Spiral Galaxies: Origin by Gravitational Vectors

Merging Theory

Wolfgang Westenberger

D73732

A INTRODUCTION

More than half of all big galaxies are spiral galaxies. Generally we find a double spiral figure, for example **M 74** (= NGC 628) or **M 83** or **ESO 269-57.**
Each of two spiral arms arises from opposite position at the central bulge. Sometimes these arms are splitting up, see **NGC 1232** or our **Milky Way** or **M 101.**
Spiral arms will shine for billions of years. If they consisted permanently of only the same stars, the arms would be winded up around the bulge within a few revolutions. That's called the winding up problem.
Up to now it is supposed that a collision of two spiral galaxies of similar size will result in an elliptical galaxy. Considering vector effects you will see a different result, confirmed by astronomical observations.

Arranging snapshots of astronomical observations in correct sequence you will get some kind of movie about the origin and development of spiral galaxies.

B METHODS

Using fundamental physical laws we find the origin of spiral arms and spiral galaxies.

Imagine there is a galaxy moving straight ahead through the universe in any direction whatever. Unless acted upon by a force, the galaxy moves at a constant velocity when viewed in an inertial reference frame – according to **Newton's first law of motion**. Any moving galaxy has got an inertial force deriving from linear momentum of mass and velocity. Linear momentum as well as inertial force is a vector quantity of direction and magnitude.
Imagine a second galaxy moving along on its own way in any other direction, casually approaching the first galaxy. Both galaxies will interact by gravity. When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction to that of the first body – according to the **third law of motion**. Gravity is also considered as a vector quantity of direction and magnitude. Its direction is on the straight line between both galaxies. Gravitational force vector and inertial force vector are at work on behalf of a galaxy in different directions. Quantity of gravitational force is dependent on mass and distance – according to **Newton's gravitation law**. So the gravitational force of an approaching mass will increase inversely proportional to the square of distance. The smaller the distance the higher will get acceleration and velocity.
So we get a tangential vector of inertial force in previous direction. And a second vector of gravity towards the neighbouring galaxy. We construct a **parallelogramm of forces** and get a resultant vector of current direction of movement and updated linear momentum.
At the next position the gravity vector will be increased because of decreasing distance. Flight paths of both galaxies will bend towards each other. The more the gravitational vector is growing the more the galaxy track will be bent towards the other galaxy at any further position. Finally each galaxy will execute a spiral movement, resulting in a double spiral figure around the common single centre of gravity, as we know from spiral galaxies.
Gravitational vectors result in spiral movement of two approaching galaxies. So two precursor galaxies are united to a new spiral galaxy. That's the origin of spiral arms and spiral galaxies.

C RESULTS

Tails on trails of approaching.
In some cases the flight path of an approaching galaxy is illuminated by a shining tail as you can see at **NGC 4676**, the famous Mice interacting galaxies. This shining matter consists of lost stars and gas and dust that failed in orbiting the galactic centre. The reason is a difference of gravitational vectors on behalf of different distances.

Differential gravitation by different gravitational vectors.
Imagine a gravitation centre and a straight line intersecting. And in one direction there are three neighbouring positions upon the straight line.
The first position next to the centre will get a stronger gravitational force towards the gravitation centre than the middle or the distant position. That's the consequence of Newton's gravitation law. Those three positions will get different acceleration towards the gravitation centre although interacting each other by gravity.
External stars of any galaxy are orbiting the galactic core. Inertial force of a star in a stable orbit is balanced with the gravitational vector towards the galactic centre.
Now we regard two galaxies approaching.
At greater distance, the neighbouring galaxies will not disturbe orbiting stars of the other galaxy. Let's regard three positions of one galaxy, first an external star in direction of the second galaxy, the second one equivalent to the galactic core of the first galaxy, and the third one an external star at the back of the galaxy, opposite to the second galaxy.
While both galaxies are approaching, the gravitational vector of the second galaxy on the first position, the external star, will be greater than on the second position, the core. This difference of gravitational vectors will disturb the orbit of an external star. Inertial force of the external star will no longer be balanced with the gravitational vector towards its galactic centre. This results in increasing radius of the external star to the galactic centre.
On the other side external stars at the back of the galaxy, at the third position, will get a smaller gravitational vector of the other galaxy than the core. Therefore the galactic core of the first galaxy will be pulled away from the stars at the rear by the gravitational vector of the second galaxy, also resulting in increasing radius of the external stars at the back of the galaxy.
We may call this the differential gravitation within a galaxy.
This dissociation of gravitational vectors will result in dissociation of movement. At a certain point the unity of the core and the external star will be interrupted.
In consequence we see a spiral arm running ahead or figures like a handle at the rear of the disc, for example **M 51** (Whirlpool) or **Stephan's Quintet** or **Arp 256**.
When dissociation of movement increases, stars at the rear will fail in orbiting the core, sometimes resulting in a tail, following slowly the main part of the galaxy. At this stage, original spiral structures of precursor galaxies are broken up, see **NGC 4676, Arp 188** (Tadpole Galaxy, PGC 57129), **NGC 4038 + 4039** (Antennae galaxies), **Arp 243** (NGC 2623).

Bars deriving from interposed galactic matter.
When coming closer a lot of stars will be held by gravity between both cores, building a bridge or provisional bar. You can see increasing density of stars between the cores of colliding galaxies **NGC 2207 and IC 2163** as well as **NGC 4676**.
After a spiral uniting of both galactic cores we get a barred spiral galaxy.
An early barred spiral galaxy consists of a bar of stars and two symmetric tails or arms, such as **NGC 7479** or **NGC 1300 or NGC 1365**.

About the origin of spiral and bulge.
The distance between the flight paths of both galaxies is bridged by the future galactic plane. The tilt of the future galactic plane will be a compromise between the directions of the precursor galaxies.
Approaching galactic cores are turning into more and more spiral movement at increasing acceleration. So future spiral arms are prepared.
The two cores of the precursor galaxies will fuse to one common bulge of the new spiral galaxy.
At **Arp 243** you see the two cores immediately before merging. In addition you see the two tails of approaching, and some faint structure around the central illuminated region, here you can realize preceding spiral movement.
The very cores will orbit each other for a long time, first in a spiral way and then in a circular way, because of conservation of linear momentum. So for a long time you can find two gravitational centres in spiral galaxies as it is observed in **M 31 Andromeda** and many others, and sometimes you can observe a little spiral structure within the central bulge, see **NGC 1300.**

Provisional spiral arms are unobtrusive.
Early barred spirals consist of a bar and arms (or tails) and in addition of a fine and unobtrusive circular area of matter. Both external arms or tails mark the boundary of this area, see **NGC 1365.**
After building a bar, both cores begin a high speed spiral movement around the common gravitational point of both galaxies. Some neighbouring stars will get accelerated and will follow the spiral way. Because of differential gravitation, some stars of the core will be lost on the way to the new galactic centre. Lost matter following the cores marks the spiral way unobtrusively, so provisional spirals are almost invisible at the beginning.
Within the fine circular area of **NGC 1365** the quick spiral movement of both cores had already happened. You can see the illuminated bulge resulting from merging cores, leaving some unobtrusive trails in a circular area, the furure spiral arms in the future disc.
At **NGC 1365,** you see a somewhat angular transition from the tails to the disc, regarded in a visible spectrum; but UV-light pictures show continuing movement of hot materials in a perfect spiral way.

Development of bar and disc.
Provisional bar consists of stars joined together by approaching galactic cores, see **NGC 4676** or **NGC 2207 and IC 2163**. The whole bar has got a torsional moment corresponding to direction and velocity of approaching galaxies.
Stars of the provisional bar on the one hand will build the future galactic disc and on the other also will be a part of the future bulge and permanent bar, together with the stars of the cores.
When the cores are leaving the ends of the provisional bar and are moving on at increasing acceleration, the main part of the provisional bar will continue its circular movement by the circular moment, independently from accelerated movement of the cores. The provisional bar will be stabilized by its inner gravity, this means by the gravitational vectors among all of its stars, and will

continue slow circular movement.
Some stars at the ends of the bar will follow the cores directly, others will be dislocated from the bar and begin orbiting independently from the bar into the same direction as the cores and the future spiral arms are orbiting.
This way the ends of the bar will get instable and diminish. When cores after each half revolution are crossing through the bar, another portion of the bar will be removed and follow the core; distant regions of the bar will get more and more instable. Cores on their spiral way will cross repeatedly through the bar and will accelerate the matter of the bar, like a beater or curl will accelerate and mix dough.
When the stars outside the bar are moving slowly by a tangential linear momentum, the gravitational force of the central masses will attract them, so they get accelerated and drift to a closer distance to the centre, until the velocity is high enough to remain in a stable circular orbit. This way galactic disc is built bit by bit. And provisional bar will melt to the size of a typical permanent bar of a barred galaxy.

The last spiral revolutions of the very cores are happening within the bar and the new bulge. After the very cores did their spiral way, they represent the gravitational centre of the new spiral galaxy.
Before stable state is reached, convoying stars and clouds of both very cores will meet and merge to the new bulge of the new spiral galaxy, resulting in a heavy star burst. Beams of energy and matter are flung up and down by magnetic fields in a right-angled way from the centre of the new bulge. That's called the **Seyfert galaxy stage**.

Flight paths of stars within a provisional bar are predominantly irregular. When the new galactic centre is established, flight paths of stars will change into more regular but off-centred orbits around the galactic centre.

Orbiting spiral arms by conservation of momentum.
The spiral way of galactic cores is marked by lost stars because of differential gravitation.
A star losing the strict connection with the core will move on independently. It has got a linear momentum in tangential direction. Therefore it will no longer follow directly the core but will drift somewhat in circular direction.
There is a parallelogramm of forces, built by the inertial force of the star and a common gravitational vector deriving from the sum of all gravitational vectors of the central mass of both cores and of the stars in the bar.
The linear momentum will not vanish, because of conservation of momentum. This results in orbiting movement of the matter in the provisional spiral arm. That's the reason why spiral arms are orbiting the centre like a clock hand.

Permanent reconstruction of spiral arms by shining matter.
Within spiral arms density of matter is about 10 to 20% higher than in the remaining disc. (The difference of brightness is much greater than the difference of mass.)
Stars of the galactic disc are orbiting the galactic centre. Observations show that stars of an inner radius have higher velocity than spiral arms. Orbiting stars and clouds move into the high density region of the spiral arm, resulting in collision of matter and formation of new stars illuminating the spiral arm. In contrast spiral arms at outer radii have higher velocity than orbiting stars.
Why?
At the beginning velocity of the provisional spiral matter is different from the velocity of circular orbiting matter of the new galactic disc. Therefore collisions with circular orbiting matter will start.

Circular orbiting dust and gas clouds will collide with the spiral matter of more density.
Let's regard the development of stars at an inner radius. Stars and clouds of higher velocity are coming from behind into the spiral arm causing collisions and new stars. Therefore the origin of new stars is rather in the rear of the spiral arm. These big new stars move at higher velocity through the spiral arm towards the front of the spiral arm. Near the front of the spiral arm the end of these bright new stars will occur.
When bright shining big stars are exploding as a supernova they blow hugh masses of gas and dust into all directions. That means matter of exploding clouds will collide with matter within the spiral arm towards the galactic centre and towards the rear. On the other side, in direction ahead and towards the edge of the disc, exploding matter will penetrate into calm regions, troubling them by initiating collisions of matter, new stars, illuminating and so on, that means: The illuminated region of the spiral arm is drifting ahead. And this way permanent reconstruction and movement of the inner parts of spiral arm will also continue towards the outer regions resulting in a continuing movement ahead as well as sideways.
Therefore density of the spiral arm **will result in density** by additional matter of the orbiting disc. That's the reason for self-continuing illumination.
Now we can call them the permanent spiral arms.
That's the causal origin of what is called “density wave“ [1].

Orbiting speed of stars at outer radii is about the same as at inner radii; that means higher angular velocity of inner stars; therefore orbiting time of outer stars will exceed orbiting time of inner stars. In contrast spiral arms are orbiting at about constant angular velocity and constant orbiting time. Angular velocity of spiral arms is higher than angular velocity of outer stars.

The first original matter of the provisional spiral will approach the centre more and more until reaching the future bulge, or it will quit the very spiral some day because of too high speed. After a while original matter of provisional spirals may have left the very spirals, but the spiral keeps on shining because of permanent reconstruction.
Permanent reconstruction of spiral arms from inner radii towards outer radii is the reason for constant orbiting of spirals, independant from velocity of orbiting stars in outer regions. And also the reason for widening of the outer part of the spiral arm.
Probably reconstruction of the spiral arm near the bulge can overtake the continuing self-reconstruction of outer parts of the spiral arm. This way spiral arms split up.
That's what we can observe in spiral galaxies like **NGC 1232.**

Example and synopsis of early spiral galaxy stages.
At **NGC 6782** you can see a clear overview of the first stages of a spiral galaxy:
So called outer arms are symmetrical tails of appraoching precursor galaxies; whereas inner arms represent spiral arms, already orbiting.
The so called outer ring represents the border of galactic matter, formerly captured between both cores; the so called outer bar represents transition from provisional bar to galactic disc.
The so called inner ring represents the border of united stars of both cores and simultaneously the border of the bulge of the new galaxy.
The more oval figure within the new bulge, the so called inner bar, probably results from not yet completely performed uniting of both cores.

Tails vanishing.
Tails of approaching consist of moving matter. In contrast spiral arms are permanently reconstructed and consist of alternating matter. Arms of early barred spiral galaxies are the transition from tails to spiral arms, see **NGC 1365.**
Matter of the tails is moving towards the united galaxy according to the gravitational vector of the galaxy and to the inertial force vector of tail matter. That means tail matter will get more accelerated by decreasing distance to the galaxy. Because of the inertial force it will not enter into the very galaxy but will float above or below the plane. (Each tail will colonize opposite space on behalf of the galactic disc plane.)
So globular clusters within the galactic halo may arise. And also nearby dwarf galaxies.
At a later time total tail matter will have joined the galactic halo and will have built dwarf galaxies respectively. This way tails are vanishing.

D DISCUSSION

What about the "density wave theory"?
Up to now it is a common assumption that any "wave" of gravity will result in a spiral arm of density.
But any fundamental theory of the origin of spiral galaxies has to explain where spiral patterns in galaxies do come from.
It is not sufficient to suppose any unrealistic arrangements of flight paths of stars, resulting in a kind of spiral, as proposed by Bertil Lindblad.
Density wave theory describes continuing reconstruction of spiral arms in inner regions of the galactic disc where orbiting materials collide with spiral arm matter of more density. [1]
But describing collision of orbiting matter in the regions of spiral arms is not a theory about the origin of spiral galaxies.
Postulating a preformed spiral way of gravitation at a higher degree than in the rest of the disc, without giving any causal explanation for the origin of stronger gravitation and of spiral form, may be called a speculative and incomplete theory.

A complete theory should explain the origin of spiral arms as well as the origin of tails and of globular clusters in a galactic halo. And also explain continuing circular movement of spiral arms at constant angular velocity. And also development of plane and bulge. And also direction of orbiting disc and spirals. And of warps.

The answer may be the merging theory of spiral galaxies.

What are the conditions of merging galaxies, and when will the final spiral start?
Approaching galaxies will attract each other by increasing gravitational vectors. The flight paths will be bent towards the common single gravitation centre of both galaxies and velocity will increase.
If the inertial force vector of each galaxy stays greater than the gravitational vector towards the other galaxy, distance between both galaxies will increase again after a momentary approach.
But if the gravitational vector towards the second galaxy exceeds a **crucial limit**, which is exactly corresponding to the inertial force vector of the first galaxy, further approach and finally merging of both galaxies will be inevitable. The reason is that the gravitational vector will increase by square of decreasing distance according to Newton's gravitation law, whereas velocity and inertial force vector will increase by less degree (- more exactly: by root of decreasing distance according to Kepler's laws of planetary motion). In consequence the gravitational vector will exceed the inertial force vector more and more, visible by a closer flight path in the shape of a spiral. Because of Newton's third law of motion both galaxies will interact, so we get a double spiral figure, if both galaxies are similar sized.

If approaching galaxies move at different velocity, the more speedy galaxy will transfer some of its linear momentum to the other one, this is called **momentum transfer**. (That's why the Moon is slowing down.) This way the more speedy galaxy will, relatively, slow down and the slow galaxy will be accelerated by momentum transfer. Velocity of both galaxies will be aligned to some extent.

In case one galaxy will cross in front of the second, the common single gravitation centre will change direction on behalf of the second galaxy, therefore the second galaxy has to change the direction of movement before the final spiral starts. In this case the galaxy in front will fix the direction of spiral movement, and then the gravitational vectors will start the spiral.

Why are tails well observable and provisional spiral arms are not?
Galactic tails as you see at **NGC 4676** are illuminated by galactic matter that failed in orbiting the accelerated home galaxy because of differential gravitation, see above. Tail materials will follow the trail of the galaxy more slowly, getting accelerated in direction of the common single gravitation centre.
If the unity of star and core is lost at a moment when the star moves in forward direction, it will be more speedy in direction of the common single centre than if a star is lost while moving towards the rear. Though all materials of tail are moving towards the centre and all materials attract each other towards the very middle of the trail, there are different individual velocities, resulting in collisions and star bursts and illuminated tails.
On the other side provisional spiral arms are faint, containing less matter. Velocity of these matter will increase towards the centre. Trail matter of provisional spirals will not result in heavy collisions as materials of tails do, see **NGC 4038 + 4039** .
When collisions between the orbiting disc and the spirals set in, unobtrusive provisional spirals will change into illuminated permanent spiral arms.
In some cases there are also faint tails of appraoching, see **NGC 3310**. Illumination of tails is dependent on the quantity of lost materials, probably according to the tilt of the precursor galaxy disc to the direction of the flight path of the galaxy. (If the plane of the galactic disc is right-angeled on the direction of appraoching, no relevant dissociation of the gravitational vector will exist, only minimal loss of matter will illuminate the tail. Presumably most tails of appraoching will stay unobtrusive.)

How is the galactic plane established?
The trail of an approaching galaxy will build some kind of approaching plane. The future disc plane will be a compromise of both approaching planes, see **M 81** (appraoching tails above and below the disc).
When the final spiral is starting, the cores will move symmetrically to the future plane on their spiral way towards the common single gravitation centre. First the trail of the cores will not yet be in the plane of the future disc, but in different hights. Early spiral arms, one above the very galactic plane and one below, will attract each other towards the very galactic plane, further orbiting because of the linear momentum. In early spiral galaxies, sometimes there are different hights of spiral arms, see **Arp 188** or **M 58** or **M81.**
Some galactic discs seem to be bent out of shape, because the final plane is not yet perfectly adjusted, see **ESO 510-G13** or **NGC 7331.**
Transition of approaching rest materials to the galactic disc will build the warps. Because of the development of the plane as a compromise between both approaching planes, both warps will get opposite directions.

Arriving at central regions of the future galactic plane, regular spiral movement of both cores will be disturbed, because the distance in the third dimension has to be levelled out. The vertical distance of the very cores will get greater than the horizontal distance. The very cores will change direction of revolution each time the greatest distance changes in another dimension. At high speed both cores will approach by leaving their spiral way. At the same time the stars of both cores will be merged to the bulge of the new galaxy.
You see a snapshot of this final tarantella at **Arp 243** (NGC 2623).
Therefore we assume that in most cases the observable plane of galactic centres is different from the plane of the disc.
So the development of the bulge gives the explanation why flight paths of stars in the bulge usually are not in the galactic disc plane, and why no spiral arms can be found in the bulge.

What about the symmetric figure of spirals?
Two precursor galaxies of about the same size will build a rather symmetric double spiral. Probably also up to a certain difference of size, precursor galaxies result in a symmetric spiral. Assuming one spiral figure is short in comparison with the other one, it may be enlarged by the permanent reconstruction mechanism of orbiting disc materials. As both spiral arms will be penetrated by the same extent of matter per time, brightness and extent of permanent spiral arms are mostly identical and symmetric.
This way symmetrical spirals may derive from somewhat different sized galaxies.

Merging galaxies: spiral or not?
Two galaxies of about the same size will build a new spiral galaxy. Therefore the future meeting of Milky Way and Andromeda will result in a super spiral galaxy.
If a small galaxy meets a big spiral or elliptical galaxy, the small one will be melted and joined to the big one without serious result on behalf of the shape of the big one. The gravitational vector of the little one did not exceed the inertial force vector of the big one.
(If a big spiral galaxy merges with a little galaxy, this may result in a further, third spiral arm, certain circumstances provided. In this case symmetry will be lost.)

If a spiral meets a very big elliptical galaxy, the spiral will be melted and joined to the elliptical one. Spiral figure of the precursor galaxy will vanish.

Why are the biggest galaxies elliptical?
Very small and irregular dwarf galaxies may merge and build another small galaxy. Small elliptical galaxies merging will get a little spiral galaxy. Spiral galaxies will increase by merging repeatedly. The first stage of a spiral galaxy will be a barred galaxy. The ends of a permanent bar are the starting points of spiral arms. Reconstruction of spiral arms will also change the ends of the bar, so the bar will get shorter and the ends are integrated as parts of spiral arms. Flight paths of stars within bulge and bar will change from off-centred to more circular. This way bulge and bar will get more spheroid.
The natural sequence of barred galaxy development seems most likely from SBc to SBb to SBa in Hubble's scheme.

Permanent spiral arms will not exist for ever. They will be splitted up by permanent reconstruction inclusive of overtaking mechanism, see above. And they will be disturbed by merging additional small galaxies. At last, spiral arms will scatter and will be parted in bright regions looking like clouds, see for example **M 63** or **NGC 4414** or **NGC 2841.**
The natural sequence of spiral galaxies can be supposed from Sc to Sb to Sa to S0.

Probably in the long run the complete disc will be joined to the bulge, resulting in an elliptical galaxy, consisting of the former bulge of the spiral galaxy including the whole disc matter. Momentum transfer from orbiting stars to the centre may also be an important mechanism.
Probably elliptical galaxies first are more spheroid, at a future time spherical like **M 87**.

If a hugh ellipse is established without any other galaxy of similar size nearby, every new merging galaxy will enlarge the ellipse, but no bigger spiral will result, because the gravitational vector of the second galaxy will be too small for resulting in a spiral movement of the big galaxy, see **M 87** or **Arp 142** or **NGC 1316.**
Therefore the biggest galaxies must be ellipticals.

**SUMMARY. Using gravitational vectors on interacting galaxies we find the origin of:
Double spiral figures; galactic tails; spiral arms; continuing movement and constant angular velocity of spiral arms; galactic disc and bulge; plane of galactic disc; different plane of galactic gravitation centres; activity of Seyfert galaxies; opposite direction of warps; the biggest elliptical galaxies.**

That's all about the origin of spiral galaxies.

Reference:
[1] Lin C.C. et al. 1969 ApJ p.721