The Relationship between Masers and Active Galactic Nuclei studied using Optical and X-Ray Telescope Data

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Abstract

[very rough filler] wanted to compare masers and AGN to learn about how they are related and what masers can tell us about AGN, distance, SMBH etc. used optical and x-ray data. crossmatched the list of maser detections and control group with various surveys and looked at numbers. concluded this and that.

1 Introduction

[very rough filler] hard to figure out with current understanding masers can tell us about what's happening far away and how far etc. so we look at galaxies with masers compared to those without and various spectroscopic data to understand more deeply what the masers are telling us and then we can learn about what's happening, how old, how far, etc.

Outline Section **??** discusses methods. Section **??** shows results. Section **??** concludes.

2 Methods

Crossmatch maser list and maser control of surveyed non-masers with X-Ray and Optical telescope survey data to learn more about what masers can tell us about AGN.

2.1 Building a Maser Control Sample

The Megamaser Cosmology Project has provided a list of all 4,464 (as of the spring of 2013) surveyed galaxies[1]. This list includes all galaxies surveyed; as such it includes many duplicates as well as most of the masers. In order to effectively gather statistical data it was necessary to establish an appropriate control group, requiring removal of any duplicates as

well as all detected masers.

The first steps taken were to filter out all duplicates and then to crossmatch with the maser list in order to identify and then remove all maser detections. The raw data text file was converted into the appropriate format and duplicates were removed by name using code in the command-line programming language AWK. Below is the code used to result in 3,617 results:

Code 1: Duplicate Name Removal (AWK)

```
BEGIN {OFS=","}
$1 ~ /Source/{print "name,ra,dec,velo"}
$1 !~ /Source/{
   gsub("C-","C")
   if ($1 != A){
      RA = ($2 + ($3 / 60) + ($4 / 3600))*15
      if ($5 > 0 || $5 == "+00"){
         DEC = $5 + ($6 / 60) + ($7 / 3600)
      }
      if ($5 < 0 || $5 == "-00"){
         DEC = $5 - ($6 / 60) - ($7 / 3600)
      }
      print $1,RA,DEC,$8
   }
 A = $1
 }
```

After this, duplicates were removed using another AWK code which removed duplicates according to position. The list was already sorted by right ascension, so declination values of consecutive rows were compared and if they were within ten arc seconds, only the first would be printed. The following code reduced the results to 3,485 results:

Code 2: Positional Duplicate Removal (AWK)

```
BEGIN {OFS=","}
$1 ~ /Source/{print "name,ra,dec,velo"}
$1 !~ /Source/{
   gsub("C-","C")
   if ($1 != A){
      RA = ($2 + ($3 / 60) + ($4 / 3600))*15
      if ($5 > 0 || $5 == "+00"){
         DEC = $5 + ($6 / 60) + ($7 / 3600)
      }
      if ($5 < 0 || $5 == "-00"){
         DEC = $5 - ($6 / 60) - ($7 / 3600)
      }
```

```
        if (D - DEC > 0.00277 || D - DEC < -0.00277){
           print $1,RA,DEC,$8
        }
     }
     A = $1
     D = DEC
  }
```

An SQL query then crossmatched this result with the list of all maser detections. Anything with either the same name or within 10" was considered a valid result:

Code 3: Positional Crossmatch (SQL)

```
select
   c.name, c.ra, c.dec, c.velo, m.name
from
   maserlist2012 m, mctrl c
where
   m.name = c.name OR ((m.ra-c.ra)*cos(m.dec))*((m.ra-c.ra)...
   *cos(m.dec)) + (c.dec-m.dec)*(c.dec-m.dec) < 0.000008
```

The result of this crossmatch was only 128, as opposed to the size of the maser list, which was 151. Presumably, the all-surveyed results should include each of the 151 masers. Further steps had to be taken to investigate this issue later on. The only way to increase the results to 151 masers was by an increase in radius to 36". Of the new 23 results, some were not actual matches but different galaxies entirely, so a preliminary assumption was made that some of the maser list has not been included in the "all-surveyed" list, as the radius should have accommodated for error in coordinates; rather it began including other galaxies instead. The 128 results were filtered from the list of 3,485 unique objects using the following AWK code to yield 3,357:

Code 4: Filter (SQL)

```
select
   c.name, c.ra, c.dec, c.velo
from
   mctrl c
where
   c.name NOT IN (Select name FROM allposname)
```

This was then crossmatched using Code 3 manipulated to look in the SDSS DR9 spectroscopy table SpecObjAll. A total of 2,181 matches were found.

At this point further steps were still required to confirm a more precise filtering of maser detections from the all-surveyed sample. In order to accomplish this, the prior steps were done in reverse order to ensure a comprehensive view comparing the maser list with the

entire all-surveyed sample.

The first step was to return to the long list of 4,485 all-surveyed and crossmatch it to the maser list using Code 3. 782 results were found at 10". This was repeated at 6' to acquire a new sample that would more than accommodate for any reasonable error in coordinates. 807 results were found given this very large radius. The 25 additional results were each individually interpreted by hand. Various internet resources were used such as the SDSS Navigator[**?**] in order to confirm whether or not each object was a maser detection, a unique non-detection, or a duplicate. Table 1 displays this information:

Table 1: Radii Gap Margin

Name	RA	DEC	Velo	Treatment
*005420-233309	13.5854	-23.5525	9680	Keep, unique from NGC235A
0437170	69.3208	66.62833	770	Exclude, J0437+6637 duplicate
0508212	77.0883	17.3689	5049	Ambiguous so exclude because 19.9"¿10"
0719308+5921184	109.879	59.3551	3258	Exclude, UGC3789 duplicate
*091958+264455	139.992	26.7485	7898	Keep, unique from IC485
*120210+351355	180.543	35.2319	10077	Keep, Unique from J1202+3519
*2MASXJ11092911+2841293	167.371	28.6914	9847	Keep, Unique from J1103-0052
*IC486	120.088	26.6135	8062	Keep, unique from IC485
IC694	172.072	58.5507	3064	Exclude, they are arp299
NGC3690A	172.081	58.5371	3064	Exclude, they are arp299
NGC3690B	172.102	58.534	3064	Exclude, they are arp299
NGC4151half	182.598	39.3804	995	Exclude, NGC4151 dupe see 995
*NGC4156	182.707	39.4728	6755	Keep, unique from NGC4151
NGC4258N	184.733	47.3082	466	Exclude, NGC4258 duplicates
NGC4258NN	184.731	47.3109	466	Exclude, NGC4258 duplicates
NGC4258NNN	184.731	47.3137	466	Exclude, NGC4258 duplicates
NGC4922B	195.316	29.3061	7056	Exclude, NGC4922/130125+291849 dupe (see velo in masers)
NGC520a	21.1437	3.79497	2266	Exclude, 520 duplicates
NGC520b	21.145	3.78969	2266	Exclude, 520 duplicates
NGC520m1	21.1451	3.78408	2266	Exclude, 520 duplicates
NGC520m2	21.145	3.79525	2266	Exclude, 520 duplicates
NGC520m3	21.1395	3.78972	2266	Exclude, 520 duplicates
NGC520m4	21.1505	3.78975	2266	Exclude, 520 duplicates
*NGC5256A	204.587	48.242	8211	Keep, unique from NGC5256
*notMrk78	115.674	65.1436	11137	Keep, unique from Mrk78

The marked galaxies* were determined to be unique from the maser list. Those 8 galaxies were kept in the control by removing them from the list of 807 used for filtering. The unmarked galaxies were determined to be maser matches and were left in the filter list. The remaining filter filter list contained 799 objects. It turns out that these 799 represented 120 of the maser detections from the maser list. It was later discovered that the 128 found earlier did include some duplicates, and actually represented 119 maser detections.

This inclusion of new items to the filter list may help remove a few maser detections that could have been missed by the previous filter because of coordinates imprecise to some degree between 10" and 6'. Additionally, one new maser detection was completely unaccounted for. As such, it became necessary to filter these 799 results again from the all-surveyed list and then remove all duplicates from that list using slight variations of Codes 3, 1, and 2 in that order. The resulting maser control list, confirmed to have excluded all maser detections and duplicates within 10", contained 3,342 unique galaxies.

2.2 Relating Maser Detections and Control to SDSS DR9 Data

Now that both a maser control sample and a maser detection sample were both available, data analysis could begin. The Sloan Digital Sky Survey (SDSS) has an vast collection of optical spectroscopic and photometric data collected from a 2.5 meter telescope in New Mexico at Apache Point University[**?**].

Not all of the surveyed galaxies are necessarily in the SDSS data releases, and they must be identified by position in order to retrieve their associated data, so the maser detection and maser control lists were crossmatched by a radial position of 10" using Code 3 adjusted to the appropriate data tables within Data Release 9 (DR9) within SDSS. When crossmatched against SpecObjAll, 47 matches were found from the list of 151 maser detections, and 2,181 matches were found from the list of 3,342 maser control galaxies.

photometric results...

3 Results

4 Conclusions

References

[1] *MCP All-Surveyed List*. 2013.

`http://www.gb.nrao.edu/~jbraatz/H2O/sum_dir_sort.txt`

[2] *SDSS Navigator*. 2013.

`http://skyserver.sdss3.org/public/en/tools/chart/navi.asp`

[3] *Sloan Digital Sky Survey*. 2013.

`http://www.sdss.org/`