



Indian Seamless Celestial Globe: completed in 1631 by Muhammad Salih Thattvi from Sindh province, now in Pakistan



Chinese Celestial Globe: made around 1830 CE by Qi Mei-Lu from Wuyuan, now the Jiangxi province

# Visuospatial Reasoning in using Projective Sky Maps

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# Learning Elementary Astronomy

- Building spatial mental models
  - Positions and motions of celestial bodies
  - Astronomical sizes & distances; Terrestrial time scales
  - Translating 2-D, static representations into 2-D or 3-D dynamic models
- Model Based Reasoning
  - Careful observations (mostly at night) for a long period of time
  - Mastering the tools (telescope) and representations (star charts)
  - Projection techniques; multiple representations
  - Changing frames of reference

# Theoretical Framework

- Embodied Cognition
- Multimodality
- Visuospatial Thinking
- Multiple External Representations (MER)
- Cultural knowledge

# An exploratory study

- Context - Indian National Astronomy Olympiad
- Students' qualitative responses on an alt-azimuth projection sky map
- Task analysis
- Interviews of 20 students - videotaped and coded

# Participants

- 515 High school students - INAO 2014
- Aspirants for the Astronomy Olympiads (IAO Junior and IOAA Senior)
- Selection by national and state-wise quotas

## IAO Junior

- Top 1.6% from ~20,000 juniors (National Standards Examination in Junior Science)
- 240 (age 13-15; mean 14.9)

## IOAA Senior

- Top 3.6% from ~8,700 seniors (National Standards Examination in Astronomy)
- 275 (age 15-18; mean 17.6)

# Sex Ratio

**Total**  
515  
10% Girls

13-15 years	Junior	Junior OCSC*	Junior Team
Number of students	240	20	3
Girls	19%	0	0
15-18 years	Senior	Senior OCSC**	Senior Team***
Number of students	275	37	6
Girls	3%	5%	17%

\* Cutoff 39/100

\*\* Cutoff 58/100

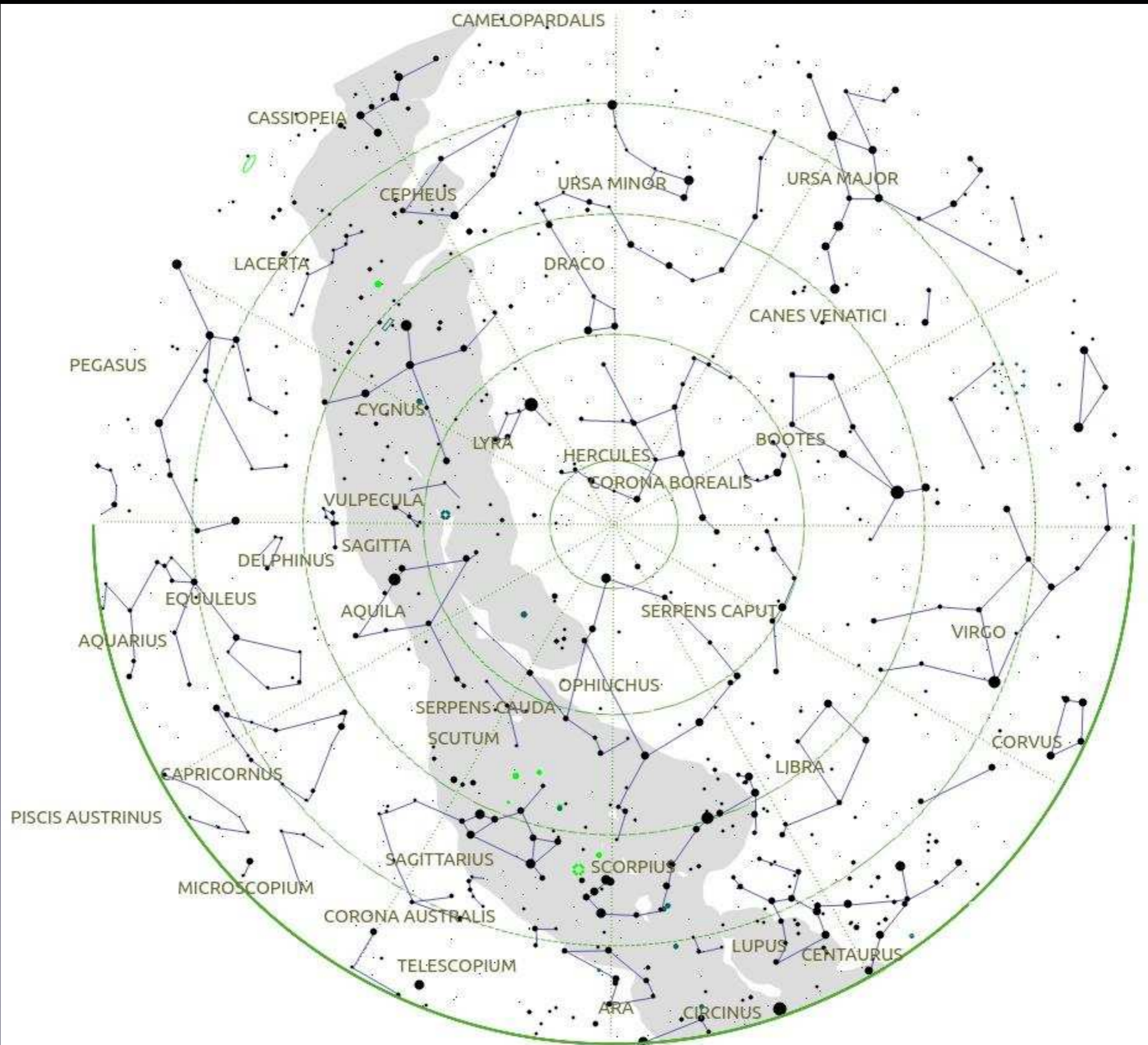
\*\*\* 5 members of 2014, 1 of 2013

# Task - Reading & Inferencing from a star chart

The skymap below corresponds to the sky above Nagpur ( $21^\circ$  N,  $79^\circ$  E at 09:00 am on 1st February 2014 ... sky map is seen lying down on the ground (feet to the South), facing the sky with map in your hand. Thus, East is on the left of the map and West is on the right. Answer the following questions

Question paper is available here:

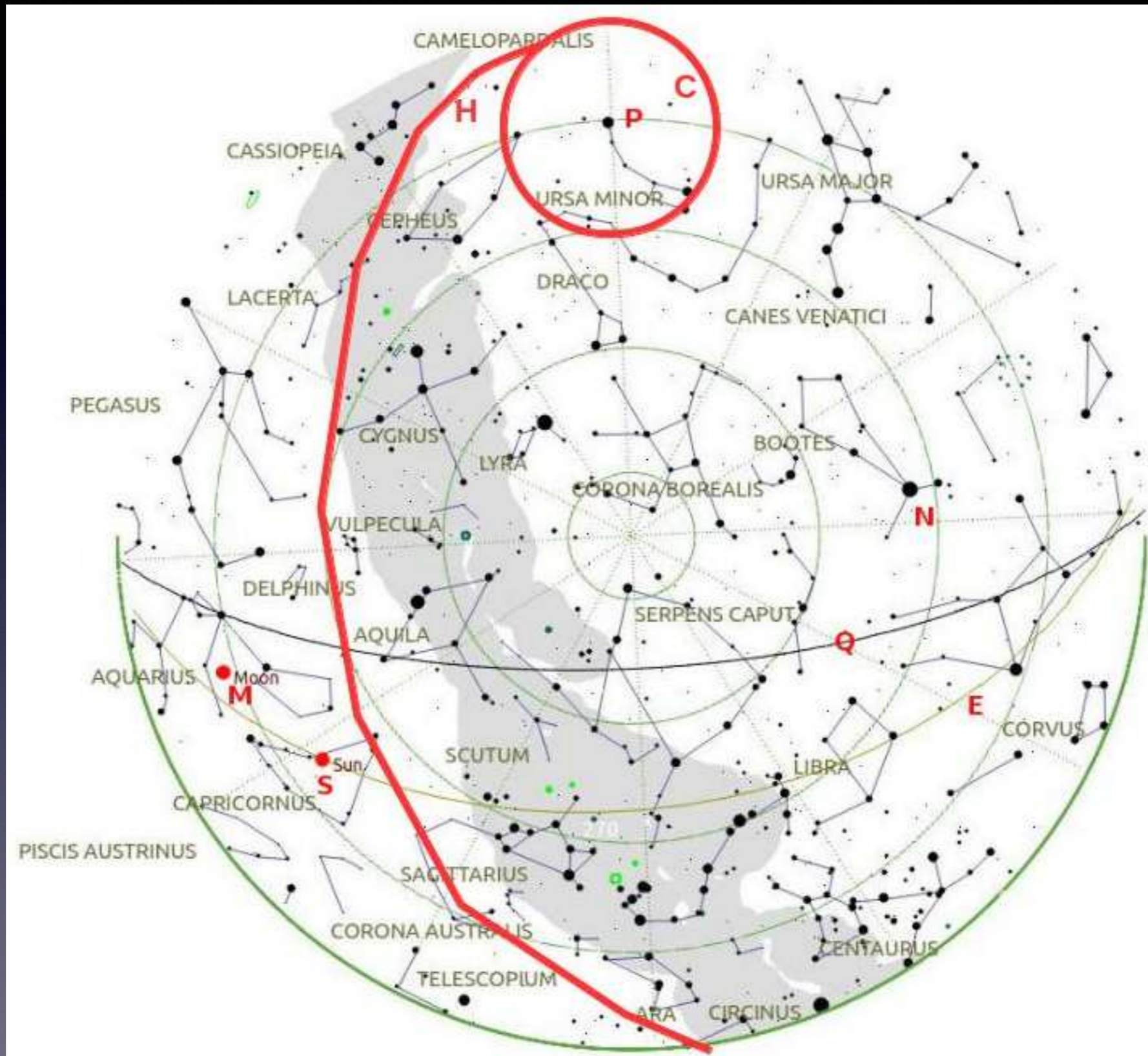
<http://olympiads.hbcse.tifr.res.in/uploads/ino14-qp-sol/inao-2014-qp-sol>





- a. Mark Polaris.
- b. Circumpolar stars for a given place ... never go below the horizon. Draw the boundary of this region.
- c. Celestial equator is a projection of the Earth's equator in the sky... locus of points equidistant from the north and south poles. Draw it approximately.
- d. Ecliptic is the imaginary yearly path of the Sun in the sky. Draw it approximately.
- e. Mark approximate position of the Sun.
- f. Yesterday was new moon day. Mark current position of the moon.
- g. Which star was very close to the Zenith at 06:00 am today?
- h. Draw a line showing the horizon at 07:00 am today.

# Solution



# Correct response rates

Question	Percentages of correct responses					Team J (out of 3)	Team S (out of 6)
	Total (515)	Junior (240)	Senior (275)	OCSC J (20)	OCSC S (37)		
Polaris	44	31	56	85	78	3	6
Circumpolar region	10	4	16	35	60	2	5
Celestial equator	13	3	22	15	57	0	5
Ecliptic	18	3	30	10	65	0	3
Position of sun	10	2	17	10	43	0	3
Position of moon	2	0	4	0	11	0	3
Zenith star at 6am	10	4	14	15	38	1	2
Horizon at 7am	3	0	5	5	30	0	3
Que. score (max15)	2	0.8	3	4	8	6	10
$r$ (Que. score, total score)	0.60	0.56	0.56	0.8	0.36	0.16	0.48

# Popular response rates

Question Attempted %	Most popular response	Next most popular
Polaris 94%	Correct 44%	Random 14%
Circumpolar region 66%	Loop too big 19%	Loop around zenith 18%
Celestial equator 73%	Straight line through zenith 28%	Random 21%
Ecliptic 60%	Random 25%	Correct 19%
Position of sun 71%	Random 42%	On ecliptic 17%
Position of moon 56%	Random 39%	On ecliptic 6%
Zenith star at 6am 50%	Random 31%	Correct or close to correct 20%
Horizon at 7am 56%	Straight line 23%	Random 15%

# General observations

- Minimum initial astronomical knowledge
- Some cultural knowledge
- Improvement with age, interest and training
- Age improvement in theory more than observation
- Training helps in observation

# Interviews

- 20 Junior students (12 Junior Science; 8 Junior Astro - with 6 days training, including 3 nights sky observation)
- Duration: 3-11 minutes (Average ~6 minutes)
- Syntax - mapping chart to sky
  - E/W reversal,
  - Zenith, Horizon
- Reasoning
  - Position of the sun
  - Position of the moon

# Students' Strategies

- Syntax - mapping chart to dome of sky
  - E/W reversal - challenge for JS; easy for JA
  - Zenith, Horizon - as above; terminology unfamiliar to JS
- Reasoning
  - Position of sun - 10/12 JS from time of day; 7/8 JA from ecliptic
  - Position of moon
- Gestures in space (Metaphorical)
  - East-West reversal - 11/12 JS ; 6/8 JA
  - Zenith: 11/12 JS ; 1/8 JA
  - Horizon: 8/12 JS ; 1/8 JA
  - Position of the moon: 6/12 JS ; 6/8 JA

	eclipse explanation	Correct explanation	Total students
JS	8	1	12
JA	2	4	8

# Conjectures from the data

- Reasoning and inferencing is shaped by prior knowledge
- Gestures reflect underlying reasoning process
  - Reasoning on map (deictic gestures, diagram-based) (less elaborate reasoning, more efficient)
  - Connecting map with knowledge and observations (metaphoric gestures, in space) (more elaborate reasoning, early stage)



# General conclusions

- Spatial reasoning is challenging
- Cultural, other facts and terminology help
  - Need less elaborate reasoning
  - Helps diagram-based reasoning
- Gestures and actions (metaphoric and deictic)
  - aid in simple inferences
  - aid in communication

# References

- Web acknowledgements (Coverpage)
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