Manual for viewing DOT solar movies and papers with examples

1. Dutch Open Telescope (DOT) solar movies and scientific papers how to reach With example of solar rim

DOT Movies are reachable with the link:
https://robrutten.nl/dot/dotweb/dot-albums/movies/album.html
This webpage starts with some instructions for downloading and watching the movies. Best first to download the movie (right mouse button) and play locally. Then, two vertical lists of movies, first a short test movie, followed by a movie list in chronologic order with an image and name of each movie, both are links to the movie. Mostly the avi file (Windows Media Player) is on the left side and the mov file (Quick Time player) on the right side. But sometimes, it is the other way round, so not consequently kept in the make of the website. The movie files have ingrained a playing speed of 10 images per second. This is a correct speed to view the movies. The normal 30 or 24 images are to fast for correct playing. Other movie players sometimes do not follow the ingrained speed of 10 images. If possible, choose the 10 images per second in the player menu, or choose play all images for smooth playing.

Direct reach of a specific movie is possible with a direct link. An example is a movie of the solar rim:
M01 https://robrutten.nl/dot/dotweb/dot-albums/movies/2003-11-04-AR10486-ca-limb.avi
M01 https://robrutten.nl/dot/dotweb/dot-albums/movies/2003-11-04-AR10486-ca-limb.mov
The outgoing gas streams at the rim, the fine fibrils in the chromosphere, and the bright solar surface are visible simultaneously because of the low stray light of the DOT. The sunspots appear as flat dark pancakes amidst the bushes of chromospheric fibrils. The large upward gas stream is called a surge, which was visible during a few hours. It may have resulted from magnetic reconnection.
The research paper resulting from this movie is reachable with the direct link:
P01 https://robrutten.nl/dot/dotweb/dot-pubs/2005AAp...444..265T.pdf

In addition to direct links, the scientific papers, resulting from the DOT, are reachable from the list in:
https://robrutten.nl/dot/DOT_scientific.html
The individual papers in this chronologic list are reachable by the link underneath the author and title names, for this paper:
K. Tziotziou, G. Tsiropoula, P. Sütterlin, 2005
DOT tomography of the solar atmosphere V. Analysis of a surge from AR10486
P01 A&A 444, 265

Initially, the movies were produced in mpg format from the data files of the processed camera images. Files in mpg format can be found on the webpage
https://robrutten.nl/dot/dotweb/dot-movies/dircontent.html
At this page, one can choose a movie, for example the movie of the solar rim:
M01 2003-11-04-AR10486-ca-limb.mpg
Of course, one can also reach the movie directly with the link:
M01 https://robrutten.nl/dot/dotweb/dot-movies/2003-11-04-AR10486-ca-limb.mpg
The mpg movies do not have a play-velocity of 10 images per second ingrained in the file. The standard of 30 images per second used by players is too rapidly. First, this is too quick to follow well the changes in the depicted structures. Secondly, often the computer processor is not quick enough to show the larger images at that rate. As a result, the movie is played jerkily in the course of which parts of the movie are omitted. Briefly, it simply is hideous. With some players like Mplayer and VMPEG, one can adjust the velocity and choose the sensible play-velocity of 10 images per second. Advantage of the mpg movies is smaller file size for the same resolution. With the mentioned players, smooth presentation is possible with a less fast processor.

2. Spots, Granules, Bright Points

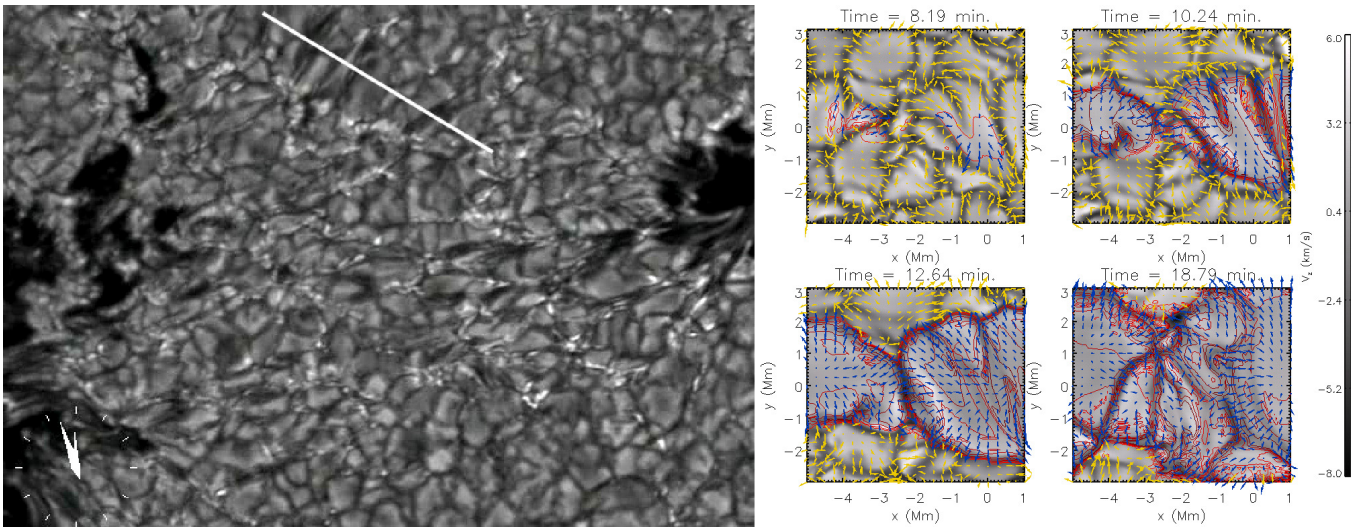
M02 https://robrutten.nl/dot/dotweb/dot-albums/movies/2001-04-01-AR9407-gb.avi
M02 https://robrutten.nl/dot/dotweb/dot-albums/movies/2001-04-01-AR9407-gb.mov
M02 https://robrutten.nl/dot/dotweb/dot-movies/2001-04-01-AR9407-gb.mpg
Early in 2001, a new camera system has been installed at the DOT with a larger field and same high-resolution. This is a movie of a sunspot recorded shortly after the installation of the new camera system. Outside the sunspot a typical granulation pattern of rising gas bubbles approximately 1000 to 2000 km in diameter is present. In the centre of the bubbles, where the gas rises, the gas is a few hundreds of degrees warmer (6500 degrees) than in the dark lanes where the gas rapidly falls down to deeper layers of the sun. Bright structures are in the dark granular lanes of out breaking magnetic tubes, the so called Bright Points, in fact small bright structures and not points. The integrated effect of the Bright Points over the whole sun possibly forms the third important part of the total magnetic field of the sun.

Other solar physics research was already shortly after the observations. It was found that the radial structures in the penumbra of the sunspot have typical dimensions between 0.3 and 0.7 arc seconds, corresponding to 200 till 500 km on the solar surface. Below 0.3 arc seconds the power spectrum of the penumbra structures goes down, whereas for a region with many bright points the power spectrum remains high till the resolution limit of the telescope of 0.2 arc seconds:
P. Sütterlin, 2001
The size of penumbral fine structure
P02 A&A 374, 21
P02 https://robrutten.nl/dot/dotweb/dot-pubs/suetterlin2001.pdf
A second paper based on these observations is:
B. Bovelet, E. Wiehr, 2003
Dynamics of the solar active region fine structure
P03 A&A 412, 249
P03 https://robrutten.nl/dot/dotweb/dot-pubs/bovelet-wiehr2003.pdf

The Bright Points are well visible in the spectral region from 430.0 till 431.0 nm, where many CH absorption lines are present, called G-band. So the sun spot shown in the movie with the link here before is made in the light through a G-band spectral filter. A continuum part of the solar spectrum without CH lines is in the very nearby spectral region from 431.6 till 432.2 nm. The bright points are only weakly visible in the inter-granular lanes. A movie with next to each other a field in G-band and Continuum is in:
M03 https://robrutten.nl/dot/dotweb/dot-albums/movies/2001-10-17-QS-gb-bc.avi
M03 https://robrutten.nl/dot/dotweb/dot-albums/movies/2001-10-17-QS-gb-bc.mov
M03 https://robrutten.nl/dot/dotweb/dot-movies/2001-10-17-QS-gb-bc.mpg
The magnetic field in the bright points dissociates the CH molecules. The deeper hotter tube parts are visible.

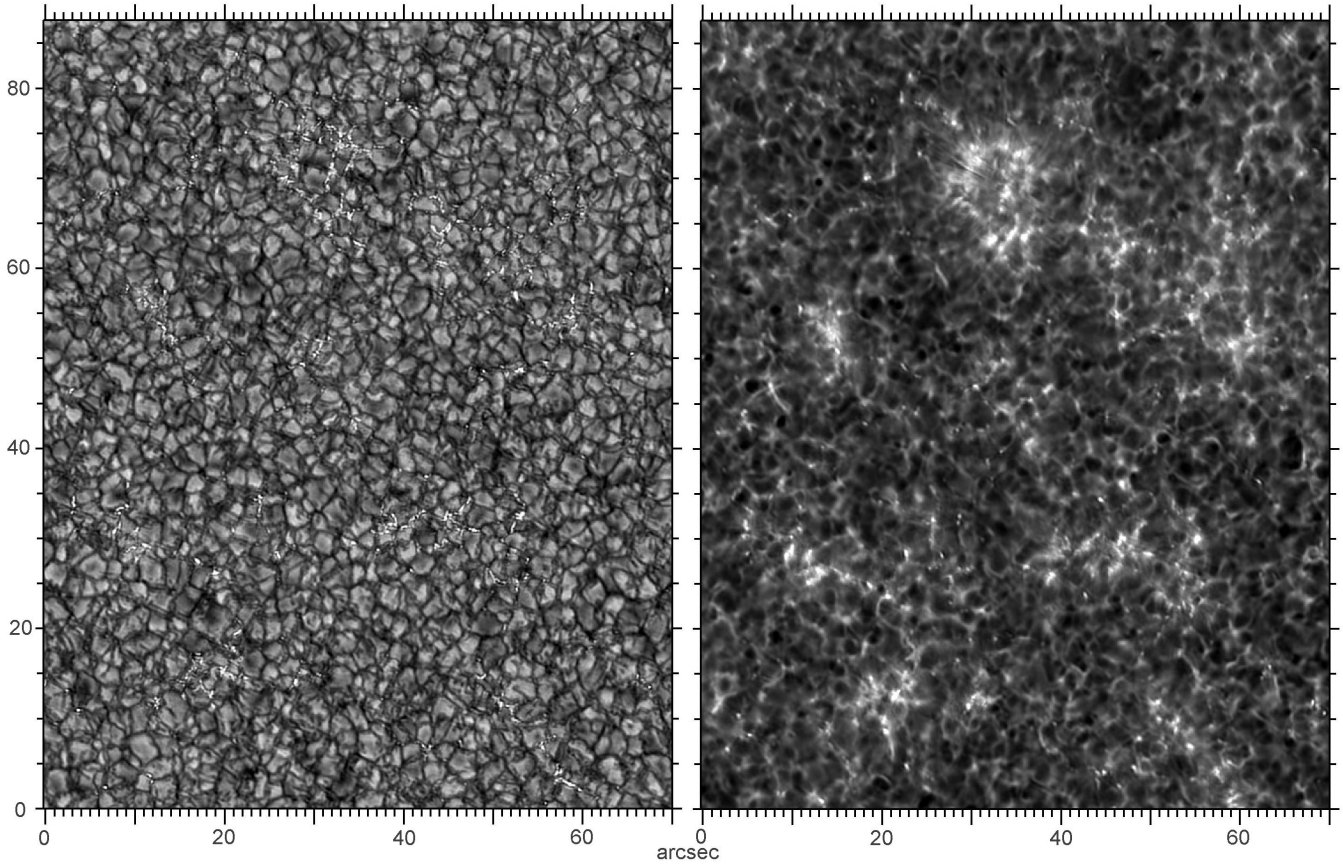
A movie, with next to each other on the left side G-band, on the right side Continuum and in the middle subtracted G-band mines continuum, is in:
M04 https://robrutten.nl/dot/dotweb/dot-albums/movies/2001-10-19-AR9669-gb-bc-diff.avi
M04 https://robrutten.nl/dot/dotweb/dot-albums/movies/2001-10-19-AR9669-gb-bc-diff.mov
M04 https://robrutten.nl/dot/dotweb/dot-movies/2001-10-19-AR9669-gb-bc-diff.mpg
Explanation of the physics of the Bright Points is in the research paper:
P. Nisenson, A. A. van Ballegooijen, A. G. de Wijn, P. Sütterlin, 2003
Motions of isolated G-band bright points in the solar photosphere
P04 ApJ 587, 458
P04 https://robrutten.nl/dot/dotweb/dot-pubs/nisenson-etal2003.pdf

M05 https://robrutten.nl/dot/dotweb/dot-albums/movies/1999-10-21-AR8737b-gb.avi
M05 https://robrutten.nl/dot/dotweb/dot-albums/movies/1999-10-21-AR8737b-gb.mov
M05 https://robrutten.nl/dot/dotweb/dot-movies/1999-10-21-AR8737b-gb.mpg
Movie in G-band recorded immediately after a small eruption of a solar flare seen on satellite images of the high solar atmosphere, the corona. Between two groups of sunspots of opposed magnetic polarity, violently-moving structures are visible as Bright Points. Moreover, the granulation shows abnormal forms and movements. Ten years later, this abnormal granulation has shown up at computer simulations of flux tubes, with a strong magnetic field, that rise from underneath the solar surface upward into the photosphere, see in
P05 A. Tortosa-Andreu and F. Moreno-Insertis, 2009, Magnetic flux emergence into the solar photosphere and chromosphere, A&A 507 pp.949-967 section 3.2 with Fig. 2 on page 952 with reference to this DOT movie.
An image, taken out of the movie, is here after with next to it images of the simulation.



Left: Image of movie. Along the white line, a row of abnormal granules elongated perpendicular to the line. In the centre between the two spots, elongated granules are in spot-to-spot direction with many Bright Points. Right: Numerical computer simulation of the abnormal granules by rising magnetic flux tube braking out.

Quiet solar area in the G band (left) and in Ca II H 396.85nm (right, filter 0.135nm) are in the DOT movie:
M06 https://robrutten.nl/dot/dotweb/dot-albums/movies/2002-12-08-QS-gb-ca-L7.avi
M06 https://robrutten.nl/dot/dotweb/dot-albums/movies/2002-12-08-QS-gb-ca-L7.mov
M06 https://robrutten.nl/dot/dotweb/dot-movies/2002-12-08-QS-gb-ca-L7.mpg
The Ca II H images at right sample the low chromosphere, about 400 km higher up, brighter where clusters of magnetic elements occur, the Bright Points visible on the left side. These patches of enhanced brightness outline the chromospheric network, which coincides with the magnetic network constituted by the magnetic elements in the photosphere, see also movie image here below with added scale in arcsec (725km on the sun / arcsec):



The granulation pattern is partially reversed in the low chromosphere: at this height, the gas above the lanes tends to be brighter than the gas above the granules. The outgoing gas streams, the fine fibrils in the chromosphere visible at the solar rim, are along the magnetic tubes based in the Bright Points and go upward heating the chromosphere. Relationship between Bright Points and magnetic field can be studied with the combination of G-band and Ca II H movie images:

A.G. de Wijn, R.J Rutten, E.M.W.P. Haverkamp, P. Sütterlin, 2005
DOT tomography of the solar atmosphere IV. Magnetic patches in internetwork areas
P06 A&A 441, 1183
P06 https://robrutten.nl/dot/dotweb/dot-pubs/2005AAp...441.1183D.pdf
The observations of June 16, 2003 are used for the paper, movie is:
M07 https://robrutten.nl/dot/dotweb/dot-albums/movies/2003-06-16-QS-gb-bc-ca-rc-L7.avi
M07 https://robrutten.nl/dot/dotweb/dot-albums/movies/2003-06-16-QS-gb-bc-ca-rc-L7.mov
M07 https://robrutten.nl/dot/dotweb/dot-movies/2003-06-16-QS-gb-bc-ca-rc-L7.mpg
G-band (430.5nm width 1.0nm) is left top, Blue continuum (431.9nm width 0.6nm) is right top,
Ca II H (385.85nm width 0.13nm) is left bottom, Red continuum (655.05nm width 0.24nm) is right bottom.
The pixels are bound to keep image size for smooth playing, so the showed resolution on the screen is reduced for showing 4 spectral wavelengths together. The Bright Points are still well visible, but somewhat less sharp. The data in full resolution are stored in the DOT data base and are used for the calculations.

3. Velocity measurements from the images

The Bright Points are also visible in the blue wing of the Hα line 656.28-0.08nm with tuneable filter width 0.025nm, see the paper:
J. Leenaarts, P. Sütterlin, R.J. Rutten, M. Carlsson, H. Uitenbroek, 2005,
Small-scale magnetic elements as bright points in the blue Hα wing
P07 ESA SP-596, 15
P07 https://robrutten.nl/dot/dotweb/dot-pubs/2005ESASP.596E..15L.pdf
and movie with G-band (430.5nm width 1.0nm) is left top, Ca II H (385.85nm width 0.13nm) is right top,
Hα blue wing (656.20nm width 0.025nm) is left bottom, Hα core (656.28nm width 0.025nm) is right bottom
M08 https://robrutten.nl/dot/dotweb/dot-albums/movies/2004-10-06-filament-gb-ca-haw-hac.avi
M08 https://robrutten.nl/dot/dotweb/dot-albums/movies/2004-10-06-filament-gb-ca-haw-hac.mov
M08 https://robrutten.nl/dot/dotweb/dot-movies/2004-10-06-filament-gb-ca-haw-hac.mpg
The Hα blue wing images show the high velocities in vertical direction of more than 30km/sec. Also, the structures moving fast over the solar surface show these velocities in direction parallel to the solar surface.
The Hα centre images show the magnetic field directions in the high chromosphere above the solar surface about 2000km, value depends on the solar activity.

Vertical-velocity values can be found by use of several images in both line wings of Hα in combination with line core. Example -0.07, -0.035, +0.035 and +0.07nm from line centre (in movie in milli Ångström -700, -350, +350, +700)
M09 https://robrutten.nl/dot/dotweb/dot-albums/movies/2004-10-16-AR10682-4xhaw.avi
M09 https://robrutten.nl/dot/dotweb/dot-albums/movies/2004-10-16-AR10682-4xhaw.mov
M09 https://robrutten.nl/dot/dotweb/dot-movies/2004-10-16-AR10682-4xhaw.mpg
The result is shown in the movie with Hα Doppler at right bottom together with Hα core, G-band and Ca II H
M10 https://robrutten.nl/dot/dotweb/dot-albums/movies/2004-10-16-AR10682-gb-ca-hac-had.avi
M10 https://robrutten.nl/dot/dotweb/dot-albums/movies/2004-10-16-AR10682-gb-ca-hac-had.mov
M10 https://robrutten.nl/dot/dotweb/dot-movies/2004-10-16-AR10682-gb-ca-hac-had.mpg
Hα Doppler shows: Waves come out of the sunspot, dark is towards us, bright is down to the solar surface with the used calculation method. One can see that powerful streams of gas arise from the sunspot centre at upper left. At upper right at the rim of the sunspot, a few fast-arising and disappearing black spots are visible. Simultaneously, bright regions are in the Ca II H line at the same place. Obviously, bubbles of gas are being flung away here.

Hα Doppler movie on another day together with Hα core, G-band and satellite observations in the far-ultraviolet iron line FeX at 17.1nm are in the movie:
M11 https://robrutten.nl/dot/dotweb/dot-albums/movies/2005-07-09-AR10786-gb-hac-had-171.avi
M11 https://robrutten.nl/dot/dotweb/dot-albums/movies/2005-07-09-AR10786-gb-hac-had-171.mov
M11 https://robrutten.nl/dot/dotweb/dot-movies/2005-07-09-AR10786-gb-hac-had-171.mpg
Satellite observations are combined with DOT observations. Two sunspot groups with opposed magnetic polarity, see the G-band image of the solar surface at upper left. In the line centre of Hα, at upper right, transformation of colliding magnetic field into heat occurs in the bright stringy ear-shaped region. At bottom right, satellite images are shown of far-ultraviolet light at a wavelength of 17.1nm (171 Ångström) in a spectral line of ionised iron FeX, which show the solar atmosphere higher than visible in Hα. The same region as shown in Hα is brightened up with bright rising stripes of gas moving to the left. At bottom left, Hα Doppler shows radial velocities, consequently in the line-of-view, determined from the images in the Hα line wings; again dark colour means moving away from the solar surface. Dark regions and stripes are visible above and at right next to the brightening region in Hα and FeX. Again, streams arise out of the spot cores. In the G-band images, regions with abnormal granulation are present in the granulation field

between the sunspot groups, see also the previously mentioned movie of 1999-10-21-AR8737b. The movie of the radial velocities in Hα Doppler shows a lot of fine structure and for this reason can be seen separately on a larger scale with higher resolution on the screen:
M12 https://robrutten.nl/dot/dotweb/dot-albums/movies/2005-07-09-AR10786-had.avi
M12 https://robrutten.nl/dot/dotweb/dot-albums/movies/2005-07-09-AR10786-had.mov
M12 https://robrutten.nl/dot/dotweb/dot-movies/2005-07-09-AR10786-had.mpg
And alternating, G-band with moving Bright Points in the low photosphere and Hα Doppler in the higher chromosphere with waves is shown in:
M13 https://robrutten.nl/dot/dotweb/dot-albums/movies/2005-07-09-AR10786-morph-had-gb.avi
M13 https://robrutten.nl/dot/dotweb/dot-albums/movies/2005-07-09-AR10786-morph-had-gb.mov
M13 https://robrutten.nl/dot/dotweb/dot-movies/2005-07-09-AR10786-morph-had-gb.mpg
The place of the waves can be located relative to the spots and the Bright Points.

4. Large fields in high resolution by mosaics

From larger mosaics in G-band, CaIIH and H-alpha, the field parts with sunspots are shown alternating in the movie:
M14 https://robrutten.nl/dot/dotweb/dot-albums/movies/2005-07-08-AR10786-morph-gb-ca-ha.avi
M14 https://robrutten.nl/dot/dotweb/dot-albums/movies/2005-07-08-AR10786-morph-gb-ca-ha.mov
M14 https://robrutten.nl/dot/dotweb/dot-movies/2005-07-08-AR10786-morph-gb-ca-ha.mpg
A complex sunspot region is shown. The H-alpha images show the complex pattern of magnetic fields. In the bright stringy regions, magnetic fields of opposed polarity collide and are neutralized, in the course of which, the magnetic-field energy is transformed into heat. The black thread bands, called filaments, are arches of relatively cooler gas above the solar surface. Outside the solar rim such filaments are visible as luminous arches against the black celestial background, called prominences.

The DOT is well suited for the make of mosaics because of its equatorial mount. The pointing cycle to make mosaics has been automated. In this way, movies of mosaics are made in which the dynamical processes on the sun are visible over large fields, see the paper:
R.H. Hammerschlag, G. Sliepen, F.C.M. Bettonvil, A.P.L. Jägers, P. Sütterlin, Y. Lin, S.F. Martin, O. Panasenco, E.P. Romashets, 2013
Large-field high-resolution mosaic movies
P08 SPIE Optical Engineering, August issue 2013
P08 https://robrutten.nl/dot/dotweb/dot-pubs/2013-Optical-Engineering.pdf
The images in the paper can be viewed enlarged on the screen to see the details.