Interpreting an ENA image

Energetic neutral atoms (ENAs) are produced when a high velocity ion collides with a neutral atom and the ion picks up an electron from the neutral, thus becoming an ENA. Near Mars this occurs when ions from the solar wind collides with atoms in the Martian atmosphere. A property of ENAs is that they travel in straight lines since they, as neutrals, are unaffected by magnetic and electric fields.

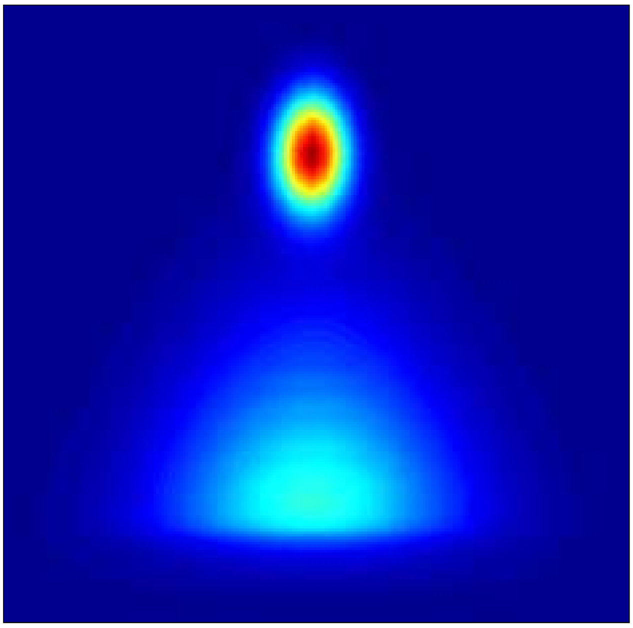
On ASPERA-3 there are two instruments that detect ENAs, the Neutral Particle Imager (NPI) and the Neutral Particle Detector (NPD). These are cameras, but instead of detecting light (photons) as an ordinary camera does, they detect ENAs. The NPI has high spatial resolution, but no energy resolution. This corresponds to a camera that takes sharp pictures, but only in black and white. The NPD has lower spatial resolution, but also energy resolution. This corresponds to a camera that takes grainy pictures, but in colour.

When Mars Express goes into orbit around Mars in 2003, the NPI and NPD will start to take pictures of Mars and the surrounding region of space. It is difficult to interpret these images directly. The brightness of the images is proportional to the number of incoming ENAs from that direction. The only thing we know is from which direction the ENAs came, not how far away they were produced. Since each produced ENA corresponds to a collision between an ion and an atom in the Martian atmosphere, if we knew where the detected ENAs were produced, we would know more about how the ions and the neutral atoms are distributed around Mars.

Simulated ENA images

One way to solve this problem is to construct a computer model of the Martian environment. This model includes how the ions flow around Mars, the composition of the Martian atmosphere and how ENAs are produced by ion-atom collisions. We can then compute what an ENA image would look like from a certain point. In the figure we see an example of such an image, which we call a simulated ENA image.

The computer model contains several parameters, such as the incoming velocity of the ions from the solar wind and the thickness of the Martian atmosphere. A simulated ENA image will look different if we change these parameters. Given a picture taken by the NPI or the NPD (a "real" image), we can use this to extract information. We generate simulated images for different parameter values until we find a simulated image that looks like the real image. It is likely that the simulation parameters that generated this matching image are close to the real parameters, so we now have an estimate of the solar wind ion velocity and all other parameters at the moment in time when the real image was taken. We say that we have extracted parameters from the image.



An example of a simulated ENA image. The different colours correspond to the amount of incoming ENAs from that direction. Red means a lot of ENAs and dark blue little. The red dot is in the direction of the sun since a lot of ENAs are generated in the solar wind. The horizontal feature is the limb of Mars. It is straight, not curved, since the image is in polar coordinates. The light blue region corresponds to ENAs generated inside the bow shock of Mars.

Doing it quickly

Although today's computers are fast, generating a simulated ENA image can take several minutes. To find a simulated image that matches the real image, we might have to generate thousands of simulated images, corresponding to different parameter values. This means that the parameter extraction can take hours or even days. This is not acceptable, as we would like to know the parameters as soon as possibly after the real image is taken. There are two ways to shorten the time for the parameter extraction. First of all, we can generate each simulated image faster. Secondly, we can minimize the number of simulated images that we have to generate to find a match to the real image. We can do this by using clever algorithms, and there is ongoing development of such algorithms. If there is a need for even faster parameter extraction, we can achieve this by solving the problem on a parallel computer.

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