teresting phenomenon triggered us to investigate what drives such a rapid expansion of human cognitive networks.

The evolutionary cortical expansion of the human brain may be inherently determined by the information encoded in the human genome. Although humans share the majority of their genes with other non-human primates, some human-specific genes, for instance the NOTCH2NL gene as discussed in Dr. Frank Jacobs' (UvA) article in the previous issue of Amsterdam Science Magazine (issue 8, page 13), may regulate the growth of cortex in the human brain. Recent research from the lab of Dr. Martijn van den Heuvel (VU) has further suggested a set of "human-accelerated" (HAR) genes to be important for the evolutionary expansion of human higher-order cognitive networks. HAR genes are defined as genes associated with the segments of the human genome that are conserved throughout vertebrate evolution, but are strikingly different in humans (see Figure).

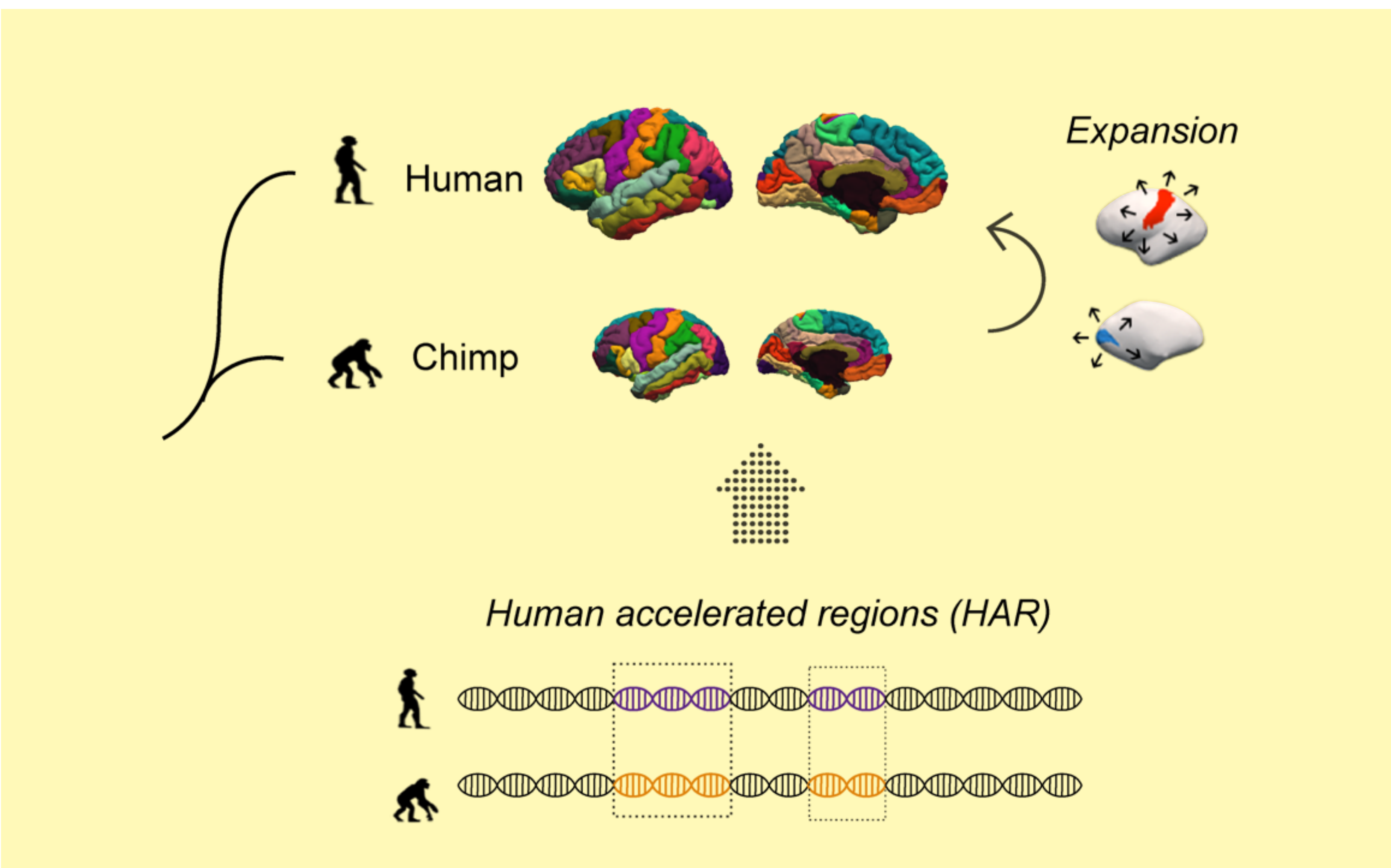
By integrating gene expression data and comparative neuroimaging data of humans and chimpanzees, we found that the rapid evolutionary cortical expansion of cognitive networks in the human brain runs parallel with high expressions of HAR genes. Examining gene expression across primate species has also shown that HAR genes are differentially more expressed in higher-order cognitive networks in humans in contrast to the chimpanzee and macaque.

Our findings thus suggest that the increased expression of HAR genes may regulate the formation and expansion of cognitive networks in the human brain. As HAR genes are involved in the formation of synapses and dendrites (contact points and extensions of brain cells, respectively), such an up-regulated HAR gene expression also implies more complex neural circuits in the cognitive networks in humans compared to non-human primates.

HAR genes may also influence brain functions in our daily life. Genome-wide association studies have identified genetic variants that are associated with the activity of brain functional networks. HAR genes were found to be specifically associated with genetic variants related to the functional activity of the default-mode network, a network particularly important for social cognition and involved in multiple brain disorders. Interestingly, HAR genes were also found to be associated with genetic variants related to intelligence and sociability, and brain disorders such as schizophrenia and autism. These results imply a trade-off in human evolution: HAR genes brought us more complex cognitive abilities; however, they can also made our brain more vulnerable to brain disorders. Ω

→ Reference
Y. Wei et al., *Nature Communications* 10, 4839 (2019). doi: 10.1038/s41467-019-12764-8

↓ Figure
The human accelerated regions (HARs) of the genome are associated with the larger expansion of cognitive networks during evolution of the human brain as compared to the brain of the chimpanzee.



Mapping the universe with the largest optical telescope on Earth

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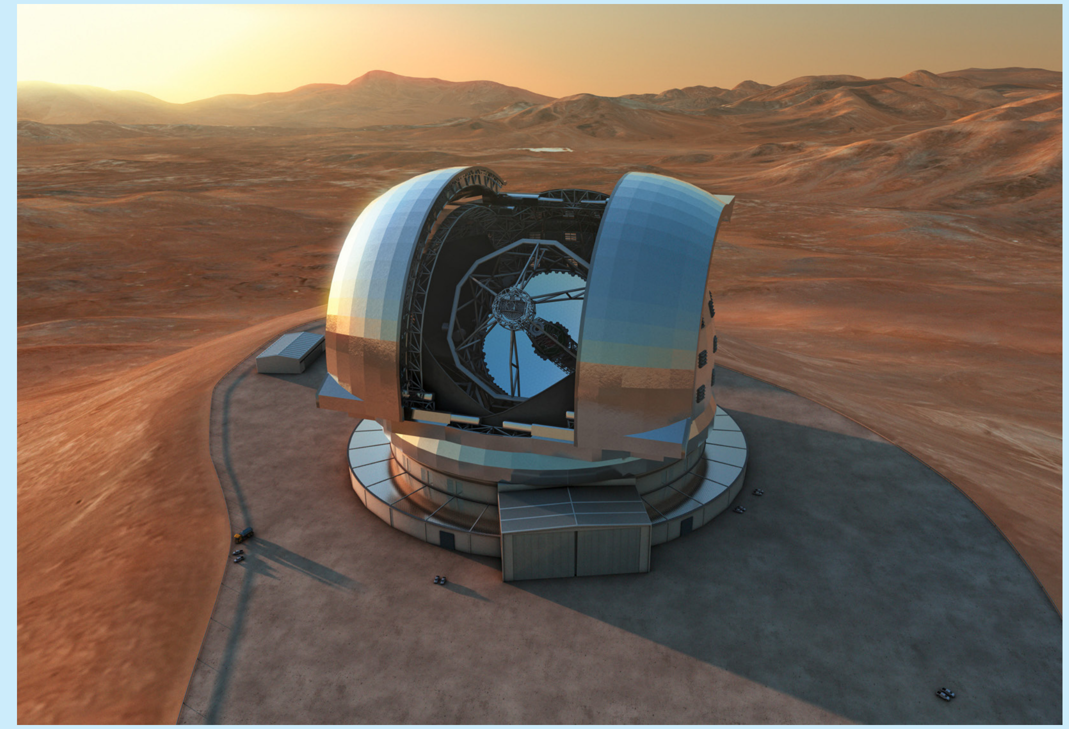
→ Reference
J. Japelj et al., *Astronomy & Astrophysics* 632, A94 (2019). doi: 10.1051/0004-6361/201936048



↑ Figure
Artist's impression of the Extremely Large Telescope, which is being constructed in Chile. Credit: ESO/L. Calçada

→ On the largest scales, all clusters of matter in the universe today are linked together by web-like filaments of cosmic gas, forming an inconceivably vast, intricate structure called the cosmic web. The structure of this web contains important information about how the universe evolved, but it is so large, and its filaments so faint, that observing it directly has been extremely difficult so far. With the Extremely Large Telescope, the largest telescope ever to be built, we will soon see the cosmic web more clearly than ever before.

Cosmology is the science that attempts to understand the origin and evolution of the universe. Thankfully, imprints of the history of the universe are left on the cosmic web. By mapping out the large-scale structure of the universe, we don't just learn how matter is spread throughout space today, but also what it looked like billions of years ago. This is because the light that we see today from the furthest corners of the universe has taken many billions of years to reach us, allowing us to glimpse what the ancient universe looked like. More locally, the evolution of the cosmic web can also teach us about galaxy development: galaxies are born in the web and their growth is intimately linked with how matter is distributed around them.

Unfortunately for us, mapping the web is difficult because the filaments connecting galaxies and galaxy clusters are extremely faint. However, we can use a trick. The clouds of hydrogen making up the filaments leave an imprint on the light coming from galaxies behind them. Depending on the distance between us and a galaxy, these clouds absorb different parts of its spectrum. The spectrum of a distant galaxy therefore teaches us about the locations and sizes of the clouds in the direction of that galaxy.

Rather than looking at a single galaxy, we can observe a large number of galaxies that lie close to each other in the sky (see centrefold image pag. 12). By using advanced interpolation techniques to reconstruct the gas in all directions, we obtain a three-dimensional map of the web in front of the observed background galaxies. A similar tomography technique is used in medical applications to map the networks of the human brain. We use it on a vastly different scale: that of the cosmic web.

Measuring the spectra of thousands of faint galaxies with a high precision requires *big* telescopes. The European Southern Observatory has recently started the construction of what will be the largest optical telescope on Earth—the 39-metre Extremely Large Telescope (ELT). Located on the top of Cerro Armazones in Chile, this telescope will stand in a dome the size of a football field and will be the world's biggest eye on the sky. One of the instruments on the telescope, currently being developed by a large international consortium, will be the multi-object spectrograph MOSAIC. It will enable us to measure the light spectra of hundreds of faint galaxies in a single measurement and to make a detailed map of the cosmic web at unprecedented distances.

The tomography of the cosmic web is a relatively new technique, which means that we do not yet fully grasp the practical requirements necessary to carry it out successfully. We need to run simulations to optimise the way galaxy observations will be carried out and improve our analytical tools. We performed a series of simulations, combining cosmological simulations of the universe and models of MOSAIC's performance, and demonstrated that the ELT and MOSAIC can map the cosmic web at distances that no other telescopes and instruments can. With a resolution of about eight million light years, we can study in detail how properties of galaxies, such as their mass, depend on their position relative to the filaments of the web, and thus understand how galaxy evolution depends on the gas in the web. The mapping of the cosmic web will be one of the most ambitious projects of the ELT, and our study lays the foundations for the preparations that will follow in the years before the ELT and MOSAIC become operational. Ω

"We will see the cosmic web more clearly than ever before"