ESOcast Episode 63: Flexible Giants — The Evolution of Telescope Mirrors	
00:00 **[Visuals start]** **[Narrator]** 1. The clear night sky offers one of the most beautiful views in nature. The eye adapts to the dark and the pupil widens to collect more light and thus allow fainter stars to become visible. But the light-collecting area of the human eye is tiny. To peer much deeper into the night sky astronomers need telescopes with enormous primary mirrors to do a much better job.	**00:00** **[Visuals start]** Nice night timelapses VLT footage focus on main mirror
00:35 **ESOcast intro** 2. This is the ESOcast! Cutting-edge science and life behind the scenes of ESO, the European Southern Observatory. Exploring the ultimate frontier with our host Dr J, a.k.a. Dr Joe Liske.	ESOcast introduction
00:55 **[Dr J]** 3. Why do astronomers want to have bigger and bigger telescopes? Well, it's pretty simple actually! There's only two reasons: The number one reason is that the bigger the primary mirror of your telescope, the more light you can collect per unit time. And that means you can observe fainter and fainter objects. The number two reason is that the resolution of your telescope, that is the sharpness of the images that you can make with your telescope depends on the size of your primary mirror. The bigger your telescope, the sharper the images you can make. But what are the limits? How big can you make a telescope? And what are the challenges encountered by telescope builders in making bigger and bigger mirrors?	Dr J in virtual studio. Background image: Animation principle of a reflecting telescope Footage of VLT main mirror?

01:39 **[Narrator]** 4. Since the invention of the reflecting telescope, mirrors have become larger and larger. When ESO's 3.6-metre telescope at La Silla started operations in 1977 it was a typical example of the classical design of the largest telescopes of that period. The primary mirror consisted of a single glass dish with a diameter of 3.6 metres.	La Silla footage/ 3.6-m footage
02:08 **[Narrator]** 5. In order to make such a big mirror stiff and solid it has to be relatively thick — which makes it very heavy: The 3.6-metre mirror is about half a metre thick and weighs some 11 tonnes! To allow this very weighty mirror to be pointed precisely, a massive, yet precisely balanced telescope structure has to be built around it. Telescopes with even larger, thicker and hence heavier mirrors have been constructed, but eventually it became obvious that the limit of the classical design had been reached. Did telescope engineers have to give up at this point and stop dreaming of even bigger telescopes?	Animation demonstrating the thickness/diameter ratio of 3.6-m mirror. 3.6-m telescope. Animation showing how mirror grows in terms of diameter and thickness. Distant 3.6-m shot
02:56 **[Dr J]** 6. Well, of course not. But paving the way to larger *and* lighter mirrors required some innovative thinking. The result was ESO's New Technology Telescope, or NTT for short. The NTT was a truly revolutionary telescope at the time it was built, because it featured a system called active optics. Now, before the invention of active optics, telescope mirrors had to be thick and therefore heavy in order to be stiff, but *with* active optics telescope mirrors could be allowed to be flexible and therefore relatively light and thin.	NTT footage Animation of a classical mirror versus a thin mirror
03:33 **[Narrator]** 7. The thin mirror of the NTT is even more likely to bend due to gravity. With active optics the flexible mirror is placed on a complex support system with computer-controlled actuators that adjust the shape of the mirror, and compensate for the bending of the mirror during observations. This	Schematic animation of mirror resting on actuators? Maybe show an animation of the mirror deforming and being corrected? PK

way, the best possible image quality is preserved at all times.	
04:03 **[Narrator]** 8. The NTT was a tremendous success! Although its main mirror is 3.6 metres in diameter it is only 24 centimetres thick. The new mirror design made it possible to break the 6-metre barrier of classical telescopes and strive for larger mirrors in the 8-metre class.	NTT footage
04:29 **[Narrator]** 9. Telescopes like ESO's Very Large Telescope, or VLT. The VLT consists of 4 Unit Telescopes with primary mirrors of 8.2 metres diameter. Each mirror blank is only 17.5 cm thick and weighs only some 23 tonnes. Naturally, active optics plays a vital role here. The shape of the mirror is actively controlled by means of 150 axial force actuators. Based on the latest available technology, the VLT delivers images of outstanding optical quality.	ESO VLT, mirror, etc.
05:13 **[Dr J]** 10. But a solid, single-piece 8-metre mirror is pretty much at the limit of what can be handled, transported and maintained. To be able to construct telescopes with even larger light-collecting areas, you really have no choice but to split up the primary mirror into individual pieces called segments. It was the concept of a segmented primary mirror that allowed astronomers and engineers to conceive truly gigantic telescopes. Telescopes such as the future European Extremely Large Telescope, which is currently in its early stages of construction.	Mirror during handing/recoating Animation mirror gets bigger and segmented.
05:50 **[Narrator]** 11. The E-ELT will have a gigantic main mirror 39 metres in diameter. It will be made up of 798 individual hexagonal segments, about 1.4 metre wide and just 5 cm thick. Each segment and its position with respect to the neighbouring segments are computer-controlled by the active optics system to maintain the perfect overall shape of the main mirror and its outstanding surface precision. All in all, the main mirror offers an unprecedented light-collecting area of 978 square metres, which will collect	E-ELT animation

about 15 times more light than any other existing telescope.	
06:43 **[Dr J]** 12. With its 39-metre primary mirror, the European Extremely-Large Telescope will be *by far* the largest optical and near-infrared telescope in the world. And not just at its time of completion but for decades to come. However, I’m sure that won’t stop the engineers from conceiving of ways to build even larger telescopes. Who knows what size barrier will be cracked in the distant future?	E-ELT animation NTT/VLT inside night timelapses
07:08 **[Outro]** 13. This is Dr. J signing off for the ESOcast. Join me again next time for another cosmic adventure.	
07:15 **[Outro]**	ESOcast is produced by ESO, the European Southern Observatory. *ESO, the European Southern Observatory, is the pre-eminent intergovernmental science and technology organisation in astronomy designing, constructing and operating the world’s most advanced ground-based telescopes*.