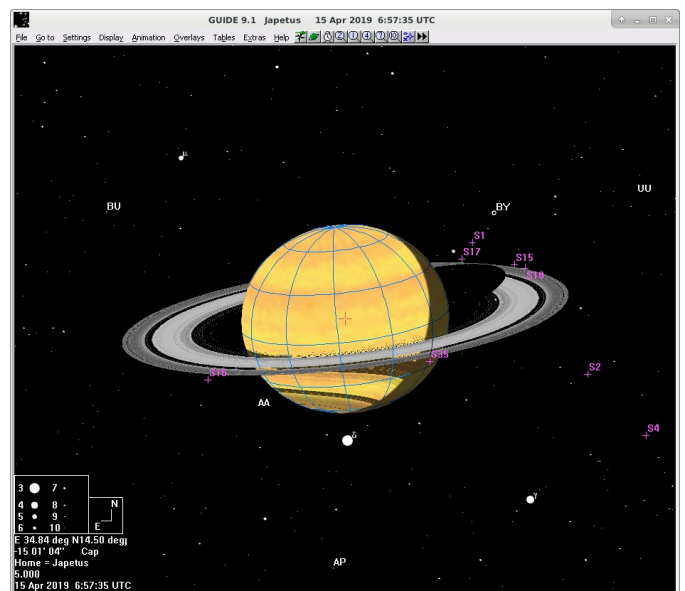
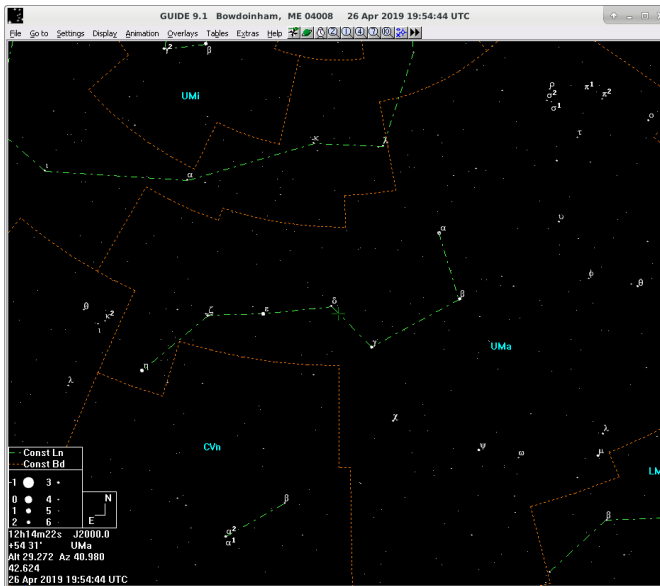


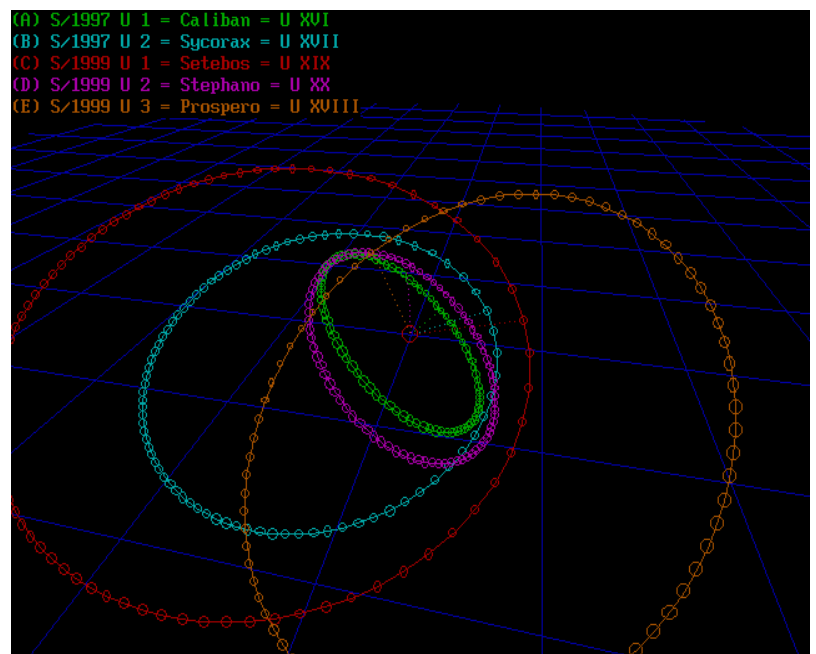
# Find\_Orb : software to determine orbits from observations

## Origin story :

- First version circa 1997, to read optical observation data and find an orbit
- Based on code written for desktop planetarium/star charting; this provided “basic astronomical functions”



- Intended for educational purposes, both of its users and its developer
- Interactive only, to force you to think about what you're doing
- Originally for asteroids and comets; quickly added irregular gas giant satellites, artificial satellites
- At the time, filled a near-void (publicly available software to determine orbits was rare to nonexistent)



## Evolution :

- Still some educational use, but increasing use by observers
- Switch to emphasis on being easy to use, possibly by very tired and busy observers; orbits should be (and increasingly are) found automatically
- Development proceeds on Windows GUI and Linux text-based versions...



**FIND\_ORB Orbit Determination Software**

Open... Perturbers:  Mercu  Mars  Urani  Venu  Jupite  Nepti  Earth  Satur  Pluto  Moor  Asteroids All Perturbers Off Epoch 2019 Apr 26

R1: 0.0553 AU R2: 0.0614 AU

Orbital elements: COGXN82  
 Perihelion 2019 Jan 27.568987 +/- 0.0765 TT = 13:39:20 (JD 2458511.068987)  
 Epoch 2019 Apr 26.0 TT = JDT 2458599.5 Earth MOID: 0.0268 Ve: 0.0721  
 M 142.24194188 +/- 0.07 Me: 0.0312 Gray  
 n 1.60850742 +/- 0.000611 Peri. 15.90263 +/- 0.015  
 a 0.72141860 +/- 0.000183 Node 32.04356 +/- 0.0014  
 e 0.5139557 +/- 0.000648 Incl. 13.58735 +/- 0.028  
 P 0.61/223.81d H 25.7 G 0.15 U 7.8  
 q 0.35064135 +/- 0.000556 Q 1.09219584 +/- 0.000196  
 From 30 observations 2019 Apr. 25-26 (24.9 hr); mean residual 0".308

YYMMDD	RA (J2000)	dec	sigmas	mag	ref Obs	Xres	Yres	delta	R
1904 25 15587	G96	12 11 49.38	-05 47 54.7	.67-	.42+				
1904 25 16155	G96	12 11 43.35	-05 48 14.3	.83-	.67-				
1904 25 16722	G96	12 11 37.43	-05 48 32.2	.46+	.13-				
1904 25 17289	G96	12 11 31.42	-05 48 50.6	.37+	.14-				
1904 25 24309	G96	12 10 17.48	-05 52 34.6	.29+	.17+				
1904 25 24431	G96	12 10 16.19	-05 52 38.5	.08+	.11+				
1904 25 24552	G96	12 10 14.92	-05 52 42.5	.01+	.08-				
1904 25 24674	G96	12 10 13.63	-05 52 46.2	.22-	.06+				
1904 25 29986	F51	12 09 25.704	-05 55 05.53	.13+	.06-				
1904 25 30051	F51	12 09 25.069	-05 55 07.36	.72+	.16+				
1904 25 31281	F51	12 09 12.269	-05 55 46.21	.11+	.04-				
1904 25 31345	F51	12 09 11.611	-05 55 48.09	.19+	.09+				
1904 25 318423	H01	12 08 59.20	-05 56 31.1	.02+	.10+				
1904 25 325348	H01	12 08 52.16	-05 56 52.3	.04-	.00				
1904 25 32572	F51	12 08 58.872	-05 56 26.56	.26-	.04-				
1904 25 32636	F51	12 08 58.236	-05 56 28.49	.13+	.03+				
1904 25 332491	H01	12 08 44.92	-05 57 14.0	.10-	.01+				
1904 25 33865	F51	12 08 45.503	-05 57 06.68	.29-	.04+				
1904 25 33928	F51	12 08 44.880	-05 57 08.64	.12+	.03+				
1904 25 341510	H01	12 08 35.83	-05 57 41.4	.09+	.07-				
1904 26 04320	807	11 58 11.05	-06 28 33.6	.30-	.03-				
1904 26 04802	807	11 58 06.75	-06 28 46.3	.34-	.17+				

Elong 149.5 Phase 28.9 RA vel -10.72"/hr decvel -2.17"/hr dT=1.46 sec  
 ang vel 10.94"/hr at PA 258.6 radial vel 9.890 km/s cross 0.02 1.6 days ago  
 Delta=.05626 r= 1.0548 mag=20.40 mag (computed)=20.64 2019 Apr 25 7:49:02.20  
 Sigma 0.50" NEOCP Obj alt 62.0 az 161.9 Sun alt -39.2 az 308.5 GAIA-DR1  
 Mag sigma 0.5; time sigma 1  
 Pan-STARRS 1, Haleakala (N20.707235 W156.255910) US/Hawaii  
 COGXN82 C2019 04 25 32572 12 08 58.872-05 56 26.56 ~4PG0 20.4 wUNEOCPF

**Terminal - Find\_Orb -- Orbit Determination**

```

R1: .05529 R2: .06137 help Full Herget epoch Vaisa resid Gauss constr New Quit Epoch all perts
(1)Mer (2)Ven (3)Ear (4)Mar (5)Jup (6)Sat (7)Ura (8)Nep (9)Plu (10)Moo (a)Ast
Elong 149.9 Phase 28.6 RA vel -10.83"/hr decvel -2.19"/hr dT=+.051 sec
ang vel 11.05"/hr at PA 258.6 radial vel 9.964 km/s cross -0.08 1.6 days ago
Delta=.05580 r= 1.0546 mag (computed)=20.34 2019 Apr 25 5:53:32.92
Sigma 0.50" NEOCP Obj alt 50.9 az 192.3 Sun alt -39.9 az 331.7 GAIA-DR2
time sigma 1 17:22:39
Orbital elements: COGXN82 Score: 0.551858
Perihelion 2019 Jan 27.568987 +/- 0.0765 TT = 13:39:20 (JD 2458511.068987)
Epoch 2019 Apr 26.0 TT = JDT 2458599.5 Earth MOID: 0.0268 Ve: 0.0721
M 142.24194172 +/- 0.07 Me: 0.0312 Gray
n 1.60850742 +/- 0.000611 Peri. 15.90263 +/- 0.015
a 0.72141860 +/- 0.000183 Node 32.04356 +/- 0.0014
e 0.5139557 +/- 0.000648 Incl. 13.58735 +/- 0.028
P 0.61/223.81d H 25.7 G 0.15 U 7.8
q 0.35064135 +/- 0.000556 Q 1.09219585 +/- 0.000196
From 30 observations 2019 Apr. 25-26 (24.9 hr); mean residual 0".308
YYYY MM DD.DDDDD RA (J2000) dec sigmas mag ref Obs Xres Yres delta R
* C2019 04 25.15587 12 11 49.38 -05 47 54.7 -4PDA 20.4 GVNEOCPG96 .673+ .416+ .05529 1.05
C2019 04 25.16155 12 11 43.35 -05 48 14.3 -4PDA VNEOCPG96 .828- .672- .05532 1.05
C2019 04 25.16722 12 11 37.43 -05 48 32.2 -4PDA 20.6 GVNEOCPG96 .464+ .135- .05536 1.05
C2019 04 25.17289 12 11 31.42 -05 48 50.6 -4PDA 20.4 GVNEOCPG96 .370+ .138- .05539 1.05
C2019 04 25.24309 12 10 17.48 -05 52 34.6 -4PDA 20.4 GVNEOCPG96 .291+ .171+ .05579 1.05
C2019 04 25.24431 12 10 16.19 -05 52 38.5 -4PDA VNEOCPG96 .080+ .113+ .05579 1.05
* C2019 04 25.24552 12 10 14.92 -05 52 42.5 -4PDA VNEOCPG96 6.4m+ .079- .05580 1.05
C2019 04 25.24674 12 10 13.63 -05 52 46.2 -4PDA VNEOCPG96 .216- .058+ .05581 1.05
* C2019 04 25.29986 12 09 25.704-05 55 05.53 -4PG0 20.6 wUNEOCPF51 .126+ .060- .05611 1.05
* C2019 04 25.30051 12 09 25.069-05 55 07.36 -4PG0 20.6 wUNEOCPF51 .719+ .159+ .05611 1.05
C2019 04 25.31281 12 09 12.269-05 55 46.21 -4PG0 20.7 wUNEOCPF51 .109+ .038- .05618 1.05
C2019 04 25.31345 12 09 11.611-05 55 48.09 -4PG0 20.7 wUNEOCPF51 .190+ .087+ .05619 1.05
C2019 04 25.318423 08 59.20 -05 56 31.1 -4PDA 20.1 GVNEOCPH01 .023+ .102+ .05623 1.05
C2019 04 25.325348 08 52.16 -05 56 52.3 -4PDA 21.8 GVNEOCPH01 .035- 816µ+ .05627 1.05
C2019 04 25.32572 12 08 58.872-05 56 26.56 -4PG0 20.4 wUNEOCPF51 .264- .035- .05626 1.05
C2019 04 25.32636 12 08 58.236-05 56 28.49 -4PG0 20.5 wUNEOCPF51 .128+ .029+ .05626 1.05
C2019 04 25.332491 08 44.92 -05 57 14.0 -4PDA 20.5 GVNEOCPH01 .101- 6.2m+ .05631 1.05
C2019 04 25.33865 12 08 45.503-05 57 06.68 -4PG0 20.6 wUNEOCPF51 .294- .036+ .05633 1.05
C2019 04 25.33928 12 08 44.880-05 57 08.64 -4PG0 20.6 wUNEOCPF51 .117+ .029+ .05633 1.05
C2019 04 25.341510 08 35.83 -05 57 41.4 -4PDA 20.2 GVNEOCPH01 .094+ .070- .05636 1.05
C2019 04 26.04320 11 58 11.05 -06 28 33.6 -4OCL 20.8 VuNEOCP807 .296- .031- .06046 1.05
C2019 04 26.04802 11 58 06.75 -06 28 46.3 -4OCL 20.7 VuNEOCP807 .336- .169+ .06048 1.05
C2019 04 26.05296 11 58 02.36 -06 28 59.5 -4OCL 20.6 VuNEOCP807 .145- .163+ .06051 1.05
C2019 04 26.16812 11 56 26.42 -06 36 27.1 -4OCL 21.1 GVNEOCP152 .221+ .017+ .06121 1.05
(734) Farpoint Observatory, Eskridge (N38.890107 W96.001400) US/Kansas
(807) Cerro Tololo Observatory, La Serena (S30.169136 W70.805900) Chile
(F51) Pan-STARRS 1, Haleakala (N20.707235 W156.255910) US/Hawaii
(G96) Mt. Lemmon Survey (N32.442754 W110.788720) US/Arizona
(H01) Magdalena Ridge Observatory, Socorro (N33.984833 W107.189333) US/New Mexico
(I52) Steward Observatory, Mt. Lemmon Station (N32.442547 W110.788920) US/Arizona
    
```

# On-line Find\_Orb

Updated 2018 June 16

Special note about A/2017 UI = 11 = 'Oumuamua = interstellar object

Use the form below to get orbital elements and ephemerides from astrometric observations.

Suggested quick start: **Don't panic!** Copy/paste your observations in the large text window below, and/or click on "Browse" to pick a file containing the astrometry, and/or enter an object name.

Feed it *all* of your observations. There is almost never any benefit in giving the program a subset.

Then click the "compute orbit and ephemerides" button. Usually, that'll be all you need to do. If it isn't, hit the back arrow and look a little more closely at your options ([options documented here.](#)) If you're still not getting things to work, [contact me.](#)

[Click here if you just want orbital elements and/or ephemerides for an object, and don't have astrometry for it.](#)

Here are [a few hints that may be useful.](#)

Note that the orbit will be computed from all observations, from all three possible sources (cut/pasted, uploaded, or from MPC data), whether their designations match or not. So you can mix-and-match the three input sources, if you have (for example) some new observations of an object already known to MPC.

This is a modified, simplified, non-interactive version of the [Find\\_Orb](#) program.

There are [several other tools for asteroid observers](#) on this site.

Cut/paste observations in the [80-column MPC format](#), [PSV or XML ADES](#), or the [AstDyS/NEODys .rse format](#) below. Don't worry about it if some other text is copied in as well; extra text will simply be disregarded.

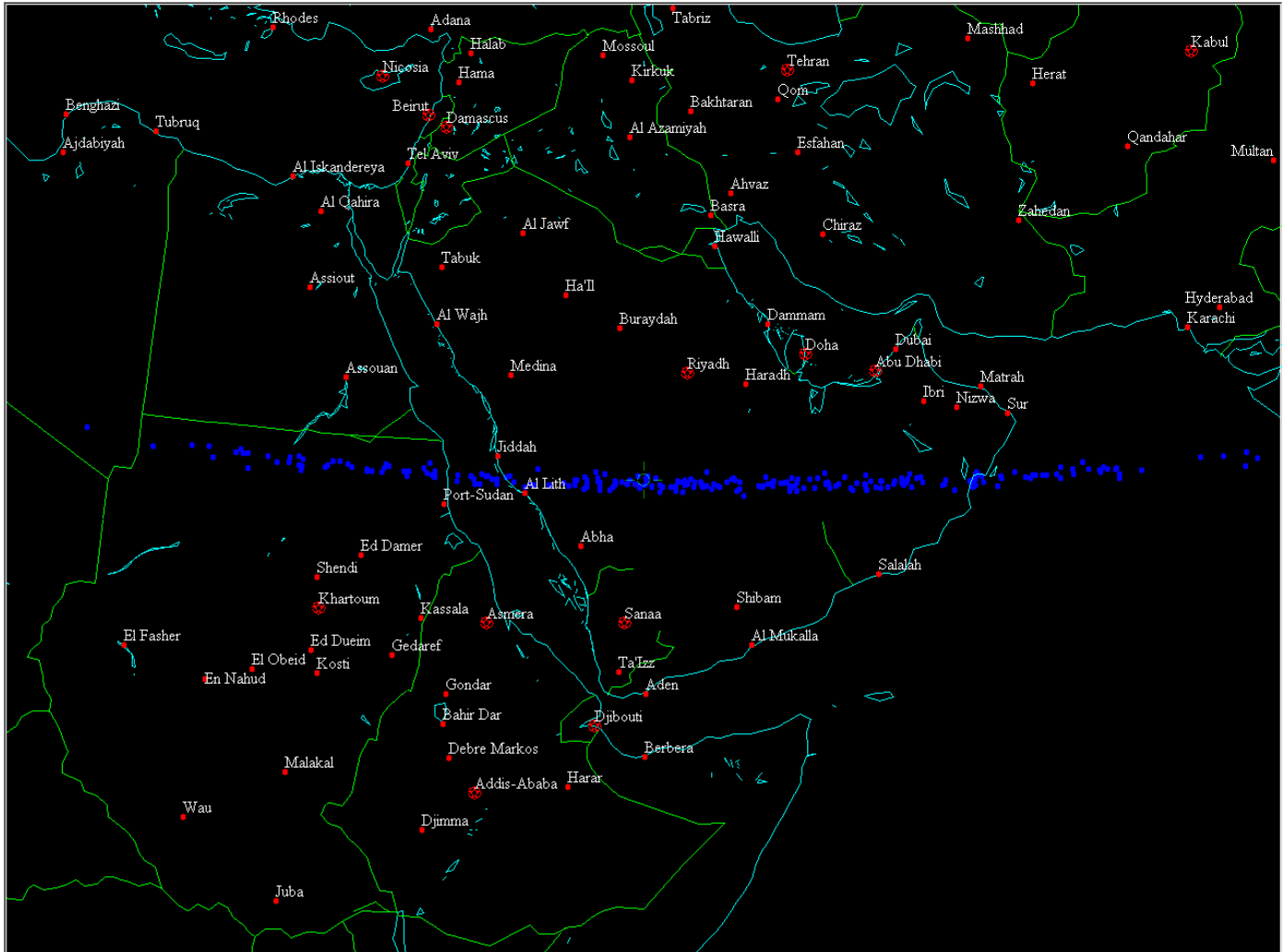
Paste astrometry here, and/or upload it using the 'browse' button below.

```
Terminal - phred@phred: /tmp/sftp
File Edit View Terminal Tabs Help
4: C0GXN82; a=0.722, q=0.351, e=0.514, i=14 H=25.7 MOID 0.027 39 obs; 2019 Apr. 25-27
5: C0H3G32; a=1.261, q=1.089, e=0.094, i=22 H=24.4 MOID 0.099 40 obs; 2019 Apr. 25-28
6: C0HRZ92; a=1.812, q=0.963, e=0.469, i=4 H=24.1 MOID 0.046 38 obs; 2019 Apr. 2-28
7: C0HWV82; a=1.586, q=1.019, e=0.358, i=3 H=27.0 MOID 0.016 18 obs; 2019 Apr. 26-28
8: C0HZP02; a=1.037, q=0.406, e=0.608, i=3 H=23.6 MOID 0.002 83 obs; 2019 Apr. 4-28
9: C0J1XX2; a=0.961, q=0.880, e=0.085, i=11 H=25.9 MOID 0.036 35 obs; 2019 Apr. 26-28 (47.1 hr)
10: C0J2QW2; a=1.536, q=0.842, e=0.452, i=10 H=25.6 MOID 0.040 26 obs; 2019 Apr. 25-28
11: C0J3W02; a=3.171, q=1.479, e=0.536, i=22 H=20.6 19 obs; 2019 Apr. 26-28 (47.5 hr)
12: C0J4AG2; a=1.669, q=0.913, e=0.453, i=2 H=29.0 MOID 0.003 8 obs; 2019 Apr. 26 (3.5 hr)
13: C0J4FK2; a=2.458, q=0.417, e=0.830, i=6 H=27.0 MOID 0.004 18 obs; 2019 Apr. 26-28 (47.5 hr)
14: C0J5502; a=2.564, q=1.030, e=0.598, i=27 H=22.0 MOID 0.224 27 obs; 2019 Apr. 26-28 (46.8 hr)
15: C0J55U2; a=2.280, q=1.365, e=0.402, i=6 H=23.4 MOID 0.357 14 obs; 2019 Apr. 26-28
16: C0JCM92; a=0.790, q=0.445, e=0.436, i=8 H=24.0 MOID 0.024 42 obs; 2019 Apr. 2-28
17: C0JDDW2; a=2.307, q=1.402, e=0.392, i=11 H=19.6 MOID 0.434 17 obs; 2019 Apr. 26-28 (47.6 hr)
18: C0JHKY2; a=2.308, q=1.577, e=0.317, i=8 H=18.6 16 obs; 2019 Apr. 27-28 (23.0 hr)
19: C0JJKQ2; a=1.401, q=0.585, e=0.583, i=26 H=22.3 MOID 0.004 35 obs; 2019 Apr. 27-28 (22.8 hr)
20: C0JKLW2; a=1.718, q=1.067, e=0.379, i=14 H=23.3 MOID 0.065 20 obs; 2019 Apr. 27-28 (22.2 hr)
21: C0JLX2; a=5.159, q=4.569, e=0.114, i=32 H=13.6 15 obs; 2019 Apr. 27-28 (21.8 hr)
22: C0JKP42; a=1.858, q=1.754, e=0.056, i=22 H=18.9 11 obs; 2019 Apr. 27-28 (22.1 hr)
23: C0JKPE2; a=1.832, q=1.797, e=0.019, i=23 H=18.0 15 obs; 2019 Apr. 27-28 (23.7 hr)
24: C0JKR52; a=1.362, q=1.052, e=0.228, i=10 H=25.8 MOID 0.049 19 obs; 2019 Apr. 27-28 (24.6 hr)
25: C0JKTJ2; a=1.575, q=0.966, e=0.386, i=6 H=25.1 MOID 0.059 18 obs; 2019 Apr. 27-28 (21.7 hr)
26: C0JKTF2; a=1.193, q=0.877, e=0.264, i=35 H=21.3 MOID 0.070 15 obs; 2019 Apr. 27-28 (23.2 hr)
27: C0JKTU2; a=2.402, q=3.691, e=0.737, i=132 H=15.1 17 obs; 2019 Apr. 27-28 (22.9 hr)
28: C0JNEH2; a=2.592, q=1.396, e=0.461, i=13 H=19.0 MOID 0.441 16 obs; 2019 Apr. 28 (3.5 hr)
29: C0JOSH2; a=1.850, q=1.651, e=0.107, i=23 H=19.4 7 obs; 2019 Apr. 28 (89.2 min)
30: JA0004; a=2.719, q=11.614, e=0.489, i=9 H=11.3 24 obs; 2019 Apr. 2-26
31: N09epty; a=1.061, q=0.695, e=0.345, i=38 H=19.6 MOID 0.056 15 obs; 2019 Apr. 16-27
32: N09epwh; a=1.844, q=0.990, i=105 H=15.4 55 obs; 2019 Apr. 9-28
33: P10N9GX; a=1.044, q=1.026, e=0.018, i=18 H=24.7 MOID 0.040 3 obs; 2019 Apr. 16 (27.3 min)
34: P10N9pn; a=3.194, q=2.778, e=0.130, i=28 H=16.0 10 obs; 2019 Apr. 16-28
35: P10NaaB; a=1.047, q=0.989, e=0.055, i=2 H=27.4 MOID 0.009 3 obs; 2019 Apr. 22 (22.8 min)
36: P10NcAa; a=1.124, q=1.060, e=0.057, i=1 H=27.0 MOID 0.049 5 obs; 2019 Apr. 24-25 (23.4 hr)
37: P10NcAb; a=3.151, q=1.405, e=0.554, i=5 H=21.8 MOID 0.405 12 obs; 2019 Apr. 24-28
38: P10NcAc; a=2.223, q=1.636, e=0.264, i=4 H=18.7 12 obs; 2019 Apr. 24-28
39: P10NcAd; a=2.284, q=1.407, e=0.384, i=4 H=20.4 MOID 0.392 7 obs; 2019 Apr. 24-27
40: P10NedV; a=2.312, q=0.743, e=0.679, i=8 H=22.3 MOID 0.036 6 obs; 2019 Apr. 24-28
41: P10Negk; a=2.455, q=1.247, e=0.492, i=3 H=23.1 MOID 0.240 22 obs; 2019 Apr. 7-27
42: P10Negn; a=1.810, q=1.644, e=0.092, i=25 H=20.6 13 obs; 2019 Apr. 9-27
```

and an on-line version (upload astrometry, get an orbit) and a non-interactive batch version. The software is used both to analyze astrometric data and to figure out where and when to look for objects (observational planning).

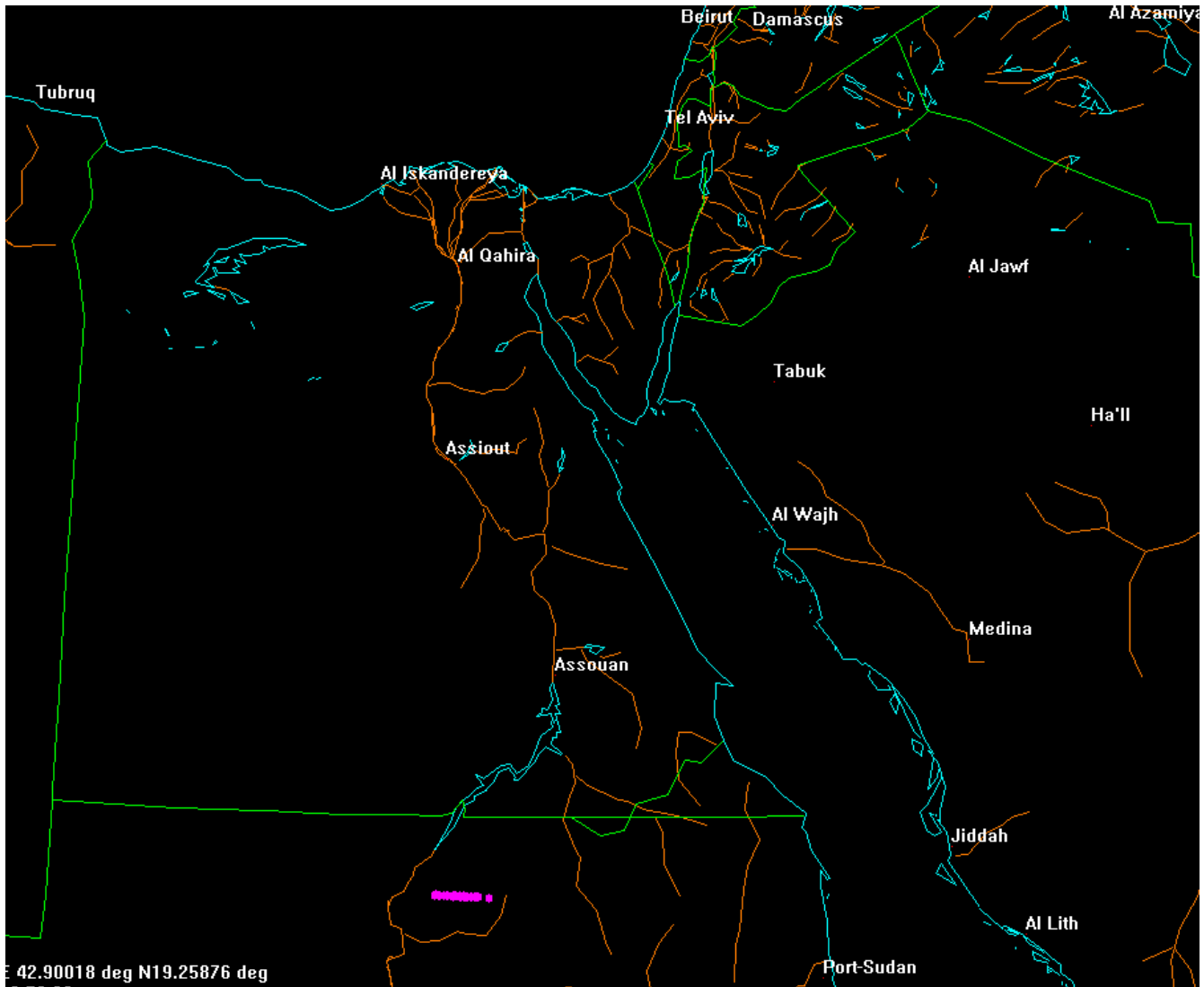
### First small impactor:

- 2008 TC3 is found by the Catalina Sky Survey on 2008 October 6, and enters the atmosphere over northern Sudan, 2008 October 7. Impact is predicted independently by MPC, JPL, me, and a Find\_Orb user in the UK (Peter Birtwhistle). Orbit determination and impact prediction capabilities are available to world + dog.



- Find\_Orb was not entirely ready for this event. After 2008 TC3 (sadly, not before), the ability to create plots of the possible impact area was added (such as the above, based on the initial data we had.)

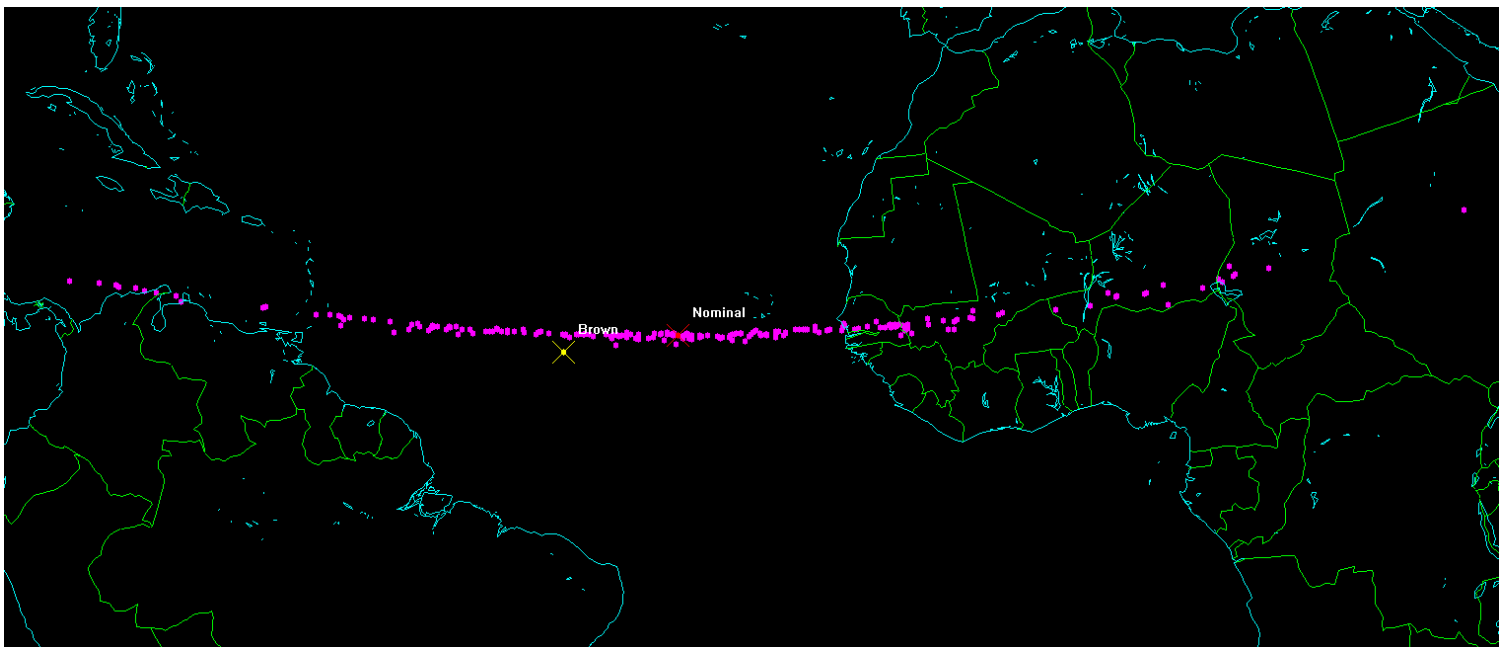
Fortunately, we did get further data from telescopes in Australia, and the impact region decreased a lot...



...and eventually, with further data, was a mere kilometer across.

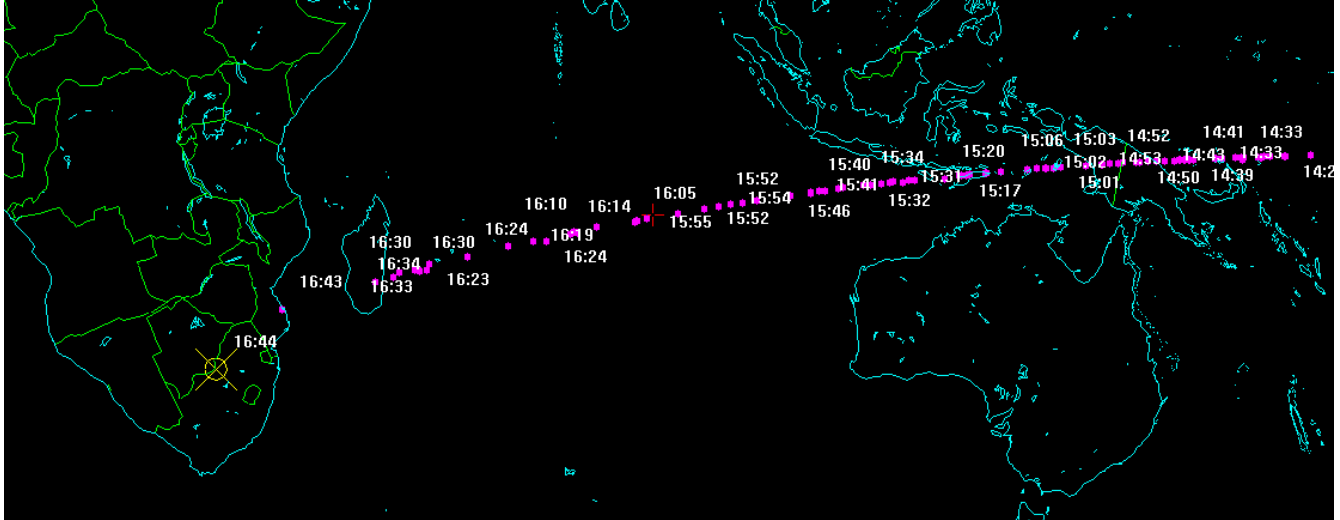
## 2014 AA: The second impactor

- 2014 Jan 1 : this object was (also) found by CSS, but wasn't recognized as an impactor until approximately the time it probably hit us, so we didn't get much astrometric data
- Just based on the data we did get, it could have hit anywhere from Africa to Central America. Infrasonic detection by the CTBT sensors narrowed it down to the point indicated with a yellow X.
- Object was overlooked partly due to data reporting limitations (no uncertainties given for the observations). This problem remains only partially fixed five years later.



### The third impactor : 2018 LA

- 2018 Jun 3: JPL's Scout system figured this one out first, almost immediately
- Catalina re-measured their observations, resulting in my generating the following map of possible impact locations :



- Object was observed entering atmosphere over Botswana (yellow circle-X)
- ATLAS submitted observations shortly after impact
- Getting follow-up data for such objects from ATLAS on a regular basis would be a game-changer