A. T. SARSEMBAYEVA, A. T. SARSEMBAY

(Al-Farabi Kazakh national university, Almaty)

11 APRIL 2013 SOLAR FLARE:
MAGNETOHYDRODYNAMIC PROCESSES

Abstract

Was defined reconnection rate of solar flare observed with the SOHO Michelson Doppler Imager (MDI). Measured physical parameters solar flare of 11 April 2013, such as the temporal scale, size and magnetic flux density. Estimated reconnection inflow velocity, coronal Alfven velocity, and reconnection rate using the observed values. The inflow velocity are distributed from a few km s^{-1} to several tens of km s^{-1}, and the Alfven velocity in the corona are in the range from 10^3 to 10^4 km s^{-1}. Hence, the reconnection rate is 10^{-4}. We find that the reconnection rate in a flare tends to decrease as the GOES class of the flare increases.

Keywords: Solar flares, corona, magnetic fields, reconnection rate.

Кілт сөздер: Күн жарқылы, тәж, магнит өрісі, қайта ұштасу жылдамдығы.

Ключевые слова: Солнечные вспышки, корона, магнитное поле, скорость пересоединения.

INTRODUCTION. In the energy release process in solar flares, magnetic reconnection is generally considered to play a key role. The reconnection rate is an important quantity, because it puts critical restrictions on the reconnection model. It is defined as $M_A \equiv V_{in}/V_A$ in nondimensional form, where V_{in} is the velocity of the reconnection inflow and V_A is the Alfven velocity. It gives the normalized value of the reconnected flux per unit time. In spite of its importance, what determines the reconnection rate in flares is still a question [1].

In spite of its importance, what determines the reconnection rate in flares is still a question. In the steady reconnection model of Sweet (1958) and Parker (1957), the reconnection rate is $M_A = (\mathrm{Re}_m)^{-1/2}$, where $\mathrm{Re}_m = (V_A L/\eta)$ is the magnetic Reynolds number defined with the Alfven velocity, and η is the magnetic diffusivity, $\eta \sim 10^4 (\frac{T}{10^6 K})^{-3/2} cm^2 s^{-1}$. In the solar corona, if the resistivity is attributed to Coulomb collisions (Spitzer 1956), the typical value of Re_m is $\mathrm{Re}_m \sim 10^{14}$, which means that $M_A \sim 10^{-7}$ and the estimated timescale of the flare is about 1 yr [4]. This is, of course, too slow to explain flares whose timescales are about 10^2–$10^3 s$. On the other hand, Petschek (1964) pointed out that the previous model lacks the effects of waves and suggested his model with $M_A \lesssim \pi / [8 \ln(8 \mathrm{Re}_m)]$. The special feature of this model is that M_A has a weak dependence on Re_m. In this model $M_A \lesssim 10^{-2}$ when $\mathrm{Re}_m \sim 10^{14}$, and the estimated timescale is consistent with the observed value [2].

DATA ANALYSIS. The amount of energy released during a flare, E_{flare}, can be explained by the magnetic energy stored in the solar atmosphere [1],

$$E_{flare} \sim E_{mag} = \frac{B_{cor}^2}{8\pi} L^3 , \tag{1}$$

where L is the characteristic size of the flare and B_{cor} is the characteristic magnetic flux density in the corona. Since the released magnetic energy balances the energy flowing into the reconnection region, we can describe the energy release rate as [5]

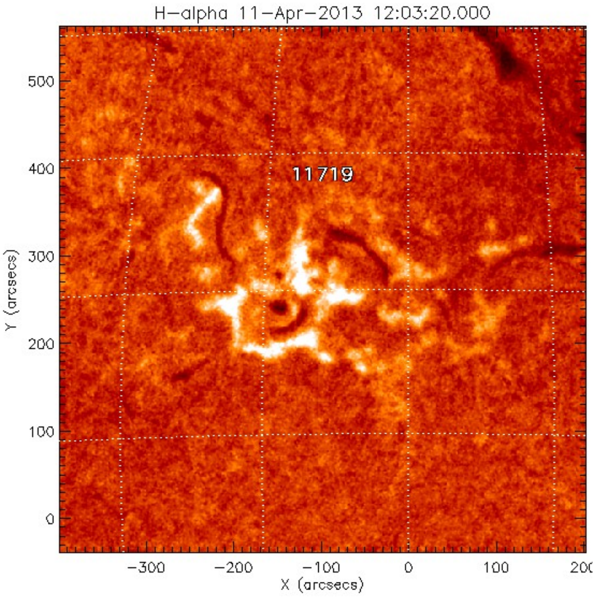
$$\left| \frac{dE_{mag}}{dt} \right| \sim 2 \frac{B_{cor}^2}{4\pi} V_{in} L^2 , \tag{2}$$

where V_{in} is the inflow velocity of the plasma. Therefore, the time required for the energy inflow to supply the flare energy is estimated as [3]

$$\tau_{flare} \sim E_{flare} (\left| \frac{dE_{mag}}{dt} \right|)^{-1} \sim \frac{L}{4V_{in}} \tag{3}$$

and this should be the timescale of the flare. Using this timescale, we can estimate the inflow velocity V_{in} as

$$V_{in} \sim \frac{L}{4\tau_{flare}} . \tag{4}$$



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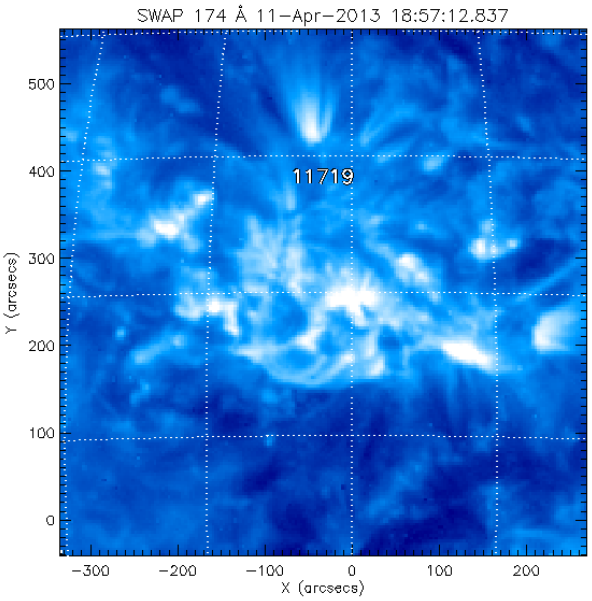

SWAP 174 Å 11-Apr-2013 18:57:12.837

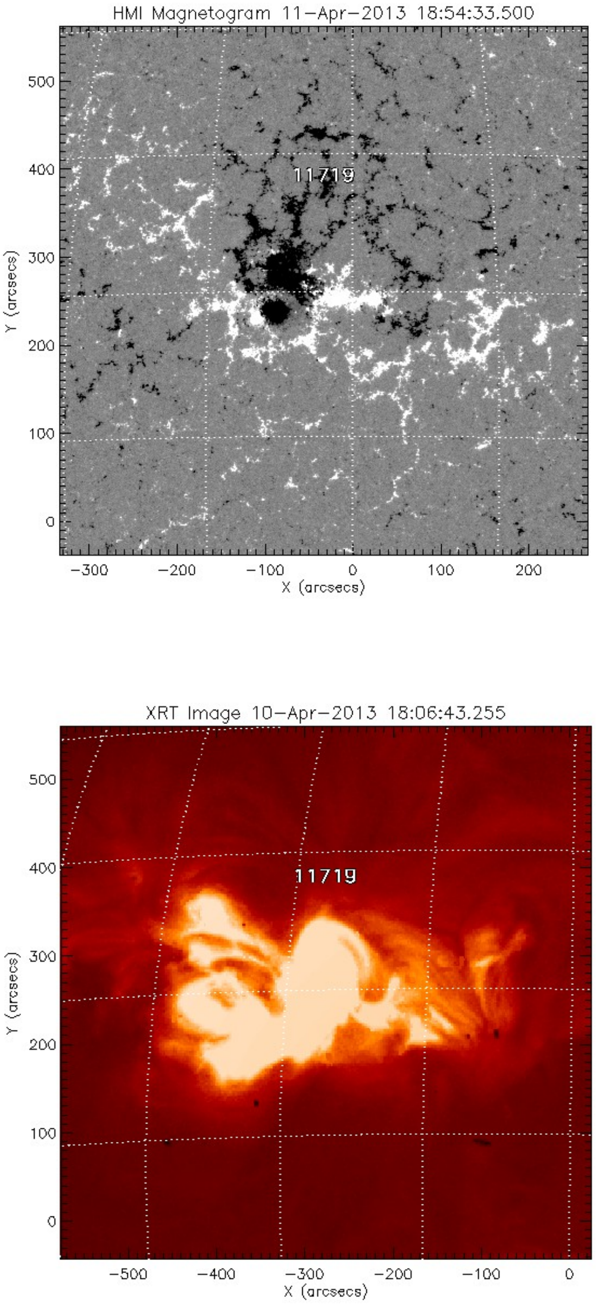

Figure 1 – The active region 11719 on the range H_α, SWAP 174Å, HMI Magnetogram, XRT [7]

To evaluate the reconnection rate in nondimensional form, $M_A \, \epsilon \, \frac{V_{in}}{V_A}$, we must estimate the Alfven velocity in the inflow region: $V_A = \frac{B_{cor}}{(4\pi\rho)^{1/2}}$. Hence, if we measure the coronal density ρ, the spatial scale of the flare L, the magnetic flux density in the corona B_{cor}, and the timescale of flares τ_{flare}, we can calculate inflow velocity V_{in}, Alfven velocity V_A, and reconnection rate M_A [1].

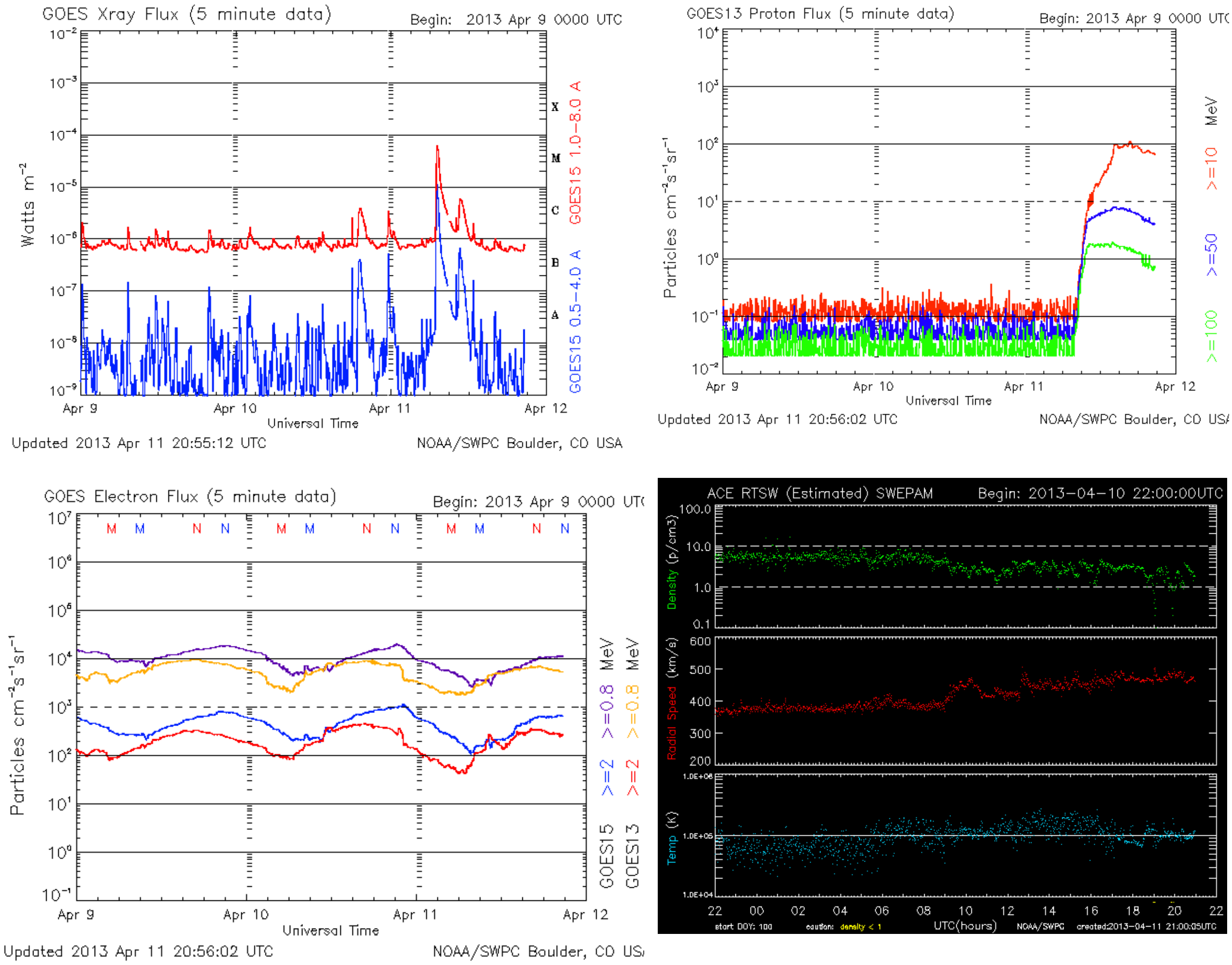

Figure 2 –The total flux of the proton, electron and X-rays (data from GOES 13 and GOES 15 [7]

RESULTS

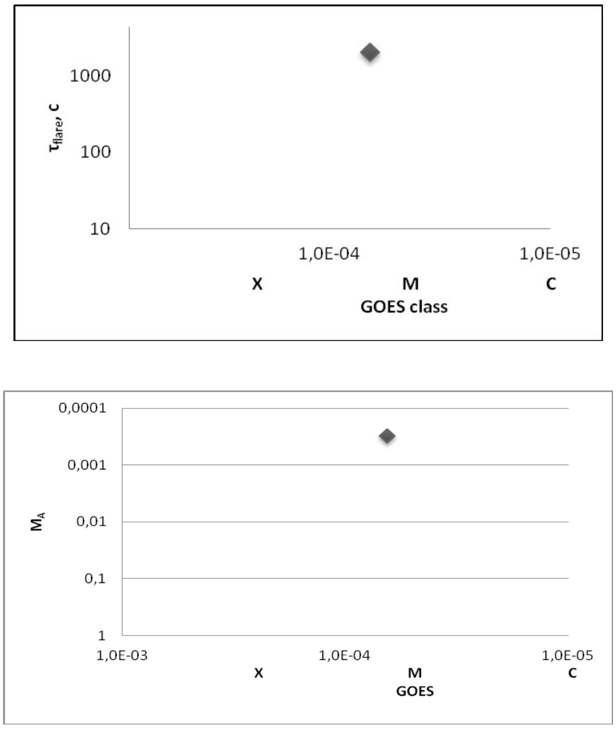

Figure 3 – Timescale τ_{flare}, reconnection rate M_A plotted against the GOES class of each flare

Using the above described method, we analyze solar flare of 15 April that have been registered in 2013 year. Examined the dependence of the reconnection rate from GOES class of solar flares. Figure 3 shows the dependence of the reconnection rate from GOES class.

CONCLUSION. The values of reconnection rate are distributed in the range from 10^{-4}. Here, the value of the reconnection rate decreases as the GOES class increases. The value of the reconnection rate obtained in this is within 1 order of magnitude from the predicted maximum value of the Petschek model.

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Резюме

А. Т. Сәрсембаева, А. Т. Сәрсембай

(әл-Фараби атындағы Қазақ ұлттық университеті, Алматы қ.)

2013 ЖЫЛДЫҢ 11 СӘУІРДІҢ КҮН ЖАРҚЫЛЫ: МАГНИТТІГИДРОДИНАМИКАЛЫҚ ҮРДІСТЕРІ

Күн жарқылының қайта ұштасу жылдамдығы SOHO Michelson Doppler Imager (MDI) бақыланды. 2013 жылдың 11 сәуірінде тіркелген күн жарқылының физикалық параметрлері, яғни кеңістік көлем, өлшемі және магнит өрісінің тығыздығы. Ағынның қайта ұштасу жылдамдығының, тәждік Альфвен жылдамдығы және ұштасу жылдамдығының мәндері анықталды. Ағынның жылдамдығы бірнеше кмс$^{-1}$, ал тәждегі Альфвен жылдамдығы 10^3–10^4 кмс$^{-1}$ аралығында таралған. Жарқылдағы қайта ұштасу жылдамдығының мәні GOES класының өсуіне байланысты азайып отыр деп есептейміз.

Кілт сөздер: Күн жарқылы, тәж, магнит өрісі, қайта ұштасу жылдамдығы.

Резюме

А. Т. Сарсембаева, А. Т. Сарсембай

(Казахский национальный университет им. аль-Фараби, г. Алматы)

МАГНИТОГИДРОДИНАМИЧЕСКИЕ ПРОЦЕССЫ СОЛНЕЧНОЙ ВСПЫШКИ 11 АПРЕЛЯ 2013

Скорость пересоединения солнечной вспышки наблюдалась в SOHO Michelson Doppler Imager (MDI). Были измерены физические параметры солнечной вспышки, зарегистрированной 11 апреля 2013 года, т.е. пространственный масштаб, размер и плотность магнитного потока. Оценена приблизительная скорость пе-ресоединения притока, корональная альфвеновская скорость и скорость пересоединения. Скорость притока распространяется от нескольких кмс$^{-1}$ до нескольких десятков кмс$^{-1}$, а

Альфвеновская скорость в короне находится в диапазоне от 10^3 до 10^4 $кмс^{-1}$. Следовательно, скорость пересоединения 10^{-4}. Мы считаем, что скорость пересоединения во вспышке уменьшается с увеличением класса вспышки, зарегистрированной спутником GOES.

Ключевые слова: солнечные вспышки, корона, магнитное поле, скорость пересоединения.

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