FLOWS OF MASS, MOMENTUM AND ENERGY IN THE SOLAR ATMOSPHERE A SOHO-ORIENTED VIEW OF COLD LOOPS

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ABSTRACT

This work is dedicated to the study, in the framework of known models of coronal loops, of cold long loops observed in several spectral lines by SOHO. In particular an observation made by SOHO/CDS in the O V (629.73 A) line show a very high speed flow along a loop. The comparison with steady state siphon flow loop models leads to the conclusion that **such loop cannot be in steady state**; in particular no steady state solution with maximum temperature in the range of a few 10^5 K can be obtained. Some suggestions on the possible characteristics of the loop dynamic state are discussed and a preliminary analysis, in terms of a loop dynamically heated by microflares and alternating between coronal conditions and chromospheric temperatures, is presented. Suggestions on how to observe the dynamic behaviour of such cold loops are also discussed. The cold EUV loops observed in detail by SOHO instruments can provide information on a less known aspect of solar loop physics, one which may be quite important in the overall balance of flows of mass, momentum and energy in the solar atmosphere.

Key words: cold loops, MHD, SOHO.

1. INTRODUCTION

There is a multitude of dynamic events, involving flows of plasma, which take place in the solar atmosphere. We have knowledge of different events and of several facets of their phenomenology, however a clear view of the complex relation among them is still missing. More specifically, an accurate and complete description of the flows of mass, momentum and energy, and of their balance, in the solar atmosphere is far from being available.

The X-ray data collected with Yohkoh (cf. the book edited by Uchida, Watanabe, Shibata and Hudson, 1994) have shown us, with a wealth of data and with richness of details, the flows of plasma in the very dynamic X-ray emitting solar corona. Recently SOHO, observing in many EUV spectral lines and bands, has started to show a rather complementary view. I take this opportunity to address a new highlighted by SOHO observations.

I will discuss of the cold, long loops observed in EUV by SOHO instruments: they are in a thermal regime apparently different from that of the hot loops shown by the X-ray telescopes. It appears, furthermore, that they may be subject to significant flows of plasma and not in steady state. I find such an aspect quite important since these loops may be very common in the EUV emitting solar atmosphere seen by SOHO.

I will take advantage of a specific, quite detailed, observation made with SOHO and will discuss it in the framework of the knowledge coming from accurate models of plasma flows. The focus will be therefore on the fluid, macroscopic, behaviour of the plasma in the solar confined atmosphere.

2. THE OBSERVATION

Our reference will be the set of detailed observations, in the form of spectroheliograms and spectra taken in several lines, of an active region on the solar limb made with SOHO/CDS and discussed by Brekke, Kjeldseth-Moe and Harrison (1997).

In particular, their O V (629.73 A) spectroheliogram, presented in Fig. 1 clearly shows a few loops; along one, Brekke *et al.* find conspicuous Doppler shifts of the spectral line, indicative of a coherent flow along the loop, at a maximum measured speed *along the line of sight* of 60 Km/s. This line preferentially forms at a temperature of 2.5×10^5 K and the sound speed at such a temperature is ≈ 80 Km/s. The Doppler shifts occurr along the whole loop with a coherent pattern (Fig. 2); the plasma, therefore, appears to flow coherently at a speed whose component along the line of sight is very close to the sound speed. It is worth noting that the flow speed may be even higher than the sound speed if one takes into account that such a loop appears to be only slightly bent toward the observer.

From the loop height of $\approx 7 \times 10^9$ cm, easily measurable in the image, one derives an overall lenght of $\approx 2 \times 10^{10}$ cm *if the loop is semicircular.* The loop, as shown by Brekke *et al.*, is not strictly uniform in brightness, however the surface brightness does not vary by more than a factor of 2.5 along the loop as shown in Fig. 2. Such a characteristic, along with the other features of the loop, will play a crucial role in the rest of our discussion.

The pressure scale height at 2.5×10^5 K is just 1.3×10^9 cm and therefore the plasma present in a substantial amount up to the top, and making the loop so bright at the apex, can hardly be in hydrostatic equilibrium.

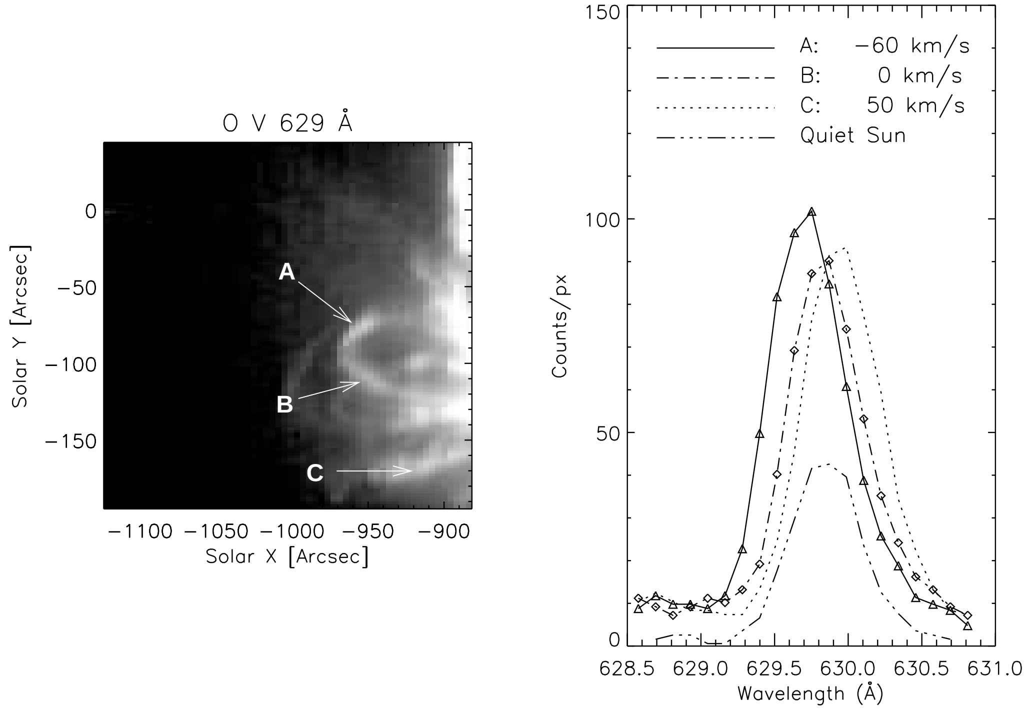

Figure 1. Left panel: The loop system of an active region, observed at the solar limb in the O V (629.73 A) line with SOHO/CDS. Right panel: the line shapes and the relevant Doppler shifts at the points marked in the left panel (Courtesy of Brekke et al. 1997).

The presence of flow along the loop is, therefore, not surprising; however the almost supersonic speed along the line of sight is certainly unexpected, only on the basis of these facts.

3. THE STEADY STATE MODEL OF THE FLOW

This observation is highly suggestive of the presence of siphon flows inside the loop, a phenomenon modelled by several authors (for a list of them see Orlando, Peres and Serio, 1995a) in an effort prompted mostly by the consideration that coronal loops typically connect very different parts of the Sun's surface; since physical conditions of plasma at the two extremes of a loop are significantly different a flow from one loop footpoint to the other can be easily triggered by an unbalance of pressure between the two footpoints (Cargill and Priest, 1980; Priest 1981). One can assume a steady state flow since the time taken by the flow to balance eventually the pressure difference is significantly longer than the flow crossing time.

On the other hand there has been limited (if any) observational evidence of siphon flows; perhaps the most convincing ones being those reported by Brekke *et al.* (1992) and that by Kjeldseth-Moe (1988) whereas one would have expected widespread evidence of siphon flows. It is worth noting, however, that no extensive campaign of observations to detect them has been undertaken. Siphon flow models cannot explain the ubiquitous redshifts observed in the transition region lines, in fact such models predict blueshifts (Antiochos, 1984).

At first sight, such SOHO/CDS observations could be one of the first detailed templates to compare siphon flow models with. In order to interpret and analyze the observations by Brekke *et al.* (1997), among the accurate and detailed models devised so far, I will use the siphon flow model by Orlando, Peres, and Serio (1995a, 1995b) because I have an easy access to its results.

The siphon flow model by Orlando *et al.* considers steady flow from one loop footpoint to the other (both located where the plasma is at a temperature of 2×10^4 K). The loop geometry and plasma flow, is shown in Fig. 3 for the case of a critical flow (see below) which allows to illustrate the features of the fluid flow. The loop is semicircular with a constant cross section; the mass, momentum and heat flow occurr only along the field lines so the model is one-dimensional. The differential equations are:

$$\rho v = j \tag{1}$$

$$\rho v \frac{\partial v}{\partial s} = -\frac{\partial p}{\partial s} + \rho g \tag{2}$$

$$\frac{1}{2}\left(5\,p\,\frac{\partial v}{\partial s} + 3\,v\,\frac{\partial p}{\partial s}\right) - \frac{\partial}{\partial s}\left(\kappa \frac{\partial T}{\partial s}\right) = \mathcal{Q} - \frac{p^2}{4\,k_B^2\,T^2}\,\mathcal{P}(T) \tag{3}$$

where $\rho = \mu m_H n$ is the plasma mass density, n the particle number density, s the coordinate along the loop, v the plasma bulk velocity, $p = 2nk_BT$ the pressure, $g = g_o cos\left(\frac{\pi s}{2L}\right)$, the gravity, $\kappa = 9.2\ 10^{-7}\ T^{5/2}$ the plasma conductivity derived by Spitzer (1962), T the temperature, $\mathcal{Q}(s,t)$ the input heating power per unit volume, k_B the Boltzmann constant, $\mathcal{P}(T)$ the radiative losses per unit emission measure, m_H the hydrogen atomic mass, μ the average atomic mass.

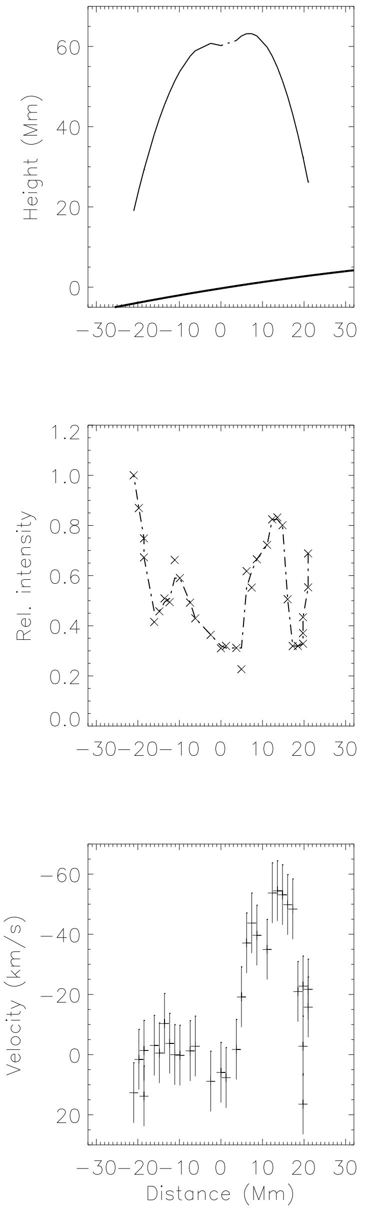

Figure 2. This figure refers to the observation shown in Fig. 1. Top panel: loops outline; middle panel: loops brightness in arbitrary units; lower panel: line shift along the loops (Courtesy of Brekke et al. 1997)

The equations are solved with two independent numerical codes each based on a different numerical scheme: the Runge Kutta method and the Bulirsch Stoer method, each very accurate and reliable by itself. The solutions

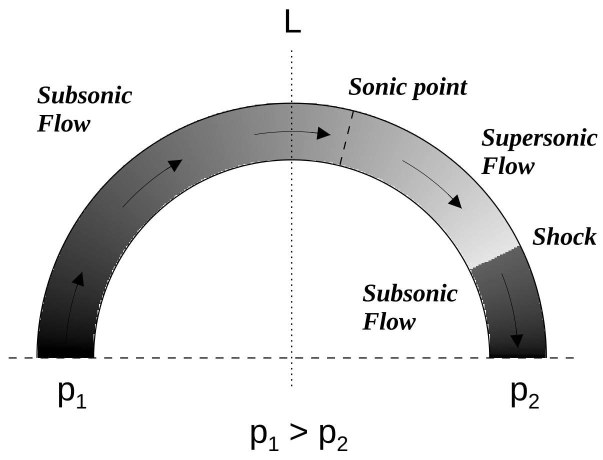

Figure 3. Siphon flow loop model: sketch of the loop geometry and of the flow for a critical case (cf. text) undergoing a shock in the descending leg, before reaching the chromosphere.

of the two codes are compared so as to grant a solution correct and unaffected by numerical effects. The high intrinsic accuracy and the use of adaptive step size grants Orlando et al. to handle accurately the steep gradients of the transition region and, more in general, the global configuration of the atmosphere; power expansion is used to handle the points where the flow becomes critical (where the flow speed equals the sound speed or the gradient of plasma speed is zero) .

The model includes most of the dominating physical effects. Orlando et al. have made a complete and accurate exploration of the solution space, made very complex by the presence of heat conduction. There are four classes of solutions: in the first the flow is subsonic along the entire loop, in the second, the critical solution, it starts subsonic at one footpoint of the loop and becomes supersonic passing through a critical point, (there is also a symmetric critical solution where the flows starts supersonic at one footpoint, decelerates and become subsonic stopping, practically, at the other footpoint), in the third there is a solutions at supersonic speed along the entire loop, in the fourth there are entirely unphysical, double valued solutions. [1] Furthermore the plasma flow, both in the critical and in the supersonic solution, being supersonic in the descending branch, must shock before decelerating at very slow speed in the chromosphere. Orlando *et al.* have analized in detail all the classes of solutions, including the shocked solutions.

Analogously to what has been made for the static solutions, (Rosner, Tucker and Vaiana, 1978; Craig, Mc Clymont and Underwood, 1979) Orlando *et al.* have determined the scaling laws governing the solutions; such scaling laws are more compicated than the static loops scaling laws since they have to include the speed at one of the footpoints, typically the ascending one. Scaling laws provide important guidelines on coronal loop physics and they provide the relations between the parameters governing the physical solutions, thus they provide a good

[1] It remains to be explained how a flow may start supersonic at the base of the transition region.

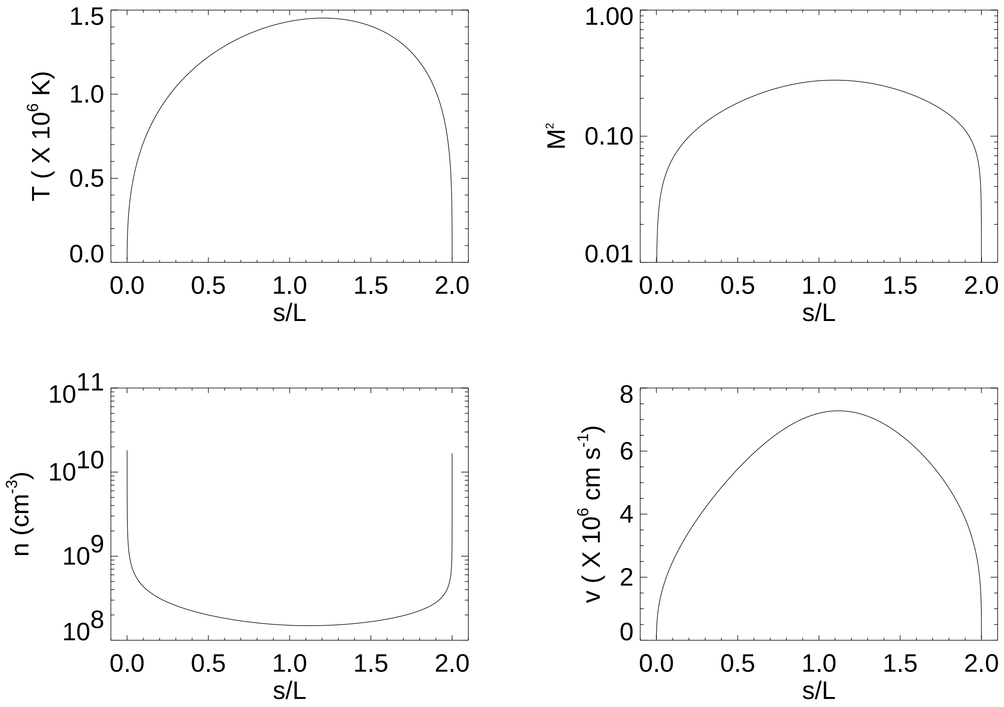

Figure 4. Results for a siphon flow in a loop whose total length is 4×10^9 cm, the maximum temperature is 1.45×10^6 K, the base pressure is 0.1 dyn cm-2, and the plasma speed at the base of the ascending flow is 6×10^4 cm s^{-1}. The panels show the plasma temperature (top left panel), the hydrogen number density (bottom right panel), the squared Mach number (top right panel) and the flow speed along the loop (bottom right panle) vs. normalized field line coordinates (the total loop length corresponds to 2L).

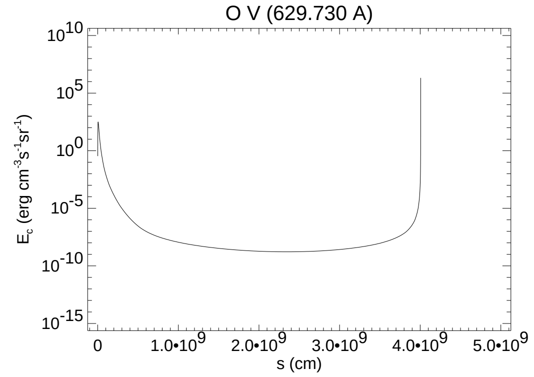

Figure 5. Distribution of emission in the O V (629.73 A) line along the loop, computed from the results shown in Fig. 4, taking into account non-equilibrium ionization.

grasp and a global knowledge of the solutions. For instance they are of considerable help, when looking for some solution, since one can prescribe directly the correct conditions, thus avoiding useless attempts.

The numerical and physical accuracy of the model turn out to be very importatn both when making physical predictions and when making detailed comparison with observations.

A detailed comparison of such a model with observations can be achieved by synthesizing the emission from the profiles of density, temperature and velocity along the loop computed with the code(s). The emission in any spectral line or band of interest over the pixel is derived by integration of the emission measure over the size of the pixel as $\int n^2(s)\ G(T(s))\ A\ ds$ where n is the hydrogen number density, G(T) is the line emission efficiency of the solar plasma per unit emission measure and A is the loop cross sectional area. Alternatively, one can consider just the integrand along the loop, as we will do in the following figures. Analogously one can synthesize the emission of the loop in the focal plane of any instrument, as long as one knows the effective area vs. energy of that instrument. In this way it is easy to synthesize the loop emission as seen, for instance, in the EIT bands or in any optically thin line detected by SUMER, CDS or UVCS.

Fig. 4 shows an example of the solution obtained for a typical coronal loop with overall lenght 4×10^9 *cm*, from one footpoint to the other, maximum temperature 1.45×10^6 K, base pressure 0.1 dyn cm-2, and plasma speed at the base of the ascending flow 6×10^4 cm s^{-1}. Fig. 5 shows the distribution of surface brightness in the line of O V (629.73 A), computed from the results of Fig. 4 and *taking into account the non- equilibrium ionization*, shows that the footpoints are brighter than the apex of the loop by approximately 10 orders of magnitude. Emission profiles with analogous large (many orders of magnitude) difference between footpoints and top are obtained from all the solutions with maximum plasma temperature at coronal temperatures, i.e. in the 10^6 K range, including those undergoing shocks. On the other

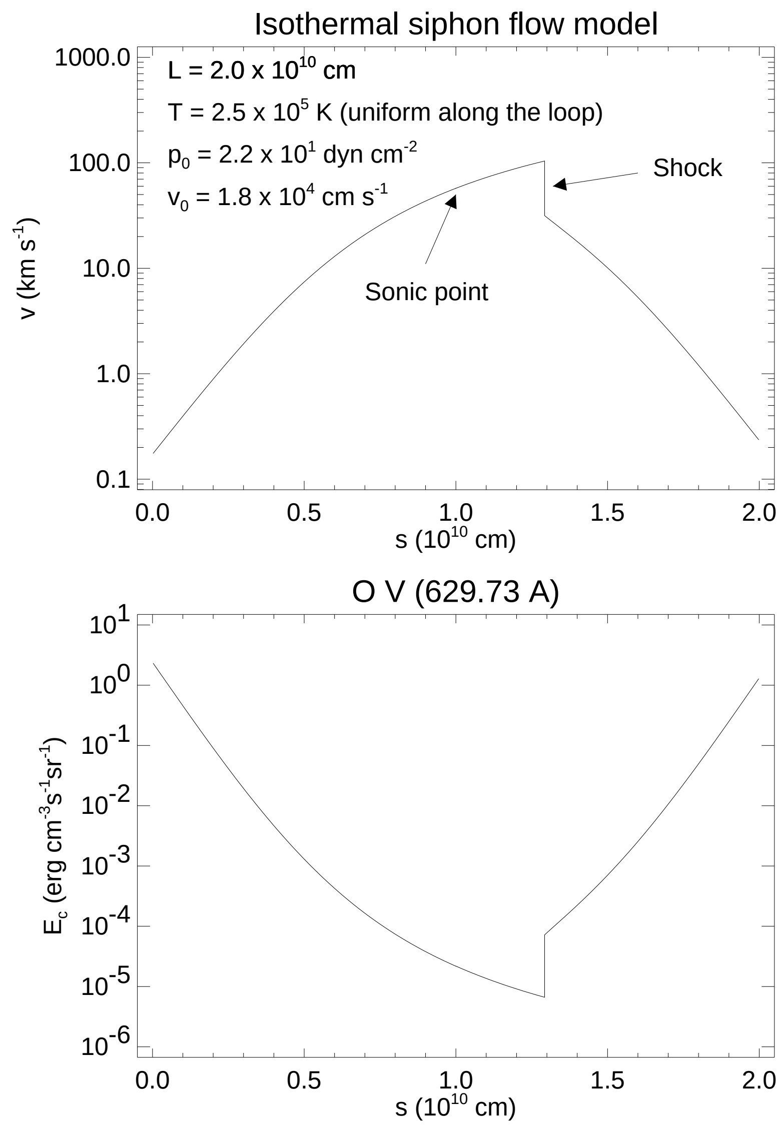

Figure 6. Flow speed (upper panel) and brightness along the loop (lower panel) for an isothermal siphon flow loop model, at the temperature of 2.5×10^5 *K (i.e. that of maximum O V (629.73 A) line formation), reaching the sonic point and shocking before descending to the chromosphere. The loop length (*2×10^{10} *cm) has been chosen equal to that inferred for the loop observed by Brekke et al. (1997).*

hand the cold loop analyzed by Brekke *et al.* does not show such extremely brighter footpoints (Brekke, private communication) and the surface brightness is much more uniform as shown in Fig. 2. Some parts of the loop close to the top are even rather bright.

The discrepancy of the siphon flows model calculations with this observation can be mostly ascribed to two factors: going from one footpoint to the apex, the temperature increases to coronal values, bringing the plasma away from the temperature of maximum O V line formation which thus occurs only in a narrow region close to the loop footpoint, and the density falls along the loop, thus reducing even more the emission efficiency, in general, and in such a line in particular.

An alternative may be, then, to look for a siphon flow loop solution with maximum temperature around the range of O V maximum formation, i.e. a few $\times 10^5$ K. However there is no solution of loop physics, neither static nor subject to a siphon flow, in this temperature range, since it is not possible to obtain energy balance in all the points of the loop among energy input, thermal condution and the other energy terms, unless one prescribes a somehow *ad hoc* energy input (for a review on coronal loops cf. Bray *et al.* 1991). Therefore there seem to be no easy solution assuming a siphon flow with a realistic energy balance equation.

But even worse, as I am going to show, *even if the plasma is isothermal and at the best temperature to emit the line of interest, we cannot reproduce the observations by Brekke et al.* with a steady siphon flow loop model. The point of such an excercise is to show that even in this extreme and unphysical condition, the steady siphon flow model cannot reproduce the O V observations.

Fig. 6 shows the solution obtained for a siphon flow, at a uniform temperature of 2.5×10^5 K, in a loop with overall length 2×10^{10} cm (the observed value) and with a a flow which becomes supersonic, reaching 100 Km s^{-1} and shocks before returning to the chromosphere. The lower panel shows that, again, the O V emission undergoes 5 orders of magnitude decrease along the loop: the density decreases going up, to maintain a constant mass flow since the velocity increases, and even more decreases the emission since it depends on the square of the density.

It is worth noting that, analogously, the long, cool loops rooted in sunspots, observed in several EUV spectral lines by Skylab/S055 and studied by Foukal (1976) have resisted the fitting in terms of hydrostatic loops (Pallavicini *et al.* 1981). A more recent and thorough study by Peres and Orlando (1996), attempting to fit them with the more general siphon flow model, was equally unsuccessful as long the authors used the normal energy balance differential equation, including thermal conduction, radiative losses and a uniform heating term; instead they got some success assuming isothermal siphon flow. Given the little realism of the latter model, Peres and Orlando concluded that such cold loops may be dynamic and unstable as, on the other hand, some spectroheliograms, taken hours apart, may suggest (Foukal 1976).

The extension of the cold loop cannot be explained in terms of ionization delay alone (Noci *et al.* 1989), i.e. the non-equilibrium ionization state due to the rapid transit of the flowing plasma past the steep temperature gradient in the transition region: for usual values of the recombination and ionization factor from O V and a density of 10^8 cm^{-3} one gets a lenght of the O V emitting region of the order of 10^9 cm i.e. significantly shorter than the observed loop. A size of 10^{10} cm would be obtained for a density of 10^7 cm^{-3}, unrealistically too low for any observed loop. Furthermore, non-equilibrium ionization has already been taken into account in the emission profiles computed from the models and reported above.

The relatively uniform brightness (implying an even more uniform density) and the apparently uniform temperature are strongly in disagreement with any steady state loop model and therefore suggest either a significant departure from the plasma physics adopted in the models or a dynamic state.

On the basis of the flow speed and the geometry in the paper by Brekke *et al.*, it is easy to show that the loop flow crossing time is $\approx 3 \times 10^3$ s, the radiative time, assuming a density of $\approx 10^9$ cm^{-3}, is $\approx 10^3$ s and comparable values are derived for the free fall time. On the other hand the time taken by SOHO/CDS to raster the image reported in Brekke *et al.* was quite long: 53 min (because several spectral lines were observed simultaneously) and only one image per spectral line was taken. Therefore, if the loop was in a non-steady dynamic state, as our discussion so far seem to show, we have no sequence of images to show any evidence of variability; we can only infer an indirect evidence. It is also worth noting that, quite likely, given the long time required by the spectroheliogram scan, as compared with the loop characteristic evolution time, in the picture different parts of the loop are observed at different phases of the evolution, even several tens of minutes apart.

4. THE DYNAMIC MODEL OF THE FLOW

If the loop is not steady, then, what is happening?

Maybe it is a loop cooling from a previous hot coronal (a few 10^6 K) temperature and the cooling plasma is raining down along the legs. However, if this is the case it appears hard to reach supersonic, or close to supersonic, speeds very high in the loop, as instead observed.

A more plausible hypothesis is, instead, that the plasma in the loop, previously cold, has been suddenly heated and may eventually reach coronal conditions: the overheating of the chromosphere may lead to a chromospheric evaporation at almost sonic or supersonic speeds. Furthermore, this hypothesis would fit well in the paradigm which predicts that the heating in coronal loops is not continuous but rather intermittent, i.e. the heating occurs through erratic heat pulses (Parker 1983, 1988).

Modeling a loop subject to transient heating requires a hydrodynamic, time dependent model like the Palermo-Harvard hydrodynamic model of confined plasma (Peres *et al.* 1982, Peres and Serio, 1984; Reale, Peres and Serio, 1985) which I will use in the following. The Palermo-Harvard model assumes semi-circular loop geometry, with constant cross section, and both loop feet anchored in the photosphere, quite similarly to the steady state siphon flow model geometry. Since mass and heat flow occurr essentially only along the magnetic field lines, the model is one-dimensional.

The model is based on the differential equations of mass, momentum and energy conservation of the plasma, described as a fluid, taking into account most of the crucial macroscopic effects occurring in a coronal plasma:

$$\frac{dn}{dt} = -n\frac{\partial v}{\partial s} \tag{4}$$

$$n m_H \frac{dv}{dt} = -\frac{\partial p}{\partial s} + n m_H g + \frac{\partial}{\partial s}\left(\gamma\frac{\partial v}{\partial s}\right) \tag{5}$$

$$\frac{d\mathcal{E}}{dt} + w\frac{\partial v}{\partial s} = \mathcal{Q} - n^2\beta\mathcal{P}(T) + \gamma\left(\frac{\partial v}{\partial s}\right)^2 + \frac{\partial}{\partial s}\left(\kappa\frac{\partial T}{\partial s}\right) \tag{6}$$

$$p = (1+\beta) n k_B T \qquad \mathcal{E} = \frac{3}{2}p + n\beta\chi \qquad w = \frac{5}{2}p + n\beta\chi \tag{7}$$

with the same definition of the variables as in the siphon flow model plus γ the plasma viscosity (Spitzer, 1962), β the ionization fraction of hydrogen, and χ the hydrogen ionization potential.

The heating includes a steady heating term, which maintains the loop in steady coronal conditions, and a variable term which, in the case of flares, can be strong and impulsive; in the following I will discuss the particular case of microflares.

The differential equations have been translated into difference equations which are solved in a numerical code. The code has been continuously upgraded; in its most recent version it allows for non-symmetric solutions and incorporates a regridding algorithm which at any time provides a very fine resolution in all the loop and, in particular, in the transition region, even during flares when the transition region steepens and moves rapidly along the loop (Betta *et al.*, 1997).

From the results of this code, namely the distributions of temperature, density and velocity along the loop, we can easily compute the distribution of surface brightness in any line or band of interest, analogously to what already discussed for the steady siphon flow model.

In the following I will show just preliminary results on hydrodynamic simulations of microflare heating and on how they may point to a solution to the present problem of cold long loops. Some general results on microflares have already been published by Peres, Reale and Serio (1993).

In the microflare heating model of a coronal loop, we assume that the loop, on the time average, is maintained close to the coronal conditions predicted by steady models such as that by Rosner, Tucker and Vaiana (1978), or its generalization to include gravity effects by Serio et al (1981).

The initial conditions of the loop are those of a hydrostatic one, but we let it evolve without any steady uniform heating; instead there is a pulsed time dependent heating: either a periodic sequence of identical pulses or a sequence of random pulses of variable intensity and duration (the case presented in the following); in both cases the power delivered is constant during each pulse. As for the randomic sequence both the time sequence and their duration is random with a Poissonian distribution, the characteristic time scale of the pulse duration is $1/10$ of their repetition time. Both for the periodic and the random heating, the total energy released in each pulse equals that deposited in the analogous steady state loop, over the end of the previous pulse and the end of the ongoing one and therefore the time average of the heating released is the same as in the steady state loop.

The heating is, in any case, the product of a time modulating factor and a spatial distibution. As for the spatial distribution we can prescribe either a beam heating (Nagai and Emslie, 1984; Reale, Peres and Serio, 1985) or a prescribed function of space (in the light of our ignorance of the real heating mechanism). The spatial distribution, in the case presented here, is according to a gaussian centered on the loop apex and with a $\sigma =$ one eigth of the total loop length.

The heating makes the loop plasma temperature rise and fall maintaining it, on the average, in coronal conditions. As a specific, selected example, Fig. 7 shows the evolution of the maximum temperature, located at the apex, of a loop of overall lenght 2×10^{10} cm, initial maximum temperature 1.5×10^{6} K and subject to a randomic heating with 3600 s characteristic repetition time. The loop length is the same as that observed by Brekke *et al.*; during its coolest phases the loop plasma is at a few 10^5 K.

Fig. 8 shows the brightness distribution at selected times, reported in the figure. The O V surface brightness along the loop, especially at the coolest moment, i.e. just before the turning on of the heating, is much more uniform than in the initial steady loop (although still not like teh observed one). There is a better agreement with the observations by Brekke *et al.* even though the top temperature of the loop never reaches that of maximum O V line formation. It is worth noting that this specific calculation was not devised with the purpose of fitting the observed

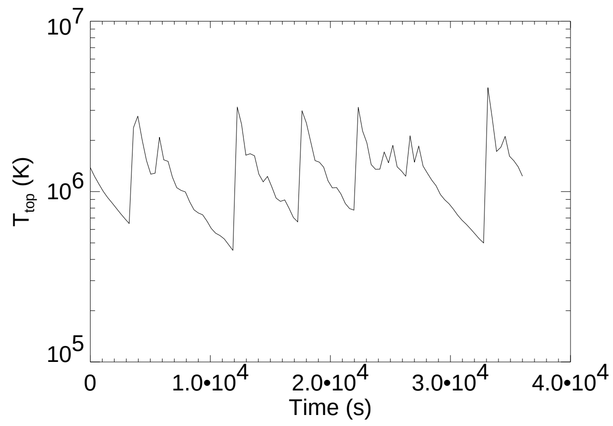

Figure 7. Evolution of the maximum plasma temperature, located at the loop apex, of a loop undergoing a sequence of random heat pulses (microflares). The initial configuration is that of a loop in hydrostatic conditions and steady energy balance, with a total length of $2 \times 10^{10} cm$*, maximum temperature of* 1.5×10^{6} *K and subject to a randomic heating with 3600 s characteristic repetition time.*

loop but just selected among those of a set being used for a work on microflares models; therefore there is ample room for improvement in fitting the observations.

5. CONCLUSIONS

This paper has been dedicated to the cold loops, i.e. those typically observed by SOHO, and has focused on a specific good observation as a guide to understand the flows of mass, momentum and energy in the EUV emitting atmosphere confined inside such loops.

The cold long loops appear to be dynamic and, quite likely, in a non- steady state, in analogy to what hinted already by Foukal (1976) and, more recently by Peres and Orlando (1996). Thanks to the capabilities of SOHO/CDS Brekke *et al.* confirm such a scenario, can show a supersonic flow and, more than in the past, hint at a dynamic behaviour.

Steady state loop models do not fit the observation of such a cold long loop. If one assumes a realistic steady state energy balance equation, solves for a set of realistic coronal solutions and synthesizes the emission from them, obtains a range of several orders of magnitude of the brightness along the loop, which is not observed. Even if one assumes a non-realistic isothermal siphon flow at the temperature of maximum line formation (2.5×10^5 K) obtains five orders of magnitude difference of brightness from footpoint to apex, again at variance with observations. One is therefore led to the conclusion that none of the steady state models work and, therefore, that such loops are not in a steady state.

As for possible paths for modelling, if one is going to insist in assuming steady conditions, one may think of some non-thermal mechanism driving such flows, an area still to be explored.

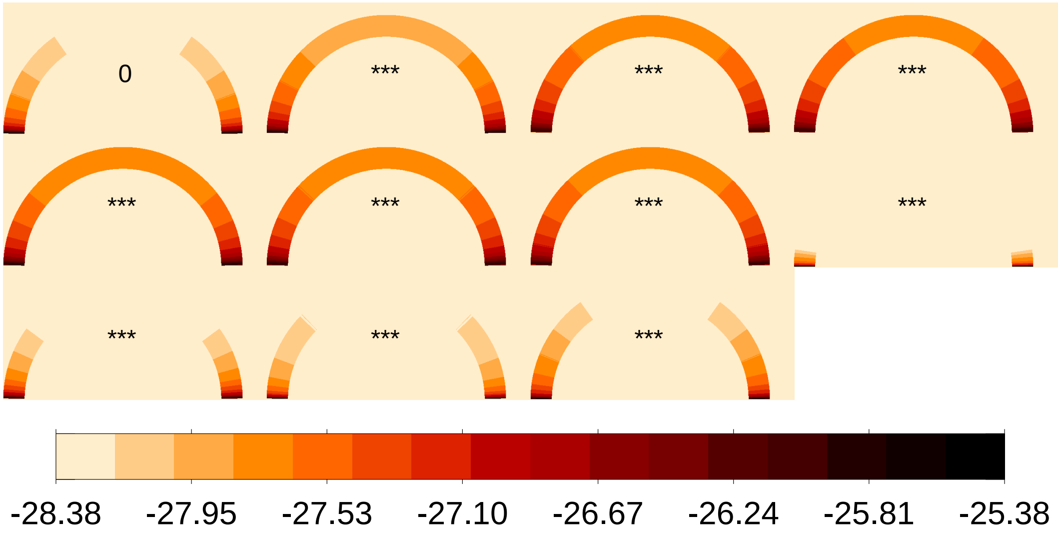

Figure 8. Brightness along the loop, in a relative logarithmic scale (see template at bottom: black is bright, white is faint), in the O V (629.73 A) line, for the dynamic model reported in Fig. 7. Each small loop, from left to right and from top to bottom, correspond to the following times, according to the same timing as in Fig. 7: 0 s (initial time), 2520 s (just before the first deep minimum of temperature), 11520 s and 11880 s (just before the second deep minimum), 32040 s, 32400 s and 32760 (just before the last deep minimum), 33120 s (very close to the heating phase and characterized by the high temperature), 33480 s, 33840 s and 34200 s (in the final cooling phase).

On the other hand one may consider a non-steady state model, most plausibly the non-steady heating of a loop filled with rather cold and tenuous plasma or a loop driven, by a repetitive heating, back and forth from coronal to cold looop conditions and viceversa. In the case of a thermal driving, a non-symmetric heating may bring more easily to fast supersonic flows. It is worth noting that a dynamic model has a much more complex solution space than a steady one and, therefore, devising the solution properly fitting some observation is a more demanding task than with a steady model. In this presentation I have shown a preliminary solution which already shows a more uniform O V surface brightness along the loop than steady siphon flo models.

As for the observations, on the other hand, one may recommend to observe, when possible, such cold loops with a faster observing cadence, concentrating on very few lines (or bands) or even only one spectral line and to make faster sequences rather than isolated images: very likely fast sequences should show evolving cold long loops. A sequence with similar characteristics has been presented (SOHO/CDS Run 7749; Harrison, presented in this workshop) and indeed it shows that the cold loops are evolving.

As an aside let me note that many authors (Parker, 1983, 1988; Litwin and Rosner, 1993; Van den Oord, 1992) have predicted that the loops are formed by a bundle of magnetic field lines threads, each erratically heated by microflares. It is worth noting, therefore, that observations of macroscopic, coherent flow inside individual loops (i.e. bundles of heated magnetic field threads, according to this view) can help us to assess a transversal macroscopic scale over which such threads act coherently.

It appears that cold loops may be characterized by phenomena significantly different from those seen in hot coronal loops, or otherwise some of them may represent a transition phase from hot to very cold loops. In any case they deserve a lot of attention since they are an aspect of solar physics studied only limitedly so far and certainly are an important aspect in the balance of flows of mass, momentum and energy, one which SOHO can certainly help us to know better, if not to understand.

ACKNOWLEDGMENTS

I acknowledge useful discussions and help in some calculations by S. Serio, S. Orlando, F. Reale, and R. Betta. This work was partially supported by the Ministero dell'Universitá e della Ricerca Scientifica e Tecnologica, and by Agenzia Spaziale Italiana.

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