Question 1:

Dear Cheap Astronomy – How do binary stars form?

It's been estimated that around 50% of main sequence stars in the Universe are in binary or more complex star systems. Of course, if you think about it, this means that at least two thirds of all main sequence star systems are single star systems like the Sun.

Nonetheless, it's fair to say that multiple star systems are relatively common. The gravitational mechanics involved in one star capturing another star into a stable orbit require extraordinary fine-tuning, like a precision snooker shot. So, it is difficult to believe that all the multiple star systems that are out there are the result of random gravitational captures.

The most likely scenario for the origin of the vast majority of binary systems is that both stars form together out of the same collapsing dust cloud. It has been quite difficult to confirm this by observation within dust-enshrouded stellar nurseries. But, recently, infrared space telescopes and ground based radio telescope arrays have had some success.

The data they collected from under the shrouds of stellar nurseries identify a number of spherical star clouds, which perhaps contain a single forming star, as well as irregular clouds that probably contain two or more forming stars. There have also been a small number of confirmed observations of one cloud hosting two significant centres of mass – each of which are radiating a lot of heat. These, we are fairly sure, are growing protostars in proto-binary systems. So, although the data is hard to come by, it does seem likely that binary stars are generally siblings formed from the same collapsed dust cloud.

People sometimes refer to Jupiter as a failed star, which almost became a binary with the Sun – but if it failed, it failed very, very badly. You would need 13 Jupiter masses just to kick off the deuterium burning that a brown dwarf manages, let alone the hydrogen fusion of a main sequence star, which requires at least 80 Jupiter masses. So, it is fair to say that Jupiter, is not by any stretch of the imagination a failed star. It is just a very successful planet.

But OK, one can imagine that if the solar system had formed from a bigger, or at least a denser cloud with one star forming at its centre and another large mass orbiting it you might get a binary system. The orbiting mass would first clear its orbit achieving momentary planet-hood, but would then continue to grow in mass as more matter was drawn in from the still-collapsing dust cloud.

By the time the dust cloud had fully collapsed and stellar accretion was done you might get one large main sequence star being orbited by a smaller main sequence star.

And that isn't necessarily the end of the story. After forming, it is likely that the two stars will begin to exchange mass. The more massive one, being more massive, would have a larger solar wind output, some of which would be taken up by the smaller star, making it bigger while the other got smaller. But more importantly, as stellar evolution progresses, you might get something like the Algol paradox.

The Algol system contains the binary Algol A and Algol B, which appear to break the rule that big stars live fast and die young, since the less massive star is progressing towards its red giant phase – a clear sign of old age – while the more massive star is still youthfully burning through its main sequence. Since it is assumed that both stars formed at about the same time out of the same dust cloud, this is a seeming paradox. But it is readily explained by realising that the more massive star must have begun progressing towards its red giant phase first. But as it swelled up, some of its mass got caught in the other star's gravity well. The subsequent mass transfer could have slowed down the bigger star's evolution, but sped up the smaller ones.

Going forward, as the smaller star swells towards its red giant phase, the larger star may begin to draw mass back upon itself – perhaps enough to pause the smaller star's progression to a red giant, while recommencing the larger star's progress.

And, perhaps, finally, one star will evolve all the way from red giant to white dwarf. Then as the other star continues to donate mass, that white dwarf may explode as a type 1a supernova – which is how some, but not all, binaries may finally end their long partnership.

Question 2:

Dear Cheap Astronomy – How come globular clusters stay globular, while stellar systems and galaxies form disks?

Globular clusters are pretty bog-standard astronomical objects. Our own galaxy has hundreds of them and, as our astronomical resolution improves, it is becoming clear that most other large galaxies also have hundreds, or even thousands, of them.

After Saturn, Jupiter and the Moon, a globular cluster is usually the next object that people with cheap, backyard telescopes will go for. You can even pick some of them out with binoculars. However, explaining how all these globular clusters actually come to be continues to vex many astrophysicists and cosmologists.

Most of the globular clusters we can see are about 12 billion years old – which, in a 13.8 billion year old Universe, is pretty darn old. These old clusters retain no gas or dust that might support further star formation. They are also very tightly bound, with many globular clusters orbiting close to the main bulge of our galaxy without being disrupted by all the gravitational torsions that they are exposed to. In contrast, open star clusters are generally collections of young stars that have just recently emerged from a nearby stellar nursery. We expect that nearly all the stars in open clusters will get dispersed far and wide, later on in their life.

Current thinking is that globular clusters arise in regions which support very efficient star formation. It's thought that very dense regions of gas allow a whole bunch of stars to form simultaneously, in close-proximity to each other. Their formation depletes all the gas and dust that is in that region, so that no later generations of stars can form after that first generation. Furthermore, forming in such close proximity fixes all those stars into a mutually-binding gravitational matrix that both creates and sustains the cluster's globular geometry.

Newly-forming galaxies generally form from more irregular gas clouds. So, star formation is not very efficient, which means that stars form haphazardly and often at wide distances from each other. There is also lots of unbound gas and dust left over. All that unbound gas and dust sustains particle-to-particle interactions across the structure of the forming galaxy – the same way it does across newly-forming stellar systems . Interactions and collisions between adjacent particles obey conservation of momentum principles and particles that gain velocity from a collision get spread outwards. The density of the cloud generates enough gravity to hold those spread-out particles in a loose orbit and the dominant vector of motion eventually drives all of them to orbit in the same direction. So, through these particle-to-particle interactions, an irregular cloud usually collapses down into a flat, spinning disk.

But, in the absence of any intervening gas and dust, stars in a globular cluster don't have a mechanism to disperse their momentum outwards and so they stay locked in their globular formation, over vast eons of time.

But, remember that globular clusters are tiny little things compared to a galaxy. In fact, globular clusters are the products of galaxy formation. A galaxy forms from an extremely large gas cloud that slowly compacts down due to gravity. Within that compacting cloud, small pockets of gas and dust can reach just the right consistency and stability to support the formation of a globular cluster. This is why most of the galaxies that we know about have hundreds and thousands of globular clusters, even the very old elliptical and lenticular galaxies. Once formed, globular clusters retain their shape over eons, while their parent galaxies grow and evolve, undergoing mergers and collisions and finally reddening and then fading into galactic old age.

So, I hope that answers your question, but before we finish, here's a bit of globular cluster myth-busting.

One: While most globular clusters are old, we can still observe a few new ones forming in the modern Universe. It's just that the conditions required for effective star formation are much rarer in the more-expanded, higher-metal-content Universe of today.

Two: While most globular clusters we see today only contain medium-sized stars and dim white dwarves, they once had stars of all different sizes. However, all their big stars died young, as big stars are want to do. Many of those big ones probably died as supernovae. As evidence of this, we have recently begun finding black holes within globular clusters.

Three: If a globular cluster runs into a gas cloud and fills up with new gas, it could host new star formation. Then you could have multiple star generations within the one globular cluster. It is rare, but it can happen.

Lastly, this isn't a myth-bust – but more of a fun fact. Astronomers think they have identified two distinct globular cluster populations within the Milky Way, which have two distinct types of metallicity. This may be evidence of a past merger between a proto-Milky Way and another large galaxy that had its own signature collection of globular clusters. Cool, huh?