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Astronomers use new model of dust in galaxies to remeasure the total energy output of stars in the universe

An edge-on view: The light-blocking effect of dust is particularly clear in the case of the galaxy NGC 891. Image: C. Howk (JHU), B. Savage (U. Wisconsin), N. A. Sharp (NOAO)/WIYN/NOAO/NSF

Anyone gazing up on a dark clear night is greeted by the spectacle of thousands of powerful fusion reactors - the stars. These balls of extremely hot gas are generating unimaginably large quantities of energy. Even the stars within a cube of "only" one light year on a side, taken at a random position in the universe, generate on average 40 quadrillion kilowatthours in one year.
This would be enough to meet the current energy consumption needs of mankind 300 times over. Even so, it now appears that from our vantage point we are only registering about half the total energy released by stars in our part of the universe; the other half is being absorbed by miniscule particles of dust floating in the vast expanses of interstellar space within galaxies.

This is the conclusion reached by a team of astrophysicists from institutes around the world, including the Max Planck Institute for Nuclear Physics in Heidelberg. The results have implications for our understanding of the creation and evolution of galaxies through cosmic history (*The Astrophysical Journal*, 10 May 2008).

Galaxies are gigantic systems containing billions of stars bound together by gravity.

Our sun is one of around 200 billion stars in the Milky Way, which is a typical example of one such system. If we could view the Milky Way from the outside, the combined light from the stars would appear like a giant Catherine wheel. Since almost all stars are located within galaxies, and since in any case stars become too faint to be detected individually if they are too far away, the total light emitted by galaxies has to be investigated in order to measure the total energy output from stars in the universe.

Like smoke in the earth's atmosphere

But galaxies contain not only stars, but also the still mysterious "dark matter" responsible for most of the gravitational binding, together with smaller quantities of gas and dust. Whereas the dark matter is thought to be perfectly transparent, and the gas affects the propagation of only a small fraction of the starlight, dust particles in galaxies can absorb large parts of the energy radiated by stars, making the stars seem dimmer, in exactly the same way that dust and smoke in the earth's atmosphere can make the sun appear dimmer. When this happens, the dust particles are heated and emit heat radiation appearing in the infrared part of the electromagnetic spectrum. The law of conservation of energy dictates that the infrared energy emitted by each dust particle exactly balances the energy of the absorbed starlight. In fact, such a radiation balance applies to all celestial bodies, whether they are individual dust particles or whole planets, like our earth, where, in conjunction with the atmospheric "greenhouse" effect, it determines the global temperature.

In the case of galaxies, the total energy of starlight absorbed depends critically on how the dust particles are distributed in relation to the stars. To investigate this, Cristina Popescu of the University of Central Lancashire in England und Richard Tuffs of the Max Planck Institute for Nuclear Physics in Heidelberg developed a model describing how dust is distributed in relation to the main morphological components of stars in the central regions and disks of galaxies. The model predicts the difference between the total light actually emitted by the stars in a galaxy, and the total light inferred from the observations, by calculating the dimming effect of the dust.

earth.

To test the model, the scientists used it to predict the difference in energy between the total emitted and the total measured starlight for more than 10.000 nearby galaxies. Indeed, it turned out that this predicted energy difference closely matched measurements of the energy in infrared heat radiation being emitted by the dust grains in the galaxies.

Baptism of fire

"The fact that the observations so closely matched the predictions makeus confidence that we really now understand the radiation of energy from galaxies and thereby from the universe as a whole over a wide range of wavelengths", said Cristina Popescu. Richard Tuffs added: "The results very clearly show that interstellar dust particles have a very pronounced effect on the observed starlight from galaxies in the local universe." Having passed this baptism of fire with flying colors, the model enabled the astronomers to quantify exactly how much starlight is being blocked by dust.

In particular, a long-standing apparent paradox, whereby the infrared radiation emitted by dust sometimes seemed to exceed estimates of the total emitted starlight, has been resolved. "You can’t get more energy out than you put in - we knew that something wasn’t quite right there," said teamleader Simon Driver of the University of St Andrews in Scotland. In reality much more of the starlight is being channeled through dust particles than previously thought. So now it turns out that there is no problem with the energy balance of the universe after all.

More mass in central regions

"Our results have their biggest impact on observations of the central regions of galaxies, in which supermassive black holes are hidden," said team-member Alister Graham of Swinburne University in Australia. In reality the nucleii of galaxies are up to five times brighter than observed. This means, according to the model of Popescu and Tuffs, that a somewhat larger mass of stars is also hidden in the central regions. This has consequences for our picture of how galaxies formed and grew over cosmic time.

In the near future the researchers aim to take a more detailed look at individual galaxies using two new facilities soon to come into operation: The VISTA telescope in Chile and the infrared space observatory "Herschel," which is scheduled to be launched at the end of July: "VISTA will allow us to see further through the dust, whereas Herschel will directly detect the emission from the dust," explained Jochen Liske of the European Southern Observatory.

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