August 2018 stellar occultation by 2014-MU69
México - Colombia - USA collaboration

In this document we summarize the preparatory findings by researchers of the Instituto de Astronomía, UNAM resulting from our work in the collaboration to observe the stellar occultation by MU69 from Colombia. We have contacted and met with numerous people in Colombia and Mexico to invite them to collaborate in this project since November 2017. We have created an informative website (http://taos2.astrosen.unam.mx/convocatoriaMU69.html) for sharing information and establishing communication with different groups in Colombia.

I. Weather

We have analyzed existing data in the IDEAM-Colombia on cloud coverage for numerous ground weather stations in Colombia, particularly in candidate regions, over the last 30 years, corresponding to the 1st week of August.

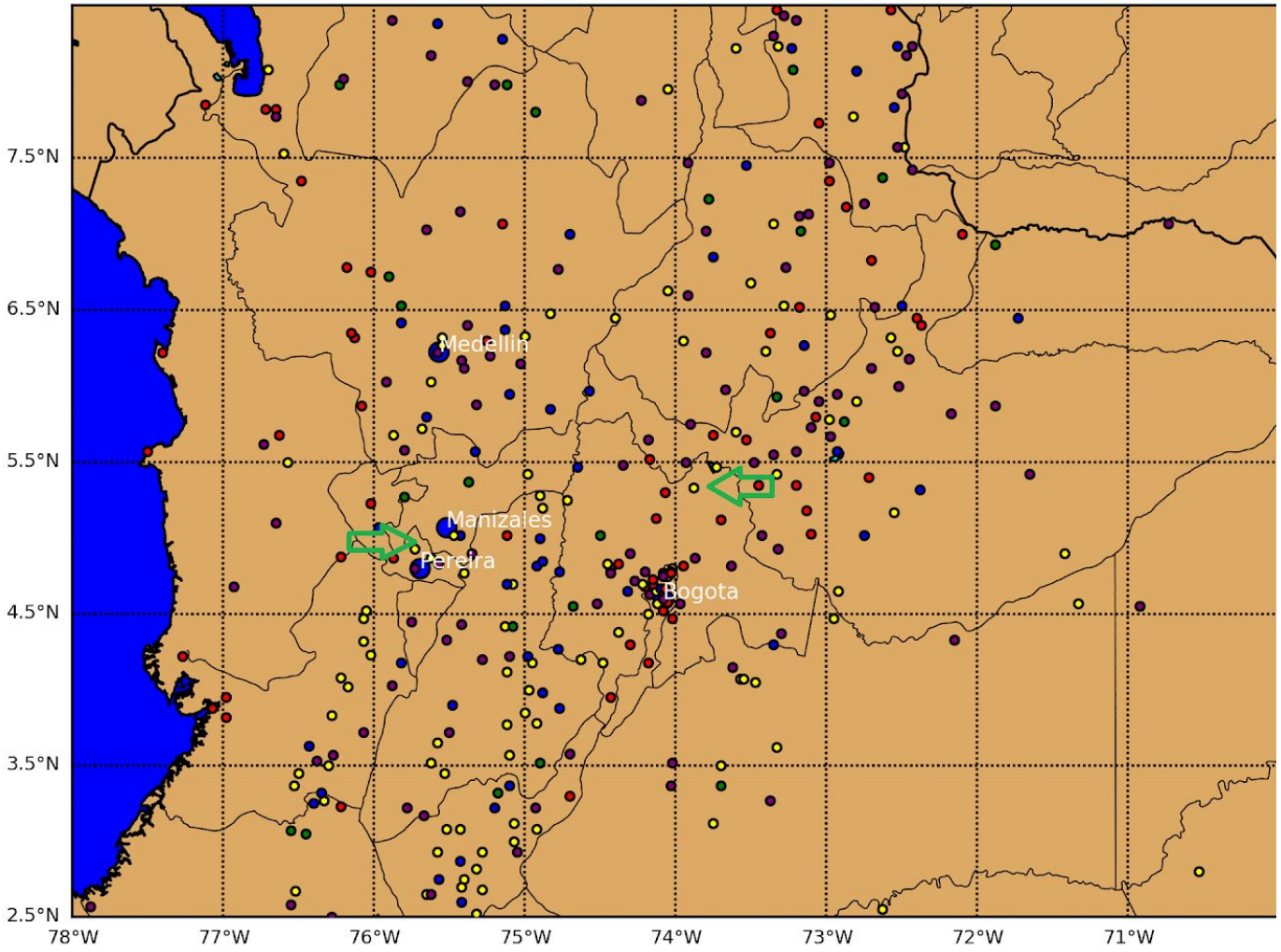

Fig. 1. Mean cloud coverage (MCC) observed at 19:00 in the first week of August over 30 years. Each colored small circle in the map is a weather station. MCC is given in eights Green: MCC < 4 eights, Blue: 4 < MCC < 5, Yellow: 5 < MCC < 6, Purple: 6 < MCC < 7, Red: 7 < MCC < 8.

The methodology for measuring the cloud coverage is based on direct observation of the sky, the observer divides it in eight sections and records how many eighths are covered, this observation is carried out on a daily basis, three times during daylight. For fig. 1 we took the measurement at 19:00 hours for all the stations in the zone where the occultation will be observed, and extracted the data for the first week of August over 30 years, this means that for each point we should have the average over ~210 measurements, but this number depends on the availability of the station at that hour.

The convention about the clear sky says: less than 3 eighths is considered as clear sky, from 3 to 6 eights is considered as partially covered sky, and more than 6 eights is considered as covered sky.

Given that, from fig. 1 green and blue stations are the most suitable regions for placing a telescope for observing the stellar occultation next 4th of August. Even yellow circles will still give a chance for placing a telescope. According to this summary purple and red circles must be avoided. Green arrows indicate well known regions, suitable and recommended for observations according to the experience of our Colombian collaborators.

II. Human resources

Here we present the list of people that have committed to participating in the observing campaign of the occultation. The asterisk after each name indicates the person is a professional or experienced astronomer. UNAM will organize observing workshops for all observers to assure they can obtain good data if weather permits.

Universidad de Pereira
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Universidad Industrial de Santander
Jonhatan Pisco*: (Observatorio,Bucaramanga)

Bogotá region
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Raúl Joya* (Universidad Sergio Arboleda): raul.joya@usa.edu.co
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Cali
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México
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Bosco Hernández*, IA-UNAM
Sergio Silva*, IA-UNAM
Javier Serna [$], IA-UNAM, Colombian
Benjamín Hernández [$], IA-UNAM
Mauricio Reyes*, IA-UNAM
Joel Castro*, IA-UNAM
Cindy Valencia [$], CICESE, Colombian
Victor Rico [$], CICESE, Colombian

The $ sign after each name indicates that funds for their travel support is not yet assured.

III. Telescopes and cameras

- Meade LX 200 16" f/10 Observatorio Astronómico Universidad Tecnológica de Pereira. This telescope is installed in the Observatory of Pereira and cannot be moved. (Fixed)
- Celestron 14" Observatorio Universidad Nacional de Manizales (Fixed).
- Celestron 14". Asociación de astrónomos aficionados (ASASAC)
- Celestron 14" Alfonso Vicini
- Celestron Ultima 11" f/10 Observatorio Astronómico Universidad Tecnológica de Pereira.
- Celestron 10". ASASAC
- Telescopio de 10" en Bucaramanga, depends on the transportation.
- Three Meade 10" (Universidad Libre de Colombia)
- Meade 10", Universidad Nacional de Colombia
- Celestron 9.25", Universidad Nacional de Colombia
- Telescope 8", with CCD, filter wheel, and field rotation compenser, Bogotá.
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- Telescopio Ritchey-Chrétien marca RC-Optical, 16", Open-Truss, Carbon fiber. IA-UNAM, México. Funds for its transportation not assured.
- Two 14" telescopes: ecuatorial Orion HDX110 EQ-G, f/10, Automatic alignment with 16 channels GPS, power 12 V, UANL México

- Cameras: SBIG ST2000, STF8300 y STXL6001; Check operation at 5Hz. Universidad de Pereira.
- Cámaras o QHY174, SBIG ST 402, Universidad Nacional de Colombia
- About to buy a QHY174M-GPS camera in Universidad de Pereira.
- Cameras acA2000-165uc - Basler ace y pco.pixelfly, need to check if ocular can be removed. Universidad de Pereira
- Cámara EMCCD Andor iXon modelo DU-897D-CS0-#BV. IA-UNAM, México
- Two QHY174-GPS cameras, UANL México.

IV. Proposal of sites for observation.

People from Colombia have been working with us in the determination of the best option for observation. We considered four factors for deciding among proposals:

1) Weather, in particular clouds
2) Access, distances from the proposed site to the closer road
3) Transversal alignment to the shadow path, linear regression R^2
4) Standard deviation of heights

Given that, we prepared

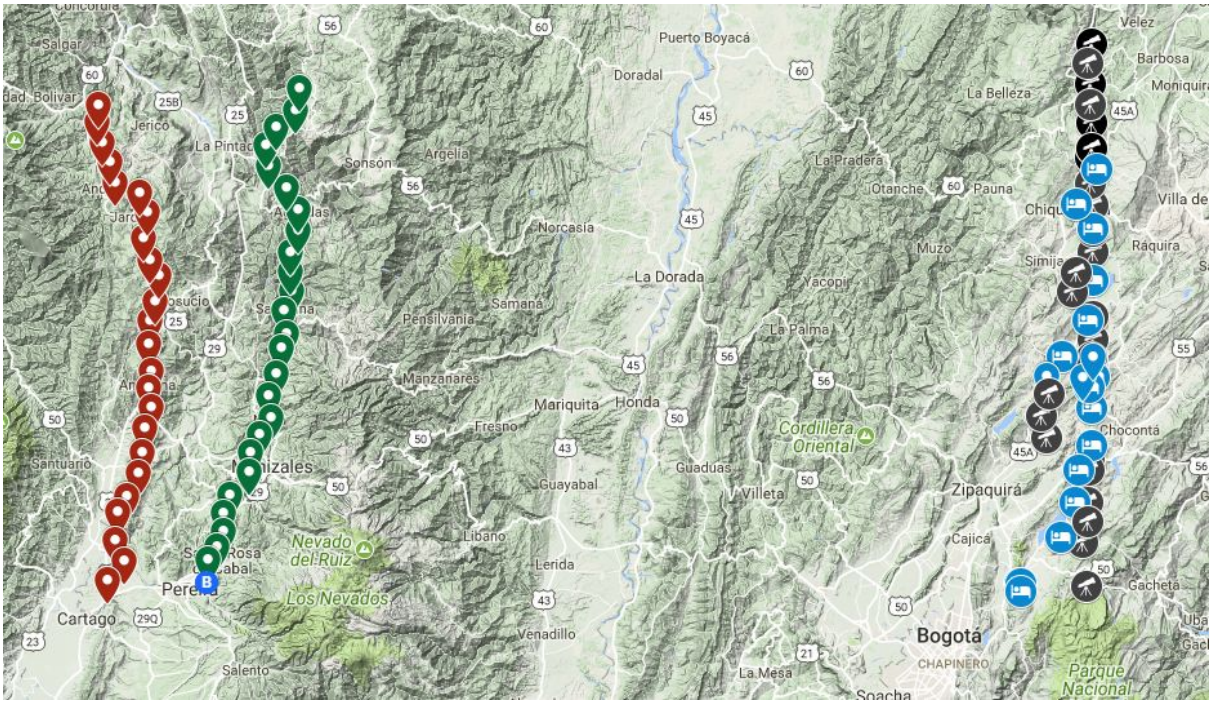

Figure 2. Three best locations for the deployment of observation stations in Colombia. On the left, the western mountain range in red; in the center, the central mountain range in green; and on the right, the eastern mountain range in black.

Trayecto 1. Corredor occidental del Río Cauca.

Punto	Latitud grados (°)	Longitud O grados (°)	Altura SNM metros (m)	Distancia metros (m)	Referencia Distancia
1	4.77694	75.8677	1,000	1,000	Al E carretera 25. Cerritos Cartago (Ris)
2	4.81739	75.83244	1,100	900	Al E carretera 25. Cerritos - La Virginia (Ris)
3	4.86238	75.85184	1,000	1,800	Al E carretera 25. Cerritos - La Virginia (Ris)
4	4.92241	75.84815	1,200	2,000	Al E carretera 25. Al Este río Risaralda (Ris)
5	4.96192	75.82214	1,300	600	Al E carretera Belalcazar - San José (Cal)
6	5.00296	75.79819	1,300	900	Al E carretera Belalcazar - San José (Cal)
7	5.04947	75.79115	1,500	700	Al E carretera Belalcazar - San José (Cal)
8	5.09889	75.78875	1,580	500	Al E carretera San José - Risaralda (Cal)
9	5.14676	75.7797	1,600	350	Al E carretera San José - Risaralda (Cal)
10	5.18566	75.77832	1,600	200	Al O carretera Risaralda - Anserma (Cal)
11	5.21959	75.77596	1,620	500	Al E carretera Anserma - La Virginia (Cal)
12	5.27472	75.78403	1,780	300	Al E carretera Anserma - Riosucio (Cal)
13	5.32771	75.78369	2,200	600	Al O carretera 25. (Cal)
14	5.36599	75.76721	2,000	2,000	Al O carretera 25. (Cal)
15	5.42085	75.75759	2,150	1,000	Al O carretera Riosucio - Jardín (Cal)
16	5.45571	75.77854	2,400	800	Al O carretera Riosucio - Jardín (Cal)
17	5.50083	75.79296	2,700	2,500	Al O carretera Riosucio - Jardín (Cal)
18	5.55584	75.78437	2,780	1,250	Al E carretera Riosucio - Jardín (Ant)
19	5.59565	75.80017	2,180	800	Al E carretera Riosucio - Jardín (Ant)
20	5.61871	75.85098	1,800	2,000	Al E carretra Jardín - Andes (Ant)
21	5.66279	75.86437	1,380	2,000	Al E municipio de los Andes (Ant)
22	5.70378	75.87947	1,220	700	Al E carretera Andes - Hispania (Ant)
23	5.74753	75.89012	1,100	600	Al E carretera Andes - Hispania (Ant)
24	5.7929	75.89284	1,100	1,500	Al E carretera Andes - Hispania (Ant)
Altura SNM media			1,650	25,500	**Suma total de distancias**
Desviación estándar Altura			529		

(Ris) Departamento Risaralda (Cal) Departamento Caldas (Ant) Departamento Antioquia

Figure 3. Table for western route. With coordinates, heights in m and distance to main roads. The standard deviation for heights is 529 m and the total distance from the main roads is 25,500 m.

Trayecto 2. Sobre la cordillera central

Punto	Latitud grados (°)	Longitud O grados (°)	Altura SNM metros (m)	Distancia metros (m)	Referencia Distancia
1	4.82132	75.65356	1,640	1,000	Al O de Pereira (Ris)
2	4.84703	75.6355	1,850	600	Al S carret. Pereira - Santa Rosa de Cabal (Ris)
3	4.88128	75.6213	1,700	0	Santa Rosa de Cabal (Ris)
4	4.91839	75.62233	1,500	100	Al E carretera 29. Pereira - Chinchiná (Ris)
5	4.95756	75.60687	1,450	600	Al E carretera 19. Pereira - Chinchiná (Cal)
6	5.00514	75.56731	1,650	0	Carretera 29. Chinchiná - Manizales (Cal)
7	5.04699	75.5643	1,400	500	S carretera 50. Manizales - La Felisa (Cal)
8	5.0853	75.54456	1,650	500	Al S municipio la Linda (Cal)
9	5.1224	75.52106	1,750	100	Al E de carretera secundaria (Cal)
10	5.16788	75.52551	1,920	0	Municipio de Neira (Cal)
11	5.21472	75.50972	1,900	200	Al N de carretera secundaria. Astromelia (Cal)
12	5.26908	75.49873	1,950	0	Municipio de Aranzazu (Cal)
13	5.29916	75.48774	1,950	500	Al E carretera Aranzazu - Salamina (Cal)
14	5.34907	75.49152	1,600	500	Al E carretera Aranzazu - Salamina (Cal)
15	5.38821	75.47521	1,750	1,500	Al S de Salamina (Cal)
16	5.43042	75.47873	1,550	500	Al E carretera Salamina - Pacora (Cal)
17	5.47144	75.47899	1,950	300	Al O carretera Salamina - Pacora (Cal)
18	5.51646	75.46294	1,950	400	Al O carretera Salamina - Pacora (Cal)
19	5.56029	75.46345	1,700	200	Al O carretera Pacora Aguadas (Cal)
20	5.60846	75.4874	1,580	200	Al S carretera secundaria (Cal)
21	5.65442	75.52452	1,000	200	Al E carretera La Pintada - Arma (Cal)
22	5.69922	75.5319	700	200	Al E carretera La Pintada - Abejorral (Ant)
23	5.73547	75.50984	2,000	200	Al E carretera La Pintada - Abejorral (Ant)
24	5.77228	75.46749	2,350	600	Al E carretera La Pintada - Abejorral (Ant)
25	5.81958	75.46071	2,100	200	Al O carretera que llega al Abejorral (Ant)
Altura SNM media			1,702	9,100	**Suma total de distancias**
Desviación estándar Altura			340		

(Ris) Departamento Risaralda (Cal) Departamento Caldas (Ant) Departamento Antioquia

Figure 4. Table for the central route. With coordinates, heights in m and distance to main roads. The standard deviation for heights is 340 m and the total distance from the main roads is 9,100 m.

Trayecto 3. Cordillera oriental

Punto	Latitud grados (°)	Longitud O grados (°)	Altura SNM metros (m)	Distancia metros (m)	Referencia Distancia
1	4.81731	73.7828	2,840	1,000	Al O de carretera secundaria, San Martín (Cun)
2	4.90696	73.78896	2,840	0	Sobre cruce de carreteras secundarias (Cun)
3	4.95411	73.77912	2,950	100	Sobre cruce de carreteras secundarias (Cun)
4	4.99445	73.77865	2,900	200	Al N Vía Laguna de Guatavita (Cun)
5	5.06337	73.77722	2,620	324	Al N carretera 55. Bogotá - Tunja (Cun)
6	5.08538	73.77516	2,580	0	Sobre carretera, desvío carretera la Playa Suesca
7	5.13166	73.86744	2,600	0	Sobre carretera a Nemocón (Cun)
8	5.17724	73.87831	3,150	200	Al N carretera la Pluma - Cucunuba (Cun)
9	5.22322	73.86123	2,700	150	Al O carretera Zipaquirá - Ubaté (Cun)
10	5.25951	73.77061	2,560	500	Al E carretera Cucunubá - Leguanzaqué (Cun)
11	5.30104	73.76928	2,540	700	Al O carretera Ubaté - Cucumbá (Cun)
12	5.33967	73.76769	2,560	324	Al E carretera a Guachetá (Cun)
13	5.38753	73.76684	2,540	600	Al E carretera Ubaté -Chiquinquirá (Cun)
14	5.44011	73.81223	2,650	100	Al E carretera Susa - Fúquene (Cun)
15	5.49037	73.80223	2,600	0	Sobre cruce de carreteras secundarias (Cun)
16	5.52342	73.76808	2,540	250	Al N carretera San Miguel de Serna (Boy)
17	5.56866	73.76838	2,580	2,500	Al E de carretera secundaria (Boy)
18	5.62192	73.76885	2,540	200	Al E carretera Villa de Leyva - Chiquinquirá (Boy)
19	5.66932	73.77207	2,600	200	Al E carretera Chiquinquirá - Saboyá (Boy)
20	5.72257	73.77319	2,850	650	Al E de carretera secundaria (Boy)
21	5.74375	73.77113	2,950	0	Sobre carretera secundaria (Boy)
22	5.79772	73.77191	2,350	1,000	Al O Vía a Jesús María (San)
23	5.93572	73.77324	1,950	200	Al E Vía a Jesús María (San)
24	5.87969	73.77319	1,800	0	Sobre carretera secundaria a Jesús María (San)
25	5.92462	73.77953	2,000	0	Sobre carretera Sucre - Guavata (San)
26	5.93439	73.77181	250	100	Al N de carretera secundaria (San)
Altura SNM media			2,502	9,298	**Suma total de distancias**
Desviación estándar Altura			551		

(Cun) Departamento Cundinamarca (Boy) Departamento Boyacá (San) Departamento Santander

Figure 5. Table for the eastern route. With coordinates, heights in m and distance to main roads. The standard deviation for heights is 551 m and the total distance from the main roads is 9,228 m.

Given the information of above we build a matrix of decision.

Creteria	Factor of value	Weight	Value for creteria		
		%	Western	Central	Eastern
Meteorología	Cloud coverage	30%	4 to 5	5 to 6	5 to 7
Acceso	Sum of distances to road	30%	25,500	9,100	9,298
Ajuste a unalínea recta	Parameter R^2 of linear regression	20%	0.0345	0.6735	0.1008
Variación altura	STD of heights along the route	20%	529	340	551

Figure 6. Summary of the information for each route.

Taking into account the values from figure 6 and personal opinions of our collaborators in Colombia, the final evaluation is the following:

- **for western route was is 6.6**
- **for central route 7.3**
- **for eastern route 7.5**

According to our assessment the best route is the eastern mountain range.