

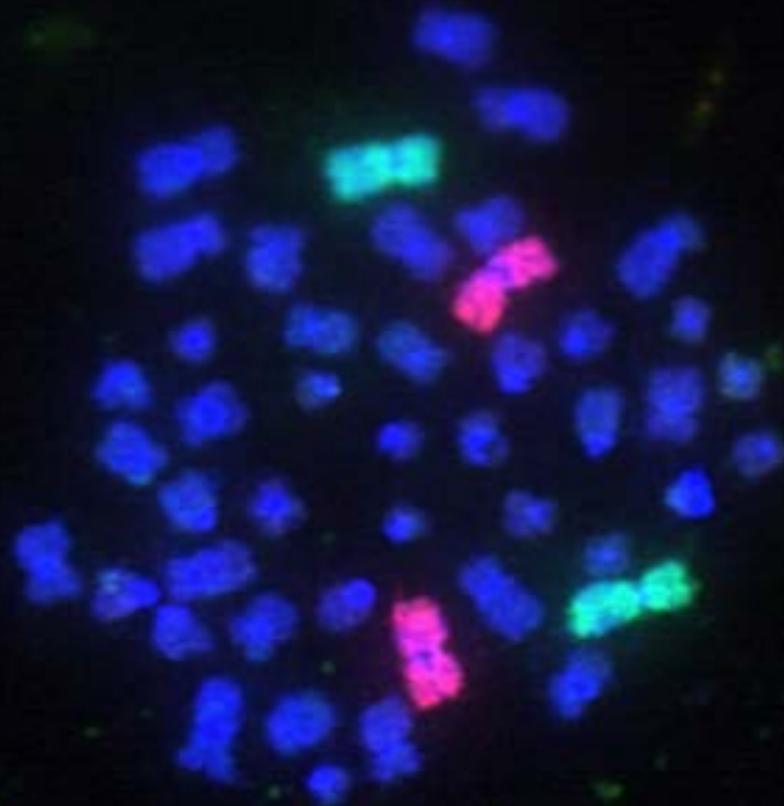
# *Biodosimetry flight protocols and results*

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# Technique

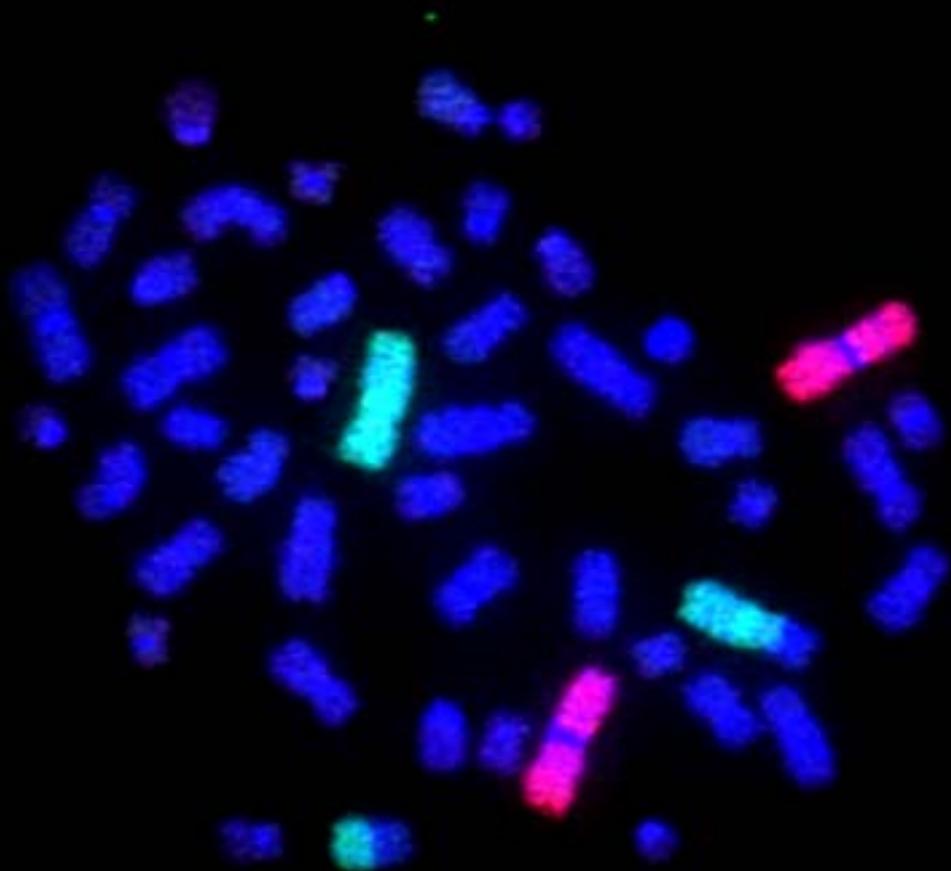
- **Blood was drawn from astronauts  
no more than three months prior to flight  
and within two weeks of return**
- **Pre-flight samples were irradiated with gamma rays**
- **Lymphocytes were stimulated to grow in culture**
- **Chromosome spreads were collected 48 hours later**
- **Chromosomes were “painted” using chromosome specific fluorescence DNA probes**
- **Exchanges in painted chromosomes were analyzed using fluorescence microscope**

**Spread with chromosomes 2 and 4 painted**



**Both chromosomes are normal**

example of a reciprocal translocation  
involving chromosome 2



# Using translocations to measure dose

## Advantages

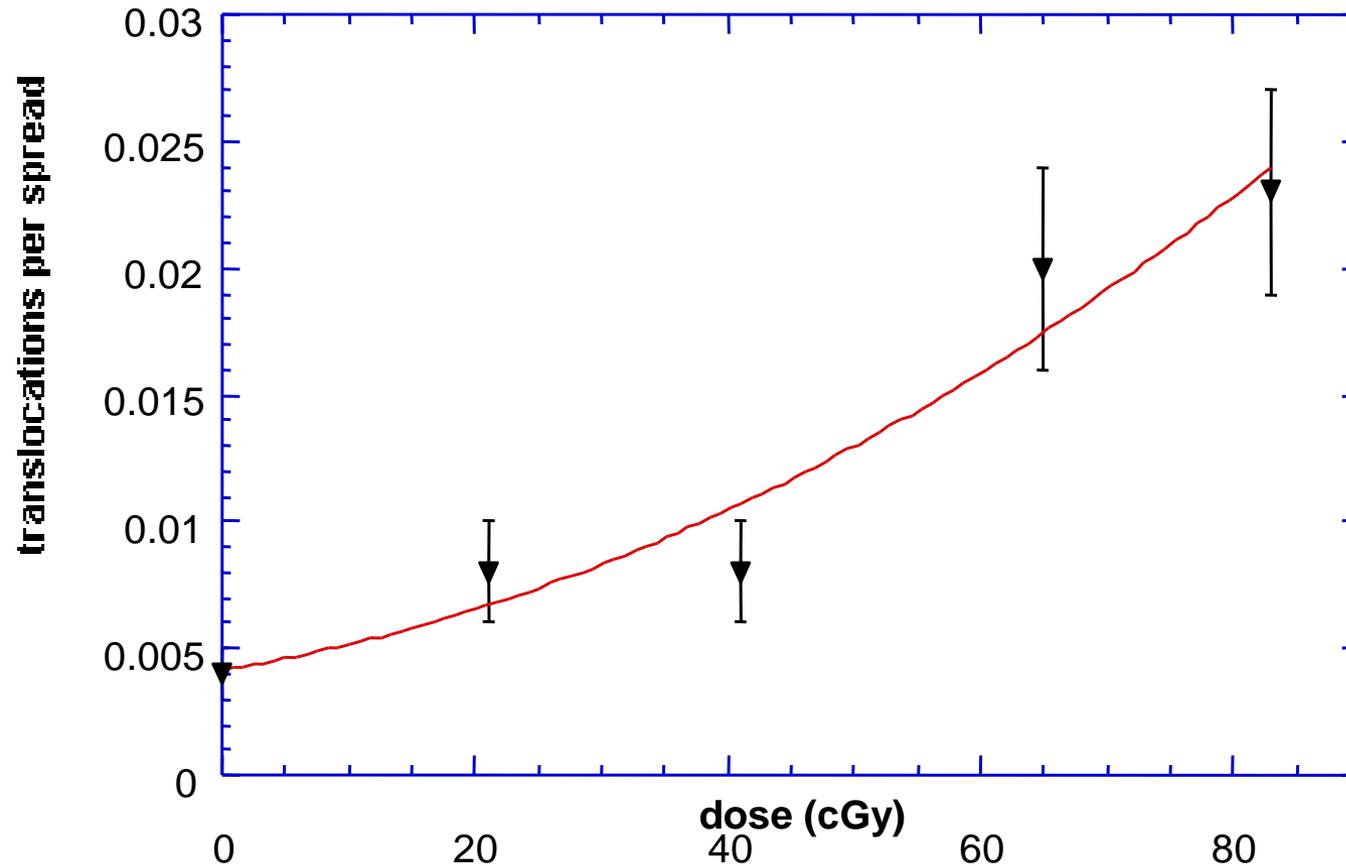
- easy to identify using FISH
- widely used technique for measuring exposures to radiation workers and accident victims
- stable in the body and persist for years after exposure
- provide a profile of radiation-induced chromosome injury over an individual astronaut's career
- associated with genomic instability and cancer development, and therefore may be an indicator of cancer risk

## Disadvantage

- Control levels of translocations are high, however it is possible to obtain individual background levels by sampling blood prior to mission

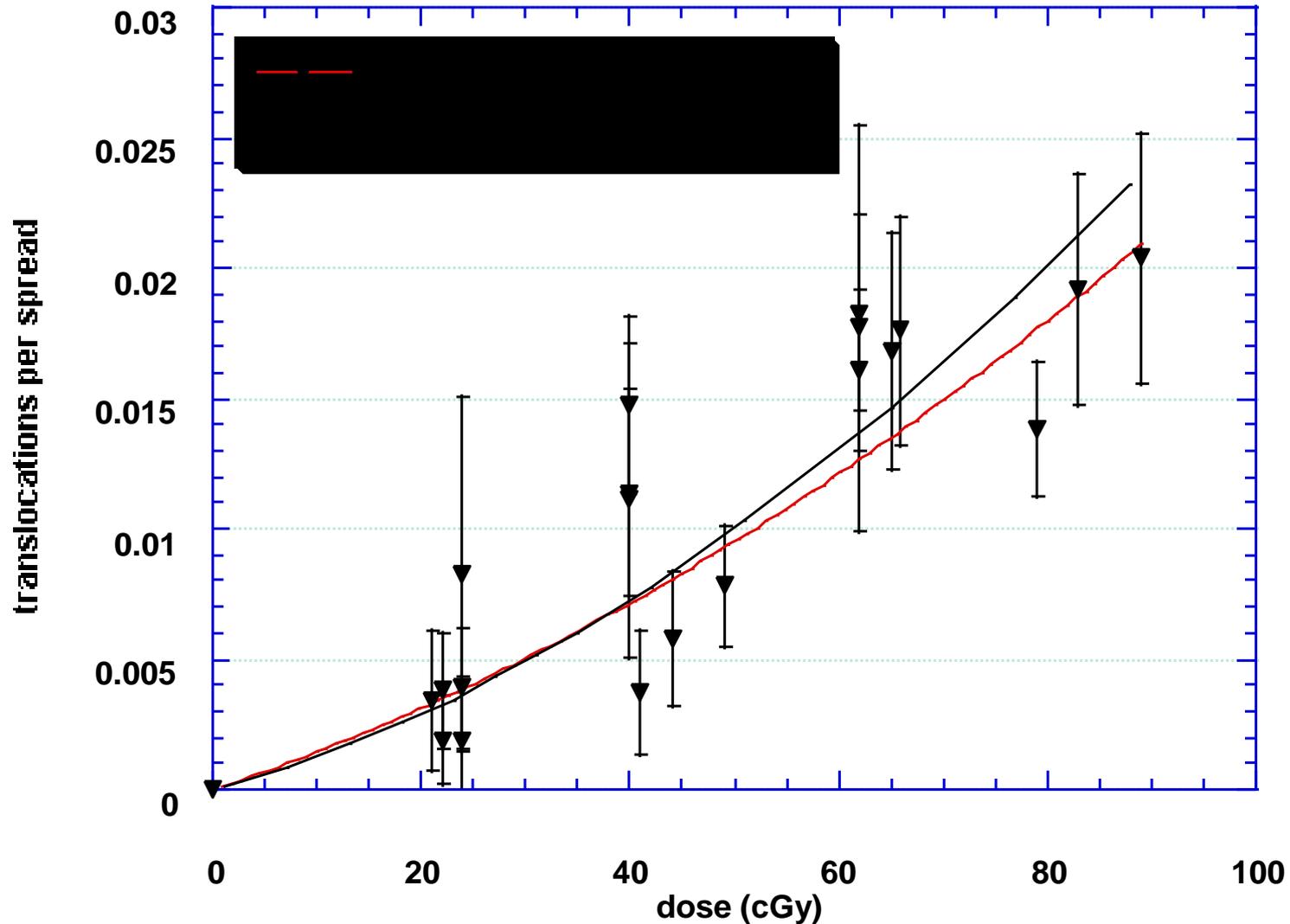
# Individual dose response curve

**Crewmember 6**  
**translocations in chromosomes 1 and 2**  
**after in vitro gamma exposure**



# Combined calibration curve for all six astronauts

translocations measured in 16% of the genome using chromosome painting technique after X-ray and gamma ray exposure



# Dose estimates using translocations

Crew member	sample	total spreads analyzed	translocations		in-flight dose measured from combined pre-flight curve (cSv)
			No.	Freq. x10 <sup>3</sup>	
1	pre-flight	3792	12	3.2	21
	R+9	4843	30	6.2	
2	pre-flight	2852	7	2.4	27
	R+0	4672	26	5.6	
3	pre-flight	742	3	4.0	21
	R+9	2630	19	7.2	
4	pre-flight	1884	3	1.6	18
	R+12	4677	20	4.3	
5	pre-flight	3995	4	1.0	9
	R+0	4056	9	2.2	
6	pre-flight	4381	19	4.3	0
	R+10	6556	27	4.1	

# Additional analysis of crewmembers 1 and 5

Crew member	sample	chromosomes analyzed	total spreads analyzed	translocations		in-flight dose measured from combined pre-flight curve (cSv)
				No.	Freq. $\times 10^3$	
1	9 days after mission	2 and 4	4843	30	6.2	21
	114 days after mission	2 and 4	3604	20	5.5	17
5	days of landing	2 and 4	4056	9	2.2	9
	240 days after mission	2 and 1	4745	14	2.9	13

# RBE calculations

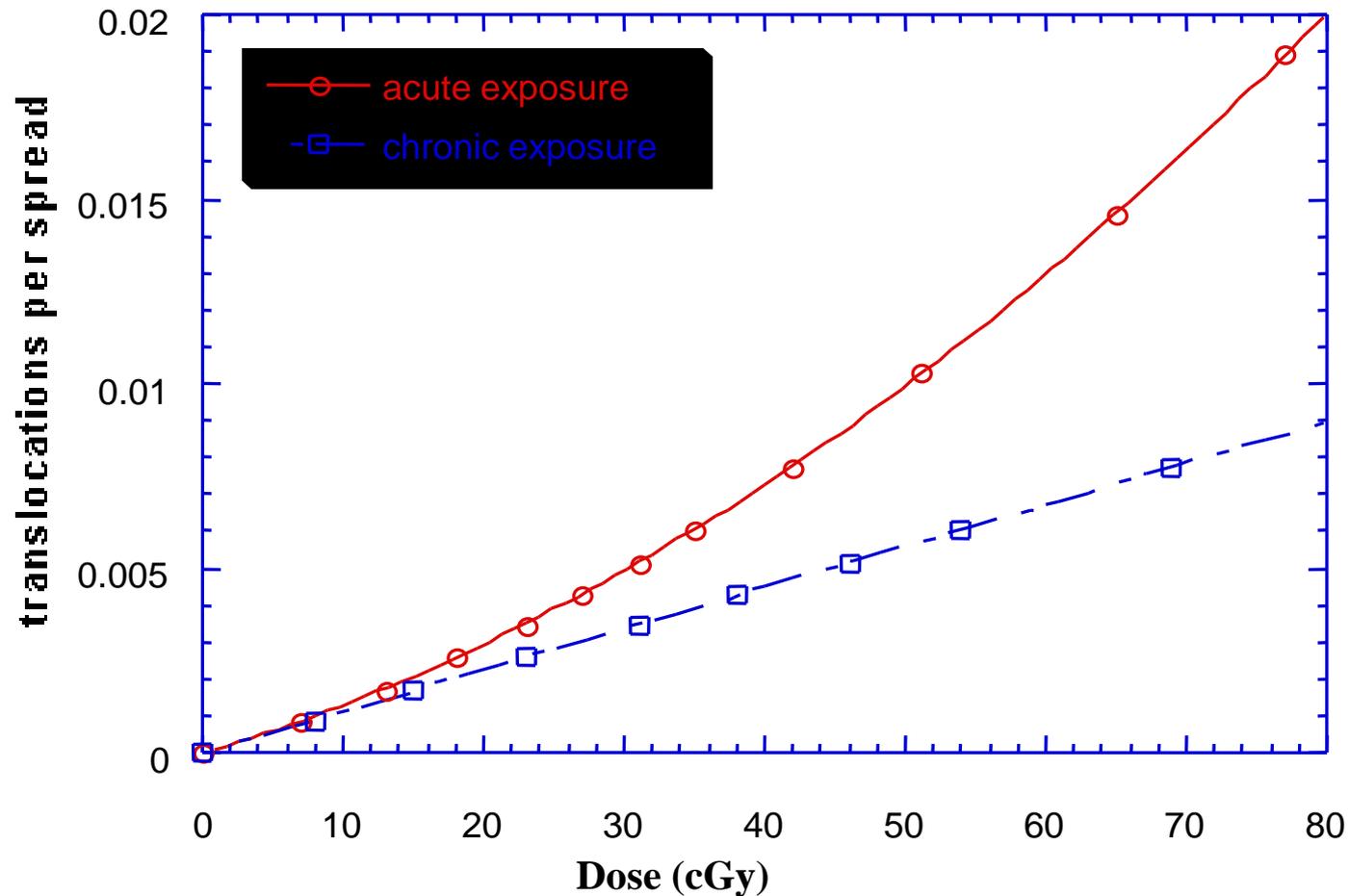
<b>Crew member</b>	<b>Mission Duration (Days)</b>	<b>Average Q ICRP-60</b>	<b>Physical Dose* (cGy)</b>	<b>Biodosimetry Dose (cSv)</b>	<b>RBE</b>
1	115	2.59	5.0	21	4.2
2	115	2.59	5.3	27	5.1
3	115	2.59	4.1	21	5.2
4	127	2.30	4.5	18	4
5	144	2.37	6.7	9	1.3
6	141	2.48	3.6		
Average		2.44			3.96

**\* values were corrected using TLD dose efficiency with LET and TEPC measured LET spectrum. Correction was approximately 20%**

# Dose response for chronic and acute exposures

translocations measured in 16% of the genome after x-ray exposure

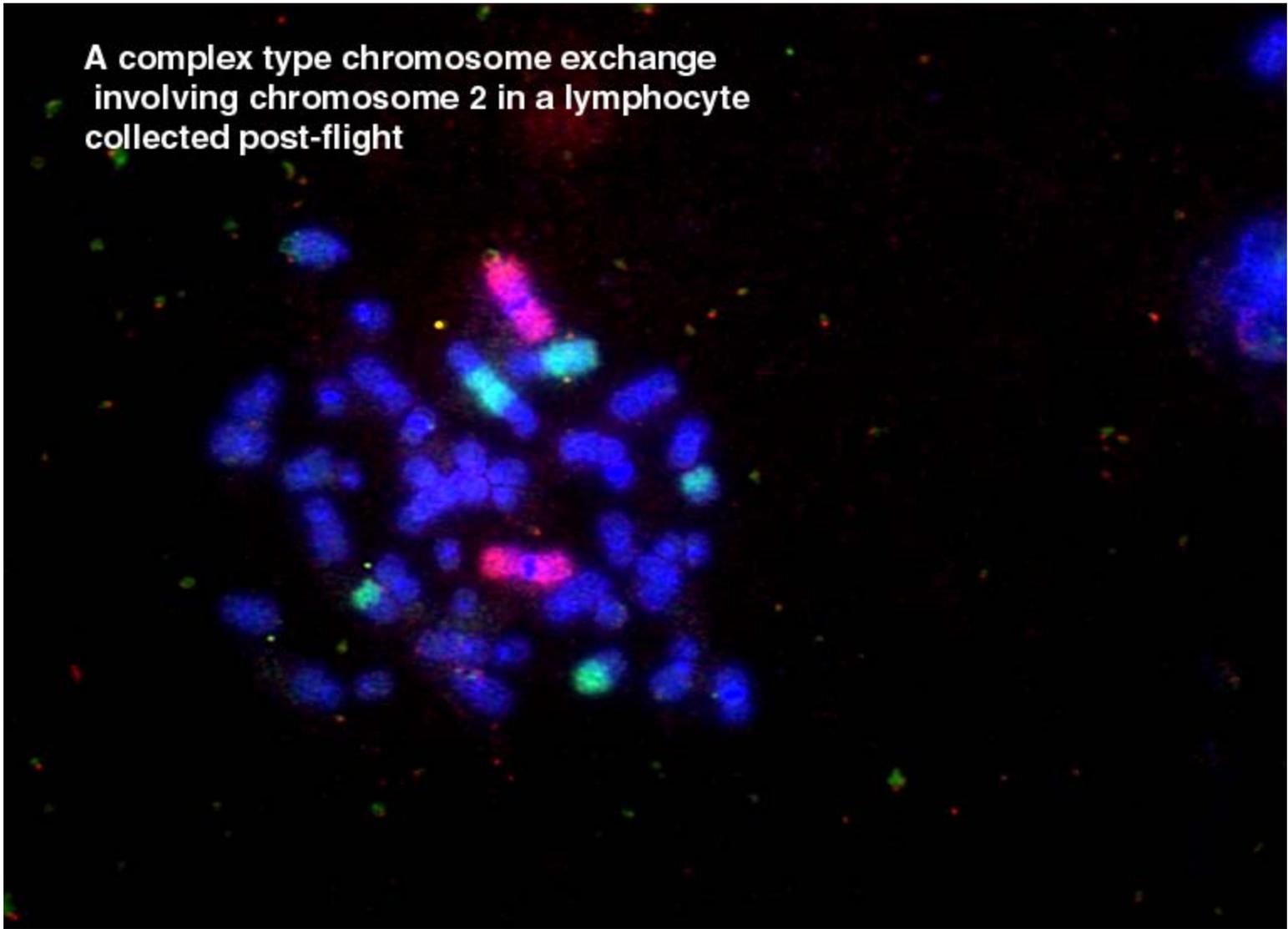
data from Edwards Rad. Res.1996



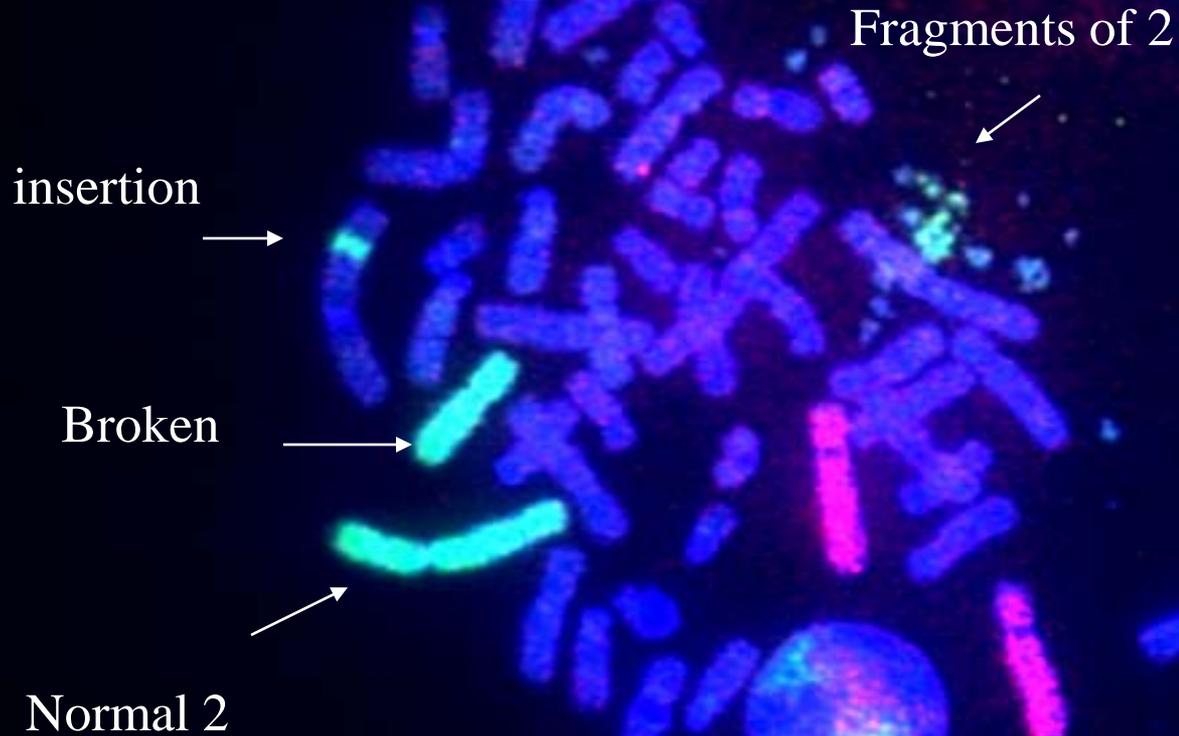
## Complex type chromosome exchanges

- **an aberration is defined as complex if it involves three or more breaks in two or more chromosomes**
- **high LET radiation is more efficient for inducing complex exchanges**
- **an increased percentage of complex exchanges is a signature of high LET radiation exposure**

**A complex type chromosome exchange  
involving chromosome 2 in a lymphocyte  
collected post-flight**



Damaged chromosome 2 in human lymphocyte cell  
collected post-flight

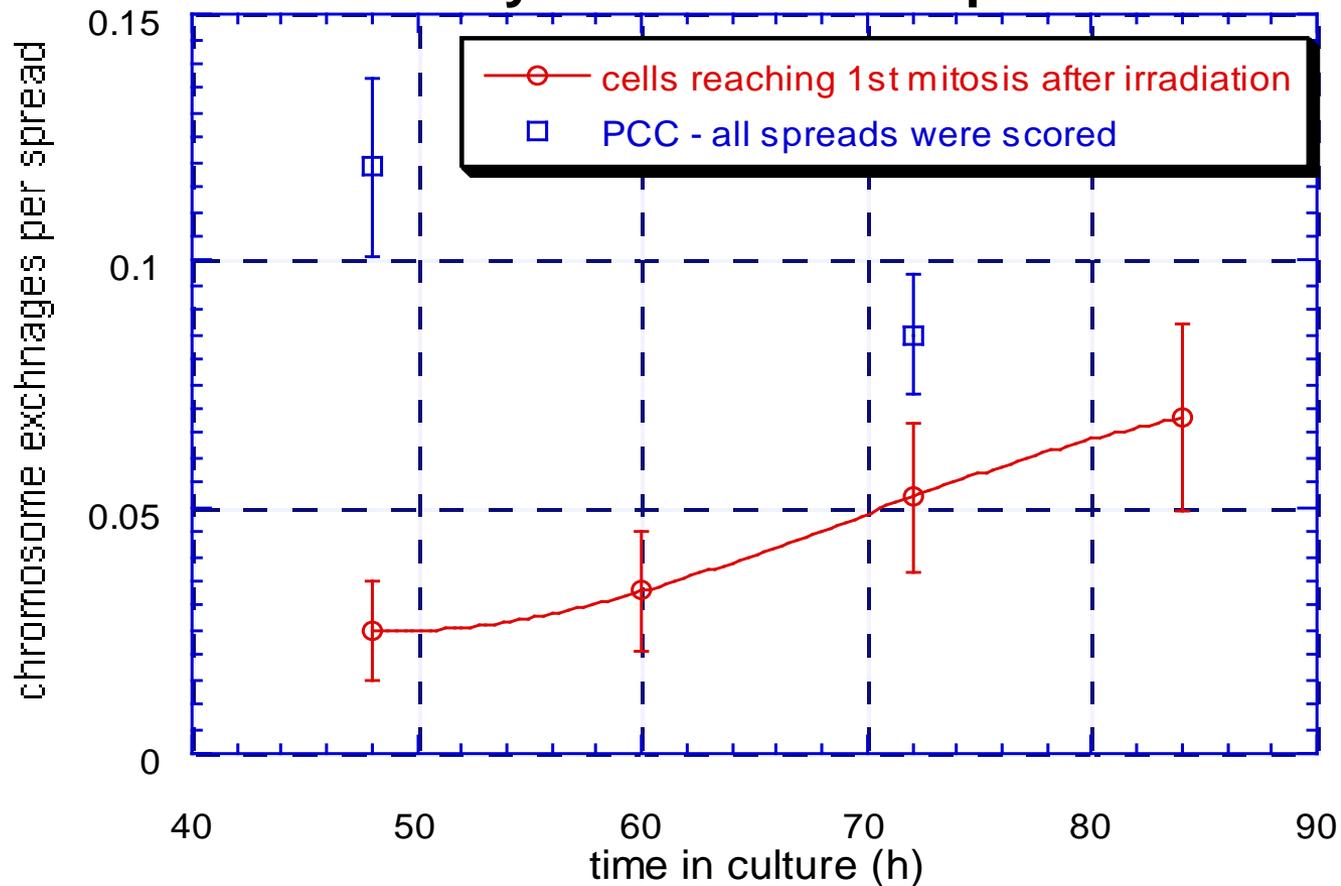


## Complex exchanges detected in lymphocytes from crewmembers 6 and 5

<b>crewmember</b>	<b>sample</b>	<b>total spreads analyzed</b>	<b>total number of exchanges</b>	<b>number of complex exchanges</b>
6	pre-flight	4381	24	1
	R+10	6556	41	7
5	pre-flight	7259	23	0
	R+0	3553	25	6

# Effect of mitotic delay on expression of chromosome damage

**Exchanges in chromosomes 2 and 1 in lymphocytes reaching first mitosis at different times after irradiation with 0.3 Gy of 1 GeV/u iron particles**



# Space Station Missions

- Perform biodosimetry on all astronauts after flights of 3 months or more
- Analyze all types of chromosome exchanges using M-FISH and FISH with three chromosome paint probes
- Collect Prematurely Condensed Chromosome spreads to eliminate problems with mitotic delay