**////Title: SCARLET: Exploring the Universe in Unprecedented Detail**

**////Standfirst:**

Wide-area scans of the sky are an important tool for astronomers as they seek to learn more about the universe. However, as the latest observation techniques have become increasingly sensitive, faint objects within these surveys can appear to blend together. Through his research, Dr Peter Melchior at Princeton University presents a computer-based framework for disentangling these blended sources, and for artificially reconstructing the components they contain. Named SCARLET, the technique could soon help astronomers to study the depths of the observable universe in unprecedented levels of detail.

**////Main text:**

Unlike targeted observations, astronomical surveys don’t have a specific goal in mind as they search the sky. Instead, astronomers use them to map out particular regions just to see what they will find. This enables them to explore a wide range of phenomena which would have escaped the focus of targeted observations – including new exoplanets, galaxy clustering, and rare distant galaxies.

Recently, these surveys have come to cover ever larger areas, in ever increasing levels of detail, and in many regions of the electromagnetic spectrum – from radio waves and microwaves, to X-rays and gamma rays. This is revealing many objects which, until now, have been too faint for our instruments to detect. Such a high level of detail is now driving investigations into phenomena both within and beyond our galaxy, and even into the large-scale structure of the universe as a whole. However, the extreme sensitivities of modern survey techniques are now presenting a new and unique problem.

Because these observations can detect so many objects, there is now an increasing risk that multiple objects may overlap, so that astronomers will view them as a single feature. Named ‘blending’, this effect means that the idea of completely isolated objects in large-scale surveys is becoming obsolete. Recent studies have even reported that for some survey techniques, as many as 58% of all observable galaxies could be affected by blending.

Dr Peter Melchior and his team at Princeton University decided that this problem called for a more advanced approach, capable of separating blended sources within the survey images built up from several different regions of the electromagnetic spectrum.

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In 2018, the researchers introduced a de-blending framework named SCARLET. This computer-based approach first describes the scenes picked up by astronomical surveys as a mix of blended light sources. It then uses specialised algorithms to introduce constraints that are useful for describing optical images – including the symmetry of blended components relative to their brightest points, as well as the variation in brightness within them.

From this information, SCARLET can model the objects contained within blended sources – essentially recreating individual components artificially. This approach has now allowed Dr Melchior and his colleagues to de-blend survey images reliably, even under widely varying viewing conditions. To test their approach, they used SCARLET both to disentangle individual components in crowded extragalactic scenes, and to separate a galaxy from light emission of its ‘active galactic nucleus’ – a region at its centre that is sometimes so bright, it can outshine the entire rest of the galaxy.

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Building on the success of their initial demonstrations, the team next aimed to account for the different types of data gathered by large-scale sky surveys. This information is remarkably diverse; for example, the ground-based Vera C. Rubin Observatory Legacy Survey of Space and Time, currently under construction in Chile, will make its observations across six segments of the optical to near-infrared electromagnetic spectrum. In contrast, the Nancy Grace Roman Telescope and the upcoming Euclid Mission will each survey the sky at longer wavelengths – both as satellites on orbits around the Sun.

So far, accounting for this diversity when de-blending sources has presented SCARLET with a significant challenge. Each of these missions are expected to yield unprecedented scientific results by themselves – but Dr Melchior’s team recognise that their observations will also be complementary, and could be used to address each other’s shortcomings.

For example, what the Euclid Mission lacks in sensitivity and spectral resolution, the Rubin survey should be able to compensate for with its more sensitive observations from several segments of the spectrum. Furthermore, while the images taken by Rubin are limited in their spatial resolution, Roman and Euclid can provide supplementary images that are several times sharper.

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In their latest study, Dr Melchior and his colleagues presented an extension to SCARLET, which can jointly model the astronomical images taken using different instruments. They tested this technique using simulated survey images, which closely mimic real observations made by Euclid and Rubin. They then modelled the simulated surveys of both instruments – first independently, and then jointly – allowing the two surveys to complement each other.

Repeating the test multiple times, and varying the degree of blending in the simulations during each run, allowed them to recreate the variable viewing conditions experienced by each instrument. As the team hoped, SCARLET’s extension enabled them to produce significantly more accurate models of individual galaxies. When the images from both instruments were modelled together, as opposed to being handled separately, they calculated that blending-related errors could be reduced by ten-fold.

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As astronomical surveys become ever more sophisticated, they will be able to pick out increasingly faint objects, which occupy the furthest reaches of the observable universe. Without the right approach to de-blending, researchers would risk overlooking the important insights these observations could provide. Dr Melchior’s team now believes that SCARLET and its joint modelling extension is an important tool for astronomers as they aim to avoid this issue.

By artificially reconstructing the features observed by multiple surveys at the same time, the researchers believe that their approach could feasibly be used to identify galactic, extragalactic, and even cosmic-scale features which have so far remained hidden due to blending. In turn, SCARLET may soon pave the way for important new insights into how galaxies behave, and potentially even a new understanding of how our universe is structured on a cosmic scale.

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This SciPod is a summary of the paper ‘SCARLET: Source separation in multi-band images by Constrained Matrix Factorization’, from Astronomy & Computing. [doi.org/10.1016/j.ascom.2018.07.001](https://doi.org/10.1016/j.ascom.2018.07.001)

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