ASTRONOMY & CAMERA OBSCURA

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1. Why did we decide to write about this topic?

During the year 2011 we stumbled across an interesting project by EAAE – Sunrise project. The project consisted of making a camera obscura and shooting the visible turn of the Sun during the equinoctial. Two consecutive years we took part by sending our pictures to the organizers. The process of making the camera and the potential which it gave us when taking pictures tickled our interest. We searched what other astronomical phenomenon and objects can be shot by the camera obscura. In this project we will show you our research and a few pictures which we have taken.

2. History of the camera obscura

The Latin word camera means room, and obscura - dark.
For the first time the term "camera obscura" was mentioned during the 17th century by the German scientist Johannes Kepler, but its use had been known since the centuries BC. There is a theory according to which the effect was known ever since the Paleolithic. It is thought that for some cave drawings of animals, the effect of achieving an image in a dark room through small holes was used. The researches in this area belong to Matt Gatton.
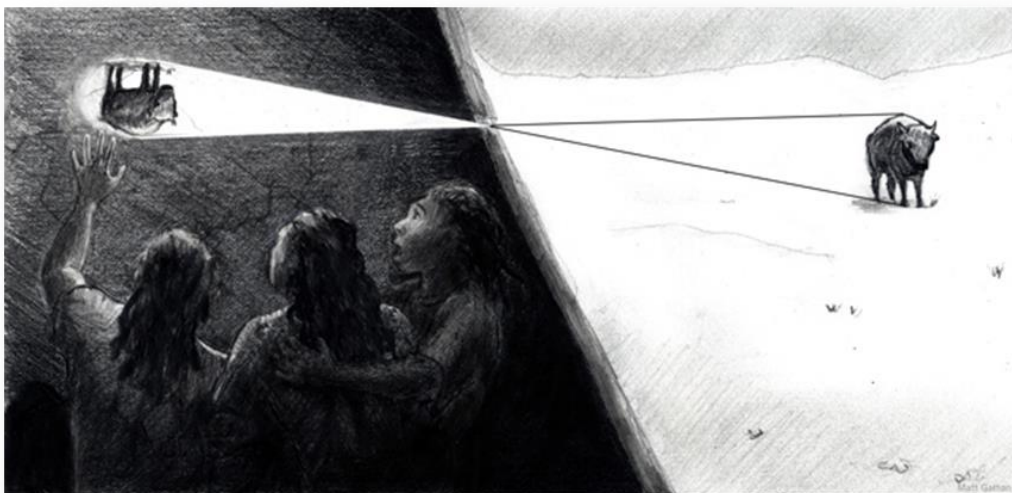
The first notes of researches on the effect of the camera obscura belong to the Chinese scientist Mo -Tzu (470-391 BC). He was aware that the light spread straight and by this method he explained the appearance. During the same time in Ancient Greece the philosopher Plato described that the rays of light were outgoing from the eyes and they fell on the objects. He also reflected on the origin of shadows which he described in the handwriting "The myth in the caves".

We decided to show this effect. We made a rectangular hole in a piece of cardboard and watched image of the Sun on a white sheet.

Aristotle was also interested in the phenomenon caused by the camera obscura. He watched the sickle-like images of the Sun, projected on the shadow of the trees. It occurs when light passes through the small holes in their leaves before the maximum phase of the solar eclipse appears. Aristotle noted the smaller the holes are the clearer the image was. He also wrote that the "solar light passing through the small holes of the leaves of the trees, the holes of a sieve, the holes of a basket even the interlaced fingers create round bright spots on the earth". These spots are always round, regardless the form of the hole. Aristotle described all of that in an essay "The form of the eclipse". The phenomenon is known as "The Aristotle's question".

The way the camera obscura works was first explained by the Iraqi mathematician, physicist and astronomer Ibn al-Haytham during the 10th century. He reached the conclusion that the widely accepted theory in those years for light spread (that the light comes out of the eyes and light the objects) wasn't true.Ibn al-Haytham himself created a camera obscura after seeing the light pass through the holes in curtains. He improved his creation when he saw that the smaller the hole was the more sudden the image was.

For the first time the camera was used by Leonardo da Vinci while sketching landscapes. He described the action in his work "Treatise on Painting". During the year 1688 Johannes Can created a portable camera obscura, provided with a

mirror placed under 45 degrees, which projected the image on a horizontal matted plate. This allowed painters to transfer landscapes in paper.

A lot of painters use the camera obscura while creating their masterpieces – landscapes, portraits, sketches. In those times the camera was a large box provided with a system of mirrors for deviation of the light. Often, instead of a hole, a lens is used so that the brightness can be increased. In time the lenses got more complicated and when light-sensitive materials were created the camera obscura was turned into a camera.

3. How does the camera obscura work?

The camera obscura is a simple type of device with which you can achieve an optical image of objects. It is a light-tight box with a hole and a wall and opposite to the wall there is a screen matted glass or thin piece of white paper). The solar rays, which pass through the hole that has a diameter close to 0.5-5mm, create an upside-down image on the screen. The camera obscura marked the beginning of the creation of cameras.

- *Scheme:*
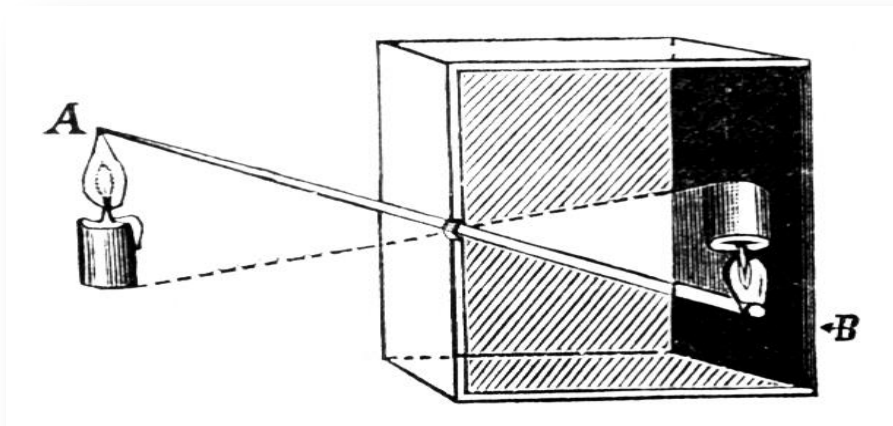
- *Formula:*

The hole, which plays the role of an objective without lens, must be very small – close to 0,5 mm to achieve a sudden image. The smaller the hole is the more contrast the image is but not illuminated enough. Furthermore, the reduction of the diameter of the hole leads to the appearance of the effect of diffraction and the image gets unclear. For the first time Josef Petzval created a method of calculating the optimal diameter of the hole. The formula which is used today was developed by Lord Reilly:

$D = 2\sqrt{(1/2)f\lambda}$

Where D is the diameter of the hole, f – the focus distance (the distance between the hole and the screen), and λ is the length of the wave of the light.

The ratio f/d just as with the lens determines the number of the diaphragm (relative hole). For example a camera with f=100 mm and diameter of the hole d=0.5 has a number of the diaphragm which is 200. If we increase the hole with 1mm we will reduce by 100. The bigger the number is the more the brightness of the camera is reduced because the brightness is S = (d/f)2.

The shutter of these types of cameras can be something non-transparent placed by hand in front of the hole so that light doesn't get through. The time for exposure is longer than the one of the conventional photography. Because of the low brightness of the hole the exposures can vary between minutes and days.

- ***Problem:*** *To make a camera obscura.*

    For our camera obscura we used a box and a candle. We calculated the diameter of the hole for f=27cm=0.27m и λ=500nm=500x10^{-9}m(the wavelength of green light).

$$D=2\sqrt{\left(\frac{1}{2}\right)f\lambda}$$

$$D=2\sqrt{\left(\frac{1}{2}\right)0.27\text{x}500\text{x}10^{-9}}$$

$$D=16.43\text{x}10^{-3}=0.01643m=1.64mm$$

These are pictures made by our camera obscura. The image of the candle flame is enlarged and inverted.

4. Pinhole camera.

The pinhole camera is a camera obscura which has a light-sensitive material or CCD matrix instead of a screen. In our times some photographers use these kinds of cameras because the achieved images with these kinds of cameras have a soft draw,the ideal linear perspective and a great depth of the brightness.
We solved to turn our digital camera Canon EOS 350D into pinhole camera. We took off the lens, and in its place put a ring and foil with a small hole.

- ***Problem 1:** Calculation a focal length.*

  To a predetermined diameter of the hole, our task was to find the focal length of the formula Lord Reilly. For the value of λ we took the wavelength of the green color of the spectrum of light.

  $D=0.25x10^{-3}m$

  $λ=500nm=500x10^{-9}m$

  $D=2\sqrt{\left(\frac{1}{2}\right)fλ}$

  $D^2 = 2fλ$

  $$f = \frac{D^2}{2λ}$$

  $f = \frac{(0.25)^2}{2x500x10^{-9}}=0.065m=6.5cm$

- ***Problem 2:*** *Calculation of the visual field (angular range). (The field of view (FOV))*

In photography, the field of view is that part of the world that is visible through the camera at a particular position and orientation in space; objects outside the FOV when the picture is taken are not recorded in the photograph. It is most often expressed as the angular size of the view cone, as an angle of view.

The field of view (FOV) of a pinhole camera depends on the size of the screen and the distance of the screen from the pinhole, we decided to use some formula in photography –
FOV = 2 x arctg (d/2f)
Where our focus distance is f= 65mm and the matrix is 22.2mm x 14.8mm. From our calculations the FOV is 22,7°.

Unfortunately the picture taken by us wasn't focused because the hole on the folio wasn't the right size.

5. Astronomy and camera obscura.

- *Sunrise project*

Sunrise project was organized by the European association for teaching astronomy (EAAE). The manager of the project is S. Ekko from Finland. The idea of the project is to make long exposures during sunrise and sunset with the camera obscura on different latitudes during the equinoctial. The teams, who took part in the project, shared and compared images via internet.
The tasks for the project were:

-to compare the different pictures in order to find the differences in the different latitudes;

-to find the increasing angles in order to find how it is linked with the latitude;

-if the images are taken during the equinoctial, to determine the latitude, by changing the angle in which the Sun rises;

We chose to show you two pictures of sunrise and sunset. They were made on different latitudes. The first one was made by a team in Finland; the second one was made by us in the town of Khaskovo, Bulgaria.

You can see in the picture that during the same time for the different latitudes the Sun rises (sets) at a different angle compared to the horizon (the red line). This angle gets smaller the more north you make the picture. As you know the latitude can be found by the formula: $\phi=90-h$, where h is the angle at which the Sun sets (rises) compared to the horizon.
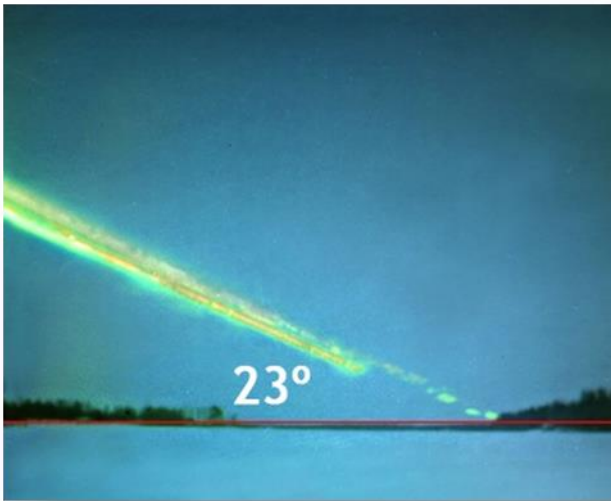
✓ **Sunrise**
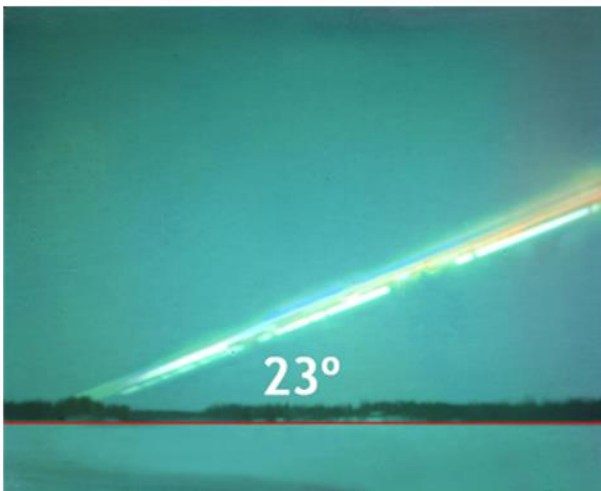
Taken in Rovaniemi, Finland 20.3.2011
Coordinates: 66.3° N 21.9
φ=90°-23°= 67°
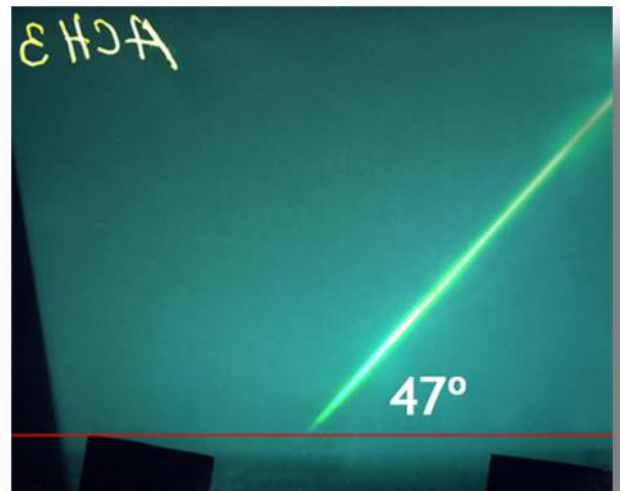
Taken in Haskovo, Bulgaria
around vernal equinox 2011
Coordinates: 41.9° N 25.5° E
φ=90°-47°= 43

✓ **Sunset**

Taken in Rovaniemi, Finland 20.3.2011
Coordinates: 66.3° N 21.9° E
φ=90°-23°= 67°
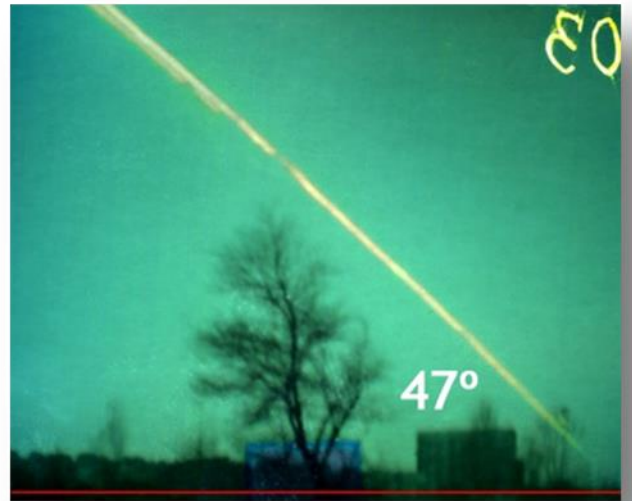
Taken in Haskovo, Bulgaria
around vernal equinox 2011
Coordinates: 41.9° N 25.5° E
φ=90°-47°= 43°

We will show you some pictures from our observation place. We had to find places with clear horizon in the East or West direction, so we placed our cameras on the roofs of buildings.

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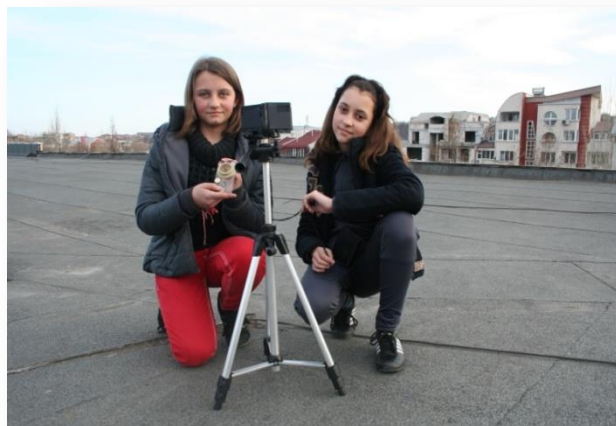
During the astronomy camp in the National Astronomy Observatory "Rozhen" during the month of August 2012 we placed two cameras obscura. We used the first one to shoot the sunset and the second one to shoot the sunrise. These are our pictures:
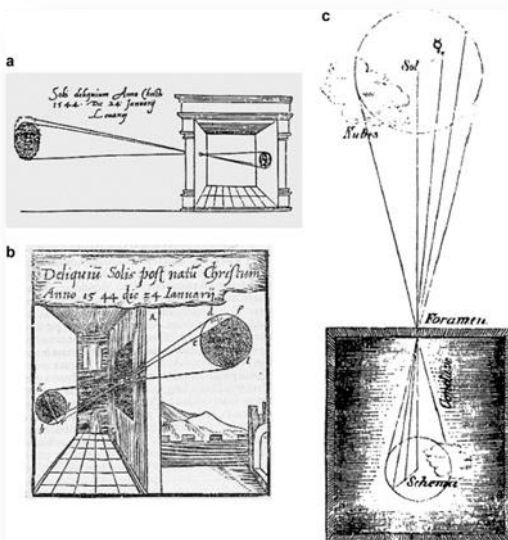

Sunrise

Sunset

- *Camera obscura and Sun*

  This is the effect of a camera obscura by the needles of the pine tree. These pictures were taken by Georgi Kokotanekov, a former student in our observatory.

- *Sunspots*

 Sunspots were previously observed using a camera obscura.

Some early drawings of astronomical use of a camera obscura: (a) 1544 solar eclipse observation by Gemma Frisius from Frisius (1545); (b) the same observation from Regiomontanus (1561); and (c) sunspot observation in 1607 by Kepler (1609).

- *Venus transit*

 We found pictures of a passage of Venus in front of the solar disk made by camera obscura.

The Transit of Venus, as seen through a spontaneous camera obscura formed by his office blinds.By Joseph Francis.The photo was taken on June 6, 2012.
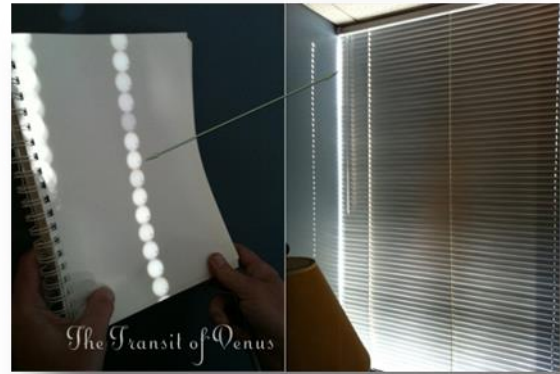
Florian Nehonsky
Canon EOS 18mm Fisheye
June 8, 2004
Vienna, Austria
KuffnerSternwarte Wien

- *Partial phases of the Sun eclipse*

The Astronomy Observatory at the Youth Center took part in the expedition for observing the full Solar Eclipse – 29th of March 2006. The expedition was in Cide, Turkey. Before the beginning and the end of the full phase of the Solar Eclipse we had the opportunity to observe the effect of the camera obscura. On the ground and on the water the effect of the Solar sickle was achieved by the leaves of the palms and the back of the plastic chairs.
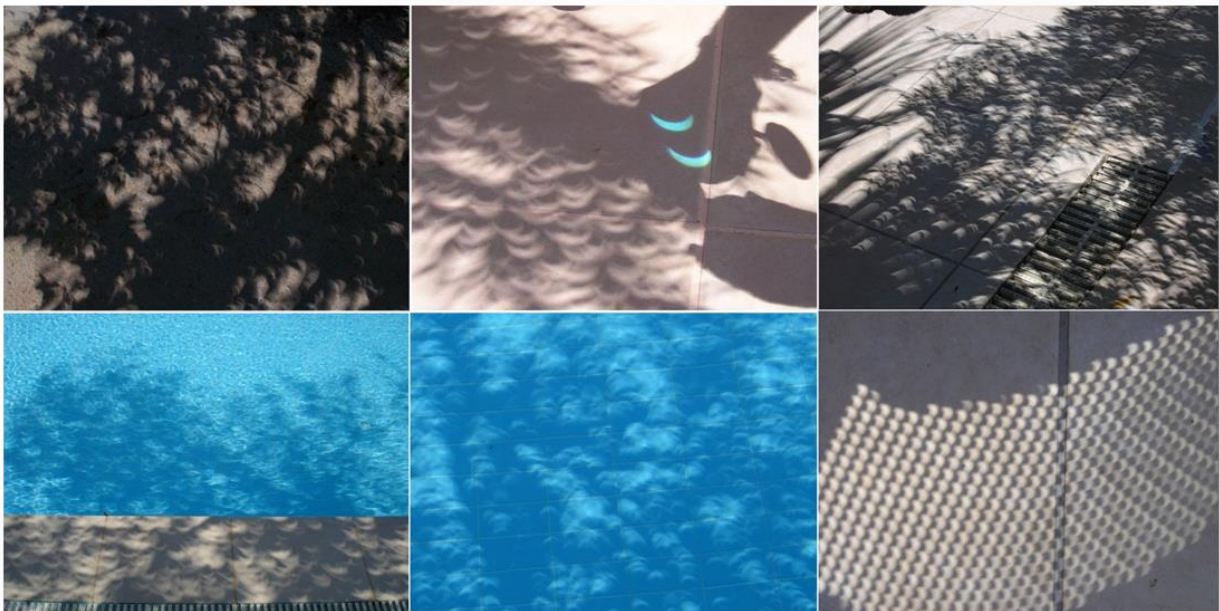
- *Shooting the path of the moon*

  ✓ Full Moon

With the camera obscura you can also shoot the move of the Moon during a Full Moon. We show you three pictures made by Gregg D. He shares in his blog: "Catching up on my blog, I'm posting another Lunar triptych from the March 21st full moon. This was a new camera I had built for doing triptychs. The new camera allows some adjustment to the relative view of each pinhole. Actually, it is 3 cameras mounted to a single bracket."

Full Moon, March 21, 2008

  ✓ Moon eclipse

Ross Togashi
Total Moon Eclipse on December 10, 2011.
Pinhole Camera, f/133, exp. 12 h and film Kodak Ektar 100

✓ Our picture of the moon using the camera obscura

We will show you our attempt to shoot the moon using the camera using a box with small holes on it.

- *New World Mission– NASA (for observed exoplanets)*

The NASA Institute for Advanced Concepts (NIAC) currently is studying a proposal for a space mission that could produce images of planets orbiting a distant star. The plan calls for an opaque, lightweight, football-field-size, orbiting "starshade" with a 9 meter hole at its center. A spacecraft carrying imaging equipment would trail the starshade by tens of thousands of miles. In effect, this setup would be a gigantic pinhole camera.

"To me, one of the most interesting challenges in space astronomy today is the detection of exo-solar planets," said team leader Webster Cash, an astronomer at the Center for Astrophysics and Space Astronomy in Boulder, Colorado. "The beauty of the pinhole as an optical device is that it functions as an almost perfect lens," he explained. "This device would remove the limiting problem of light scattered from the parent star due to optical imperfections."
To acquire an image of an exoplanet, the system — dubbed the New Worlds Imager (NWI) — would carefully align the starshade and imaging spacecraft on its target. According to Cash, NWI would have sufficient resolution to detect exoplanets as small as the Moon.
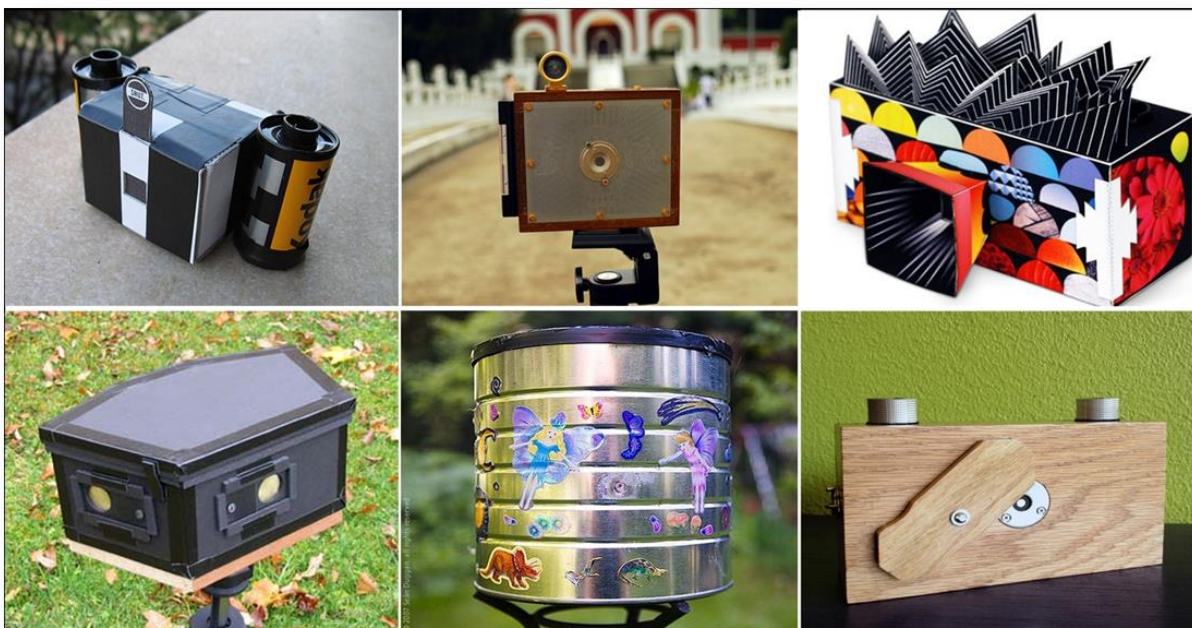
"In its most advanced form, the New Worlds Imager would be able to capture actual pictures of planets as far away as 100 light-years, showing oceans, continents, polar caps, and cloud banks." NWI also could search for oxygen, methane, and water vapor in exoplanet's atmospheres.

Artist's concept of the New Worlds Observatory. The dark, flower-shaped object in the center is the star shade. Credit: NASA and Northrop Grumman

6. **Types of pinhole cameras**

We will show you some interesting ideas for pinhole cameras.

7. Bibliography

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http://www.nasa.gov/centers/goddard/news/topstory/2008/planet_search.html