Возможное рациональное объяснение для наблюдаемой депрессии, связанных с активными областями Солнца с волокнами в дециметровом радиодиапазоне от 1.5 ГГц до 1.7ГГц

A plausible explanation for the observed dip in the decimetric radio spectrum of the solar active regions with the overhanging chromospheric filaments

Yelagandula Naga Varun

The observed phenomenon in the decimetric radio spectrum from 1.5 GHz to 1.7 GHz at the active regions with filaments

These pictures and the experimental data are taken from the following source

[Ovchinnikova, Nina et al., Observation at radio frequencies of the hydroxyl (OH) absorption line in filaments and prominences above active regions of the Sun, Solar-Terrestrial Physics, vol. 10, issue 3, pp. 18-24, DOI:10.12737/stp-103202403], **from hereon 2024 paper.**

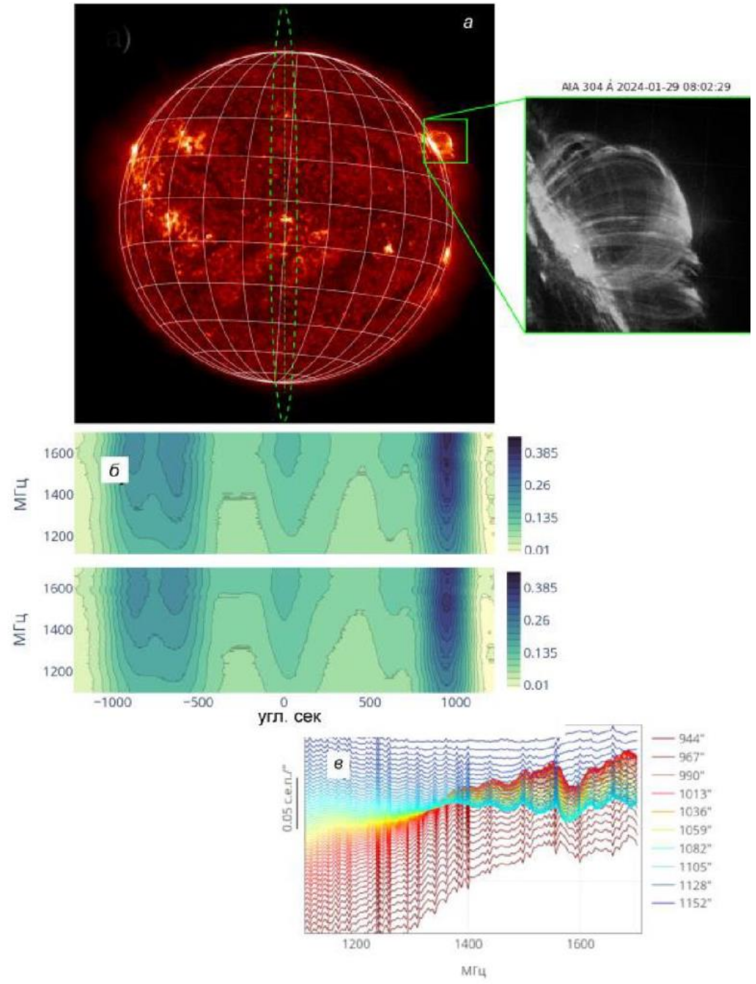
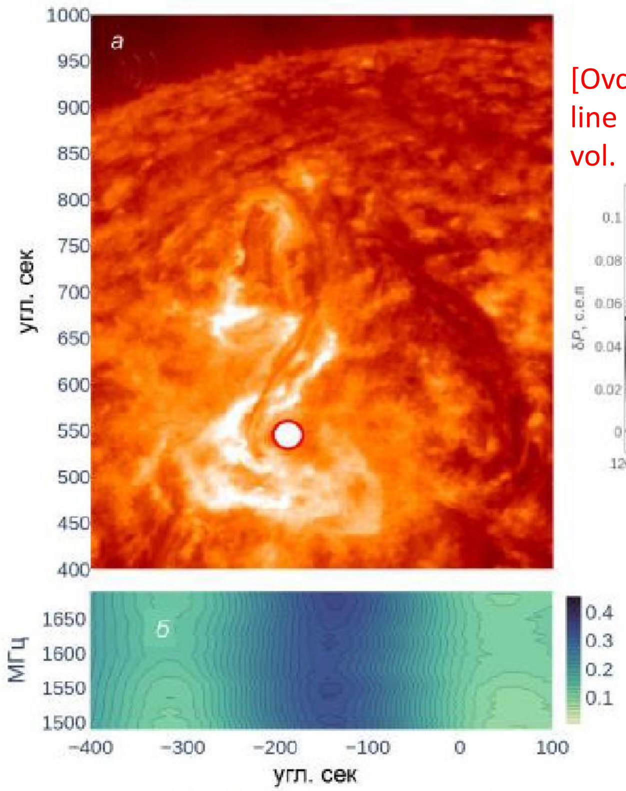
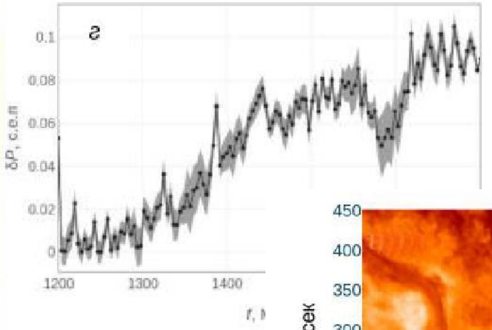
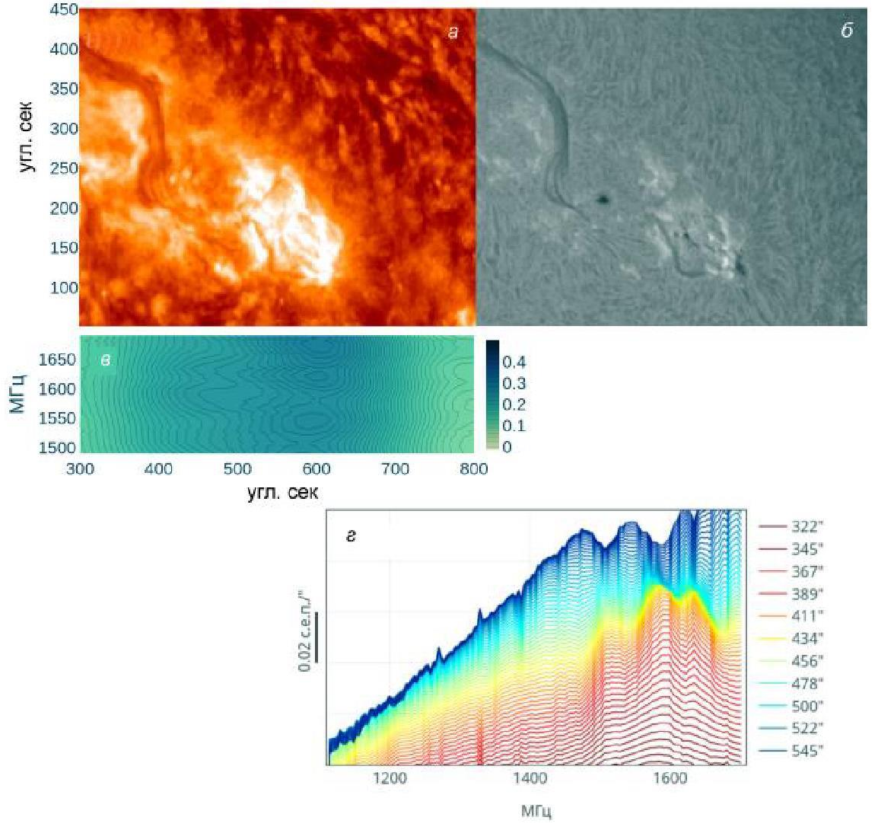


Рис. 2. Наблюдения 29 января 2024 г.: *а* — снимок SDO/AIA 304 Å, штриховая линия — положение ДН на частоте 1600 МГц в момент прохождения оси азимута в транзитном режиме; *б* — спектрограмма Солнца в транзите в двух поляризациях после обращения свертки с ДН; *в* — спектры радиоизлучения после обращения свертки с ДН области от +940″ до +1100″ от центра солнечного диска, соответствующей корональному дождю (на врезке)







The explanation based on the absorption due to OH radical is incorrect

First let us start with the explanation for the observed dip in terms of the absorption due to the **OH radical** in the solar filaments that are in the vicinity of an active region.

It is claimed that the OH radical's transition corresponding to the frequency $\sim \mathbf{1650}\ \boldsymbol{MHz}$ is responsible for the observed phenomenon. The cold filament that protrudes on and above the active region supposedly absorbs this frequency leading to the absorption of the energy corresponding to this frequency.

Now the pictures showing this dip in the decimetric radio spectrum show clearly that the width of the absorption is definitely of the order of $\sim \mathbf{10}\ \boldsymbol{MHz}$. This is especially interesting as we know that the reasons for the broadening of the spectral emission or absorption lines are as follows:

1. Thermal Doppler broadening
2. Turbulence
3. Stochastic Stark effect (Very important in proton rich environment like solar corona)
4. Pressure induced broadening due to the stochastic Van der Waals interactions.
5. Ordered motion such as rotation or vorticity of the medium which as a whole is observed as a point object.

Among the above-mentioned reasons, the most common are the thermal Doppler broadening and broadening due to the stochastic broadening. In the (2024 paper), the authors had used the following algorithm for evaluating the absorption coefficient, we briefly summarize the steps involved here:

1. Obtain the line intensity $S_{ij}(T_{ref})$ and the partition function $Q(T_{ref})$ for the OH radical at 1650 MHz at the reference temperature $T_{ref} = 296K$ using the HITRAN database at https://hitran.org/.

2. Then obtained values are then used to evaluate the line transition intensity $S_{ij}(T)$ at a temperature of interest which in their case is $T = 5000\ K$. To do this the following formula is used:

$$S_{ij}(T) = S_{ij}(T_{ref}) \frac{Q(T_{ref})}{Q(T)} \frac{e^{\frac{-h\nu_{ij}}{kT}}}{e^{\frac{-h\nu_{ij}}{kT_{ref}}}} \frac{1 - e^{\frac{-h\nu_{ij}}{kT}}}{1 - e^{\frac{-h\nu_{ij}}{kT_{ref}}}}$$

3. Later the line profile is considered either as a Gaussian, Lorentzian or a Voigt (convolution of a Gaussian and a Lorentzian) depending upon the situation under consideration. If the pressure is extremely feeble then the line profile was chosen as per the recommendation of the HITRAN site as a Gaussian line profile due to the **thermal Doppler broadening**.

4. The half width at half maximum is then calculated as follows: $$\mathrm{W(T)} = \sqrt{\frac{2kT\ln(2)}{mc^2}}\nu_{ij}$$

Now the line profile equation is given by: $$f_G(\nu, \nu_{ij}, T) = \sqrt{\frac{\ln(2)}{\pi W(T)^2}} \cdot e^{-\frac{(\nu_{ij}-\nu)^2 \cdot \ln(2)}{W(T)^2}}$$

Now the absorption coefficient is calculated as follows: $$k_{ij}(\nu, \nu_{ij}, T) = S_{ij}(T) \cdot f_G(\nu, \nu_{ij}, T)$$

The essence of this expression is that more the number of entities that are inclined towards the transition from the i to the j state, more is the absorption. That is if the line width is broad then, there are lesser favorable entities (OH radicals in this case) to undergo the transition. Similarly, the narrower the line width the greater the absorption.

Now let us look at the Doppler broadening due to the thermal motion which is given by the following expression: $\boldsymbol{\delta f = \sqrt{\frac{8kTln(2)}{mc^2}}f}$

Here we have $k = 1.380645 \times 10^{-23}$ is the Boltzmann's constant, $c = 299792458\ m/s$ is the velocity of light, m is the mass of the particle involved in the light matter interaction, f is the frequency of the spectral line, δf is the broadening of the frequency due to thermal Doppler broadening and T is the temperature of the medium.

With this formula we can actually calculate the broadening of the OH radical's molecular spectral line in the frequency $\sim 1650\ MHz$ at the temperature $T = 5000\ K$. This gives us the frequency broadening as $\delta f{\sim}20\ KHz$, where as the observed broadening of the frequency at ~1650 MHz by RATAN 600 is ~10 MHz which corresponds to the temperature $T{\sim}1.22 \times 10^9 K$, i.e., temperature even hotter than the hottest parts of the corona and sure several orders of magnitude higher than the dissociation energy of the OH radical which corresponds to the temperature ~40000 K. Therefore, the assumption that the dip in the decimetric radio domain at frequencies from 1.5 GHz to 1.7 GHz is absurd and incorrect.

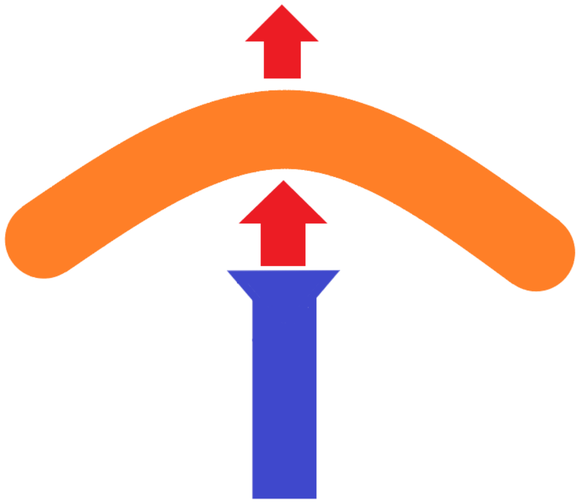
In the (2024 paper), this broadening which is **1000 times** than the thermal Doppler broadening is attributed to the Zeeman effect. This assertion has a logical flaw as the magnetic field changes the degeneracy of the states and one cannot use blindly the formulae with the values of degeneracy without the magnetic field. Also, as said any broadening be it due to the stochastic Stark effect or Zeeman effect or pressure induced broadening should be accounted in the calculation of the absorption coefficient. If one looks carefully at the formulae prescribed at the HITRAN web site, one immediately notices that the line profile function $f_L(\nu, \nu_{ij}, T)$ is inversely proportional to the half width at half maximum (HWHM) if the shape of the profile is taken constant. In other words, the real line profile can be expressed correct to the order of magnitude as follows: $f_L(\nu, \nu_{ij}, T) \sim \frac{const}{\text{HWHM}} \Phi(\nu_{ij}, \nu, T)$

Here $\Phi(\nu_{ij}, \nu, T)$ is the shape function of the actual observed line. As the HWHM in the present case is around 1 MHz, the results corresponding to the absorption coefficient were exaggerated by 1000 times. **This mistake renders the calculated absorption coefficient in (2024 paper) incorrect.**

Now the reason associated with the turbulence cannot be invoked to the extent needed because such an intense turbulence should have heated plasma considerably due to the motion of different layers of plasma against the internal friction. Also, the reason associated with the ordered motion can likewise be excluded due to its absence in the other data.

Another important flaw that completely discredits the obtained results is the use of a very primitive form of the Beer Lambert's law given by:

$I = I_0 e^{\alpha(\nu,T)u}$



The problem with such an equation is that even if the overhanging filament is brighter than the active region, one still obtains an absorption as there is no term representing the emission due to the filament itself. The proper differential equation in the present context will be the radiative line transfer equation given by

$$\frac{dI}{dx} = -\alpha(\nu,T) \cdot I + j(\nu,T)$$

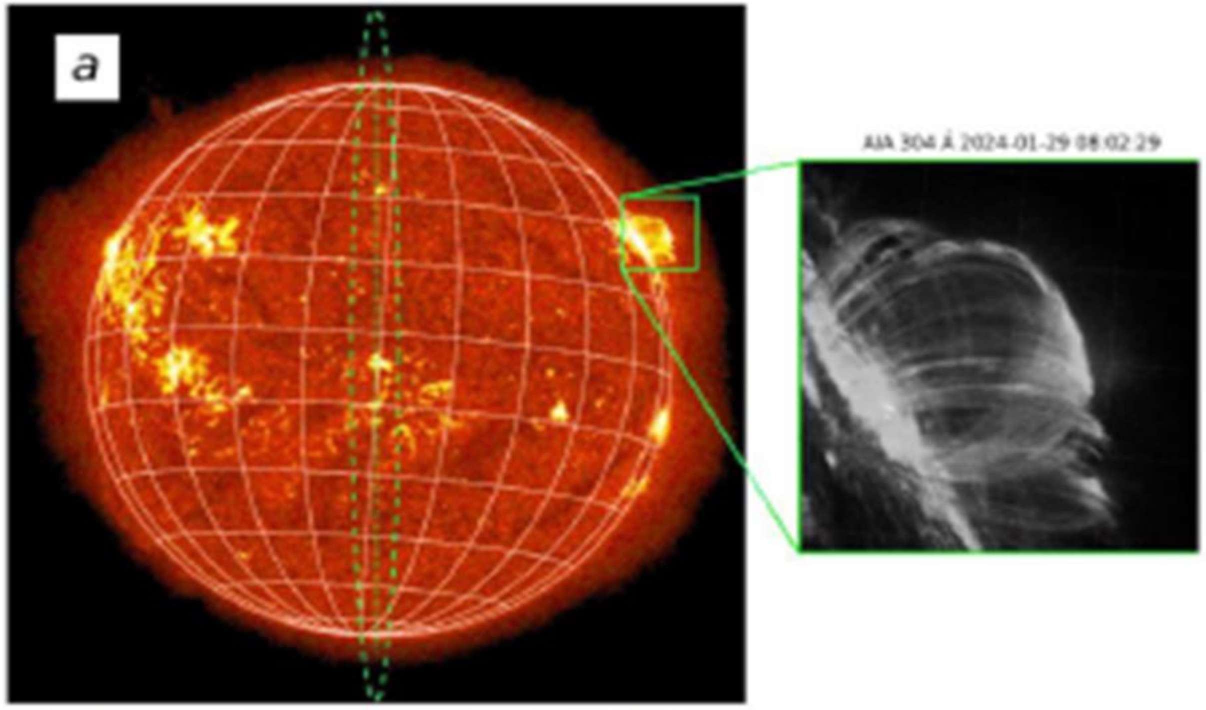
Here $j(\nu,T)$ represents the emission due to the filament itself. It can be easily noticed that once $j(\nu,T) \sim 0$ then the above equation gives the well-known laboratory relevant Beer Lambert's law.

There is also one other logical loop hole in the analysis of the 2024 paper. Let us look at the figure 2a. Here we present it once again for convenience. It can be clearly noticed that the active region is a flaring active region and the coronal arcade is glowing brilliantly in the 304 Å. Therefore, the temperature should be greater than or around 80000 K i.e., the temperature is a bit too much for the existence of the OH radical as the temperature of dissociation for the OH radical is around 40000 K. Hence the proposed presence of the OH radical necessary for the observed absorption is logically inconsistent.

Also, the equilibrium between the unionized and ionized species of the OH radical that is the equilibrium between $OH \leftrightarrow OH^+$ is not considered. This is crucial because OH^+ is more stable than OH as the dissociation energy of the OH^+ molecular ion is around $\sim 5\, eV$ whereas the dissociation energy of the OH radical is around $\sim 4\, eV$. Therefore, a fraction of the produced OH should exist in the form of OH^+ molecular ion reducing the amount of OH available for the absorption.

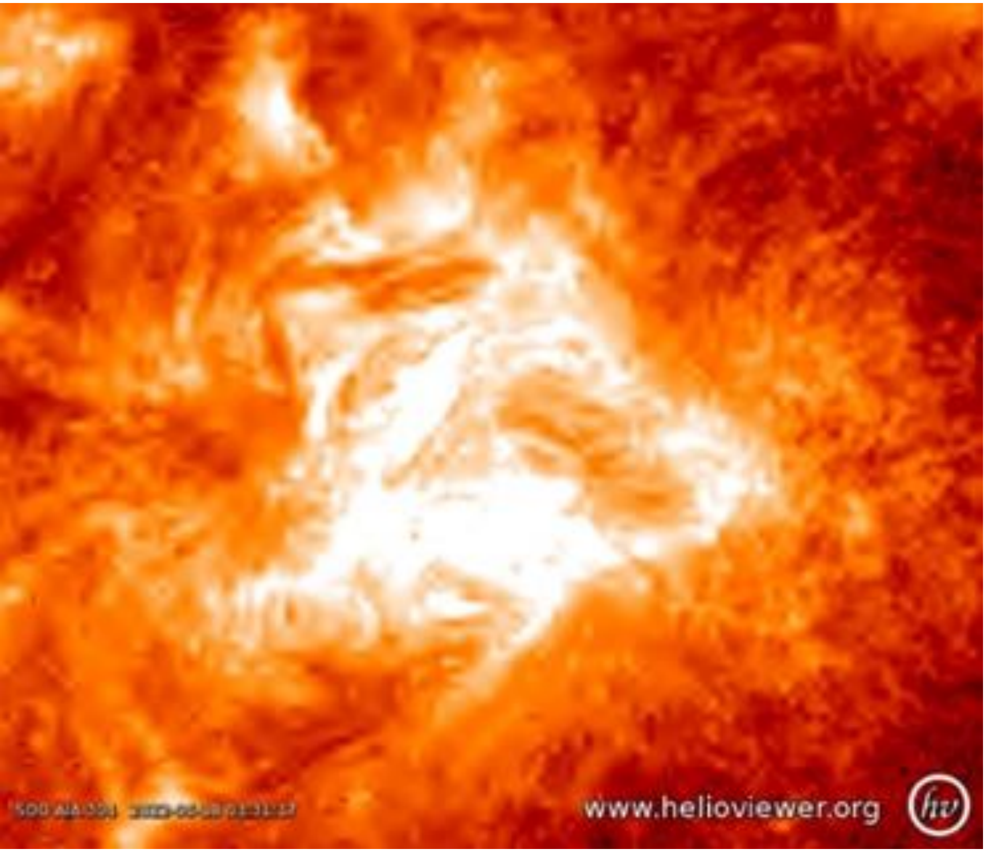
These pictures are taken from the following source

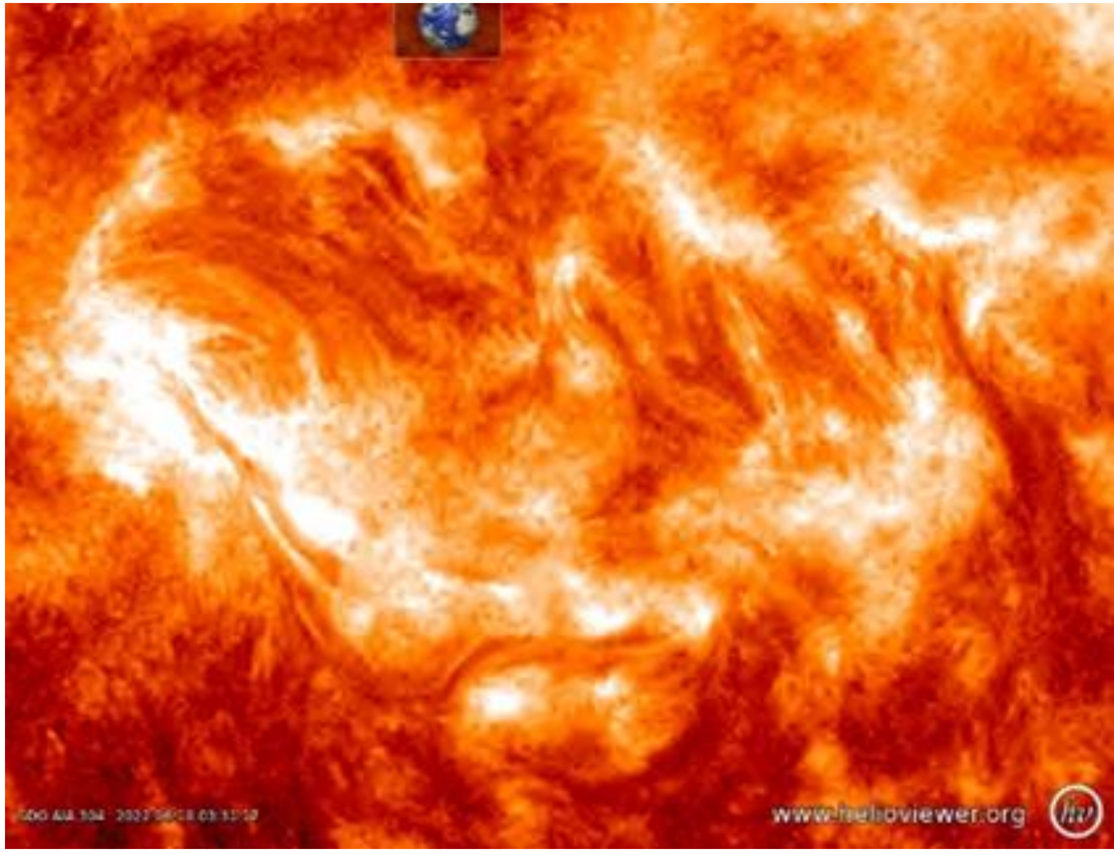
Ovchinnikova, Nina et al., Observation at radio frequencies of the hydroxyl (OH) absorption line in filaments and prominences above active regions of the Sun, Solar-Terrestrial Physics, vol. 10, issue 3, pp. 18-24, DOI:10.12737/stp-103202403

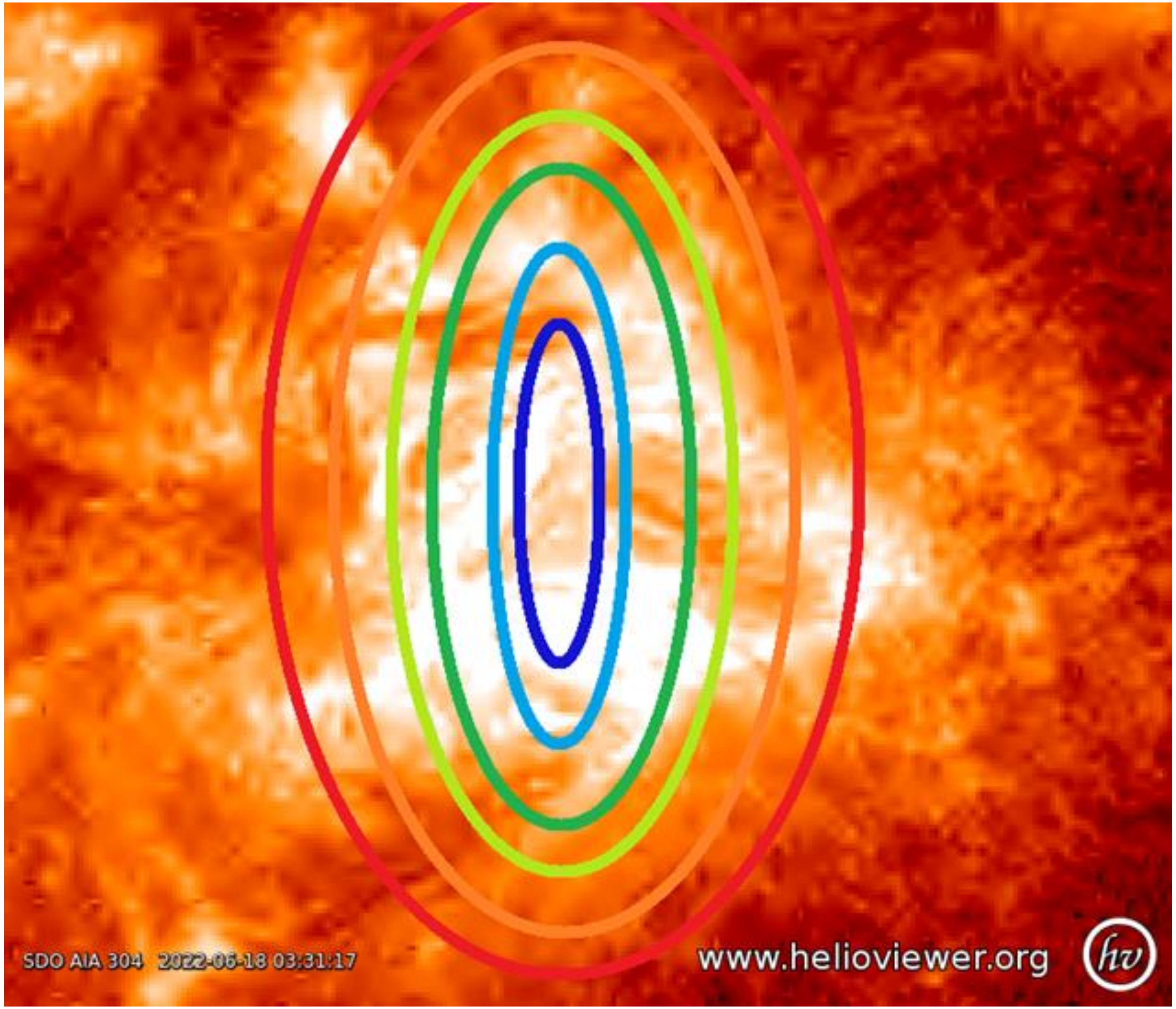


A plausible explanation for the observed dip

Let us look at the active regions as seen in the 304 Å of the SDO. They usually look as the following:

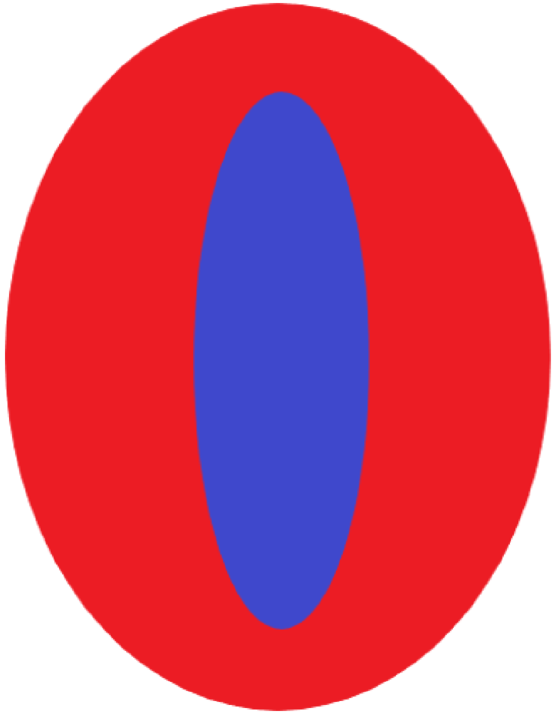


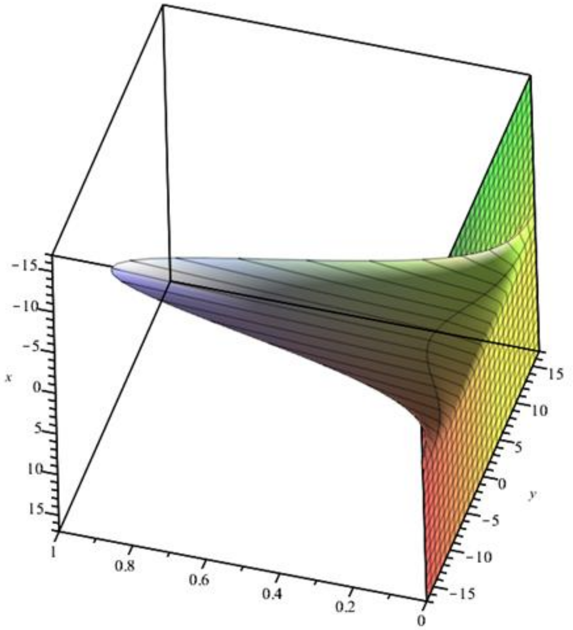



SDO AIA 304 2022-06-18 03:31:17
www.helioviewer.org

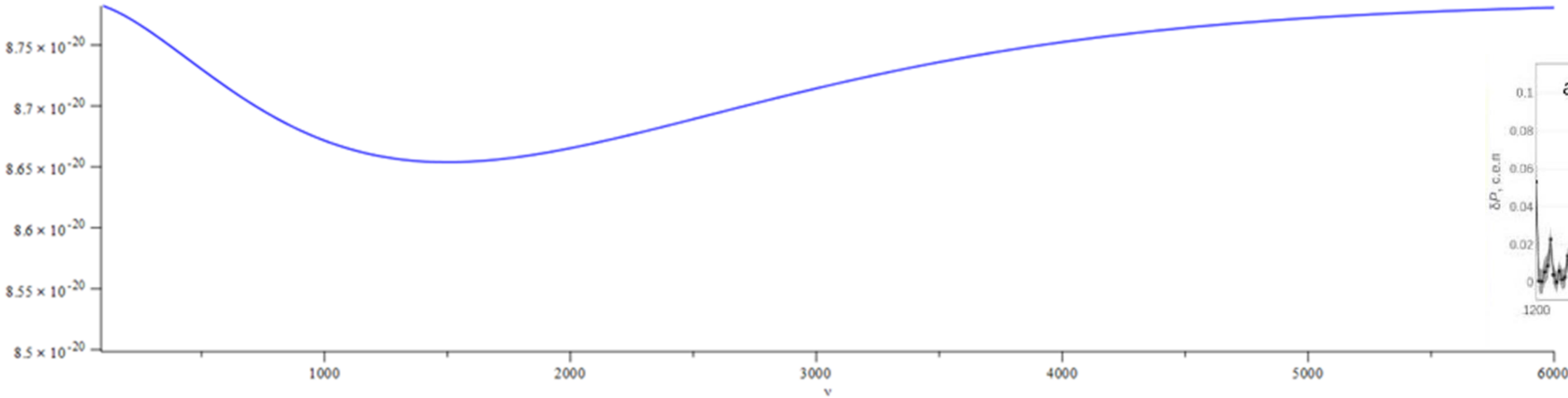
Generalized scenario

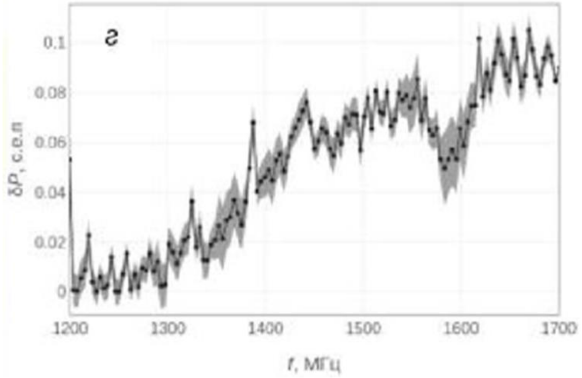
$$S(\nu, \mathrm{T}) = \frac{\pi k T}{2 D_1 D_2} - \frac{2kT}{D_1 D_2} e^{-\frac{\nu}{\nu_p}} \int_0^{\frac{\sigma_a}{\sigma_x}} e^{-p^2} dp \cdot \int_0^{\frac{\sigma_b}{\sigma_y}} e^{-q^2} dq$$





But the depression is wide and not as the one observed in the experimental RATAN 600 data shown here at the bottom right

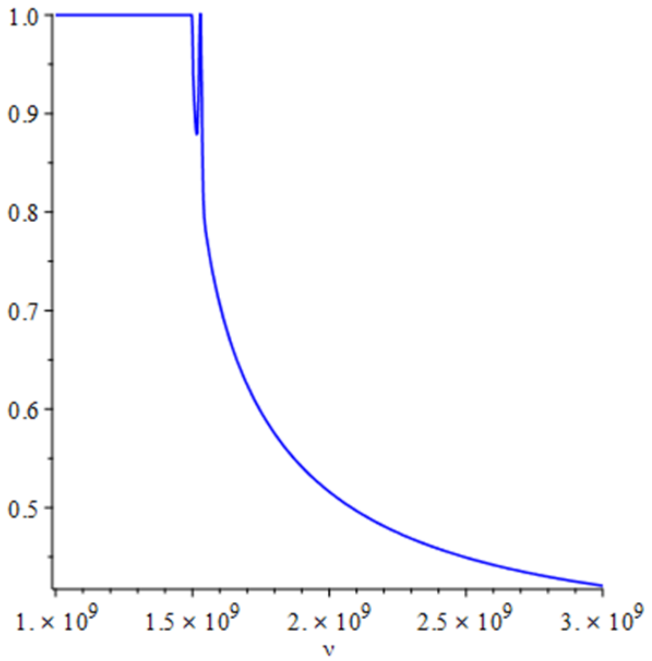




Emergence of a very interesting effect

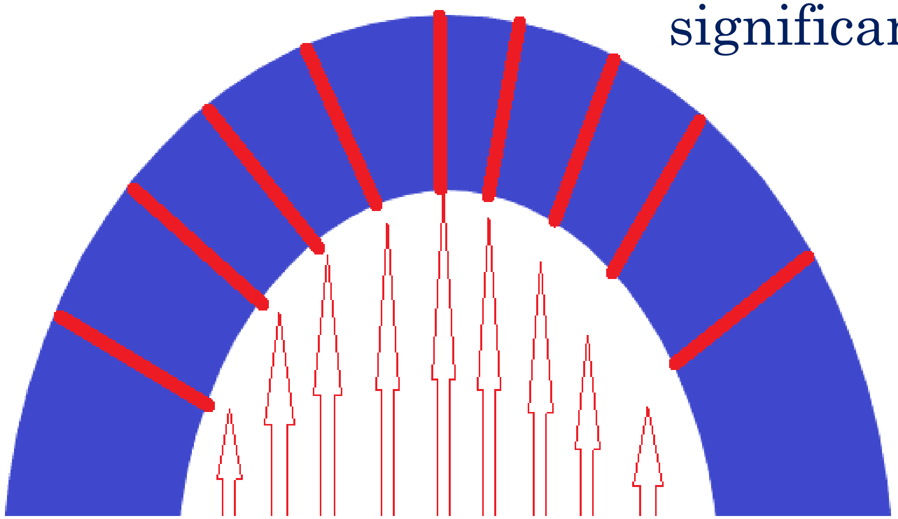
$$\frac{Sin\ i}{Sin\ r} = v_i/v_r \sim c/v_r \sim \mu_{fil} \sim \frac{1}{\sqrt{1 - \frac{\omega_p^2}{\omega^2}}}$$

We call it the
"Defocusing Cloud Effect (DCE)"

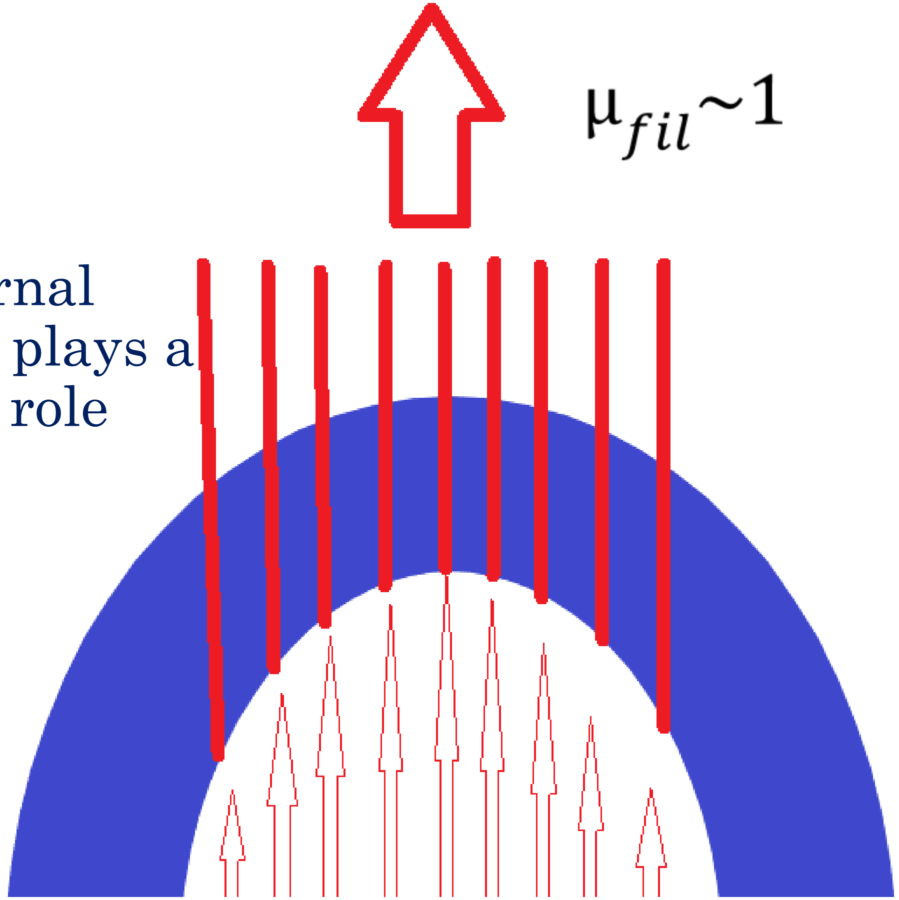


$$\mu_{fil} \sim \frac{1}{\sqrt{1 - \frac{\omega_p^2}{\omega^2}}} \sim \infty$$

Total internal reflection also plays a significant role

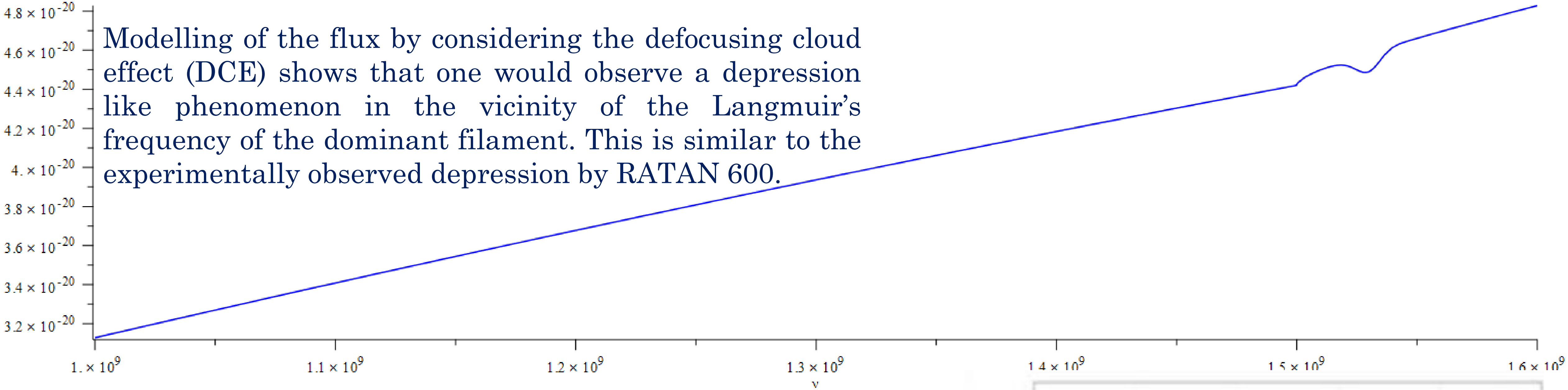


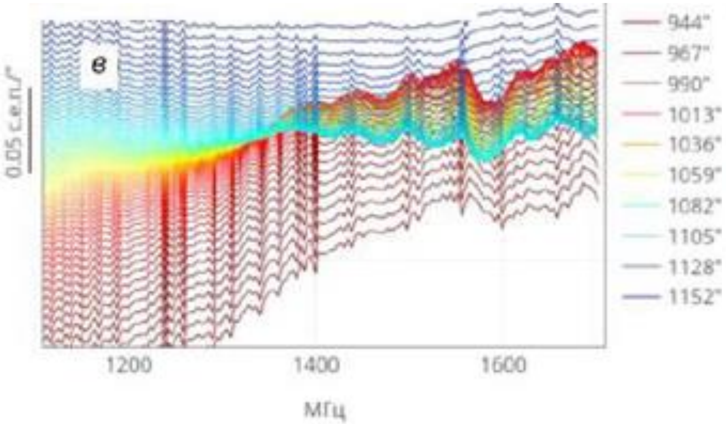
$$\mu_{fil} \sim 1$$

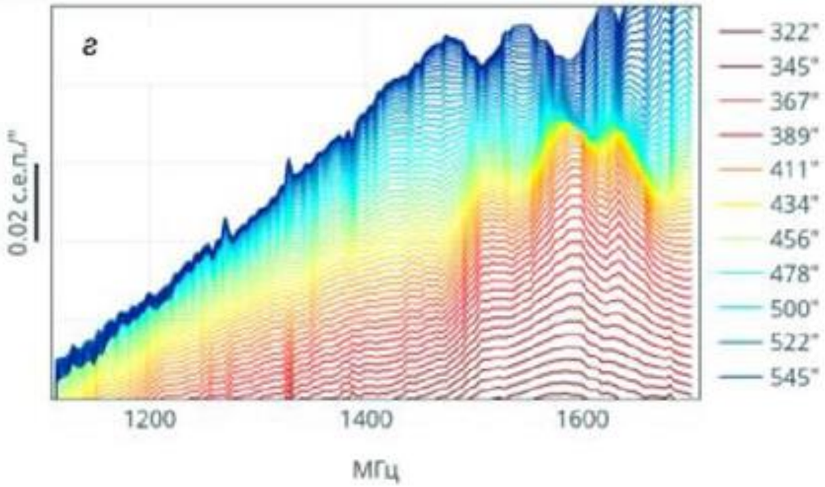


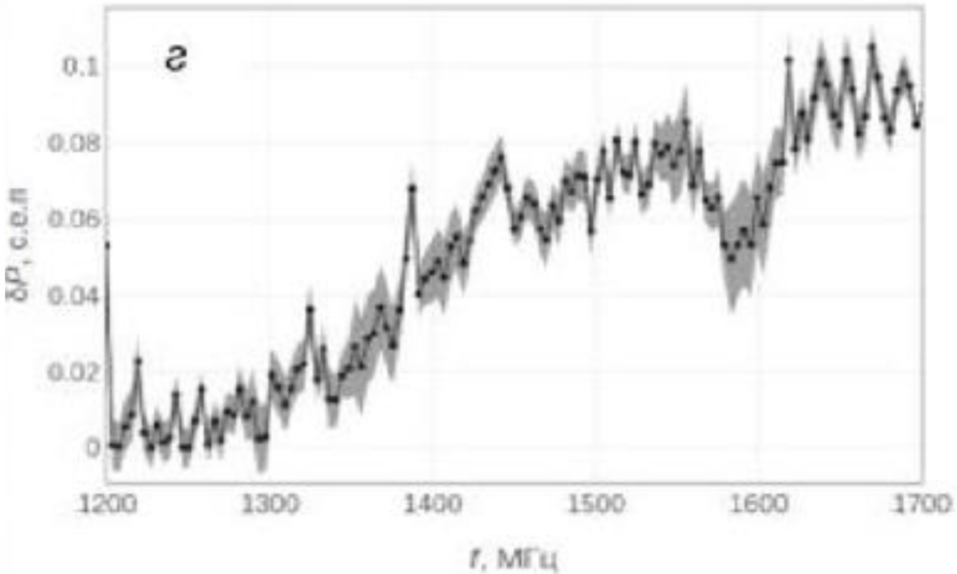
The observed depression

Modelling of the flux by considering the defocusing cloud effect (DCE) shows that one would observe a depression like phenomenon in the vicinity of the Langmuir's frequency of the dominant filament. This is similar to the experimentally observed depression by RATAN 600.









The above three pictures representing the depression as observed by RATAN 600 are taken from the following source

Ovchinnikova, Nina et al., Observation at radio frequencies of the hydroxyl (OH) absorption line in filaments and prominences above active regions of the Sun, Solar-Terrestrial Physics, vol. 10, issue 3, pp. 18-24, DOI:10.12737/stp-103202403

Conclusion

- We conclude that the explanation of the observed depression in the RATAN 600 data in the decimetric radio spectrum is not due to the absorption by the OH radical, as such an absorption would demand anomalously large amount of the OH in the filaments. Also, the fact that such a depression is found even in the active flaring regions, whose temperatures can easily exceed 40000 K excludes the possibility of the absorption due to OH radical as the dominant effect in the observed phenomenon.
- As a rational alternative, the observed depression may be caused due to the defocusing cloud effect combined with the effects related to the radiation profile of the RATAN 600.
- We present results of our modelling to reinforce our idea and show that the depression is primarily related to the Langmuir's frequency of the dominant filament.