Voyager 3 Project
Part I of II

by

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Amateur planetary photography is a highly specialised form of astrophotography where we take pictures at extreme focal lenght and are often limited to a few minutes at a time because of the planets rapid rotations.
The level of resolution that can be achieved is entirely dependent on the seeing which might be optimal only once or twice a year, at least here in Sweden.
But it has undergone a significant revolution in recent years thanks to high quality telescopes and optical accesories becomming more affordable, the development of a wide range of sophisticated software and advanced techniques that let us achieve results that were only possible with professional equipment just a few years ago.

As a teenager living in central Paris at the beginning of the 70s, I was invited to my high schools astronomy club one evening and was shown Saturn in a small telescope.
The unexpectedly beautiful view of the planet that night became the starting point of my life-long passion for astronomy and especialy for the solar system.
I have always lived in big, light-polluted cities where many deep space objects are simply out of reach.

I soon bought a 114/900, one the most affordable entry-level Newton telescopes of that time, with a spherical mirror of 114 mm diameter and 900 mm focal lenght on a very simple hand controled equatorial mount.
I started by making drawings of the sunspots, the lunar craters and the major planets with their moons but very soon I also wanted to take pictures as a complement.
I had a simple rangefinder camera, a "Braun Paxette" that I used in an afocal setup (what would be called digiscoping nowadays) by putting it on a separate tripod, quickly lining up the optical axis of the lens to the 6 mm eyepiece and exposing for 1/4 sec while the object drifted through the field of view. This was the maximum exposure time that I could use to avoid motion blur as the mount had no tracking.
Then there was a long wait for several days as the roll of "Ektachrome 160" film was processed and returned from the photo lab.
Some of my best pictures from that period were of Jupiter, taken in the evening of September 20, 1974.
The disc of the planet was only 1,7 mm wide on the original slides but showed nonetheless some dark bands and an elongated and distinct GRS.
Although the quality is far from what we are capable of achieving today, it's interesting to compare these early images with those sent back from Pioneer 10 and 11 in 1973 and 1974, the first ever flybys of Jupiter, and also to the aspect of the planet in recent years as shown in our Voyager 3 project.

I am now a professional photographer and digital imaging artist since the early 80s.
The most exciting aspect of combinig astronomy and photography is that we are now able to reveal what’s invisble to the eye, either by increasing the resolution or by accumulating and combining long time exposures to bring out extremely faint objects.
We also dispose of all the power of the digital post-processing that lets us accelerate an event through time-lapse animations or change the vantage point through the use of 3D-renderings.

Some years ago, I discovered the fascinating Voyager 1 sequence on internet, showing the intricate motion of Jupiter’s cloudbelts for 28 consecutive days during the probes final approach to the planet in the spring of 1979.
There is the speeding equatorial System1, the rotating Great Red Spot (GRS) and a multitude of local vortices that are not easy to grasp in this short animation.
The old saying could be slightly adjusted to "an animation says more than thousand pictures"!

A test performed early in 2012 of blinking two of my images of Jupiter taken 24 days apart, revealed some features that seemed to have remained more or less in the same spot while most had moved by quite an amount.
That led to some dicussions on one of our local swedish astronomy forum, especially with Martin Högberg who clearily shared my interest for the subject.

At the beginning of 2014, Jupiter was to reach its highest point in the northern sky during its 12-years orbit around the Sun.
From Stockholm, at a latitude of 59,3°N, it would culminate at an altitude of more than 54°.

I contacted Martin in the first week of December 2013 to discuss some early plans for a long term visual project on Jupiter that we could hopefully start just after New Year.
We would take high resolution pictures of Jupiter as continously as possible with the ambition of realising an animated cylindrical map of the planet that would reveal the intricate movements of its cloudbelts for a period of 3 to 4 month. That period corresponds to somewhere between 210 and 290 rotations of Jupiter.
Our model was the fantastic color movie taken by NASA's Cassini spacecraft showing 24 Jupiter rotations on a cylindrical map http://en.wikipedia.org/wiki/File:PIA02863_-_Jupiter_surface_motion_animation.gif .

This was our first ambitious goal. We thought that If we could achieve this, we could possibly also be able reenact the Voyager 1 flyby at a later stage.

We started an intense mail correspondance to discuss the guidelines and the technical requirements for this project but very early on we realised that we had to be more than just the two of us for this big project.
I launched a call on our local astronomy forum for others to join in and soon we were seven dedicated astrophotographers, Martin Högberg, Johan Warell, Torbjörn Holmqvist, Roger Utas, Göran Strand, Daniel Sundström and myself, Peter Rosén.
This was a major feat in itself as it is usually quite a solitary hobby for most of us amateurs and that we perform mainly when the rest of our families have gone to sleep at night and quite often after a day at work.
Most of us had never met in real life but it was like we knew each others from having discussed and given feedback on each others forum posts for many years.

Determination was in fact a key element because living in a country up in the north, often subject to bad weather and low temperatures in winter, Sweden is not really the ideal place to to carry out such a project from.
We hoped that our geographical spread over the southern part of the country would help us overcome some of the obstacles with the bad weather and temperatures as low as -20° C or less. It did indeed help but at times we had clouds that covered the whole country for weeks in a row.
The telescopes we used were Newtons and Schmitt-Cassegrains in the range of 200-250 mm and we regularily checked and optimized the colimation.

But lets jump back to the start. We performed many initial tests at the beginning of December 2013, using the powerful free software ”Winjupos” with some test images, gaining more and more knowledge and continously adapting the guidlines for the project, including everything from filenaming to finding the best working procedures.
Winjupos let you change the projection of the planetary images so they can be mapped on a flat surface with precise coordinates, just like a world atlas is a flat representation of the earth.
As the planet rotates and displays new sides, the mapped pictures are represented by a displacement along the horisontal axis. In theory 3 to 4 images should be sufficient to cover the whole surface of a map but depending on the seeing and other atmospheric conditions, many more might be needed to get a good detail definition.
The polar projections show the planet as seen directly from above or bellow the respective poles. For this particular projection, the planets rotation translates into a rotation around the polar axis. This view is almost magical. While only using our ground based telescopic images, it allows us to show the planet from a perspective normaly reserved to the spacecrafts orbiting over its poles at a distance close to 600 million kilometers from earth!

To summarize, our optimistic challenge was to unroll the surface of Jupiter, rotation after rotation, in a long and uninterupted flow for a period of 90 to 120 days!
Much of our internal communication was about local weather conditions and the best time to shoot in order to get the images that would fill the gaps in the map, like pieces in a jigsaw puzzle.
During the day we adapted to the ordinary 24 hours clock at work and with our families but at night we switched over to a 10 hour ”jovian” clock, or 9h 55m 30s to be more precise. All our planning was completely synchronized to Jupiters rotation period.
The highest priorities were not only to get the best possible images but even more importantly, to cover the whole surface of Jupiter in the shortest possible time so we had to take pictures as often as possible.

Everyone were to stack their own images the way they were used to, while leaving a little headroom for more adjustments and sharpening at a later stage.
All the pictures were sent to me for a first round of post-processing to give them a homogeneous color balance and contrast. They were then forwarded to Martin Högberg who performed all the Winjupos transformations.
He then returned 3 projections for every picture to me, one ”Cylindrical” and one ”Stereographic Polar” for each polar view.
I imported these projections into Photoshop and stitched them together into maps covering the whole of Jupiters surface.
It was especially important that the transition between individual pictures, but also from one map to the next, would run seamlessly for the whole period of the project.

We managed to complete our first map on the 28th of December 2013 which was ahead of schedule and this left us excited during the New Year period.
We were clearily on track and everything seemed to work just as planned.

But then the weather deteriorated and was the most overcast for January and February since 1988 in the Stockholm area, the rest of the country not being much better off.
It took us another two weeks to finish our second complete map.
The main problem that we had to face was that the equatorial zone called System 1 rotates 7,63° more rapidly per day than the slower System 2 (the northern and southern latitudes).
This differentiated drift corresponds to 107° in two weeks time which was way too much of course.
But we kept working on, hoping to find a solution later on to this major problem.

At the end of March, although the weather conditions were quite good, the receding position of the planet along with the nights getting rapidly shorter up here in the north made us decide to end the first part of the project.
By then we had taken more than one million frames, stacked into 560 still images which were in turn assemled into 18 complete maps, one for every 5 days on average, but in reality they were very unevenly spread in time.

It was exciting to animate these maps as we saw the features in System 2 come to life for the first time, GRS slowly drifting while pumping the system of white clouds in the South Equatorial Belt (SEB), the yellow Oval BA that is on it’s way towards its rendez-vous with GRS approximately every second year. A little bit higher up we could follow the fast laned 3 white ovals whose mutual positions and shape have given them the nickname ”Mickey Mouse”.

But the Equatorial Zone (EZ) just showed a multitude of features jumping around eraticaly. Obviously we needed more maps and they had to be evenly spaced in time to get some order in this high-speed chaotic lane.
Some precise drift tables and lot of testing with some morphing programs clearily showed that this was the way to go.
Morphing is a technique that has been widely used in the film and music clip industry to create special transitions between sequences. A good example is the transformation of the faces at the end of Michael Jackson clip "Black or White " of some years ago.
But it is also a powerful tool in scientific applications. Nasa for example used it to create animation frames between still images of the breakup of comet 73P/Schwassmann–Wachmann in 1995, photographed by the Hubble Space Telescope http://en.wikipedia.org/wiki/73P/Schwassmann–Wachmann .

In morphing programs you work with two still images at a time, placing dots on specific features in the first image and draging the corresponding dot to match the position of the same feature in the second image.
The morphing software can then generate any number of intermediate frames and animate them in a fluid and correct way.

But in our case, the intricate movement of Jupiters cloudbelts proved to be too complex to be easily manipulated this way because there were too many adjacent features that moved in opposite directions. The morphing programs that I used could simply not handle this sort of strain in the transition areas without generating artificial scars on the surface.

I finaly decided to try another approach and divided the surface of the planet into 4 areas, each with less conflicting movements and animate them individualy, generating 90 steps for the 90 days period. They corresponded to one each for the the northern and southern System 2, one for the equatorial belt, the Sytem 1, and an additional one to reduce the strains on the transition area between the two systems.
All the frames were then assembled in Photoshop and this time resulted in a very fluid animation. System 1 now flowed on like a rapid and coherent stream across the surface of the planet!
Our animation shows the evolution of Jupiters cloudbelts over a period of 90 days in just 7,2 seconds which corresponds to an acceleration of the timeflow of more than one million times!

At this stage we had reached our first big goal of reproducing the animated maps in a similar way as those from the Cassini mission.
We now had to find a way to free ourselfs from earth gravity and make animations that would reproduce the approach and flyby of Jupiter from any direction in space.

My astronomy software "StarryNightPro+ 6" allows the user to simulate space flights.
It also lets the user import his own still image to be used as a surface models for the planet. By combining these two features, I was able to produce stop motion sequences by advancing to the next position in space and time, loading a new still image and take a screenshot at every step.
When animating the resulting screenshots, we knew that we had finaly achieved our goal of producing a 2014 version of the Voyager 1 approach and flyby, using only images taken with our own backyard telescopes.

At the end of May 2013, we had spent more than 3 month of acquiring images and many thousands of hours of postprocessing to end up with some 7-seconds long animations!
We named our virtual spacecraft "Voyager 3" as a tribute to the original probes that were sent up more than 37 years ago and that still made the headlines when Voyager 1 reached the boundary of interstellar space in 2013.
(http://www.nasa.gov/mission_pages/voyager/voyager20130912.html#.VHxaFqURl3g).

We decided to present our work to the astronomical community in the form of a movie.
Göran Strand has some strong experience in video editing so he was to take care of assembling our material.
As we live in different cities and it had to be done outside of our working hours, we communicated by mail and long telephone conversations, often starting late at night and ending the sessions at 2 or 3 in the morning.
We not only wanted to show the final results but also give some background explanations to the imaging processes involved without getting too technical.
After 2 weeks of hard work we were satisfied with the result and were finaly able to publish our film on Vimeo on the 16th of June.

We have since received a very positive response, not only from amateurs around the world but also from the professional community.
We have had articles and mentions published online on several sites, among others Universe Today, The Planetary Society, PetaPixel, SpaceWeather, The Creator's Project etc...
Anthony Wesley from Australia, well renowned for his high quality planetary photography, was invited to give the closing lecture at the professional "Saturn Science Conference" last summer on

the subject of "High Resolution Planetary Imaging of Mars, Jupiter, Saturn, Uranus. Current state-of-the-art in Amateur capabilities, hardware and software". He contacted us and wanted to include our video in his presentation, which we gladly agreed to, of course.
We received quite a positive feed-back from this event:
"Your video was mentioned and discussed many times by Saturn scientists at the conference."

Johan Warell also got contacted by Glenn Orton who is specialised in infrared monitoring of Jupiter and currently working at JPL on the Juno mission.
He also asked for permission to show our film at a NASA meeting and again at the Juno science team meeting to illustrate how amateurs can contribute to long term planetary monitoring. On both occasions it was very well received.
This may result in a collaboration with the Juno team on some visual aspects of the program when the satellite will reach Jupiter in July 2016.

One of the most striking changes in Jupiters surface when comparing the original sequence to ours is how much the GRS has decreased in size during the last 35 years:
It's width has lost 30% and it has a much rounder shape.

This has been a unique experience and exciting adventure for all of us in the project but also very challenging and time-consuming.
Many amateur astronomers have asked if we would consider doing a follow-up.
Considering the amount of work and efforts that went into this project, the answer is: absolutely NOT! Well, at least not before New Year :-)