Astronomy
Our Invisible Sun

Narration
This is a sunrise on Earth as no-one will ever see it, but it is our Sun nevertheless. Only with x-ray vision could we see this, but not from the surface of the Earth. This remarkable image was obtained by the YOHKOH x-ray telescope orbiting high above our atmosphere. Another satellite, Solar Max, recorded this image in ultraviolet light. And this radio image of our Sun was made by the Very Large Array in New Mexico. Only when an eclipse blocks the full glare of the Sun can we glimpse with our own eyes some of the magnificent features of our normally invisible Sun. Highly magnified the surface of the visible Sun, the photosphere, looks like this. Porridge-like granules of up-welling plasma at a temperature of almost 6,000 Kelvin. And that's all we would see if the Sun had no magnetic field. In fact we see a lot more different features, such as sunspots and huge arching prominences reaching hundreds of thousands of kilometres into space – and tremendous explosions of energy in flares – all dramatic evidence of unseen magnetic forces. To investigate these phenomena astronomers must 'look' right across the spectrum, from radio waves through visible and ultraviolet to x-rays and gamma rays.

Professor Hal Zirin
Even though our Sun is 93 million miles away, that's as close as we'll ever get to a star. And even with the most powerful telescopes we can't see any features on the other stars. Yet with our solar telescopes we can zoom in and see all kinds of interesting and wonderful phenomena on the surface of our Sun. So let's go have a look at our own star today and see what it's doing.

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Only an earthquake in June 1992 managed to stop Zirin and his colleagues for a few months from their continuous Sun-watch. The observatory is sited on Big Bear Lake, high in the hills east of Los Angeles, to take full advantage of the clean mountain air and stable atmosphere above the cool water. Under these near-perfect conditions they can obtain superb images at visible wavelengths.

Bill
Hal, this region has really developed rapidly since this morning. Notice that there's penumbra now around the entire leading umbra.

Professor Hal Zirin
That's kind of the beginning of the end of its growth, but maybe these spots here will do it. Funny, it just started out as this little thing yesterday. Anyway – here in the Big Bear dome we have a nest of three telescopes which enable us to look at the Sun in different scales. Because we're limited by the size of our film frame or video frame – so we have one telescope that looks at about a twenty-fifth of it and one that really zooms in and gives us high resolution. Now the high resolution telescope – you need a big telescope and you need to use a vacuum, so you don't have a lot of air moving around inside the tank and we throw away most of the light, maybe 9,999 parts out of the thousand of the light we get. Then we also have to track very carefully because we're looking at things that are the size of a hotel in San Francisco, as seen from here in Big Bear. So we have very accurate tracking mechanisms which follow the Sun photo-electrically. Now the mirrors that are banging and clanking back and forth direct the light to different cameras and different filters of different wavelengths. If we looked in just normal light we would only see the surface of the Sun. When we use the very narrow filters we can see the atmospheric phenomena, things moving around and then finally we can use these narrow filters to study the magnetic field which really dominates what happens once you get above the surface of the Sun. What happens is when the magnetic field is strong; the light is broken into rotating rightward, and beams rotating leftward. And with our hardware we can separate out these beams, put them in the computer, and subtract them

and determine what the direction and magnitude of the magnetic field is. Then we try and go back and understand how these strong magnetic fields generate big eruptions and solar flares.

Narration
Over the years the running of this small observatory has generated one of the biggest libraries of solar events in the world.

Professor Hal Zirin
Here in the lodge we've accumulated a number of pictures of the Sun which shows some of the things we're interested in. If you look at the surface without a filter, just in general white light, all you see is what we call granulation, a lot of convective clouds coming to the surface, and the only aspect of the magnetism you can detect is the sunspots, because in the sunspots the field is so strong it can dominate the pressure of all the gas there, but as you go higher into the atmosphere, the gas pressure reduces and the magnetic field remains strong until very soon it dominates – so when you look in our filter in hydrogen alpha, then the atmosphere is absorbent and therefore we can see all the gases in the atmosphere.

Now they have a wonderful loop shape because their motions are determined by the lines of force going from one magnetic field to the other, and that's what we see around the sunspot with a strong magnetic field. Because the sun is so large and the sunspot is relatively small, it's not accidental that the sunspot just comes up there. It's probably part of this whole three-dimensional structure of magnetic field that's coming up from inside the Sun. And something seems to happen as it reaches the surface which produces these twistings and stresses, and the effects that produce solar eruptions. We see this over and over as this image here, where we see a burst of material squirting out from near the sunspot. What's actually happened is a new spot has come up next to the sunspot and in making its peace with the existing magnetic fields a lot of energy is released and when the energy is released you see it's trapped in the magnetic fields and therefore focused into this long ejection which we call a surge.

And here we see a bi-polar sunspot, we see one sunspot of one magnetic field and then the follower is of the opposite magnetic field. And there are lots of lines of force connecting them. In any given sunspot cycle only one magnetic polarity will lead in each hemisphere. Now around the back of this thing we see a dark filament curling and that's a cloud of gas which is up above the surface and scatters the light coming up from the surface. It sits on an area where the magnetic field is just changing between pointed towards us and pointed away from us. And in that area the field lines will be horizontal and that's why they keep the material up. When we look sideways at the edge of the Sun we get some of the most graceful phenomena of curtains of this gas, somewhat like an aurora on the Earth, but different in the sense that this cloud may last for weeks. Now they are supported by the magnetic field but the odd thing is when they finally give up the ghost, they don't fall down, they erupt outwards. And they'll erupt outwards in enormous clouds which form what we call 'coronal mass ejections' and which may come out all the way to the Earth. Now as the sunspots break up the magnetic fields that are involved with them don't disappear, but they spread out over the surface and if you look at almost any part of the Sun with a sensitive enough magnetograph and take a long enough exposure – this particular one was six thousand frames – you can see that there are magnetic fields almost everywhere. And they're moving around and they're forming and reforming and there's a peculiar effect in which they gradually drift up to the poles of the Sun and they reverse the polarity of the Sun every eleven years. All the things we've looked at so far have been creatures of the magnetic field of the Sun and the big eruptions that we see are basically the result of rapid evolution and change in the magnetic field, which builds up a very strong stress, just like happens in earthquakes, where the crustal motions of the Earth store up energy which is finally released.

And in this movie, which we made of the magnetic evolution of one of the most active sunspot groups of all time, you can see how the motions of the magnetic field are changing the thing all the time and if we were looking at it in hydrogen alpha we would see the great eruptions that were produced by this rapid change in the magnetic field which took place over a six or seven day period. We feel that by studying these in detail we can learn to understand and even predict the occurrence of this kind of activity.