Comets and Coronal Mass Ejections
Teacher Notes

| TI-Nspire CAS | Investigation | Student | 90min |

Aim:

The aim of this investigation is to determine the distance a comet moves in a period of time, thus determining the speed of a comet as it approaches the Sun. The comet's speed will also be compared with the speed of a coronal mass ejection (CME) from the Sun. Digital technology and Pythagoras' theorem will be used throughout.

National Curriculum Statement: Find the distance between two points located on a Cartesian plane using a range of strategies, including graphing software (ACMNA214)
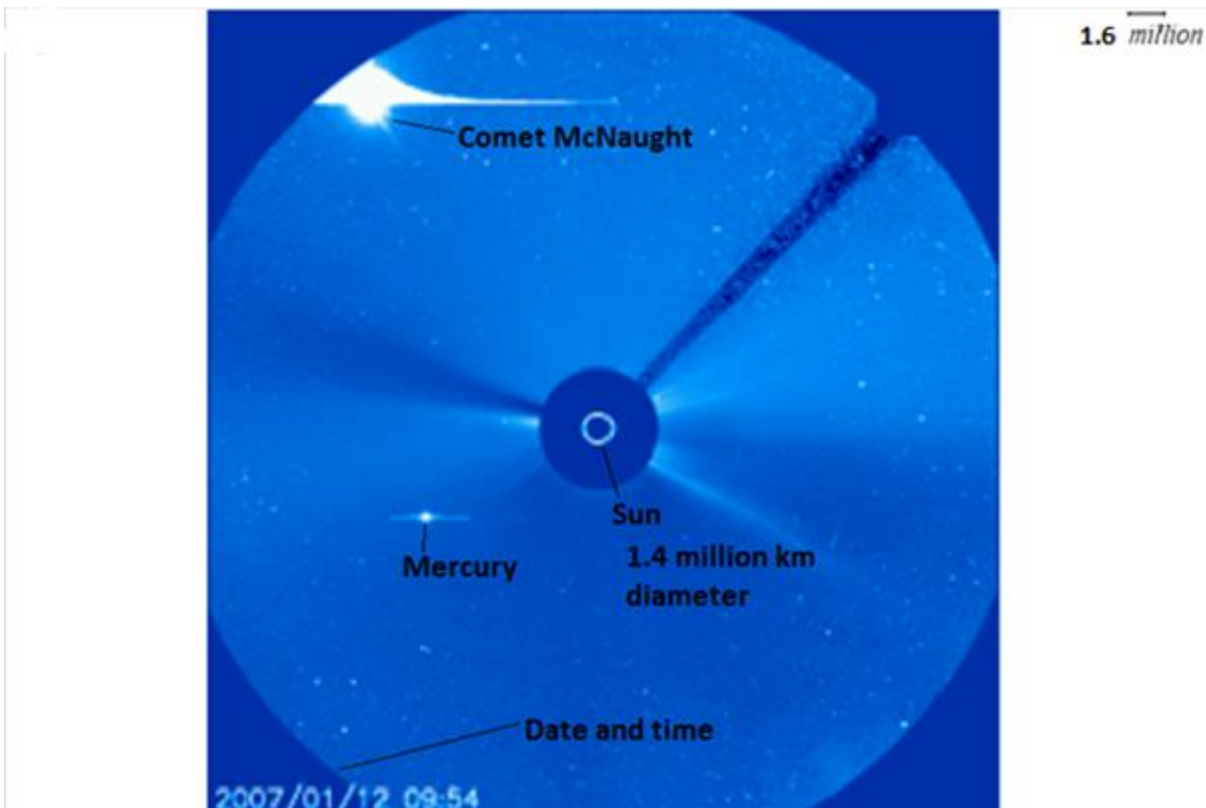
Equipment:

For this activity you will need:

* TI-Nspire CAS (or TI-Nspire)

* TI-Nspire CAS file: Comets and CMEs

Problem Description:

A coronagraph is a telescopic attachment used to block out the Sun's glare so that nearby objects can be resolved. The coronagraph image overleaf was obtained from Solar and Heliospheric Observatory (SOHO) located at http://soho.nascom.nasa.gov/. It represents Comet McNaught as it approached the Sun in early January 2007. The comet appears to be approaching the planet Mercury (the bright object in the foreground). The Sun is represented by the white circle in the middle of the coronagraph. It has a diameter of 1,400,000 kilometres. The diameter is used in determining distances travelled by the comet. The speed of the comet can be calculated by using several images and determining how far it moves in a given time interval. The date and time are included in the bottom left hand corner. The dark blue region around the Sun is the area blocked by the coronagraph.

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Technology:

During this activity, students will need to use the TI-Nspire file: "Comets and CMEs". This file can be distributed using TI-Navigator, the TI-Nspire docking station or the teacher/student software. To distribute the file using the Teacher software, use the **Tools** menu and select the **Transfer Tool.** Locate the TI-Nspire file on your computer and then start the transfer. Once the file is transferred to the first handheld, unplug the handheld and continue plugging in each student's handheld device. Once all the students have the file, stop the transfer. Note that students can also transfer files from one handheld device to another from within the **My Documents** folder. Note also that multi-port USB connectors can be used to transfer files to several handhelds at the one time.

This activity requires access to the "Comets and CMEs" TI-Nspire document. This document should be loaded on your device before proceeding.

Once the document is on your handheld, press **home** and select **My Documents**. Locate the "Comets and CMEs" document and press **enter** to open.

✎ Part of in this investigation requires calculations to be performed. The Scratchpad is a place where calculations can be computed and then discarded. To access the Scratchpad press **home** and select **Scratchpad** (or press **A**). Alternatively, press the ▱ key (this key is not available on a Clickpad).

Navigate to page **1.2** (shown opposite). Comet McNaught (top left hand corner) is shown orbiting the Sun and appears to be heading towards Mercury. The small white circle in the centre represents the Sun which has a diameter of 1,400,000 kilometres.
To see the motion of the comet over time scroll quickly through the remaining pages by using the **mouse** or by pressing **crtl + right arrow**.
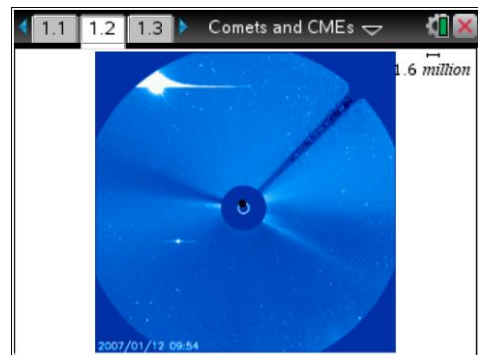
Navigate to page **1.3.** This page includes a grid which can be used in conjunction with Cartesian coordinates. The image is ghosted when in this mode. The grid can be switched on and off.
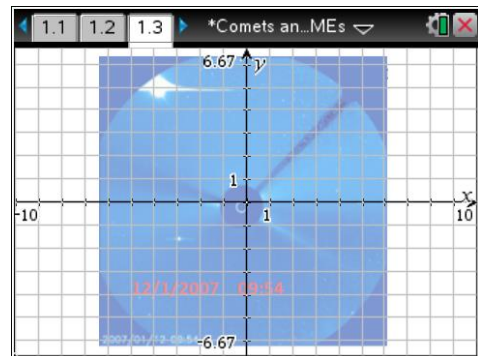
To remove the grid, press **menu > View > Plane Geometry**.
To insert the grid, press **menu > View > Graphing**.
(Note – when you return to **Graphing** mode, press **esc** to hide the **Graph Entry Line**)
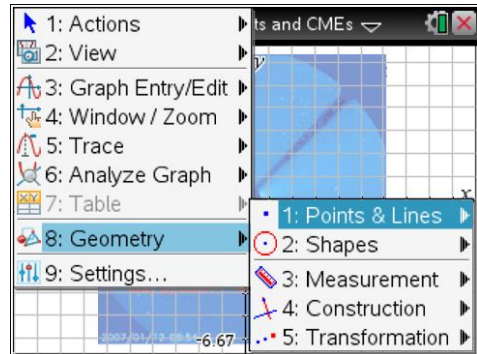
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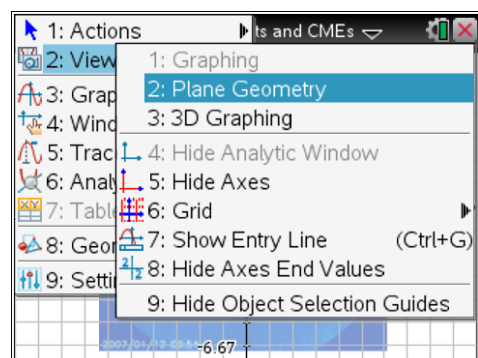
Assigning Cartesian Coordinates

We now want to place points onto the grid to represent the comet as it moves across the screen.

Step 1

    (i)   Press **menu > Geometry > Points & Lines**.
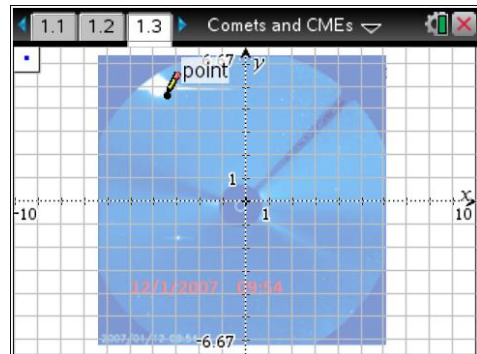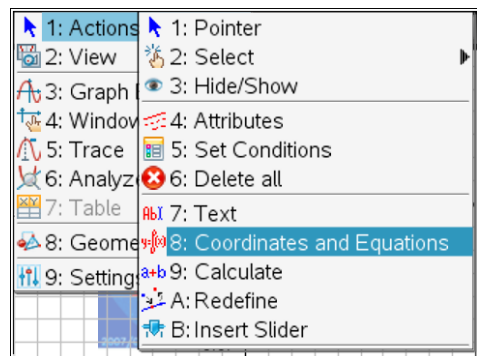
    (ii)   Select **Point**.
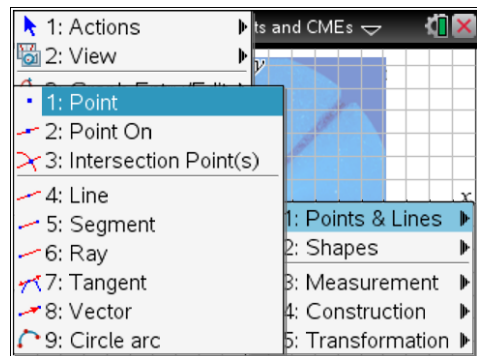
Step 2

    (i)   Use the mouse to place a point at the head of the comet.

    (ii)   Press **menu > Actions > Coordinates and Equations**.

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(iii) Use the mouse to click on the point and the coordinates will appear. For example, these coordinates are **(−3.58, 4.59)**. You can drag the coordinates to a more convenient location if desired.
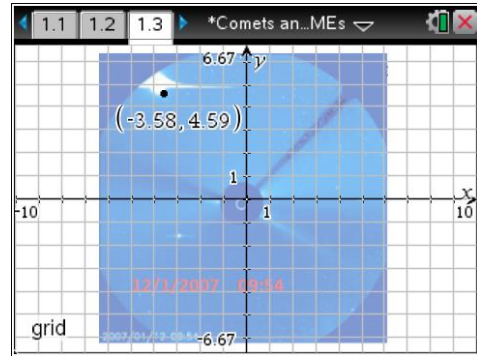
(iv) Note the date and time in the bottom left hand corner. You may need to turn off the grid in order to accurately read the date and time. The date and time are **12/1/2007** and **09:54**.
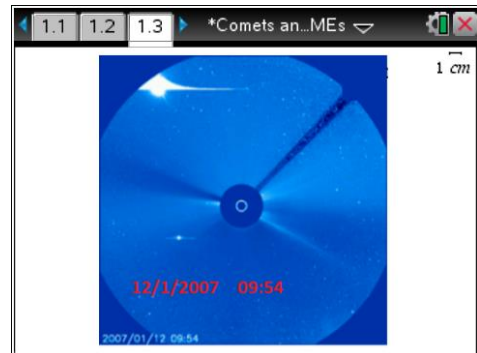
(v) Navigate to page **1.4** and place a point at the head of the comet. Determine the Cartesian coordinates, and the date and time. The coordinates are **(−4.28, 1.49)**. The date and time are **13/1/2007** and **11:54**.
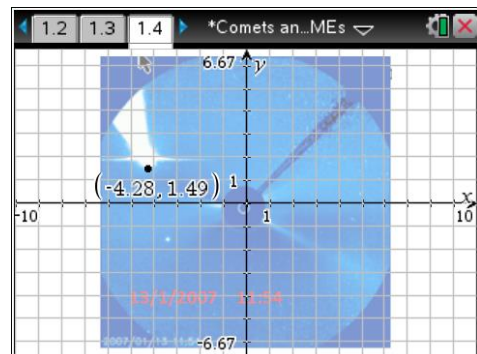
Questions

1. Complete the table below for the date, time and coordinates for Comet McNaught.

Image	Date	Time	Coordinates
Screen 1.3	12/1/2007	09:54	(−3.58, 4.59)
Screen 1.4	13/1/2007	11:54	(−4.28, 1.49)
Screen 1.5	13/1/2007	21:54	(−4.47, 0.377)
Screen 1.6	14/1/2007	10:54	(−4.4, −1.38)

These values will vary according to accuracy of the coordinates selected by the students.

Pythagoras' theorem can be used to determine the distance between two points on the Cartesian plane.

The distance between the points (x_1, y_1) and (x_2, y_2) is:

$$distance = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

From the table above the time interval between screen 1.3 and screen 1.4 is 26 hours. The distance between the coordinates is:

$$d = \sqrt{(-3.84 - -4.28)^2 + (4.7 - 1.49)^2}$$

$d ≈ 3.24$ units.

Using the diameter of the Sun as 1,400,000 kilometres; then the width of one square on the grid is approximately equal to two Sun diameters. Therefore one unit on the grid represents 2,800,000 kilometres.

The distance moved by Comet McNaught in 26 hours is 9,072,043 kilometres (3.240015 × 2,800,000).

Since speed = $\frac{distance}{time}$, then the speed of Comet McNaught is:

$$= \frac{9,072,043 \text{ kilometres}}{26 \text{ hours}}$$

= 348,925 km/hr, which is 5,815 km/min or 97 km/second.

2. Using the Scratchpad, complete the table below for Comet McNaught.

Start and finish time	Time interval (hours)	Distance moved (km)	Speed km/hr	Speed km/min	Speed km/sec
12/1/2007 (09:54) 13/1/2007 (11:54)	26	9,072,043	348,925	5,815	97
13/1/2007 (11:54) 13/1/2007 (21:54)	9	$\sqrt{(-4.28 - -4.47)^2 + (1.49 - 0.377)^2}$ $= 1.1291$ units $1.1291 \times 2,800,000$ $= 3,161,480$	$\dfrac{3161480}{9}$ = 351,276	5,855	98
13/1/2007 (21:54) 14/1/2007 (10:54)	13	$\sqrt{(-4.47 - -4.4)^2 + (0.377 - -1.38)^2}$ = 1.75839 units $1.75839 \times 2,800,000$ = 4,923,492	$\dfrac{4923492}{13}$ = 378,730	6,312	105

Note: Notice how the comet is speeding up as it gets closer to the Sun. Student answers may vary by a small percentage due to the size of the point on the images allocated by the calculator.

3. Use the results from the table to determine the average speed of Comet McNaught. Express the average speed in km/hr, km/min and km/sec.

Average speed = 359,644 km/hr, 5,994 km/min or 100 km/sec

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The following questions relate to Comet Neat (which appeared in February 2003) and a coronal mass ejection (CME) from the Sun. Determine the speed of both the Comet and the coronal mass ejection.

Greater accuracy is obtained when the activity is completed in the computer view mode.
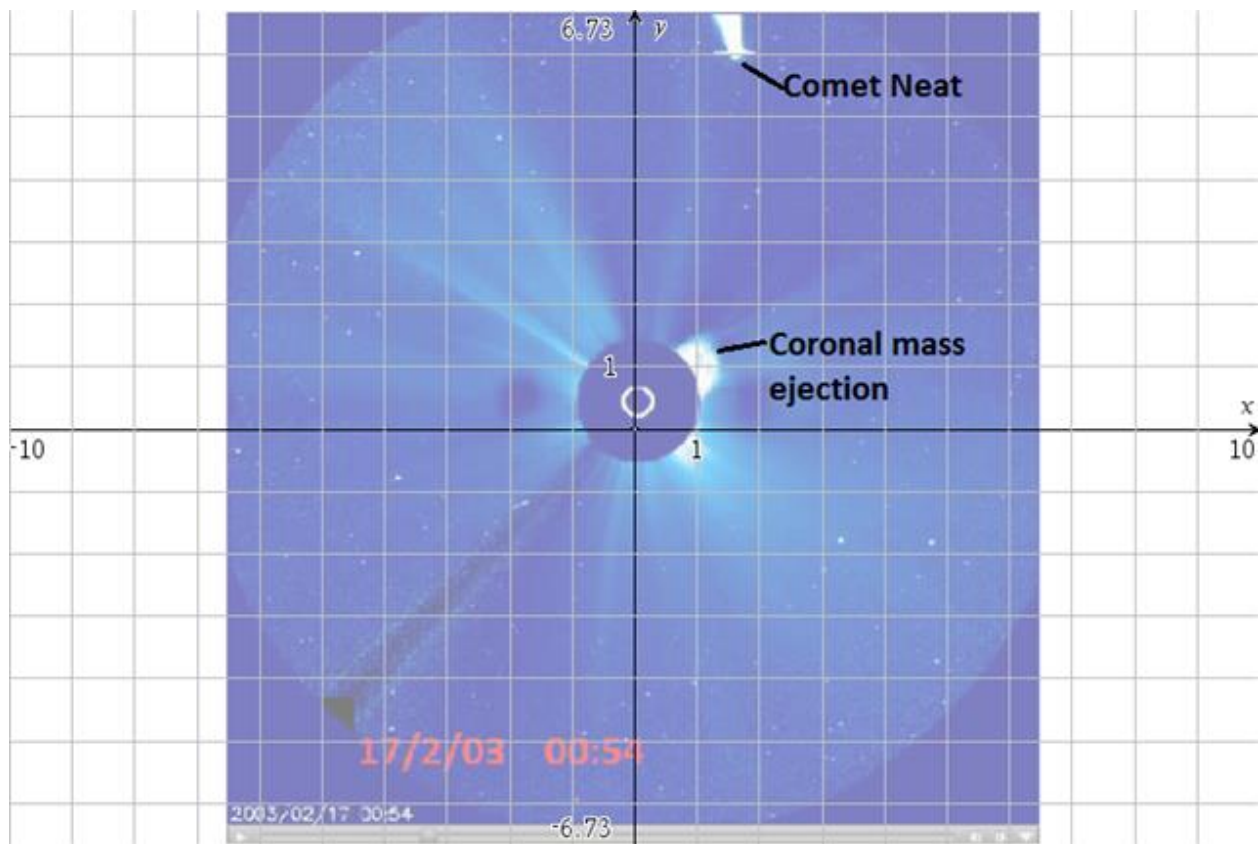
4.   Assign coordinates for each of the following screen images of Comet Neat.

Image	Date	Time	Coordinates
Screen 1.8	17/2/03	00:54	(1.57, 5.66)
Screen 1.12	17/2/03	05:54	(2.08, 5.41)
Screen 1.14	17/2/03	11:54	(2.64, 4.59)
Screen 1.18	17/2/03	22:54	(3.52, 3.4)

Results will vary.

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5. Complete the table and determine the speed of Comet Neat.

Start and finish time	Time interval (hours)	Distance moved (km)	Speed km/hr	Speed km/min	Speed km/sec
00:54 05:54	5	$\sqrt{(1.57-2.08)^2 + (5.66-5.41)^2}$ $= 0.567979$ units $0.567979 \times 2,800,000 = 1,590,341$	$\dfrac{1590341}{5}$ $= 318,068$	5,301	88
05:54 11:54	6	$\sqrt{(2.08-2.64)^2 + (5.41-4.59)^2}$ $= 0.992975$ units $0.992975 \times 2,800,000 = 2,780,330$	$\dfrac{2780330}{6}$ $= 463,388$	7,723	129
11:54 22:54	11	$\sqrt{(2.64-3.52)^2 + (4.59-3.4)^2}$ $= 1.48003$ units $1.48003 \times 2,800,000 = 4,144,084$	$\dfrac{4144084}{11}$ $= 376,735$	6,279	105

Results will vary.

6. Determine the average speed of Comet Neat. Express the average speed in km/hr, km/min and km/sec.

Average speed = 386,064 km/hr, 6,434 km/min or 107 km/sec

7. Assign coordinates for each of the following screen images of a coronal mass ejection.

Image	Date	Time	Coordinates
Screen 1.8	17/2/03	00:54	(1.32, 1.38)
Screen 1.9	17/2/03	01:54	(1.57, 1.89)
Screen 1.10	17/2/03	03:54	(2.58, 2.77)
Screen 1.12	17/2/03	05:54	(3.65, 3.58)

Results will vary.

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8. Complete the table and determine the speed of coronal mass ejection.

Start and finish time	Time interval (hours)	Distance moved (km)	Speed km/hr	Speed km/min	Speed km/sec
00:54 01:54	1	$\sqrt{(1.32-1.57)^2 + (1.38-1.89)^2}$ = 0.567979 units 0.567979 × 2,800,000 = 1,590,341	$\dfrac{1590341}{1}$ = 1,590,341	26,506	442
01:54 03:54	2	$\sqrt{(1.57-2.58)^2 + (1.89-2.77)^2}$ = 1.33959 units 1.33959 ×2,800,000 = 3,750,852	$\dfrac{3750852}{2}$ = 1,875,426	31,257	521
03:54 05:54	3	$\sqrt{(2.58-3.65)^2 + (2.77-3.58)^2}$ = 1.34201 units 1.34201 × 2,800,000 = 3,757,628	$\dfrac{3757628}{3}$ = 1,252,543	20,876	348

Results will vary.

9. Determine the average speed of the coronal mass ejection. Express the average speed in km/hr, km/min and km/sec.

Average speed = 1,572,770 km/hr, 26,213 km/min or 437 km/sec

10. Compare the speed of Comet Neat with the coronal mass ejection.

Average speed of Comet Neat is 386,047 km/hr, 6,434 km/min or 107 km/sec.

Average speed of a CME = 1,572,770 km/hr, 26,213 km/min or 437 km/sec

The CME is approximately 4.1 times faster than Comet Neat.

11. There are additional coronal mass ejections shown up to screen **1.30**. Select two screens and determine the speed of this CME. Compare its speed with the speed of the previous CME.

Start and finish time	Time interval (hours)	Distance moved (km)	Speed km/hr	Speed km/min	Speed km/sec
05: 54 08: 54	3	$\sqrt{(1.93-3.18)^2 + (3.44-5.43)^2}$ = 2.35002 units 2.35002 × 2,800,000 = 6,580,056	$\dfrac{6580056}{3}$ = 2,193,352	36,556	609

Results will vary. These answers are for screens **1.20** and **1.21**.