# Comparison of TV Magnitudes and Visual Magnitudes of Meteors

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The generally accepted belief is that a meteor, with a large amount of infrared rays, can be captured brighter than it actually is by infrared-sensitive image intensifiers (I.I.) or CCD. We conducted observations of meteors using three methodologies: 1) I.I. attached with a filter that has visual magnitude equivalent to human eye spectrum sensitivity at night vision, 2) I.I. without the filter and 3) visually to determine meteor magnitudes. A total of 31 members of the astronomical club at Meiji University observed 50 meteors in Perseids, 19 meteors in Geminids as well as 44 sporadic meteors and the results were tabulated. The results helped us understand that on average I.I. can capture meteors brighter than visual observation by the magnitude equivalent of 0.5 for Perseids, 1.0 for Geminids and 0.5 for sporadic meteors.

For I.I. with a filter that has equivalent spectrum magnitude with the human eye at night vision, it turned out that we could obtain almost the same magnitude with observation by the human eye.

We learned that a bright meteor with negative magnitude can be observed by I.I. brighter than the human eye. From several examples, we found I.I. could capture a meteor with about -1 visual magnitude brighter by about three magnitudes. We could probably do so because a bright meteor with negative magnitude may contain more infrared rays and the brightness could be amplified.

## 1 Introduction

Magnitudes are important yardsticks to express the mass of meteoric materials and conventionally visual magnitude or photographic magnitude have been used as the index (Opic, 1958; Verniani, 1967). Since a meteor contains more infrared rays (Borovicka et al., 1999), the generally accepted belief is that meteors can look brighter when photographed by new observation instruments such as I.I. or CCD with more sensitivity to infrared rays. By obtaining precisely the difference between conventional and new magnitudes of the same meteors, we are able to compare the conventional and new observation in a correct manner. However, it appears that this comparison has not yet been implemented in a full scale. We would like to report the results of the comparison of I.I. and visual observations.

## 2 Comparison between TV Magnitudes and Visual Magnitudes

Shigeno and Toda conducted a series of observations to determine meteor magnitudes by both I.I. and visual observations: one time in April and two times in August 2004. During the observations, we found a total of 21 meteors; for each meteor, its TV magnitudes were brighter than visual magnitude by 0.2 to 2.6 magnitude or 1.2 magnitude on average. It will be attributed to I.I. that is also sensitive to infrared rays and capture brighter image of meteors as they contain more infrared rays.

We studied between TV magnitudes and visual magnitudes (Mtv-Mv) could be changed or not by other factors. Figure 1 shows the relation between visual magnitude (Mv), angular velocity (Va) and velocity of observation (VO) where the trend is not clear yet (Shigeno and Toda, 2005).

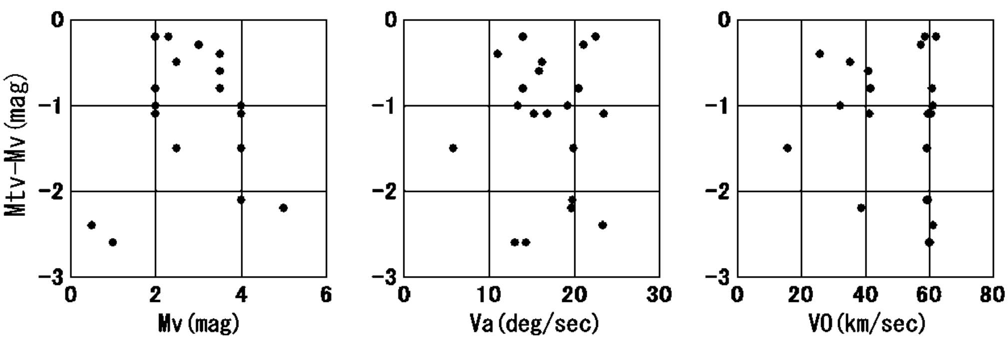


*Figure 1* - Comparison between deviation(TV magnitude - Visual magnitude)(Mtv-Mv) and Visual magnitude(Mv), Angular velocity(Va), Observed velocity(VO).

## 3 Observation by I.I. with Filter for Spectrum Magnitude Equivalent of Visual Magnitude

The above observation method cannot determine the correct visual magnitude. We, therefore, observed to determine meteor magnitudes by three other methods: 1) I.I. with a filter that has the same amount of spectrum magnitude with visual magnitude at night vision (MtvF), 2) I.I. without the filter (Mtv) and 3) visually. Magnitudes of TV meteors were obtained from the relations between brightness, size and magnitudes of fixed stars and corrected by angular velocity. A total of 31 members of Meiji University's astronomical club observed 50 meteors in Perseids, from August 11 to August 13, 2007, 19 meteors in Geminids on December 14 of the same year and 44 sporadic meteors. The results are shown in Table 1 as tabulations by observers for comparison of magnitudes by I.I. and visual observation.

### 3.1 Comparison of Mtv with MtvF

As shown by the upper column titled "Mtv-MtvF" of Table 1, we obtained the following data: -0.5 magnitude for Perseids, -1.0 magnitude for Geminids and -0.5 magnitude for sporadic meteors. These results suggest that without filter observation shows brighter than the observation with filter by 0.5 to 1.0 magnitude. In the table, SD indicates the dispersion of data as standard deviation and the results ranged from +/-0.6 to 0.7 magnitude, meaning they were the variation of data but not errors in the average values.

### 3.2 Comparison of Mv with MtvF

The middle column of Table 1 shows the tabulated results by observers. Negative values mean that the observers had estimated brighter than actual while positive values mean they had estimated darker. We learned that some observers had estimated brighter by almost one magnitude while others had estimated darker. However, from the total results of all the observers, i.e., "All Visual Observation Data" in the bottom column of Table 1, it turned out that the difference between the average of Mv and the average of MtvF was somewhere between 0.0 to 0.2 magnitude and the difference was minimal. That means MtvF in this report was almost meant to be Mv. However, we also learned data variation by the observers was rather large at +/-0.8 to 0.9 magnitude.

### 3.3 A bright meteor with negative magnitude

A bright meteor with negative magnitude can be caught by I.I. brighter than visual observation. Figure 2 is a list of typical examples of meteors with negative magnitudes. They are classified as approximately -1 magnitude by visual observation whereas 1) MtvF are brighter by approximately 1 magnitude and 2) Mtv are further brighter by approximately 2 magnitudes.

We assume the reason for the above item 1 is due to the fact that the magnitude by TV observation is to determine the brightest spot instantaneously while visual observation determines averaged magnitude. Therefore, as a brighter meteor may likely generate more light instantaneously, TV observation may estimate the magnitude brighter than visual observation.

For the reason noted in item 2, we assume that brighter meteors with negative magnitude may be caught brighter as they may contain a large amount of infrared rays.

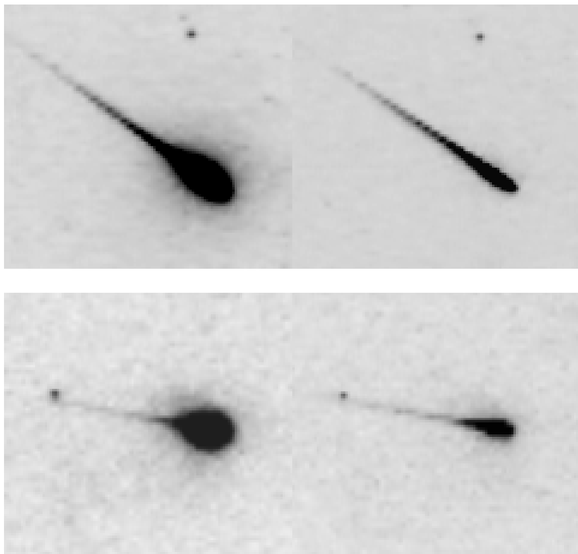

*Figure 2* - Bright meteors with negative magnitude.
Upper photo. : No.P40 Aug.12,2007 17:07:50(UT) Per.
Upper left : Mtv = -4.0mag.
Upper right : MtvF = -1.7mag.
Mv = -0.5mag.

Lower photo. : No.G05 Dec.14,2007 13:42:39(UT) Gem.
Lower left : Mtv = -4.8mag.
Lower right : MtvF = -2.2mag.
Mv = -1.4mag.

Filter : SCHOTT BG18 2mm (Filter that has equivalent spectrum magnitude with the human eye at night vision (400nm-600nm).)
Spectrum sensitivity of I.I. : 350nm-900nm.

*Table 1* - Tabulations by observers for comparison of magnitudes by I.I. and visual observation.
Mtv-MtvF : Comparison of magnitudes by without a filter(Mtv) and with a filter(MtvF).
Mv-MtvF : Comparison of magnitudes by Visual magnitude(Mv) and with a filter(MtvF).

| Perseids | | | | Geminids | | | | Sporadic | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Observer | No. | Mean | SD | Observer | No. | Mean | SD | Observer | No. | Mean | SD |
| Mtv−MtvF | 50 | −0.5 | 0.7 | Mtv−MtvF | 19 | −1.0 | 0.6 | Mtv−MtvF | 44 | −0.5 | 0.6 |
| Mv−MtvF | | | | Mv−MtvF | | | | Mv−MtvF | | | |
| Hosogi | 2 | −1.4 | 0.4 | Sato | 3 | −0.9 | 1.2 | Sakaguchi | 1 | −1.4 | 0.0 |
| Yamashita | 2 | −0.9 | 0.3 | Hirota | 2 | −0.7 | 0.6 | Saito.Y | 3 | −1.1 | 0.4 |
| Katabami | 2 | −0.7 | 0.1 | Oshima | 3 | −0.5 | 1.6 | Saito.S | 1 | −1.1 | 0.0 |
| Kitagawa | 1 | −0.5 | 0.0 | Arai | 1 | −0.4 | 0.0 | Katabami | 2 | −1.0 | 0.5 |
| Okuyama | 3 | −0.3 | 0.9 | Kanaya | 4 | −0.3 | 0.7 | Yamada | 2 | −0.6 | 0.8 |
| Sakaguchi | 2 | −0.3 | 0.7 | Yamashita | 2 | −0.2 | 0.3 | Iino | 2 | −0.6 | 1.3 |
| Shinsha | 2 | −0.3 | 0.4 | Ogawa.H | 2 | −0.2 | 0.3 | Sato | 8 | −0.5 | 0.9 |
| Kinoshita | 13 | −0.3 | 0.7 | Yuriya | 2 | −0.2 | 1.0 | Okuyama | 2 | −0.4 | 0.1 |
| Yuriya | 18 | −0.3 | 0.6 | Matsuzaki | 1 | 0.0 | 0.0 | Kitamura | 5 | −0.4 | 0.5 |
| Sato | 9 | −0.2 | 0.6 | Kinoshita | 6 | 0.0 | 0.9 | Kanaya | 12 | −0.3 | 0.7 |
| Wakasa | 10 | −0.2 | 0.6 | Wakasa | 4 | 0.2 | 1.1 | Kinoshita | 9 | −0.2 | 1.0 |
| Ogawa.Y | 21 | −0.2 | 0.8 | Ogawa.Y | 9 | 0.3 | 0.8 | Kato.T | 7 | −0.1 | 0.7 |
| Matsuzaki | 3 | −0.2 | 1.4 | Shigeno | 3 | 0.5 | 0.6 | Ogawa.Y | 15 | −0.1 | 0.9 |
| Doi | 3 | −0.2 | 0.3 | Matsuda | 5 | 0.5 | 0.7 | Matsuda | 4 | −0.1 | 0.7 |
| Kanaya | 7 | −0.1 | 0.7 | Kitamura | 5 | 0.7 | 0.9 | Oshima | 7 | −0.1 | 0.7 |
| Saito.Y | 3 | −0.1 | 0.5 | Yamada | 2 | 0.8 | 0.8 | Yuriya | 21 | −0.1 | 0.5 |
| Noto | 4 | −0.1 | 1.7 | Saito.Y | 3 | 1.7 | 0.7 | Matsuzaki | 4 | 0.0 | 0.5 |
| Arai | 20 | 0.0 | 0.8 | | | | | Arai | 11 | 0.1 | 0.6 |
| Iino | 8 | 0.0 | 1.0 | | | | | Wakasa | 9 | 0.1 | 0.6 |
| Kato.T | 2 | 0.1 | 1.0 | | | | | Yamashita | 3 | 0.2 | 0.3 |
| Oshima | 8 | 0.1 | 0.7 | | | | | Doi | 3 | 0.3 | 0.6 |
| Kato.S | 2 | 0.2 | 0.9 | | | | | Kurosaki | 4 | 0.4 | 0.4 |
| Kurosaki | 3 | 0.5 | 0.4 | | | | | Toda | 9 | 0.5 | 0.9 |
| Hirota | 3 | 0.6 | 1.0 | | | | | Kato.S | 1 | 0.6 | 0.0 |
| Toda | 13 | 0.7 | 1.1 | | | | | Hirota | 2 | 0.6 | 0.2 |
| Shigeno | 17 | 1.0 | 0.7 | | | | | Hosogi | 2 | 0.9 | 0.8 |
| Kitamura | 2 | 1.2 | 0.3 | | | | | Shigeno | 17 | 0.9 | 0.6 |
| | | | | | | | | Kitagawa | 1 | 1.6 | 0.0 |
| All Visual | 183 | 0.0 | 0.9 | All Visual | 57 | 0.2 | 0.9 | All Visual | 167 | 0.0 | 0.8 |

## 4 Conclusion

Previous infrared spectrum observation of Perseids had discovered several molecular bands such as 630-670nm and 730-780nm nitrogen molecular bands as well as many kinds of atomic luminescent lines such as 777nm oxygen atomic luminescent lines (Ebizuka, N., personal communication). We learned that these infrared rays make meteors look brighter by 0.5 to 1.0 magnitude; especially meteors of negative magnitudes can make the difference of brightness larger. Meanwhile, we also learned that I.I. with the filter that has the same amount of spectrum magnitude with visual magnitude at night vision can observe meteors with almost identical magnitude of visual observation.

We would like to express our gratitude for valuable advice from Mr. Mitsuru Terada for the relations between magnitude and mass of meteors and from Mr. Noboru Ebizuka for the infrared spectrum.

## 5 Supplementary Notes

We studied the relation between magnitudes and image sizes of fixed stars in order to precisely obtain magnitudes of meteors. Figure 3 shows the results of observations from two types of often-used objective lenses: 85mm/F1.2 and 24mm/F1.4, respectively. The relation between magnitudes of fixed stars darker than 0 magnitude and the size of image can be approximated into an almost straight-line. However, we learned that fixed stars brighter than 0 magnitude may make the image size bigger rapidly. This would be because of the characteristics of I.I. Then, we chose straight-line approximation at an area darker than 0 magnitude while we used quadratic functional approximation at another area brighter than 0 magnitude in Figure 3 by straight-line and curved line. Figure 3 shows the case of observation without the filter and the approximation is different in the case of observation with the filter.

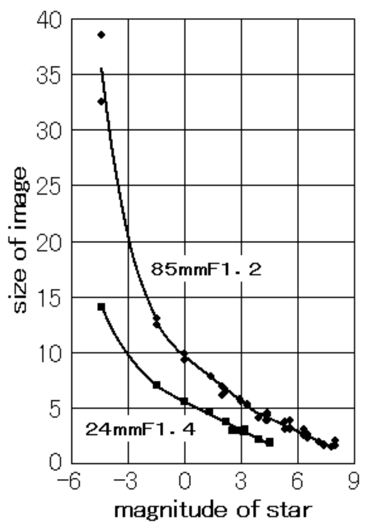


*Figure 3* - Comparison between magnitude of star and size of image.

Figure 4 shows a fire ball discovered at TV observation of a Leonids meteor swarm in 2001 (Shigeno et al., 2003). The original data was recomputed by the methodologies in this report and the magnitude turned out to be Mtv: -7.6. Unfortunately, however, we did not observe this meteor visually. That particular day happened to be a meteor storm occasion and a large number of people were observing but there was no report of such a bright meteor. The actual magnitude of visual observation of the meteor is assumed to be about -4 as there is a difference of approximately 3.5 magnitudes between Mv and Mtv as shown in Figure 2.

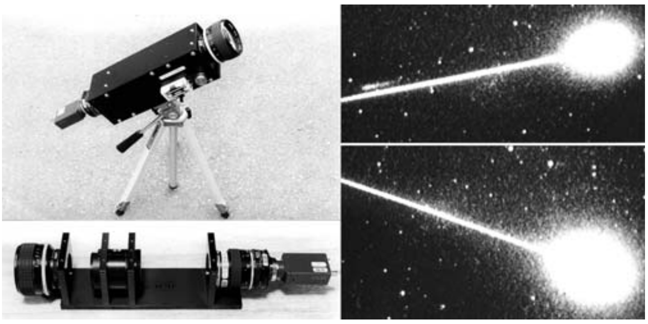

*Figure 4* - The figure on the left shows the TV observation equipment. The device with the Image Intensifier (Delft High Tech XX1470 etc.). The figure on the right shows an example of a double station TV meteor. ID: MSSJBZ on Nov 18 2001 at 18:19:34 (UT). TV magnitude (Mtv) = -7.6.

## References

Opic E. J. (1958). "Physics of meteor flight in the atmosphere", Interscience Publishers, Inc, 148.

Verniani F. (1967). "Meteor Masses and Luminosity", Smithsonian Contributions to Astrophysics, Vol.10, 181-195.

Borovicka J., Stork R., Bocek J. (1999). "First results from video spectroscopy of 1998 Leonid meteors", Meteoritics & Planetary Science, 34, 987-994.

Shigeno Y.,Toda M. (2005). "Double-station TV meteor observations(2004.08.11-12)", Nippon Meteor Society, Apr,2005.

Shigeno Y., Shioi H., Shigeno T. (2003). "Radiants and orbits of the 2001 Leonids", The Institute of Space and Astronautical Science Report SP No.15, 55-62.

All meteors have been opened to the public. http://www.imo.net/files/data/msswg/