust extends to much greater distances,

observations could also be extended along the ecliptic plane and toward the ecliptic poles, up to $50R_{\odot}$ (12.5°). According to Makarova et al. (1994), the brightness of the Sun in the selected spectral region is about $B_{\odot} \approx 2.8 \times 10^7 \text{ J}/(\text{s}\cdot\text{m}^2\cdot\mu\text{m}\cdot\text{sr})$. The zodiacal dust brightness at $50R_{\odot}$ (from Figure 4) is estimated as: $10^{-11} B_{\odot} \approx 2.8 \times 10^{-4} \text{ J}/(\text{s}\cdot\text{m}^2\cdot\mu\text{m}\cdot\text{sr})$. The minimum ZL brightness may reach two orders of magnitude lower: $10^{-13} B_{\odot} \approx 2.8 \times 10^{-6} \text{ J}/(\text{s}\cdot\text{m}^2\cdot\mu\text{m}\cdot\text{sr})$ (per Figure 1). In a study by Kuznechik et al. (2007), the radiance of major night-sky components was measured near the galactic pole and zenith at wavelengths 0.53 and 0.69 μm in Minsk and surrounding areas. Estimates were given for lunar scattered light, the Milky Way, zodiacal light, airglow, and artificial light pollution. The zodiacal light brightness in the direction of the galactic pole (in the absence of the Moon) was: $B_{\text{zo}} = 1.533 \times 10^{-5} \text{ J}/(\text{s}\cdot\text{m}^2\cdot\mu\text{m}\cdot\text{sr})$. The estimated sky brightness under full Moon conditions at 0.5 μm wavelength was: $B_{\text{moon}} \approx 5,25 \times 10^{-4} \text{ W}\cdot\text{m}^{-2}\cdot\text{sr}^{-1}\cdot\mu\text{m}^{-1}$, though the authors suggest this value is likely overestimated and should be about one order of magnitude lower. Interestingly, our estimate of the zodiacal light brightness at $50R_{\odot}$ is only about 2 times lower than the full Moon sky brightness, indicating that testing the spectrograph's sensitivity for such tasks can be performed even during full Moon nights. *Required Equipment:* A small telescope with an aperture of 30–40 cm, equipped with a spectrograph capable of recording spectra in the λ 5000–6000 \AA range in a single frame with a dispersion of 0.175 $\text{\AA}/\text{pixel}$. In this spectral region, the Doppler velocity scale is approximately 60 km/s per \AA , which allows for a radial velocity measurement accuracy of 4–6 km/s. The 30-arcminute-long slit of the spectrograph should be oriented radially with respect to the Sun, covering the range from 4 to 16 R_{\odot} is about 1/10,000 of the daytime sky brightness, whereas at an elongation of $50R_{\odot}$, the difference between the zodiacal light and the daytime sky brightness reaches a factor of 10^6 . The main challenge lies in pointing the telescope at the near-Sun region from multiple positional angles around the Sun, ideally with a 30° step. If close solar pointing is not feasible, observations may be limited to scanning more distant regions using the spectrograph slit—either along the ecliptic plane or toward its poles.

Conclusion. Scanning the inner region of the Solar System using a telescope equipped with a long-slit spectrograph for measuring dust radial velocities, detecting emission clouds, and identifying atomic emissions provides a unique opportunity to study the dynamics of these phenomena and investigate their origins. Space-based astronomical observations are typically oriented toward the anti-solar direction to study galactic and extragalactic objects, leaving nearby regions of space significantly underexplored. For instance, SOHO mission data indicate that approximately 200 comets fall into the Sun each year. It is evident that as they approach the Sun, they release significant amounts of dust and gas. The lack of observational data in the near-Sun region is largely due to the challenges posed by the Sun's intense brightness. Even with solar shielding, slight pointing errors can damage highly sensitive instruments. Due to the exceptional complexity of such experiments, no new observational data on dust dynamics in the near-Sun region have been obtained to date. The most noteworthy recent results come from the Parker Solar Probe mission (Szalay et al., 2024), which flew through the innermost

regions of the zodiacal cloud. According to the cited study, most of the dust mass is concentrated in extremely fine particles with radii of approximately 0.6–1.4 μm , rather than in larger particles with radii around 30 μm , as previously believed (Leinert, 1975). In addition, they estimated the power-law exponent describing how dust concentration changes with distance to be $\alpha = 1.1 \pm 0.3$, over the range 0.1 to 0.25 AU. Based on observations from the 2008 solar eclipse conducted by FAI researchers, the average particle radius was found to be 1.15 μm (Shestakova and Demchenko, 2016). The same study also determined the power-law exponent for dust concentration with distance to be $\alpha = 1.08$, closely matching the Parker Solar Probe results. It is also worth noting the results from the March 29, 2006 eclipse, which turned out to be unexpected. The exponent was significantly steeper: $\alpha = 2.2$, while the average particle radius remained within a similar range of about 0.9 μm (Shestakova and Demchenko, 2016). The reason for this discrepancy was that the near-Sun region had been filled with cometary dust released by Kreutz group comets that passed near the Sun one day before the eclipse. The accuracy of our experiments, even though they were carried out from the ground, demonstrates the high efficiency of the method for measuring the radial velocities of near-Sun dust. Given that many active processes take place in the inner Solar System - including the destruction of small bodies, comets, and meteoroid streams - it is necessary to intensify research efforts in this region. The processes occurring there may have a significant influence, including on conditions affecting life on Earth.

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