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NEW DEFINITION OF DISCOVERY FOR SOLAR SYSTEM OBJECTS AND DISCOVERY CREDIT RULES

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1 DEFINITIONS: ACTORS

Observer Either a person or a team claiming credit for submitting some astrometric data and accepting that they become public.

Orbit Computer Either a person or a team claiming credit for submitting the results of computations, containing orbit solutions, with uncertainty, and identifications.

IAU Data Center The organization (with a mandate from the IAU) receiving and immediately publishing, with submisison time stamp, the data submitted by both Observers and Orbit Computers. It can also act as Orbit Computer, assign Discovery Credit and build a statistical Observation Error Model.

Solar System Object (SSO) Includes natural bodies orbiting in the Solar System: asteroids, comets, transneptunian objects, [natural satellites should be included, but theory is different]. [Problem: major planets. What is the definition? Who handles their data?]

2 DEFINITIONS: DATA

Observation A set of data uniquely defining a position on the celestial sphere at a given time, e.g., time, two angles (R.A., DEC.) and possibly an apparent magnitude. Should always be provided with the metadata necessary to assess the accuracy.

Detection of a Moving Object (DMO) An Observation corresponding to a real moving object, which is a SSO. In real cases (as opposed to simulations) we do not know which Observations are *false*, that is belong to no real body, which belong to a fixed star and which are DMO.

Very Short Arc (VSA) A number of OBS, possibly with ancillary data, which can be interpreted as a sequence of observations of one and the same SSO. Note a VSA should be proposed by the Observer, before any attempt to fit an orbit, in good faith, that is having done the best possible effort to ensure that it can be *true*. This is the type of data to be submitted to the Data Center.

3 DEFINITIONS: COMPUTED QUANTITIES

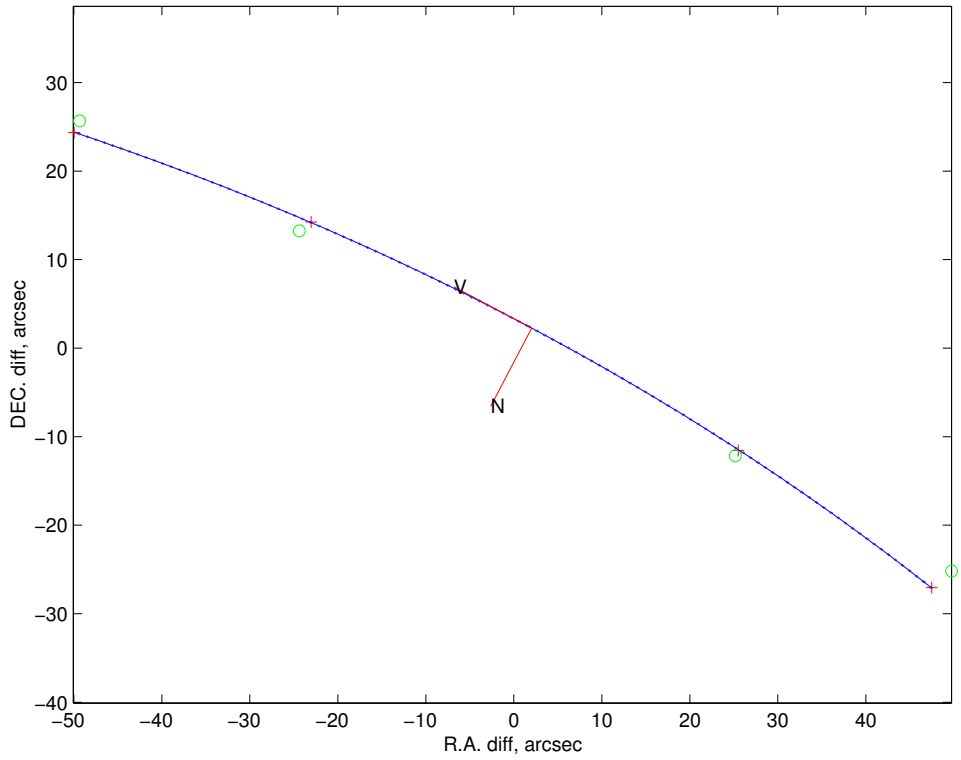
Orbit 6 orbital elements and an epoch time, uniquely defining an initial condition for the motion of a SSO. **Preliminary** Orbit if it fits the observations but is by no means determined by them, or **Least Squares** Orbit if it is obtained by a fit of the observations with 5 to 6 free parameters.

Identification (ID) A set of VSA, together with a Least Squares Orbit fitting all of them within the estimated accuracy of the observations.

Observed Arc (ARC) A set of observations, obtained by identifying a number of VSA, which can be interpreted as a sequence of DMO of one and the same SSO.

Curvature A measure of the deviation of the Observed Arc from a great circle, traced with uniform speed on the celestial sphere. The curvature is **Significant** if the deviations of the individual observations from a great circle cannot be due only to observational error (according to the Error Model).

4 DEFINITIONS: TOO SHORT ARC



Too Short Arc (TSA) An Observed Arc too short to compute a useful Least Squares Orbit. Most VSA are also TSA, because in modern surveys they are formed with OBS separated by a very short time, which does not allow for Significant Curvature.

Attributable (ATT) A mathematical object describing all the significant information contained in a TSA: a 4-dim vector (an arrow tangent to the celestial sphere) with a date and an optional apparent magnitude. A Least Squares Orbit cannot be computed from a TSA because there are essentially 4 constraints and either 5 or 6 free parameters.

5 DEFINITIONS: ARC TYPE, DISCOVERY

Arc of Type N An Observed Arc which can be split into exactly N disjoint TSA in such a way that each couple of TSA consecutive in time, if joined, would show a significant curvature. This definition is meant to replace the currently used definition of *N-nighter*, an observed arc containing observations belonging to exactly N distinct nights.

Discovery A set of observations of a SSO, forming an Observed Arc of Type N with $N \geq 3$; there must be a unique full least squares orbit fitting the data with residuals compatible with the Error Model; the object needs to be a New SSO. It is also required that the data contain enough photometric information to fit an absolute magnitude. The Observations forming the ARC have to have been submitted to the Data Center, either at once or at different times (by one or more Observers); the Orbit, and the critical Identification (allowing a Type 3 Arc to be built) must have been either submitted to the Data Center by Orbit Computers or computed by the Data Center itself.

Discovery of a comet A Discovery as above, complemented with enough observational data to prove that there is a directly detectable cometary activity.

6.1 NUMERICAL TEST ON MPC DATA I

Using the November 2005 data update. In this test, the critical value of curvature is set at $\chi^2 = 1$, of "Z-sign" at 3 (third derivative effect).

Arc Typ	Good orb curvature	Good orb no curv	Bad orb no curv	Bad orb curvature	Total
1	0	12	17,675	11	17,698
2	3,927	232	61,987	6,460	72,606
3	14,961	127	2,853	4,542	22,483
4	13,076	46	304	784	14,210
5	10,289	14	25	110	10,438
6	7,885	3	2	20	7,910
> 6	23,398	1	0	10	23,409

In the Table, No curvature means $\chi^2 < 100$.

67% of Type 3 have a "good" orbit, meaning $RMS(q) < 0.1$ AU, $RMS(e) < 0.1$.

6.2 NUMERICAL TEST ON MPC DATA II

Using the March 2006 data update. In this test, the critical value of curvature is set at $\chi^2 = 9$, of "Z-sign" at 4.

Arc Typ	Good orb curvature	Good orb no curv	Bad orb no curv	Bad orb curvature	Total
1	0	87	56,114	12	56,213
2	14,117	319	36,781	11,124	62,341
3	17,916	53	126	1,443	19,538
4	14,646	7	5	72	14,730
5	10,630	0	0	7	10,637
6	7,321	0	0	0	7,321
>6	15,141	0	0	5	15,146

93% of Type 3 have a "good" orbit, meaning $RMS(q) <$ 0.1 AU, $RMS(e) < 0.1$.

In the Table, No curvature means $\chi^2 < 100$.

6.3 NUMERICAL TESTS: TYPE-NIGHTS

Arc Types (columns) and number of nights with observations (rows)for the test with $\chi^2 = 1$, $RMS_{min} = 3$.

Nts	Type 1	Type 2	Type 3	Type 4	Type>4	Total
1	3120	52	4	2	4	3182
2	14554	66088	3260	376	81	84359
3	20	6088	14610	1689	448	22855
4	4	373	4183	8888	1951	15399
>4	0	5	426	3255	39273	42959
Tot	17698	72606	22483	14210	41757	168754

Arc Types (columns) and number of nights with observations (rows) for the test with $\chi^2 = 9$, $RMS_{min} = 4$.

Nts	Type 1	Type 2	Type 3	Type 4	Type>4	Total
1	3482	20	5	3	3	3513
2	52599	41809	173	30	30	94641
3	123	17394	5593	125	117	23353
4	9	3082	9531	3065	250	15937
>4	0	36	250	11507	32704	48493
Tot	56213	62341	19538	14730	33104	185926

7 DISCOVERY CREDIT RULES I

Discovery credit is assigned to everybody involved in the discovery: in many cases the credit has to be shared. **Priority** is attributed for a predominant contribution.

1. If a single Observer provides enough data for a Discovery, with a clear indication that these data belong to a single SSO, this implies full Discovery Credit.

2. If a single Observer provides enough data for a Discovery, without indication that they belong to the same SSO, the Discovery Credit is shared with the Orbit Computer submitting the Identification, the Observer has Priority.

3. If different Observers have contributed to the data for a Discovery, Credit is shared among them and among the Orbit Computer(s) performing the Identification(s).

4. The Discovery procedure is closed at the time in which enough data and computations have been submitted.

5. If one of the Observers has supplied data forming an Arc of Type ≥ 2, clearly indicating that these data belong to the same SSO, then he/she has Priority.

7 DISCOVERY CREDIT RULES I

6. If the data come from different Observers and all the Observers have supplied Arcs of Type 1, the Orbit Computer providing the Identification has Priority.

7. If some computations are performed by the Data Center, it can get the corresponding credit by using the date of publication in place of the date of submission.

8. Nobody can have credit for data and/or computations which were not public at the time.

9. If an object can be considered Discovered at the time the observations proving its cometary nature are submitted, the Observers supplying the astrometry and Orbit Computers share the Credit for Comet Discovery with the Observer(s) supplying the proof of cometary nature.

10. If the Observed Arc of an object is insufficient to form a Discovery at the time the cometary nature is established, the Observer submitting the proof of cometary nature can get Credit for Comet Discovery only if and when the Observed Arc becomes of Type at least 3.

8 NAMING RIGHTS RULES

Naming Right If there is one actor having either full Discovery Credit or Priority, he/she has the right to propose a name for the object discovered. The IAU Small Bodies Naming Committee (SBNC) will generally accept this name, unless it violates some of the IAU naming rules. If no one has Priority, the discoverers share the Naming Right, and they can propose a name by agreement; in case of disagreement the SBNC will decide.

Naming Right for Comets If and when there is enough evidence that a discovered SSO is a Comet, the comet name is composed by combining the names of the actor having Priority for the Discovery, and the name of the Observer having Credit for the Comet Discovery, the *[latter/former]* listed first.

9 THE IMMEDIATE FUTURE

What is going to happen in practice with the next generation full sky surveys? The following is a citation from *A PROPOSED DATA EXCHANGE STANDARD FOR PAN-STARRS*, by A. Milani, L. Denneau, F. Pierfederici and R. Jedicke, 25/7/2006:

The Pan-STARRS MOPS export data products shall be of the following categories:

1) DISCOVERY 2) PRIORITY 3) ATTRIB_KNOWN 4) ID_CORRECTION 5) UNIDENTIFIED

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4.1 Discovery claims

Discovery Claims: a DataBase (DB) of identifications, normalized in the most strict sense (neither discordancies nor alternative orbit solutions are allowed; nominal least squares orbits only), each one qualifying as a Discovery, that is Arcs of Type > 2; in practice, ids with at least 3 tracklets at opposition and at least 4 at the sweet spots.

However, whatever discovery definition and set of credit rules the IAU will adopt **before** the beginning of operations of Pan-STARRS shall be used, provided A) it allows the surveys to compute their own scientific results, such as discoveries, not just to be supplier of data B) it is an algorithm, implemeyable in fully automated software.