Getting closer to the Deep Sky : the StarTrack project

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Introduction

Among basic sciences, astronomy enjoys a privileged place among the general public, whatever their age. This enthusiasm is reflected in the existence of associations of amateur observers, the holding of popular events such as the “Night of Stars” in France, and the publication of dedicated popular magazines. However, despite this interest, a large part of the public rarely observes the sky and has a poor knowledge of it. This is unfortunately even more true among young people. It is enough to poll high school students to discover that less than 20% of them have already spotted the Milky Way. This situation is obviously linked to light pollution and the significant urbanization of the population. However, even though recent studies show that more than half of the worldwide population can no longer see the Milky Way, preserved areas, though not numerous enough, sometimes persist at relatively reasonable distances (~ 30 km) from urban centers. The results of the survey mentioned above do not change much when the question is asked to students in big cities or in more rural areas, while the latter have dark areas spared from light pollution much closer to home than the former. A great lack of knowledge about the observation opportunities therefore exists.

Contemplating a beautiful starry sky is a source of wonder, which will fill a lot. But how to go further, beyond the knowledge of the most common constellations and discover fainter celestial objects? Making this step is complicated by several factors. It requires adequate equipment, often expensive and difficult to master. Moreover, the objects are small in the sky. Instruments with large magnifications have small fields of view, which also applies to binoculars to some extent. More than one enthusiast was discouraged by the difficulty of getting the desired object into the field of view of their instrument (although the advent of "GOTO" technology on advanced telescope mounts has represented a considerable advance). These difficulties discourage many and few will accept the investment in money and learning time necessary to taste the pleasures of amateur astronomy. Can an intermediate approach be developed between visual and telescopic observations? Photography with a standard camera equipped with a telephoto lens and placed on a small mount (compensating for the apparent rotation of the sky) may constitute such an approach. A fairly long exposure reveals objects invisible to the naked eye and the large field of view ensures that the desired object is within. Even if the object is small in the photo with few details, it will be interesting to compare the image with those obtained with more powerful instruments. We present here a DIY astronomical mount at a very low cost (a few tens of euros). This setup allows photography of the Milky Way and of relatively extended deep-sky objects with relatively long exposure times (15-30s).

Description of the proposed mount

The maximum allowed exposure (T) without tracking depends on the focal length F (“500-rule”):

$$T\ (s) = 500\ /\ F\ (mm)$$

Example: T ~ 3 s for a focal length of F = 150 mm. For longer durations, the rotation of the sky has excessively visible effects by creating streaks behind objects (“trailing stars”). The proposed mount allows this duration to be exceeded by about a factor of 5 to 10 (T = 15-30 s for a focal length of 150 mm).

The mount is based on the concept of "barn door" ("barn door"). The design by Martin Ankor is described at the following URL: https://www.thingiverse.com/thing:2377686. Two plates hinged about an axis deviate from each other with an angular velocity corresponding to the sidereal rate. One of the platelets is attached to a photographic stand. The rotation of the other wafer, carrying the camera, is provided by a stepper motor via a curved threaded rod and a gear system. The control is performed with an arduino nano microprocessor. Some improvements have been made to the original design, in particular through the addition a bearing for the main gear. Most parts are printed using a 3D printer (files and images, as well as the arduino code are available at ftp://www.cenbg.in2p3.fr/astropart/StarTrack/). This technique has many advantages: the cost is very low, the mechanical dimensions are met at a sufficient level of precision, the assembly work is minimal. The stepper motor is controlled by an Arduino microprocessor. The project described here uses an arduino nano, but an arduino uno will also do (but the provided box will not contain it). The cost price is about 30-40 € (between 4 and 20 € for the arduino, 5-8 € for the stepper motor and its controller, 9 € for the three ball bearings, 5 € hardware). Added to this are a ball-head mount (~ 15 €) to support the camera and a green laser (10 €) for alignment, possibly an external USB power supply (type "Powerbank" to charge a mobile phone, about 20 €).

The alignment is simple, fast and fairly accurate using a green laser placed within a cradle attached to the frame. Simply orient the tripod plate supporting the mount so that the laser beam points towards the Polaris star[1]. This alignment can be checked regularly during the observation session. The laser can also be used to orient the camera, placing it in a cradle attached to the flash shoe of the camera[2]. The laser beam is directed towards the desired object by orienting the supporting camera loosened in the ball mount during this operation then blocked before shooting.

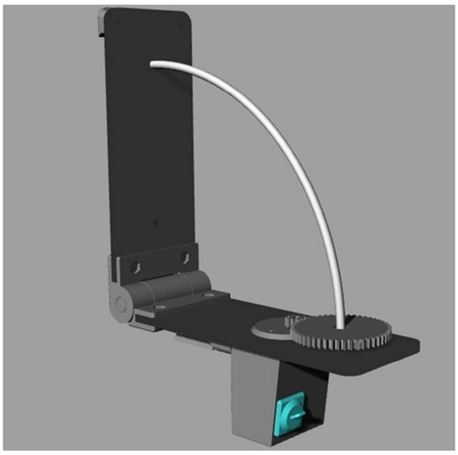

Figure 1 Left : Schematic of the proposed mount (Credit : Martin Ankor). Right: example of realization (fixed to a tripod).

[1] See photo at ftp://www.cenbg.in2p3.fr/astropart/StarTrack/20190901_102439_resized_1.jpg
[2] See photo at ftp://www.cenbg.in2p3.fr/astropart/StarTrack/20190901_105547_resized_1.jpg

Some examples of photographies

All pictures below were shot within 25 km from Bordeaux with a compact camera (Canon G16, 12 Mpx, F/D=2.8), ISO 3200, 30 s exposure.

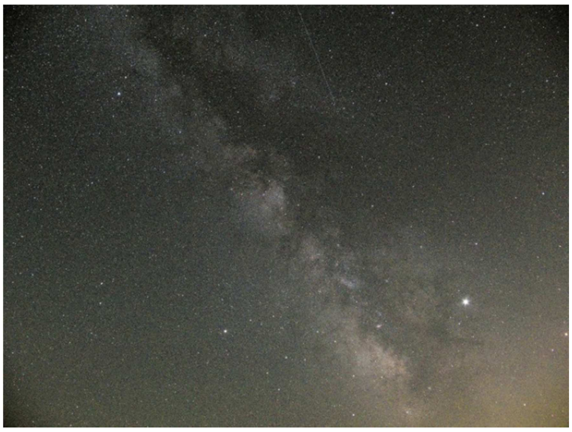

Figure 2. The Miky Way toward the Galactic center.

Figure 3. Region centered on the America Nebula.

Figure 4 M31 with (left) and without (right) sky tracking

Figure 5. Another view of M31.

Figure 6. Central region of the Milky Way

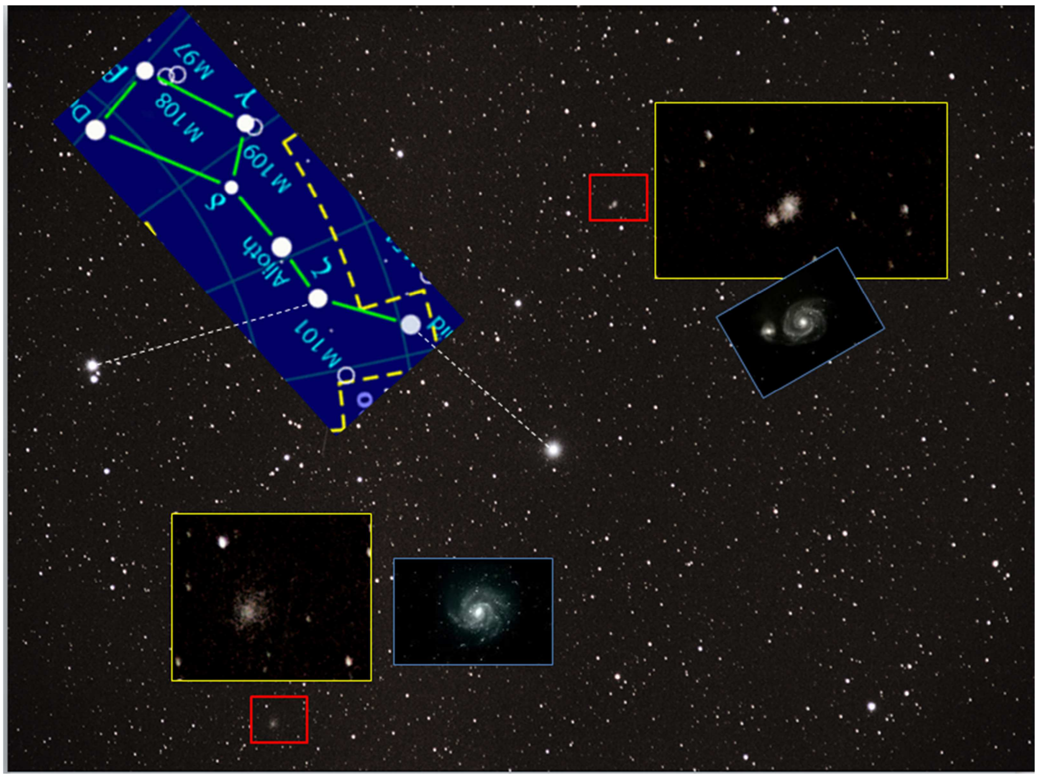

Figure 7. Big Dipper sky region (exposure 5x30s, stacking with the DeepSkyStacker freeware). The two bright stars are Mizar and Alkaid, located at the end of the Dipper and separated by about 7°. The red boxes encompass the spiral galaxies M51 (top) and M101 (bottom). These boxes are blown up in the yellow insets and compared to photos obtained with a 8-inch telescope in the blue insets.

Camera settings

Although it is difficult to be very specific given the variety of cameras on the market, below are some general tips:

• focusing distance: infinity. Disengage the autofocus if possible and focus manually.

• Sensitivity (ISO): do tests, but ISO 1600 or 3200 is a good starting choice; ISO 3200 is often the maximum value allowed by compact cameras.

• RAW format if possible to allow for post processing;

• Manual mode

- Full aperture (closing one stop often improves the lens performance);
- Exposure speed: 15-30 s or longer if possible. Perform tests based on the quality of the sky tracking, estimated from the star sizes;

• triggering: self-timer or via WIFI if the device permits, to avoid vibrations when triggering.

Mount construction

The .stl files, as well as some photos, of the parts to be printed are available at:

ftp://www.cenbg.in2p3.fr/astropart/StarTrack/

Ball bearings

• 2 bearings 22 mm (2.70 €) https://www.rs-online.com/web/p/products/6189957/

• 1 ball bearing 32 mm (3.72 €) https://www.rs-online.com/web/p/products/6190323/

• 1 switch (0.84 €) https://www.rs-online.com/web/p/products/7346918/

Screws

• 8 #2.5x8 screws, 2 #2.5 nuts

• 2 #3x20 screws, 2 #3 nuts, 2 #3 washers

• 6 #5x20 screws, 2 #6x 15 screws, 8 #5 nuts, 2 #5 washers

• 2 #8x40 screws, 2 #8 nuts

• One 25 cm-long #6 threaded rod.

The threaded rod must be curved with a radius of curvature of r = 177 mm. In the absence of a bender, this radius of curvature can be obtained by bending the rod around an object of the same diameter (a thick plywood template or a conical post for example). This technique is easier using a longer rod (~ 50cm). The regularity of the curvature can be checked using a template (to print[3]).

The #6 rod pitch is 1mm, so the #6 nut rotating around this rod and driven by the large gear will produce a displacement of the rod and thus the top plate of 1 mm per revolution. A day of tracking in the sky (24h = 86400s of tracking in the sky) corresponds to $2\pi r$ = 1112mm. A distance of 1 mm must be travelled in 86400/1112 = 78s, which represents the rotation period of the large gear wheel. The parameters in the arduino code are chosen accordingly.

Arduino nano

Cheap clones are available:

https://www.amazon.fr/dp/B07GYK1LXL/ref=pe_3044141_189395771_TE_3p_dp_1

Drivers for these clones are available at: https://sparks.gogo.co.nz/ch340.html

Arduino code :

ftp://www.cenbg.in2p3.fr/astropart/StarTrack/mount.ino requiring the AccelStepper library: ftp://www.cenbg.in2p3.fr/astropart/StarTrack/AccelStepper/

Stepping motor

The stepping motor is a 28YBJ-48 DC 5V 4 Phases with a driving module ULN2003.

https://www.cdiscount.com/juniors/radiocommande-robot/28ybj-48-dc-5v-4-phase-5-fil-moteur-pas-avec-conse/f-1208503-auc7422950996265.html

Ball-head mount

Example:

https://www.amazon.fr/SIOTI-M%C3%A9tallique-Inclinable-Num%C3%A9rique-T%C3%A9l%C3%A9phone/dp/B071GQLJKZ

[3] ftp://www.cenbg.in2p3.fr/astropart/StarTrack/gabarit_tige.stl