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Generating Astronomy Mosaic Images

This application will generate deep links you can use to create mosaic images of your favorite astronomical objects.

As a sample, I used the application to generate this 2.73 x 1.8 degree mosaic of NGC4085 and NGC4088 (in the upper right) and NGC4102 (in the lower left). Turns out it also captured NGC4157 (near the middle of the right edge), as well as (apparently) NGC4187 (in the lower right) and NGC4068 (a bit above and to the left of NGC4102). I'm not sure I see those last two, however… (This information determined via https://nova.astrometry.net/.)

When I used the application to generate the links, it created 30 links for a 5x6 array. After taking the initial images, I ended up having to retake a few images because frame rotation ended up creating some holes in the mosaic (see below for an excerpt of this intermediate stage). For larger mosaics it may be a good idea to use a larger overlap percentage than the default to avoid this type of situation. (See the section “Specifying parameters”

For comparison, here’s the approximate size and location of one of the tiles overlaid on top of the mosaic.

Note that it's also a good idea to make sure your collimation and focus are set properly – you want your mosaic to be as good as it can be! (So please don't look too closely at the sample mosaic above – I was focused on testing the application and not the final quality of the image!)

Requirements for Use

- python3 with pip
- A Unistellar telescope
- An application that will generate mosaics from the individual photos this application will help you take. (I've used Bimostitch – it seems to work well, but I'd like to hear about your favorite!)
- A willingness to share ideas for how to improve the application, make use of the output files, etc!

Preparation

- Download GenerateMosaic.py to a directory of your choosing
- Open a python3 command prompt. (In the commands listed below, I assume you use `python` to invoke python3, and `pip` to invoke the corresponding version of pip.)
- Run the following commands to install the libraries required by GenerateMosaic.py:
  - `pip install geopy`
  - `pip install geocoder`
  - `pip install astropy`
  - `pip install requests`
  - `pip install urllib3`
  - `pip install matplotlib`

Running GenerateMosaic

- Open a python3 command prompt. (In the commands listed below, I assume you use `python` to invoke python3)
- Switch your command prompt to the directory containing GenerateMosaic.py
- Run the following command:
  - `python GenerateMosaic.py`

Specifying parameters

To generate the mosaic, the application needs some information. You will see the following prompts:

- `Enter the name of an object (or 'done' or just hit enter to finish):`

  This prompt is looking for the name of a deep-sky object like M51 or NGC4085 that is known to the NED database. Future versions may expand the lookups to include other sources as well.

  If the specified object is found, you will see a message like this:

  ```
  Found object M31: RA: 10.684799, Dec: 41.269076, Size: 0.0
  ```

  If the specified object is not found, you will see a message like this:

  ```
  Failed to retrieve data for object: Stephen's Quintet
  ```

  You can enter multiple objects, one per prompt. When you're done entering the objects for your mosaic, simply hit enter or type `done` and hit enter.

- `Enter the type of telescope you are using ('EV1', 'EV2', 'Equinox1', 'Equinox2', 'Odyssey', 'Other'):`

  This prompt is designed to tell the application what size field of view your telescope has. It knows the sizes of the field of view of the current Unistellar models (EV1, EV2, Equinox 1, Equinox 2, and Odyssey – both Pro and standard), so you can simply type in the name and press enter.

  Note: If you enter an incorrect telescope name (or if you simply press enter), you'll get this message, indicating that the application is assuming you have an EV2 telescope:

  ```
  Invalid telescope type. Assuming 'EV2' telescope.
  ```

  If you're using a different telescope than one of the specified Unistellar models, simply type Other and press enter and you'll get the following prompts:

  ```
  Enter the field of view width of the telescope (in arcminutes):
  Enter the field of view height of the telescope (in arcminutes):
  ```

  You can then enter your own telescope's width and height.

- `Enter the overlap percentage between tiles (0-100) - default is 40%:`

  This prompt as asking how much you'd like the tiles to overlap each other. Enter an integer between 0 and 100 (without the "%" symbol). Keep in mind that the application does NOT consider field rotation between images. This means that if you are taking long exposures, or if you are taking many exposures, the images will be rotated more and more relative to each other as time progresses during your observing run. This means that you may need a higher overlap between tiles so you can ensure that you (or an application) can figure out where the tiles line up with each other.

  If you only need a few tiles, and/or if your exposures are short, you may be able to get away with a smaller overlap.

- `Enter the size of the border as a percentage of the mosaic's size (0-100) - default is 20%:`

  This prompt is asking how much extra space you'd like between the objects and the edge of the mosaic, as a percentage of the minimum size of the mosaic. This is largely an aesthetic decision, but bear in mind that if you specify no border, part of your objects may be cut off, as the mosaic links are calculated based on the centers of the objects. If you simply hit enter, it will allow for a border of 20% of the dimensions of the mosaic.

- `Enter the decimal value of the aspect ratio of the desired mosaic (width/height) - default is 16/9, enter min for smallest mosaic size:`

  This prompt is asking for the aspect ratio of the mosaic you'd like to produce. Note that you must provide this as a decimal value (for example, the default of 16 by 9 would be entered as `1.77777`.

  If you'd like to use the default value of 16 by 9, you can simply hit enter.

  If you'd like the smallest mosaic possible with the specified objects, type `min` and press enter.

  If you enter an invalid value (or if you simply hit enter), you will see this message and

the resulting mosaic will use a 16 by 9 aspect ratio:

```
Invalid aspect ratio. Using default value of 16/9.
```

- `Enter the name of the file to save the links to (or just hit enter to skip):`

  If you'd like the links saved to a file, type the name of the file and hit enter. Otherwise, if you simply hit enter, the links will be displayed to the screen.

  If you do specify a file name, you will get this further prompt, asking for the type of file you'd like to produce (text, csv, or html). Note that if you simply hit enter, it will produce an html file.

  ```
  Enter the type of output to generate (html, csv, text) - default is html:
  ```

- ```
  Where will you be observing from? Please choose one of the following:
    1) Provide an address
    2) Enter a latitude and longitude
    3) Use my current location (default)
  ```

  This prompt allows you to specify your observing site, either by providing an address, a latitude and longitude, or by using your current location. If you simply press enter, the application will use your current location.

  If you select options (1) or (2), further prompts will ask for your address, or your latitude and longitude.

- `Enter the observing date and time (YYYY-MM-DD HH:MM) -- default is tonight at 9pm:`

  This prompt allows you to indicate when you will start the observations. Note that you must provide the date and time in a specific format – so 8:30pm on April 18, 2025 would be specified as `2025-04-18 20:30`
  ```

If you simply press enter, the application will assume the observations will start at 9pm on the day you're running the application.

After the final prompt, the application:

- display the RA/Dec and Alt/Az coordinates of the objects specified
- generate the links for the tiles of the mosaic in the specified format (or will display them on the console)
- display two graphs showing the tiles in the mosaic in relation to each other and in relation to the objects – one graph will be in Alt/Az coordinates, and one will be in RA/Dec coordinates.

Output Files

Sample output files are shown below, along with thoughts on how they can be used. Note that the application generates Unistellar links – see the following section on how to use those links once you've opened them in the Unistellar app.

Text Output

This is a fairly bare-bones text file with a header and one line for each link.

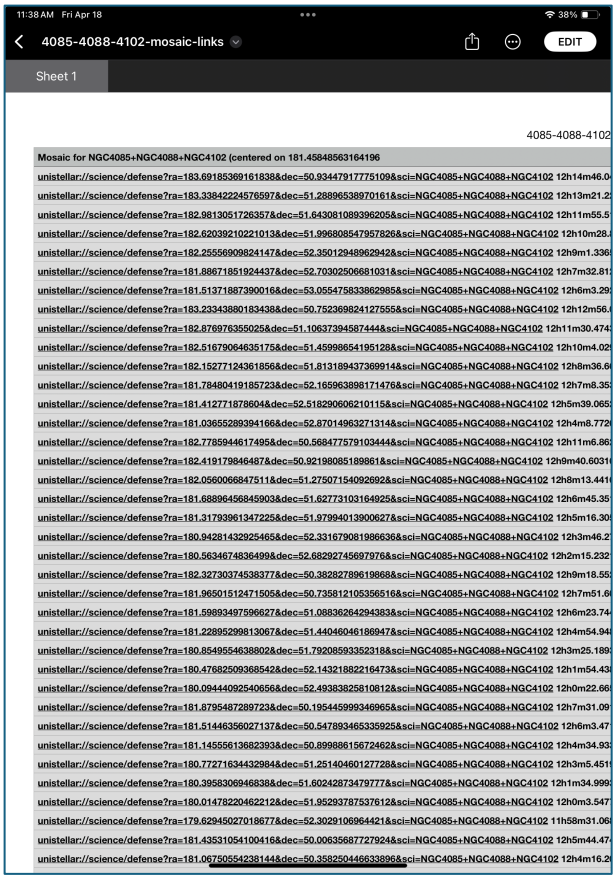
```
Mosaic for NGC4085+NGC4088+NGC4102 (centered on 181.45848563164196,
51.53432058157115) (7x6) tiles of size 1641.6' x 1231.1999999999998 arcsec

unistellar://science/defense?ra=183.69185369161838&dec=50.93447917775109&sci=
NGC4085+NGC4088+NGC4102 12h14m46.04488598841044s 50d56m4.1250399039364005s

unistellar://science/defense?ra=183.33842224576597&dec=51.28896538970161&sci=
NGC4085+NGC4088+NGC4102 12h13m21.22133898383254s 51d17m20.275402925792065s

...
```

This file can be copied to a cloud service, then opened on your mobile device and you can click the links to open each link. For example, I copied this file to Apple's iCloud, then opened it in Numbers (the Apple spreadsheet app). In that application, I can click each link to open it in the Unistellar app.



CSV File

This file is designed to be opened in a spreadsheet; it contains an overall header, column headings, then a row for each link. The data in each row includes the row and column within the mosaic, the Unistellar link, the right ascension, and the declination.

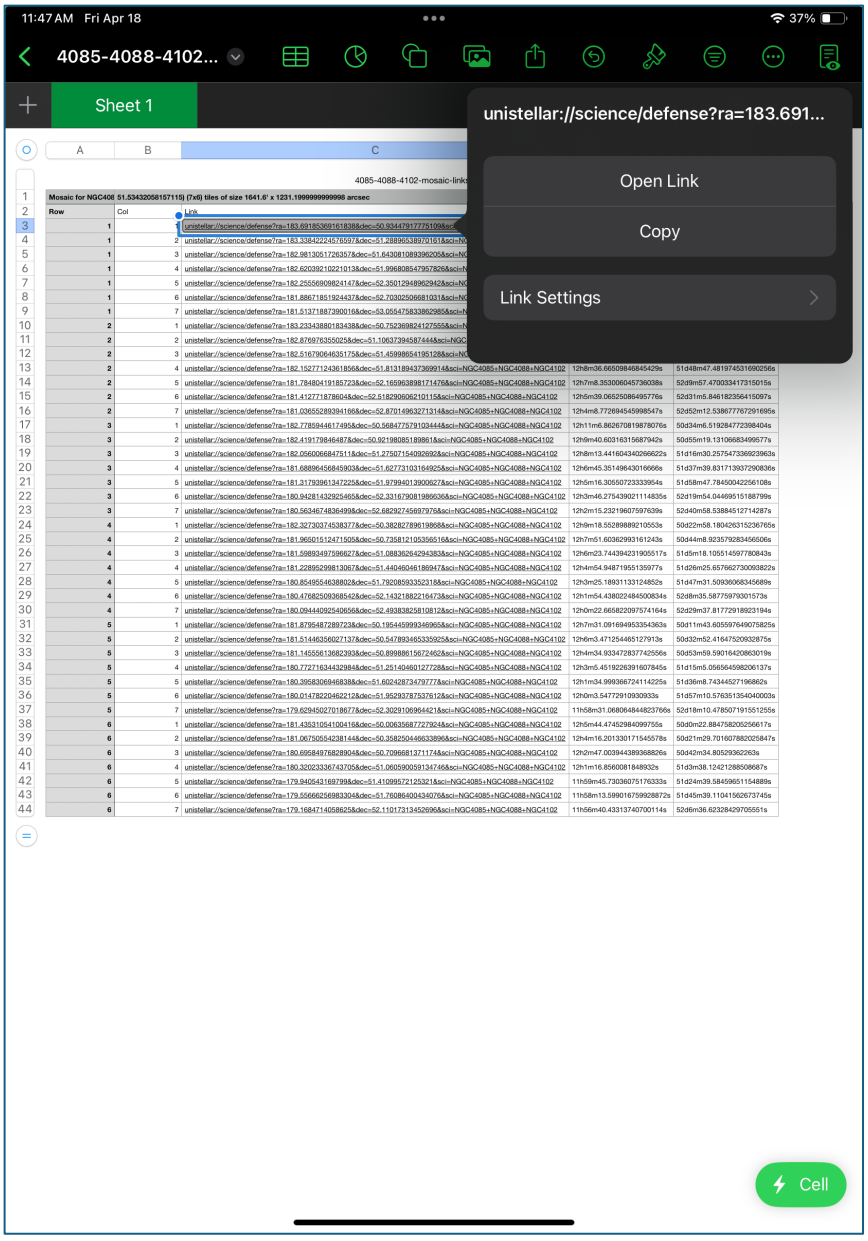
```
Mosaic for NGC4085+NGC4088+NGC4102 (centered on 181.45848563164196, 51.53432058157115)
(7x6) tiles of size 1641.6' x 1231.1999999999998 arcsec

Row,Col,Link,RA (hms),Dec (dms)

1,1,unistellar://science/defense?ra=183.69185369161838&dec=50.93447917775109&sci=NGC40
85+NGC4088+NGC4102,12h14m46.04488598841044s,50d56m4.1250399039364005s

1,2,unistellar://science/defense?ra=183.33842224576597&dec=51.28896538970161&sci=NGC40
85+NGC4088+NGC4102,12h13m21.22133898383254s,51d17m20.275402925792065s
```

As with the text file format, this file can be copied to a cloud service, then opened with a spreadsheet app on your mobile device and you can click the links to open each link. For example, I copied this file to Apple's iCloud, then opened it in Numbers (the Apple spreadsheet app). In that application, I can click each link to open it in the Unistellar app.



HTML File

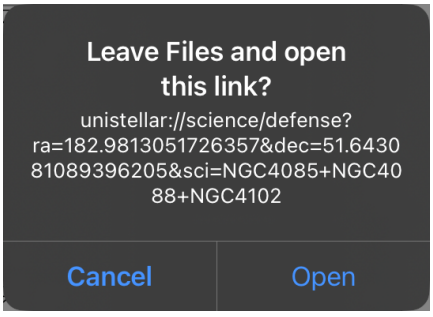
This file is designed to be copied to a cloud service, then opened on a mobile device in a browser or an application that can render HTML files. This file contains an overall header followed by a table containing the Unistellar links. Each row of the table contains a checkbox, the row and column number in the mosaic (formatted as a clickable Unistellar link), along with the right ascension and the declination.

This file allows for easy marking of the checkboxes to indicate which links you've obtained pictures of. That said, I have not figured out a way to easily save the checkbox status (other than taking a screenshot).

Mosaic for NGC4085+NGC4088+NGC4102 (centered on 181.45848563164196, 51.53432058157115) (7x6) tiles of size 1641.6' x 1231.1999999999998 arcsec

	Link	RA (hms)	Dec (dms)
☑	Row 1 Col 1	12h14m46.044885988841044s	50d56m4.1250399039364005s
☑	Row 1 Col 2	12h13m21.221338983832 54s	51d17m20.275402925792065s
☐	Row 1 Col 3	12h11m55.513241432568066s	51d38m35.091921826336936s
☐	Row 1 Col 4	12h10m28.894104530431832s	51d59m48.51077264817509s
☐	Row 1 Col 5	12h9m1.336583577951842s	52d21m0.4661626659010043s
☐	Row 1 Col 6	12h7m32.81244461864844s	52d42m10.890240517124017s
☐	Row 1 Col 7	12h6m3.292529736038432s	53d3m19.713001906746957s
☐	Row 2 Col 1	12h12m56.02531244025158s	50d45m8.531366859199352s
☐	Row 2 Col 2	12h11m30.47432520599841s	51d6m22.94620514797655s
☐	Row 2 Col 3	12h10m4.029755124420262s	51d27m35.95155102461145s
☐	Row 2 Col 4	12h8m36.66509846845429s	51d48m47.4819745316902 56s
☐	Row 2 Col 5	12h7m8.353006045736038s	52d9m57.4700334173150 15s
☐	Row 2 Col 6	12h5m39.06525086495776s	52d31m5.8461823564150 97s
☐	Row 2 Col 7	12h4m8.772694545998547s	52d52m12.538677767291695s
☐	Row 3 Col 1	12h11m6.862670819878076s	50d34m6.519284772398404s
☐	Row 3 Col 2	12h9m40.60316315687942s	50d55m19.13106683499577s
☐	Row 3 Col 3	12h8m13.441604340266622s	51d16m30.257547336923963s
☐	Row 3 Col 4	12h6m45.35149643016666s	51d37m39.831713937290836s
☐	Row 3 Col 5	12h5m16.30550723333954s	51d58m47.78450042256108s
☐	Row 3 Col 6	12h3m46.275439021114835s	52d19m54.04469515188799s
☐	Row 3 Col 7	12h2m15.23219607597639s	52d40m58.53884512714287s
☐	Row 4 Col 1	12h9m18.55289889210553s	50d22m58.180426315236765s
☐	Row 4 Col 2	12h7m51.60362993161243s	50d44m8.923579283456506s
☐	Row 4 Col 3	12h6m23.744394231905517s	51d5m18.105514597780843s
☐	Row 4 Col 4	12h4m54.94871955135977s	51d26m25.657662730093822s
☐	Row 4 Col 5	12h3m25.18931133124852s	51d47m31.509360683456 89s
☐	Row 4 Col 6	12h1m54.438022484500834s	52d8m35.58775979301573s
☐	Row 4 Col 7	12h0m22.665822097574164s	52d29m37.81772918923194s
☐	Row 5 Col 1	12h7m31.091694953354363s	50d11m43.605597649075825s
☐	Row 5 Col 2	12h6m3.471254465127913s	50d32m52.41647520932875s
☐	Row 5 Col 3	12h4m34.933472837742556s	50d53m59.59016420863019s
☐	Row 5 Col 4	12h3m5.4519226391607845s	51d15m5.056564598206137s
☐	Row 5 Col 5	12h1m34.999366724114225s	51d36m8.74344527196862s
☐	Row 5 Col 6	12h0m3.54772910930933s	51d57m10.576351354040003s
☐	Row 5 Col 7	11h58m31.068064844823766s	52d18m10.478507191551255s
☐	Row 6 Col 1	12h5m44.47452984099755s	50d0m22.884758205256617s

In this screenshot, I copied the HTML file to Apple's iCloud, then opened it within the Files app on my iPad. Clicking one of the links brings up this dialog – clicking Open switches to the Unistellar app with that link.



Using the Unistellar Links

(Note: These screenshots are based on version 4.0.0 of the Unistellar app on iPhone.)

When you click the link and go to the Unistellar app, you'll see this screen (though likely with different coordinates):

Click Go(?) and wait for the telescope to slew to the location. You'll know it's done when the app displays this screen:

At this point, do NOT click Save. Instead, click the left arrow at the top left corner of the screen. That will take you to this screen:

From here, click the X at the top left corner to go to this screen:

Then click the Watch button, and you'll go to the normal observation screen for skywatching and photography. You can click the Enhanced Vision button () to begin taking the photo of this tile of the mosaic.

Ideas for Enhancements

Some of the things I'd like to add to this application (and please send me your ideas!). Note that some of them may not be possible without enhancements from Unistellar. Some also won't be possible with the current form of the application.

- Allow the user to pass parameters on the command line, eliminating user prompts for the supplied parameters.
- Account for observation time when calculating the tile centers, allowing for rotation and adjusting the tile centers to ensure proper overlap.
- Do a better job of dealing with the weirdness of spherical coordinates and the fact that a tile that is 45 arcminutes wide and 34 arcminutes tall may cover more than that area in terms of RA/Dec or Alt/Az depending on where the object is in the sky.

- Determine if the mosaic tiles will be visible at the specified date and time of observation.
- Expand the list of objects supported (e.g., how about planets!)
- Automatically slew to the target when clicking the link.
- Automatically trigger Enhanced Vision mode, rather than requiring the user to exit the science screen, go to the watch screen, then click the Enhanced Vision button.
- Tag the photos Unistellar produces with the mosaic information (what objects are in the mosaic), along with the row/column of the tile.
- Automatically feed the images to an image-stitching application (like Bimostitch).
- (Maybe) Automatically generate the mosaic within the app.